Development of a methodical framework for a seamless air cargo supply chain, from a transaction cost perspective, focusing on Direct Trucking Pick-ups

An exploratory case study for KLM Cargo.

Student	Ir. F. M. Sickler	Report	Private Report
Student number	4094085	Date	19-03-2018
Report number	2018.TEL.8207	Confidential	Yes

Master Thesis
ME2190

3mE - Transport Engineering & Logistics

March 19, 2018

Development of a methodical framework for a seamless air cargo supply chain, from a transaction cost perspective focusing on Direct Trucking Pick-ups

A case study at KLM Cargo

Master Thesis

By

Ir. F.M. (Femke) Sickler

In partial fulfillment to obtain the degree of **Master of Science**
in Transportation Engineering and Logistics
at the Delft University of Technology
March 2018

Master Thesis		
	Author	Ir. F.M. (Femke) Sickler
	Student number	4094085
	e-mail	fmsickler@gmail.com
	Curriculum	Transport Engineering & Logistics
	University	Delft University of Technology
	Faculty	Mechanical, Maritime and Materials Engineering
Graduation Committee	Formal Chair	Dr. R.R. (Rudy) Negenborn
	First Supervisor	Dr. W.W.A. (Wouter) Beelaerts van Blokland
	Second Supervisor	Dr. ir. J.H. (John) Baggen
	Third Supervisor	Dr. J. (Jafar) Rezaei
	First External Supervisor	Ir. G.F.J. (Gregory) Camoenie
	Second External Supervisor	Ing. S. (Sanja) Mravik

Colophon

Title:	Development of a methodical framework for a seamless air cargo supply chain, from a transaction cost perspective focusing on Direct Trucking Pick-Up - A case study for KLM Cargo
Author:	Ir. F.M. (Femke) Sickler
Graduation date:	March 2018
Curriculum:	MSc. Transport Engineering and Logistics Faculty of Mechanical, Maritime and Materials Engineering (3mE) Delft University of Technology
Graduation committee:	**Formal Chair** Dr. R.R. Negenborn Full Professor Delft University of Technology Faculty of Mechanical, Maritime and Materials Engineering Department: Marine and Transport Technology **First Supervisor** Dr. W.W.A. Beelaerts van Blokland Assistant Professor Delft University of Technology Faculty of Mechanical, Maritime and Materials Engineering Department: Marine and Transport Technology **Second Supervisor** Dr. ir. J.H. Baggen Assistant Professor Delft University of Technology Faculty of Civil Engineering and Geosciences Department: Transport and Planning **Third Supervisor** Dr. J. Rezaei Associate Professor Delft University of Technology Faculty of Technology, Policy and Management Department: Transport and Logistics **External Supervisor 1** Ir. G.F.J. Camoenie Director Operations Europe Air France, KLM & Martinair Cargo Department: Area Operations Europe **External Supervisor 2** Ing. S. Mravik Operations Development Manager Air France, KLM & Martinair Cargo Department: Area Operations Europe

The content of this report is confidential

It is peculiar that:
when you transport something by ***car****,*
it's called ***ship****ment,*
but when you transport something by ***ship****,*
it is called ***car****go.*

Preface

This thesis is the final research performed for the completion of the degree of Master of Science in Transportation Engineering & Logistics of the faculty of Mechanical Engineering at the Delft University of Technology. The purpose of the master thesis research is to apply the theory and knowledge gained in the two-year program in an real-life problem situation. After completing my Bachelor degree in Aerospace Engineering and executing the double degree program in combination with MSc. Engineering & Policy Analysis (EPA) at the faculty of Technology Policy and Management, I wanted to combine all knowledge gained during my education with company experience. After performing the EPA graduation project at KLM Cargo, I feel extremely blessed and grateful to have had the opportunity to also perform my TEL master thesis research at KLM Cargo.

This research has been conducted for Air France KLM Cargo from September 2017 till March 2018. During this period, the direct trucking pick-up cargo supply chain has been compared with the traditional cargo supply chain and improvements suggested and modelled. This innovative, pioneering and challenging project allowed me to experience the project management, people management and data availability challenges that are encountered in large technological problems. The learning curve has been extremely steep, but I believe these challenges were successfully overcome and as a consequence made me a better engineer. I'm proud of the finished product and believe that additional knowledge has been created for all parties in the cargo supply chain.

First, I would like to specially thank my supervisor at Air France, KLM & Martinair Cargo, Gregory Camoenie, for providing me with the opportunity to execute my thesis with him, for the support, guidance and many games we always played (where I was always the loser). Secondly, I would like to express my deepest gratitude to Sanja Mravik, who assisted me with all problems encountered on the trade lane Denmark - Amsterdam, information assistance, allowed me to gain insight in the KLM Cargo processes, patiently answered all my questions, interesting discussions, valuable advice and guidance with the thesis project. I'm also thankful to the graduation committee and the help each one of its members provided. Rudy Negenborn, for his trust in my abilities and guidance in the right direction. Wouter Beelaerts van Blokland, for his commitment, motivation, unlimited assistance and thorough feedback to help me bring this master thesis to a higher level. John Baggen, for his great enthusiasm from the first time we met and valuable guidance. Last but not least, Jafar Rezaei, for enthusiastically joining the graduation committee at the last moment, despite his high conference preparations work load. This work could not have been completed without you.

This has truly been an amazing experience and I appreciate every single person who assisted me with this master thesis research. Many have taken the time to allow me to interview, answer my extensive and frequent questions, give me a tour or allowed me to participate in the process; to fully understand, not only on management level but also on operational level. The field research journeys to Denmark, exploring the ground handlers' warehouse and being part of the team (thanks to Duncan, Kenneth and Marco) are moments I will never forget. In addition I had the honor of begin selected as a Face Up! Air Cargo Career Competition finalist by IATA, to present my EPA thesis at the World Cargo Symposium 2018 in Dallas, TX, USA. For this nomination I would like to thank all KLM employees for their unlimited help and support! I can truly say that I have had the unique opportunity to get to know many aspects of the air cargo industry.

Lastly, I would like to thank my family, who in spite of being far, are always present in my life through their unlimited love, motivation, guidance and providing opportunities for exploration. This achievement is for you and your unconditional support throughout the difficult times and your sincere joy in the good ones. There are no words that can express my gratitude and love to you. In addition, I would like to dedicate this hard work to Jayde, who always welcomed me in her home as part of the family, with unconditional love and affection. I hope you rest in peace and are playing tennis in doggy heaven. You will always be in my heart. Finally my friends, for being always there for me, not just for the duration of this project, but for the support during my entire studies at the TU Delft, encouraging me to the end and for being part of this memorable adventure.

I wish you a pleasant reading,

Ir. F. M. Sickler
Delft, March 2018

Summary

KLM Cargo is responsible for the handling and transporting of air cargo, by road and air from 83 stations in Europe, to the hub at Amsterdam Schiphol Airport. The air cargo industry has seen the cargo market grow from a side business to a profitable industry (Reis & Silva, 2016). The air cargo industry is critical for serving markets that demand high speed. Goods are often high value, time sensitive, perishable and require reliability for the transportation of goods.

In recent years, a consolidation shift has been observed in the air cargo industry by more integration of the supply chain. Integrators engage in forwarding, forwarding agents operate their own aircraft and airlines bypass the forwarding agents, by striking direct structural deals with major customers (Merkert et al., 2017). This last development in the field of the air cargo road feeder service (RFS) is also known as Direct Trucking Pick-up (DTP).

In the current air cargo business models, all cargo is delivered via a freight forwarder to combination carriers (carrying both passengers and cargo). Forwarders control around >85% of the retail channels for general cargo (Reis & Silva, 2016), (Azadian et al., 2017) and (Hellberg & Sannes, 1991). In the existing organizational cargo structures there is no direct link from customer to combination carriers (Huang & Hsu, 2016) and (Onghena et al., 2014). The traditional model of air cargo transportation, has been challenged in recent years. The boundaries between the different segments of the cargo industry are blurring (Onghena et al., 2014). This shows the need for research regarding the green field of the DTP model, researched in this thesis. It is important for the combination air cargo carriers to consider how to deal with future competition. Integrators, performing direct deliveries, currently account for 5 - 10% of the air cargo freight volume (Azadian et al., 2012). In an era where time is money, customers want their cargo to be transported as fast as possible. Every day extra transit represents an ad-volorem tariff of 0.6 - 2.3% (Hummels & Schaur, 2012). KLM Cargo strives to become a competitive (speed at affordable cost), reliable and quality carrier for air cargo. With DTP, KLM Cargo wants to compete with the integrators gaining market share and monetary advantages.

The scientific gap was identified by several scholars. (Feng et al., 2015) has categorized literature according to the number of published papers and has identified several research gaps. For air cargo transportation in combination with RFS, some research has been performed, however research is lacking in the field of DTP. (Walcott & Fan, 2017) state that research regarding cargo transport systems remains under-examined in both theory and case study. According to (Heinitz et al., 2013) there is a lack of publicly available data, differentiating between freighter and truck operations. Therefore it can be concluded that the research regarding DTPs is a green field and further academic research is needed (Merkert et al., 2017).

To study DTP a case study was needed, it was performed at KLM Cargo. The practical gap was stated as follows: currently, the DTP supply chain is characterized by overtime, firefighting and blindness (incorrect and / or incomplete data). There is a gap between the desired performance and the current performance and it is not clear what KPIs influence this gap. Furthermore, it is unknown how the KPIs can be improved and what the theoretical performance could be in terms of arrival performance at the hub in Amsterdam. The research question is “*What are the criteria to design a seamless supply chain for the Direct Trucking Pick-up cargo flow for KLM Cargo?*" The case study was executed for the trade lane Billund (Denmark) - Amsterdam (The Netherlands), studying the city pair of Kolding - Amsterdam and Horsens - Amsterdam.

To be able to answer the above-mentioned research question a seamless supply chain had to be designed. The key supply chain business process must penetrate the functional silos within the company and the various corporate silos in the supply chain (Lambert & Cooper, 2000). A seamless supply chain is a system of interconnected and interdependent forces that operate in union to accomplish overarching supply chain objectives (Martichenko, 2013). An advantage of the direct pickups is that carriers can bypass the middleman in the traditional supply chain and collect directly at the customers (Gunasekaran et al., 2002). This results in savings in transportation costs as economies of scale can be obtained (Lin et al., 2012). To design a seamless supply chain the theory of Lean Manufacturing was applied to the air cargo industry. According to (Bendell, 2005) Lean (...) is the systematic pursuit of perfect value through the elimination of waste in all aspects of the organization's business process. (Martichenko, 2013) has adapted the 7 types of wastes of the lean manufacturing theory to be applicable for a supply

chain. These 7 types of waste were used to describe the transition from a traditional business model to a DTP business model. In addition, the 7 types of waste were used to answer the research question and function as KPI's to arrive at a seamless supply chain.

Moving a large amount of freight in a seamless supply chain over great distances is a complex business that involves many firms and requires ongoing coordination between them with respect to both the physical movement of goods and the management and exchange of information (Schwarz, 2006). The cargo industry is largely influenced by its international regulatory environment, it is one of the more heavily regulated sectors of the global economy (D. Bowen & Youngdahl, 1998). Due to the heavy regulations, the supply chain can be characterized by being highly asset specific (Jong de & Beelaerts van Blokland, 2016). Due to the fact that the air cargo industry has to comply with all IATA set regulations (International Air Transport Association, 2016a), the processes, assets and components are asset specific for reasons of safety.

According to (Arnold, 2000) the definition of asset specificity is that the assets can be used exclusively in the air cargo transport industry. Asset specificity is described in the Transaction Cost Economics (TCE) theory of (Williamson, 1981). The definition of a transaction is described as “A transaction occurs when a good or service is transferred across a technologically separable interface". Current academic research does not provide a TCE perspective on the air cargo industry, studying the number of goods or services transferred across a technologically separable interface. By using transactions as a KPI, complementary to the lean manufacturing KPIs, the air cargo operation can be measured from a transaction cost perspective. An economic transaction can best be explained by the comparison with mechanical systems. Efficient mechanical systems, are systems where friction and loss of energy are minimized. The economic counterpart is to ensure that parties involved in the exchange operate harmoniously (Williamson, 1979). It is important to minimize misunderstandings and / or conflicts in transactions that can lead to delays, breakdowns and other malfunctions in the system. In accordance with the stated definition of a transaction, in this thesis the practical definition of a transaction used is when one stage of activity terminates and another activity begins. The actions performed in the supply chain are a combination of physical (technical) and information actions.

To make the system work, the virtual networks of information exchange between air cargo firms are as important as the physical networks of airports, warehouses, trucks and airplanes. Electronic Data Interchange (EDI) is developing at a fast pace in the air cargo industry. The rise of internet and spread of modern information systems have deeply affected the operations (Schwarz, 2006). EDI's direct impacts are to; increase the amount of data capture, decrease the amount of transcriptions and decrease the delays between dispatch and receipt of messages. This generally results in decreasing; error incidences, exception-handling process times and data caused delays in the business process. The measurable variables are time, resource consumption and control. The objective for EDI applications is to reduce the transaction costs through improving the efficiency of routine work and of exception handling, but also through reducing the incidence of exceptions (Wrigley & Clarke, 1994).

An exploratory case study was executed for KLM Cargo, in which information was collected and evaluated about both theory and practice, in order to assess how exactly research could best contribute to the development of theory (Dul & Hak, 2008). During this case study an in-depth case study for both the traditional air cargo business model and DTP business model was executed, for a research period from September 2016 - September 2017. First flowcharts were designed for the current state of both processes, using swimlane diagrams. Following the swimlanes were transferred into two Value Stream Maps (VSM) to only study the specific part of the company that adds value to the system. Finally, each VSM was transformed from a static model into a dynamic model. The static model shows the observations and evaluations of the processes within a system at one specific moment in time. For the transformation to the dynamic VSM models, discrete event simulation was used. Using the discrete event simulation tool Simio, a model was created serving as a test platform for the air cargo industry. Simulation can be used to explore various opportunities of process improvements and the impact of the proposed changes before implementation.

The key performance indicators for this research are: throughput time (from a supply chain perspective), costs (from a company perspective) and transactions (from a transaction cost economics perspective). The KPIs for throughput time comprises of an information aspect (documentation processing) and a physical aspect (physical acceptance time and unloading time). The costs can be divided in transportation costs and handling costs. The transactions KPI is also divided in an information perspective and a physical perspective. From the swimlanes and the KPI scores it can be concluded that the current DTP supply chain is characterized by overtime, firefighting and blindness as it is strongly human-driven and human-dependent. Many deviations occur from the standardized process, inducing a high risk of cargo damage and data discrepancies. Much duplication efforts can be observed including compliance and security issues, information is not accessible for all parties and there are limited update of EDI opportunities resulting in excessive paperwork. Finally, a lack of internal and external feedback procedures can be observed.

Currently, the total throughput time of the DTP business model (15.75 hours) is almost half of the throughput time of the traditional business model (29.49 hours), however the throughput time of the DTP model can still be decreased. Based on the observations, several design options are proposed. KLM Cargo selected the following five design options as the most promising:

1. Introducing new / additional measurement points in the DTP supply chain.
2. Building a simulation model to facilitate the comparison between the traditional and DTP supply chain.
3. Collaboration in the DTP supply chain.
4. Digitalization in the DTP supply chain.
5. Correct information in the DTP supply chain.

To analyse the five designs, they were integrated into the framework as test platform. This platform was built using discrete event simulation modelling. In this model, the traditional and the DTP supply chain models were tested using identical KPIs. The impact of each of the three improvement designs for the DTP supply chain (no 3-5) was obtained by comparing the results with the current state KPI performance. It can be concluded that all designs, tested with the discrete event model improve / enhance the DTP supply chain.

Below each scenario is explained in more detail, the suggested improvements are key to improve one or both supply chains. For scenario 1 several measurement points should be implemented in the DTP supply chain to create visibility and allow future analysis. The CIQ (industry standard) milestones should be re-designed, or a functionality should be created to make customization of the milestone order possible, to allow for structural feedback between the different parties in the supply chain. For scenario 2, when looking at the individual transactions in the traditional model, it could be concluded that the different processes are shorter than the same steps in the DTP supply chain. However, when looking at the total throughput time of cargo, the DTP supply chain is 40% faster than the traditional supply chain. Evaluating the current trucking schedule could help reduce the throughput time in the traditional supply chain. Scenario 3, 4 and 5 suggest improvements for the current DTP setup. For design option 3, by improving the physical collaboration between all parties in the DTP supply chain, the acceptance time will be reduced with 30%. In addition, with this scenario the unloading time is the lowest compared to all other scenarios. It shows a reduction of 14.9% compared to the current state. Design option 4, by digitizing the DTP supply chain, a severe reduction was observed in the documentation processing time, total throughput time for documentation and a small reduction in unloading time. Design option 5 represents an ideal situation, where the information should be made digitally available and correct. The documentation processing, total throughput time documentation and unloading time reduce significantly. However, this is a situation to be aimed for in the future. Realistically, design option 4, digitalization, will be more feasible in the near future rather than immediately.

When considering the cost and time aspects of the supply chain, it could be concluded that the DTP business model looks more favourable, compared to the traditional business model. However, these five scenarios should be interpreted with caution. Many other factors need to be taken into account when comparing the two business models. Examples of these factors are; amount and type of cargo, proximity to a network point, customs, liability and safety (compliance issues), information and communication issues. To employ the DTP business model, first these factors should be discussed and agreed upon by all parties in the supply chain.

In conclusion, this thesis studied the traditional air cargo flow and the DTP flow for a case study from Billund (Denmark) towards Amsterdam (The Netherlands). DTP is often performed as a special offer to the customers, with the intention to transport cargo faster and cheaper. However, this has never been studied properly. To recapitulate the main research question is:

"What are the criteria to design a seamless supply chain for the Direct Trucking Pick-up cargo flow for KLM Cargo?"

To design a seamless supply chain, an in-depth case study was executed for both the traditional and the DTP cargo flow. Using the discrete event simulation tool Simio, a model was created serving as a test platform for the air cargo industry. Based on the simulation results the main research question can be answered. The criteria to design a seamless supply chain for the DTP cargo flow for KLM Cargo are:

1. Minimize the number of physical and information (re-work, double, manual) transactions.
2. Introduce electronic data interchange.
3. Ensure collaboration between the different parties in the supply chain.

For scientific research it is recommended to study the performance with a larger data set than the 1 year data set currently used. Using a larger data set, external influences can be identified and prediction models can be generated to predict future cargo trends. Further for both the type of goods and the company (KLM Cargo) has been posed to limitations in this research. Currently, only non-exceptional export goods were studied. It is recommended to take into account the exceptional cargo. For future research, it is recommended to study other markets in other regions and compare results.

For KLM Cargo it is recommended that before implementing DTP, first a solid proof of concept should be generated. Based on this proof of concept, strict rules should be set with the customer. Since DTP is an exclusive service, customers gain a faster and personalized service, risks are reduced, less transactions are executed and the costs are reduced since the GHA is bypassed, customers should pay for that. In order to design the price, the internal costs of KLM Cargo have to be determined. Essential elements have to be identified to create a culture of continuous feedback in a seamless supply chain. It is recommended to set the culture to strive to excellence. On hub operation level it is recommended that a policy should be designed concerning the order in which trucks and documents are handled, but also regarding cargo processing further in the chain. The current DTP schedule should be redesigned, looking at the best days of the week and the best time slots in order to ensure quick handling at the hub. The hub should strive for operational excellence. Finally, the legal and compliance aspect of the DTP model should be studied in more detail.

The limitations of the research are: The availability of the right and reliable data has been limited. Often, this was not a system and / or analysis tool related problem, but due to manual input of data prone to human-error and therefore not available or incorrectly entered. Combing this with the numerous available legacy systems, resulted in scattered data from which intelligence could only be gained after careful pre-processing.

This research has presented several contributions to scientific literature. The first contribution is additional scientific research to the currently limited existing research in the air cargo industry. The second contribution is a pioneering exploratory case-study research, regarding DTPs. The third contribution, a framework is proposed on how to design and improve a seamless supply chain for the DTP service. Final contribution, a simulation is generated exemplifying the functionality of the proposed framework.

Samenvatting

KLM Cargo is verantwoordelijk voor het afhandelen en transporteren van luchtvracht, over de weg of via de lucht, tussen 83 stations in Europa en de hub op Schiphol Airport, Amsterdam. De luchtvracht is binnen de luchtvaartindustrie, uitgegroeid van een secundaire onderneming naar een winstgevende onderdeel (Reis & Silva, 2016). Luchtvracht is essentieel voor goederen die met grote snelheid getransporteerd moeten worden. Deze goederen hebben vaak een hoge marktwaarde, tijd speelt een belangrijk rol, het zijn vaak houdbare producten en ze moeten vliegen zoals geboekt.

In de afgelopen jaren heeft er een consolidatie verschuiving plaatsgevonden in de luchtvrachtindustrie,door integratie in de bevoorradingsketen. Integrators nemen taken over van expediteurs, expediteurs investeren in eigen vliegtuigen en luchtvaartmaatschappijen passeren expediteuren in de keten, door directe afspraken te maken met klanten (Merkert et al., 2017). De laatstgenoemde ontwikkeling, specifiek op het gebied van wegvervoer, heet Direct Trucking Pick-up (DTP).

In de bestaande luchtvrachtbusinessmodellen, moet alle vracht voor een combinatie-luchtvaartmaatschappij (vervoeren zowel passagiers als vracht), via een expediteur worden aangeleverd. Expediteuren controleren meer dan 85% van alle handelskanalen voor algemene vracht (Reis & Silva, 2016), (Azadian et al., 2017) en (Hellberg & Sannes, 1991). In de huidige organisatorische luchtvrachtmodellen, bestaat geen directe link tussen de klant en de combinatie-luchtvaartmaatschappij (Huang & Hsu, 2016) en (Onghena et al., 2014). Het traditionele model voor luchtvrachttransport, staat de laatste jaren op losse schroeven. De scheidingslijnen tussen de verschillende segmenten en partijen in de luchtvaartindustrie beginnen te vervagen (Onghena et al., 2014). Dit toont de noodzaak aan, om vanuit academisch perspectief de ontwikkeling van het DTP model te onderzoeken, zoals in dit onderzoek wordt gedaan. Het is voor de combinatie-luchtvaartmaatschappij belangrijk om te onderzoeken, hoe om te gaan met de huidige en toekomstige concurrentie. Integrators, die de vracht reeds direct bij klanten afleveren, controleren 5 - 10% van de luchtvrachtvolumes (Azadian et al., 2012). In een tijdperk waarbij tijd geld is, willen klanten hun vracht zo snel mogelijk getransporteerd hebben over de hele wereld. Elke additionele dag van transport, staat gelijk aan een ad-volorem prijs van 0.6 - 2.3% (Hummels & Schaur, 2012). KLM Cargo streeft ernaar om een sterke concurrentiepositie aan te nemen, door snelheid aan te bieden tegen een competitieve prijs en de reputatie te hebben van een betrouwbare luchtvaartmaatschappij die kwaliteit levert. Met de DTP service, wil KLM Cargo concurreren met de integrators. KLM Cargo wil het marktaandeel vergroten en zo een kostenvoordeel behalen.

Dat meer wetenschappelijk onderzoek nodig is in de luchtvrachtindustrie, wordt door verschillende geleerden benadrukt. (Feng et al., 2015) heeft alle beschikbare literatuur over de industrie, gecategoriseerd op basis van het aantal gepubliceerde artikelen. Op basis van deze artikelen heeft hij verschillende tekortkomingen in wetenschappelijk onderzoek geidentificeerd. Enig onderzoek is gedaan naar luchtvrachttransport in combinatie met wegtransport, echter nog niet naar DTP. (Walcott & Fan, 2017) benadrukt dat onderzoek naar luchtvrachttransportsystemen nog onvoldoende heeft plaatsgevonden, in zowel de theorie als in de praktijk. Volgens (Heinitz et al., 2013) is er een gebrek aan publiekelijk beschikbare data, die het verschil tussen freighter en vrachttruck operaties benadrukt. Daarom kan er geconcludeerd worden, dat onderzoek naar DTPs een nog niet eerder onderzocht onderwerp is, wat verder wetenschappelijk onderzoek vereist (Merkert et al., 2017).

Om DTP te kunnen onderzoeken was een casusstudie nodig, uitgevoerd bij KLM Cargo. Het praktische probleem van KLM Cargo is als volgt: in de huidige situatie wordt de DTP keten gekarakteriseerd door overtijd, brandjes blussen en gebrek aan inzicht (foute en incomplete data). Er bestaat een groot gat tussen de gewenste prestatie en de huidige presentatie en het is onduidelijk welke KPIs dit gat kunnen verkleinen. Verder is het onduidelijk hoe de KPIs verbeterd kunnen worden en wat de theoretische prestatie zou kunnen zijn, in termen van aankomstprestatie op de hub in Amsterdam. De onderzoeksvraag is: *"Wat zijn de criteria, om een naadloze keten voor de Direct Trucking Pick-up vrachtstroom voor KLM Cargo, te ontwerpen?"* De casusstudie is gedaan voor de handelsroute Billund (Denemarken) - Amsterdam (Nederland), door het stedenpaar Kolding - Amsterdam en Horsens - Amsterdam te onderzoeken.

Om de bovenstaande onderzoeksvraag te kunnen beantwoorden, moest er een naadloze keten worden ontworpen. De belangrijkste bedrijfsprocessen binnen de keten, moeten door de huidige silo's van bedrijven heen prikken, evenals door de verschillende bedrijfssilo's in de gehele keten (Lambert & Cooper,

2000). Een naadloze keten is een systeem van met elkaar verbonden en van elkaar afhankelijke partijen die gemeenschappelijk opereren om de overkoepelende ketendoelen te bereiken (Martichenko, 2013). De toegevoegde waarde van DTPs is dat luchtvaartmaatschappijen de tussenpartij in de traditionele luchtvrachtketen kunnen overslaan en direct bij de klant kunnen ophalen (Gunasekaran et al., 2002). Dit resulteert in lagere transportkosten doordat er schaalvoordelen behaald kunnen worden (Lin et al., 2012). Voor het ontwerp van een naadloze keten voor de luchtvrachtindustrie, werd de theorie van Lean Manufacturing gebruikt. Volgens (Bendell, 2005) is lean het systematische nastreven van de perfecte waarde toevoeging, door eliminatie van afval in alle aspecten van de bedrijfsvoeringprocessen. (Martichenko, 2013) heeft de 7 vormen van afval van de lean manufacturing theorie aangepast, zodat ze toegepast kunnen worden op een waardeketen. De 7 typen afval zijn gebruikt voor het beschrijven van de transitie van het traditionele businessmodel naar het DTP businessmodel. Daarnaast werden de 7 typen afval gebruikt bij het beantwoorden van de onderzoeksvraag, omdat ze als KPI gebruikt werden om een naadloze keten te ontwerpen.

Het verplaatsen van grote volumes vracht in een naadloze keten, over grote afstanden, is een complex proces waarbij veel partijen betrokken zijn. Daardoor vereist dit continue coordinatie tussen de partijen, bij zowel de fysieke verplaatsing van vracht als bij het beheren en uitwisselen van informatie (Schwarz, 2006). De luchtvrachtindustrie wordt grotendeels beinvloed door de internationale wetgeving. Het is een van de zwaarst gereguleerde industrieen van de wereld (D. Bowen & Youngdahl, 1998). Door deze zware regulaties, kan de keten gekarakteriseerd worden als zeer activa specifiek (Jong de & Beelaerts van Blokland, 2016). Mede door het feit dat de luchtvrachtindustrie moet voldoen aan alle IATA gespecificeerde regulaties (International Air Transport Association, 2016a), zijn de processen, activa en componenten zeer activa specifiek om veiligheidsredenen.

Volgens (Arnold, 2000) is de definitie van activa specifiek, dat de activa alleen maar gebruikt kunnen worden in de luchtvrachtindustrie. Activa specificiteit wordt beschreven in de Transactie Kosten Economie (TCE) theorie van (Williamson, 1981). De definitie van een transactie is beschreven als: *"een transactie vindt plaats als goederen of services verplaatst worden over een technologisch scheidbare interface"*. Huidig wetenschappelijk onderzoek heeft de luchtvrachtindustrie nog niet onderzocht vanuit dit perspectief. Door transacties te introduceren als KPI, als toevoeging aan de traditionele lean manufacturing KPI's, kan de luchtvrachtoperatie gemeten worden van een transactiekostenperspectief. Een economische transactie kan het best worden beschreven door een vergelijking met een werktuigbouwkundig voorbeeld. Efficiente werktuigbouwkundige systemen, zijn systemen waar wrijving en energieverlies worden geminimaliseerd. Vertaald naar een economisch voorbeeld, is ervoor zorgen dat de partijen in de keten informatie en goederen harmonieus uitwisselen (Williamson, 1979). Het is belangrijk om de misverstanden en conflicten in transacties, die kunnen leiden tot het niet functioneren van het systeem, te minimaliseren. In overeenkomst met de bovengenoemde definitie van een transactie, is in dit onderzoek de praktische definitie van een transactie gebruikt. De praktische definitie van een transactie is: *"als het stadium van een activiteit eindigt en een andere activiteit begint"*. De activiteiten die worden uitgevoerd in de keten zijn: fysieke activiteiten, informatie activiteiten of een combinatie van beiden.

Om het systeem functioneel te maken, zijn de virtuele netwerken ten behoeve van informatie-uitwisseling in de keten, even belangrijk als de fysieke netwerken in de vorm van luchthavens, magazijnen, vrachtwagens en vliegtuigen. Elektronische gegevensuitwisseling (EDI) ontwikkelt snel in de luchtvracht industrie. De opkomst van internet en moderne informatiesystemen, hebben de activiteiten in de keten sterk beinvloed (Schwarz, 2006). De grootste voordelen van het gebruik van EDI zijn; vergroting van de hoeveelheid verzamelde gegevens, vermindering van het aantal transacties en het reduceren van de tijd tussen de verzending en het ontvangst van berichten. Dit resulteert in een afname; van de hoeveelheid fouten die gemaakt worden, van de afhandelingstijden, van het aantal uitzonderingen en van het aantal vertragingen, veroorzaakt door een gebrek aan informatie in de keten. De meetbare variabelen zijn tijd, middelenverbruik en controle. Het doel van EDI toepassingen is om de transactie kosten te verlagen door het efficienter inrichten van routinematig werk, door het aantal uitzonderingen te verminderen en door het aantal uitzonderingen in de processen te verminderen (Wrigley & Clarke, 1994).

Voor KLM Cargo is een verkennend casusonderzoek uitgevoerd, waarbij informatie is verzameld en geevalueerd met betrekking tot de praktijk alsook de theorie. Dit is gedaan om te kunnen beoordelen hoe onderzoek de beste bijdrage kan leveren aan de ontwikkeling van theorie (Dul & Hak, 2008). Tijdens het onderzoek is een diepgaand casusonderzoek uitgevoerd voor zowel het traditionele businessmodel voor luchtvracht als het DTP businessmodel voor een onderzoeksperiode van september 2016 tot september 2017. Eerst zijn er stroomdiagrammen ontworpen om de huidige situatie voor beide processen te identificeren. Daarna zijn de stroomdiagrammen omgezet naar twee Value Stream Maps (VSM), om alleen de relevante en specifieke onderdelen van het bedrijf te bestuderen die waarde toevoegen aan het systeem.

Ten slotte is elke VSM omgebouwd van een statisch model naar een dynamisch model. Het statische model toont alleen de observaties en valuaties van de processen binnen een systeem, op een bepaald moment in de tijd. Voor de transformatie naar een dynamisch model, is gebruik gemaakt van discrete event simulatie. Met de discrete event simulatietool Simio, is een model ontworpen dat dienst doet als een testplatform voor de luchtvrachtindustrie. Simulatie kan worden gebruikt om de verschillende mogelijkheden voor procesverbeteringen en de impact van voorgestelde wijzigingen voor de invoering te verkennen.

De belangrijkste prestatie indicatoren voor dit onderzoek zijn: doorlooptijd (vanuit het perspectief van de toeleveringsketen), kosten (vanuit een bedrijfsperspectief) en transacties (vanuit het oogpunt van een transactie-kosteneconomie). De KPI's voor doorlooptijd bestaan uit het informatie-aspect (documentverwerking) en de fysieke aspecten (fysieke acceptatietijd en lostijd). De kosten kunnen worden verdeeld in transportkosten en grondafhandeling kosten. De transactie KPI is tevens verdeeld in een informatie-perspectief en een fysiek-perspectief. Uit het stromendiagram en de KPI-scores kan worden geconcludeerd dat de huidige DTP-keten wordt gekenmerkt door overwerk, 'brandjes blussen' en blindheid, dit is voornamelijk te wijten aan de hoeveelheid mensenwerk. Er zijn veel afwijkingen van het gestandaardiseerde proces, waardoor er een verhoogd risico ontstaat op ladingschade en op gegevensverschillen. Ook zijn er veel dubbele acties geconstateerd, veroorzaakt door onder andere compliance- en beveiligingsproblemen, doordat informatie niet voor alle partijen toegankelijk is en doordat er beperkt gebruik gemaakt wordt van EDI-mogelijkheden, wat leidt tot veel papierwerk. Ten slotte is er een gebrek aan interne en externe feedbackprocedures.

Momenteel is de totale doorlooptijd van het DTP-model (15,75 uur). Dit is bijna de helft van de doorlooptijd van het traditionele bedrijfsmodel (29,49 uur). Desondanks zijn er nog steeds besparingsmogelijkheden te identificeren, met betrekking tot de doorlooptijd binnen het DTP-model. Op basis van de resultaten zijn er, in overleg met KLM Cargo, verschillende ontwerpverbeteringsopties (scenario's) voorgesteld. Op basis van deze ontwerpverbeteringsopties heeft KLM Cargo de onderstaande, vijf meest belovende scenario's geselecteerd:

1. Introductie van nieuwe / additionele meetpunten in de DTP keten.
2. Vergelijken van traditioneel model met DTP-model met behulp van een simulatiemodel.
3. Samenwerking in de DTP keten.
4. Digitalisering van de DTP keten.
5. Juiste informatie in de DTP keten.

Om de vijf verschillende ontwerpverbeteringsopties te analyseren, werden deze in het simulatie testplatform getest. Voor zowel het traditionele simulatiemodel en het DTP-simulatiemodel werden de scenario's getest op identieke KPI's. De resultaten van alle drie verbeteringsopties voor de DTP (nr. 3-5), werden vergeleken met de huidige KPI-prestaties, om de impact van de scenario's te meten. Het kan geconcludeerd worden dat alle scenario's die getest zijn in het simulatiemodel, een verbetering van het DTP-model laten zien.

Onderstaand zijn de scenario's in wat meer detail beschreven. Het doel van de ontwerpverbeteringsopties is om een of beide ketens te verbeteren. Voor scenario 1, moeten verschillende meetpunten worden geimplementeerd in de DTP-distributieketen om zichtbaarheid te creeren en toekomstige analyse mogelijk te maken. De CIQ (industriestandaard) meetpunten moeten opnieuw ontworpen worden, of een functionaliteit om de meetpunten te kunnen personaliseren zou toegevoegd moeten worden, om structurele feedback tussen de verschillende partijen in de keten mogelijk te maken. Voor scenario 2, kijkend naar individuele transacties in het traditionele model, zou men kunnen concluderen dat de doorlooptijd van de processen korter is in vergelijking met dezelfde processen in het DTP-model. Echter, kijkend naar de totale doorvoertijd van de lading, is de DTP keten 40% sneller dan de traditionele keten. Evaluatie van het huidige truckschema zou kunnen helpen om de doorlooptijd van de traditionele keten te verlagen. Scenario's 3, 4 en 5 zijn verbeteringsopties voor de huidige DTP inrichting. Ontwerpoptie 3, door de samenwerking in de DTP keten te verbeteren, vermindert de fysieke acceptatietijd met 30%. Bovendien, is met dit scenario de lostijd het laagst in vergelijking met alle andere scenario's. Het scenario laat een vermindering van 14,9% zien ten opzichte van de huidige situatie. Ontwerpoptie 4, het digitaliseren van de DTP keten, toont een grote verlaging in documentatieverwerkingstijd, alsook in de totale documentaire doorlooptijd en slechts een kleine verbetering in uitlaadsnelheid. Ontwerpoptie 5 laat de ideale situatie zien, waar alle informatie digitaal beschikbaar en correct is. De documentatieverwerking, de totale documentaire doorlooptijd en de uitlaadtijd nemen in dit scenario aanzienlijk af. Dit is echter een situatie die in de toekomst moet worden nagestreefd. Realistisch gezien, is ontwerpoptie 4 (digitalisering), haalbaar in de nabije toekomst en niet zozeer per direct.

Kijkend naar kosten en tijd, zou geconcludeerd kunnen worden dat het DTP businessmodel gunstiger lijkt dan het traditionele businessmodel. Echter, voorzichtigheid is geboden bij de interpretatie van de vijf scenario's. Vele andere factoren moeten in acht genomen worden bij het vergelijken van de twee businessmodellen. Voorbeelden van deze factoren zijn; de hoeveelheid en het type lading, de afstand tot het dichtstbijzijnde netwerkpunt, Douane-, aansprakelijkheids- en veiligheid issues, informatie en communicatie problemen. Om het DTP-bedrijfsmodel in te zetten, moeten eerst de bovenstaande factoren ontworpen, besproken en overeengekomen worden met alle partijen in de keten.
In conclusie, deze scriptie heeft onderzoek gedaan naar het traditionele keten en de DTP keten met behulp van een causonderzoek van Billund (Denemarken) naar Amsterdam (Nederland). DTP is een uniek model dat aan klanten wordt aangeboden met het doel om vracht sneller en goedkoper naar de hub te transporteren. Dit is alleen nog nooit goed onderzocht. Hieronder, wordt de onderzoeksvraag herhaalt:

"Wat zijn de criteria, om een naadloze keten voor de Direct Trucking Pick-up vrachtstroom voor KLM Cargo, te ontwerpen?"

Om een naadloze keten te ontwerpen is een diepgaande casusstudie uitgevoerd voor zowel de traditionele keten als voor de DTP keten. Met behulp van een simualtiemodel, is een testplatform ontworpen voor de luchtvrachtindustrie. Op basis van de resultaten van het simulatiemodel kan de onderzoeksvraag worden beantwoord. De criteria om een naadloze keten voor DTP vrachtstroom voor KLM Cargo te ontwerpen zijn:

1. Minimaliseren van het aantal fysieke en informatie (opnieuw uitvoeren-, dubbele-, handmatige) transacties.
2. Introduceren van electronische gegevensuitwisseling.
3. Samenwerking van alle partijen in de keten.

Vanuit academisch perspectief wordt er aangeraden om in de toekomst extra onderzoek uit te voeren met een grotere data set, dan de 1 jaar data set die voor dit onderzoek is gebruikt. Door een grotere data set te gebruiken, kunnen externe factoren geidentificeerd worden en voorspellingsmodellen gegenereerd worden. Verder zijn in dit onderzoek voor zowel het bedrijf als voor het type goederen aannames gedaan. In het huidige onderzoek worden alleen standaard goederen onderzocht. Voor de toekomst is het aan te raden om extra onderzoek te doen naar niet-standaard goederen. De laatste aanbeveling is om onderzoek te doen naar andere market en regios en deze te vergelijken met het resultaat uit dit onderzoek.

Vanuit praktisch perspectief wordt aan KLM Cargo aangeraden dat voordat het DTP model geimplementeerd wordt, dat er eerst een proef model wordt gedraaid. Op basis van deze proef kunnen duidelijke regels worden afgesproken met de klant. Aangezien DTP een exclusieve service is, waarbij klanten een persoonlijk en snellere service krijgen met verminderd risico, transacties en kosten, kan de klant hier ook (extra) voor betalen. Om een prijsvoorstel te bepalen moeten eerst de interne kosten van KLM worden bepaald. Daarnaast, moeten essentiele elementen moeten bepaald om een cultuur van continue terugkoppeling te creeren in de naadloze keten. Het wordt aanbevolen om een cultuur te creeren die streeft naar excellentie. Op hub operatie niveau wordt er aangeraden om een beleid te ontwerpen over de truck afhandeling volgorde en vracht afhandeling volgorde. Het huidige DTP schema moet worden herontworpen waarbij de beste dag van de week voor aanlevering van vracht in acht wordt genomen. Daarnaast moet de hub ook streven naar operationele excellentie. Ten slotte, moet de wetgeving en conformiteit van het DTP model worden bestudeerd in meer detail.

De beperkingen van dit onderzoek zijn: de beschikbaarheid van goede en betrouwbare data was beperkt. Dit was niet een systeem of analyze methode probleem maar door handmatige invoer van data. Daardoor is de data onderworpen is aan menselijke fouten, resulterende van fouten bij invoer. Dit gecombineerd met de hoeveelheid legacy systemen waarin KLM Cargo opereert, resulteert in verspreide data sets, waar alleen informatie uit gehaald kan worden na voor-analyze.

Dit onderzoek heeft verschillende bijdragen gelevert aan de wetenschap. Allereerst, een wetenschappelijk onderzoek aan het huidige beperkte wetenschappelijke onderzoek in de luchtvrachtindustrie. Ten tweede, een baanbrekend verkennend casus onderzoek naar DTPs. Ten derde is er een kader ontworpen over hoe een naadloze keten ontworpen en verbeterd kan worden voor de DTP dienst. Ten slotte, is een simulatie model ontworpen om de functionaliteit van het kader te laten zien.

Table of Contents

II Measure 32

List of Abbreviations

Abbreviation	**Full Meaning**
abb.	Abbreviation
AF	Air France
AFKL	Air France - KLM
AKE	Type of Aircraft Container, Type of ULD
APU	Auxiliary Power Unit
ARR	Arrival
AWB	Air Waybill
AWD	Documents delivery to forwarder
AWR	Documents received at destination airport
BKD	Airline freight booking and route planning
BPR	Business Process Re-engineering
BSCC	Basic Service Combination Carrier
BSF	Basic Service Freighter
BUP	(Shipper) Build Up Pallet
CCB	Cargo Center Billund
CDG	IATA Airport code for Paris Charles de Gaulle
CIQ	Identifies quality standards for the air cargo industry
CMR	Convention Relative au Contract de Transport International de Marchandises par la Route
CPI	Continuous Process Improvement
CSO	Customer Service Organization
DEP	Departure
DK	Denmark
DLV	Freight delivery to forwarder
DMADC	Adapted methodology: Define, Measure, Analyse, Design, Control
DMADE	Adapted methodology: Define, Measure, Analyse, Design, Evaluate
DMAIC	Methodology: Define, Measure, Analyse, Improve, Control
DTA	Direct To Agent
DTP	Direct Trucking Pick-up
EDI	Electronic Data Interchange
EGFL	European Green Fast Lane
FFM	Freight Flight Manifest
FHL	House Air Waybill
FHL'	Updated House Air Waybill
FIFO	First-In-First-Out
FOH	Freight On Hand
FSCC	Full Service Combination Carrier
FSFO	Full Service Freighter Operator
FSU	Flight Status Update
FTL	Full Truck Load
FWB	Air Waybill
FWB'	Updated Air Waybill
GHA	Ground Handling Agent
GSA	General Sales Agent
HAWB	House Air Waybill
H.W.	Half Width
HWB	House Waybill
IATA	International Air Transportation Association
JIT	Just In Time

Abbreviation	Full Meaning
KLM	Koninklijke Luchtvaart Maatschappij (Royal Dutch Airlines)
KPI	Key Performance Indicator
LAT	Latest Acceptance Time
LDP	Lower Deck Pallet
LM	Lean Manufacturing
LTL	Less than full Truck Load
M-ULD	Mix-Unit Load Device
MAWB	Master Air Waybill
Max.	Maximum
MDP	Main Deck Pallet
Min.	Minimum
MOP	Master Operating Plan
MRN	Unique identifier for the export movement per year and country
NFD	All freight and documents ready for pick-up
NL	Netherlands
NP	Network Planning
OT	On Time
OTA	On Time Arrival
OTD	On Time Departure
OTP	On Time Performance
PDP	Pickup and Delivery Problems
QoS	Quality of Service
RCF	Cargo has arrived in the cargo bay at final destination
RCS	Cargo and documents are received ‘Ready For Carriage’ and accepted by airline (handler)
REP	Reporting
REST	Remote Explosive Scent Tracking
RFS	Road Feeder Service
RM	Revenue Management
RTK	Revenue Tonne Kilometer
SCM	Supply Chain Management
SCO	Supply Chain Orientation
SFSCC	Separate profit and loss Full Service Combination Carrier
T-ULD	Through - ULD
TAT	Turn Around Time
TCE	Transaction Cost Economics
TOC	Theory of Constraints
TQM	Total Quality Management
Trad.	Traditional
ULD	Unit Load Device
VRP	Vehicle Routing Problem
VRPPDTW	Vehicle Routing Problem with Pickup and Delivery with Time Window
VSM	Value Stream Map

Definitions

Term	Definition
"as-is" model	Description of the system (current situation) in such a way that the kind of system and its behaviour can be studied and understood.
"to-be" model	A description of a new situation for the system.
Agent / Shipper / Customer	The person or company that is physically and administratively responsible for shipping the goods.
Air Waybill	A paper document made out by or on behalf of the customer, which evidences the contract between the customer and airline for the carriage of cargo over the routes of the airline.
Airline / Carrier	Air carrier means a person who undertakes directly by lease or other arrangement to engage in air transportation.
Asset specificity	Much and complex information and / or products have to be exchanged before, during and after the exchange of goods.
Cargo	The goods carried by a ship, aircraft, or other large vehicle.
Cargo Receipt	Document which is provided to the customer, upon customer's request by the carrier creaying a shipment record as a substation for the issuance of an Air Waybill and which permits identification of the shipment.
CIQ Milestones	Cargo CIQ is an IATA interest group with the mission of creating and implementing quality standards for the worldwide air cargo industry.
CMR	An agreement for the international transport of goods per road. These are the shipping documents for road transportation.
Confidence Interval	A statistical means for showing how accurately the mean average of a value is being estimated.
Consignment	One or more pieces of goods accepted by the airline from one customer at one time and at one adress, receipted for in one lot, and moving on one Air Waybill or one shipment record to one consignee at one destination address.
Continous System	System is defined by differential equations that specify the rate of change (system changes at a specific rate).
Deterministic System	Does not introduce variation in a system.
Digitalization	Making digital everything that can be digitized and the process of converting information into digital format.
Digitization	The process of converting information into a digital format. Information is organized into discrete units of data.
Discrete System	System changes at discrete points in time (at certain event times).
DTP	A carrier operated truck that transports freight from a specific customer / forwarder at the location without the freight being handled at the carrier's origin and / or destination airport location.
DTP Air Cargo Supply Chain	Supply chain including the customer, trucking company and carrier.
Electronic Data Interchange	The exchange of documents in standardized electronic form, in an automated manner, directly from an application supporting one organization to an application supporting another.
Extreme Conditions Test	The model structure and outputs should be plausible for any extreme and unlikely combination of levels of factors in the system.
FFM Message	Provides the details of consignments loaded onto a specified flight.

Term	**Definition**
FHL Message	Provide a "checklist" for the freight forwarder / customer Air Waybills associated with the Master Air Waybill.
FHL' Message	The message that contains House Waybill data is sent by the origin freight forwarder / customer with potential updates made by the origin ground handler on the data.
Framework	A system of rules, ideas or beliefs that is used to plan or decide something.
Freight Forwarder	The party arranging the carriage of goods including connected services and / or associated formalities on behalf of the customer or consignee.
FSU Message	Notify / update interested parties with a change of status.
FWB Message	Transmit a complete set of Air Waybill data.
FWB' Message	The message that contains Air Waybill data, sent by the origin freight forwarder / customer, with potential updates made by the origin ground handler on the data.
Ground Handling Agent	The entity authorised to act for or on behalf of the carrier for accepting, handling, loading / unloading, transiting or dealing with cargo.
Half-Width	The margin of error is usually defined as the "radius" (or half the width) of a confidence interval for a particular statistic from a survey.
House Manifest	Document containing the same information as the cargo manifest and additional details on freight amounts.
House Waybill	Document made out by an freight forwarder / customer which specifies the contract between the customer and the agent for the arrangement of carriage of goods.
Lean	The systematic pursuit of perfect value through the elimination of waste in all aspects of the organization's business process. It requires a very clear focus on the value element of all products and services and a thorough understanding of the value stream.
Methodical	According to a method or done in a very ordered careful way.
MRN	Customs Declaration. Unique number that is automatically allocated by the customs office that accepts the declaration. Identifier of the member states from which the movement originates, export movement per year and country.
Non-terminating Model	There is no natural end point that determines the length of a model simulation run.
Processes	Relationships between inputs and outputs, where inputs are transformed into outputs using a series of activities, which add value to the inputs.
Replication	A run in a simulation model that uses specified streams of random numbers, which in turn cause a specific sequence of random events.
RCS	Update status and is considered by the carrier as ready for carriage on this date at this location.
SCO Mentality	The recognition by an organization of the systemic strategic implications of the tractical activities involved in managing the various flows in a supply chain.
Seamless	A system of interconnected and interdependent forces that operate in union to accomplish overarching supply chain objectives.
Sensitivity Analysis Test	Changing the values of the input and internal parameters of the model to determine the effect upon the model's behavior or output.
Shipment	A large amount of goods sent together to a place, or the act of sending them.

Term	**Definition**
Shipment Record	Any record of the contract of carriage preserved by the carrier, evidenced by means other than an Air Waybill.
Silo Mentality	When departments can't or won't easily share information with others, each only operating and optimizing their own area of expertise.
Standard Deviation	A measurement of the degree to which each number in a set of numbers is different from the average.
Stochastic System	Introduces randomness to represent variation in systems.
Supply Chain	A set of three or more entities (organizations or individuals) directly involved in the upstream and downstram flows of products, services, finances and / or information from a source to a customer.
System	Broad term used to describe a set of related components that work toward some purpose.
Terminating Model	There is a natural end point that determines the length of a model simulation run.
Traditional Air Cargo Supply Chain	Supply chain including the customer, freight forwarder, ground handling agent, trucking company and carrier.
Transaction	A transaction occurs when a good or service is transferred across a technologically separable interface.
Transient Output	The distribution of the output is constantly changing.
Validation	The process of ensuring that the model is sufficiently accurate for the purpose at hand.
Value	Any action or process that a customer would be willing to pay for.
Verification	The process of ensuring that the model design has been transformed into a computer model with sufficient accuracy.

** The corresponding citation of the definition can be found in the chapter where the definition is used for the first time within this thesis.*

List of Figures

List of Tables

Part I

Define

1 Introduction

This chapter introduces the research performed for KLM Cargo. This chapter consists of seven paragraphs in which the research- context, field, problem, scope, objective, questions and design are discussed. The set-up for this chapter is shown in Figure 1.1.

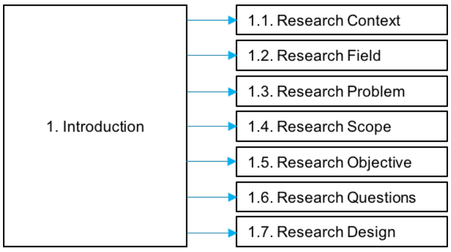


Figure 1.1: Chapter 1

1.1 Research Context

The air cargo industry has grown significantly over the past years. In 2014 the world air cargo industry increased with 4.8% and in 2015 with 1.9% (Boeing World Air Cargo Forecast Team, 2017). The largest growths were found for the trade lanes Middle East - Europe, Asia - North America and Europe - Asia. In 2016, the air cargo industry was responsible for transporting goods equivalent to 5.5 trillion U.S. dollars, meaning that every day 18.6 billion dollars were transported via air (International Air Transport Association, 2017). Of the total value of trade, 35% was transported by air while this was less than 1% of the world trade volume. The air cargo industry is critical for serving markets that demand high speed, where the goods are often of high value, time sensitive, perishable and require reliability for the transportation of goods. Examples are: the pharmaceutical, live animals, electronic devices, e-commerce and postal parcel industry.

It is predicted that over the next 20 years, the air cargo industry worldwide will grow with another 4.2%. Meaning that the 223 billion revenue tonne kilometer (RTK - 1 tonne transported 1 km) of cargo transported in 2015 will increase to 509 RTK in 2035 (Boeing World Air Cargo Forecast Team, 2017). According to (Kupfer et al., 2017), the main determinants for the air cargo demand is merchandise trade, therefore he modelled various future scenarios, to conclude that the air cargo industry will grow significantly in the coming years. Although stable growth for the air cargo industry is expected, the carriers need to continuously improve and remain competitive. The air cargo business experiences difficulties due to competitive pricing, low margins on prices and technological improvements. The overall demand for air cargo transportation is derived from factors beyond the control of air-cargo firms. However, it can be stated that intercontinental air-cargo traffic closely parallels macro-economic growth rates in the economies being linked (Schwarz, 2006).

The air cargo market is experiencing momentous developments that may impact strongly on future trends (Merkert et al., 2017). An important growing phenomenon is the road feeder service (RFS) of freight towards large intercontinental hubs (examples in Europe; Schiphol, Paris CDG). With a view of achieving potential benefits of scale, freight forwarders and customers like to see air freight grouped in a single hub, as this allows them to transport and consolidate freight in the largest possible quantities. This is a trend break with the past when air freight was synonymous with relatively small volumes and comparatively high costs. This consolidation trend also results in constant shifts in the air cargo value chain; integrators engage in forwarding, forwarding agents operate their own aircraft, carriers bypass the forwarding agents by striking direct structural deals with major shippers (Merkert et al., 2017). According to (Merkert et al., 2017) there is no such thing as a single, unique, air freight model. The market is heterogeneous, with multifarious players with different business models. One of the important topics meriting further academic research is the carriers collecting freight from customers (shippers / freight forwarders are summarized as customer(s) from this moment onward) directly. This research addressed this scientific gap with a study on Direct Trucking Pick-up (DTP).

1.2 Research Field

This research is conducted for the cargo department of the company Air France - KLM (from now on referred to as KLM Cargo). KLM Cargo is responsible for the transportation of 1.2 million tons of cargo over 2016, resulting in a combined revenue on 2.5 billion euros with Air-France. Cargo is transported to 457 destinations across 157 countries (including trucking) (Air France KLM Cargo, 2017). Due to the predicted increase of the amount of cargo to be transported in 2035, it is expected that the volumes of KLM Cargo will also increase. This means that KLM Cargo will have to innovative to be able to handle the predicted amount. All the cargo handled by KLM Cargo is processed at the hub at Amsterdam Schiphol Airport.

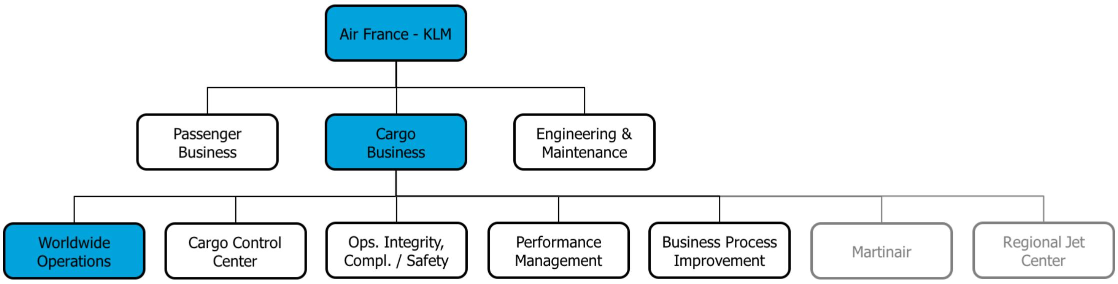


Figure 1.2: Structure Air France - KLM (KLM, 2017)

KLM Cargo is responsible for the handling and transportation of cargo by road and air from 83 stations in Europe to the hub at Amsterdam Schiphol Airport and vice versa. KLM Cargo consists of many departments among which, worldwide operations, cargo control center, operations integrity, compliance and safety, performance management, business process improvement and KLM subsidiaries Martinair and regional jet center as shown in Figure 1.2. This research is executed for the department worldwide operations and the specific section Operations Europe. Operations Europe is responsible for all trucking and handling operations for the 8 European markets ([1] Benelux, [2] France, [3] Germany & Austria, [4] Iberia, [5] Italy & Switzerland, [6] Nordic, [7] UK & Ireland and [8] Central East Europe).

Table 1.1: Types of Cargo Handled at KLM Cargo - adapted from (Consultant Decision Support, 2017)

Type of cargo	**Description**	**Percentage**
Transit cargo aircraft - aircraft	Cargo that arrives at the hub by aircraft and departs from the hub by aircraft	14.5 %
Transit cargo truck - truck	Cargo that arrives at the hub by truck and departs from the hub by truck	0.2 %
Transit cargo aircraft - truck	Cargo that arrives at the hub by aircraft and departs from the hub by truck	14.0 %
Transit cargo truck - aircraft	Cargo that arrives at the hub by truck and departs from the hub by aircraft	33.6 %
Import cargo	Final destination of the cargo is Amsterdam. This cargo is collected from the hub by forwarders	19.8 %
Export cargo	Cargo that has the origin Amsterdam. This consists of local delivery to Amsterdam and DTP from Europe with acceptance in Amsterdam	16.4 %
Other	Unclassified	1.5 %

Cargo is transported from numerous locations in Europe to Amsterdam by truck and / or aircraft. The cargo delivered to the hub can be divided in 6 types of cargo as shown in Table 1.1. This research will focus on export cargo. Export cargo is cargo that arrives at the hub at Amsterdam Schiphol Airport from other locations in Europe (including the Netherlands) that has a destination other than the Netherlands. The acceptance of the export cargo is executed at the hub.

Export cargo can be delivered in several ways to the hub. Customers can deliver their cargo directly to the hub in Amsterdam, called export delivery (Figure 1.4). Cargo from the stations in Europe (outstations) can be transported either by flight (Figure 1.3), line-haul truck (Figure 1.3) and / or DTP truck. In the latter case it is called export delivery, as acceptance is performed in Amsterdam (Figure 1.4). A line-haul truck allows for regular and scheduled transportation of cargo between two major cities or locations, also known in literature as a hub and spoke structure (see Chapter 2). The line-haul truck operates from the ground handling agent (GHA) who is contracted by the carrier to handle their cargo and update information on behalf of the carrier. Therefore the cargo arrives 'Ready for Carriage' (RFC) at the hub and only needs to be re-located to the designated destination buffer at the hub in Amsterdam. The DTP truck allows for direct cargo collection from the customer. In literature DTP is defined as: "a carrier-operated truck (that is under carriers designation) that transports freight to or from a specific customer / forwarder at a location without the freight being handled at the carrier's (of their designated service provider's) origin and / or destination airport location" (International Air Transport Association, 2008). As DTPs arrive un-checked at the hub, all RFC checks still need to be performed upon arrival at the hub. There exist two types of DTP; ad-hoc and structural DTPs. The main difference between the line-haul truck and DTP truck is that the line-haul truck often transports cargo from different customers consolidated at an outstation by a GHA in Europe, while the DTP truck collects the cargo directly from the customer, thus only transporting the cargo of this one customer. The difference between cargo delivered by the customer to the hub (export delivery) and DTP is that for export delivery the customer arranges the transportation of cargo to the hub and for DTP the carrier arranges the transportation of cargo.

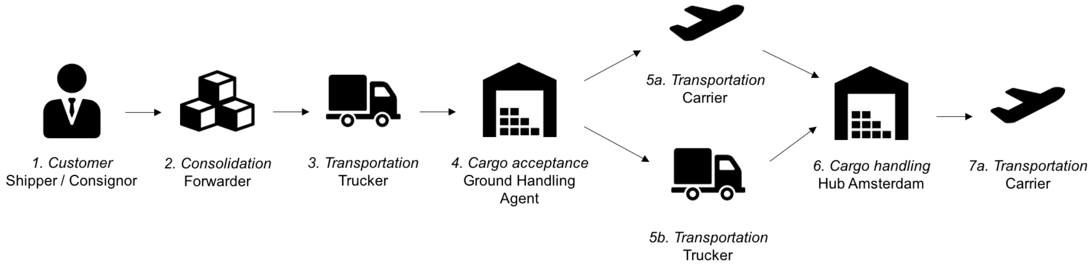


Figure 1.3: Traditional Air Cargo Supply Chain - adapted from (Sickler et al., 2017)

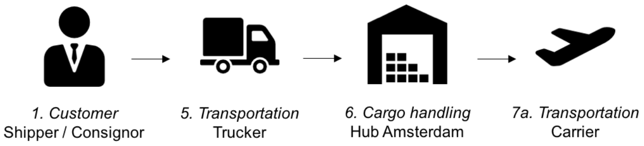


Figure 1.4: DTP Air Cargo Supply Chain - adapted from (Sickler et al., 2017)

Previous research focused on the low performance of the traditional air cargo supply chain via the GHA (Sickler et al., 2017) with the goal to improve the acceptance procedure, trucking schedule and data communication, to increase the on time performance. This research was performed for the European Green Fast Lane (EGFL) project aiming for enhancing the flow of goods between the GHA and the hub (Spoor, 2017). The next step for KLM Cargo is to design a seamless supply chain for the DTP chain and to manage this supply chain. For companies providing essential services, such as transportation, it is of great importance to control the supply chain. Currently, it is unclear for KLM Cargo how to improve and control the performance of the DTP supply chain.

1.3 Research Problem

KLM Cargo strives for becoming a competitive and qualitative carrier for air cargo. With the aim to transport the cargo as promised to the consignee. As mentioned, one of the ways that cargo is delivered to the hub is by DTP. The low delivery quality of the DTPs have a significant influence on the hub performance. In the next two sections the scientific and practical problem statement are discussed.

1.3.1 Scientific Problem Statement

The scientific problem comprises that limited scientific research has been performed regarding air cargo in general. Carriers used to focus primarily on passenger transport, as this was the most profitable industry. However, over the past years, air freight has developed from a by-product to a crucial element in the competitive struggle for market share (Merkert et al., 2017). All scientific literature published, regarding the air cargo industry until 2015, has been categorized by (Feng et al., 2015) according to topic in the supply chain and how much has been publicized about that certain topic. From (Feng et al., 2015)'s research it can be concluded that little to no scientific research has been performed regarding DTP. Often the existence of RFS offered by the carriers are acknowledged, but omitted from (further) research such as the connectivity model by (Boonekamp & Burghouwt, 2017). Therefore it can be concluded that the research regarding DTPs is a green field and further academic research is needed (Merkert et al., 2017). A more detailed literature study on the air cargo industry, including RFS is presented in Chapter 2.

The scientific objective is to contribute to air cargo literature with a focus on DTP research. This research will present several contributions to scientific literature. The first contribution is additional scientific research to the currently limited existing research in the air cargo industry. The second contribution is a pioneering exploratory case-study research regarding DTPs. The third contribution is a proposed framework on how to design and improve a seamless supply chain for the DTP service. Final contribution is a generated simulation, exemplifying the functionality of the proposed framework.

1.3.2 Practical Problem Statement

Currently, the DTP supply chain is characterized by overtime, firefighting and blindness. Information is often unavailable, resulting in problems such as unexpected arrival times at the hub, CIQ milestones (as defined in Definitions) are not triggered, accounting does not have a manifest etc. etc. This results in cargo arriving too late at the hub in Amsterdam accompanied with limited available information about the cargo, resulting in rework and correction time. Furthermore, the involved parties in the supply chain feel a lot of pressure and are unable to oversee the supply chain. The pressure is mainly caused by the criticality of shipments making their connecting flights in Amsterdam. Currently, it is unclear how to improve, manage and control the DTP supply chain to prevent the issues of overtime, firefighting and blindness. Finally it is unclear what key performance indicators (KPIs) influence the performance in this supply chain, how the KPIs can be improved and what the theoretical optimal performance could be by designing a seamless supply chain. Due to the current low arrival performance of DTP at KLM Cargo and the problem context the following practical research gap has been identified:

There is a gap between the desired performance and the current performance and it is not clear what KPIs influence this gap. Furthermore, it is not known how the KPIs can be improved and what the theoretical performance could be in terms of arrival performance at the hub in Amsterdam.

The arrival of trucks at the hub in Amsterdam is highly uncertain, especially for DTP trucks. No forecast models are currently generated as data is unavailable. The practical objective is to perform an exploratory case study to identify the data needed to generate forecast models and how to design a seamless supply chain to structurally communicate the data. With this research KLM Cargo will gain a detailed insight in the current situation, what the KPIs are, how these KPIs can be influenced and what the theoretical arrival performance of DTP can be.

1.4 Research Scope

In this section the research scope will be presented. First the case study and the system boundary of the research are presented. The case study selection process is explained in more detail in Chapter 4. Secondly, the research level of analysis are presented.

1.4.1 Case Study

The case that was studied, was determined based on the largest DTP volume in Europe during 2016 - 2017. This was the single trade lane Billund (Denmark) - Amsterdam (The Netherlands). The intention was to focus on the DTP and how this could have additional value for KLM Cargo, opposed to the traditional route via a GHA. The seamless supply chain boundary for this research is defined, from customer until the cargo arrives at the hub in Amsterdam. Therefore the part of the supply chain before the customer and after the arrival at the hub in Amsterdam were not taken into account. Only the activities at the hub in Amsterdam are part of the KLM Cargo, the remainder of the activities such as trucking, GHA etc. are performed by contracted third parties. Therefore the system boundary as indicated in red in Figure 1.5 is from departure at the customer until the RCF milestone is given at the hub. For this research the type of cargo was limited to export cargo. The time frame for the measurements in the current state was 1 year from September 2016 until September 2017. This research period was chosen as enough data points were available during the period of 1 year, additional seasonal influences were averaged when simulating the data.

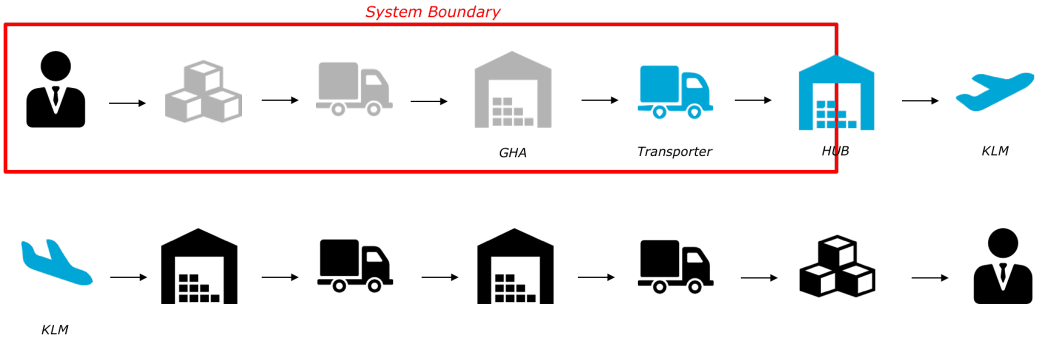


Figure 1.5: Research System Boundary

1.4.2 Levels of Analysis

The analysis can be performed on several levels. It is important to consider the larger processes on a higher level as well as the in depth processes. In depth processes can be processes that are necessary to execute single transactions. When the execution of processes of one level influence the execution of processes on another level this could result in problematic inter-dependencies (Horvath & Möller, 2004). In this thesis an in-depth case study was performed for KLM Cargo, as described in Section 1.4. The company analysis has been divided into levels for closer investigation. This research took the following levels into consideration; Company (Level 1), Service Product Groups (Level 2), Product Group Department (Level 3), Product Process (Level 4), Transactions (Level 5). Figure 1.6 shows the respective levels.

- *Level 1: Company*: The company has been divided into three major divisions; being passenger services, engineering & maintenance and cargo.
- *Level 2: Cargo*: The division under study is Cargo. Cargo consists of different types of cargo; export cargo, import cargo and transit cargo. For the analysis it has been chosen to focus on the export cargo, specificallt DTP cargo, originating from Europe and being transported to worldwide destinations (outside Europe).
- *Level 3: Export Cargo*: In this level, one specific product and its associated processes will be analysed. The export cargo has been chosen as this type of cargo as it imposes the most problems for KLM Cargo's operations. Export cargo has to be screened and checked in Amsterdam and therefore creates the most work. Export cargo consists of cargo being delivered by forwarders at the hub or with a DTP.
- *Level 4: Direct Trucking Pick-up*: This level investigates the different process steps in DTP. DTP was investigated as this process was unknown for KLM Cargo. It was compared to the traditional process. The methods used to analyse this level are: case studies, interviews, swimlane mapping, value stream mapping and discrete event simulations described in Chapter 4, Chapter 5 and Chapter 6 respectively.
- *Level 5: Transactions*: This level investigates the transactions between specific product related processes. The changes and improvements for the DTP model would need to be implemented on this level. The last step of this research was to run scenarios using simulations to discover the effects of proposed changes and improvements. The other methods used to analyse this level were described above in Level 4.

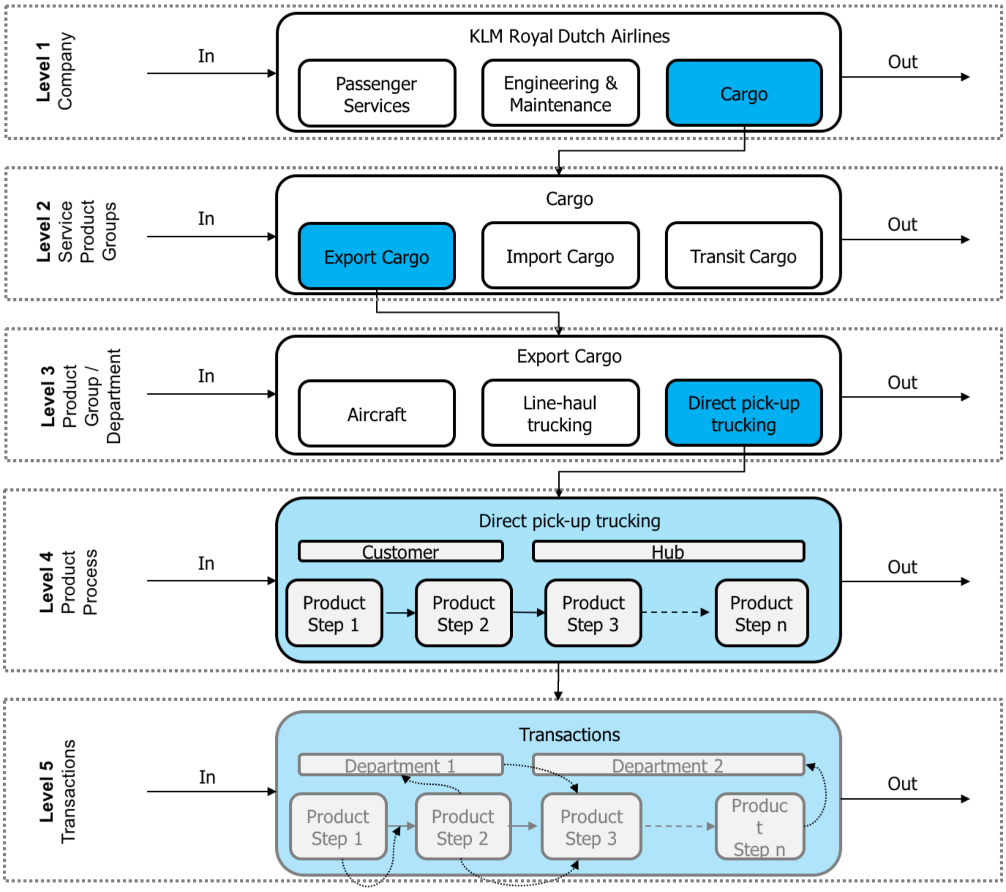


Figure 1.6: Company Levels to Investigate - adapted from (Jong de & Beelaerts van Blokland, 2016)

1.5 Research Objective

This research focused on the development of a theory-oriented framework to design and improve the DTP supply chain. The case study at KLM Cargo was used to test the framework. Based on the research problem and research scope, the following research objective was defined:

Determine the criteria to propose a framework for a seamless air cargo supply chain, from a transaction cost perspective, focusing on the DTP supply chain and apply this framework at KLM Cargo to improve the DTP performance.

1.6 Research Questions

The following main research question was formulated based on the research objective:

What are the criteria to design a seamless supply chain for the Direct Trucking Pick-up cargo flow for KLM Cargo?

The main research question was answered using various sub-research questions. The following sub-research questions were formulated based on the methodology and literature research:

1. Which research has already been performed on the; air cargo industry, air cargo business models, seamless supply chains, hub-and-spoke structures and electronic data interchange?
2. Which methods can be used to measure, analyse and improve seamless supply chains?
3. Which stakeholders are involved in the process and which are most critical?
4. How is the current traditional cargo flow organized and what is the performance?
5. What are the bottlenecks for the current traditional cargo flow?
6. How is the current DTP flow organized and what is the performance?

7. What are the bottlenecks for the DTP cargo flow?
8. What KPIs can be used to assess the current performance and different design options?
9. Which framework can be developed to create a test platform to test design options?
10. How does the performance of the traditional flow compare to the DTP flow?
11. Which design options does KLM Cargo have to improve the performance of the DTP process?
12. What is the impact of the design options on the performance of DTP flow?

1.7 Research Design

The research design used for answering the main research question and the sub-research questions is the DMADE cycle. In this section, the research approach, research outline, expected research output and data usage will be discussed.

1.7.1 Research Approach

The DMAIC cycle is an approach adapted from the Six Sigma methodology (Reid & Sanders, 2011) and is the inspiration for the used DMADE cycle, which was used for answering the main research question. This approach is used as it is applicable to an operations case-study as defined by (Dul & Hak, 2008) with their intervention cycle for solving a practical problem (problem finding (D), problem diagnosis (M), design of intervention (A), implementation (I) and evaluation (C)). The five-step plan stands for Define, Measure, Analyse, Improve and Control. DMAIC is a widely used tool to structure, research, improve and optimize processes. The first step (define) is the exploratory phases; in which background information is provided. The second and third step (measure and analyse) are part of the current state phase, where the current state is identified. The last 2 steps (improve and evaluate) are the future state phase in which the root causes of the problem are eliminated and the continuous improvement process is designed. This research slightly deviated, as this research does not aim for a real implementation, but more for a reflection on the design alternatives. The various phases of the research are indicated on the left side of Figure 1.8.

The first adaption of he DMAIC cycle was based on the design of W.W.A. Beelaerts van Blokland, namely the DMADC cycle. In the DMADC cycle the 'Improve' step is replaced with the 'Design' step. As this research aims to design a new framework to design and improve a seamless supply chain instead of real implementation, this adaptation was used. The second adaption was based on the objective of the research. The objective was to provide a reflection on the design alternatives, instead of designing a continuous improvement process. In Chapter 7, the design alternatives for improvement were developed and tested. Therefore, the 'Control' phase was replaced with the 'Evaluate' phase, as also identified by (Dul & Hak, 2008). In this phase, instead of monitoring and maintaining the process, the impact of the design options on assets and resources for improvement was discussed and a reflection on the contribution of this research to theory took place. In Figure 1.7 the adapted DMADE cycle is presented. Below the different steps of the cycle were described:

Define: In the define phase the goals and value of the research are identified. In this phase the research context, field, problem, scope, objective, questions, design is described in the Introduction. In addition the literature review and theory analysis are part of this phase.
Measure: In the measure phase the relevant statistics and processes are measured and collected to categorize and size the problem. In this phase the stakeholders are identified, data from an exploratory case study are used and the current state of the process is investigated.
Analyse: In the analyse phase, all the collected measurements are analysed. The information is analysed to identify the constraints in the DTP process that prevent on-time arrival (OTA) performance. The analysis was performed using discrete event simulation.

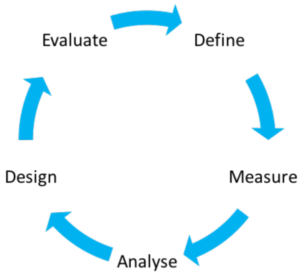


Figure 1.7: DMADE cycle - adapted from dr. W.W.A. Beelaerts van Blokland

Design: In the design phase, the design options are proposed and their impact on the processes is measured using a discrete event simulation model as test platform.
Evaluate: In the evaluate phase, the impact of the design options on assets and resources for improvement will be discussed. In addition a reflection will take place on the contribution of this research to theory.

1.7.2 Research Outline

In Figure 1.8 the research outline for this research is visualized. The blue boxes each represent a topic to be discussed and indicate in which chapter this topic was discussed. This research was divided in 4 phases as shown on the left side of the outline. The right top corner of each phase, indicates how the phases are related to the DMADE cycle. This research started from a generic, non-case specific perspective with a literature study. The literature supports this research to find a design to develop a simulation framework for the seamless supply chain. The DMADE design methodology was implemented by proposing a design for the seamless supply chain. Finally the evaluate phase presents the results and compares the various scenarios. In this phase an evaluation of the scientific and practical contribution was also presented.

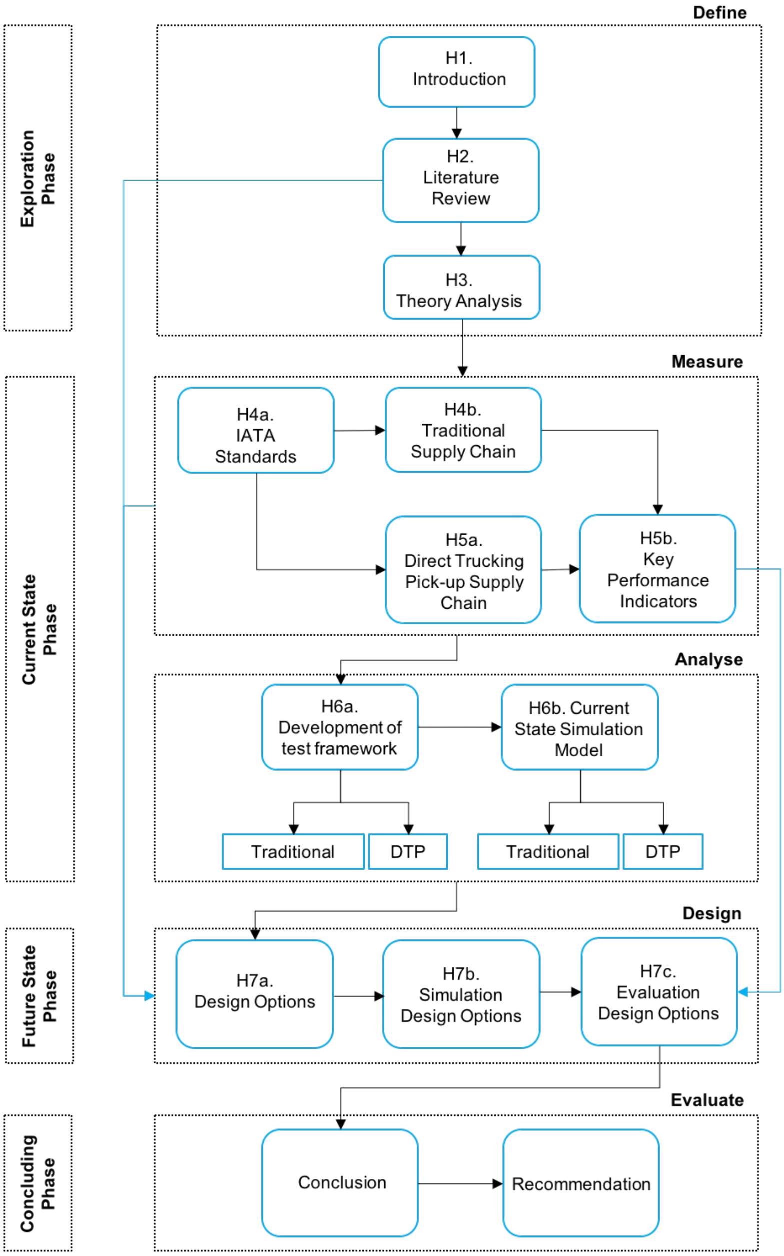


Figure 1.8: Research Outline

1.7.3 Expected Research Output

The expected research output is:

1. Insight in which research has already been performed in the air cargo industry, air cargo business models, seamless supply chains, hub-and-spoke structures and electronic data interchange.
2. Which methods can be used to measure, analyse and improve a seamless air cargo supply chain.
3. Case study for KLM Cargo for city pair Billund - Amsterdam.
4. Current process measurements and analysis of the traditional flow.
5. Current process measurements and analysis of the DTP flow.
6. KPIs will be designed to measure the air cargo supply chain.
7. A framework will be designed as test platform to simulate the traditional flow.
8. A framework will be designed as test platform to simulate the DTP flow.
9. Design options to improve the DTP supply chain.
10. Model implementation and simulation of design options.
11. Discussion of the contribution of this research to theory.
12. Discussion of the contribution of this research to practice.

1.7.4 Data Usage

A literature review was needed to be able to compare and analyse existing practices, applied in the logistic field, with the green field of this research. Literature can help to find and combine different concepts and theories that are not found in current individual reports. Literature was used to create a framework to design a seamless supply chain for DTP and to create a framework to function as a test platform to improve the supply chain. In addition, literature was used to gather more insight in the air cargo industry, hub-and-spoke structures, DTP service, integrated supply chains and supply chain management. Previous research at KLM was used to identify what had already been researched at KLM (not limited to cargo but also other departments with relevant processes or cargo). The most frequently consulted websites were Scopus, Google Scholar and the Delft University of Technology library. Because of the limited research within the aviation industry journals from outside the aviation sector were also considered.

As simulation and a case study were a key part of the research, literature related to these topics were also considered. When scientific literature was not available, limited or outdated, interviews were be conducted within the industry which were able to provide additional information. For the case study, the data bases of KLM Cargo were used to gather all required data for the research. Data that was unavailable, was measured during the research for a limited period of time or an educated assumptions was made, in consultation with KLM operational staff or management. During the case study, observations and measurements of the processes provided insight in the current situation.

2 Literature Review

In this chapter the context of the problem is described in more detail by means of a literature review. First, the literature approach will be discussed, focusing on the method used. Second, previous research performed by the Delft University of Technology is is presented. Followed by literature regarding the air cargo industry and the air cargo business model. Next a study is performed on supply chains, focusing on integrated and seamless supply chains. Finally the hub-and-spoke structure including RFS and electronic data interchange is discussed. In this chapter sub-research question 1 will be answered: *Which research has already been performed on the air cargo industry, air cargo business model, seamless supply chains, hub-and-spoke structures and electronic data interchange?*. The set-up of this chapter is shown in Figure 2.1.

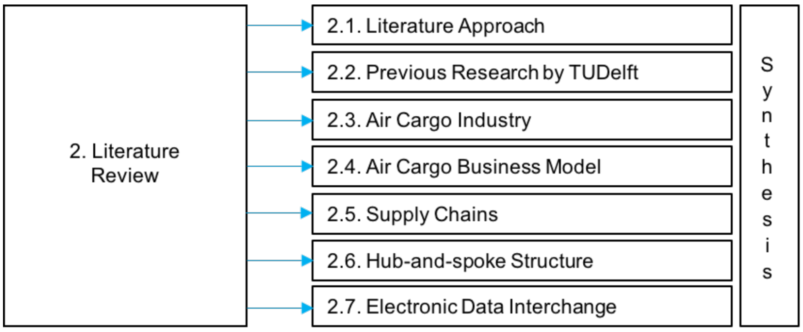


Figure 2.1: Chapter 2

2.1 Literature Approach

By using a literature review, also known as desk research, material produced by others is used (Verschuren & Doorewaard, 2010). A literature review will be conducting entailing that books, articles, conference papers and other publications will be reviewed. In addition also secondary data will be used. Using this data can save time and effort as a literature review is a quick way to obtain a large amount of data. Caution should be in mind when using the data, the purpose and biased data should be clearly identified. The literature sources can be found in online academic databases for scientific papers such as Scorpus, Google Scholar, ScienceDirect and the digital and hard copy library of the Delft University of Technology. Key words used for this research are: "air cargo" "business model", "supply chain", "seamless", "integrated", "ground handling agent", "direct pick up", "road feeder service", "integrators", "electronic data interchange", "IATA standards", "carriers", among others.

2.2 Previous Research by TUDelft

Previous research performed at KLM Cargo in the academic field include the redesign of the cool chain for air transport of perishable goods for KLM Cargo by (Voort van der et al., 2016), focusing on the supply chain of roses from Kenya to Amsterdam. (Bronsing et al., 2013) Used linear programming to minimize the cost for the cargo flow between the Menzies and KLM warehouses for KLM Cargo and Martinair Cargo. (de Vreede et al., 2015) Focused on enhancing the performance of the cargo acceptance process from a supply chain perspective for KLM Cargo, examining the acceptance process for export delivery at the hub in Amsterdam. In addition (Sickler et al., 2017) has researched the cargo value chain for KLM Cargo with regard to the acceptance process, trucking schedule and data communication for the trade lane Denmark Amsterdam for the traditional supply chain including the freight forwarding agent. For KLM Cargo (D'Engelbronner et al., 2012) researched how to provide a reliable and accurate forecast method for cargo handling demand at the KLM Cargo warehouse for export cargo.

Research performed by graduate students of the Delft University of Technology regarding the air cargo industry (outside KLM Cargo), include an analysis of the potential for more collaborative horizontal transport concepts at Schiphol to improve the inner airport truck transport by (Ankersmit et al., 2013).

Research has also been performed for a central pick-up and drop-off point for air cargo at Schiphol by (Donk van der et al., 2015). (Kallen et al., 2015) Researched the possibility of implementing a fast-track facility for cargo transshipment at Amsterdam Schiphol Airport as a possibility to facilitate the handling of the increasing cargo volumes in a limited area. (Tzimourtos et al., 2015) Modelled the global air freight transport to illustrate the demand and network flows. Concluding, non of the previous researches focused on RFS or DTP cargo flow.

2.3 Air Cargo Industry

Historically, most combination carriers (transporting both passengers and cargo) main business was passenger transportation, consigning the air cargo business to a secondary role (Rhoades, 2016). Over the years the market developed and the air cargo service providers began occupying the space left in the belly of the combination carriers. According to (Reis & Silva, 2016), (Allaz, 2004) researched that combination carriers often lack the means (e.g. know-how, technology and business model) to be competitive in the air cargo market. To be competitive, combination carriers need to invest in the cargo division. However, due to the secondary importance of the cargo division to combination carriers, such investments may not be affordable. As the belly space would otherwise be vacant, combination carriers are willing to accept the minimum margins on the cargo transportation to ensure the cargo business remains in operation (Reis & Silva, 2016). Wide-bodied passenger aircraft, have considerable spare hold space which, if used to carry freight can provide an additional source of revenue at marginal cost. (Doganis, 2006) confirms that the air transportation business is characterized by marginal profits and cyclical behavior. The maximum return on invested capital for passenger and combination carriers is seldom above 5% per year, which is below the weight average cost of capital and the returns in other competitive industries (Button, 1996).

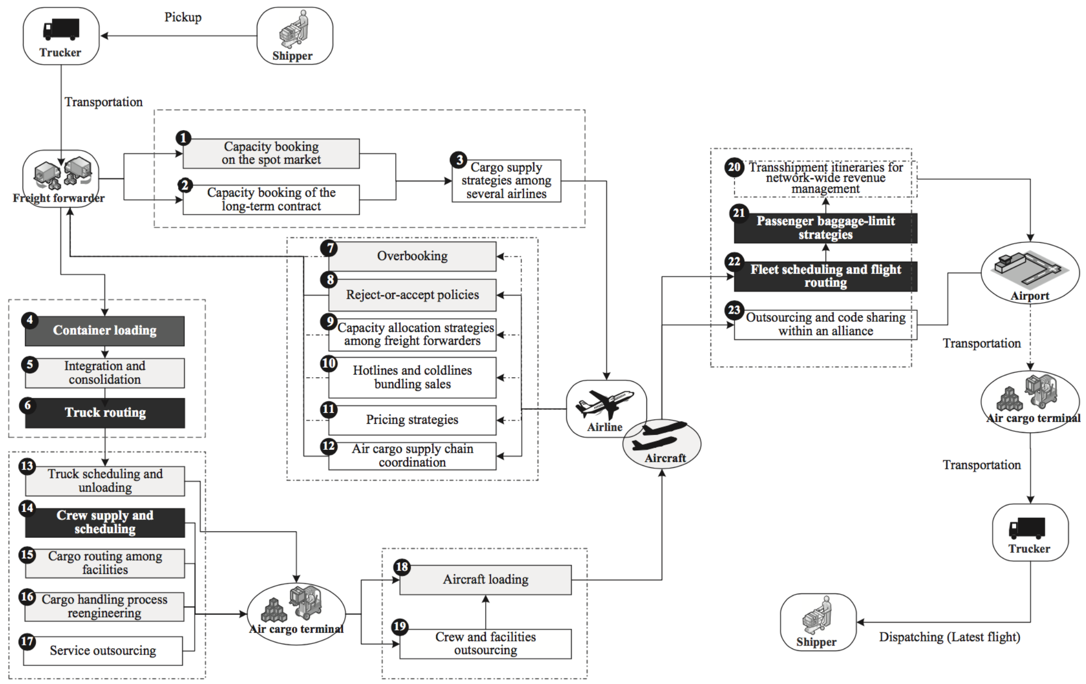


Figure 2.2: Air Cargo Operations: Process and State of Research (Feng et al., 2015)

Due to the small margins, combination carriers face the big challenge of managing their cargo operations efficiently. Strategic operation plans need to be developed to be able to adapt and respond in a timely manner to changes in the competitive environment (Nobert & Roy, 1998). Since the 1990's an increasing amount of scientific theoretical research has been performed to address the air cargo operations problems (Feng et al., 2015). However, most problems, real-world air cargo problems in particular, remain unsatisfactorily solved due to the complexities of the air cargo operations.

To categorize the various scholars, (Feng et al., 2015) has made a comparison between the research performed regarding theoretical models and real-situation problems. He has identified that often a case study is needed to prove the implementation of the theoretical models. (Walcott & Fan, 2017) agree that research regarding air cargo transport systems remain under-examined in both theory and case studies. For the traditional air cargo supply chain (Feng et al., 2015) has depicted the decision process for air cargo operations as illustrated in Figure 2.2. The shadowed rectangles indicate the degree to which the decision problems have been investigated. Dark grey indicate that the problem has been solved in literature with realistic situations. Grey that it has been examined in literature, but gaps remain between theories and realities and white indicates that the research areas are currently underdeveloped. An another way to categorize scientific research performed regarding the air transportation industry is by studying the changing interests of what academics publish. (Ginieis et al., 2012) categorized 1059 publications from 1997 and 2009 and concluded that the main topic often is management, airports followed by passengers, representing 29.7%, 21.6% and 11.9% respectively. No significant research was performed on air cargo operations, RFS or DTP operations.

Two of the topics that are both underdeveloped according to (Feng et al., 2015) are of importance to this research. First; for the integrated operations (Feng et al., 2015) highlights several gaps. He identifies that "truck scheduling coordination of cargo terminals and freight forwarders is an interesting research problem". DTP research is not mentioned at all in Feng's research and the freight forwarders can also be identified as a customer. This research will focus on the design of a seamless supply chain, aiming to allow for truck scheduling coordination. Secondly, he states that an integrated simulation model is needed to examine various control rules to maximize the performance of the service system. This research will contribute to this scientific gap as a framework will be developed to serve as a test-platform to aim for a higher arrival performance and therefore the performance of the service system can increase. Thirdly, (Feng et al., 2015) mentions that the integrated operations of the cargo terminal need to be modelled as a stochastic programming problem to minimize the waiting time and maximize the utilization of service facilities. With the simulation model presented in this research a stochastic test platform is developed and the waiting time and utilization of the service facilities can be determined for DTP trucks. The other topic that is relevant to this research is the air cargo supply chain coordination. Currently the most important players in an air cargo supply chain are the carriers and the forwarders. One of the main challenges for carriers is demand estimation and capacity planning. To improve this forwarders have to share their demand information, however this is in conflict with the forwarders' interest because it can encourage carriers to charge higher prices to forwarders and that a carrier works with multiple forwarders and forwarders collaborate with multiple carriers. This research does not focus on forwarders but the same problems exist with DTP for customers. This research will contribute to this problem with the design of a seamless supply chain in which information will be provided to the carriers on which a demand forecast can be based.

Another main development in the air cargo industry is the importance of just-in-time (JIT) logistics. Customers want their cargo to be transported as fast as possible for a reasonable price to the final destination. However, according to IATA (International Air Transport Association, 2016b), the main problems currently in the air cargo supply chain for customers are efficiency (reducing costs) and reliability. To be able to improve delivery performance freight forwarders and customers must plan and manage their routes more efficiently (Azadian et al., 2012). In case of DTP the task of the GHA is taken on by the carrier and the carrier must plan and manage the route more effectively. Often logistic disruptions arise in the air cargo supply chain. (Azadian et al., 2012) investigated the benefits of a dynamic (online) routing of a time sensitive air cargo on the air cargo network from an origin airport to a destination airport while accounting for real-time and historical information (e.g. delays, cancellations, capacity availability) to optimize a given shipment criteria (e.g. cost, delivery lead-time). For the DTP this research aims to design a seamless supply chain based on real-time and historical information to adapt the arrival performance and update the status for the on-time arrival for the connecting flight.

The transportation of large amounts of freight, both in volume and weight, over great distances is a complex business that involves many companies in the supply chain. This requires ongoing coordination between the various parties both for the physical movement of goods and for the management and exchange of information regarding the goods. To transport freight cross-border (internationally) adds an additional layer of complexity as additional regulations have to be taken into account, ranging from licensing requirements to customs and security regulations (Schwarz, 2006). As shown in Figure 1.3 many parties are involved in the traditional air cargo supply chain. To make the system work, the virtual networks of information exchange between the various parties is as important as the physical networks of airports, warehouses, trucks and airplanes. Traditionally the core function of a freight forwarder is to function as the intermediaries between the customer and the carrier. Most freight forwarders consolidate the cargo and coordinate the exchange of information between the two parties. Pure freight forwarders are non-asset-based firms, meaning that they neither own nor operate facilities or vehicles that deal with the physical movement of goods. Freight forwarders operate in the virtual space of information exchange and the corresponding information networks of the customers and carriers. They are (often) not involved in the direct exchange of goods.

As mentioned above, the air cargo industry operates in one of the more heavily regulated sectors of the global economy for flight safety reasons. These regulatory restrictions prevent quick adaptations in the form and scope of the business models in the air cargo industry as well as restructuring the industry itself. Many players in the industry view the restrictions as a major barrier to further global consolidation of the air cargo industry and require carriers and integrated express carriers to outsource many functions to local firms (Schwarz, 2006). The traditional model of air cargo transportation, as elaborated in Figure 1.3 has been challenged in recent years. The most visible change is that the freight forwarders, which traditionally has been a highly fragmented industry, have started to evolve from a pure non-asset model to operating their own trucking fleet and warehouses, to handle goods on the way to and from the airports (J. Bowen & Leinbach, 2004).

The processes of logistics outsourcing have been enabled by advances in IT. Information exchange and processing not only takes place across firms but also in various locations, across nations, in different socio-economic context and can function independently of the flow of goods. IT deployment theoretically enables more direct relationships, and information exchange between air carriers and customers. This results in bypassing forwarders who are the traditional intermediaries. However even though integrators have already adopted this business model and are selling directly to customers, the current market environment prevents combination carriers from bypassing the forwarders (Schwarz, 2006).

2.4 Air Cargo Business Model

The different air cargo business models for combination carriers have been studied by (Reis & Silva, 2016). He has studied 10 different combination carriers among whom Air France - KLM Cargo. From this study it can be confirmed that the main customers for combination carriers are intermediaries with as freight forwarders of general sales agents (GSA). It is estimated that freight forwarders control around 85% of the retail sales channels according to (Reis & Silva, 2016), (Azadian et al., 2017) and (Clancy et al. 2006). For general cargo (Hellerman, 2006) indicated an interval between 90% and 95% is controlled by freight forwarders. (Reis & Silva, 2016) identifies that the air cargo business has gained little attention from academics and the few studies that do, don't deal with business models.

(Reis & Silva, 2016) and (Dewulf 2014) identified five air cargo strategies: Basic Service Freighter (BSF), Full Service Freighter Operator (FSFO), Basic Service Combination Carrier (BSCC), Full Service Combination Carrier (FSCC) and Separate Profit and Loss Full Service Combination Carrier (SFSCC). According to (Reis & Silva, 2016) Air France - KLM Cargo is on the edge of the FSCC strategy and the SFSCC. This means that KLM Cargo as a carrier offers a medium range product differentiation (e.g. time definitive deliveries), with the services being sold by a professional sales team and a broader range of GSAs (Lobo & Zairi, 1999). The air cargo network (destinations) rely heavily on the passenger network, although independent cargo routes can be defined. Most of the cargo is carried in the passenger aircraft. Additionally, for specific cargo routes, ad-hoc chartered freighters can be hired or a small fleet of dedicated freighter aircraft may also be used (Reis & Silva, 2016). In the next subsections, the air freight networks and the integrator business model are discussed in more detail.

2.4.1 Air Freight Networks

For air freight, the carriers can be classified in 3 categories, the combination carriers, conventional all-cargo carriers and the integrated carriers. Several researchers have designed an organizational structure for the air freight network. The organizational structure designed by (Huang & Hsu, 2016) is similar to the structure designed by (Onghena et al., 2014) and a combination can be found in Figure 2.3. In the current models of air freight networks it can be seen that for combination carriers, all cargo must flow through the supply chain using the freight forwarder (indicated in orange) as a middle man.

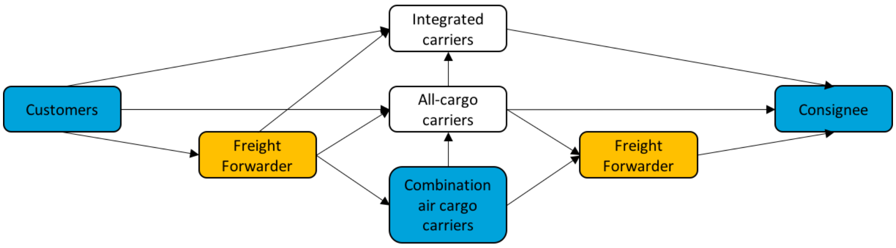


Figure 2.3: Organizational Structure of Air Freight - combination from (Huang & Hsu, 2016) and (Onghena et al., 2014)

The main shipments of the combination carriers come from freight forwarders, who consolidate the cargo from customers. For conventional all-cargo carriers and the integrated carriers the shipments may come from both the freight forwarders and the customers. The integrated carriers can provide door-to-door service independently. The integrated carriers have established an integral supply chain system by which they can provide a complete and prompt service for customers (Huang & Hsu, 2016). The non-integrated service providers, such as the conventional all-cargo carriers and combination carriers have to cooperate in order to deliver air cargo services from customer to consignee. The main reason why 90% is transported via freight forwarders while integrators have the experience and know-how to deliver door-to-door is the fact that this is only cost effective for shipments less than 70 - 150 lbs (Azadian et al., 2012).

An important trend is that the boundaries between the different segments of the air cargo industry are blurring. This has led to increased competition but also cooperation between market players of different segments (Onghena et al., 2014). It is important for the combination carriers to consider how to deal with future competition. KLM Cargo is a combination carrier and according to the existing models, combination carriers only receive shipments from customer through freight forwarders. However, with the trend of the boundaries blurring, it is important to consider the customers delivering the cargo directly to the carrier, introducing DTP. According to the existing models this is not a possibility jet. This scientific gap will be explored in this research.

2.4.2 Integrators

As identified in Section 2.4.1 the current organizational structures for air freight lack the possibility for customers to directly deliver cargo to the carrier, this has to be executed through freight forwarders. However, a large competitor according to market share of combination carriers, integrated carriers are able to transport cargo directly from customer to consignee. Currently, integrators only account for a small fraction of the total airfreight volume (5 - 10%) (Azadian et al., 2012). They are able to deliver door-to-door and therefore are inspirational for the DTP design.

The air cargo market is heterogeneous consisting of different sub-markets, such as general air freight, air express and postal services. Currently, there are only four companies that are fully integrated across all transport modes: FedEx, UPS, DHL and TNT Express (Onghena et al., 2014). Integrators are situated at the intersection of all 3 sub-markets and therefore able to control all aspects of a logistics service. This means that they compete and cooperate with all the actors in these 3 sub-industries. Combination carriers such as KLM Cargo are involved in general air cargo industry and the postal services industry.

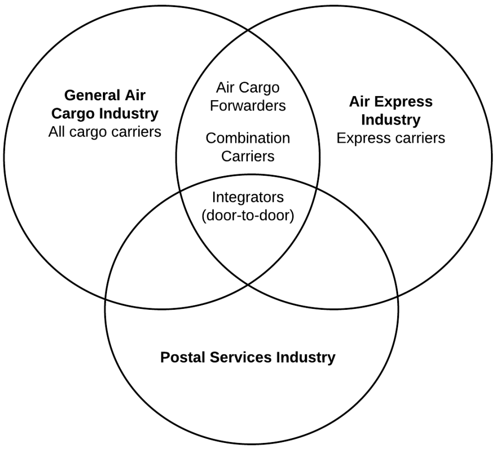


Figure 2.4: Cargo Industries (Onghena et al., 2014)

2.5 Supply Chains

As identified in the previous Section 2.4.1, the non-integrated service providers, such as the conventional all-cargo carriers and combination carriers have to cooperate with freight forwarders in order to deliver air cargo services from customer to consignee. As KLM Cargo (a combination carrier), relies on collaboration through the supply chain, this chain must be investigated. To start with the definition, Supply Chain Management (SCM) is the management of the flow of goods which includes the movement and storage of raw materials, work-in-process inventory and finished goods from point of origin to point of consumption. The term supply chain management was introduced by Keith Oliver in an interview for the Financial Times in 1982 (Laseter & Oliver, 2003). Oliver wanted to develop a vision which aimed at penetrating the functional silos within the various departments of the company. Production, marketing, distribution, sales and finance had to closely cooperate to generate a step-function reduction in inventory and simultaneous improvement in customer service. The distinction between supply chains and supply chain management is that the former is something that exists (often referred to as a distribution channel), while the latter requires management efforts by the organizations within the supply chain.

Supply chain and supply chain management have been defined by many scholars (Monde la & Masters, 1994), (Stevens, 1989), (Houlihan, 1988), (Cooper et al., 1997) and (Arnold, 2000). The definition of a supply chain used in this research will be: "*a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer*" (Mentzer et al., 2001). Three degrees of supply chain complexity are identified by (Mentzer et al., 2001). First of all the 'direct supply chain, as illustrated in Figure 2.5'. Secondly, the 'extensive supply chain' as illustrated in Figure 2.6. Thirdly, the 'ultimate supply chain', as illustrated in Figure 2.7). A direct supply chain consists of a company, a supplier and a customer involved in the upstream and / or downstream exchange of products, services, finances and / or information. An extended supply chain includes suppliers of the immediate supplier and customers of the immediate customer, all involved in the upstream and / or downstream exchange of goods and information. An ultimate supply chain includes all the organizations involved in all the upstream and downstream flows of goods from the ultimate supplier to the ultimate customer (Mentzer et al., 2001). The ultimate supply chain illustrates how complex supply chains can be. KLM Cargo currently is developing from a extensive supply chain towards an ultimate supply chain. KLM Cargo is outsourcing tasks to external companies, such as trucking and handling. However, to remain competitive, this thesis researches the possibility to reduce the number of parties involved and aiming towards a DTP (Direct) supply chain.

Figure 2.5: Direct Supply Chain - adapted from (Mentzer et al., 2001)

Figure 2.6: Extended Supply Chain - adapted from (Mentzer et al., 2001)

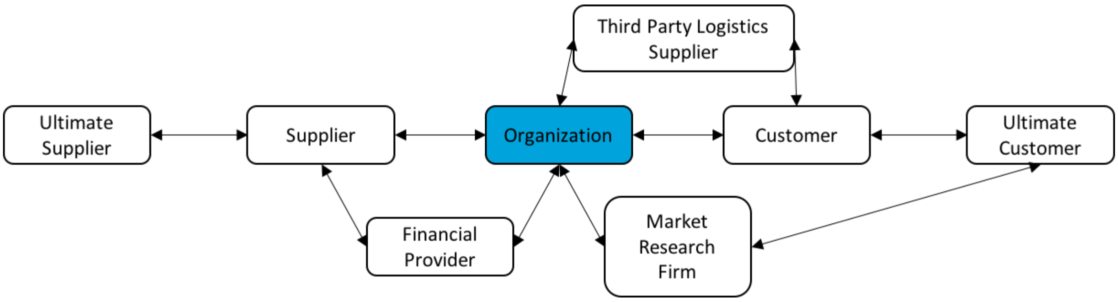


Figure 2.7: Ultimate Supply Chain - adapted from (Mentzer et al., 2001)

In Section 2.3 it was determined that the air cargo is heavily influenced by its international regulatory environment. (Schwarz, 2006) described it as a complex business that involves complex transportation systems. These systems require coordination, information exchange and information processing on a high level. To make the system work, the virtual networks of information exchange between air cargo firms are as important as the physical networks of airports, warehouses, trucks and airplanes. Therefore air cargo supply chain can be characterized by being highly asset specific (Jong de & Beelaerts van Blokland, 2016). The actions performed in the supply chain are a combination of physical (technical) and information (administrative, such as certification, registration, regulation, compliance) actions. Due to the fact that the air cargo industry has to comply with all IATA set regulations (International Air Transport Association, 2016a), the processes, assets and components are asset specific for reasons of safety. According to (Arnold, 2000) the definition of asset specificity is that the assets can be used exclusively in the air cargo transport industry. (Williamson, 1981) identifies three kinds of asset specificity, namely site specificity, physical asset specificity and human asset specificity in his theory of Transaction Cost Economics (TCE). Williamson's TCE theory will be described in more detail in Section 3.2.2. First in the next two sections, a seamless supply chain and supply chain trends will be discussed in more detail.

2.5.1 Seamless Supply Chain

In Section 2.5 different types of supply chains were introduced. This subsection describes how to arrive at a seamless supply chain. For creating a seamless supply chain, supply chain management is needed. (Lambert & Cooper, 2000) identify that supply chain management is a new way of managing the business and its relationships. The main business processes in the supply chain must penetrate the functional silos within the individual companies and the various corporate silos in the supply chain. This results in business processes evolving to supply chain processes that are linked across intra-and inter-company boundaries. According to (Thomson, 2016) silos happen when departments either can't or won't easily share information with other departments. As a result departmental priorities supplant the company's long term goals. For most companies, mission-critical dependencies on suppliers are essential to competing successfully. For example, it's hard to share demand forecasts and share demand changes to suppliers when working in silos. Impaired communication between suppliers and the business leads to poor supply visibility, slow or stalled innovation, weak collaboration and increased risk of unexpected events such as missing delivery deadlines. This phenomenon is also known as the 'silo-mentality'.

The relationships built in a supply chain are characterized by long term relationships that require considerable strategic coordination. According to (Mentzer et al., 2001) single companies have to address: commitment, interdependence, key processes, leadership, organization compatibility, top management support, trust and vision. To achieve supply chain management three or more companies with a supply chain orientation (SCO) mentality are needed. The SCO mentality is defined as " the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in a supply chain" by (Mentzer et al., 2001). The SCO mentality can be enhanced by cooperation, focus, information sharing, integration of key processes, inter functional coordination, long-term relationships, shared risks and rewards, similar customer service goals. If all this is in place, this can lead to lower costs, improved customer value, customer satisfaction and a competitive advantage. In this research this is defined as a "**seamless supply chain**". Where the flow of goods and information flows seamless between the different parties and / or individuals in the cargo value chain.

This definition of a seamless supply chain is confirmed by (Martichenko, 2013), who identifies a seamless supply chain as a system of interconnected and interdependent forces that operate in unison to accomplish overarching supply chain objectives. They identify several key principles to accomplish an overarching supply chain:

- Eliminate all waste in the supply chain.
- Include all parties in the supply chain.
- Reduce lead time.
- Create flow level (leveling the flow of material and information).
- Use pull systems.
- Increase velocity and reduce variation.
- Collaborate and use process discipline with all parties in the supply chain.
- Focus on total cost of fulfillment.

2.5.2 Supply Chain Trends

According to (Schmidt et al., 2013) there are several developments in the air cargo industry among which; wider geographical sourcing and distribution, vertical disintegration of production, speed of product flow, increased direct deliveries and disintermediation, smaller and more frequent shipments, e-commerce and cost awareness.

Over the past decades a wider geographical sourcing of supplies and distribution of finished products has emerged. As transportation costs become cheaper, the deregulation of the transport industry and the opening of free trade zones and regional trade agreements products are shipped all over the world (Hummels, 2007). Although cost advantages can be made through global shipping, many hidden costs and issues appear such as transportation and logistics, customs and tariffs, currency risks, quality issues and a need for higher inventory levels as well as variable lead times (Yu et al., 2008). As companies are more vulnerable to supply chain risks they might diversify their sourcing and distribution strategies for each product (Christopher, 2011). For the air cargo industry this implicates that products that were formerly transported by plane are now transported by truck, resulting in the emerging of new trade lanes. For KLM cargo this implicates that more cargo is expected to be transported from Denmark to the rest of the world with Amsterdam Schiphol Airport as a transit point.

The vertical disintegration of production refers to the fact that business focus on their core competencies by specializing and gaining scale advantages. Therefore the number of production steps is increasing. Vertical disintegration increases the number of upstream and / or downstream parties (Schmidt et al., 2013). This is also confirmed by (Mentzer et al., 2001) with his theory regarding the ultimate supply chain as illustrated in Figure 2.7.

In an era where time is money, customers want their cargo to be transported as fast as possible to its destination. During the 1990s several supply chain principles such as JIT, lean and agile logistics were introduced for the improvement of ICT systems and integration decision making. Goods such as components or parts are most time-sensitive. Every extra day in transit represents an ad-valorem tariff of 0.6 - 2.3% according to (Hummels & Schaur, 2012). This trend can be observed within KLM Cargo. Were traditionally parts would be shipped via a GHA, customers are now interested in directly transporting their goods to gain competitive time and monetary advantages.

Due to the advancement and integration of information and communication technologies providers offer more door-to-door transport services. As a result of the direct deliveries in the process, carriers can bypass the middle-men in the traditional supply chain, in the case of the air cargo industry, the GHA, and distribute goods directly to consumers (Gunasekaran et al., 2002). This is also known as vertical integration. Vertical integration is a strategy where a company expands its operations, for example when a company also owns its supplier. Vertical integration can reduce costs, improve inefficiencies by reducing transportation costs and reducing the turn around time (Investopedia, 2017). In the traditional air cargo supply chain the GHA handled the cargo on behalf of the carrier. The GHA is in this case the supplier of the carrier. For the DTP supply chain, the carrier performs the handling activities themselves within their own warehouse. Therefore this can be seen as a form of vertical integration, namely backwards vertical integration, where the company takes over the activities upstream the supply chain.

2.6 Hub-and-Spoke Structure

Large carriers often operate the cargo network via hub-and-spoke networks, meaning that cargo is consolidated in a location other than the hub (called outstation) and transported via a direct link to the hub. An outstation is defined as a point of pick-up and delivery while a hub is a point of consolidation. In this research the business model including the GHA, using the traditional line-haul trucking will be referred to as the traditional model. (Lin et al., 2012) identified that eliminating outstation-to-outstation direct loads results in saving in transportation costs as economies of scale can be obtained.

To transport freight efficiently, air carriers bundle the shipments that are delivered to the outstations before transporting them towards the hub (Rezaei et al., 2017). There are three options for bundling freight, on ‘through unit load devices’ (T-ULD), where all freight for the same connecting flight at the hub are build, on ‘mix unit load devices’ (Mix-ULD), where freight for different flights at the hub are build based on connecting time to the connecting flight (short connection time is ‘hot’, long connection time is ‘cold’), and loose freight in trucks. Advantages of transporting cargo on pallets is that it reduces the time needed to load and unload the trucks and lowers transport and storage costs (Rezaei et al., 2017).

2.6.1 Road Feeder Service

In recent years, air freight is also transported by road. This is called “forwarder trucking”, “line-haul” or “direct-delivery”. Often the road-transportation is a substitution for freighter or combined flights, also called “airline trucking”, “road feeder service (RFS)” or “trucked flights” (Heinitz et al., 2013). The trucks and freight are transported under a published flight number. Trucking air freight is often performed for secondary airports or fragmented markets, where the weekly amount of consignments may not reach the quantity threshold justifying the costs of (extra) aircraft operations. These markets are therefore dependent on stable, cost-effective, frequent trucking connections to an air cargo hub (Heinitz et al., 2013). Often carriers perform both flights and trucks, with trucks being able to transport the (over-)capacities, and customers wanting to pay a lower kilogram rate for their freight. According to the Boeing World Air Cargo Forecast Team, the truck flight frequencies in Europe have grown steadily at a 2.2% increase each year over the past 10 years and is expected to keep this pace for the next 15 years (Boeing World Air Cargo Forecast Team, 2017). Limited research has been performed regarding RFS. Research regarding RFS has solely focused on truck routing such as (Derigs et al., 2011) Vehicle Routing Problem (VRP) model. Developments in RFS have great potential to change dramatically over the next decades due to technology developments such as wireless communication, cloud computing, sensor devices and vehicle electronics, all in the field of Electronic Data Interchange (EDI). According to (Liang et al., 2016) a new integrated goods transport system based on optimized logistics, real-time traffic information, vehicular communications, collaborative driving and autonomous vehicles are the future. These developments are all related to information technology in the transportation industry. This research will contribute to the information technology development regarding the specific branch of RFS, DTP.

The main difference between expeditors’ forwarding for airport access / egress and RFS, is that in RFS a trucking company is trucking between a GHA or forwarder and the hub, on behalf of the air carrier and for the forwarding companies it is their own responsibility. Another difference is that RFS operates as carrier-exclusive, as an integral part of the carriers’ timetable and will thus become part of the route-search on time space graphs (Heinitz et al., 2013). According to (Selinka et al., 2016) the movements by service can be divided as shown in Table 2.1.

Table 2.1: Air Freight Breakdown by Movements by Service (Selinka et al., 2016)

Service	% of truck movements
RFS Scheduled	58.5
RFS Ad-hoc	21.4
Export by forwarder	7.5
Import by forwarder	12.6

In the business model as identified by (Reis & Silva, 2016) in Section 2.4 the aspect RFS is highlighted. He states that all strategies either have an own RFS or a subcontracted form of RFS. They are common in the domestic and continental market. For FSCC / SFSCC (such as Air France - KLM Cargo) the RFS may also take place in other countries or continents. According to the business model, the SFSCCs offer their customers extensive global connections alongside their involvement in cargo operations (i.e. customized cargo services), responding to specific needs. KLM Cargo is on the edge of evolving from an FSCC to an SFSCC, however to become an SFSCC they have to offer their customers extensive global connections and customized cargo services. One of the customized cargo services is the offering of the DTP service. Currently there is no business model for this service and therefore this research will focus on developing a seamless supply chain for DTP.

One of the scientific gaps identified by (Heinitz et al., 2013) is that there is a “lack of publicly available data differentiating between freighter and truck operations”. In addition (Heinitz et al., 2013) identifies that the air cargo demand assignment problems covering the entire transport chain are rarely stressed in the available literature. Furthermore, carrier network problems are often studied excluding the demand side, thus avoiding the demand assignment problem. Therefore this research will perform an exploratory case study at KLM Cargo to gain data insight in the direct truck operations.

2.6.2 Direct Trucking Service

To the best of our knowledge, literature on DTP in the air cargo industry is not yet available. (Patel et al., 2006) has researched the optimal air cargo pickup schedule for a single delivery location. He identified that this is a stochastic problem with random flight arrival times, random custom clearance times and random travel times. His models can be used to determine the optimal pick-up times for manufacturing companies for single delivery location. This is equivalent to the Direct To Agent (DTA) trucking, where the cargo is directly delivered to an agent instead of picked-up from a customer. (Patel et al., 2006) states in his research that, to the best of his knowledge, this problem has not yet been studied in literature.

(Azadian et al., 2012) studied an unpaired pickup and delivery problem with time dependent windows from a perspective of the freight forwarding agent. The freight forwarding agent is responsible to simultaneously select air cargo flight itineraries and schedule the pickup and delivery of customer loads to the airport. In practice DTP operates via the same principle, however the freight forwarding agent is not included and these tasks are performed by the carrier. Customers want reliable cargo transportation that ensures safe arrival of the goods at the destination for a reasonable price. All other operational concerns they leave to either the GHA or in the case of DTP to the carrier itself. In the traditional model GHAs are responsible for the pickup and delivery of customers' loads, which is often performed by a fleet of hired trucks (Azadian et al., 2017). Carriers operate via the same principle, where the collecting of the freight is outsourced to a third party. Continuing, (Azadian et al., 2017) mentions that when the load to be collected at the customer is less-than-truck-load (LTL), which is a common case for air cargo, consolidating loads of multiple customers in a single truck trip provides an opportunity to reduce logistics costs. When a LTL truck load is needed carriers often use the traditional supply chain via the GHA, who consolidates all cargo on behalf of the carrier. However, if a full-truck-load (FTL) can be shipped directly from the customer, it is more cost effective to directly ship the cargo to the hub, to eliminate the 'external' handling cost to be paid to the GHA and the number of transactions performed.

The problem of pickup and delivery problems (PDP) have been studied by (Berbeglia et al., 2007). The PDP can be divided in many-to-many problems, one-to-many-to-one problems and one-to-one problems. The DTP problem is classified as a one-to-one problem, where the load can be picked up from a customer location and can only be delivered to one delivery location associated with the customer. One of the one-to-one problems is the Vehicle Routing problem with Pickup and Delivery with Time Windows (VRPPDTW), where visiting a pickup or delivery location is only allowed during a predefined time window. DTP has time window constraints as a certain slot time is allocated to the truck at the customer for loading and the truck has a given slot time at the hub for unloading. However, these problems are mostly vehicle routing problems addressing the problem of optimizing the truck, while this research addresses designing a seamless supply chain for DTPs. Therefore it can be concluded that currently no research has been performed regarding the design of a seamless supply chain for DTPs.

According to the local conditions of Air France KLM Martinair cargo from 1 November 2017 (AirFrance KLM Martinair Cargo, 2017) the customer can be either a customer or a representing agent. For further research there is no significant difference in the air cargo industry if cargo is collected from a customer or a representing agent, both allow for DTP. Therefore from this moment onward, no differentiation shall be made between a customer and a freight forwarder and this party shall be named customer.

2.7 Electronic Data Interchange

As identified in Section 2.6.1 EDI is developing at a fast pace in the air cargo industry. The introduction of internet and implementation of modern information systems have a great effect on the way the air cargo industry operates (Lobo & Zairi, 1999). Traditional faxes and paper documentation is replaced by business-to-business e-commerce and electronic data interchange systems (Schwarz, 2006). For integrators such as UPS or FedEx, the internet has enabled a seamless integration of information flows into the transportation process. EDI allows for customers to receive real-time booking, pricing and tracking information. Real-time allows for information updates when irregularities and / or delays occur. In an era where time is money, customers increasingly demand visibility from their logistic provider. Many companies are working with JIT systems and lean operations, which requires them to react quickly to unforeseen events. Integrators have the ability to use EDI on a large scale as all elements in the chain are owned by them, allowing their own system to talk with itself. However, for a carrier, the parties in the chain are numerous, allowing various difficulties in compatibility between systems of the different customers, freight forwarders, GHA's and carriers. In Appendix E EDI used in the air cargo industry is explained in more detail.

EDI is important for the adoption of certain business models such as JIT logistic systems. As EDI has gradually been introduced in the industry and now has a widespread adoption by the trade community.

Port communities can now offer advanced data-handling and processing systems as well as providing their core competency of good-handing facilities (Wrigley & Clarke, 1994), as will be explained in the next section.

2.7.1 Levels of EDI Adoption EDI

EDI is often applied as ports want to gain a competitive advantage over each other. Ports support the physical and information flow of goods and compete with each other on effectiveness, efficiency and adaptiveness of their systems. Existing customers are only loyal if the service is satisfactory (e.g. cargo tracking and real-time information) and communications are available with their systems. Ports want to attract repeat business from loyal customers and new business from existing and new customers. Customers base decisions on which port or carrier to use on a wide range of attributes including port charges, speed of entry, supporting infrastructure etc. (Wrigley & Clarke, 1994).

Ports can be differentiated from each other on several variables; control, resource consumption and time. Control means that the port can provide flexibility in cargo movements and surveillance of the goods flow. Real-time tracking, the knowledge of the physical location of goods and the status of goods (for example temperature) is important to customers. Resource consumption refers to costs of labour efforts to handle the goods. High costs are often induced by routine processing of information flow and especially by the very high levels of exception handling. EDI can assist by providing applications that can reduce the transaction costs. The efficiency of the routine work and exception handling can be increased as well as reducing the occurrence of exception handling. Finally, time refers to the period that goods are restrained from moving because either physical or information processing delays.

In this research the transactions are separated in physical and information transactions. From a physical perspective the ports can differentiate by offering base services, value-added services or superior services. If the port only offers the traditional physical transit services it is called base services. If additional physical services such as repair, testing and customized assembly are offered it is called value added services. A port can also aim to offer superior services by adopting high standards in quality and costs. A superior services port attracts transshipments and intermediate processing of goods which would otherwise pass through other ports closer to the point of origin. From an information perspective a port can choose to place greater emphasis on support for information exchange. If data can pass reliable, accurate, quick and cheap it is called base-services. For value-added services support document flow, management of databases and end-to-end support from consignee to consignee can be offered. If ports offer clients to handle their data which relates to goods passing through other ports it is called superior services (Wrigley & Clarke, 1994). In Table 2.2 an overview of the various strategies can be found.

Table 2.2: Strategic Framework - adapted from (Wrigley & Clarke, 1994)

	Base services	**Value added services**	**Superior services**
Physical aspect	Physical transit point	Physical logistics point	Physical logistics hub
Data aspect	Data transit point	Data logistics point	Data logistics hub

2.7.2 Advantages of EDI

EDI refers to the exchange of information, data and documents in a standardized electronic form, preferably in an automated manner. The application supporting one business sends it to an application supporting its trade partners business. Some important characteristics of EDI are:

- An electronic transmission medium (e.g. e-AWBs) is used rather than physical media (e.g. paper AWBs).
- Standards, structures and formats for messages can be determined such that all messages can be translated, interpreted and checked for compliance by different systems of various companies.
- The time between sending and receiving decreases significantly for electronic documents.
- Information does not have to be manually re-entered in the system, reducing the error-rates and manual labour.
- The information can be directly processed by the application software.

EDI becomes more important in the air cargo industry and poses several advantages compared to the traditional paper and fax communication. As the purchase and movements of goods and services across national boundaries, also known as international trade becomes more important open and acceptably quick communications among the many partners is required. Historically, the effectiveness and efficiency of a port's physical good movement determines by the ability to attract business away from the competition. EDI offers effective and efficient communication channels among the many partners for relatively low cost. In addition, EDI offers the advantage of reduced data capture volume and error-rates resulting in time and cost savings. The cost of trade can be reduced by streamlined clearance mechanisms and real-time cargo tracking allows for speed and reliability (Wrigley & Clarke, 1994). As the competition between carriers increases, the information systems become key elements in their strategic positions. Advantages of EDI include that internal efficiencies can be gained but also that new trade is attracted. EDI's direct impacts are to reduce the amount of data capture, transcription and the delay between dispatch and receipt of messages. These generally result in a decreased incidence of errors, less time spent on exception-handling, and fewer data caused delays in the business process. Benefits can be gained in: inventory management, transport and distribution, administration and cash management.

In the important characteristics of EDI is stated that standards, structures and formats can be determined. Communications and document standards become available, these value-added information services can be categorized in two classes:

1. The acknowledgement, creation, delivery and processing or information.
2. Additional services such as maintenance of databases including cargo tracking, cargo tagging, customs clearance, financial services, movement schedules, notifications on cargo arrival and hazardous and controlled goods, traffic statistics and resource availability.

2.8 Synthesis

This chapter aims to provide more insight in the scientific problem context by answering the sub-research question: *Which research has already been performed on the air cargo industry, air cargo business model, seamless supply chains, hub-and-spoke structures and electronic data interchange?*

The **air cargo industry** has seen the cargo market grow from a side business to a profitable industry (Reis & Silva, 2016). (Feng et al., 2015) has categorized literature according to the number of published papers and has identified several research gaps. For cargo transportation some research has been performed, mostly with regard to RFS, however research is lacking in the field of DTP. (Walcott & Fan, 2017) state that research regarding cargo transport systems remains under-examined in both theory and case study. According to (Heinitz et al., 2013) there is a lack of publicly available data differentiating between freighter and truck operations. Moving large amount of freight over great distances is a complex business that involves many firms and requires ongoing coordination between them with respect both to the physical movement of goods and to the management and exchange of information (Schwarz, 2006). The cargo industry is largely influenced by its international regulatory environment, it is one of the more heavily regulated sectors of the global economy (J. Bowen & Leinbach, 2004). This supply chain can therefore be characterized by being highly asset specific (Jong de & Beelaerts van Blokland, 2016). The actions performed in the supply chain are a combination of physical (technical) and information actions.

In the current **air cargo business models** all cargo is delivered via a freight forwarder for combination carriers. Forwarders control around >85% of the retail channels for general cargo (Reis & Silva, 2016), (Azadian et al., 2017), (Hellberg & Sannes, 1991). In the existing organizational cargo structures there currently is no direct link from customer to combination carriers (Huang & Hsu, 2016) and (Onghena et al., 2014). The boundaries between the different segments of the cargo industry are blurring (Onghena et al., 2014) showing the need for research regarding the green field of the DTP model, researched in this thesis. Integrators, performing direct deliveries, currently account for 5 - 10% of the air cargo freight volume (Azadian et al., 2012). In an era where time is money, customers want their cargo to be transported as fast as possible. Every day extra transit represents an ad-volorem tariff of 0.6 - 2.3% (Hummels & Schaur, 2012). With DTP, KLM Cargo wants to compete with the integrators gaining time and monetary advantages. To be able to do this a **seamless supply chain** must be designed. The key supply chain business process must penetrate the functional silos within the company and the various corporate silos in the supply chain (Lambert & Cooper, 2000). A seamless supply chain is a system of interconnected and interdependent forces that operate in union to accomplish overarching supply chain objectives (Martichenko, 2013). A result of the direct deliveries is that carriers can bypass the middleman in the traditional supply chain and distribute directly to the customers (Gunasekaran et al., 2002). This results in savings in transportation costs as economies of scale can be obtained (Lin et al., 2012).

Electronic Data Interchange is developing at a fast pace in the air cargo industry. The rise of internet and spread of modern information systems have deeply affected the operations (Schwarz, 2006). EDI's direct impacts are to reduce the amount of data capture and transcription and the delay between dispatch and receipt of messages. These generally result in a decrease incidence of errors, less is time spent on exception-handling, and fewer data caused delays in the business process. The measurable variables are time, resource consumption and control. The objective for EDI applications is to reduce the transaction costs through improving the efficiency of routine work and of exception handling, but also through reducing the incidence of exceptions (Wrigley & Clarke, 1994).

In the literature review several scientific research gaps were identified with regard to a seamless supply chain for DTP in the air freight industry. Below a list of the identified gaps is provided:

1. In the existing organizational structures of cargo delivery the structure for direct delivery from the customer to a combination carrier is missing. (Huang & Hsu, 2016), (Onghena et al., 2014).
2. Missing publicly available data differentiating air from truck operations (Heinitz et al., 2013).
3. Lack of academic research in the air cargo business and it's models (Reis & Silva, 2016).
4. Cargo transport systems research is under-examined (both theory and case-studies) (Walcott & Fan, 2017).
5. Under-examined truck scheduling coordination for cargo terminals (Feng et al., 2015).
6. Missing integrated simulation models to examine various control rules (Feng et al., 2015).
7. Lack of information sharing within the supply chain (Feng et al., 2015).
8. Missing real-time shipment status updates and how to deal with logistic disruptions (Azadian et al., 2012).

3 Theory Analysis

In this chapter, the theory analysis will be presented. First, the theory approach will be presented followed by the supply chain process improvement theories and the research methodologies will be discussed. In this chapter sub-research question 2 will be answered: *"Which methods can be used to measure, analyse and improve (seamless) supply chains?"* The set-up of this chapter is shown in Figure 3.1.

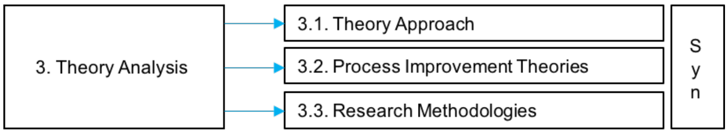


Figure 3.1: Chapter 3

3.1 Theory Approach

According to (Dul & Hak, 2008) a step-wise approach to research is needed, as displayed in Figure 3.2. Step 4 Research strategy is discussed in this chapter. Several possible research strategies (experiment, survey, case study) are evaluated and as a result the research strategy is determined. It is important to find a fit between the research strategy and the specific research objective as introduced in Chapter 1. According to (Dul & Hak, 2008) several research strategies exist among which, exploration, theory testing, theory building, hypothesis testing, hypothesis building and descriptive research.

Below a short description of each type of research is presented. In this research an exploration approach is used, namely collecting and evaluating relevant information about TCE in a case study at KLM Cargo to assess how this can contribute to the development of TCE.

1. **Exploration**: Information regarding theory and practice is collected and examined in order to assess how research can contribute to theory development.
2. **Theory-building research**: Based on evidence gained from observing a number of instances of the object of study, a new proposition is formulated.
3. **Theory-testing research**: Propositions are tested.

Figure 3.2: Stepwise Research Approach - according to (Dul & Hak, 2008)

3.2 Process Improvement Theories

This section aims to explore different methods to create solution alternatives that can lead to improvements in the air cargo supply chain and identify the main elements used in these methodologies. First a definition of a process is stated as: *"Processes are relationships between inputs and outputs, where inputs are transformed into outputs using a series of activities, which add value to the inputs"* (Aguilar-Saven, 2004). The most popular process improvement methodologies include Business Process Re-engineering (BPR), Continuous Process Improvement (CPI), Total Quality Management (TQM) and Organizational Transformation (OT). These process improvement methodologies are often used in the manufacturing industry, service industry, medical industry (Cima et al., 2011) (Mason et al., 2014) or for aviation in the engineering & maintenance department. For the air cargo industry, especially with regard to the information flow the implementation and the effect of process improvement theories studied are limited.

To improve processes in a business is essential for business development, management of change and quality improvement. In its basis, business process improvement consists of process mapping and analysis, resulting in greater understanding of the process and possible re-design (Bendell, 2005). Many different methodologies are known with the purpose of Process Improvement. A (non-exhaustive) number of these methodologies are: Lean, Six Sigma, Lean Six Sigma, Total Quality Management, Theory of Constrains, Statistical Process Control, Agile, Critical Path Method, Phase-Gate and Critical Chain. In Appendix A the various methods are discussed and compared. Lean manufacturing and TCE are identified as suitable theories for this case study and the reason why they are suitable and more details will be described below.

3.2.1 Lean Manufacturing

Lean manufacturing emerged from the Ford production plants. Henry Ford started with focusing on activities that are of value for the customer and therefore eliminating activities that were non-value added to the customer. Lean became famous by Toyota in Japan and the Toyota Production Systems and was made known to the world by (Womack et al., 1991) with their book: “The machine that changed the world”. The Lean philosophy is to improve the production process by eliminating waste, unnecessary actions, reduction of variability, JIT production, single piece flow and linking processes that create value. (Bendell, 2005) provides a clear definition of what it means to use lean:

“Lean (...) is the systematic pursuit of perfect value through the elimination of waste in all aspects of the organization’s business process. It requires a very clear focus on the value element of all products and services and a thorough understanding of the Value Stream”.

Overall, lean is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and should therefore be eliminated. Value is defined as any action or process that a customer would be willing to pay for. For the original design of the lean organization for the manufacturing industry, (Womack et al., 1991) identified the following five core principles. The 7-types of waste that are identified with non-value adding to customer value are arranged according to the acronym TIMWOODS. The original Toyota system ‘Lean’ is designed for manufacturing, however the air cargo transportation supply chain is a non-manufacturing supply chain. Therefore (Martichenko, 2013) has translated the 7 steps of waste for manufacturing in 7 steps of waste for the supply chain. If all waste is eliminated from the supply chain so that only value remains this will result in a seamless process.

Core principles Lean

1. The elimination of waste.
2. The identification of the value stream.
3. The achievement of flow through the process.
4. Introducing pull.
5. Achieving continuous pursuit of perfection.

7 Types of waste

1. **T** - Transport: unnecessary movement of product.
2. **I** - Inventory: holding places for unnecessary inventory.
3. **M** - Movements: inactive goods.
4. **W** - Waiting & delays: excessive wait times.
5. **O** - Over production: human effort - activity that does not add value.
6. **O** - Over processing: system complexity - extra, additional, unnecessary, steps and confusing processes.
7. **D** - Defects: containers that transport air or allow damage.

KLM Cargo is seeking for options to enhance the current supply chain performance by reducing cost and time for the shipment process, which can be done by minimizing waste according to the lean manufacturing method. To identify the wastes in the supply chain, a through analysis of the current air cargo supply chain will be needed to identify the current performance and the wastes which is done in Chapter 4.

The expected performance that the Lean principle can have on the air cargo supply chain is:

1. More visibility in the air cargo value chain: more transparency.
2. Cost savings due to reduction of non-value adding processes.
3. Shorter through-put-times.
4. Reduction of human-errors, higher quality of service (QoS).
5. Being flexible to change.
6. Less inventory costs (inventory, warehousing).

Application of Lean

Many companies and organisations have been studied from the lean thinking perspective, among whom in the aerospace industry: KLM Engineering & Maintenance (E& M), Fokker Aerospace, Alenia, Rolls-Royce, Stork Fokker AESP, Airbus Hamburg, Eurocopter. In the air cargo sector lean thinking is still in its infancy. It is interesting to apply the lean thinking to the air cargo industry as it is a very complex industry with many actors, development of automization is lacking compared to other industries and according to some actors there are many possibilities for innovation. Lean implementation is often measured using KPIs such as inventory, on time performance, throughput time and work in process. Lean implementation can lead to elimination of defects, reduction of production and development costs, reduction of cycle time and inventory levels, increased profit margin and improved customer satisfaction (Jong de & Beelaerts van Blokland, 2016).

However, regarding this research the lean indicators are insufficient to describe the entire air cargo industry system. A financial economic perspective taking fixed assets into account is still missing. As described in Chapter 2, the air cargo industry is characterized as a highly regulated industry with numerous fixed assets. Therefore in the next section the TCE theory will be studied in search of additional KPIs to compliment the lean indicators for the study of air cargo transportation systems.

3.2.2 Transaction Cost Economics

TCE is a method used as a theory for vertical integration. The TCE theory has been used in the aerospace industry for the APU maintenance (Jong de & Beelaerts van Blokland, 2016). However, it has not yet been studied in the air cargo industry. Therefore in this thesis an in-depth case study using the TCE theory will be performed. As identified in the previous section, lean manufacturing does not cover the financial economic perspective of transactions. Therefore the TCE theory will be used complementary to lean in this research.

TCE originates from John R. Commons in 1934 who proposed that the transaction is a basic unit of economic analysis (Williamson, 1981). Commons identified that the exchange of goods and services between technologically separable entities can be influenced by it's governance. Following Ronald Coase in 1937 recognized that the boundary of the firm is a decision variable for which an economic assessment is needed. Earlier in 1931 Karl Llewelyn already identified that transactions come in many forms and sometimes counteract firms instead of contributing to their purposes. In 1979 Williamson proposed the theory on TCE with his publication "Transaction Cost Economics: The Governance of Contractual Relations (Williamson, 1979). Williamson's initial contribution emphasized the benefits of vertical integration, the final message was that different kind of transactions need different kind of governance structures. Williamson defines a transaction as:

"A transaction occurs when a good or service is transferred across a technologically separable interface".

In accordance with the stated definition of a transaction, in this thesis the practical definition of a transaction used is when one stage of activity terminates and another activity begins. An economic transaction can best be explained by the comparison with mechanical systems. Efficient mechanical systems are systems where friction and loss of energy are minimized. The economic counterpart is to ensure that parties involved in the exchange operate harmoniously (Williamson, 1981). It is important to minimize misunderstandings and / or conflicts in transactions that can lead to delays, breakdowns and other malfunctions in the system. (Williamson, 1988) identifies three critical dimensions for transactions. First, uncertainty; second, the frequency with which the transactions recur and third, the degree to which durable, transaction specific investments (asset specificity) are required to realize least cost supply. The TCE theory focuses on these dimensions by studying the comparative costs of supply chain management (planning, adapting, monitoring tasks) under alternative governance structures.

TCE combines the disciplines contract law, organization theory and economics, introducing the transaction, economic and financial perspective (Williamson, 1986). According to (Williamson, 1981) the most important assumptions with this theory are that humans are subject to bounded rationality and that some agents are given to opportunism. Of the three dimensions; uncertainty, recurrence and asset specificity this thesis will focus on asset specificity. Only recurrent transactions are of interest for this research, as each shipment has to travel through the air cargo supply chain, with numerous shipments transported on a yearly basis, this recurrent transactions. Uncertainty is unavoidable in the air cargo supply chain as many parties are involved. (Williamson, 1986) positions asset specificity as the most critical dimension. Therefore this research will focus on asset specificity with uncertainty and frequency taken into account but studied in less detail.

The issue with asset specificity is that large fixed investments are needed but also that these investments are specialized to a particular transaction (called transaction idiosyncrasy). According to (Williamson, 1981) there are three types of asset specificity, namely site specificity, physical asset specificity and human asset specificity. Asset specificity in the air cargo supply chain is present in the site specificity, building and special tooling. These are all directly related to the quality and safety standards of the product set by the air cargo industry. A transaction can have low- or high asset specificity. If a transaction has low specificity, it is often for a simple transaction, little information has to be exchanged (Arnold, 2000). In case of high asset specificity, much and complex information and / or products have to be exchanged, before, during and after the exchange of goods (Arnold, 2000). This results in high market transaction costs. Goods and services with high specificity cannot be used on other transactions without huge additional costs. For the air cargo industry the processes and services are highly regulated by the airline and air cargo authorities for safety reasons and can therefore be classified as having high specificity.

Transactions are necessary for a system to generate value and they can take place randomly. Therefore to introduce the uncertainty, frequency and specifications of the transaction, the KPIs can be tested using discrete event simulation. In Section 3.3.6 the discrete modelling theory will be described in more detail.

3.3 Research Methodologies

In this section several research methodologies, which will be used in this thesis are described. First the case study is described which was build based on field research and interviews. The method of interviews will be described next in the subsection survey research. Based on literature identified in Chapter 2 constraints are identified. These constraints are compared with the observations gained from field research as presented by a swimlane of the current state. Following the swimlane diagram will be simplified and turned into a value stream map, where the each of the transactions as identified in the swimlane will be grouped according to the accompanying stakeholder (who are identified in Appendix C.). These methods are used for a specific case study, namely for the trade lane Billund - Amsterdam. Finally, the VSM diagram is digitalized into a Discrete Event Model for experimentation. Each of these research methodologies will be elaborated below.

3.3.1 Case Study

For the exploratory case study the research methodology of (Verschuren & Doorewaard, 2010) is used, in combination with the research methodology of (Dul & Hak, 2008). There are two types of case studies, practice-oriented case studies and theory-oriented case studies (Dul & Hak, 2008). The practice oriented case studies aim to describe the design options, implementation, evaluation and / or usefulness of a theory approach for a specific situation and / or company. The theory-oriented case studies aim to build theory by studying numerous instances of the topic that is studied. In this research a combination of both theories is used as described in Section 1.7. The aspect from practice-oriented case studies is to describe design options for a specific situation and company but the implementation phase is not executed (D,M,A,D phases as described in Section 1.7). In these phases theories will be used, without the aim of contributing to the development but to use them in practice (such as Lean Manufacturing, Six Sigma etc.). The aspect from theory-oriented case studies used is a contribution to the development of the TCE theory. This aims to build the theory by exploring both the traditional model and the DTP model as object of study (phases D,D,E in Section 1.7). The TCE is used complementary to the Lean methodology to identify KPIs for the air cargo industry. In addition to specifying the unique distinction in TCE in the form of the information and physical aspect.

The case study is performed using several methods, such as questioning (interviews), field research (observations of transport / handling processes as well as the study of documents). Using as case study a deep insight into the problem at hand can be gained, taking into consideration all its aspects. The researcher will gain a profound insight into the way various processes take place, and the reason why they develop in one way instead of another.

3.3.2 Survey Research

A survey is a type of research in the course of which the researcher tries to gain an overall picture of a comprehensive phenomenon spread out over a stretch of time and / or space (Verschuren & Doorewaard, 2010). The survey research is used to design the scenario's that will be presented in Chapter 7. Information that can not be gained from the survey research is gathered by questioning. According to (Verschuren & Doorewaard, 2010) questioning can be classified into two categories poll and interview. The latter will be used in this research and can also be divided into two categories; by telephone and face-to-face. Interviews will take place face-to-face and with individuals and with groups. The most open way of interviewing will be used, where a list of questions are prepared but the option to interact with the interviewee remains open. Depending on the response, the interviewer can create new or additional questions during the interview.

3.3.3 Constraint Identification

Constraints can be formed by may different drivers. The drivers are based on Total Quality Management and Lean Six Sigma as discussed in Section 3.2.1 and in more detail in Appendix A. An overview of these drivers is shown below. In Chapter 4 the applicable constraints in case study on the air cargo supply chain of KLM Cargo are identified through measurement and observation.

1. Defects
2. Environment
3. Flow
4. Inventory
5. Machine
6. Man
7. Material
8. Measurement
9. Method
10. Motion
11. Over processing
12. Over production
13. Transactions
14. Transport
15. Waiting time

3.3.4 Swim Lane Diagram

A swimlane is a flowchart, which shows a process from start to finish. At the same time the swimlane divides the steps in functional areas to distinguish which departments or employees are responsible for each set of actions. Each lane represents a different area of responsibility or department. Each step or process in the swimlane indicated by a block is listed in chronological order in its appropriate lane. It is important to gain knowledge about which department is responsible for which process to speed up the process of correcting inefficiencies and eliminating delays. A swimlane can help to clarify responsibilities and gain insights for departments in what activities other departments perform. Swimlanes are created for the booking process, customer process, GHA process and the hub process. By describing the processes and parameters, a complete picture of the air cargo value chain for both the traditional and DTP flow arises. This combination enables to identify problems or 'wastes' in accordance with Lean Manufacturing.

3.3.5 Value Stream Mapping

Value Stream Mapping (VSM) is part of the Lean theory and was introduced in 1999 with the publication of the book *Learning to see - value stream mapping to create value and eliminate muda* (Rother & Shook, 1999). Within VSM, "value" is defined as a capability provided to a customer of the highest quality, at the right time and at an appropriate price (thus what the customer buys) (Atieh et al., 2016). VSM is a planning tool to optimize results and eliminate waste.

What is Value Stream Mapping

VSM is used for a quick analysis of product flows through a manufacturing system from raw material to delivery. VSM is a tool for visualization, analysis and redesign of the supply chain. The end product is a single-page map that graphically illustrates all processes in the current state of the system under study (Hines & Rich, 1997). In Section 3.3.4 the swimlane theory was described. The difference between a swimlane, which describes the complete activities of all companies involved and the VSM is that the VSM only includes the specific parts of the company that adds value to the system under study. VSM can be used for any enterprise to become lean. For visualization VSM uses a flow chart with symbols known as "the language of lean". Visualising the flow of materials and information, companies gain insight into their processes. An overview of the symbols used and their meaning is explained in Appendix A. VSM is often used when localized improvement events are not enough and analysis is needed to provide vision to connect all improvement activities (Atieh et al., 2016).

VSM is used in many industries. (Leite & Vierira, 2015) provided an overview about the creation, principles, evolution, and practices of the lean philosophy oriented to the services sector. Regarding the air (cargo industry) VSM has been used in aircraft maintenance (kumar Kasava et al., 2015). Elimination of aircraft services costs, flow and speed of service delivery, and creation of a service experience for customers (Leite & Vierira, 2015) and air transport service by (D. Bowen & Youngdahl, 1998). In this thesis VSM is used to map the current state of the air cargo supply chain based on the swimlane earlier designed. A VSM has been designed for the standard traditional air cargo value chain and for the DTP air cargo value chain.

Simulation supporting VSM

VSM is a tool for analysing the value flows. It's strengths are: fast, easy to perform, cheap, no special tools or computer programs required, simple, easy to learn, easy to understand, solid basis for discussions and decisions, increases understanding of the customer, can often be performed directly with the people involved in the system (Solding & Gullander, 2009). However, VSM also has some weaknesses, starting with it's manual nature. A VSM creates a static model out of observations and evaluations of the processes within a system. It only gives a snapshot of the situation at one specific moment in time. Therefore it a VSM can not be used to study a dynamic problem. VSM is a simplification of the real situation and can only be generated for one flow at a time. Finally, due to it's static nature it is difficult to experiment with new systems and layouts when designing improvements.

Therefore many researchers aim to enhance VSM with a complementary tool to handle uncertainty and the model dynamics. Many researchers used simulation to enhance VSM. Using this combination more than one product can be analysed at a time and a real-time view of the system can be generated. Simulation can be used to make VSM dynamic and provide a way to explore various opportunities of process improvements and the impact of the proposed changes before implementation. A dynamic VSM can assess the differences between the current state and future state but can also identify all areas that need improvement. A dynamic VSM (combination of traditional VSM with discrete event modelling) has been used by (Abdulmalek & Rajgopal, 2007) studying a large integrated steel mill, (Mcdonald et al., 2002) for a manufacturing plant and by (Parthanadee & Buddhakulsomsiri, 2014) for the coffee industry. In this thesis research a swimlane will be constructed of the current situation. Following a simplification of the swimlane in the form of a VSM will be generated, creating a static tool as with a snapshot of the current situation. Finally the static VSM will be enhanced with discrete event modelling to create a dynamic tool to serve as a test platform for the air cargo industry.

3.3.6 Discrete Event Simulation

In this section the selection for the discrete event simulation modelling software is described. The objective of this research is to *Determine the criteria to propose a framework for a seamless air cargo supply chain, from a transaction cost perspective, focusing on the DTP supply chain and apply this framework at KLM Cargo to improve the DTP performance.* The proposed framework has to be tested using a test platform. This will be done using Simio as a modelling tool. In this section the modelling type, used software tool, discrete event simulation theory, as-is and to-be models and the combination of value stream mapping and discrete event simulation modelling is described.

Modelling type and used software tool

To start modelling, first the correct type of modelling and software platform have to be chosen. A simulation modelling approach is selected to make it possible to experiment (easily) with the air cargo system. If the experiments are to be implemented in the real operation, the disturbances for the processes of the hub will cause large impositions. In addition it will be very expensive and time consuming to experiment in real life example as all the personnel and operations need to be informed when to perform which activity. Also, it may not always be possible to describe the system mathematically. A system is a set of related components that work toward some purpose (Kelton et al., 2011). To gain understanding of the system a model of the system is used. Many types of models exist, such as physical models (e.g. wind tunnel testing with airplanes), analytical models (mathematical representations) and simulations. Computer simulation is the imitation of a system or an operation and its internal processes and transactions. A simulation is performed over a certain time and in appropriate detail to draw conclusions about the system's behavior (Kelton et al., 2011). Model simulations are often used for the design, emulation and operation of systems.

Two types of simulations exist, they are either stochastic of deterministic. A stochastic simulation introduces randomness in the system to represent the variation. Deterministic models have no variation. There are two main types of simulation, discrete and continuous, which refers to the changing nature of states that describe the system. Queuing lengths and occupation of assets can only change at discrete points in time (called event times), while other states such as pressure in a tank or temperature in an oven can change continuously over time. Continuous systems are defined by differential equations that specify the rate of change. For discrete systems four modelling paradigms have evolved, event models, process models, objects and agent-based models.

For this research it is chosen to use simulation opposed to an analytical model. For analytical models the system is expressed as a set of equations that describe how the system state changes over time. These equations are solved using algebra and calculus (White & Ingalls, 2009). The result is often a general, closed-form solution, which gives the state at any given time as a function of the initial state, the input and model parameters.

Due to the fact that an air cargo handling hub handles processes in a (discrete) queuing manner a discrete event model is chosen for simulation.

1. Trucks are loaded one-by-one at the customer.
2. Trucks are unloaded one-by-one at the GHA.
3. Cargo is handled one-by-one at the customer and the GHA.
4. The documents are handled one-by-one at the GHA.
5. ULDs are build one-by-one at the GHA.
6. Trucks are loaded one-by-one at the GHA.
7. Documents in Amsterdam are handled one-by-one.
8. Physical acceptance of cargo in Amsterdam is handled one-by-one.

Simio is selected as the modelling tool as it is a multi-paradigm tool that combines the event-, process-, object- and agent based models. Simio allows for simulating complicated systems.

Discrete Event Simulation Theory

Discrete event simulation theory consists of a software package that performs actions on the environment of a system. These actions are based on inputs, which cause changes in the initial conditions of the system. This is called a state, a state influences the output of the simulation. Summarizing the inputs cause changes in the system state and these are reflected by changes in the output (White & Ingalls, 2009). Below a short description of all the elements that can be found in the simulation tool Simio are described:

- **Entities**: The inputs are represented by the arrival of entities. These entities flow through the system and change the system state variables. An entity can represent anything that can cause a state change (transactions, physical objects, people and / or information) (White & Ingalls, 2009).
- **Attributes**: Entities can have attributes, characteristics of a given entity that are unique to that entity.Attributes are critical to understand the performance and function of entities in the simulation.
- **Activities**: Activities are processes and logic in the simulation. There are three major types of activities that can occur in a simulation: delays, queues and logic.
  - **Delay activity**: A delay activity occurs when the flow of an entity is suspended for a definite period of time.
  - **Queue activity**: A queue activity occurs when the flow of an entity of suspended for an unspecified period of time. Entities can be waiting for resources to become available or for a certain system condition to occur.
  - **Logic activity**: Logic activities allow the entity to effect the state of a system through the manipulation of state variables or decision logic (White & Ingalls, 2009).
- **Events**: Events are conditions that occur at a point in time which cause a change in the state of the system. An entity interacts with activities to create events.

- **Resources**: Resources represent anything in a simulation that has a constraint capacity. Resources are time-shared by entities, entities must queue for busy resources and entities are typically delayed after seizing a resource. Common examples of resources are workers, machines, nodes etc.

The software package of discrete event simulation works with a random number generator. The random number generator allows the software to generate a random number between 0 and 1. Often this random number generator is a pseudo random number generator meaning that each time the order of the random numbers is the same unless the seed is changed. The random number generated will be used to sample random distributions to generate values. For each run in the simulation, called an iteration or replication, a random number will be generated.

As-is and To-be models

For the current state an "as-is" model will be developed in Chapter 4 for the traditional model and Chapter 5 for the DTP model, to understand the current situation. The "as-is" model is a description of the system of the current situation in such a way that the kind of system and its behavior can be studied and understood. The validity of the model, if it is conform reality should be checked. In Chapter 7, the "to-be" model will be designed to understand new situations. The description of new situations for the system is useful to specify alternative solutions to the problems perceived, analyse potential solutions and to explain and demonstrate favourable alternatives to the problem owner. The 'as-is' and 'to-be' models and the in-depth modelling approach are described in more detail in Appendix F. In Figure 3.3 the relation between the "as-is" model and the "to-be" model is briefly shown. In the next chapter, Chapter 4 the "as-is" model will be developed for the current state of the traditional flow, followed by the "as-is" model of the DTP flow in Chapter 5. The "to-be" model will be developed in Chapter 7.

1. Problem identification and specification.
2. Validation.
3. Diagnose problem.
4. Pre-evaluation.
5. Evaluation.
6. Search for solutions.
7. Choice and implementation.
8. Post evaluation.

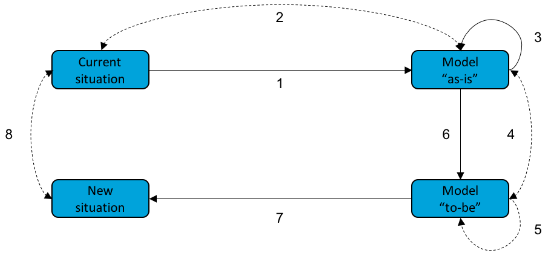


Figure 3.3: Relation between "as-is" and "to-be" model - adapted from (Verbreak, 2015)

3.4 Synthesis

In this Chapter the sub-research question *Which methods can be used to measure, analyse and improve seamless supply chains?* was answered. This chapter explored several process improvement theories and research methodologies. The process improvement theories used for this research are:

1. Lean manufacturing
2. Transaction cost theory

The research methodology used for this research are:

1. Case study
2. Survey research
3. Swim lane diagrams
4. Value stream mapping
5. Discrete event modelling

The relation between theory and the set-up of this thesis is displayed in Figure 3.4. Based on literature study the lean manufacturing method will be used as process improvement theory as explained in Chapter 2. As lean manufacturing does not cover the transaction cost perspective, transaction cost economics theory will be used complementary to lean to identify additional KPIs. Based on theories such as lean manufacturing, six sigma and total quality management several constraints are identified. A case study will be performed where a swimlane is developed and all the constraints are identified. The case study consists of field research and survey research for both the traditional flow and DTP flow. The swimlane will be simplified and generated into a VSM. As the VSM is a static tool it will be enhanced with discrete event simulation to generate a dynamic VSM able to explore various opportunities of process improvements and their impact.

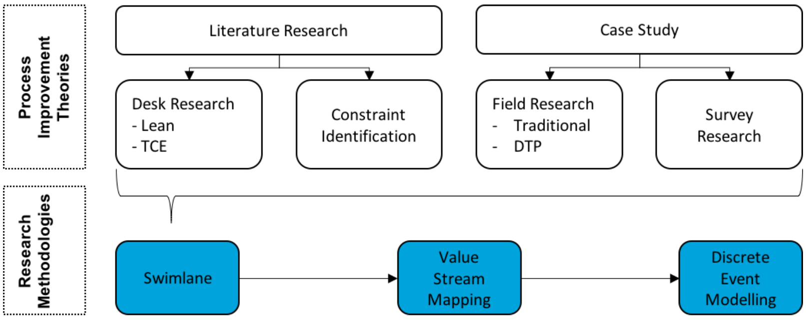


Figure 3.4: Theory Synthesis

Part II

Measure

4 Traditional Air Cargo Supply Chain

This research seeks to contribute an as-is analysis of air cargo road transport, with a focus on the DTP supply chain. A model representation of the entire traditional and DTP supply chain will be developed and tested. In order to design the physical and information aspect of the seamless supply chain for air cargo, it is necessary to have a common and clear business process and standards. In this chapter, first the measurement approach is explained followed by the selection of the case study Billund - Amsterdam. Next, the IATA industry standards are discussed. Finally, the traditional air cargo supply chain case study is performed. The three sub-research questions that will be answered in this chapter are: *Which stakeholders are involved in the process and which are most critical?*, *How is the current traditional export cargo flow organized and what is the performance?* and *What are the bottlenecks for the current traditional export cargo flow?* The set-up for this chapter can be found in Figure 4.1

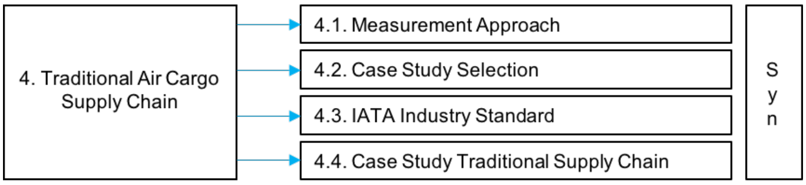


Figure 4.1: Chapter 4

4.1 Measurement Approach

This section describes in short the measurement approach:

1. First, by means of literature study and interviews a high-level flow has been determined for the city pair of Billund (DK) - Amsterdam (NL)
2. Second, the various high-level processes have been analysed in more detail by visiting the various parties. Field research has been performed at the customer DSV, customer Schenker, GHA Cargo Center Billund (CCB) and the Amsterdam Schiphol Airport hub. During this field research the steps in the swimlane were identified by means of observations and interviews. The swimlanes designed for each party can be found in Appendix D.
3. Third, the swimlane diagrams are generalized and combined to form one single integrated swimlane for traditional line-haul trucking (as introduced in Section 1.4.2. The swimlanes illustrate the level five, transactions between the different parties and processes during the cargo journey. The swimlanes are digitalized and discussed with various employees and managers from different departments to validate the current processes. To strengthen the swimlane diagrams a cargo journey for the traditional lane has been made in Appendix D.
4. Fourthly, based on the swimlane, several processes have been grouped together to design a VSM. The details describing the combination of several processes is described in Appendix D. For the VSM, the time needed to perform (a group of) processes are measured based on data base analysis, interviews, observations and measurements. KLM data set of 1 year was used to digitalize to generate a dynamic VSM diagram. From these measurements a time distribution or average process time has been determined. The data is validated by employees of KLM as described in Section 6.7. The data is analysed using Matlab.

4.2 Case Study Selection

According to (Dul & Hak, 2008) there exist several types of case studies as described below. In this research a parallel single case study will be researched. For DTP 2 single case studies are studied and compared with the case study of the traditional flow. The selection of the case study is described below.

1. **Comparative case study**: a small number of real life cases are selected and the measurements are qualitatively analysed.

2. **Parallel single case study**: a number of single case studies are simultaneously tested for the same design option without each of them taking into the outcome of the other.
3. **Serial single case study**: Each single case study does take into account the outcome of the previous tests.

Currently, KLM Cargo transports most cargo from Europe towards the hub in Amsterdam using the traditional supply chain business model. DTP is only performed when convenient for the customer. The practical problem statement as described in Chapter 1 is that: “it is unknown what the theoretical performance of DTP is and the advantages and disadvantages that can be gained by employing DTP” compared to the traditional model. In this section an overview of the current traditional model performance is provided. The performance of the traditional model can be compared to the DTP model performance as described in Chapter 5. However to compare both models, a case study has to be selected.

First all locations from where both traditional flows and DTP flows for KLM Cargo are employed have to be mapped. KLM has 84 locations from where DTP was performed in 2016, either structurally or ad-hoc as shown in Figure 4.2. Structural DTP is a service which transports goods directly from the forwarder to the hub on a structural basis, this is a re-occurring daily, weekly or monthly event. For a measurement period from 1 January 2016 - 01 September 2017 the top 5 origins for DTP in terms of weight (kg) of cargo are displayed in Table 4.1.

Table 4.1: Top 5 DTP locations 2016-2017

#	Origin	Abb.	Country	Weight [tons]
1	Billund	BLL	Denmark	3704
2	Stockholm	ARN	Sweden	2641
3	Frankfurt	FRA	Germany	2588
4	Copenhagen	CPH	Denmark	1805
5	Helsinki	HEL	Finland	1485

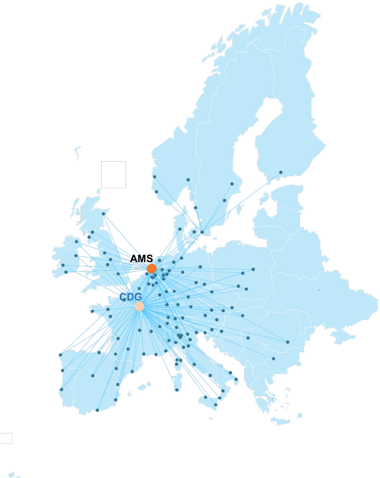


Figure 4.2: AFKL Trade Lanes

For the case study selection several criteria were taken into account:

1. Station must have both traditional and DTP flow.
2. DTP must be a structural DTP flow.
3. A significant amount of cargo must be transported to have sufficient data points.
4. For KLM Cargo the origin is stated as the nearest network point, however, the pick-up address must be situated within 25 km range from the network point. Therefore the origin must be from 1 or 2 large customers and not from numerous smaller customers.
5. Collaboration of customer to participate in this research.

Based on these criteria, the station Billund (BLL) was selected. The traditional cargo flow for Billund goes through the GHA: CCB. For the DTP flow, Billund has the most transported weight in tons over the measurement period originating from two major customers located near Billund. Stockholm, ranking as second in Table 4.1, is identified as unsuitable for the case study as the freight transported originates from numerous smaller customers and therefore multiple case studies would be needed, which is unfeasible in the dedicated research period. Frankfurt would haven been a suitable study, however, Frankfurt is in a different market than the other top four locations, inducing different local conditions, rules and regulations. The two major customers in Billund are ‘DSV Air and Sea’ (from this moment onward referred to as DSV) and ‘Schenker Air and Sea’ (from this moment onward referred to as Schenker).

4.3 Stakeholder Analysis

In this section the sub-research question: *Which stakeholders are involved in the process and which are most critical?* will be answered. According to (Enserink et al., 2010) stakeholders are: *“those parties that have a certain interest in the system and / or that have some ability to influence that system either directly or indirectly”.* In Appendix C an extensive stakeholder analysis is performed (adapted from (Sickler et al., 2017)) including problem formulation, criticality- and depencencies- and actor inventory is performed. The power interest matrix constructed in the appendix is presented below in Figure 4.3.

The stakeholders that are classified as key players are the stakeholders that will be used to develop the swimlanes.

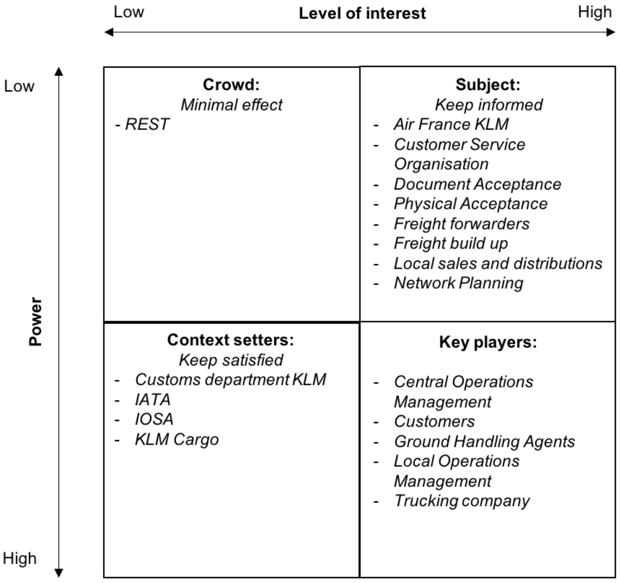


Figure 4.3: Power Interest Matrix of the Stakeholders

4.4 IATA Industry Standard

In Appendix B the IATA industry standard is described in Section B.4. IATA is the International Air Transportation Association and determines in collaboration with all parties in the air cargo industry the standards. They have developed a master operating plan (MOP) in which all the responsibilities of each party are elaborated. For this research the first 13 steps of the MOP are used and explained in Appendix B. An interesting observation is that KLM Cargo operates different from the industry MOP. In the MOP the parties involved in the industry are forwarder for booking the cargo, GHA for handling and loading the aircraft, carrier for transporting the cargo and GHA at destination to receive the cargo. KLM Cargo operates with a hub, where they perform GHA activities themselves, but only for cargo originating from Amsterdam. Cargo origination from Europe is accepted by a GHA at origin and the hub only serves as a transit point.

4.5 Case Study - Traditional Supply Chain

The air cargo value chain in the traditional perspective can be divided into 6 high level steps as shown in Figure 4.4. First, the customer wants to transport a piece of cargo. Second, the freight forwarder consolidates the various pieces of cargo from different customers and makes a booking with a carrier. Third, the freight forwarder transports the consolidated cargo to the GHA. Forth, the GHA accepts on behalf of the carrier the cargo. Fifth the carrier sends a truck to collect the cargo at the GHA. Sixth, the carrier transports the cargo towards the hub and loads it on the connecting flight.

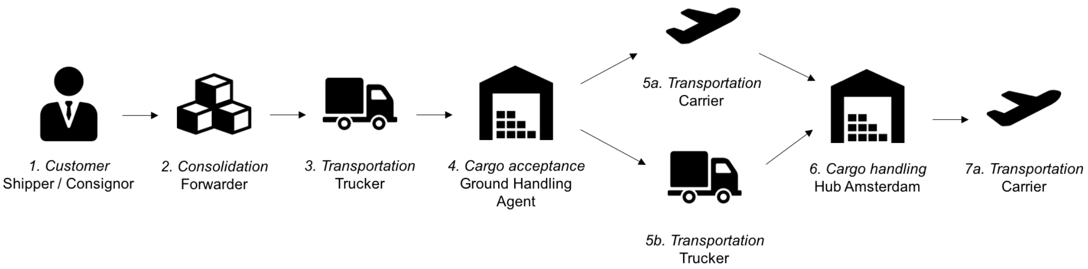


Figure 4.4: Traditional Air Cargo Supply Chain

4.5.1 Swimlane

For the case study of the traditional model the various steps are studied in detail by performing field research and interviews at several parties (as described in Chapter 3. For this research the research parties are: DSV, Schenker and CCB in Denmark, Jan de Rijk logistics and the KLM Cargo hub at Amsterdam Schiphol Airport. The entire "as-is", current state flow processes has been identified and are presented by making use of a swimlane. As described in Section 3.3.4 a swimlane is a horizontal lane in which all activities performed by an actor or department are shown. The critical stakeholders are the key players as identified in Figure 4.3 in Section 4.3, are located on the left side of the swimlane. Each step as illustrated in Figure 4.4 is classified in a 'swimming lane' as presented in Figure 4.5.

The processes performed by each stakeholder have been classified in physical cargo processes (indicated in orange) and information processes (indicated in green), which leads to a clear roadmap for both the physical cargo flow and the information flow. To indicate a physical transaction between two processes a normal arrow is used (e.g. a paper / document / package is physically transported for the process). To indicate a digital transaction between two processes a striped arrow is used (e.g. information is send by a computer system). In addition, the processes in which a manual action from an employee is needed is indicated in blue, an action that has already been performed (double action) in the chain in yellow, and a repair action in red. The various milestones in the process are visualized by pink triangles. These milestones are used to measure the on time performance (OTP) of the cargo. The full traditional air cargo supply chain journey is presented in Appendix D.

Figure 4.5: Swimlane Traditional

4.5.2 Value Stream Mapping

In this section the VSM is designed based on the swimlane presented in Figure 4.5. The VSM is a simplification of the swimlane diagram. This simplification is justified in the meta-model as described in Section 6.3.2. This simplification is possible as the individual steps are taken into account using the TCE theory, as introduced in Section 3.2.2. Using the TCE theory, the transactions are classified in information transactions and physical transactions as shown in Figure 4.5. Section D.3 describes in detail how each of the blocks (processes), in the VSM diagram presented in Figure 4.6 are selected based on the swimlane. The blue color in the VSM diagram represents the general process both involving the physical flow and the information flow. After reporting, the two flows split and from there green represents the information flow and orange the physical flow. Below the VSM diagram the duration of each process is indicated. The average of each duration is stated, as in reality there is the distribution of the duration is significant due to the uncertainty in the system depending on the varying number of packages / AWBs and type of packages. The distributions for each process can be found in Section 4.5.3. Currently the VSM is a static tool as described in Section 3.3.5 and will be The VSM diagram will be enhanced with discrete event modelling to create a dynamic tool to serve as a test platform, which will be performed in Chapter 6.

Figure 4.6: VSM Traditional

4.5.3 Measurements

In this section measurement results are presented of the traditional supply chain. Measurements are gathered from data-bases on a data set of 1 year (September 2016 - September 2017). If data was unavailable interviews and field research has been performed in Billund, Horsens and Kolding in Denmark and Schiphol in the Netherlands.

Cargo at the Customer

Cargo originates from the customer DSV / Schenker. To be able to compare the traditional supply chain model with the DTP model the same amount of cargo must be transported through the system. The number of packages transported are taken from the database of the DTP in Section 5.3.3.

Domestic Trucking

Once the cargo has been collected during the day, the customer prepares the cargo for transportation to the GHA. The domestic truck is arranged by the customer. Based on interviews it is determined that the domestic truck is a loose loaded truck and will depart on the times displayed in Table 4.2. The domestic truck is often arranged by the customer themselves.

Table 4.2: [Traditional] Domestic Truck Customer - GHA (Mauritzen, 2017)

Company	Domestic Truck Departure	Transport time to CCB	Truck Loading
Schenker	17:00 - 18:30	45 minutes	1 - 2 hours
DSV	17:00	50 minutes	1 hour

Ground Handling Agent

The truck arrives at the GHA as indicated in the traditional swimlane in Figure 4.5 by the green background. The truck driver delivers the cargo papers to the documentation department of CCB. The truck driver gets assigned to an unloading dock and the loose loaded cargo is unloaded, taking about 1 - 2 hours as shown in Table 4.2. When unloaded, the Freight On Hand (FOH) milestone is given. The FOH means that the cargo has arrived at the warehouse. The cargo must be delivered before the latest acceptance time (LAT), the LAT is at least 4 hours before departure, otherwise the cargo is labeled as late. When the cargo arrives after the departure milestone, the cargo is labeled as not delivered and will require a new booking. After receiving the cargo in the warehouse and the cargo is checked, scanned, weighed and the cargo accepted in the KLM network by the GHA. By triggering the RCS milestone, KLM accepts the cargo in it's network, meaning that both the cargo and documentation has to be correct and complete. The promise to the customer to fly is booked is made at this point. For this research the assumption is made that no split parcels are transported. The GHA is not only responsible for the correct documentation (e.g. customs and MRN) but also for the build up of the freight. The documentation and cargo processing is from now on referred to as (cargo) handling.

The GHA process as illustrated in the swimlane in Figure 4.5 is a process of a party contracted by KLM Cargo. KLM imposes certain conditions about the handling of freight and if they are fulfilled, the process is the responsibility of the GHA. Therefore KLM has little influence on the process of the GHA. The contracted time in which the handling must be performed is 4 hours. Therefore this step in the VSM will be simplified to 4 hours as shown in Table 4.3.

Table 4.3: [Traditional] Ground Handling Agent

Company	Handling time
Cargo Center Billund	4 hours

Truck Reporting at GHA

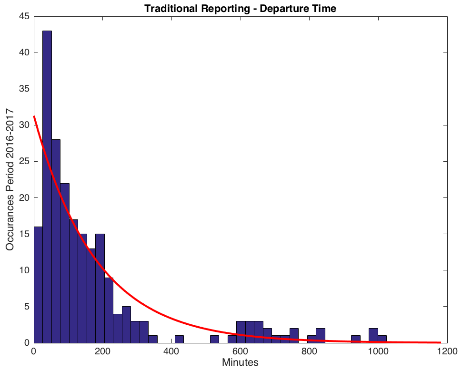


Figure 4.7: [Traditional] Difference between REP and DEP milestone

The truck is ordered by the network planning (NP) department of KLM. Following the trucking company, sends a truck to the GHA to collect the cargo and transports it to Amsterdam. The reporting time of the truck is 1 hour before departure in case of ULD loading and 2 hours before departure in case of loose cargo loading. In this case study the assumption is made that for the traditional model only ULDs are transported from the GHA to the hub in Amsterdam. This assumption is made as according to the contract with the GHA they are responsible for the build up of the ULD, releasing the hub of the workload. The occasional occurrence that not enough ULDs are available are not taken into account in this research.

In Table 4.4 the line-haul trucking schedule for Billund can be found. The numbers 1-7 indicate the day of departure with 1 representing Monday and 7 Sunday. On the left side of the Table the truck number which is equal to a flight number (as described in Chapter 2 the RFS operates with trucks operating under a flight number) is indicated. The departure time is the scheduled departure time from Billund and the arrival time is the scheduled arrival time in Amsterdam.

Table 4.4: [Traditional] Truck Schedule Billund

Truck Number	Departure	Arrival	1	2	3	4	5	6	7
KL8978	02:00	20:00		X	X	X	X	X	X
KL8986	03:00	21:00		X	X	X	X	X	X
KL8984	04:00	22:00		X	X	X	X	X	X
KL8982	05:00	23:00		X	X	X	X	X	X
KL8980	**06:00**	**23:59**		**X**	**X**	**X**	**X**	**X**	**X**
KL8488	14:00	08:00	X	X	X	X	X	X	
KL8486	15:00	09:00	X	X	X	X	X	X	
KL8484	16:00	10:00	X	X	X	X	X	X	
KL8482	17:00	11:00	X	X	X	X	X	X	
KL8480	**18:00**	**12:00**	**X**	**X**	**X**	**X**	**X**	**X**	

From Figure 4.7 it can concluded that the average time between reporting and departure of the truck is 179 minutes, equivalent to 3 hours. The loading of the truck however, only takes 15 minutes according to (Hansen, 2017) as the ULDs are fully prepared and are transported using a roller bed. As we are mainly interested in the value added actions of the cargo 15 minutes is used to represent the process. For further research it could be investigated whether the waiting time of the truck is due to the fact that the truck arrived too early or if the GHA did not have the capacity to handle the truck. If the truck arrives 5 hours before scheduled loading, the truck will have to wait until the GHA has a slot available.

Table 4.5: [Traditional] GHA Truck ULD loading

Company	Handling time
Cargo Center Billund	15 minutes

Number of ULD per Truck

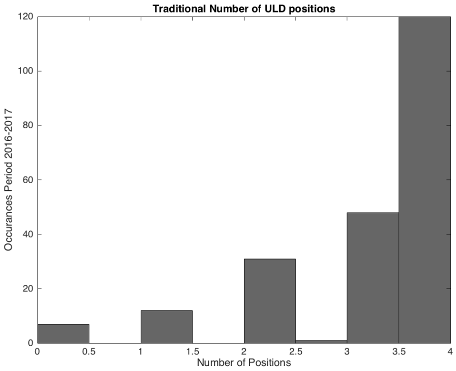


Figure 4.8: [Traditional] Number of ULDs per Truck

The average number of ULD's per truck for the period of September 2016 - September 2017 is 3.2 ULD's. This is in accordance with the norm used by KLM Cargo for scheduling manpower. The data on which the scheduling is based, is from 2013 and is displayed in Table 4.6. With 3.2 ULD's, 4 positions in a truck need to be ordered and paid. Therefore, for calculations 4 ULD's, equivalent to a FTL is used. An interesting observation in Table 4.6 is that the weekend peak is visible, as the number of ULD's on average is higher.

Table 4.6: [Traditional] Number of ULD's per Truck

Day of the week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Number of ULD per Truck	3.2	3.2	3.1	3.1	3.4	3.5	3.7

Truck Transit Time from GHA to Hub

The truck transit time from CCB to Schiphol is subject to many uncertainties during transportation, such as road blockages, traffic jams and other unforeseen circumstances. Over the period of 1 year (September 2016 - September 2017). The contracted trucking time for Jan de Rijk is 14 hours for a FTL and 18 hours for a LTL. From the distribution shown in Figure 4.9 it can be determined that the mean of the trucking time is 810 minutes equivalent to 13 hours and 30 minutes. Therefore it can be concluded that the FTL time is based on the average trucking time.

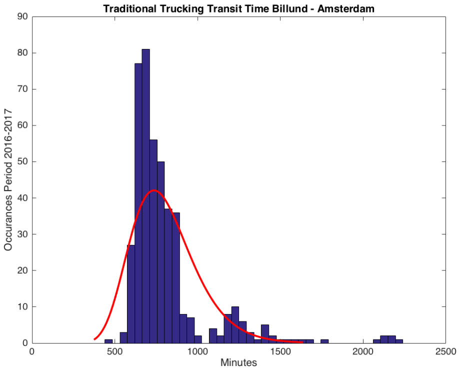


Figure 4.9: [Traditional] Truck Transit Time

Documentation Process in Amsterdam

The documentation process takes on average 2 minutes per AWB. The documentation process consists of many sub-processes. For the VSM model these processes are summarized as 1 process with an average time of 2 minutes, as shown in Appendix D. The distribution for the number of cargo for which one AWB is created is the same as for the DTP model to compare the throughput time. If the documentation is incorrect and the documentation department at KLM Cargo can not repair it, the documentation is returned to the GHA for an updated document. The shipment is stopped at the hub until a new or corrected document arrives. The opening hours of the GHA are shown in Table 4.8. Due to the fact that KLM Cargo is open 24/7, a reply with the corrected documents can take significant time.

Table 4.7: [Traditional] Documentation Procedure

	Avg.
Number of AWBs	1
Duration [minutes]	2

Table 4.8: [Traditional] GHA Opening Hours

Day	Opening Hours
Monday	06:00 - 00:00
Tuesday - Friday	00:00 - 04:00 06:00 - 00:00
Saturday	00:00 - 04:00 05:00 - 00:00
Sunday	08:00 - 21:00

REST Process

REST is also known as RASCargO (Remote Air Sampling for Canine Olfaction) regulated in Eu- rope as commercially available cargo screening technology according to (DiagNose, 2010). KLM Cargo is offering the REST procedure since 2013 and outstations do not mandatory have to secure the cargo for KLM. If requested by customers to secure the cargo in the outstations, this is billed to the customer. If the cargo is secured at the hub, KLM charges the customer via “other charges" on the AWB. This is only applicable for trucked cargo, flown cargo, also handled by the GHA must be secured before loading an aircraft.

For the traditional supply chain the truck is almost always made secure at CCB, the GHA in Billund. The GHA is contracted to make the cargo secure for flown cargo. For trucked cargo it is the decision of the customer if they want their cargo to be secured at the origin (CCB) or at the hub in Amsterdam. This decision is often based on costs and therefore the origin is chosen. It is expected that most often the truck arrives secured at the hub in Amsterdam. For the traditional supply chain only 1.3% of the trucks need to go to the REST procedure. The remaining 98.7% can directly go to the unloading docks.

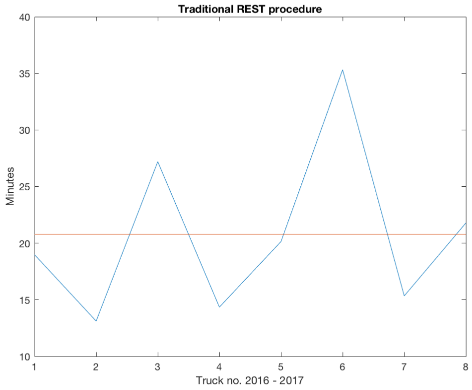


Figure 4.10: [Traditional] REST Procedure

Table 4.9: [Traditional] REST Procedure

# Secure trucks	# Unsecure trucks	% REST Procedure	Average Time REST
600	8	1.3%	21 min.

Unloading of Cargo

The duration of unloading the cargo from the truck at the hub is shown in Figure 4.11. The average of the unloading time is 7.1 minutes. This is for the traditional air cargo value chain where all cargo is loaded onto ULD’s. The unloading time is dependent on the number of ULD’s that are loaded in the truck. When the number of ULD’s is taken into account it can be calculated that the average time it takes to unload 1 ULD, is 2 minutes and 15 seconds as shown in Figure 4.12.

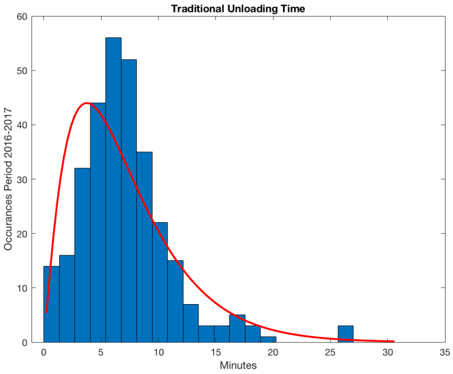


Figure 4.11: [Traditional] Unloading Time

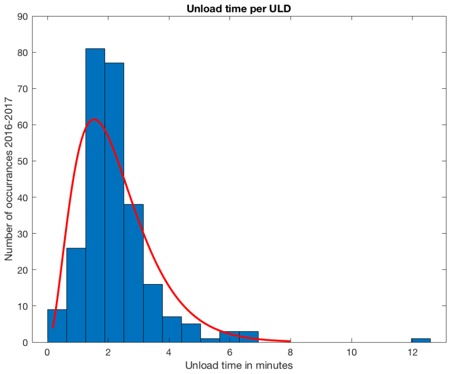


Figure 4.12: [Traditional] Unloading Time per ULD

Cargo Processing

As the cargo is already handled, processed and checked at the GHA on behalf of KLM Cargo, no extra checks need to be performed when arrived at Schiphol. In case of mix-ULDs, the cargo needs to be broken down and distributed to the correct location in the warehouse. The breakdown of a truck pallet is performed with 6 employees and takes 14 - 18 minutes. When the cargo is stored in the correct buffer in the warehouse and the documentation is also accepted in the systems the cargo will receive the status Received Cargo and documents from Flight (RCF). The RCF milestone officially states that the cargo has arrived in the bay at final destination or transit station. The status RCF is regarded as the research boundary for this thesis as determined in Section 1.4. After the RCF status, when all cargo for a flight is complete, an aircraft ULD is built for further transportation by air. The building of an aircraft ULD with 2 employees takes 55 minutes for a main deck pallet (MDP), 40 minutes for a lower deck pallet (LDP) and 25 minutes for an AKE (container).

Table 4.10: [Traditional] Cargo Processing

# Employees	RCS check	# Employees	Build up MDP	Build up LDP	Build up AKE
6	14-18 min.	2	55 min.	40 min.	25 min.

4.5.4 Electronic Data Interchange

As described in Section 2.7, EDI is developing at a fast pace in the air cargo industry. The rise of the internet and spread of modern information systems have deeply affected the way the air cargo industry operates, as business-to-business e-commerce and proprietary electronic data interchange (EDI) systems replace faxes and paper documentation (Schwarz, 2006). However the industry is adopting EDI at a slow pace resulting in a lot of remaining paperwork and email communication. In Appendix E a flow chart for the current EDI is shown in Figure E.1. The communication between the different parties as identified in Figure 4.4 for the traditional model is displayed. The color scheme of orange for physical transactions and green for digital transactions is adopted. Red indicates that information is still communicated using paper.

4.6 Synthesis

In this chapter the current state measurements for the traditional air cargo flow was performed. First the case study selection was performed, and the trade lane Billund - Amsterdam was chosen for the case study with customers Schenker and DSV.

To answer the third sub-research question: *Which stakeholders are involved in the process and which are most critical?*, a stakeholder analysis was performed in Appendix C. The most important stakeholders are; central operations management, customers, GHA, local operations management and the trucking company.

To answer the fourth sub-research question: *How is the current traditional export cargo flow organized and what is the performance?*

- A swimlane was designed for the current traditional air cargo flow. Based on the swimlane, measurements were performed by field-research, data gathering from systems and interviews. Observations based on the swimlane diagram include: there are many transactions in the system. In addition many double, re-work, manual transactions both from a physical and information aspect are performed making the product susceptible to damage and human errors.
- Next the swimlane was simplified to a VSM diagram incorporating the duration of each transaction.
- Following measurements were performed of the traditional system. From the measurements performed it can be observed that:
  - The waiting time increases significantly as the product goes through various parties, each performing their own checks and processes.
  - The current process is strongly human-driven and human-dependent.
  - Many deviations occur from the standardized process.
  - Truck arrivals not leveled over the week. As a consequence there is a high work load on weekends especially in the evenings.
  - Truck slots at Amsterdam not according to schedule, random serving of trucks.
- The current traditional EDI:
  - No internal feedback on the work performed, resulting in repair actions needed.
  - Involves a lot of paperwork, EDI is slowly adopted.
  - No feedback provided to GHA.
  - Duplication effort as the (same) inputs have to be done in different systems.
  - No differentiation is currently made between handling a paper AWB or an eAWB.

The fifth sub-research question *What are the bottlenecks for the current traditional export cargo flow?*, was answered by comparing the traditional model with the IATA standards and the lean methodology using the constraints identified in Section 3.3.3. The main bottlenecks are many double or non-value adding actions, many human actions, lack of information and long waiting times.

5 Direct Trucking Pick-up Supply Chain

This research contributes to an as-is analysis of the air cargo road transport with a focus on the DTP supply chain. In the previous chapter a detailed current state measurement was performed for the traditional supply chain and in this chapter the DTP supply chain will be addressed. First, the measurement approach is presented, followed by the transition from the traditional supply chain to a DTP supply chain. Next the case study is performed for DTPs and finally the KPIs are designed based on the measurements performed on both the traditional and DTP model. The three sub-research questions that will be answered in this chapter are: *How is the current Direct Trucking Pick-up flow organized and what is the performance?*, *What are the bottlenecks for the Direct Trucking Pick-up cargo flow?* and *What KPIs can be used to assess the current performance and different design options?* The set-up for this chapter can be found in Figure 5.1.

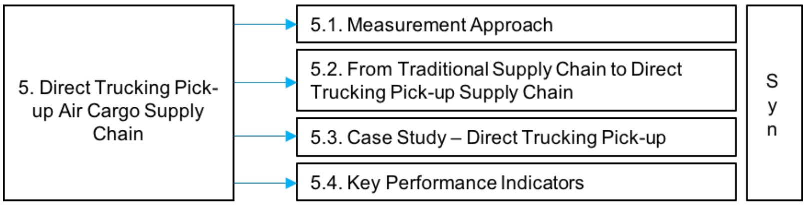


Figure 5.1: Chapter 5

5.1 Measurement Approach

This section describes in short the measurement approach. The measurement approach will be performed similar to the traditional measurement approach executed in Chapter 4. This way the two models can be compared with each other.

- First, using literature and the constraint identification the transition from a traditional supply chain to a DTP supply chain is explained.
- Second, the various high-level processes have been analysed in more details by visiting the parties included. Field research has been performed at the customer DSV, customer Schenker and at the Amsterdam Schiphol Airport hub. During this field research the steps in the swimlane were identified by means of observations and interviews. The swimlanes designed for each party can be found in Appendix D.
- Third, the swimlane is combined to one single integrated swimlane for DTP (as introduced in Section 1.4.2). The cargo journey for DTP can be found in Appendix D.
- Fourth, based on the swimlane, several processes have been grouped together to design a VSM. The details describing the combination of several processes is described in Appendix D. A KLM data set of 1 year was used to construct a dynamic VSM diagram. The data is analysed using Matlab.
- Fifth, based on the literature study performed in Chapter 2, the traditional supply chain measurements performed in Chapter 4 and the DTP supply chain measurements performed in this chapter, (Chapter 5), the KPIs are designed. The KPIs will be used to develop a test platform to analyse both the traditional model and DTP model in the next Chapter 6.

5.2 From Traditional Supply Chain to DTP Supply Chain

The traditional supply chain will be analysed using the lean manufacturing (LM) method explained in Chapter 3. The focus will be on the 7 wastes. These 7 wastes being **Transport**, the unnecessary movement of a product; **Inventory**, holding places for unnecessary inventory; **Movements**, inactive goods; **Waiting and delays**, excessive wait times; **Over production**, human effort and activity that does not add value; **Over processing**, system complexity, additional, unnecessary steps and confusing processes and **Defects**, transporting air or allowing for damage. In Table 5.1 the various wastes are illustrated including where in the traditional supply chain they occur.

Table 5.1: Lean Manufacturing Wastes in Traditional Air Cargo Supply Chain

#	LM Waste	Customer	Transportation	GHA	Transportation	Hub
1.	Transport		X		X	
2.	Inventory			X		
3.	Movements			X		
4.	Waiting and delays			X		
5.	Over production			X		
6.	Over processing			X		X
7.	Defects			X		X

1. **Transport**: In the traditional supply chain the cargo is transported from the customer to the GHA and transported from the GHA to the hub in Amsterdam. In case a customer has enough cargo in weight and volume, to be transported directly to Amsterdam, the intermediate stop at the GHA takes extra time and money.
2. **Inventory**: In case of a FTL, the cargo only waits as inventory at the GHA to be transported with a same size truck towards Amsterdam. No consolidation activities are performed by the GHA to gain economies of scale.
3. **Movements**: The cargo is moved extra times compared to DTP.
4. **Waiting and delays**: The cargo waits in the warehouse of the GHA until the KLM truck has reported. Instead the cargo could have already been on it's way to Amsterdam.
5. **Over production**: human effort by processing information at the GHA takes effort out of the hands of KLM employees. Shipments are build on Mix-ULD's at the GHA and broken down in Amsterdam only to be built up again with shipments with the same destination.
6. **Over processing**: in case of an FTL the GHA is an extra step, increasing system complexity and introducing unnecessary steps. The cargo has significantly more transactions as identified in the traditional swimlane in Figure 4.5. Therefore the chance of damage due to extra unloading and handling increases.
7. **Defects**: More human actions introduce the cargo being prone to human error and / or damage. Due to the extra unloading, build up, unloading, break down and build up, the chance of damage increases significantly.

Taking into account the TCE theory, the number of actions to process the cargo should be reduced. In case of a FTL, it is not necessary to consolidate cargo to optimize a truck, therefore a truck can collect the cargo directly from the customer, minimizing the number of transactions. Eliminating several parties in the supply chain, can increase the speed and reduce the costs of transporting cargo. This new business model is called DTP. However by eliminating parties in the supply chain, it needs to be analysed what tasks these parties performed and where in the supply chain compensation is needed.

Comparison Traditional with DTP

The main difference between a traditional line-haul pick up and a DTP is that with the traditional flow, an extra party is omitted from the value chain, namely the GHA (indicated with a light green background in the swimlane in Figure 4.5). The GHA performs actions on behalf of the hub, decreasing the workload at the hub. However, a GHA needs to be paid for the amount of work, increasing the cost of the operation. By omitting the GHA, the documentation department at the hub has to perform the document acceptance of the cargo and the warehouse has to do the physical acceptance and the check of the cargo. The cargo has to be accepted in the KLM system as ready for carriage with all compliance checks included before being handled / transportation on an aircraft.

5.3 Case Study - Direct Trucking Pick-up

In Figure 5.2 the general air cargo value chain for DTP cargo on level four is illustrated as identified in Section 1.4.2. Based on interviews and field research a swimlane is designed for the booking process, customer process and process at the hub. These detailed swimlanes can be found in Appendix D. In Appendix D a detailed process description of the DTP can be found.

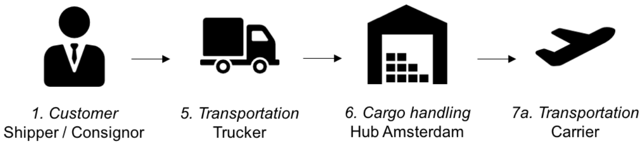


Figure 5.2: DTP Air Cargo Supply Chain

5.3.1 Swimlane

The Swimlane for DTP is shown in Figure 5.3. The critical stakeholders are the key players as identified in Figure 4.3 in Section 4.3, are located on the left side of the swimlane. The swimlane does not illustrate a time relation, however the processes have been mapped consequentially. The VSM diagram presented in the next section, will illustrate a time relation between the different processes based on field-research, interviews, observations and measurements.

Figure 5.3: Swimlane DTP

Studying level 5 of the analysis as identified in Section 1.4.2, the transactions, it can be assumed that each of the processes include a transaction. As identified in Section 3.2.2 the practical definition of a transaction is: when one stage of activity terminates and another activity begins. A transaction can be waiting, transporting and / or adding value, anything where something changes related to the cargo. In the swimlanes constructed for DTP and the traditional line-haul trucking the information transaction flows have been colored green and the physical transactions were colored orange. Double actions have been identified in yellow, manual actions in blue and red indicates re-work. A process does not have to be mutually exclusive, so a process can both contain an information and physical type of flow, as well represent re-work, manual or double action. In these cases a process, indicated by a box, has multiple colors.

5.3.2 Value Stream Mapping

In this section the VSM diagram is designed based on the swimlane presented in Figure 5.4. The VSM is a simplification of the swimlane diagram based on the meta model which will be described in Section 6.3.2. This simplification is possible as the individual steps are taken into account using the TCE Theory, as introduced in Section 3.2.2. A detailed description of which transactions are grouped together can be found in Appendix D. Using the TCE theory, the transactions are classified in information transactions and physical transactions as shown in Figure 5.3. Appendix Section D.4 describes in detail how each of the blocks (processes) in the VSM diagram presented in Figure 5.4 are selected based on the swimlane. The blue color in the VSM diagram represents the general process both including the physical flow and information flow. After reporting the two flows split, green represents the information flow and orange the physical flow. Below the VSM diagram is indicated the duration of each process. The average of each duration is given as in reality there is a large time distribution due to the uncertainty in the system, deviating number of packages / AWBs and type of packages / AWBs. The distributions for each process can be found in Section 5.3.3. The VSM will be digitalised using a discrete simulation software named Simio to experiment with the system as described in Chapter 6.

Figure 5.4: VSM DTP

5.3.3 Measurements

In this section measurement results are presented of the DTP supply chain. Measurements are gathered from data-bases on a data set of 1 year (September 2016 - September 2017). If data was unavailable interviews and field research has been performed in Billund, Horsens and Kolding in Denmark and Schiphol in the Netherlands.

Reporting at Customer

Jan de Rijk or a subcontractor, has to report at the premises of the customer (DSV / Schenker) two hours before scheduled time of departure as the cargo is loose loaded. For DSV and Schenker the data is based on information gained in the interview with an employee. The data can be found in Table 5.2 (Maansson & Madsen, 2017), (Mauritzen, 2017). The arrival of trucks is modelled according to an arrival Table, simulating scheduled appointments. The model is created such to simulate a random deviation on the exact time of arrival, so some trucks arrive early and some arrive late. There is also a no-show percentage of 5%. The arrival time deviation is set to the distribution Random.Uniform(-30,30) indicating that the truck can arrive 30 minutes early or 30 minutes late. According to (Maansson & Madsen, 2017) it takes less than 10 minutes to report at the front desk of DSV to report / check in. However, some drivers report early and following take their required break at the warehouse facility. On average the driver has to wait 30 minutes between reporting and loading of the truck. The loading takes approximately 1 hour, however this depends on cargo measurements and the difficulties. This data is shown in Table 5.2. In Table 5.3 the scheduled time of departure for the DTP trucks from Schenker and DSV can be found. Numbers 1-7 on top represent the days of the week with 1 being Monday and 7 Sunday. The numbers on the left are the truck numbers equal to flight numbers as explained in Chapter 2.

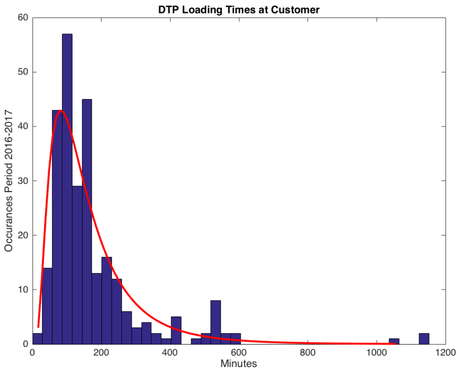


Figure 5.5: [DTP] Difference between REP and DEP Milestone

Table 5.2: [DTP] Reporting Time at Customer

Company	Reporting Time	Wait for Slot Time	Truck Loading
Schenker	5 min	0 - 30 min	1 - 2 hours
DSV	10 min	30 min	1 hour

Table 5.3: [DTP] Truck schedule Billund

Truck Number	Customer	Departure	Arrival	1	2	3	4	5	6	7
KL9362	DSV	18:00	16:00					X		
KL9368	Schenker	16:00	14:00					X		
KL9368	Schenker	16:00	06:00		X					

Number of Cargo per Truck

The number of cargo pieces that are loose loaded in the truck for customer Schenker is of relevance as this determines almost always the loading and unloading time. In case of fewer cargo pieces the loading and unloading will take a shorter amount of time, compared to when more pieces are loaded on the truck. However, this is not always the case as it is also dependent on the size of the cargo. On average for Schenker there are 104 pieces per truck and for DSV 90 pieces per truck. This information can be found for Schenker in Figure 5.6 and for DSV in Figure 5.7.

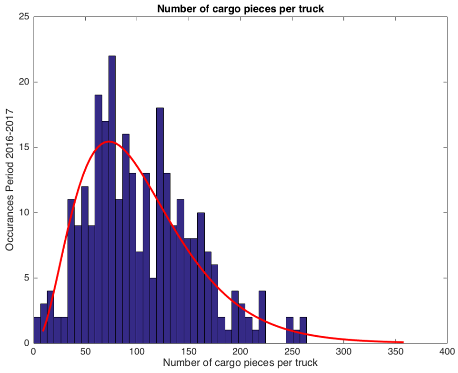


Figure 5.6: [DTP] Schenker Number of Cargo Pieces per Truck

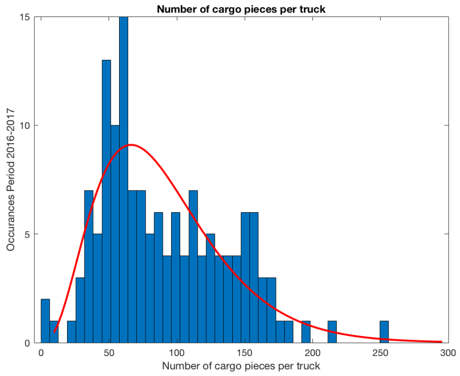


Figure 5.7: [DTP] DSV Number of Cargo Pieces per Truck

Truck Transit Time from Customer to Schiphol

The truck transit time from customer to Schiphol is subject to many uncertainties during transportation such as road blockages, traffic jams and other unforeseen circumstances. Over the period of 1 year (September 2016 - September 2017). The contracted trucking time for Jan de Rijk is 14 hours for a FTL and 18 hours for a LTL. From the distribution it can be determined that the mean of the trucking time is 742 minutes equivalent to 12 hours and 20 minutes. Therefore it can be concluded that slack is build in into the contracted trucking transit time. From Figure 5.8 it can be observed that there are two large columns, namely for a transit time of 11 hours and 16 minutes and 12 hours and 1 minute. During verification it was discovered that these two columns are outliers as they represent the default values in Jan de Rijk their systems, which communicate with KLM Cargo systems.

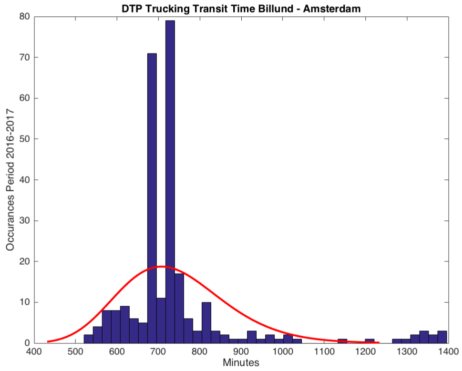


Figure 5.8: [DTP] Truck Transit Time

Documentation Process

Upon arrival at the hub the documentation and the physical cargo handling are separated. The documentation department is responsible for processing the paper documents that are transported by the truck from customer to the hub. The documentation department is open 24 hours per day, 7 days a week. The duration of documentation processing is dependent on the number of AWBs that the truck is carrying. On average the processing of an AWB is 4 to 5 minutes. In Figure 5.9 the distribution of the number of AWBs for DTP for the period of 1 year can be found. The average number of AWBs is 8 per truck as shown in Table 5.4. The exact steps that the documentation department needs to execute can be found in Figure 5.3.

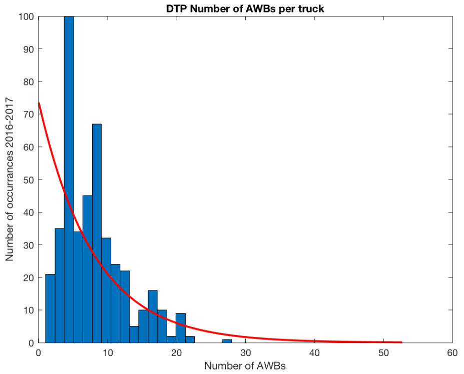


Figure 5.9: [DTP] Number of AWB per Truck

Table 5.4: [DTP] Documentation Procedure

	Minimum	Maximum	Average
Number of AWBs	1	28	8
Process duration [minutes]	5	140	40

If the documentation is incorrect and the documentation department at KLM Cargo can not repair it, the documentation is returned to the customer for an updated document as described in Section 4.5.3. The opening hours of the GHA are shown in Table 5.5.

Table 5.5: [DTP] Customer Opening Hours

Day	**Opening Hours**
Monday - Friday	09:00 - 17:00
Saturday - Sunday	Closed

REST process

REST is an abbreviation for Remote Explosive Scent Tracking. The REST department is responsible for performing the REST procedures as described in Chapter 4. In Figure 5.10 the duration of the REST procedure for the 11% of trucks that need to go through REST is shown. The other 89% is cargo from a known customer and therefore is allowed without extra checks on the hub as it is considered secure cargo. For the simulation model the data presented in Table 5.6 is taken into account.

Table 5.6: [DTP] REST Procedure

# Secure trucks	265
# Unsecure trucks	29
% REST Procedure	11%
Average Time REST	23 min.

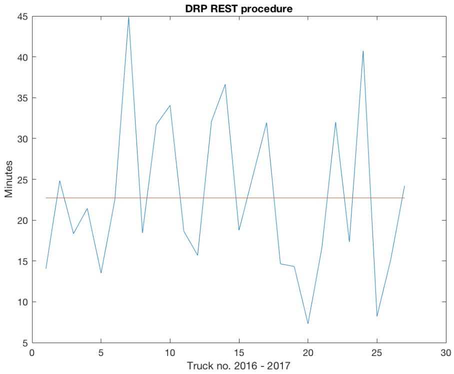


Figure 5.10: [DTP] REST Procedure

Unloading of Cargo

Almost always DTPs have loose loaded cargo. There are a few ULD loaded DTPs however for this research the assumption is made that all cargo is loose loaded. Due to the fact that the cargo is collected from the customer, no FFM is sent to the hub and therefore the unloading times at the hub are not registered in the systems. However, in interviews with employees at export intake it is stated that loose loading takes 1 hour and is performed by one employee.

Table 5.7: [DTP] Unloading of Cargo

# Employees	Duration	Duration per skid
1	60 min.	5 min.

Cargo Processing

After unloading, 1 employee needs an additional 1 hour to label and check the cargo. Next 2 / 3 employees are involved in the transportation of the cargo to the correct buffer position in the warehouse.

When the cargo is stored in the correct buffer in the warehouse and the documentation is also accepted in the systems, by the document department, the RCF milestone will be triggered. The milestone RCF is regarded as the research boundary for this thesis. After the RCF status, when all cargo for a flight is consolidated, an aircraft pallet is built for further transportation. The building of an aircraft pallet with 2 employees takes 55 minutes for a main deck pallet (MDP), 40 minutes for a lower deck pallet (LDP) and 25 minutes for an AKE (container).

Table 5.8: [DTP] Cargo Processing

# Employees	RCS check	# Employees	Build up MDP	Build up LDP	Build up AKE
1	60 min.	2	55 min.	40 min.	25 min.

5.3.4 Electronic Data Interchange

EDI is developing at a fast pace in the air cargo industry as described in Section 2.7. In Appendix E a flow chart for the current EDI is shown in Figure E.2. The communication between the different parties as identified in Figure 5.2 is shown. The color scheme of orange for physical transactions and green for digital transactions is adopted. Red indicates that information is still communicated using paper. In Appendix E the information communication responsibilities of each actor is described. The DTP communication scheme can be compared with the traditional communication scheme.

5.4 Key Performance Indicators

KPIs are variables that are used to indicate how specific configurations of the processes is performing. By making use of KPIs, it is possible to compare different configurations. According to (Paulen & Finken, 2009) KPIs are key organizational metrics that drive the performance of businesses. KPIs must be:

1. Measurable in a physical and financial unit
2. Specific, realistic and representative
3. Performed, defined and quantified consistently
4. Reflect the responsibilities of the involved departments / managers
5. Make cost elements transparent
6. Aligned with the overall organizational goals

The following new KPIs have been designed for the measurement of the performance of the air cargo supply chain:

1. **Throughput Time**: Transportation time is of great importance for air cargo. Air cargo is the fastest mode of traveling and consequently most expensive. Therefore the customer expects the cargo to be transported as fast as possible. The choice for DTPs is often based on an advantageous time / cost-structure for the customer. As one party is skipped in the supply chain less time is invested in the handling of goods. However, it is unknown if this structure is really advantageous. Within time, according to the lean concept the aim is to reduce the **waiting time**. The following times will be measured:
    (a) Documentation Time [minutes per AWB]
    (b) Total Throughput Time Documentation [minutes]
    (c) Total Physical Acceptance Time [minutes]
    (d) Total Unloading Time [minutes]
    (e) Total Throughput Time [minutes]
2. **Costs**: Costs are of great importance for a company to remain efficient and competitive. The choice for DTPs is often based on an advantageous cost-structure for the customer. However, at this moment, it is unknown if this structure is really advantageous. Therefore in this model, the cost structure will be examined. The transportation costs are dependent on the location of the pick up. For the traditional trucking the costs are determined based on contracts. For DTPs within a range of 25 km, the costs are the same as the traditional cost structure, however for each km additional to the 25 km a fee of €1.10 is taken into account. The following costs will be measured:
    (a) Total Transportation Costs [€]

    (b) Total External Handling Costs [€]

3. **Transaction Costs**: The number of transactions that have to be performed within KLM, the transaction costs contribute greatly to the internal costs. Internal costs are not always accounted as costs as no invoicing is to be paid, however the internal costs can contribute significantly to the total costs of transporting a package. **Data and physical quality** is incorporated in the number of handling actions. In case a package with insufficient quality is delivered, re-work is needed to repair the package. The re-work results in additional handling actions and therefore monetary costs. **Compliance** is also incorporated in the number of actions, if a package is not compliant or safe, extra time and handling actions are required to ensure that the package is safe for flight. Extra handling actions result in extra (internal) monetary costs. The following actions will be measured:
    (a) Total number of Transactions [-]
    (b) Total number of Physical Transactions [-]
    (c) Total number of Information Transactions [-]
    (d) Number of Re-work Transactions [-]

Overall the above named KPIs will contribute to the on time performance (OTP) by ensuring on time departure (OTD) and on time arrival (OTA).

5.5 Synthesis

In this chapter the current state measurements for the DTP air cargo flow was performed. First the transition from the traditional supply chain to the DTP supply chain based on lean principles and TCE theory is described.

To answer the sixth sub-research question *How is the current Direct Trucking Pick-up flow organized and what is the performance?* field research is performed at DSV and Schenker in Denmark, interviews are conducted and system data gathered.

- A swimlane was designed for the current DTP flow. Based on the swimlane measurements were performed by field-research, data gathering from systems and interviews. Observations based on the swimlane diagram include: compared to the traditional flow the transactions are reduced. However due to the fact that certain actions are not performed due to the fact that the GHA is omitted from the system, milestones in the supply chain are no longer triggered and information is not communicated. Therefore re-work and manual transactions from both a physical and information aspect increases.
- Next, the swimlane was simplified to a VSM incorporating the duration of each transaction.
- Following measurements were performed of the DTP system. From the measurements it can be observed that:
    - The throughput time is decreased significantly as parties are omitted from the supply chain.
    - The current process is strongly human-driven and human-dependent.
    - Many deviations occur from the standardized process.
    - Trucks are loose loaded.
    - Parcels are scattered through trucks.
    - Weighing / volume checks are incorrectly performed.
    - Unloading time increases.
    - Acceptance time increases.
    - Trucks are not leveled over the week.
    - No clear awareness of what the DTP standards should be.
    - High risk of cargo (data) discrepancies
- The current DTP EDI:
    - No FFM is sent.
    - Milestones in the supply chain are not triggered.
    - Customs documents are incorrectly delivered.
    - No internal feedback on the work performed, resulting in repair actions needed.
    - Involves a lot of paperwork and paper handling, EDI is slowly adopted.
    - Duplication effort as the (same) inputs have to be done in different systems.

  - No feedback provided to customers.
  - No differentiation is currently made between handling a paper AWB or an eAWB.
  - Information is not digitally available.
  - Information is not accessible for all parties.
  - Too much data entry and opportunities for mistakes.
  - Many ways to communicate the same information (paper, courier, e-mail).
  - Limited EDI capabilities & options available.
  - No clear awareness of what EDI standards should be.
  - High risk of data discrepancies.
  - Many different systems.

Following, the 7th research question *What are the bottlenecks for the Direct Trucking Pick-up cargo flow?* can be answered. The main bottleneck is visibility in the supply chain, limited access to EDI, inducing high risks of data discrepancies and no collaboration in the supply chain.

Finally, the 8th sub-research question *What KPIs can be used to assess the current performance and different design options?* can be answered. The KPIs used to measure the performance are:

1. **Throughput Time**
   (a) Documentation Time
   (b) Total Throughput Time Documentation
   (c) Total Physical Acceptance Time
   (d) Total Unloading Time
   (e) Total Throughput Time
2. **Costs**
   (a) Total Transportation Costs
   (b) Total GHA Costs
3. **Transaction Costs**
   (a) Total number of Transactions
   (b) Total number of Physical Transactions
   (c) Total number of Information Transactions
   (d) Total number of Re-work Transactions

Part III

Analyse

6 Discrete Event Modelling

In this chapter the framework will be developed to create a test platform to measure the current situation and test design options. First the framework development approach is introduced. Second, the assumptions on which the framework is created. Third, the model properties are defined followed by the design of the model itself. Next, the model characteristics are identified and a verification and validation takes place. Finally, the current state traditional model and DTP model are measured based on the KPIs designed in Section 5.4. In this chapter the following research questions will be answered: *Which framework can be developed to create a test platform to test design options?* and *How does the performance of the traditional export cargo flow compare to the direct pick up cargo flow?* The set-up for this chapter can be found in Figure 6.1.

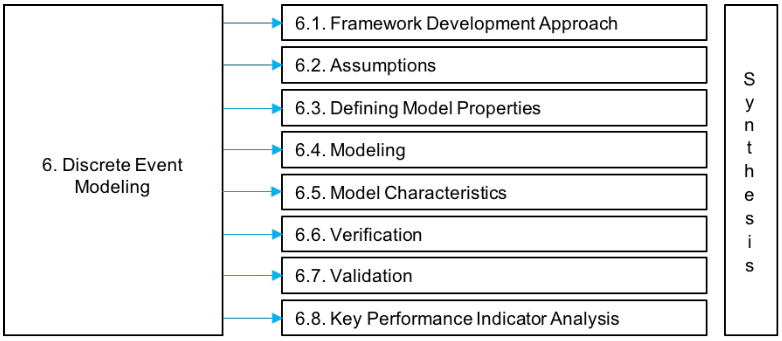


Figure 6.1: Chapter 6

6.1 Framework Development Approach

In this section a discrete event modelling framework will be developed. Several scholars suggested enhancing the VSM with discrete event simulation (as described in detail in Section 3.3.5 to explore results of improvement scenarios, prior to implementation. For this research, the preliminary model is tested by exposing the system to several improvement scenarios, which will be described in Chapter 7. Discrete event modelling will be used to study the system of the air cargo value chain. According to (Kelton et al., 2011) a system is "a part of the world that can be seen as a whole, separated from the rest of the world (environment), during a certain period of time. A system can have some internal structure (e.g. parts and relations), and (unless it is a closed system), some interaction with the environment.

6.2 Assumptions

1. The cargo demand is on a continuing basis, thus special hazards posed by deviations in the market can be disregarded.
2. Trucks are numerous and therefore always available.
3. Only FTLs - do not consider co-loading options from other stations (do consider co-loading option from same station).
4. Only loose loading trucks for DTP model.
5. Only ULD trucks for traditional model.
6. Scope of the model is from reporting at customer to RCF milestone at the hub.
7. Only cargo from DSV / Schenker is studied (for other area's other rules & regulations apply, as well as time distributions and recommendations).
8. Only city pair Billund - Amsterdam (Kolding & Horsens).
9. Only non exceptional goods, only general goods.
10. Waiting time is incorporated in the process step itself unless otherwise stated.
11. Process steps of suppliers are not optimized.
12. Simplifications are made on object classes, attributes, interactions and time aspect as described in more detail in Section 6.3.3.
13. No split parcels.

6.3 Defining Model Properties

In order to start modelling in Simio, the model properties, among which, the system boundaries, meta-model, model simplification, model entities and resources must be determined. These model properties will be described in the following sections.

6.3.1 System Boundary

The system boundary is designed with reference to the scope of the research. The model build in Simio is only valuable if the system boundary is such, that the applicable processes can be tested. The model will only study the city pair Billund - Amsterdam (Horsens - Schiphol and Kolding - Schiphol). Within the city pair only the documentation and physical cargo will be studied. As the model is a city pair it is designed to improve the Billund Amsterdam trade lane, not to optimize individual departments of KLM Cargo or departments of the customer. Therefore the model will not take into account employee or asset and resource utilization. The model will only take into account non exceptional goods. In the traditional air cargo supply chain model, dangerous goods, cold goods and other goods with extra needs can be transported. However, as no cargo check is performed for the DTP, before loading the cargo into the truck, only non-exceptional goods are allowed to be transported on these trucks.

In Figure 4.5 the swimlane for the traditional air cargo model is designed. However, due to the numerous steps in the process it is not efficient to model all the steps. Therefore for the meta-model is designed, as previously mentioned, a simplification of the model. The function of the meta-model is to represent or describe the system to be simulated. It is a simplification that highlights the properties of the model, including the model's inputs and outputs. Based on the VSM diagram a meta-model is constructed. The meta-model will be described in the next section.

6.3.2 Meta Model

Based on the swimlane model designed in Figure 4.5, several steps in the swimlane are combined into one step for simplification and a time measurement is added. First of all, in the swimlane all the different steps of documentation are displayed separately, however often it is the case that one single employee performs these actions. Therefore for the entire document handling part a certain time frame is taken into account. However, not for each separate action a time frame is measured. In the meta model, the different steps are grouped as described in Appendix D. Secondly, often updates need to be performed on the cargo booking. This step is often not performed by the customer or CSO. This information is unknown in the cargo value chain. By adding this information, a small amount of time is added to the documentation process, but no separate step is designed. Thirdly, in case extra work is performed to the cargo (re-work) this is registered and billed to the customer by the revenue management (RM). In the model, this does not have any effect on time or costs, only on the handling action. Consequently, this step will not be modelled. Fourthly, the waiting time of cargo is not measured separately in the processes. Often waiting time is incorporated in the time stamps, therefore waiting time is not modelled separately but included in the process itself. Fifthly, the process steps at the GHA in case of the traditional model are not modelled as these are suppliers. Suppliers are contracted to perform actions on behalf of KLM Cargo. As many suppliers are contracted, each of these suppliers have their own way of working with their own processes. KLM Cargo has contracts with these suppliers including the time for handling the cargo. If the suppliers manage to handle the cargo sooner than contracted, the cargo has more waiting time. If the supplier needs more time, a monetary penalty will be issued.

The meta-model consists of, for the traditional model, the customer, domestic transport, GHA, trucking and the operations at the hub at Amsterdam Schiphol Airport. The operations at the hub take into account security, REST, document acceptance and physical acceptance. For DTP the domestic transport and the GHA are omitted from the process. These parties and departments are based on the stakeholder analysis performed in Appendix C. The locations where the system ('model of cargo chain') interacts with the non-inner system ('rest of the world') are at numerous locations. As only the city pair Billund - Amsterdam is modelled, the duration of each of the processes is dependent on the occupation of each of the departments. On Fridays the customer, GHA, KLM Cargo, road transport are extra busy and might therefore take more time, while on Mondays it is more quiet. To incorporate this in the model, distributions have been made to indicate the differences at different times of the week. The arrival times of the truck can be different for each day. The external factors are not modelled separately in the meta-model. The distributions for each of the processes take into account the variation in the model.

6.3.3 Simplification before Modelling

In Chapter 4 a swimlane of the traditional air cargo value chain was presented. However this swimlane has to be simplified in a meta-model to ensure that the model will be efficient and suitable to study. According to (Verbreak, 2015) there are four types of model reduction for conceptual models. First to simplify object classes, secondly to simplify attributes and / or values, thirdly to simplify interactions and finally to simplify the time aspect. Below each of the options is discussed.

1. The object classes can be simplified by making a re-selection of the objects. Objects can be joined together or object classes can be left out. The choice to join or omit objects from the model is based on if they add value to the model, and / or if they overlap with other model objects as is performed in Appendix D.
2. Attributes can be simplified by leaving out some attributes, simplifying value ranges and /or by choosing stochastic distributions. It is chosen to leave out certain attributes in the model if they do not add value to the outcome of the research. The contractor that operates the truck does not add value to the outcome of the research.
3. Interactions can be reduced by simplifying the action patterns merge action patterns together or leave out actions. For example in the swimlane in Figure 4.5 several decisions have to be made. The interactions can be simplified by not modelling why a choice is made but by modelling the event as a chance (event will happen in x % of the cases). A process can be simplified if a process consists of sub-processes, it is not necessary to model them all to come to a conclusion of the model. In this way it is possible to make a complex process more understandable, without loosing outcomes. For example the documentation process consists of many sub-processes as shown in the swimlane in Figure 4.5. Modelling all these steps would cost a lot of unnecessary time and would make the model too complex. In the simio model these processes can be summarized in 1 process, with a certain time to represent all of the sub-processes.
4. The time aspect can be simplified by leaving out parts of the time axis and / or bundling units of time. The processes of a supplier are not modelled and therefore the different processes are bundled for the GHA into a block of 4 hours as defined per contract. To simplify the time aspect (in)dependence of moments can be assumed (Verbreak, 2015). DTPs are scheduled for Tuesdays and Fridays, therefore it is unnecessary to model the other days of the week when nothing happens.

6.3.4 Model Entities and Resources

Within the system boundary described in Section 6.3.1 there are several entities and resources that can be distinguished in the air cargo value chain. To model all the entities and objects, they have to be categorized in object classes. Below a list of model entities can be found:

Table 6.1: Model Entities

Model Entity	Traditional Model	DTP Model
Cargo	X	X
Domestic truck	X	
KLM truck	X	X
ULD	X	
Documents	X	X

6.4 Modelling

In this section the modelling generation in Simio is explained. First it is explained how the data is collected, followed by the construction of the traditional model and the DTP model in the sections below.

6.4.1 Data Collection

The data collection can be performed using several methods, first of all historical data, such as archives, computer files and registration systems. Secondly by expert opinions when data is unavailable and for checks of the data. Thirdly, measurements, the downside of taking measurements is that it takes a lot of time to collect the measurements and it is difficult to get representative data. If data is collected for a period of 2 months this data might have seasonal or individual influences. The final method to collect data is from similar systems, however the difficulty with this method is how it can be translated to the specific system that is under study.

In Chapter 4 the data for the measurements of the current state of the traditional supply chain are taken using the first method, historical data from archives, computer files and registration systems. This was done in Chapter 5 for the DTP supply chain. The data was discussed with an expert to verify the measurements taken from the system. Data that was missing, incompatible or unavailable is gathered using the second method, expert opinions. When data is available in the model it is either the original data, a theoretical distribution based on empirical data or the raw data is used. The theoretical distributions are developed based on the theory of (Law, 2011). In Appendix D, the theory of the theoretical distributions used, is explained in more detail. If data is unavailable either theoretical distributions are used or expert estimates for the parameters. The expert parameters are obtained using field research and survey research as explained in Chapter 3.

There are two types of variables present in the model. Firstly the exogenous variables, these can be split in external variables and instrumental variables. External variables are variables that can not be influenced from within the system such as arrival patterns. Instrumental variables are variables that can be influenced by decision makers such as schedules and number of resources. Secondly there are the endogenous variables, of which there are also 2 types, the output variables such as time in the system and internal variables such as a certain route time (Kelton et al., 2011).

6.4.2 Traditional Air Cargo Supply Chain

For the traditional air cargo supply chain the designed model is divided in a customer, GHA, transportation and hub part. In Figure 6.2 a print screen of the traditional model as built in Simio can be found. The model is a dynamic version of the VSM presented in Figure 4.6. Both the physical and information journey are represented in the first part of the model. From reporting onward, the model is split into the physical aspect and information aspect. The information aspect is performed in the lower part of the model.

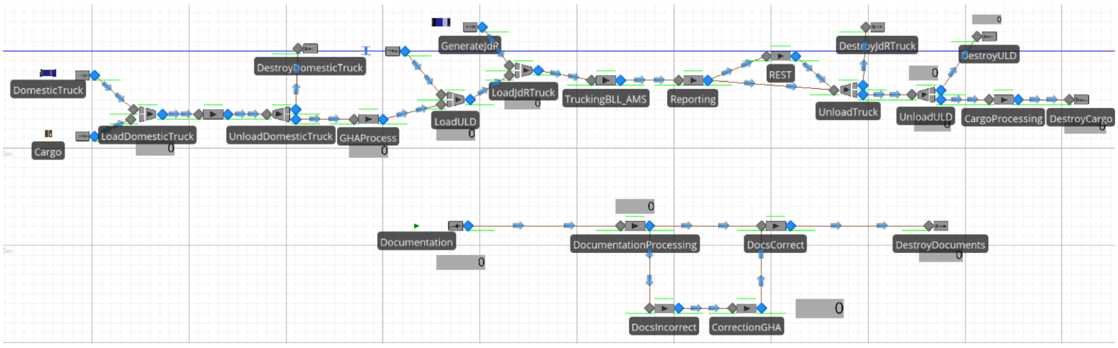


Figure 6.2: Simio model - Traditional

6.4.3 DTP Air Cargo Supply Chain

For the DTP air cargo supply chain the designed model is divided in a customer, transportation and hub part. In Figure 6.3 a print screen of the DTP model as built in Simio can be found. The model is a dynamic version of the VSM presented in Figure 5.4. Both the physical and information journey are represented in the first part of the model. From reporting onward, the model is split into the physical aspect and information aspect. The information aspect is performed in the lower part of the model.

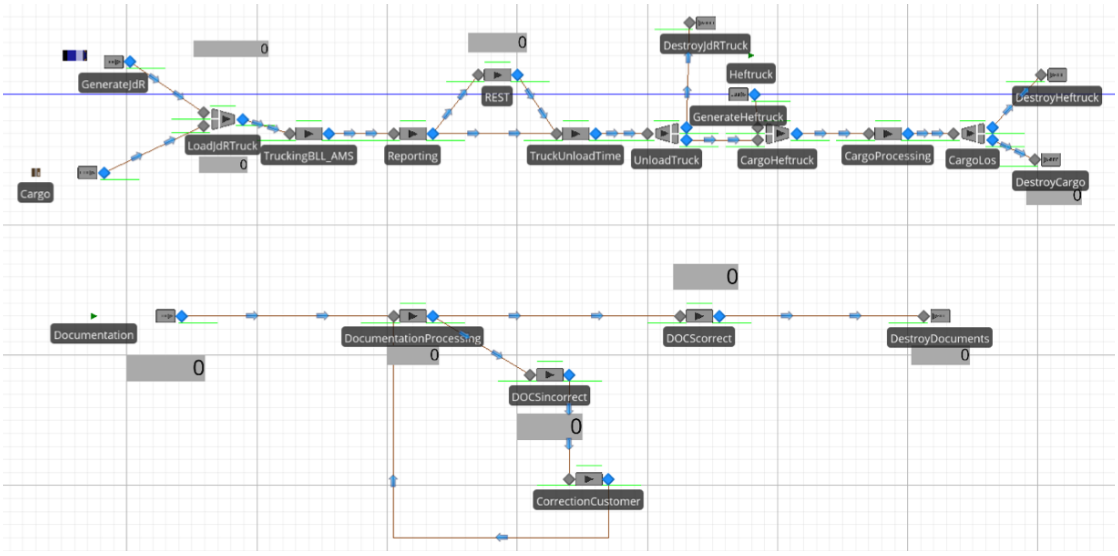


Figure 6.3: Simio model - DTP

6.5 Model Characteristics

In this section the model characteristics are presented. The model characteristics are the determination of the simulation run length, type of expected output and number of replications needed. Each of these aspects will be addressed below.

6.5.1 Length of Simulation Run

A simulation model can be classified as a terminating or a non-terminating simulation. The length of a simulation run for a terminating model is determined by the natural length of the system. In the air cargo system model, the end point is the completion of the time period under investigation e.g. the arrival of the cargo in the warehouse in Amsterdam. Therefore the model under investigation can be classified as a terminating simulation. A non-terminating simulation does not have a natural end point. Only for non-terminating models, the model user has to determine the length of the simulation run. For a non-terminating system (Kelton et al., 2011) suggests a run-length at least 10 times the length of the warm-up period.

6.5.2 Transient Output

For most terminating simulations the output of the model is transient. This means that the distribution of the output is constantly changing. For example, the number of cargo pieces transported each week is different. For any time period, the number of cargo pieces or documents generated and served is unlikely to be identical on any given day. For non-terminating simulations a steady state has to be determined to interpret the results. During the warm-up period, also known as the initial transient, the distribution of the output is constantly changing, the data is therefore unrealistic. As the air cargo simulation model that is being investigated is a terminating simulation, and the data changes, indicatively the data output is classified as transient.

6.5.3 Number of Replications

To obtain accurate simulation results, it is important to remove any initialization bias and gain enough output data from the simulation to see an accurate estimate on performance. There are two ways to handle initialization bias. The first is to run the model for a warm-up period and the second is to set initial conditions. Running the model for a warm-up period means running the model until it reaches a realistic condition and only collect results from the model after this point. The second approach, setting initial conditions, ensures that the model is placed in a realistic condition at the start of the run. As many terminating simulations start from, and return to, an empty condition the removal of initialization bias is often not applicable. Ensuring that enough output data is generated can be addressed in two ways. First, a single long run with the model, however this is only applicable for non-terminating simulations. Therefore, for terminating simulations, such as the system under investigation for this research, the only approach is performing multiple replications. A replication is defined as:

“A replication is a run in a simulation model that uses specified streams of random numbers, which in turn cause a specific sequence of random events” (Robinson, 2004).

By changing the random number streams, another replication is performed. In each replication the sequence of random events that occur during the model run changes and therefore the results obtained change as well. By taking the mean of the results gained from running multiple replications, an estimate of the model performance can be gained. Performing multiple replications is equivalent to taking multiple samples in statistics. One long run is equivalent to taking one large sample.

(Law, 2011) argues that at least three to five replications are required. However, this is just a rule of thumb and does not take the output results of the simulation into account. Models with a varied output need more replications than models with a stable output. According to (Robinson, 2004), plotting the cumulative mean of the output data from a series of replications can indicate the number of replications, starting with at least 10 replications. This method is called the graphical method and as more replications are performed the graph should become a flat line. The number of replications required is the point where the line becomes flat. Another method that can be used to determine the number of replications is the confidence interval method. The confidence interval is defines as:

“A confidence interval is a statistical means for showing how accurately the mean average of a value is being estimated” (Robinson, 2004).

For the confidence interval the following conclusions can be used. The narrower the interval, the more accurate the estimate is. In general, the higher the number of sample data, the narrower the result. Equation 6.1 can be used to calculate the confidence interval and Equation 6.2 to calculate the standard deviation. In Table 6.2 the definitions for the variables used in Equation 6.1 and Equation 6.2 can be found.

$$CI = \overline{X} \pm t_{n-1,\alpha/2} \frac{S}{\sqrt{n}} \tag{6.1}$$

$$S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n-1}} \tag{6.2}$$

Table 6.2: Confidence Interval Variable Definitions

Symbol	Definition
CI	Confidence Interval
$\overline{X}$	Mean of the output data from the replications
$t_{n-1,\alpha/2}$	Value from Student’s t-distribution with n-1 degree of freedom and significance level of $\alpha/2$
S	standard deviation of the output data from the replications
$\sqrt{n}$	number of replications
X_i	the result from replication i

A significance level (α) of 5% is often selected, as this gives a 95% probability that the value of the true mean (obtained if the model is run for an infinite period), lies within the confidence interval. This does also imply, that there is a 5% likelihood that the mean does not lie in the interval. For a 5% confidence interval, values at 2.5% significance are selected from the Student’s t-distribution (as $\alpha/2$).

If there is more than one KPI, as is the case for the simulation under study, the number of replications should be selected on the basis of the response that requires most replication. In practice the number of replications is determined from an analysis of the base model alone and than applied to all the experiments. It is preferable to overestimate the number of replications opposed to underestimating to provide a margin of safety.

6.5.4 Synthesis

In this section a summary is provided of the above described model characteristics. In Table 6.3 the characteristics as used in the model are presented.

Table 6.3: Summary of Model Characteristics

Model Characteristics		
Length of Simulation	Terminating System	48 hours
Warm-up Period	Terminating System	0 minutes
Output Type	Transient Outputs	
Number of Replications	100	

6.6 Verification

Verification and validation are important elements of a simulation study, to place confidence in a study's results. Verification and validation are performed throughout the life-cycle of a simulation study, hence, it is a continuous process. Verification is the process of ensuring that the model design (conceptual model) has been transformed into a computer model with sufficient accuracy (Robinson, 2004). Verification is a micro check of the model's content, it checks if the model is true to the conceptual model. Verification can be performed by the modeler, comparing the computer model to the model description. Verification and validation are performed for both the traditional model and the DTP model. However, in the next section only the DTP model verification will be presented(Reis & Silva, 2016). Various aspects should be checked during model coding as listed below.

1. Timings, e.g. throughput time, travel time
2. Control of elements, e.g. work schedules, arrival patterns
3. Control of flows, e.g. routing
4. Control logic, e.g. scheduling
5. Distribution sampling, e.g. the samples obtained from an empirical distribution.

This can be done using three methods: checking the code, visual checks and inspecting output reports. Each of these methods will be described below:

Checking the code: The code should be checked to ensure that the right data and logic is entered, often the most effective method to achieve this is to have an objective party check the code. Two independent students of the Delft University of Technology have checked the code for inconsistencies. *Visual checks*: The visual display of the simulation model can be used to analyse how each element behaves. Several techniques can be used such as stepping through the model event by event (Kleijnen, 1995). Stopping the model and predicting the next event, followed by a check. Creating extreme conditions, isolating areas of the model, tracing the progress of an item though the model. To perform these checks the trace option in Simio was used. Entities were followed though the model and each step, made by the entity, is checked. In addition the visual display offered by Simio was checked, the various elements in the model were given different symbols to provide visual aid. *Inspecting output reports*: The outcomes of a simulation run can be compared to the real world data.

6.7 Validation

Validation is the process of ensuring that the model is sufficiently accurate for the purpose at hand. Validation consists of two concepts: sufficient accuracy and purpose. For the first concept it should be stated that a model is per definition wrong and never 100% accurate, but that this is not the intention of a model. A model's purpose is to provide a simplified means for understanding and exploring reality. In addition accuracy is with reference to the purpose for which the model is used. There are several forms of validation according to (Robinson, 2004) are shown below:

- *Conceptual Model Validation*: determining that the content, assumptions and simplifications are sufficiently accurate.
- *Data Validation*: determining that the data is sufficiently accurate.
- *Black-box Validation*: determining that the overall model represents the real world with sufficient accuracy.

- *Experimentation Validation*: determining that the experiment provides results that are sufficiently accurate.
- *Solution Validation*: determining that the model results are sufficiently accurate.

According to (Sargent, 2005) and (Sargent, 2014) there are several validation techniques: animation, comparison to other models, degenerate tests, event validity, extreme conditions test, face validity, historical data validation, historical methods, internal validity, multistage validation, operational graphics, sensitivity analysis, predictive validation, traces and turning tests. Several of these methods have already been described by (Robinson, 2004). In the next paragraph, the additional methods will be explained. There are several difficulties that arise when validating a model as listed below:

- There is no general validity, each validation depends on the purpose of the simulation study.
- There can be no real world to compare it against.
- There many be various interpretations of a real world.
- Real world data is often inaccurate.
- Time restrictions prohibit all elements to be verified and validated.
- It is not possible to prove that a model is valid, it is the client's and modeler's confidence in the model to use it as a decision-making tool.

6.7.1 Conceptual Model Validation

The project specification should be circulated among those who have detailed knowledge of the system and feedback should be gained about the model's appropriateness. Confidence in the model can be obtained by gaining wide acceptance of the conceptual model. Assumptions and simplifications should be checked by the client and modeler and their likely impact on the model. A sensitivity analysis can be performed, in case of little confidence in assumptions and simplifications. The conceptual model for the simulation under consideration is the swimlane and VSM presented in Chapter 4 for the traditional model and the swimlane and VSM in Chapter 5 for the DTP model. The discrete model is a dynamic version of the VSM as explained in Section 3.3.5.

6.7.2 Data Validation

Data should be as accurate as possible. The sources of data should be investigated to determine their reliability. This is done in Section 4.5.3 for the traditional model and in Section 5.3.3 for the DTP model. There are numerous sources used as input for the model. KLM Cargo works with several data systems from which information was gained, analysed and coupled by the author. In addition data from the systems from Jan the Rijk was gathered and compared with data from KLM. Based on interviews this data was compared and validated. In collaboration with experts, data errors were removed from the sample. Unavailable information is compensated by information gained from field expert interviews. Data gathered from interviews was validated by field research and verification by a third individual. All data types involve human involvement, resulting in human errors and therefore inconsistencies. Timing can not be 100% accurate as data is measured and entered manually in the systems. To compensate for the inconsistencies a broad range of data points was collected (1 year data base from September 2016 - September 2017) such that the data can be deemed accurate. The data was plotted using Matlab and a boxplot constructed to identify the 95% confidence interval and the outliers.

6.7.3 Black-box Validation

In blackbox validation the overall behavior of the model is considered. This can be done by comparing the simulation model to the real world and by making a comparison with another model. For this research only the first method will be considered, comparing the simulation data to the real world data. Historic real world data, collected from systems can be used to compare the results of the simulation model under study. It is important to compare both the average levels as well as the spread. The confidence interval for the difference in the means can be calculated using Equation 6.3. The variables are explained in Table 6.4.

$$\overline{X_S} - \overline{X_R} \pm t_{2n-2,\alpha/2}\sqrt{\frac{S_S^2 + S_R^2}{n}} \tag{6.3}$$

Table 6.4: Difference in Means Confidence Interval Variable Definitions

Symbol	Definition
$\overline{X_S}$	Mean of simulated output data.
$\overline{X_R}$	Mean of real system output data.
$t_{2n-2,\alpha/2}$	Value from Student's t-distribution with 2n-2 degrees of freedom and significance level of $\alpha/2$.
S_S	Standard deviation of simulated output data.
S_R	Standard deviation of real system output data.
n	Number of observations

The simulation model is checked against empirical observations to compare the simulation results against real world data. According to (Sargent, 2005) this is where historical data is used to check if the model behaves as the system does. In Appendix F the detailed analysis of the historical data can be found. In Table 6.5 the difference between the historical data and simulation data is shown for the DTP model. It is important that the number of samples used in the simulated and real system data are enough.

Table 6.5: Comparison Simulation Data to Historical Data for DTP model

Parameter	Avg. Historical	Avg. Simulation	Δ [%]
No. of cargo [#]	108.81	109.11	+0.27 %
Truck Transit Time [min]	740.80	702.75	-5.14 %
No. of documents [#]	8.11	7.39	-8.88%
Unloading Time [min]	52.88	59.27	+ 10,78%
Cargo Processing [min]	96.60	99.32	+2.74%

6.7.4 Experimentation Validation

Experimentation validation requires accurate number of replications as described in Section 6.5.3, run-length, as described in Section 6.5.1 and sensitivity analysis and transient effects as described in Section 6.5.2.

6.7.5 Solution Validation

The aim of using simulation models is to assure the validity of the final solution. If the final solution would be implemented in the real world, the outcome should correspond to the model's results. In practice this is often not possible, as alternative solutions are not implemented to determine the effects. The purpose of simulation as described in Section 3.3.6 is to analyse effects of alternative solutions without the disruption of the system under study.

6.7.6 Extreme Conditions Test

According to (Sargent, 2005) the definition of the extreme conditions test is: *"The model structure and outputs, should be plausible for any extreme and unlikely combination of levels of factors in the system".* Extreme values are entered one-by-one in the simulation model under study and the results examined. This test is used to check if the model reacts as expected. The results for the DTP model are presented in Table 6.6. It can be concluded that the model reacts as expected for all the extreme condition scenarios. It can therefore be concluded that the model has passed the extreme conditions test. It must be stated that the test has been performed for a selected extreme condition solution space. This solution space has been selected based on argumentation provided (Sargent, 2005) and on most likely situations to occur in the real world.

Table 6.6: Model Extreme Conditions Test for DTP model

Extreme Situation	**Observations**
Zero cargo generates	Number of cargo collected is zero Number of trucks ordered is zero Number of AWB created is zero
Zero trucks available	Number of trucks departing from Denmark is zero Number of AWB created is zero Number of cargo collected / transported is zero Cargo waits at customer
No reporting employees available	Truck waits infinitely at reporting No documents created Zero cargo delivered to the hub
Cargo unloading time is zero	System runs as normal but lower throughput time
Document handling time is zero	System runs as normal but lower throughput time

6.7.7 Sensitivity Analysis

According to (Sargent, 2005) the definition of the sensitivity test is: *"This technique consists of changing the values of the input and internal parameters of the model to determine the effect upon the model's behavior or output."* This method can be used to determine how stable the variables in the model are. If the model results are very unstable it is difficult to obtain accurate conclusions from the output. In this test several variables are varied -10% and +10%. In case 10% is not possible 1 minutes is added or retracted. The selected parameters and the results can be found in Table 6.7. The normal distributions can be found in Chapter 4 for the traditional model and in Chapter 5 for the DTP model. These distributions are explained in more detail in Appendix F. The test shows that the model is limited sensitive to small changes in input variables.

Table 6.7: Sensitivity Test for DTP model

Parameter	**%**	**New value**	**Observations**
Cargo generation	+10%	119	Number of cargo in truck higher Longer throughput time More documents created Longer cargo processing
Cargo generation	-10%	97	Cargo shorter throughput time
Reporting time	+10%	1;27	Larger throughput time
Reporting time	-10%	3;33	Shorter throughput time
REST procedure	+10%	0.01	n/a
REST procedure	-10%	0.21	n/a
Unloading time	+10%	58.17	More cargo unloaded
Unloading time	-10%	47.59	Shorter throughput time
Cargo processing	+10%	106.25	Longer cargo throughput time
Cargo processing	-10%	86.93	Cargo shorter throughput time
Document generation	+10%	9	Docs longer throughput time
Document generation	-10%	7	Docs shorter throughput time
Documentation processing	+10%	3;7	Longer documentation process
Documentation processing	-10%	1;5	Shorter documentation process
Documents incorrect	+10%	0.2	More time at customer correction
Documents incorrect	-10%	0.0	No waiting time for customer open

6.8 Key Performance Indicators Analysis

This section presents the performance of the air cargo supply chain simulation based on the KPI identified in Section 5.4. The KPI analysis in this section consists of three parts. First, the throughput time will be analysed, secondly, the costs and thirdly, the transaction costs. Finally a synthesis of the outcome is presented.

6.8.1 Throughput Time

The throughput time is based on measurements taken from data systems of KLM, Jan de Rijk and measurements made in field research. In Table 6.8 the throughput time for the traditional and DTP trucks can be found. On the left side of the Table, the model type is states, the entity measured as described in Section 3.3.6, and the variable in the system under study. Following the average of that variable is given based on 100 runs of the system, the half width, minimum and maximum value of the outcome distribution. The half-width (H.W.) as described in is the margin of error, usually defined as the radius or half the width of a confidence interval. For the KPI 'Total Throughput Time' it can be observed in Table 6.8 that for DTP it is almost half (15.75 hours) compared to the traditional model (29.49 hours). The waiting time for loading is deducted from the total time in the system as the system boundary was set from departure at the customer until the RCF milestone at the hub is triggered, as described in Section 1.4. The average of the throughput time deviates slightly from the measured time in practice but still is a good representation and approximation of practice. Due to the fact that the distribution of the throughput time is so large. Regarding the minimum and maximum values it can be observed that these are realistic values and outliers are present in the model, just as in the real-world system. The throughput time consists adding the throughput times of all different parties. Below the performances as generated by the test platform in the form of a simulation are analysed and compared to the real-world times that have been measured.

Table 6.8: KPI Throughput Time

Model	Name	Variable [hrs]	Avg.	H.W.	Min.	Max.
DTP	**Cargo**	Time in System	22.82	0.91	19.04	26.15
		Waiting Time Loading	7.07	0.28	6.53	9.49
		Throughput Time	**15.75**			
Trad.	**Cargo**	Time in System	31.50	1.30	24.32	38.87
		Waiting Time Loading	2.01	0.06	1.52	2.50
		Throughput Time	**29.49**			

Unloading Time

In accordance with the simulation of 100 runs the unloading time for DTP is on average 60.78 minutes as displayed in Table 6.9. As researched in Section 5.3.3 the average unloading time is maximum 1.5 hour. Therefore this result is as expected. An interesting observation is that the maximum unloading time is 207.50 minutes equivalent to 3.46 hours. During field research one research day was performed in December just before Christmas, known as one of the busiest days at KLM Cargo. During this field research the unloading time measured was 3 hours, due to lack of space in the warehouse. Therefore outliers such as the maximum value are certainly possible. For the traditional model the average unloading time is 10.93 minutes. This is 6 times as fast as the DTP unloading time. This is as expected as the GHA already builds ULDs for the hub. Therefore at the hub the ULDs can directly be stored in the automated ULD storage system on the roof of the warehouse.

Table 6.9: Unloading Time

Model	Name	Variable [min]	Avg.	H.W.	Min.	Max.
DTP	**Cargo**	Unloading	**60.78**	21.66	7.92	207.50
Trad.	**Cargo**	Unloading	**10.93**	5.45	0.53	67.43

Cargo Processing Time

In accordance with the simulation of 100 runs the total cargo processing time for DTP is on average 79.25 minutes as displayed in Table 6.10. As researched in Section 5.3.3 the average cargo processing time is 96 minutes. This average takes into account the outliers, as the median is 48 minutes. Therefore the value from the simulation run is as expected. Compared to the processing time of the cargo that arrives through the traditional model, with an average of 1.57 minutes, the DTP cargo processing is time consuming. Due to the fact that all acceptance checks and labeling has to be performed in Amsterdam for DTP, the cargo processing takes longer. Time savings can be gained by improving this aspect of the DTP supply chain.

Table 6.10: Cargo Processing Time

Model	Name	Variable [min]	Avg.	H.W.	Min.	Max.
DTP	**Cargo**	Processing	**79.25**	26.45	3.59	190.78
Trad.	**Cargo**	Processing	**1.57**	0.09	1.07	2.27

Documentation Processing

In accordance with the simulation of 100 runs the documentation processing time for DTP is on average 4.05 minutes as displayed in Table 6.11. As researched in Section 5.3.3 the average documentation processing time is 4 - 5 minutes. This simulation result is therefore as expected. For the traditional model the documentation processing takes on average 1.94 minutes. The documentation processing for the traditional model is shorter as the documents have already been entered in the system by the GHA. This shortens the number of actions that have to be taken in Amsterdam.

Table 6.11: Documentation Processing Time

Model	Name	Variable	Avg.	H.W.	Min.	Max.
DTP	**Document**	Processing	**4.05**	0.10	3.70	4.50
Trad.	**Document**	Processing	**1.94**	0.06	1.58	2.16

Document Correction

In accordance with the simulation of 100 runs, the documentation correction for DTP takes on average 20.16 minutes as shown in Table 6.12. If documentation is incorrect it has to be repaired either by the documentation department of the hub or by the customer. An interesting observation is that for the traditional model the GHA repair of the document also takes on average 21.16 minutes. It must be stated that as will be described in Section 6.8.3 the % of re-work that has to be performed by the GHA is significantly less than for the customer. Due to the opening hours of the GHA (as displayed in Table 4.8) and the opening hours of the customer (as displayed in Table 5.5) the waiting time on average for repair is 2,5 hours for both the DTP model and the traditional model.

Table 6.12: Documentation Correction Time

Model	Name	Variable [min]	Avg.	H.W.	Min.	Max.
DTP	**Document**	Waiting	**160.64**	47.64	37.18	361.14
DTP	**Document**	Processing	**20.16**	1.93	10.44	28.08
Trad.	**Document**	Waiting	**159.25**	48.10	21.22	455.43
Trad.	**Document**	Processing	**21.16**	0.98	18.24	26.78

6.8.2 Costs

In Table 6.13 the various cost elements for the traditional trucking model and the DTP model are displayed. As the parties located in Denmark are paid in Danish Krone, all currencies are converted to Euro's, calculated on 15-02-2018. The total trucking costs are calculated using equation 6.4. The number of trucks are gained from a 1 year data base. For the trucking costs different prices are used depending on the location of the pick-up, based on distance traveled. The GHA costs are based on a price per kg. The kg transported in the same 1 year data base are 1276 ton for Schenker and 1030 ton for DSV. The costs are calculated using equation 6.5.

$$TotalTruckingCosts = TruckingCostsperTruck \cdot NumberofTrucks \tag{6.4}$$

$$GHACosts = Kgtransported \cdot PriceperKg \tag{6.5}$$

Table 6.13: Cost Analysis

Model	Variable	Customer	Costs
DTP	Trucking Costs per Truck	DSV Schenker	€735,80 €710,50
	Number of Tucks	DSV Schenker	102 191
	Total Trucking Costs	DSV Schenker	€75.051,60 €135.705,50
		Total	**€210.757,10**
	GHA Costs	-	€0.00
Traditional	Trucking Costs per Truck	-	€650
	Number of Trucks		293
	Total Trucking Costs		€190.450
	GHA Costs	DSV Schenker	€69.133,85 €85.694,60
	Total Costs		**€345.278,45**
Savings	**Potential**	Total	**€134.521,35**
		Per piece	€3,11
		Per kg	€0,06

As calculated in Table 6.13, the savings gained by transporting cargo directly, are significant. As the acceptance process and handling of cargo is performed in Amsterdam, the internal costs per cargo handling have to be taken into account. Currently, this value is unknown at the hub. It can be argued that the handling of the cargo internally is preferred as the specific assets are available already (as described in the theory of asses-specificity in the TCE theory in Section 3.2.2), investments have been made, building and electricity bill paid and knowledge is available in-house (human asset-specificity). This asset specificity means that it can only be used for cargo handling. Therefore it is beneficial to utilize the hub's means for cargo handling as much as possible instead of outsourcing the activities. Asset specificity is described by (Williamson, 1981). In addition, internal handling generates (more) work for KLM employees, while, handling cargo externally, requires payment to external parties contracted by KLM. The aim is therefore to limit the “out-of-the-pocket” payments.

Taking into account the potential savings, the savings per cargo piece and per kg can be calculated using equations 6.6 and 6.7.

$$SavingsPerPiece = \frac{TotalSavings}{NumberOfCargoPieces} \tag{6.6}$$

$$SavingsPerKg = \frac{TotalSavings}{TotalKg} \tag{6.7}$$

The price paid to the GHA (CCB) in Billund, Denmark is €0,07 per kg. If KLM is able to process the cargo for €0,06 euro per kg, they will play even as the trucking costs for the DTP model are higher. Only if they can reduce the handling costs below €0,06 euro per kg, a profit can be made by transporting it by DTP.

6.8.3 Transaction Costs

As described in Section 3 lean manufacturing theory does not include the financial economic perspective of transactions and therefore the TCE theory is used complementary to the lean manufacturing theory to identify additional KPIs. According to (Williamson, 1981) the definition of a transaction is *“A transaction occurs when a good or service is transferred across a technologically separable interface"*. In accordance with the stated definition of a transaction, in this thesis the practical definition of a transaction used is when one stage of activity terminates and another activity begins. An economic transaction can best be explained by the comparison with mechanical systems. Efficient mechanical systems are systems where friction and loss of energy are minimized. The economic counterpart is to ensure that parties involved in the exchange operate harmoniously (Williamson, 1981). It is important to minimize misunderstandings and / or conflicts in transactions that can lead to delays, breakdowns and other malfunctions in the system.

The swimlane for the traditional model is presented in Figure 4.5 and for the DTP model in Figure 5.3. In each of these swimlanes the color scheme shows physical transactions in orange and information transactions in green as described for the traditional model in Section 4.5.1 and for the DTP model in Section 5.3.1 respectively. The double actions are presented in yellow, manual actions in blue and re-work actions in red. For the transaction costs each of these processes is counted in accordance with *"one stage of activity terminates and another activity begins"*. In Table 6.14 the number of physical, information and re-work transactions can be found for both the traditional and the DTP model.

Table 6.14: KPI Transactions

KPI	**Type**	**Unit**	**Current**	
			Traditional	**DTP**
Transactions	Total number of Transactions	[#]	126	96
	Physical Transactions	[#]	76	25
	Information Transactions	[#]	53	41
	Re-work	[#]	0,16	1,7
		[%]	2,85	25,76

From Table 6.14 it can be clearly seen that the total number of transactions is significantly reduced when comparing the traditional model with the DTP model. Especially the physical transactions are reduced. In case a customer has a fragile shipment it could be beneficial to transport the shipment by direct pick up. The information transactions are also reduced, these transactions are reduced less due to the fact that a lot of information still has to be exchanged in Amsterdam with third parties such as customs. The amount of re-work in the DTP model is significantly higher than for the traditional model. Due to the fact that the GHA is omitted as middle-man, the cargo and information delivered by the customer is not checked and directly delivered to KLM Cargo. Therefore the physical acceptance department and document department of KLM Cargo have an increased workload in case the DTP model is employed.

6.9 Synthesis

In this chapter first the sub-research question: *Which framework can be developed to create a test platform to test design options?* is answered by using the VSM diagram developed in Chapter 4 and Chapter 5 and digitalizing this diagram. The framework is verified and validated using several techniques. Next the sub-research question:*How does the performance of the traditional export cargo flow compare to the direct pick up cargo flow?* is answered by running the current state simulation for both the traditional and the DTP models. The results can be found in Table 6.15.

Table 6.15: KPI Traditional vs. DTP

KPI	**Type**	**Unit**	**Current**	
			Traditional	**DTP**
Throughput Time	Documentation Processing	[minutes]	1,98	4,50
	Total Throughput Time Documentation	[minutes]	31,21	158,69
	Physical Acceptance Time	[minutes]	6,2113	95,32
	Unloading Time	[minutes]	8,64	71,80
	Total Throughput Time Cargo	[hours]	28,64	15,43
Costs	Transportation Costs	[euro]	€190.450,00	€210.757,10
	Handling Costs	[euro]	€154.828,45	€0,00
	Total costs	[euro]	€345.278,45	€210.757,10
Transactions	Total number of Processes	[#]	126	96
	Physical Transactions	[#]	76	25
	Information Transactions	[#]	53	41
	Re-work	[#]	0,16	1,7
		%	2,85	25,76

Part IV

Design

7 Design

In this chapter the following sub-research question is answered: *Which design options does KLM Cargo have to improve the performance of the direct trucking process?* Based on the analysis in the current state in Chapter 4 and in Chapter 5, improvements from both a company perspective and supply chain perspective can be proposed. This chapter introduces the proposed improvements. These improvements are so called design options for the future cargo DTP process. Each of the improvements will be modelled and simulated using a discrete event model allowing for scoring the performance of each improvement on the KPIs as introduced in Chapter 4. The performance of each improvement is compared with the current performance and the impact is identified. This chapter therefore also answers the following sub-research question: *What impact do the design options have on the performance of direct trucking pick up air cargo flow?* The set-up for this chapter can be found in Figure 7.1.

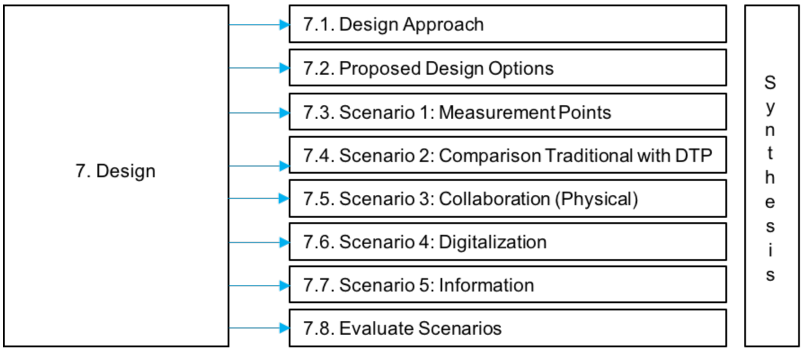


Figure 7.1: Chapter 7

7.1 Design Approach

In Appendix F the simulation project plan is presented. The design approach used in this chapter is presented in the 'to-be' phase of the project plan. As displayed in this plan, the first step is to conceptualise possible solutions, followed by generation of conceptual models for the new situation. Design options are proposed and simulated in the new model simulation, after which experiments are run on the design options. The experiment results are compared with the old situation and by using weighing factors prioritized alternatives are generated. From these design options a selection is made and this is the serving as the solution.

7.2 Proposed Design Options

Two case studies have been performed in the foregoing Measure and Analysis phase of this research. Many different research methods (as described in Chapter 3) have been used leading to a in-depth understanding of the current traditional air cargo flow, DTP air cargo flow and their performance. For certain situations the DTP flow is an improvement compared to the traditional flow, as will be presented in the first scenario. The first scenario is to compare the DTP flow with the traditional flow. Next, in case it is opportune to use the DTP flow, improvements are suggested to lead to an increased performance. The proposed design options should be able to lead to an improved performance which will be measured by scoring higher on the KPIs. Due to the fact that it is impossible to implement all proposed design options to test their effect on the performance without disrupting the daily schedule modelling is used as a tool to investigate the performance improvements of the proposed design options as explained in Chapter 3. During experimentation the aim is to obtain a better understanding of the real world system that is being modelled and look for ways to improve that system. The main aim of simulation output analysis is to obtain an accurate estimate of average (normally the mean) performance. The model has been designed in Chapter 5 and this validated model can now be used to implement all possible design options and test what the influences on the system are. This research contributes with a test platform of the traditional air cargo flow versus the DTP flow for KLM Cargo for the trade lane of Billund towards

Amsterdam.

As presented in Chapter 2 a seamless supply chain is a system which penetrates the silos within a company and the various corporate silos in the supply chain (Lambert & Cooper, 2000). Silo's occur when departments won't or can't easily share information in the supply chain (Thomson, 2016). As a result of the literature study and field research many enhancing design options are possible and all of them could be tested on their effectiveness. However, this research is limited in computing time and research time, only a select number of design options can be tested. Taking the 8 steps introduced by (Martichenko, 2013) to reach a seamless supply chain into account, together with the findings from the current state research, interviews, design research and field research a shortlist of design options were proposed to the management and operational staff of KLM Cargo. The employees were selected based on their function, their daily connection with both the traditional air cargo flow and the DTP flow. The problem owner, KLM Cargo, has the most detailed knowledge of day-to-day operations and the market trends and are therefore the selected individuals to make this decision. They were asked to rank the design options based on importance.

From the shortlist the following design options are proposed:

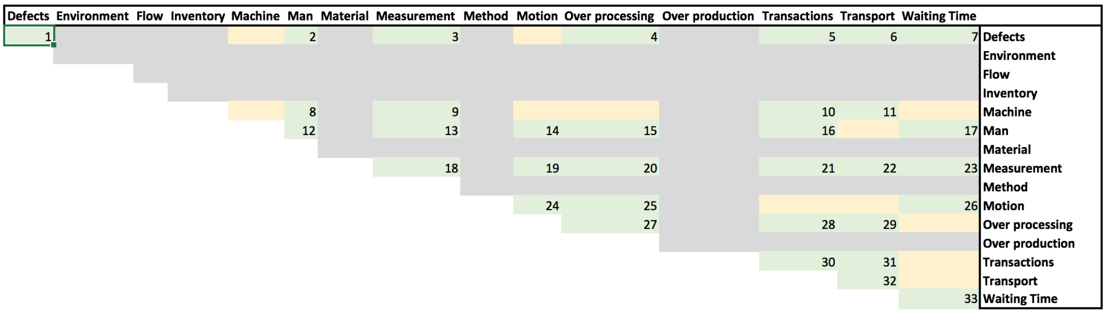
1. Total number of process steps is reduced
2. Double process steps are deleted
3. Digitalization of the air cargo supply chain
4. Reduction of man executed actions therefore prone to human error
5. Sharing information between different parties
6. Increase of on time performance
7. Reduce re-work actions
8. Reduce total costs
9. Reduce total throughput time
10. Increase feedback between all parties
11. Implement measurement points in the air cargo supply chain.

In consultation with the management of KLM Cargo a selection of this shortlist is made. They have chosen to build a test case around the most value-adding options from the perspective of KLM Cargo. This entails:

- First to be able to actually propose design options for the DTP flow, measurement points have to be implemented to allow visualization of the current daily, weekly and monthly performance. This is not a design option which can be tested using the test platform designed, however it can provide great insights for KLM Cargo.
- Secondly, based on the conclusions arising from the measurements and analysis performed in Chapter 4 and Chapter 5 respectively, feedback in the air cargo supply chain is lacking. Therefore all parties are firefighting issues but non of them are structurally solved. Therefore there should be cooperation between KLM Cargo and the customers.
- Thirdly from the perspective of digitalization, which is currently an ongoing development in the industry, a combination of the shortlisted design options is proposed based on the literature study performed in Chapter 2. Digitalization is implemented in the chain, therefore removing the double process steps, reduction of man executed actions and sharing information between the different parties.
- Fourthly, it is investigated what effect the number of re-work actions have on the supply chain and whether the feedback to the customer should be increased regarding this matter.

The shortlist was presented to the management of Air France - KLM Cargo. They were asked to rank the shortlist based on importance and asked to make a statement about why it was, according to them, the most important design option. Based on the data gained from the feedback, the following design options were selected for further investigation:

1. Design measurement points for DTP flow.
2. Comparison traditional Model with DTP model.
3. Collaboration in Supply Chain for DTP model (e.g. physical loading, on time departure).
4. Digitalization in DTP model.
5. Correct Information in DTP model.



	Defects	Environment	Flow	Inventory	Machine	Man	Material	Measurement	Method	Motion	Over processing	Over production	Transactions	Transport	Waiting Time
Defects	1					2		3			4		5	6	7
Environment															
Flow															
Inventory															
Machine						8		9					10	11	
Man						12		13		14	15		16		17
Material															
Measurement								18		19	20		21	22	23
Method															
Motion										24	25				26
Over processing											27		28	29	
Over production															
Transactions													30	31	
Transport														32	
Waiting Time															33

Figure 7.2: Constraint Matrix

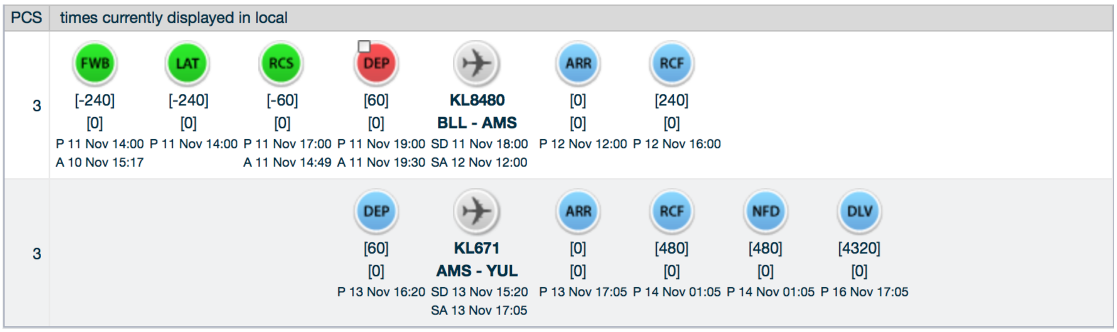
In Section 3.3.3 the constraints for air cargo supply chains were identified using the theory of Lean Manufacturing, Lean Six Sigma and TCE theory. In Figure 7.2 the constraint matrix can be found to identify the solution space. The grey area's identify constraint combinations that not possible or not applicable in the research domain. For example, the environment is an uncertain factor in the model, however, this is taken into account by scheduling truck transit times with a margin. Flow and inventory are applicable in the system, however the scope of this research does not include this aspect. The method used and overproduction are not investigated at this moment. The air cargo industry is a transportation service and not a manufacturing service, therefore over production is not a main concern. If more cargo is sold, more business and profit can be gained. The orange constraint combinations are not of interest for this research as they do not reflect the scope of the research. For example the machines used to transport, load, unload cargo are taken as is and no improvement design options are suggested. In addition waiting time is included in the process time. As identified in Chapter 4 and Chapter 5 the current measurement systems do not allow for waiting times to be measured separate from the processing time. Therefore only the processing time is taken into account and waiting time is indicated in orange for certain constraints in Figure 7.2. The green constraint are combinations that can serve as possible solutions alternatives. Below a summary of the constraints contributing to various scenarios is provided:

Table 7.1: Generation of Scenario's

Scenario	Description	Constraint numbers
Scenario 1	Measurement Points	3,5,8,9,13,18,19,20,21,22,23
Scenario 2	Traditional vs. DTP	2,4,5,15,17,20,25,27,28,29,30
Scenario 3	Collaboration	1,2,4,5,7,9,11,12,15,16,24,30,31
Scenario 4	Digitalization	1,2,5,7,8,9,10,15,16,17,30
Scenario 5	Correct information	1,2,5,8,10,12,13,14,15,16,17,30

7.3 Scenario 1. Measurement Points

According to the IATA standards, several measurement points have been defined which are illustrated in green in Appendix B in Figure B.2 and Figure B.3 . However IATA has only defined these measurement points in the cargo value chain for the traditional model. In Figure 7.3 the details of how these measurement points are used in practice is shown:



PCS times currently displayed in local

3
FWB [-240] [0] P 11 Nov 14:00 A 10 Nov 15:17
LAT [-240] [0] P 11 Nov 14:00
RCS [-60] [0] P 11 Nov 17:00 A 11 Nov 14:49
DEP [60] [0] P 11 Nov 19:00 A 11 Nov 19:30
KL8480 BLL - AMS SD 11 Nov 18:00 SA 12 Nov 12:00
ARR [0] [0] P 12 Nov 12:00
RCF [240] [0] P 12 Nov 16:00

3
DEP [60] [0] P 13 Nov 16:20
KL671 AMS - YUL SD 13 Nov 15:20 SA 13 Nov 17:05
ARR [0] [0] P 13 Nov 17:05
RCF [480] [0] P 14 Nov 01:05
NFD [480] [0] P 14 Nov 01:05
DLV [4320] [0] P 16 Nov 17:05

Figure 7.3: [Traditional] IATA Measurement Points

A green milestone indicates that the milestone is achieved, a red milestone indicates that the milestone is failed, thus that the cargo has not achieved or achieved the milestone later than planned, the blue milestones still need to take place, this is a future planned event. In the current state the milestones can not be measured for DTP as the milestones have a standard order of occurrence, based on the traditional air cargo value chain. Therefore the performance of the DTP can not be measured as the visibility of the trucks is non-existent. One of the issues is for example that the DEP is not triggered.

Table 7.2: IATA Measurement Points

Abbreviation	Description
BKD	Airline freight booking and route planning
FWB	Creation of electronic MAWB
RCS	Freight physically checked in at departure airline
DEP	Goods confirmed on board flight
ARR	Flight arrival at destination airport
RCF	Freight acceptance at arrival airlines
AWR	Documents received at destination airport
NFD	All freight and documents ready for pick-up
AWD	Documents delivery to forwarder
DLV	Freight delivery to forwarder

Only 6 milestones of the CargoIQ IATA standards are used by KLM Cargo to measure the trucking performance originating from Europe. To be able to use the data measured and compare it to the traditional model, the same milestones have to be used in the same order. In Figure 7.4 the milestones used in the traditional air cargo flow are displayed. These can be rearranged and used for the DTP air cargo flow as shown in Figure 7.5.

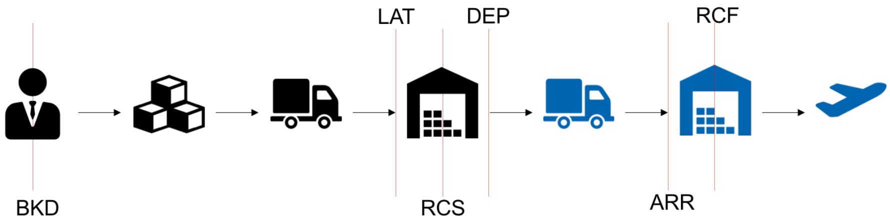


Figure 7.4: [Traditional] Milestones in the Supply Chain

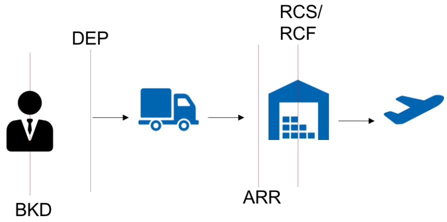


Figure 7.5: [DTP] Milestones suggested for the Supply Chain

In the current situation it is impossible to rearrange the standard CargoIQ milestones as this is a worldwide air cargo performance measurement system not flexibly designed. KLM Cargo does not have an internal measurement system and therefore uses the CargoIQ milestones. The milestones are important as liability agreements are made based on these milestones. For example; the moment the milestone RCS is given to a shipment in the traditional air cargo flow, the shipment is the responsibility of KLM Cargo. However in the DTP air cargo flow, this milestone is not given until the truck has been unloaded at the hub. This results in liability issues, such as who is responsible for the cargo during the transportation from Billund towards Amsterdam? As these CIQ milestones are currently not reflecting the accurate performance, the proposal is to trigger RCS at the same moment that RCF is given at the hub. This milestone should be triggered at the moment of departure. This requires the customer to collaborate by providing KLM Cargo with a DEP time stamp. The LAT milestone, which is also not present in the DTP air cargo flow, will be triggered at the same time as the DEP milestone. To be successful, the time offset has to be changed in the KLM systems.

7.4 Scenario 2. Comparison Traditional with DTP

In Section 6.8 the KPI analysis of the current state model is performed. Comparing the traditional air cargo flow with the DTP flow provides insights for KLM Cargo on the current performance and why a certain model should be selected. The performance of both models, based on the KPIs identified in Section 5.4 is displayed in Table 6.15.

For the throughput time, the documentation time is significantly shorter for the traditional model than for the DTP model. This is mainly due to the fact that the GHA performs most necessary actions needed to process the documents. Therefore in Amsterdam the number of actions are less. For the DTP model all paperwork has to be processed in Amsterdam requiring additional time. Therefore the total throughput time for all documentation for the traditional model is approximately 30 minutes while for DTP it can take up to 2 hours. This is also dependent on the opening hours of the GHA / Customer. If documentation is incorrect, which is only 5% for the traditional model but can be 20% for a DTP model, new documentation has to be provided by the customer. As KLM Cargo operates 24 hours per day, 7 days a week, the arrival of the truck can be at any time. However, the opening hours of the GHA are presented in Table 4.8. Therefore the reply can be slightly delayed. The opening hours of the customer are presented in Table 5.5. As their opening hours are limited the waiting time for the corrected documents can be significant.

The unloading time for the traditional model is significantly shorter, than for the DTP model. This can be explained by the fact that the former unloads 4 ULDs using a rollerbed, while for the DTP each package needs to be unloaded using a man-operated fork truck. In addition, the physical acceptance time is shorter for the ULDs as they need to be registered in the system. For the DTP, all shipments need to be made ready for carriage, including weighing, volume check, pieces count, packaging and labeling, taking extra time. For the traditional model, this process is outsourced to the GHA. Although, the individual processes for the traditional model are shorter and are less work for the hub, the total cargo throughput time is almost double. This is due to the fact that many parties are involved in the chain, and at each party wastes are introduced in the supply chain, such as consolidation, buffering and transportation. These wastes are analysed based on the theory described in Section 3.3.3. From a cost perspective, the assumption is made, together with the Area Operations Director, that the hub is able to handle the extra amount of work that accompanies the acceptance process (ready for carriage check). This assumption includes that no extra manpower has to be hired and / or equipment.

In the current set-up the booking made by a client is based on the connection time in Amsterdam. However, in the system the connection time is based on the traditional model. For the DTP model the cargo arrives 40% faster at the hub and might make an earlier flight. However, due to the limitation of the booking system, this is not feasible at the moment. Therefore, currently the hub operates as a warehouse, storing the shipments with a longer connection time. The hub is supposed to be a transit point and is not designed for storage. Therefore, in the current situation DTP is introducing pollution at the hub. This will not be researched in this thesis, but is recommended for further research. The possibility to be able to transport cargo faster to the hub, can be a competitive advantage for the carrier enabling it to compete with the integrators, as described in Chapter 2.

Transaction Cost Economics

From a TCE perspective, the number of processes for the traditional air cargo flow are larger than for the DTP flow. The fewer number of actions that need to be performed on a package, the cheaper the process. In addition the number of physical transactions is even lower (76 for traditional vs. 25 for the DTP model as displayed in the Swimlanes in Figure 4.5 and Figure 5.3), therefore less man-power is needed and the process is less prone to human-error. The same accounts for the information transactions (53 for traditional vs. 41 for DTP). Currently, due to the fact that not all outstation are able to handle digital AWB's the processes are almost the same, except that the GHA is no longer involved in the information transactions. Almost all information transactions are man handled and therefore prone to human errors. Therefore from a TCE perspective the DTP flow is favourable as it requires less handling of both the cargo and information stream.

7.5 Scenario 3: Collaboration (Physical)

If the DTP model is selected as the favourable model, several improvement design options can be proposed. In this section the first improvement design option (named scenario 3) to enhance the performance of the DTP air cargo flow from both a company and seamless supply chain perspective is introduced, namely the physical aspect of supply chain collaboration. First, the developments in the field of collaboration and how this is incorporated in the future state of the model is described. Followed by the performance of the design option on the KPIs.

7.5.1 Developments

This first DTP design option aims to improve the current DTP air cargo flow from both a company and a supply chain perspective. A seamless air cargo supply chain is of great importance to improve the performance according to (Lambert & Cooper, 2000), (Thomson, 2016) and (Mentzer et al., 2001). From the physical aspect cargo can flow seamless through a supply chain by including all parties in the supply chain (Martichenko, 2013). In addition all wastes as identified in Table 7.1 must be eliminated from the supply chain as described in Chapter 2.

From field research as described in Chapter 4 the silo mentality is clearly visible including the lack of supply chain visibility. One of the main concerns is that customers deliver their export cargo at random moments and therefore no predictability can be made on arrival patterns. There is however a pattern that cargo is often delivered on Friday and Saturday in the evening hours as companies aim to ship their weeks production before the weekend. A second observation is that customers often deliver their cargo unfit for aircraft transportation due to the strict rules and regulations regarding cargo transported on passenger aircraft. Finally, customers often deliver their cargo mixed loaded in the trucks, resulting in large unloading problems at the hub due to restricted manpower, space and equipment. Especially if the truck arrives in the peak hours this results in great delays.

The collaboration with supply chain partners could be of added value for all parties in the supply chain on both the physical part and informational part. In this section the focus lies on physical collaboration. Even though this research does not focus on the best way to establish such a performance, it does enlighten about the potential impact of a successful collaboration. This assumes that optimal arrangements between the different parties in the supply chain is possible.

In practice if all cargo would be loaded by the customer according to load plan this would result in large time reductions. KLM Cargos' NP department sends a planning to the customer which cargo should be loaded in which truck according to connection time to the flight at the hub in Amsterdam. However as explained in Chapter 4, currently cargo is loaded in different trucks than planned and often mixed. As the acceptance and ready for carriage check has to be performed in Amsterdam in case of a DTP flow, all pieces of an AWB must be present before the check can be completed. As the pieces are often scattered through the entire truck the entire truck has to be unloaded before the acceptance can be performed. Cargo that is incomplete must wait in the buffer area for the next truck to arrive, which might have the remainder of the cargo shipments. In peak hours warehouse space is the limiting factor. Therefore collaboration with the supply chain could greatly improve the acceptance in Amsterdam.

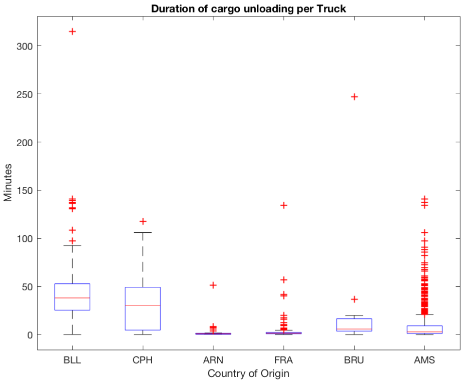


Figure 7.6: [DTP] Cargo Unloading Time

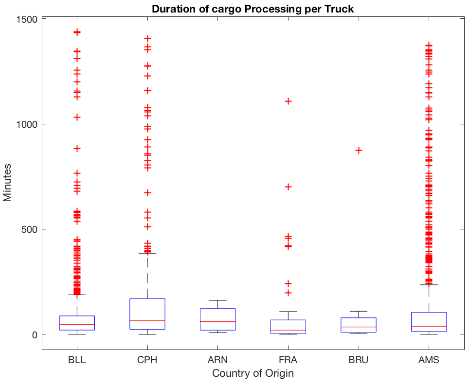


Figure 7.7: [DTP] Cargo Processing Time

If cargo would be loaded correctly by the customer, it is expected that the unloading time at Schiphol would decrease significantly. Therefore the collaboration design option is modelled in Simio by adapting mean unload time. This value is based on Figure 7.6 (described in detail in Appendix F). In this Figure the average unloading time for Billund, Copenhagen, Stockholm, Frankfurt, Brussels and Amsterdam is shown. From this Figure it can be concluded that Billund has the largest unloading time. The unloading time for the other cities is far less. The value for Brussels is used for the future state simulation, as this station has much loose cargo, just as Billund.

If the cargo would be loaded correctly by the customer, it is expected that the cargo processing time at Schiphol would decrease significantly as all packages can be found easily. Therefore the distribution of the cargo acceptance process is adapted as well. If cargo is loaded correctly in the truck, the acceptance process can be reduced significantly. The cargo processing for the various origins is displayed in Figure 7.7 (described in detail in Appendix F). In this Figure, the average cargo processing time for the same origins is shown. The cargo processing time for Billund compared to the other origins is average. However, Brussels outperforms Billund and therefore this value is again chosen for the future state simulation. For future research Brussels can be studied in an in-depth case study to identify why they outperform other stations.

7.5.2 Key Performance Indicator Analysis

The design option introduced in the previous section (Physical Collaboration) will be modelled using Simio and scored on the KPIs introduced in Section 5.4. The scores will be compared to the current state DTP performance and conclusions will be drawn from the impact of the design option. The results from the simulation model can be found in Table 7.3.

Table 7.3: KPI Results [Physical]

Variable	Data Source	Category	Unit	Avg.	H. W.	Min.	Max.
Documentation Processing	Processing	Holding Time	[minutes]	4,49	0,02	4,43	4,54
TotalTime Documents	Population	Time InSystem	[minutes]	162,20	39,36	79,02	264,12
Cargo Processing	Processing	Holding Time	[minutes]	66,69	16,46	32,63	103,40
Unloading Time	Processing	Holding Time	[minutes]	61,10	34,97	8,81	176,58
TotalTime Cargo	Population	Time InSystem	[minutes]	1313,87	86,25	1143,45	1524,72
LoadJdRTruck	Member InputBuffer	Holding Time	[minutes]	427,52	37,84	391,71	569,79
Correction Customer	Processing	Number Entered	[#]	1,82	1,22	0	17
Documentation	Population	Number Created	[#]	6,6	4,20	0	67

The first KPI, documentation processing (-0,2%) and total throughput time documentation (+2,2%) only deviates minimally from the current state DTP. This is as expected as no changes have been made on the information aspect of the system. These slight deviations can occur due the large variance in the system as indicated by the half-width value (explained in Appendix F) displayed in Table 7.3. The physical acceptance time decreases significantly with -30% compared to the current state, saving approximately 30 minutes per truck. The Unloading time also decreases significantly, namely with -14,9%, resulting in a saving of 10 minutes per truck. The total throughput time of the cargo is calculated from the departure of the customer to the moment the cargo receives the RCF milestone at the hub in Amsterdam. Therefore the waiting time for the truck at the customer is subtracted from the total time the cargo spends in the system. The total time the cargo spends in the system is decreased with -4.3% from 15,43 hours to 14,77 hours, saving 40 minutes per truck on average.

Transaction Cost Economics

The DTP swimlane presented in Figure 5.3 shows the number of transactions for the DTP flow. The first design option, collaboration in the supply chain reduces in total 4 transactions, of which 3 are physical transactions and 1 is an information transaction. Due to the fact that the cargo is loaded correctly in the truck and labels are correct, these steps can be omitted in the process at the KLM hub, saving man-power and warehouse space. In addition if the cargo is physically correctly loaded, as indicated on the flight planning sent by NP, the manifest error does no longer exist, therefore reducing the uncertainty and handling time.

7.6 Scenario 4: Digitalization

In this section the second design option to enhance the performance of the DTP air cargo flow from both a company and seamless supply chain perspective is introduced, namely the digitalization of the supply chain. First the developments in the field of digitalization and how this is implemented in the future state of the model is described. Followed by the performance of the design option on the KPIs.

7.6.1 Developments

In Appendix E, the current state of EDI in the traditional model and the DTP model is illustrated in Figure E.1 and Figure E.2 respectively. Below several developments in EDI with regard to the air cargo industry are described. In Figure E.3 in Appendix E a possible future scenario for EDI in DTP is developed, a paperless scenario.

E-freight
E-freight has been developing over the past couple of years. By making information electronically available and shared, the probability of (human-) errors and delays is reduced. In addition due to electronic handling and documentation less physical actions and interactions are required. In practice e-freight is not always the preferred state of transportation. A large limitation in the air cargo industry prohibiting the industry from developing is that not only the station at origin must be able to handle the e-freight documents (hardware, software etc.) but also the station at destination needs to be able to handle the information. For KLM Cargo there are still 60 stations world wide unable to handle e-freight. For these stations the e-AWB's need to be printed, bundled, signed etc. resulting in an increase in handling actions and paper usage, rather than the intended decrease and improvements.

E-customs
Customs oversee the compliance of shipments with the trade regulations. All transactions leaving or entering countries must be processed by customs agencies and this takes time. With the development of EDI e-customs (e-MRN) are emerging (Urciuoli et al., 2013). To be able to adopt e-customs, regulatory compliance should be ensured. Advantages of e-customs entail among others, cost savings, ease of use, time and usefulness. Disadvantages of e-customs are confidentiality issues, technical constraints and the cost of development and adoption. As time is a crucial factor in international trade, the transit time, not only in terms of physical goods movement but also information processing is important. The actions of public agencies that intervene in the administrative processing of trade flows such as customs contributes to this time. Delays associated with customs inspections can be seen as trade costs accruing to each transactions.

Above two developments in the air cargo industry with regard to EDI are described. Advantages of using EDI in air cargo industry according to (International Air Transport Association, 2013) are:

1. **Cost reduction**: eliminate paper handling, transporting and processing cost (eliminates data re-capture).
2. **Time**: reduce freight wait time + re-entering same data in different systems.
3. **Quality**: data quality means customer satisfaction.
4. **Compliance**: worldwide customs & security information available digitally.
5. **Sustainability**: contribute to environment by reducing paper consumption.

This design option is modelled in Simio by adapting the % of incorrect documentation, document processing time, document correction time and incorrect documentation time. The new values for the future state are determined based on interviews with the documentation department of KLM Cargo.

7.6.2 Key Performance Indicator Analysis

The design option introduced in the previous section (Digitalization) will be modelled using Simio and scored on the KPIs introduced in Section 5.4. The scores will be compared to the current state DTP performance and conclusions drawn from the impact of the design option. The results from the simulation model can be found in Table 7.4.

Table 7.4: KPI Results [Digitalization]

Scenario	Data Source	Category	Unit	Avg.	H. W.	Min.	Max.
Documentation Processing	Processing	Holding Time	[minutes]	3,51	0,01	3,49	3,56
TotalTime Documents	Population	Time InSystem	[minutes]	86,58	20,29	51,09	142,20
Cargo Processing	Processing	Holding Time	[minutes]	95,11	38,56	34,73	214,27
Unloading Time	Processing	Holding Time	[minutes]	67,84	38,77	12,51	196,20
TotalTime Cargo	Population	Time InSystem	[minutes]	1349,03	103,00	1127,70	1531,39
LoadJdRTruck	Member InputBuffer	Holding Time	[minutes]	427,52	37,84	391,71	569,79
Correction Customer	Processing	Number Entered	[#]	0,6	0,42	0	7
Documentation	Population	Number Created	[#]	6,6	4,20	0	67

Transaction Cost Economics

The DTP swimlane is presented in Figure 5.3. According to (Williamson, 1981) a transaction occurs when a good or service is transferred across a technologically separable interface. Transactions are necessary for a system to generate value and they can take place randomly, therefore introducing uncertainty. In the swimlane the various transactions are indicated by blocks. The orange blocks represent the physical transactions of the cargo and the green blocks the information transactions. Due to digitization of the supply chain in total 9 transactions can be removed, of which 7 are solely information transactions and 2 are both an information and a physical transaction.

7.7 Scenario 5: Information

In this section the third design option to enhance the performance of the DTP air cargo flow from both a company and seamless supply chain perspective is introduced. Namely, the ideal state of 100% correct information. First the developments with respect to information in the air cargo industry are described and how this is implemented in the future state of the model, followed by the performance of the design option on the KPIs.

7.7.1 Developments

In a world where concepts such as JIT (as explained in Chapter 2) are important to obtain a seamless supply chain, the information provision is crucial. Therefore in this section the ideal world of complete information, which needs no correction is provided. As explained in the previous design option, EDI is developing rapidly in the industry the scenario is plausible. As described in Chapter 5, currently the customer does not make a 'manifest', nor does the customer send a FFM, on which is recorded which shipments are in which truck, their size, number of pieces, weight etc. Therefore KLM Cargo is 'blind' about which cargo to expect at the hub. They only have the total booking list for that day, which does not contain the latest information, nor if the shipment was actually forwarded on "no-show" This is only discovered upon opening the truck doors.

7.7.2 Key Performance Indicator Analysis

The design option introduced in the previous section (Information) will be modelled using Simio and scored on the KPIs introduced in Section 5.4. The scores will be compared to the current state DTP performance and conclusions drawn from the impact of the design options. The result from the simulation model can be found in Table 7.5.

Table 7.5: KPI Results [Information]

Variable	Data Source	Category	Unit	Avg.	H. W.	Min.	Max.
Documentation Processing	Processing	Holding Time	[minutes]	2,51	0,03	2,42	2,56
TotalTime Documents	Population	Time InSystem	[minutes]	45,68	13,45	30,02	90,30
Cargo Processing	Processing	Holding Time	[minutes]	84,13	42,43	6,38	194,63
Unloading Time	Processing	Holding Time	[minutes]	67,25	39,30	15,34	196,20
TotalTime Cargo	Population	Time InSystem	[minutes]	1346,46	104,36	1141,21	1544,69
LoadJdRTruck	Member InputBuffer	Holding Time	[minutes]	427,52	37,84	391,71	569,79
Correction Customer	Processing	Number Entered	[#]	0	0	0	0
Documentation	Population	Number Created	[#]	6,6	4,20	0	67

In a perfect world with correct information available, the documentation processing would decrease with -44.2% and the overall documentation throughput time with 71.2%, equivalent to 113 minutes. In addition the physical acceptance time would also increase with 11.7% as correct documentation is needed to accept the cargo. Finally the total throughput time of cargo would decrease with -0.7%.

Transaction Cost Economics

In a perfect world where information is digital and all information is correct, all the steps regarding information entering in systems and information correction can be omitted. The re-work transactions are shown in red in the DTP swimlane presented in Figure 5.3. The total transactions that can be reduced are 12, of which 10 are purely information transactions and two are a combination of physical transactions and information transactions. By reducing transactions the system is standardized (as indicated as one of the wastes), variability and human-error introduction will be reduced.

7.8 Evaluate Scenarios

Each of the selected design options is tested with the test platform of direct air cargo flow using the modelling software Simio. The model is used to answer the sub-research question *"What impact do the design options have on the performance of the direct trucking pick-up air cargo flow?* In Table 7.6 the impact of each tested design option on the KPI is summarized.

Two comparisons are made, first, the comparison between the traditional air cargo flow and the DTP flow. Second, the comparison between the current state of the DTP flow and the three design options suggested to improve the DTP flow. For the first comparison, the blue color in Table 7.6 is used to indicate the difference between the two models. The darker blue the area, the more favourable is that value on that specific KPI. For the second comparison, the green color in Table 7.6 is used to indicate the impact over the different design options. The darker the green area, the greater the impact of that design option is on that specific indicator. In addition the percentage increase or decrease is calculated to provide a quantitative indication of the effect. The KPI indicated in red shows that the design option has a negative effect on the KPI.

The Table should be interpreted with caution. The individual numbers can lead to a different conclusion than when the overall impact of the KPI of a design option is considered. For example, when looking at the first comparison between the traditional air cargo flow and the DTP flow, it seems like almost all KPI's are in favor of the traditional model. However, when taking a closer look it can be seen that for individual throughput times the KPI's are more favourable but when looking at the total throughput times and costs, the DTP model is more favourable.

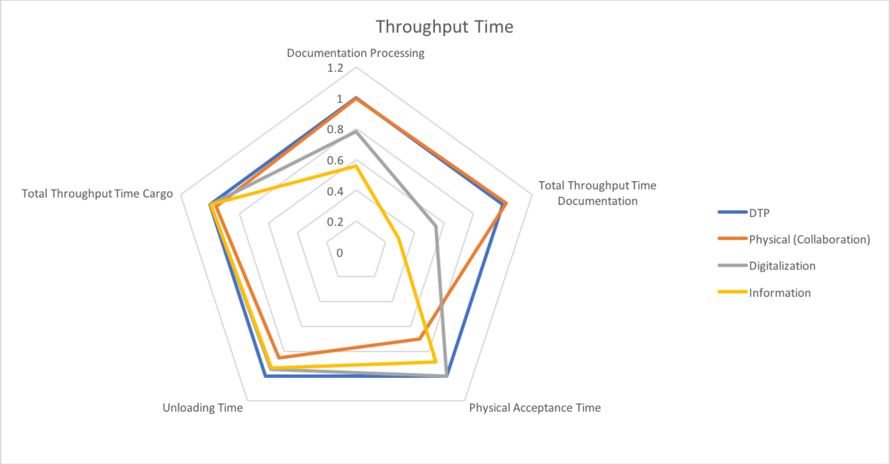


Figure 7.8: KPI Comparison for Scenarios

In Figure 7.8 the performance of each of the DTP scenarios on each of the KPIs is shown. On each of the axis of the spiderweb a KPI is shown. The current DTP scenario as indicated in blue is set as 1. The impact of each design option on the KPI is normalized and related to the blue current state reference DTP scenario. Design option 3 Physical (Collaboration) is indicated in orange and as expected reduces the physical acceptance time significantly with 30%. In addition the unloading time is lowest compared to all other scenarios, with a reduction of 14.9%. Design option 4, digitalization (indicated in grey) scores shows a severe reduction in documentation processing time, total throughput time documentation and only a small reduction in unloading time. In an ideal situation (indicated in yellow) where the information would be available and correct, the documentation processing, total throughput time documentation and unloading time reduce significantly. However, this a situation to be aimed for in the future. Realistically, design option 4, digitalization is more feasible in the near future.

In Figure 7.8 the difference in performance on total throughput time cargo is not clearly visible. Therefore in Figure 7.9 a comparison is made for this KPI between the traditional and DTP air cargo flow and the three proposed improvements for DTP. In Figure 7.9 a clear time reduction can be seen when the DTP model is used. This results in a 46% time reduction when the DTP model is used. Focusing on the three proposed design options, in Figure 7.10 it can be clearly seen that compared to the current DTP performance the design option 3 Physical (Collaboration) has the greatest impact on the Total

Throughput Time of Cargo. Compared with the current DTP performance there is a 4.3% reduction in time.

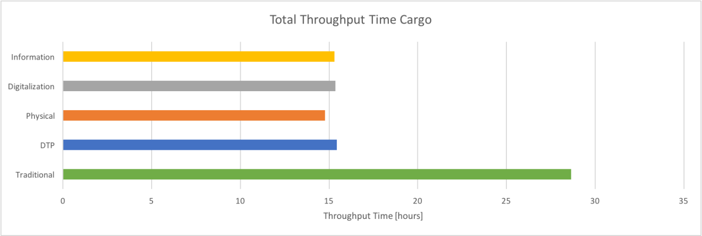


Figure 7.9: Total Throughput Time Cargo

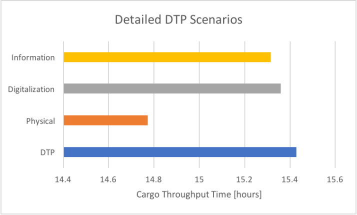


Figure 7.10: Total Throughput Time Cargo DTP Scenario Only

The research objective of this thesis is to propose a framework for a seamless air cargo supply chain focusing on DTPs as set in Chapter 1. Therefore the focus should be on the overall proportion between the different KPIs. Here the question comes to mind *“do the faster and cheaper direct trucking air cargo flow model outweigh the increased amount of work at the Amsterdam Schiphol Airport hub?”*.

7.9 Synthesis

In this chapter, first a selection was made out of the shortlisted proposed design options. This selection was created based on the measurement and analysis research phase conducted in Chapter 4 and Chapter 5 respectively, literature study performed in Chapter 2 and the selection of the management of KLM Cargo. The sub-question *“Which design options does KLM cargo have to improve the performance of the direct trucking process?”* is answered as shown below:

1. Scenario 1. Measurement Points
2. Scenario 2. Traditional vs. DTP
3. Scenario 3. Collaboration
4. Scenario 4. Digitalization
5. Scenario 5. Correct information

Next the sub-research question: *What impact do the design options have on the performance of direct trucking pick up air cargo flow?* is answered. This is shown in Table 7.6.

Table 7.6: KPI Results Summary

KPI	Type	Unit	Current		Future DTP		
			Traditional	DTP	Physical	Digitalization	Information
Throughput Time	Documentation Processing	[minutes]	1,98	4,50	4,49 -0,2%	3,51 -22.0%	2,51 -44.2%
	Total Throughput Time Documentation	[minutes]	31,21	158,69	162,20 +2,2%	86,58 -45,4%	45,68 -71,2%
	Physical Acceptance Time	[minutes]	6,2113	95,32	66,69 -30,0%	95,11 -0,2%	84,13 -11,7%
	Unloading Time	[minutes]	8,64	71,80	61,10 -14,9%	67,84 -5,5%	67,25 +6,3%
	Total Throughput Time Cargo	[hours]	28,64	15,43	14,77 -4,3%	15,36 -0,4%	15,32 -0,7%
Costs	Transportation Costs	[euro]	190.450,00	210.757,10	n/a	n/a	n/a
	Handling Costs	[euro]	154.828,45	0,00	n/a	n/a	n/a
	Total costs	[euro]	345.278,45	210.757,10	n/a	n/a	n/a
Transactions	Total number of processes	[#]	126	96	92	87	84
	Physical Transactions	[#]	76	25	22	23	23
	Information Transactions	[#]	53	41	40	32	29
	Re-work	[#]	0,16	1,7	1,82 +7,1%	0,6 -64,7%	0 -100%
		%	2,85	25,76	27,58	9,09	0,00
						🟩 🟩 🟩 🟥	Largest increase Medium increase Small increase Decrease

Part V

Evaluation

8 Conclusion & Recommendation

This chapter will first present the research conclusion by answering the main research question. The sub-research questions posed in this thesis have been answered in the synthesis of each chapter. Combined they will answer the main research question. Secondly, the recommendations will be presented and finally a discussion is held. In the discussion, the limitations of the research and the contribution to both the scientific and the practical field will be elaborated on.

8.1 Conclusion

In Chapter 1 and 2 the main research question and sub-research questions for this research were presented. To recapitulate the main research question is:

What are the criteria to design a seamless supply chain for the Direct Trucking Pick-up cargo flow for KLM Cargo?

This thesis studied the traditional air cargo flow and the Direct Trucking Pick-up (DTP) flow for a case study from Billund (Denmark) towards Amsterdam (The Netherlands). DTP is often performed as a special offer to the customers, with the intention to transport cargo faster and cheaper. However, this has never been studied properly. Currently, there is a gap between the desired performance and the current performance of DTP and it is not clear what drivers influence this gap. Furthermore, it is not known how the drivers can be improved and what the theoretical performance could be, in terms of arrival performance at the hub. To determine the criteria for the design of a seamless supply chain, first the definitions of a seamless supply chain had to be defined and methods found on how such a supply chain could be studied.

To research the above mentioned gap, an in-depth case study was executed for both the traditional and the DTP cargo flow. Using several theories, such as lean manufacturing and transaction cost economics, the current state performance was analysed. The air cargo industry can be defined as a consecutive stream of (physical and / or information) transactions. These transactions include all technical and administrative actions (such as certification, regulation, registration). Using the theory of transaction cost economics, a transaction can be defined as *"a transaction occurs when a good or service is transferred across a technologically separable interface"* (Williamson, 1981). Transactions are necessary elements for a value stream to generate value. The transaction cost theory can be used as the air cargo industry classifies by its high asset- and human specificity and uncertainty. The high asset and human specificity means that the actions can only be used exclusively for this type of service because they would be useless in other types of industries (Arnold, 2000). Current academic research does not provide a transaction cost economics perspective on the air cargo industry, studying the number of goods or services transferred across a technologically separable interface. By using these transactions as a key performance indicator, the air cargo operation can be measured from a transaction cost perspective.

Based on the measurements and on the analysis of the current state, several problems were identified and a framework had to be developed as a test platform to test several improvement scenarios. Currently, the air cargo industry is characterized by overtime, firefighting and blindness. To design a framework, the current state swimlane, that was developed during the measure and analyse phase, was simplified to a VSM. This VSM was enhanced using the discrete event simulation tool Simio. It was found that possibilities for improvement are mainly in the information (electronic data interchange (EDI)) domain and in the transaction (both physical and information transactions) domain. Transactions take place randomly, they can be used to test key performance indicators by discrete event simulation.

The key performance indicators for this research are: throughput time (from a supply chain perspective), costs (from a company perspective) and transactions (from a transaction cost economics perspective). The KPIs for throughput time comprises of an information aspect (documentation processing) and a physical aspect (physical acceptance time and unloading time). The costs can be divided in transportation costs and handling costs. The transactions KPI is also divided in an information perspective and a physical perspective. The framework was developed in the form of a discrete event model, in which the proposed design options can be tested. The selected design options (scenarios) are:

1. Scenario 1: Introducing Measurement Points to the DTP model.
2. Scenario 2: Comparing Traditional vs. DTP model.
3. Scenario 3: Collaboration in the DTP supply chain.
4. Scenario 4: Digitalization in the DTP supply chain.
5. Scenario 5: Correct Information in the DTP supply chain.

Below each scenario is explained in more detail, the suggested improvements are key to improve one or both supply chains. For scenario 1, several measurement points should be implemented in the DTP supply chain to create visibility and allow future analysis. The CIQ (industry standard) milestones should be re-designed, or a functionality should be created to make customization of the milestone order possible, to allow for structural feedback between the different parties in the supply chain. For scenario 2, when looking at the individual transactions in the traditional model, it could be concluded that the different processes are shorter than the same steps in the DTP supply chain. However, when looking at the total throughput time of cargo, the DTP supply chain is 40% faster than the traditional supply chain. Evaluating the current trucking schedule could help reduce the throughput time in the traditional supply chain. Scenario 3, 4 and 5 suggest improvements for the current DTP setup. For design option 3, by improving the physical collaboration between all parties in the DTP supply chain, the acceptance time will be reduced with 30%. In addition, with this scenario the unloading time is the lowest compared to all other scenarios. It shows a reduction of 14.9% compared to the current state. Design option 4, by digitizing the DTP supply chain, a severe reduction was observed in the documentation processing time, total throughput time for documentation and a small reduction in unloading time. Design option 5 represents an ideal situation, where the information should be made digitally available and correct. The documentation processing, total throughput time documentation and unloading time reduce significantly. However, this is a situation to be aimed for in the future. Realistically, design option 4, digitalization, will be more feasible in the near future rather than immediately.

When considering the cost and time aspects of the supply chain, it could be concluded that the DTP business model looks more favourable, compared to the traditional business model. However, these five scenarios should be interpreted with caution. Many other factors need to be taken into account when comparing the two business models. Examples of these factors are; amount and type of cargo, proximity to a network point, customs, liability and safety (compliance issues), information and communication issues. To employ the DTP business model, first these factors should be discussed and agreed upon by all parties in the supply chain.

In conclusion, this thesis studied the traditional air cargo flow and the DTP flow for a case study from Billund (Denmark) towards Amsterdam (The Netherlands). DTP is often performed as a special offer to the customers, with the intention to transport cargo faster and cheaper. However, this has never been studied properly. To design a seamless supply chain, an in-depth case study was executed for both the traditional and the DTP cargo flow. Using the discrete event simulation tool Simio, a model was created serving as a test platform for the air cargo industry. Based on the simulation results the main research question can be answered. The criteria to design a seamless supply chain for the DTP cargo flow for KLM Cargo are:

1. Minimize the number of physical and information (re-work, double, manual) transactions.
2. Introduce electronic data interchange.
3. Ensure collaboration between the different parties in the supply chain.

8.2 Recommendation

In this paragraph, first the recommendations for the air cargo industry in general are presented. The recommendations were made with regard to the scientific research gaps, contribution to the air cargo industry and the method developed. Secondly, the recommendations were made for the in-depth case study performed for Billund - Amsterdam.

8.2.1 Recommendation for Scientific Research

In Chapter 2, a literature review was performed on the air cargo supply chain. A lack of scientific research in the air cargo industry, especially with regard to trucking operations, was identified by several scholars, such as (Heinitz et al., 2013), (Feng et al., 2015), (Reis & Silva, 2016) and (Walcott & Fan, 2017). With this thesis research, a case study for the air cargo traditional line-haul trucking model and direct trucking pick-up (DTP) model have been performed, contributing to scientific research, available in the air cargo industry. This case-study has been performed for the trade lane Billund - Amsterdam, therefore only representing one trade-lane in the area of the Nordics. Additional case studies have to be performed to gain insight in all bottlenecks present in the air cargo industry. It is recommended to perform numerous case studies on different trade-lanes in different markets. In addition, it is recommended that various air cargo business models, such as co-loading, multiple contracted GHA's and multiple contracted trucking companies are studied. The framework developed in this research can serve as a test platform for studying these impacts on different stations in different regional area's as the implications of the rules and regulations can be adapted in the model.

In this thesis a case study has been performed regarding the collection of cargo directly from the customer, also known as pick-up. Using four methodical tools (swimlane, Value Stream Map (VSM), discrete event modelling and case study) the cargo pick up from the customer until delivery to the hub has been studied. The same principle can be applied for delivery to the customer, known as direct to agent (DTA). For further research the current developed framework can be mirrored and with slight adaptations, it can be used for DTA in the air cargo industry.

For future research, the model can be enhanced with a more detailed analysis. While creating the VSM, several assumptions have been made and processes identified in the swimlane grouped together to create a framework for test purposes. These assumptions were made, as detailed information regarding processes was missing. In Scenario 1, it was suggested to implement measurement points in the DTP supply chain. Using these measurements points, detailed data can be gathered and analysed, providing input for future development of an in-depth dynamic model. Focusing on the methods used to analyse the supply chain, it can be recommended that with respect to the transaction cost economic theory, the number of transactions is recommended to be introduced as a parameter in the air cargo supply chain. This would be complementary to the already existing parameters, gained from the lean manufacturing theory. Air cargo customers, generally use air transportation due to the fragile nature of their products. They want their cargo to be subject to as little transactions as possible, reducing the risk of damage and human error. In this thesis, the recurrent aspect of transactions is not taken into account and could still be studied in more detail.

In this thesis, several design options were introduced as improvement scenarios for the DTP model. One of the improvements is regarding EDI. During the World Cargo Symposium visited from 10th - 16th of March 2018 in Dallas (Texas, United States of America), it became apparent that data sharing is a key improvement point in the industry. One of the main developments to be researched, is the possibilities to use blockchain technology to control information sharing among different parties. It is recommended to study this possibility in future research.

Finally, this research is currently limited to the air cargo industry regarding the traditional model and DTP model. Further research is necessary, to test the indicators regarding other airline business models and other sectors of complex service industries. Other industries might be (sea) port communities, health care, fast moving consumer goods, flower trade, pharmaceutical industry, chemistry and /or road transportation industry.

8.2.2 Recommendations KLM Cargo

In this thesis, a test platform was designed to investigate the effect of several proposed design options, on the DTP supply chain. However, due to time and computational limitations only 3 improvement scenarios for DTP were run. It is recommended to the management of KLM Cargo, to use the test platform to test additional improvement scenarios in the future. In addition, several improvement scenarios can be combined to investigate the effect of combined scenarios.

Based on the 3 improvement scenarios that were run for the DTP model, and in order to compete with the integrators, it is recommended to further investigate the DTP model. However, with regard to the complexity of the industry, first a solid proof of concept should be generated. Based on this proof of concept, strict rules should be set with the customer. Since DTP is an exclusive service, customers gain a faster and personalized service, risks are reduced, less transactions are executed and the costs are reduced since the GHA is bypassed, it should be considered to have customers pay for that service. However, in the current state there are limited benefits for KLM Cargo, since the supply chain is polluted due to lacking or unclear processes. The DTP service should be exclusively offered to premium customers, who are willing to collaborate and provide all the needed information. A proof of concept can be generated by designing the DTP supply chain with all parties involved. The proof of concept can be developed using an iterative or agile approach, receiving and providing structural feedback from the customers. Essential elements have to be identified to create a culture of continuous feedback in a seamless supply chain. Setting the culture to strive for excellence. To set a price on the premium DTP service, offering less transactions on both a physical and information level to the customer, the internal costs of KLM Cargo have to be determined first. Currently, there is no insight in the cost of each transaction within KLM Cargo. These internal costs are also needed, to be able to compare the performance costs of the hub with the GHA costs.

Finally, on hub operation level it is recommended that a policy should be designed concerning the order in which trucks and documents are handled, but also regarding cargo processing further in the chain. Currently, the order in which trucks are handled is first-in-first-out (FIFO). The negative effect of this can be observed, when some trucks arrive late at the hub, creating congestion, but are served first instead of the trucks that arrive on time. Resulting in possible missed connections on board the trucks that arrived on time. Regarding the cargo processing, it can occur that the 'easy' trucks (carrying ULDs) are handled first, resulting in delays for the 'difficult' trucks (carrying loose cargo), even if they arrived at the hub first. Since the DTP trucks are considered as 'difficult' trucks, the current DTP schedule should be redesigned, looking at the best days of the week and the best time slots in order to ensure quick handling at the hub. Currently shipments with long connection are booked on the DTP trucks, resulting in waiting time and storage at the hub, creating too much inventory and pollution due to the limited storage space at the hub. The hub should strive for operational excellence. In passenger services, all operations are digitalized. Personnel works with apps, while in the cargo division paper AWBs are still every day practice. Finally, the legal and compliance aspect of the DTP model should be studied in more detail. In this research only the technical aspect is highlighted, as this thesis is for an engineering education.

8.3 Discussion

In the following 2 sub-paragraphs, the limitations of this research and the scientific contribution of this thesis will be discussed.

8.3.1 Limitations of this Research

For the current case study, performed for KLM Cargo, a data set of 1 year is used. However, for future research it is recommended to study the performance with a larger data set. Using a larger data set, external influences can be identified and prediction models can be generated to predict future cargo trends. Using prediction models KLM Cargo can optimize their resources and assets. In addition, due to the fact that data collection was incomplete or incorrect, seasonal influences in the data set are not taken into account. For KLM Cargo it is recommended to design and implement internal measurement points to perform an analysis on seasonal or external influences.

Both the type of goods and the company (KLM Cargo) has been posed to limitations in this research. A list of all assumptions made in the model can be found in Section 6.2. In this research only non-exceptional export goods were studied. Exception handling introduces the most constraints on the hub's acceptance system. Therefore for future research it is recommended to take into account the exceptional cargo. Moreover, the availability of the complete, right and reliable data has been limited. Often, this was not a system and / or analysis tool related problem, but due to manual input of data prone to human-error and therefore not available or incorrectly entered. Combining the previous with the numerous available legacy systems, resulted in scattered data from which intelligence could only be gained after careful pre-processing.

The largest limitation of this research is, that it was limited to one country. For future research, it is recommended to study other markets in other regions and compare results. For example, it was briefly mentioned in this research that the unloading performance of Brussels (Belgium) was exemplary. A study can be performed on why Brussels has the ability to achieve such good performance opposed to the issues introduced in the chain by DTPs from Billund.

8.3.2 Scientific Contribution

Limited scientific research has been performed on air cargo in general (Feng et al., 2015) as until recent, carriers regarded air cargo as a by-product to the core-business, passenger services. Especially research regarding the road feeder service (RFS) aspect of air cargo transportation is neglected. Research regarding DTPs is a green field and further academic research is needed (Merkert et al., 2017). This research therefore contributes to the air cargo literature with a focus on RFS and DTP. This research has presented several contributions to scientific literature. The first contribution is additional scientific research to the currently limited existing research in the air cargo industry. The second contribution is a pioneering exploratory case-study research, regarding DTPs. The third contribution, a framework is proposed on how to design and improve a seamless supply chain for the DTP service. Final contribution, a simulation is generated exemplifying the functionality of the proposed framework.

The air cargo industry can be characterized by rules, regulations and certifications due to government laws for safety of the passengers on board of combi-aircraft. As a result the products and services are highly complex in nature, in combination with high asset and human specificity. In addition uncertainty is a characteristic of the air cargo industry. Therefore the transaction cost economics theory (TCE) developed by (Williamson, 1981) can be used to analyse the industry, complementary to the already known Lean Six Sigma key performance indicators. TCE has not been used previously, to study the air cargo industry and therefore this is a greenfield, contributing to scientific knowledge. The separation of the transactions in a physical influence and information influence is also a new development regarding TCE. The discrete event simulation models provide an air cargo logistics company, the capability to simulate the effects of process improvements on the operational performance, prior to implementation. By means of three transaction alterations to a simulated DTP air cargo supply chain process, it is shown that the operational performance on the KPIs is useful to determine the boundaries of the system.

8.3.3 Practical Contribution

This research has contributed to the practical understanding of the air cargo supply chain, both for the traditional model and the DTP model. First of all, an insight in the entire cargo supply chain has been provided and the difference between the two models was identified. The case study has been performed for KLM Cargo, who until now, did not have a qualitative insight in the differences between the two models. Based on the performance of the two models, a substantiated consideration can be made between the traditional model and the DTP model. Secondly, it has been identified what the contributing factors to the variation in the throughput time and re-work are and how these variations can be omitted. This has resulted in a more stable process and a reduced throughput time. Thirdly, several improved design options are suggested to improve the current DTP performance.

References

Abdulmalek, F. A., & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. *International Journal of Production Economics*, *107*, 223–236. doi: 10.1016/j.ijpe.2006.09.009

Aguilar-Saven, R. S. (2004). Business process modelling: Review and framework. *International Journal of Production Economics*, *90*, 129–149. doi: 10.1016/S0925-5273(03)00102-6

Air France KLM Cargo. (2017). *Air France KLM Cargo - Company.* Retrieved from `https://www.afklcargo.com/NL/en/common/about{_}us/company{_}info.jsp`

AirFrance KLM Martinair Cargo. (2017). *Local Conditions ex Denmark* (Tech. Rep. No. November). Amsterdam: Air France KLM Martinair Cargo.

Ankersmit, S., Tavasszy, L., Rezaei, J., Seck, M., Audenaerdt, R., & Radstaak, B. (2013). *From vertical to horizontal collaboration in the air cargo sector - A system analysis of the value of horizontal collaborative logistics applied on inner airport air cargo transport movements at Schiphol* (Master Thesis). Delft University of Technology.

Arnold, U. (2000). New dimensions of outsourcing: a combination of transaction cost economics and the core competencies concept. *European Journal of Purchasing and Supply Management*, *6*, 23–29.

Atieh, A. M., Kaylani, H., Almuhtady, A., & Al-tamimi, O. (2016). A value stream mapping and simulation hybrid approach: application to glass industry. *International Journal of Advanced Manufacturing Technology*, *84*, 1573–1586. doi: 10.1007/s00170-015-7805-8

Ayeni, P., Baines, T., Lightfoot, H., & Ball, P. (2011). State-of-the-art of 'Lean' in the aviation maintenance, repair, and overhaul industry. *Journal of Engineering Manufacture*, *225*, 2108–2123. doi: 10.1177/0954405411407122

Azadian, F., Murat, A., & Babu, R. (2017). An unpaired pickup and delivery problem with time dependent assignment costs: Application in air cargo transportation. *European Journal of Operational Research*, *263*, 188–202. doi: 10.1016/j.ejor.2017.04.033

Azadian, F., Murat, A. E., & Chinnam, R. B. (2012). Dynamic routing of time-sensitive air cargo using real-time information. *Transportation Research Part E*, *48*(1), 355–372. Retrieved from `http://dx.doi.org/10.1016/j.tre.2011.07.004` doi: 10.1016/j.tre.2011.07.004

Bendell, T. (2005). Structuring business process improvement methodologies. *Total Quality Management & Business Excellence*, *16*(8-9), 969–978. Retrieved from `http://www.tandfonline.com/doi/abs/10.1080/14783360500163110` doi: 10.1080/14783360500163110

Berbeglia, G., Cordeau, J.-F., Gribkovskaia, I., & Laporte, G. (2007). Static pickup and delivery problems: a classification scheme and survey. *Sociedad de Estadistica e Investigacion Operativa*, *15*, 1–31. doi: 10.1007/s11750-007-0009-0

Boeing World Air Cargo Forecast Team. (2017). *World Air Cargo Forecast* (Tech. Rep.). Retrieved from `http://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/cargo-market-detail-wacf/download-report/assets/pdfs/wacf.pdf`

Boonekamp, T., & Burghouwt, G. (2017). Measuring connectivity in the air freight industry. *Journal of Air Transport Management*, *61*, 81–94. Retrieved from `http://dx.doi.org/10.1016/j.jairtraman.2016.05.003` doi: 10.1016/j.jairtraman.2016.05.003

Bowen, D., & Youngdahl, W. (1998). "Lean" service: in defense of a production-line approach. *International Journal of Service Industry Management*, *9*(3), 207–225. Retrieved from `https://doi.org/10.1108/09564239810223510`

Bowen, J., & Leinbach, T. (2004). Market concentration in the air freight forwarding industry. *Tijdschrift voor Economische en Sociale Geografie*, *95*(2), 174–188.

Bronsing, M., Tavasszy, L., van Ham, H., Oey, M., Cunningham, S., & Krol, B. (2013). *KLM cargo flow allocation optimization at Schiphol - A scenario analysis performed with a decision support system on a optimal allocation of KLM and Martinair cargo flows between KLM and Menzies warehouses at Schiphol* (Master Thesis). Delft University of Technology.

Button, K. (1996). Liberalising European aviation: Is there an empty core problem? *Journal of Transport Economics and Policy*, *30*(3), 275–291.

Christopher, M. (2011). *Logistics & Supply Chain Management* (4th ed.). Pearson Education Limited.

Cima, R. R., Brown, M. J., Hebl, J. R., Moore, R., Rogers, J. C., Kollengode, A., … Deschamps, C. (2011). Use of Lean and Six Sigma Methodology to Improve Operating Room Efficiency in a High-Volume Tertiary-Care Academic Medical Center. *American College of Surgeons*, *213*(1), 83–92. Retrieved from `http://dx.doi.org/10.1016/j.jamcollsurg.2011.02.009` doi: 10.1016/j.jamcollsurg.2011.02.009

Consultant Decision Support. (2017). *Cargo Transit Patterns - Getting insight into the transit patterns of cargo at Schiphol Cargo Hub.* Air France KLM Cargo.

Cooper, M. C., Lambert, D. M., & Pagh, J. D. (1997). Supply Chain Management: More Than a New Name for Logistics. *The International Journal of Logistics Management*, *8*(1), 1–14. Retrieved from `http://www.emeraldinsight.com/doi/abs/10.1108/09574099710805556`

D'Engelbronner, R., Tavasszy, L., van Duin, J., Oey, M., Krol, B., de Jong, J., & Camoenie, G. (2012). *Air cargo handling demand foreceseting - A support tool for short-term decisions on manpower deployment at world port* (Master Thesis). Delft University of Technology.

Derigs, U., Kurowsky, R., & Vogel, U. (2011). Solving a real-world vehicle routing problem with multiple use of tractors and trailers and EU-regulations for drivers arising in air cargo road feeder services. *European Journal of Operational Research*, *213*(1), 309–319. Retrieved from `http://dx.doi.org/10.1016/j.ejor.2011.03.032` doi: 10.1016/j.ejor.2011.03.032

de Vreede, N., Negenborn, D. R., Beelaerts van Blokland, D. W., Annema, D. J., & Krol, B. (2015). *Enhancing performance of cargo acceptance process at Air France - KLM Cargo from a supply chain perspective - An assessment of the cargo acceptance process at Amsterdam hub* (Master Thesis). Delft University of Technology.

DiagNose. (2010). *RASCargO - Remote Air Sampling for Canine Olfaction.* Retrieved 2017-06-02, from `http://www.diag-nose.com/dog{_}cargo{_}security.html`

Donk van der, M., Verbraeck, A., Warnier, M., van Ham, H., & Ritsema, H. (2015). *A high-level integrated design for a Central Pickup and Drop-off point for air cargo at Amsterdam Airport Schiphol* (Master Thesis). Delft University of Technology.

Dul, J., & Hak, T. (2008). *Case Study Methodology in Business Research* (First Edit ed.). Butterworth - Heinemann.

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., & Bots, P. (2010). *Policy Analysis of Multi-Actor Systems.* The Hague: Lemma.

Feng, B., Li, Y., & Shen, Z. J. M. (2015). Air cargo operations: Literature review and comparison with practices. *Transportation Research Part C: Emerging Technologies*, *56*, 263–280. Retrieved from `http://dx.doi.org/10.1016/j.trc.2015.03.028` doi: 10.1016/j.trc.2015.03.028

Ginieis, M., Sanchez-Rebull, M.-V., & Campa-planas, F. (2012). The academic journal literature on air transport: Analysis using systematic literature review methodology. *Journal of Air Transport Management*, *19*, 31–35. Retrieved from `http://dx.doi.org/10.1016/j.jairtraman.2011.12.005` doi: 10.1016/j.jairtraman.2011.12.005

Gunasekaran, A., Marri, H. B., Mcgaughey, R. E., & Nebhwani, M. D. (2002). E-commerce and its impact on operations management. *International Journey of Production Economics*, *75*, 185–197.

Hansen, T. (2017). *Interview Cargo Center Billund.* Billund, Denmark: KLM Cargo.

Heinitz, F., Hirschberger, M., & Werstat, C. (2013). The Role of Road Transport in Scheduled Air Cargo Networks. *Procedia - Social and Behavioral Sciences*, *104*, 1198–1207. Retrieved from `http://dx.doi.org/10.1016/j.sbspro.2013.11.216` doi: 10.1016/j.sbspro.2013.11.216

Hellberg, R., & Sannes, R. (1991). Customs clearance and electronic data interchange - A study of Norwegian freight forwarders using EDI. *International Journal of Production Economics*, *24*, 91–101.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International Journal of Operations & Production Management*, *17*(1), 46–64.

Horvath, & Möller. (2004). Supply chain performance measurement: a transaction cost thoery and value-based approach. *Performance Measurement and Management Control*, *14*, 155–184. doi: 10.1016/S1479-3512(04)14007-0

Houlihan, J. B. (1988). International Supply Chains: A New Approach. *International Journal of Physical Distribution & Materials Management*, *26*(3), 13–19. Retrieved from `http://www.emeraldinsight.com/doi/abs/10.1108/eb001493`

Huang, S.-H. S., & Hsu, W.-K. K. (2016). Evaluating the service requirements of combination air cargo carriers. *Asia Pacific Management Review*, *21*(1), 1–8. Retrieved from `http://dx.doi.org/10.1016/j.apmrv.2015.05.001` doi: 10.1016/j.apmrv.2015.05.001

Hummels, D. (2007). Transportation Costs and International Trade in the Second Era of Globalization. *Journal of Economic Perspectives*, *21*(3), 131–154.

Hummels, D., & Schaur, G. (2012). *Time as a Trade Barrier.* Cambridge. Retrieved from `http://www.nber.org/papers/w17758.pdf`

International Air Transport Association. (2008). *Cargo 2000* (Tech. Rep. No. April). International Air Transport Association.

International Air Transport Association. (2010). *IATA Direct Shipment (Cargo Agent acting as booking agent of the Airline)* (Tech. Rep.).

International Air Transport Association. (2013). *e-AWB workshop.*

International Air Transport Association. (2016a). *Air Cargo Digital Connectivity and Data Exchange Methodlogies* (Tech. Rep.).

International Air Transport Association. (2016b). *Air Cargo Industry Master Operating Plan* (Tech. Rep. No. March).

International Air Transport Association. (2017). *IATA Cargo Strategy* (Tech. Rep. No. July). Retrieved from `http://www.iata.org/whatwedo/cargo/Documents/cargo-strategy.pdf`

Investopedia. (2017). *Vertical Integration.* Retrieved 25-01-2018, from `https://www.investopedia.com/terms/v/verticalintegration.asp`

Jong de, S. J., & Beelaerts van Blokland, W. A. (2016). Measuring lean implementation for maintenance service companies. *International Journal of Lean Six Sigma*, *7*(1), 35–61. Retrieved from `www.emeraldinsight.com/2040-4166.htm` doi: 10.1108/IJLSS-12-2014-0039

Kallen, N., Verbraeck, A., van Splunter, S., Duinkerken, M., & Ritsema, H. (2015). *Multi-Perspective Design of a Fast-Track Facility for Cargo Transhipment at Amsterdam Airport Schiphol* (Master Thesis). Delft University of Technology.

Kelton, W., Smith, J., & Sturrock, D. (2011). *Simio and Simulation - Modeling, Analysis, Applications* (2nd editio ed.). Simio LLC.

Kleijnen, J. P. C. (1995). Verification and validation of simulation models. *European Journal of Operations Research*, *82*, 145–162.

KLM. (2017). *KLM Management structure Board of Managing Directors* (Tech. Rep.). Amstedam: Author. Retrieved from `https://www.klm.com/corporate/en/images/Organogram{_}mei2017{_}incl{_}namen{_}Executive{_}Team{_}tcm729-734837.pdf`

kumar Kasava, N., Yusof, N. M., Khademi, A., & Saman, M. Z. M. (2015). Sustainable Domain Value Stream Mapping (SdVSM) Framework Application in Aircraft Maintenance: A Case Study. *Procedia CIRP*, *26*, 418–423. Retrieved from `http://dx.doi.org/10.1016/j.procir.2014.07.075` doi: 10.1016/j.procir.2014.07.075

Kupfer, F., Meersman, H., Onghena, E., & Voorde, E. V. D. (2017). The underlying drivers and future development of air cargo. *Journal of Air Transport Management*, *61*, 6–14. Retrieved from `http://dx.doi.org/10.1016/j.jairtraman.2016.07.002` doi: 10.1016/j.jairtraman.2016.07.002

Lambert, D. M., & Cooper, M. C. (2000). Issues in Supply Chain Management. *Industrial Marketing Management*, *29*, 65–83.

Laseter, T., & Oliver, K. (2003). When Will Supply Chain Management Grow Up? *Strategy + Business*, *Operating*(32), 1–5. Retrieved from `https://www.strategy-business.com/article/03304?gko=54182`

Law, A. M. (2011). How to select simulation input probability distributions. In *Proceedings of the 2011 winter simulation conference* (pp. 1394–1407). Tucson, USA: Avrill M. Law & Associates, Inc.

Leite, H. d. R., & Vierira, G. E. (2015). Lean philosophy and its applications in the service industry: a review of the current knowledge. *Production*, *25*(3), 529–541. Retrieved from `http://dx.doi.org/10.1590/0103-6513.079012`

Liang, K.-Y., Hoef van de, S., Terelius, H., Turri, V., Besselink, B., Martensson, J., & Johansson, K. H. (2016). Networked control challenges in collaborative road freight transport. *European Journal of Control*, *30*, 2–14. Retrieved from `http://dx.doi.org/10.1016/j.ejcon.2016.04.008` doi: 10.1016/j.ejcon.2016.04.008

Lin, C.-C., Lin, J.-Y., & Chen, Y.-C. (2012). The capacitated p-hub median problem with integral constraints: An application to a Chinese air cargo network. *Applied Mathematical Modelling*, *36*(6), 2777–2787. Retrieved from `http://dx.doi.org/10.1016/j.apm.2011.09.063` doi: 10.1016/j.apm.2011.09.063

Lobo, I., & Zairi, M. (1999). Competitive benchmarking in the air cargo industry: Part I. *Benchmarking: An International Journal*, *6*(2), 164–191. Retrieved from `https://doi.org/10.1108/14635779910269768`

Maansson, H., & Madsen, S. (2017). *Interview Schenker.* Horsens, Denmark: KLM Cargo.

Martichenko, R. (2013). *The Lean Supply Chain: A Field of Opportunity.* Retrieved 03-10-2017, from `http://www.inboundlogistics.com/cms/article/the-lean-supply-chain-a-field-of-opportunity/`

Mason, S. E., Nicolay, C. R., & Darzi, A. (2014). The use of Lean and Six Sigma methodologies in surgery: A systematic review. *Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland*, *13*(2), 91–100. Retrieved from `http://dx.doi.org/10.1016/j.surge.2014.08.002` doi: 10.1016/j.surge.2014.08.002

Mauritzen, E. (2017). *Interview DSV.* Kolding, Denmark: KLM Cargo.

Mcdonald, T., Aken van, E. M., & Rentes, A. F. (2002). Utilising Simulation to Enhance Value Stream Mapping: A Manufacturing Case Application. *International Journal of Logistics*, *5*(2), 213–232. Retrieved from `https://doi.org/10.1080/13675560210148696`

Mentzer, J. T., Dewitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Defining Supply Chain Management. *Journal of Business Logistics*, *22*(2), 1–25. Retrieved from `http://www.aui.ma/personal/{~}A.Berrado/MGT5309/DEFININGSUPPLYCHAINMANAGEMENT{_}Metzneretal.2001.pdf`

Merkert, R., van de Voorde, E., & de Wit, J. (2017). Making or breaking - Key success factors in the air cargo market. *Journal of Air Transport Management*, *61*, 1–5. doi: 10.1016/j.jairtraman.2017.02.001

Monde la, B. J., & Masters, J. M. (1994). Emerging Logistics Strategies: Blueprints for the Next Century. *International Journal of Physical Distribution & Logistics Management*, *24*(7), 35–47. Retrieved from `https://doi.org/10.1108/09600039410070975Downloaded`

Nobert, Y., & Roy, J. (1998). Freight Handling Personnel Scheduling at Air Cargo Terminals. *Transportation Science*, *32*(2), 295–301. Retrieved from `https://pubsonline.informs.org/doi/abs/10.1287/trsc.32.3.295`

Onghena, E., Meersman, H., & Voorde, E. V. D. (2014). A translog cost function of the integrated air freight business: The case of FedEx and UPS. *Transportation Research Part A*, *62*, 81–97. Retrieved from `http://dx.doi.org/10.1016/j.tra.2014.02.002` doi: 10.1016/j.tra.2014.02.002

Parthanadee, P., & Buddhakulsomsiri, J. (2014). Production efficiency improvement in batch production system using value stream mapping and simulation: a case study of the roasted and ground coffee industry. *Production Planning & Control*, *25*(5), 425–446. doi: 10.1080/09537287.2012.702866

Patel, M. H., Dessouky, Y., Solanki, S., & Carbonel, E. (2006). Air cargo pickup schedule for single delivery location. *Journal for Computers & Industrial Egineering*, *51*, 553–565. doi: 10.1016/j.cie.2006.08.014

Paulen, B., & Finken, J. (2009). *Pro SQL Server 2008 Analytics: Delivering Sales and Marketing Dashboards*. Apress. Retrieved from `https://books.google.nl/books?id=UJoPDQEf-UMC`

Reid, R., & Sanders, N. (2011). *Operations Management - An Integrated Approach* (4th ed.). Hoboken: John Wiley & Sons Inc.

Reis, V., & Silva, J. (2016). Assessing the air cargo business models of combination airlines. *Journal of Air Transport Management*, *57*, 250–259. doi: 10.1016/j.jairtraman.2016.08.011

Rezaei, J., Hemmes, A., & Tavasszy, L. (2017). Multi-criteria decision-making for complex bundling configurations in surface transportation of air freight. *Journal of Air Transport Management*, *61*, 95–105. Retrieved from `http://dx.doi.org/10.1016/j.jairtraman.2016.02.006` doi: 10.1016/j.jairtraman.2016.02.006

Rhoades, D. L. (2016). *Evolution of International Aviation: Phoenix Rising*. Taylor & Francis. Retrieved from `https://books.google.nl/books?id=Cv8FDAAAQBAJ`

Robinson, S. (2004). *Simulation: The Practice of Model*. John Wiley & Sons Ltd.

Rother, M., & Shook, J. (1999). *Learning to See: Value Stream Mapping to Add Value and Eliminate MUDA*. Lean Enterprise Institute.

Rozenberg, A., Lodewijks, G., Beelaerts van Blokland, W., Baggen, J., Philips van Buren, G., & Gortenmulder, A. (2016). *Designing a comprehensive framework to analyze and improve engine MRO processes from an integral perspective - A case study at KLM Engineering & Maintenance Services* (Master Thesis). Delft Univeristy of Technology.

Sargent, R. G. (2005). Verification and validation of simulation models. In M. Kuhl, N. Steiger, F. Armstrong, & J. Joines (Eds.), *Proceedings of the 2005 winter simulation conference* (pp. 130–143).

Sargent, R. G. (2014). Verifying and validating simulation models. In A. Tolk, S. Diallo, I. Ryzhov, L. Yilmaz, S. Buckley, & J. Miller (Eds.), *Proceedings of the 2014 winter simulation conference* (pp. 118–131). Syracuse, New York: Department of Electrical Engineering and Computer Science.

Schmidt, F., Tavasszy, L., Ludema, M., Hartigh den, E., & Keyrouse, R. (2013). *Supply Chain Trends Impacting the Air Cargo Industry* (Master Thesis). Delft University of Technology, Delft.

Schwarz, G. (2006). Enabling global trade above the clouds: restructuring processes and information technology in the transatlantic air-cargo industry. *Journal of Environment and Planning A*, *38*, 1463–1485. doi: 10.1068/a3852

Selinka, G., Franz, A., & Stolletz, R. (2016). Time-dependent performance approximation of truck handling operations at an air cargo terminal. *Computers and Operations Research*, *65*, 164–173. Retrieved from `http://dx.doi.org/10.1016/j.cor.2014.06.005` doi: 10.1016/j.cor.2014.06.005

Shah, R., Chandrasekaran, A., & Linderman, K. (2008). In pursuit of implementation patterns: the context of Lean and Six Sigma. *International Journal of Production Research*, *46*(23), 6679–6699. doi: 10.1080/00207540802230504

Sickler, F. M., Tavasszy, L. A., Annema, J. A., Enserink, B., Spoor, S. V., & Mravik, S. (2017). *Enhancing the cargo value chain for KLM Cargo with regard to the acceptance process, trucking schedule and data communication* (MSc. Thesis). Delft University of Technology.

Sky Team. (2017). *Sky Team.* Retrieved 2017-06-02, from `https://www.skyteam.com/nl`

Solding, P., & Gullander, P. (2009). Concepts for simulation based value stream mapping. In *Proceedings of the 2009 winter simulation conference* (pp. 2231–2237).

Spoor, S. (2017). *201704 EU Green Fast Lane Roll Out - Handler.*

Stevens, G. C. (1989). Integrating the Supply Chain. *International Journal of Physical Distribution & Materials Management*, *19*(8), 3–8. Retrieved from `http://www.emeraldinsight.com/doi/abs/10.1108/EUM0000000000329`

Thomson, C. (2016). *Three silos in your supply chain and what to do about them.* Retrieved 24-01-2018, from `http://www.supplychaindigital.com/scm/three-silos{\protect.\kern\fontdimen3\font.\kern\fontdimen3\font.\kern\fontdimen3\font}`

Tukey, J. W. (1977). *Exploratory Data Analysis.* Addison-Wesley.

Tzimourtos, G., Tavasszy, L., van Duin, J., Janic, M., & Santos, B. (2015). *Air freight transport - A strategic modelling approach on a global scale* (Master Thesis). Delft University of Technology.

Urciuoli, L., Hintsa, J., & Ahokas, J. (2013). Drivers and barriers affecting usage of e-Customs âĂŤ A global survey with customs administrations using multivariate analysis techniques. *Journal of Government Information Quarterly*, *30*(4), 473–485. Retrieved from `http://dx.doi.org/10.1016/j.giq.2013.06.001` doi: 10.1016/j.giq.2013.06.001

Verbreak, P. d. i. A. (2015). *Class 3.2.2. Simulation Model Specification.* Delft: Delft University of Technology.

Verschuren, P., & Doorewaard, H. (2010). *Designing a Research Project* (second ed.). The Hague: Eleven International Publishing.

Voort van der, F., Lodewijks, P. d. i. G., Fopma, D. i. P., Beelaerts van Blokland, D. W., & Lin, i. X. (2016). *Redesign the cool chain for air transport of perishable goods by KLM Cargo* (Master Thesis). Delft University of Technology.

Walcott, S. M., & Fan, Z. (2017). Comparison of major air freight network hubs in the U.S. and China. *Journal of Air Transport Management*, *61*, 64–72. Retrieved from `http://dx.doi.org/10.1016/j.jairtraman.2016.06.006` doi: 10.1016/j.jairtraman.2016.06.006

White, K. P., & Ingalls, R. G. (2009). Introduction to Simulation. *Proceedings of the 2009 winter Simulation Conference*, 12–23.

Wikipedia. (n.d.). *Known Shipper Program.* Retrieved 23-10-2017, from `https://en.wikipedia.org/wiki/Known{_}Shipper{_}Program`

Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. *Journal of Law and Economics*, *22*(2), 233–261. Retrieved from `http://www.jstor.org/stable/725118`

Williamson, O. E. (1981). The Economics of Organization: The Transaction Cost Approach. *American Journal of Sociology*, *87*(3), 548–577.

Williamson, O. E. (1986). Transaction Cost Economics - The Comparative Contracting Perspective. *Journal of Economic Behavior and Organization*, *8*, 617–625.

Williamson, O. E. (1988). Technology and Transaction Cost Economics - A reply. *Journal of Economic Behavior and Organisation*, *10*, 355–363.

Womack, J. P., Jones, D. T., & Roos, D. (1991). *The Machine That Changed the World: The Story of Lean Production.* HarperCollins. Retrieved from `https://books.google.nl/books?id=Jz4zog27W7gC`

Wrigley, C. D., & Clarke, R. A. (1994). Electronic data interchange in international trade: frameworks for the strategic analysis of ocean port communities. *Journal of Strategic Information Systems*, *3*(February), 211–234.

Yu, C., Eggleton, S., Mak, E., Adamski, A., Barrett, R., Bolton, C., ... Fabian, T. (2008). *Global Sourcing: Shifting Strategies - A survey of Retail and Consumer Companies* (Tech. Rep.). PricewaterhouseCoopers.

A Comparison of Methodologies

In this appendix the symbols of the value stream mapping are explained in more detail in Section A.1. Following, in Section A.2 the various business process improvement methodologies are compared. In this thesis research the lean manufacturing, six sigma and transaction cost economics methodology are used.

A.1 Value Stream Mapping Process Symbols

Value-stream mapping (VSM) is a lean management method for analyzing the current state. It also allows for designing the future state. VSM is often used for manufacturing, however in recent developments it is also used in logistics, supply chain, service related industries, health care, software development, product development and administrative processes. VSM is a recognised method as part of the Six Sigma methodologies. The theory regarding VSM is explained in more detail in Section 3.3.5. In Figure 4.6 the VSM for the traditional model is illustrated and in Figure 5.4 the VSM for the DTP model. The VSM is generated using the standardized VSM symbols in Figure A.1.

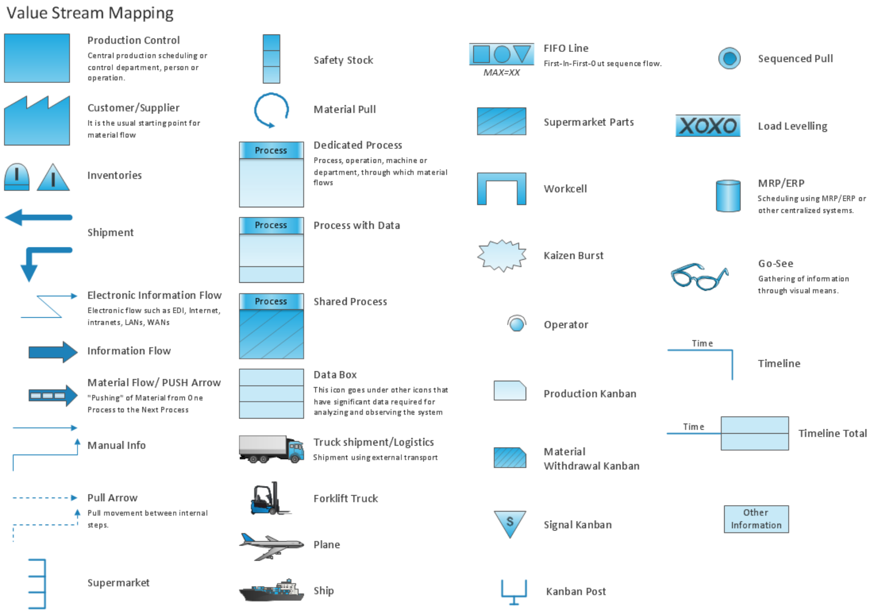


Figure A.1: VSMsymbols

A.2 Methodology Comparison

In this section the various improvement methodologies are compared with each other. Among which, lean manufacturing, six sigma, lean six sigma, total quality management, theory of constraints, business process re-engineering, business process management, creative problem solving and transaction cost economics.

Lean Manufacturing

Lean emerged from the Ford production plants. The lean philosophy is to improve the production process by eliminating waste, unnecessary actions, reduction of variability, JIT production, single piece flow and linking processes that create value. According to (Bendell, 2005) the definition of lean is: *“ the systematic pursuit of perfect value through elimination of waste in all aspects of the organization’s business process. It requires a very clear focus on the value element of all products and services and a thorough understanding of the value stream”.*

Six Sigma

Six Sigma originates from the Motorola Corporation in the 1980s. The company was striving to achieve a high level of quality. Sigma σ stands for the number of standard deviations of the processes. The quality focus is to ensure that the product characteristics are exactly what the customers want. To implement six sigma two aspects need to be taken into account. First of all, tools are presented to identify and eliminate causes of quality problems. In this research the five-step plan adopted from the Six Sigma approach is used: DMAIC (Reid & Sanders, 2011).

Lean Six Sigma

The most important overlap between Lean and Six Sigma is in the area of quality management. Lean includes quality practices such as statisctial process control and process capability measurements. Similarly six sigma embraces quality management with a focus on advanced statistical methods. Lean however, focuses on streamlining processes whereas six sigma help to identify and eliminate the root causes of problems. Leam emphasizes process flow and six sigma concentrates on process defects (Shah et al., 2008). According to (Ayeni et al., 2011) lean alone cannot effectively bring a process under control, nor can it define a sustaining infrastructure for implementation. Therefore the combination of lean and six sigma can address this issue.

Total Quality Management

Total quality management (TQM) is a theory that uses organization-wide efforts to install and make a climate in which an organization continuously improved its ability to deliver high-quality products and services to customers. The quality can be improved by eliminating cause of product defects, by making everyone in the organization responsible for the quality. TQM uses tools and techniques of quality control. An organization is judged on criteria from 7 categories, namely, leadership, strategic planning, customer focus, measurement, analysis and knowledge management, workforce focus, operations focus and results (Reid & Sanders, 2011).

Theory of Constraints

Theory of constraints (TOC) is a management paradigm that views a system as being limited in achieving more of its goals by a very small number of constraints. TOC uses a focusing process to identify the constraint and restructure the rest of the organization around it. TOC is introduced by Eliyahu M. Goldratt in 1984 in his book “The Goal”. He argues that organizations can be measured and controlled by variations on three measures: throughput, operational expense and inventory. Before a goal can be reached, necessary conditions must be met such as safety, quality, legal obligations etc.

Business Process Reengineering

Business Process Re-engineering suggests tools for redesigning a companies processes. Over the years processes have been developed in a certain manner and adopted as standards. Re-engineering asks why things are done in a certain way, questions assumptions and redesigns the processes. Re-engineering is done to increase the efficiency, improve quality and reduce costs (Reid & Sanders, 2011).

Transaction Cost Economics

Transaction Cost economic originates from John R. Commons in 1934 who proposed that the transaction is a basic unit of economic analysis (Williamson, 1981). Commons identified that the exchange of goods and services between technologically separable entities can be influenced by it’s governance. According to (Williamson, 1979) the definition of a transaction is: *“ A transaction occurs when a good or service is transferred across a technologically separable interface”.* TCE can be used to identify the number of transactions both on physical aspect and information aspect when analysing the system.

In Table A.1 the above mentioned process improvement theories can be found including some additional theories. The methodologies will be compared based on key elements, their aim, usefulness and if the methodology will be used in this thesis research.

Table A.1: Overview of Process Improvement Methodologies - adapted from (Rozenberg et al., 2016)

Methodology	Key elements	Aim	Usefulness	Applied in Thesis
Lean	Eliminate waste, identify value stream, flow, pull, continuous improvement	Pursuit of perfect value in processes through eliminaton of waste	Viable tool, however lean alone cannot adequately improve processes.	Yes
Six Sigma	Value drivers, DMAIC cycle, statistical analysis, root causes	Decrease variation and number of defects in processes	Can be used to improve existing processes. Provides an analytical framework that encompasses all stages of an improvement project	No
Lean Six Sigma	Eliminate waste by analytical basis	Combines Lean and Six Sigma	Provides tools to create an ongoing business improvement - DMAIC cycle	Yes
Total Quality Management	Customer focus, use of quality tools, quality in processes	Proactive quality approach: build quality into process and product design	Focus lies on product quality improvement instead of supply chain improvement. TQM covers tools that can be used to identify bottlenecks and root causes	Yes
Theory of Constraints	Bottlenecks, exploit and elevate	Increase flow in system	Find solutions for bottlenecks	No
Business Process Reengineering	Design new process, identify change levers, innovative solutions	Redesign whole process (green field)	Focus on creating new processes instead of improving existing processes. Can be useful to find innovative, out-of-box solutions.	No
Business Process Management	Holistic view, continuous improvement, process re-engineering	Improvements w.r.t. IT, corporate-wide impact and cross functional process management	Not in line with improvements	No
Creative Problem Solving	Brainstorming, generate ideas	Generating creative solutions	Can complement analytical, data-based approach for creating solutions with creative approach	No
Transaction Cost Economics	Financial economic perspective on transactions	Studying number of transactions in the supply chain	Can complement lean value drivers with respect to number of transactions (information and physical)	Yes

B Air Cargo Industry

In this Appendix a detailed description of the processes in the air cargo industry will be provided. The traditional air cargo industry will be described. The new developments in the air cargo industry as described in Chapter 2 will be addressed in that chapter respectively.

B.1 The Air Cargo Market

To send a shipment over a medium to long distance in a fast manner often air transportation is selected opposed to road or water transportation. For air transportation, cargo is loaded into aircraft to be transported from airport-to-airport. Air cargo is relatively expensive, but often the fastest mode of transport available. Typical air cargo consists of goods with high value and / or an operationally or commercially critical delivery time:

- Air mail
- Live animals
- Express parcels
- Perishables
- Pharmaceuticals
- Valuables
- Technical supplies
- Luxury consumer goods

The cargo can be transported using different types of aircraft, a list is provided below:

- **Passenger aircraft**: The area below the passengers, called “belly” is used for the baggage of the passengers, however often this does not occupy the entire room and therefore this is filled with additional cargo to increase revenue of the carrier.
- **Freighters**: Freighters are cargo aircraft with the only purpose of carrying cargo, no passengers are transported with this flight. This means that in both the main-deck and belly cargo can be loaded. Often freighters allow for larger cargo items to be shipped by air as they can be located on the main deck and nose-loading (large cargo door by opening the nose of the aircraft) is possible.
- **Combi-aircraft**: This aircraft transports both passengers and cargo. On the main-deck behind the passengers area cargo can be loaded as well as in the belly.

B.2 Parties in the Air Cargo Market

An individual wants to ship a parcel from e.g. Tokyo to Amsterdam. This individual can select different parties to ship their cargo with:

- **Postal companies using airmail**: mostly enveloped and parcels up to 30 kg. This air transport is usually outsourced to airlines.
- **International courier companies (couriers)**: enveloped and parcels up to 75 kg. This air transport is usually outsourced to airlines.
- **International express companies (integrators)**: envelopes and parcels up to 75 kg. Generally operate their own aircraft, only some destinations are outsourced to airlines, aircraft operators or air charter companies.
- **Air cargo forwarders**: parcels and consolidation larger than 75 kg with dimensions within aircraft capabilities. The air cargo transport is generally outsourced to airlines and sometimes aircraft operators or air charter companies.
- **Airline / Air operator / Carrier**: operate their in-house aircraft fleet and outsource only partially to certain destinations.

Postal companies, couriers, integrators and forwarders are the cargo customers of the airlines. The airlines are their suppliers or partner. According to the statistics forwarders are the most important customers of the airlines as they book and process over 80% of the air cargo consignments. The forwarders operate the customized door-to-door air cargo supply chain for their customers (the individual who wants to transport a parcel from Tokyo to Amsterdam) and the airlines deliver the airport-to-airport transportation in the chain. The combined airlines have the biggest share of the cargo air transport market.

The air cargo supply chain can be divided into several consequential stages; shipping, forwarding out, air transport, forwarding in and consignment. Each of these stages will be described in the next sections.

B.3 The Air Cargo Process

In this section the air cargo process will be described. The various parties in the supply chain as identified in the industry MOP will be mentioned including their tasks and responsibilities. All stakeholders for the case study at KLM Cargo are identified in the stakeholder analysis in Appendix C. The critical actors such as the shipper, freight forwarding agent and the ground handling agent are described in more detail below.

B.3.1 Shipper

The door-to-door air cargo process starts with the shipper. A shipper is the person or company that is physically and administratively responsible for the shipping of the goods. Often the shipper is the customer of the forwarder but the customer can also be the consignee or a third party that has ordered goods stored at the shipper's location. The shipper does not need to be the owner of the goods. For security reasons the shipper must always be a known shipper for the forwarder. In response to the September 11, 2001 attacks on the World Trade Center in New York new rules administered by the Transportation Security Administration (TSA) have been implemented (Wikipedia, n.d.). Shippers who have been screened and checked by the TSA are considered a known shipper and may tender their freight for shipment on both passenger- and cargo-only aircraft. Alternatives for unknown shippers are very limited to restrict anonymous shipments from being transported.

Air Freight Costs

Air freight is expensive and built up of many factors. transportation, handling, documentation, customs formalities all add to the cost area. Therefore a small overview of the included costs is provided below:

- **Volume:** The space occupied by the cargo is as important as the weight for the carrier. Therefore the volume is calculated in meters and the result is multiplied by a factor and following rounded to the next 500g.
- **Weight:** The total weight of the cargo in kg, including the packaging materials. The weight is of importance for the export declaration, flight and balance of the aircraft.
- **Chargeable Weight:** The weight on which air freight rate may be applied. The gross weight and the volume weight are compared and the higher one is taken as the chargeable weight.
- **Air Freight Rate:** The rate for the chargeable weight of the cargo. If the consignee is paying for the air freight, it is better to make a consolidation to get lower rates (explained below in more detail).
- **Standard Airline Surcharges**: Fuel surcharge, security surcharge, AMS surcharge (automated manifest service), screening surcharge (x-ray), dangerous goods surcharge.
- **Pre-export Charges**: export declaration, pick-up, haulage, screening charge, handling (checked, labeled, tendered), repackaging (if damaged), customs inspection.
- **Type of freight**: express freight (freight with a certain deadline), cooled freight or dangerous goods are charged higher than regular freight and therefore will be located on board of the originally booked flight first if under capacity occurs.

If goods are consolidated into one shipment, the rate is cheaper but at a price of being slower, especially if a number of goods from several shippers are consolidated by the forwarder to a certain destination. Individual shipments are more expensive because the costs cannot be spread over a bigger volume.

The dimensional weight conversion is included, since charging only by weight, lightweight, low density packages become unprofitable for freight carriers. This due to the amount of space they take up in the aircraft in proportion to their actual weight. Therefore volume is converted to a higher weight / price class. The airline will try to optimize its expensive cargo capacity of the aircraft and try to sell this capacity at the highest revenues, responsibility of the revenue management department.

The shipper is responsible for the assembly of the shipment in terms of volume, weight and packaging in order to get the best price and avoid damage to goods, people and aircraft. When the goods are ready for transport (correctly packed, labelled and with the right documents for air and road / maritime transport) the goods can be picked up by the forwarder at the shipper's warehouse, or the shipper delivers the goods to the forwarders warehouse.

B.3.2 Forwarding Out

The forwarder (also called expeditor) can be IATA certified, in which case the name changes to agent. To become an agent the forwarder must have been checked on financial status, air cargo potential, right facilities for handling air cargo, trained personnel for handling air cargo and dangerous goods, received commission form the IATA associated airlines and may use the airline's Air Waybills (AWB). The forwarder is responsible for organizing export handling, customs clearance of the shipments, air transport from a nearby airport to an airport at destination and optionally import handling and customs clearance at destination and final delivery to the consignee.

The forwarder will request / book space via the airline's sales or customer service department. Air cargo is sold for a fixed price or a fixed rate per kilogram, often with a minimum charge to cover basic expenses, fuel & security of shipment handling. Forwarders with a continuous demand of space on one or more specific routes, or with a continuous turnover with the airline overall, will negotiate and contract their own space and pricing details with the airline. "Spot-rates" can be requested for ad-hoc shipments.

After the pricing is obtained the forwarder has to make an airline booking for the shipments and get the airline's confirmation in order to assure space on board of an aircraft. The reservation will be validated against the airline's capacity, commodity and revenue management criteria, and will be officially confirmed as soon as the booking is accepted. In case of a blocked-space agreement, the forwarder has a continuous reservation (allotment) for space at one or more flight / date combinations with an airline. The following information needs to be provided in order to make a booking:

- Airline (master) air waybill number assigned
- Origin and (final) destination
- Type of goods
- Flight date
- Flight number
- Weight, volume and dimensions of shipment
- Number of pieces
- Issuing agent / contact details
- Assignment to agent's allotment
- Consignee contact details

In order to keep track of the different customer's shipments from the address of origin, to the address of destination, the forwarder makes a House Air Waybill (HWB) for each shipment. The HWB is a shipment contract between the end-customer and the forwarder. The forwarder has to prepare the shipment as Ready For Carriage (RFC), meaning the shipments requires to be; correctly packed, labeled, customs cleared for export, accompanied by the correct documents and had security checks for air transport and incoming clearance at destination. Often the forwarder consolidates shipments of different shippers traveling to the same destination. Due to the fact that consolidations are easier and faster to handle by both the forwarder and the airline. Bigger volumes get better airline pricing, continuous bigger volumes facilitate blocked space agreements between the airlines and the forwarders to create guaranteed capacity and thus better reliability for the end-customer.

The shipment (either a consolidation or an individual shipment) will receive a Master Air Waybill (MAWB), as a unique ID for the airline. The MAWB is the shipment contract between the forwarder and the airline. The MAWB provides the communication of the applicable contract terms, conditions and liability to all parties involved, proof of delivery of the goods to the carrier, acts as key for other related documents as required for customs or other authorities, provides handling instructions to all parties involved, provides a basis for invoicing for the airline / forwarder and acts as an insurance certificate. The obligations of a carrier are to deliver the shipment in the same state as they were accepted, undamaged, complete in number of colli and contents and on time. The airlines AWB or MAWB is a non-negotiable transport document, the document and goods cannot be traded. In case of large volumes and blocked space agreements with the airline, the forwarder may already prepare ready for carriage aircraft pallets (BUP - (Shipper) Build Up Pallet). This minimizes the handling time for the airline and so the overall throughput time of the shipments.

Next the goods are picked up by road transport for delivery at the warehouse of the airline's handling agent who takes care of further cargo handling for the airline. The road-transportation can be executed by in-house operated trucks or by a third party. The shipping forwarder will send a pre-alert to the receiving forwarder about the shipments and the flight details, allowing the receiving forwarder to prepare for the receipt of the cargo.

Other functions that the forwarder executed on behalf of the shipper, are the planning and controlling of transport orders, airline slot-times, flow of goods, documents as well as information in al the steps to ensure a smooth process and service. The forwarder repairs or improvises when a deviation occurs in the complex chain operated by different parties, such as change transport or airline booking. In addition they continuously maintain a structured and standardized network of commercial and operational agreements and an operational routine for all parties involved. Finally they handle claims on behalf of the (end-) customer in case goods are damaged or lost in the door-to-door or airport-to-airport process.

B.3.3 Handling Agent

The handling agent will often be a separate company contracted by the airline, but cargo handling can also be an in-house function of the airline, especially at a major hub. Depending on the kind of goods, destination and urgency, delivery at the handling agent has to be done with a certain norm-time before departure of the aircraft, also called a slot-time. A significant difference between passenger transport and cargo transport is that passengers prefer direct flights, however for cargo the number of transit points are not of significance. Therefore shipments often go into transit. Whether a direct or transit process is selected, is up to the forwarder and depends on the required price, throughput time and special cargo requirements.

Other functions of the handling agent are: to make the cargo manifest for all goods on board, for the airline's import and export declaration to customs (this is a high level customs declaration as opposed to detailed customs declaration by the forwarder of customs agent), make a notification to the captain of the aircraft to inform crew about potential risks of the cargo on board in case of emergencies as well as for the right conditioning (temperature) of the cargo holds. To plan and control bookings, slot-times, goods flow and to plan and control worldwide ULD stock.

The handling agent also performs the incoming acceptance before build up and departure of the aircraft: commercial checks (according to the booking, correct weights, numbers and volumes of pieces indicated), logistics checks (delivered RFC), flight safety checks (correct weights, numbers and volumes of pieces indicated, correct and undamaged packaging, potentially hazardous materials declared and correctly labeled and visible, correct and complete documents and labels) and security checks (known shipper and forwarder declared, correct and undamaged packaging, correct and complete documents and labels).

The goods and documents are handled separately, sorted by destination and outgoing flight number. Both are administratively connected by means of labels, documents administrated and temporarily stored, goods are handled and temporarily stored. The handling agent will start building of Unit Load Devices (ULDs) and loose cargo if applicable for the flight and the documents will be gathered in the flight bag. The various ULDs that can be used are: main deck pallets, lower deck pallets, lower deck containers, animal stables or containers, security containers, environmentally controlled containers. ULDs are designed to fit exactly in different aircraft types. The ULDs and documents are transported to the aircraft and the flight bag including cargo manifest is handed over to the crew.

During the flight the crew will set the temperature in the aircraft cargo holds according to the load sheet, in most aircraft, the temperature and air circulation of the cargo can be set per compartment. In case of transport of bigger live animals (such as horses and elephants) an animal flight attendant may fly on board and check and look after the animals during flight. At a certain time before arrival, the handling agent at origin will pre-alert (freight forwarding message) the airline's handling agent at destination about the shipments and flight details. The receiving handling agent can prepare the receipt of the shipments. At the airport of destination, the cargo and flight bag will go through the whole process again, but in reverse.

At receipt of the cargo (ULD and loose) and flight bag in the warehouse and office, the handling agent will inform the receiving forwarding agent that the shipment has arrived and the documents can be picked up. The manifest is cleared for customs when all individual shipments have been cleared and picked-up by the forwarder. Air cargo can travel in ULDs but can also be carried as loose cargo in the belly of the aircraft, like passenger luggage. Loading, unloading and handling loose cargo can be faster than the ULD process but is also less efficient and requires different handling equipment; therefore loose cargo is often used for the urgent or highest priority cargo products and in practice mostly on narrow body aircraft. It is the airline's responsibility to handle claims on behalf of the forwarder in case goods are damaged or lost in the aircraft-to-aircraft process.

B.4 Industry Standard

In Figure B.1 the overall air cargo process according to the International Air Transport Association (IATA) standards is shown. In Figure B.2 and Figure B.3 the detailed steps of the process are shown. As this research only focuses on the export process on the land side at origin, the remainder of the cargo value chain is not discussed any further. These steps are also omitted from the steps illustrated in Figure B.1, Figure B.2 and Figure B.3.

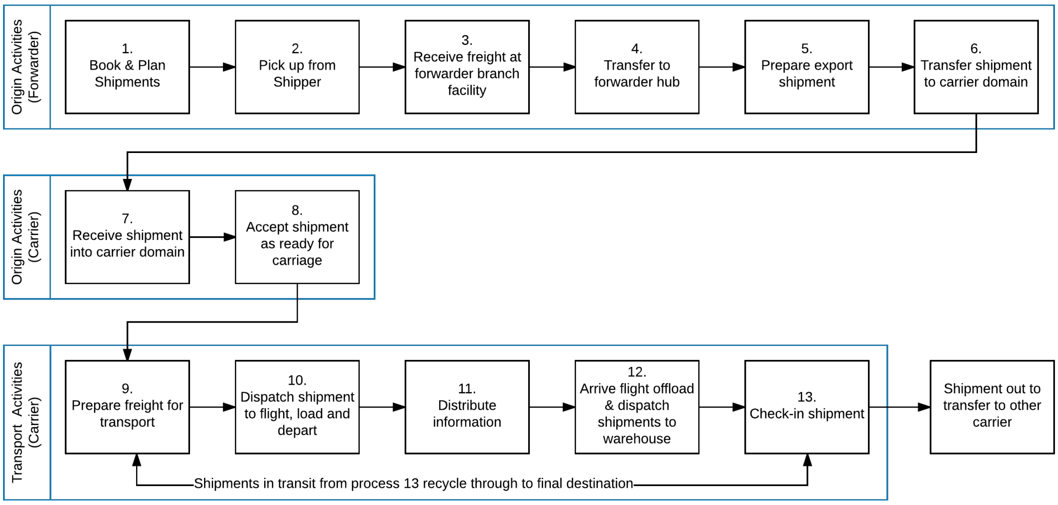


Figure B.1: IATA process

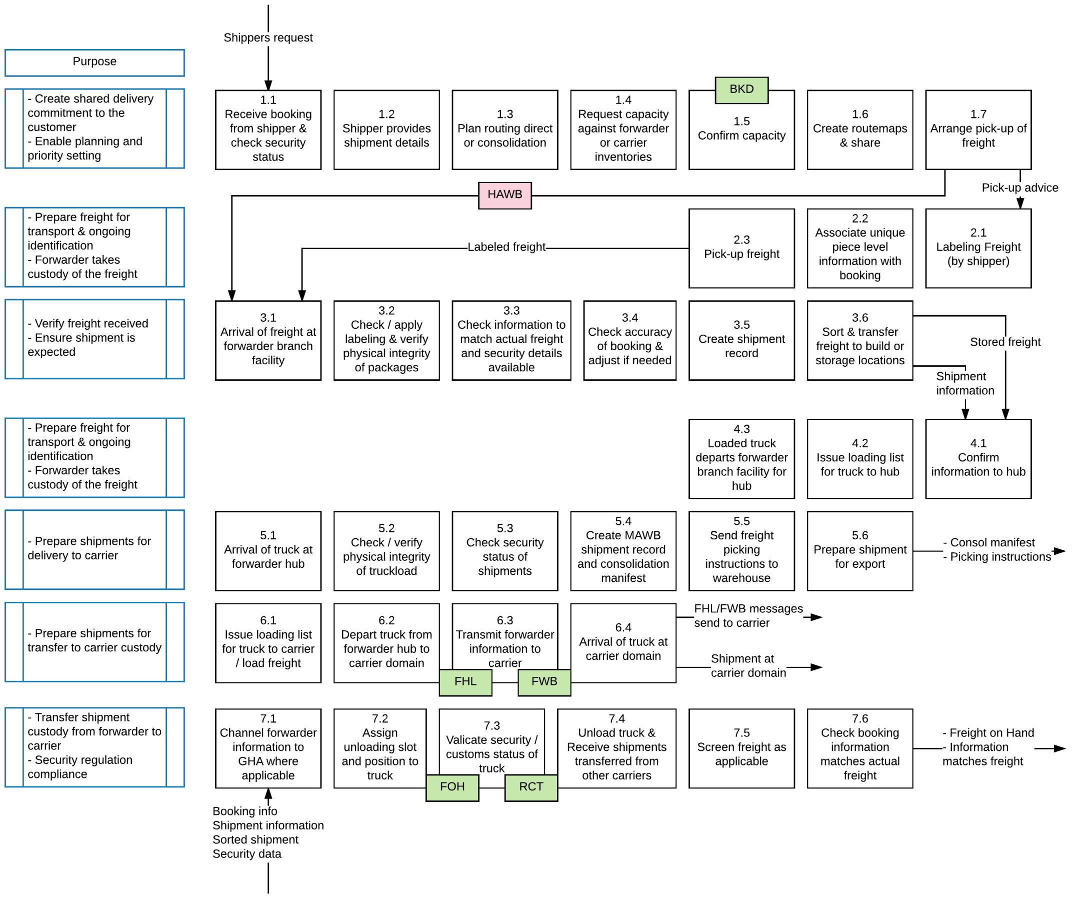


Figure B.2: IATA process in detail part 1

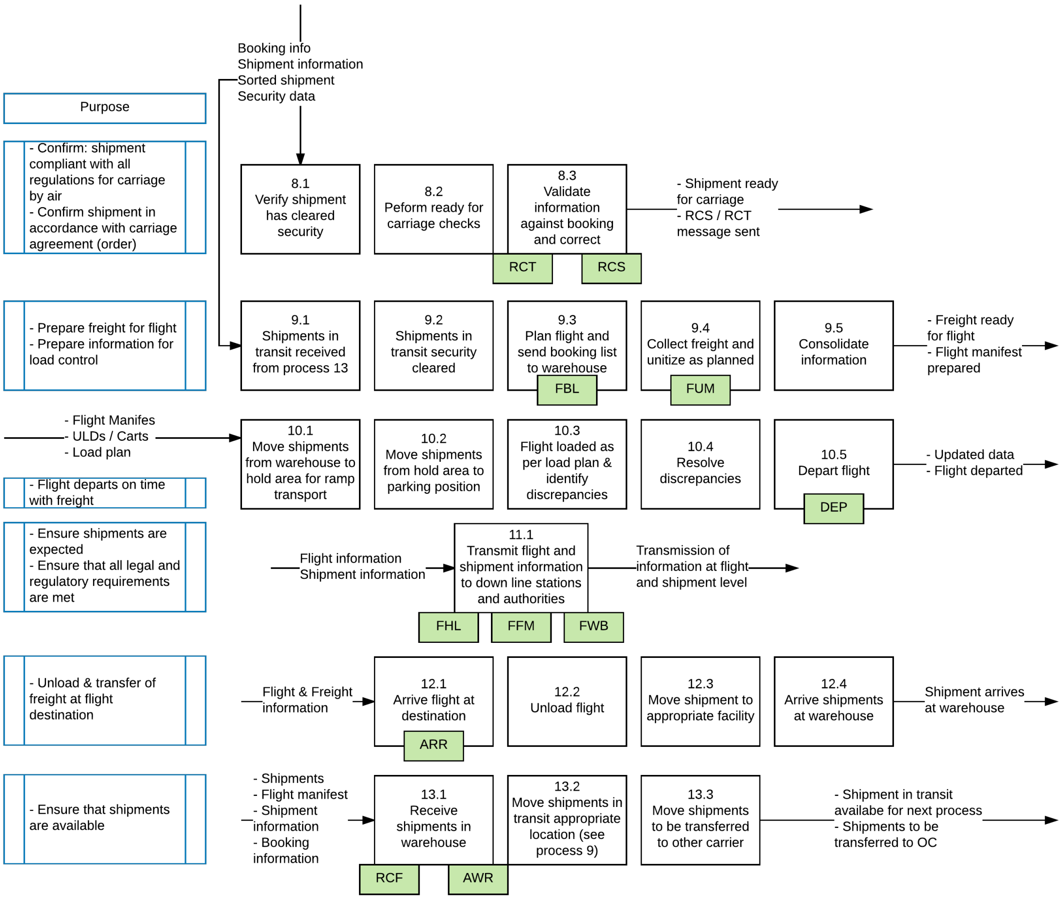


Figure B.3: IATA process in detail part 2

Comparing the industry master operating plan (International Air Transport Association, 2016b) to the observed practice (during the case study for DSV and Schenker), the following activities can be assigned to each party. 3 Scenarios are studied, the first column of Table B.1 describes the scenario as described by the master operating plan, cargo directly delivered to the carrying party from the forwarder. The second scenario represented by the second column is the traditional air cargo supply chain, operated by a ground handling agent who performs the work on behalf of KLM Cargo and the third scenario presented in the third column is the direct pick up process. In Table B.1 and Table B.2 the F stands for forwarder, G for GHA and C for carrier.

Table B.1: Comparison IATA Standard to Traditional and DTP [part 1]

#	Step description	MOP	GHA	DTP
1. Book & Plan Shipments				
1.1	Receive booking from shipper & check security details	F	F	F
1.2	Shipper provides shipment details	F	F	F
1.3	Plan routing direct or consolidation	F	F	F
1.4	Request capacity against forwarder and carrier inventories	F	F	F
1.5	Confirm capacity	F	F	F
1.6	Create routemaps and share	F	F	F
1.7	Arrange pick-up of freight	F	F	F
2. Pick up from Shipper				
2.1	Labeling Freight	F	F	F
2.2	Associate unique piece level information with booking	F	F	F
2.3	Pick up freight	F	F	F
3. Receive freight at forwarder branch facility				
3.1	Arrival of freight at forwarder branch facility	F	F	F
3.2	Check / apply labeling and verify physical integrity of packages	F	F	F
3.3	Check information to match actual freight and security details available	F	F	F
3.4	Check accuracy of booking and adjust if needed	F	F	F
3.5	Create shipment record	F	F	F
3.6	Sort and transfer freight to build or storage locations	F	F	F
4. Transfer to forwarder hub				
4.1	Confirm information to hub	F	F	F
4.2	Issue loading list for truck to hub	F	F	F
4.3	Loaded truck departs forwarder branch facility for hub	F	F	F
5. Prepare export shipment				
5.1	Arrival of truck at forwarder hub	F	F	F
5.2	Check / verify physical integrity of truckload	F	F	F
5.3	Check security status of shipments	F	F	F
5.4	Create MAWB shipment record and consolidation manifest	F	F	F
5.5	Send freight packing instructions to warehouse	F	F	F
5.6	Prepare shipment for export	F	F	F
6. Transfer shipment to carrier domain				
6.1	Issue loading list for truck to carrier / load freight	F	C	C
6.2	Depart truck from forwarder hub to carrier domain	F	F	F
6.3	Transmit forwarder information to carrier	F	F	F
6.4	Arrival of truck at carrier domain	F	F	F
7. Receive shipment into carrier domain				
7.1	Channel forwarder information to GHA where applicable	C	G	F
7.2	Assign unloading slot and position to truck	C	G	C
7.3	Validate security / customs status of truck	C	G	C
7.4	Unload truck and receive shipments transferred from other carriers	C	G	C
7.5	Screen freight as applicable	C	G	C
7.6	Check booking information matches actual freight	C	G	C

Table B.2: Comparison IATA Standard to Traditional and DTP [part 2]

#	Step description	MOP	GHA	DTP
8.	**Accept shipment as ready for carriage**			
8.1	Verify shipment has cleared security	C	G	C
8.2	Perform ready for carriage checks	C	G	C
8.3	Validate information against booking and correct	C	G	C
9.	**Prepare freight for transport**			
9.1	Shipments in transit received from process 13	C	G	C
9.2	Shipments in transit security cleared	C	G	C
9.3	Plan flight and send booking list to warehouse	C	G	C
9.4	Collect freight and unitize as planned	C	G	C
9.5	Consolidate information	C	G	C
10.	**Dispatch shipment to flight, load and depart**			
10.1	Move shipment from warehouse to hold area for ramp transport	C	G	C
10.2	Move shipment from hold area to parking position	C	G	C
10.3	Flight loaded as per load plan and identify discrepancies	C	G	C
10.4	Resolve discrepancies	C	G	C
10.5	Depart flight	C	G	C

C Stakeholder Analysis

This Appendix describes the stakeholders involved in the air cargo supply chain for KLM Cargo and their relation to one another. The stakeholder analysis is adapted from (Sickler et al., 2017). The stakeholder analysis will be performed according to the methodologies defined by (Enserink et al., 2010) in the book '*Policy Analysis of Multi-Actor Systems*'. Every phase of the stakeholder analysis is verified with a KLM employee. According to (Enserink et al., 2010) p.80: "*Actors are those parties that have a certain interest in the system and / or that have some ability to influence that system, either directly or indirectly*".

C.1 Problem Formulation

According to (Enserink et al., 2010) first the problem needs to be formulated, as an initial problem formulation is required to serve as a point of departure for the actor analysis. The problem, as identified by the problem owner, is used as a point of departure. In this case the problem owner is KLM Cargo and the perception of the problem by KLM Cargo is: in the current situation, KLM Cargo is unable to take informed decisions, regarding DTP due to lack of visibility in the chain, delays and insufficient information.

C.2 Actor Inventory

In this section, all actors involved in the traditional air cargo supply chain are identified. The boundary of the research scope is identified from the shipper until the hub, therefore all stakeholders outside this scope are not taken into account. Figure C.1, illustrates all relevant stakeholders. For each stakeholder a small description is provided below, in alphabetical order.

Accounting: Accounting is the internal KLM Cargo department, responsible for billing the flown cargo to customers, including the cargo handling and trucking costs, payment of the ground handling costs to the ground handling agents and trucking costs to the contracted trucking companies, among others. Not only the price per kg or volume is billed, but also the reparation needed such as physical cargo reparation or document reparation, or cargo securing. *The accounting department will not be taken into account in the research scope as this research only includes the DTP performance. The information to and from this department is taken into account.*

Air France Cargo: Air France is part of the Air France KLM Group and therefore operates under the same airline flag as KLM. However Air France has a different main hub, namely Paris Charles de Gaulle. *Only the cargo flow to Amsterdam Schiphol Airport will be considered in this research. Occasionally CDG cargo will be found in the KLM streams but this is in general not considered in this research.*

Air France KLM: Air France - KLM group is the carrier. KLM is part of the Air France KLM Group and divided in Cargo, Engineering & Maintenance and Passenger business. The Air France KLM Group has 2 main hubs in Europe, Amsterdam Schiphol Airport (AMS) and Paris Charles de Gaulle (CDG). *For this thesis only Amsterdam Schiphol Airport will be taken into account as the case study is performed for KLM Cargo.*

Amsterdam Airport Schiphol:
The KLM Cargo hub is located at the Amsterdam Schiphol Airport. Therefore it is subjected to the rules and regulations of Schiphol - Amsterdam Airport.

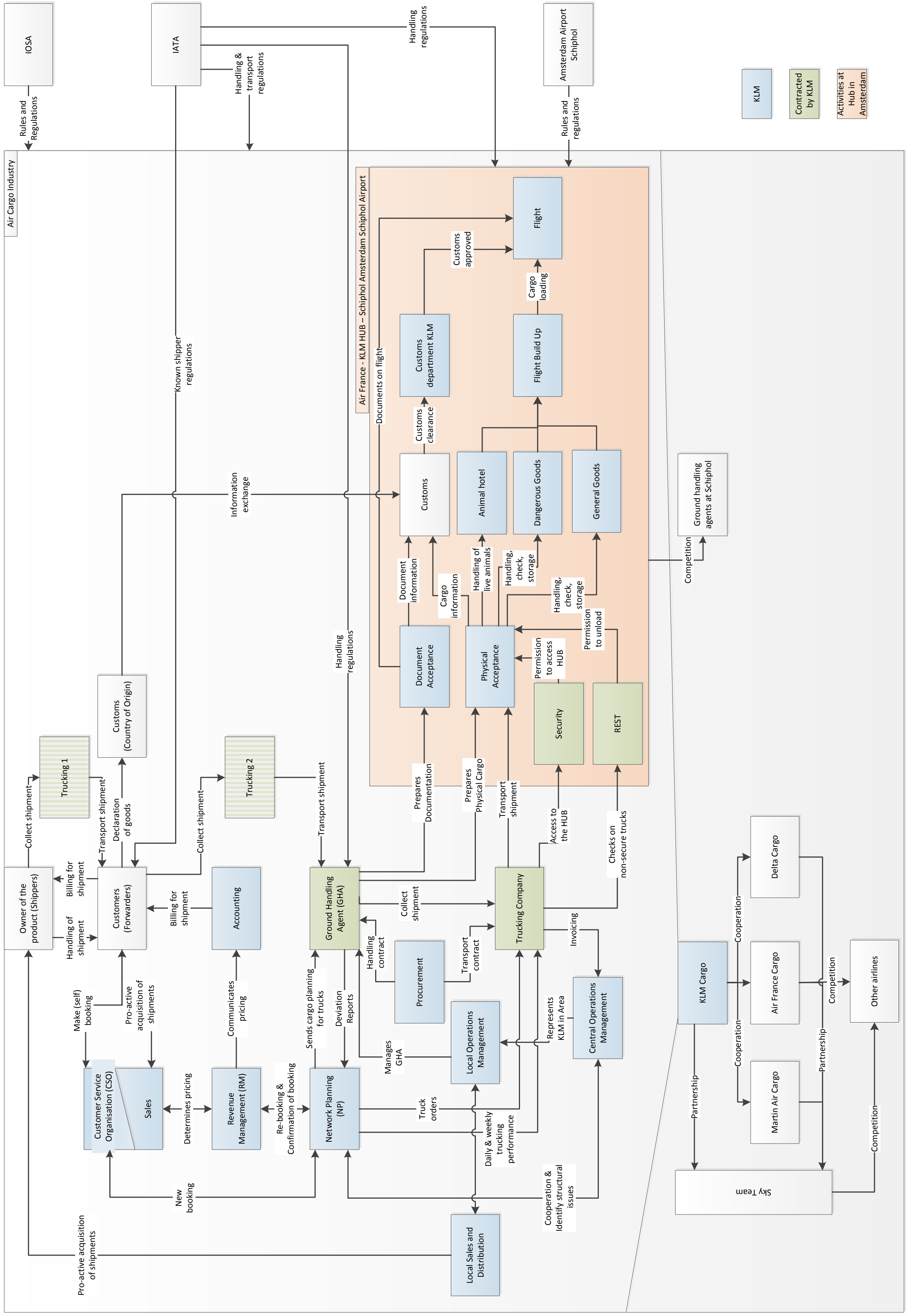


Figure C.1: Stakeholder Analysis

Animal Hotel:
The animal hotel is a department within KLM Cargo fully focused on all aspects regarding animal transportation and storage. KLM Cargo is specialized in the transportation of animals. Animals are a special handling good and therefore they must comply with several rules and regulations. The rules and regulations are party influencing the document acceptance and the physical acceptance. Generally live animals are not transported by road by KLM. *The animal hotel department is not further taken into account in this research because the scope of this research only includes cargo transported by road.*

Central Operations Management:
Central Operations Management also known as operations development managers. The eight market's in Europe are managed by four operations development managers. The markets are divided as follows: 1) Nordics and France 2) Benelux, UK and Ireland 3) Italy, Switzerland and Iberia 4) Germany, Austria and Central & Eastern Europe. They are responsible to manage the market in collaboration with the local operations management. This includes a wide range of structural issues in the supply chain related to their markets, such as customer, GHA, trucking company and hub related issues. In addition each of the operation development managers is responsible for the quarterly review with the trucking company that they are responsible for.

Customer Service Organisation:
This department is responsible as an information broker between Air France - KLM - Martinair Cargo and the customers. CSO is part of the sales division. CSO will make new bookings for customers. Customers can also make bookings themselves without directly contacting CSO. As part of CSO, the sales department is responsible for pro-active acquisition of shipments. A central CSO is located in Amsterdam and a local CSO is located in Copenhagen and Stockholm for the Nordics. The local CSO is responsible for bookings and is the single point of contact for the customers for all information regarding their bookings. Central CSO is focused on the Dutch market and serves as back-up for the local CSO's if needed. *Only the CSO located in Copenhagen, Denmark will be considered within the system boundaries of this research. The customers in the Netherlands will not be taken into account and therefore the influence of CSO in Amsterdam will be neglected.*

Customs:
External company responsible for the Execution of the governmental rules, regulations, taxes and compliance. For compliance the information on the customs documents and physical freight has to be correct. For example, it is of great importance that the cargo exported matches what it states on the papers and does not deviate. The customs department has to authority to check cargo at any time.

Customs Department KLM:
The internal customs and compliance department of KLM responsible for ensuring that the rules and regulations as stated by customs Netherlands are adhered to.

Dangerous Goods:
The dangerous department is responsible for safe transportation of dangerous goods. They specialize in the rules and regulations regarding the packaging, build-up, storage and aircraft hold. *Dangerous goods are outside the scope of the research as dangerous goods are prohibited from being transported by direct pick up trucks.*

Delta Cargo:
Delta airlines is part of the same alliance as KLM, Sky Team Cargo. When cargo is collected from customers or outstations, often delta cargo and KLM cargo are transported on the same truck to optimize space. At Amsterdam Schiphol Airport Delta Cargo is handled by the ground handling agent Menzies and located at Schiphol Oost. *In practice delta cargo is often encountered, however in the scope of this research delta cargo is omitted and not taken into account.*

Document Acceptance:
The document acceptance department at KLM Cargo is located at the front of the premises. The document acceptance is responsible for all paperwork regarding air transportation. *Document acceptance handles import, export and transit paperwork, however for the scope of this research only export cargo is taken into account.* It is important that all paperwork is correctly filled out including destination, address, weight, volume, commodity and other checks. In case of the traditional supply chain document acceptance is performed by the ground handling agent at the outstation on behalf of KLM Cargo. In case of the direct pick up, document acceptance is performed in Amsterdam.

Freight Forwarders:
A freight forwarder is a person or company that organizes shipments for individuals or corporations, to transport cargo from a manufacturer or producer to the final destination. Freight forwarders often have contracts with airlines in which they make allotment bookings, reserving a dedicated volume and weight for their customers. A freight forwarder often provides a range of services such as track and trace, preparation of documentation and physical cargo, customs clearance, booking cargo space, negotiating cargo prices, insurance, warehousing and consolidation. *For the scope of this research the freight forwarders / shippers and / or customers are all seen as the customer. They are paying a carrier, in this case KLM Cargo to transport their cargo.*

Freight Build Up:
Freight built up is part of the warehouse services of KLM Cargo. For the traditional supply chain cargo is often already built up on ULDs at the outstations by the GHA. This allows quick loading and unloading of trucks. Depending on the type of ULD, the ULD is directly transported to storage and following to the aircraft (T-ULD) or the ULD must be broken down in Amsterdam and built up with other freight (Mix-ULD). KLM Cargo also has their own break down and build up team for the handling of cargo. *For the build up only the times needed to break down and build up ULDs at KLM Cargo in Amsterdam are taken into account.*

General Goods:
Air France KLM Cargo offers a wide range of products. They can be categorized as follows: general cargo, mail, express and tailor made solutions. Mail is primarily used for postal services, express for cargo that needs speed and urgency and general cargo for all other shipments. For this research project only general cargo is taken into consideration. Tailor made solutions are products and industries that KLM offers: fresh, live animals, pharmaceuticals, safe, art, oil& gas, big, dangerous goods, mail, aerospace, automotive, fashion and hi-tech. *For DTP no special products, which require additional checks at acceptance are transported. As the cargo acceptance is done in Amsterdam, it is unknown if the products are safe to transport between the customer and the hub in Amsterdam.*

Ground Handling Agent Outstations:
If a customer only has a small shipment, either in number of pieces, volume or weight, cargo can be consolidated at a ground handling agent. The outstation handles and accepts the cargo on behalf of KLM Cargo. The outstation generates the information flow by creating the correct documentation messaging, and information for the cargo and a physical flow in which they weight, measure, count and check the cargo to ensure that the cargo complies with the requirements. In the outstations the cargo handling is outsourced to a ground handling agent. KLM classifies the ground handling agents based on their performance and prefer-ability. The purple handling agents (preferred handling agent) are preferred when contracting GHA's. The outstations are monitored by the local operations management department. *For this research Cargo Center Billund is studied as the ground handling agent. CCB is not a purple GHA.*

Ground Handling Agent Schiphol:
If cargo originates from a company in the Netherlands, the acceptance is performed by KLM Cargo in Amsterdam, there is no external ground handling company involved. In and around Amsterdam Schiphol Airport, there are numerous cargo handling agents, contracted by various airlines. For the direct pick up trucks the cargo is also accepted in Amsterdam, thus following the same procedure as cargo from the Netherlands. The ground handling agent at Schiphol Airport is KLM cargo itself.

IATA:
IATA is the abbreviation for the International Air Transport Association, which is a trade association for the world's airlines. IATA represents 275 airlines equivalent to 83% of the total air traffic. IATA formulates the industry policies on critical aviation issues. KLM Cargo has to comply with the rules and regulations of IATA.

IOSA:
IOSA is the abbreviation for IATA's International Operational Safety Audit program. IOSA is an internationally recognized and accepted evaluation system, designed to assess the operational management and control systems of an airline.

KLM Cargo:
KLM Cargo is one of the three divisions of the Air-France KLM company. KLM cargo transported 1.2 million tons of cargo over 2016, resulting in a combined revenue of 2.5 billion euros (Air France KLM Cargo, 2017). Cargo is transported to 457 destinations across 157 countries, in Europe alone already 83 stations are being served. KLM Cargo consist of different departments, this research thesis is performed for the Area Operations Europe department.

Local Operations Management:
Local operations management is the department representing KLM Cargo in a certain market. The local operations management of the Nordics market is taken into account in this research. This department is located in Stockholm. This department is responsible for the local operations for the following stations; for Denmark: Billund and Copenhagen, for Finland: Helsinki, for Norway: Oslo, Stavanger, Alesund, Kristiansand, Trondheim, Sandefjord and Bergen, for Sweden: Malmo, Stockholm, Goteborg and Norrkoping. The local operations management is responsible for the bi-weekly, monthly or quarterly reviews of the stations, depending on the size of the station. *The local operations management is taken in scope.*

Local Sales and Distribution:
Local sales and distribution is part of the local operations management team and is responsible for the sales and distribution in the Nordics. *The local sales and distribution are taken into account in this research as they are responsible for the set up of the direct trucking pick up.*

Martinair Cargo:
Martinair cargo is part of the Air France KLM group since 2008. Martinair is specialized in the feeighter business and operates both from Amsterdam Schiphol Airport hub and the Paris Charles de Gaulle hub. Martinair focuses solely on the freighter business and does not perform passenger operations. *Therefore Martinair cargo will be out of scope for this research.*

Network Planning:
Network Planning (NP) is the department within KLM Cargo, responsible for capacity management and planning. NP orders the capacity with the trucking companies, either FTL (Full Truck Load) or LTL (Less than full Truck Load), based on the actual amount of cargo on a daily level. They take into account the weight and volume of booked shipments for the next day and place the truck order, 5 hours before scheduled time of departure. Network Planning is also responsible for monitoring the reservations, build up planning for the GHA and provide feedback to CSO, RM, GHA, local-to-local CSO's and trucking companies. They are the first point of contact for the GHAs and for the trucking companies regarding daily operational questions and issues. NP is in close contact with local CSO, RM and flight planners at the hub. *NP is studied in this research.*

Other Airlines:
There are numerous other airlines competing in the air cargo market. Customers want their cargo to be transported in the fastest and cheapest manner. The competition in the air cargo industry is high. Outstations often handle multiple airlines and trucking companies also have contracts with many parties. *The other airlines will not be taken into account in the research scope of this thesis.*

Physical Acceptance:
The physical acceptance department for the traditional supply chain is located at the GHA. The GHA is contracted by KLM Cargo to accept the cargo in the KLM network on their behalf. The cargo is checked for compliance on the weight, volume, packaging, labeling and commodity among other checks. The physical acceptance department is responsible for unloading the truck, the storage and further handling of the cargo. For the DTP supply chain, the physical acceptance takes place at the hub in Amsterdam, where the cargo undergoes the same acceptance checks. *The physical acceptance is taken into the scope of this research.*

Procurement:
Procurement is a department within KLM Cargo, responsible for the acquisition of goods and services for Air France KLM Cargo group. Procurement of cargo handling is based on preferred cargo suppliers in combination with tendering. The contracts with the trucking companies are based on tendering. *The procurement department is not taken into account in the scope of this research.*

REST:
REST is the abbreviation for Remote Explosive Scent Tracking. The REST department is responsible for the REST procedures. The REST process is initiated for trucks that report in Amsterdam, carrying at least 1 shipment non-secured. Cargo can be made secure at the origin point by a customer or ground handling agent. If a truck carries non-secure cargo a procedure is initiated to ensure that there are no explosives located in the truck, this takes about 20 minutes depending on the number of trucks in the queue. The procedure consists of taking an air sample from the closed and sealed truck which is then sniffed by a K-9 (dog) specialized in detecting explosives. Without the secured status the truck is not allowed to enter the hubs premises. KLM Cargo is offering the REST procedure since 2013 and outstations are not mandatory to secure the cargo for KLM. If requested by the customer to secure the cargo in the outstations this is billed directly to the customer. If the cargo is secured at the hub, KLM charges the customer via “other charges” on the AWB. The REST procedure is only applicable for trucked cargo. Cargo to be transported by aircraft must always be made secure before loading the aircraft. *REST is taken into the scope of this research.*

Revenue Management:
Revenue Management (RM) is the department that is responsible for the revenue of the cargo and optimization of the flights. Flights / trucks are open for cargo booking 11 - 13 days before departure. RM is responsible for determining the entry conditions in terms of minimal rate per kg. Their goal is to increase the load factor on flights and at the same time achieve the highest revenue. Another task is to monitor the capacity of the flights and monitor the allotments contracts with key accounts. Allotment contracts, are contracted space agreements on certain days and or routes with a certain customer. A few days before the departure of the flight, the customer communicates the final space needed and the remaining space can be sold to another customer. The allotment rates are constant over the year, regardless of the demand for the flight, thus advantageous for the customer. Different rates apply for different types of goods, often more profitable cargo has a higher priority status. *Revenue Management is outside the scope of this research.*

Security:
The security department is responsible for secured access to the hub for authorized vehicles and personnel. When a truck reports at documentation, they should have an ACN pass, which means they are a registered truck driver. If not, they have to report at security to obtain a visitors pass. All individuals on the KLM Cargo premises must wear their company ID card to identify themselves. *Security department only plays a minor role in the air cargo supply chain*

Sky Team:
Sky Team is an alliance of cooperating airlines, established in 2000. The alliance of airlines enables the airlines to offer their passengers a larger network of destinations and number of flights, enlarging their market share and reducing costs. Being part of the Sky Team alliance, enables KLM Cargo to be transported on a flight of a Sky Team partner (Sky Team, 2017). *Sky team will only be mentioned as a stakeholder but will not be taken into account in the scope of this thesis.*

Trucking Company:
The trucking company in this research scope, Jan de Rijk (JdR), is responsible for the transportation of cargo from the customer or outstation to the Amsterdam Schiphol Airport hub and vice verse. The trucks are ordered by NP and JdR confirms the booking. It is JdR’s responsibility to report on time for loading, with the correct functional equipment, licensed driver and transport the cargo towards Amsterdam according to schedule. JdR has a contracted transit time in which they have to drive to Amsterdam (on time).

C.3 Mapping the Inter-dependencies

The relationship between the actors can be analysed by determining the dependency relations between actors. This can be done by the importance to the problem owner of resources of other actors, the extent to which those resources are replaceable and the degree to which the interests and objectives of other actors are similar. In addition the dedication of actors can be used to map the inter-dependencies between actors.

C.3.1 Resource Dependency

The criticality of an actor is dependent on if the resources can be replaced and the dependency of the resource. According to (Enserink et al., 2010) critical actors are those on whom a problem owner critically depends for solving his problem. Critical actors have either the power for realization or blocking power.

Table C.1: Resource Dependency of Stakeholders - adapted from (Enserink et al., 2010)

	Limited importance	**Great importance**
Limited options to replace	Medium dependency	High dependency
Can easily be replaced	Limited dependency	Medium dependency

Using Table C.1 the critical actors can be identified based on their resources and replaceanility. This overview can be found in Table C.2. Important resources are identified based on this research scope. Actors might have important resources for the general availability of cargo transportation, however they are not directly linked to this research and will therefore be classified as “no".

C.3.2 Dedication

The dependency on other parties is also influences by their interest in the problem and their willingness to use their resources. If an actor experiences clear costs or benefits the actor can be classified as ‘dedicated actor’, while if this is not the case the actor is classified as an ‘non-dedicated’ actor. Over time the classification of an actor can change. In Figure C.2 a power / interest matrix is constructed for the various stakeholders. Critical actors are those with a high level of power and dedicated actors are those with a high level of interest. The actors indicated as ‘yes’ in Table C.2 will be placed in the power interest matrix.

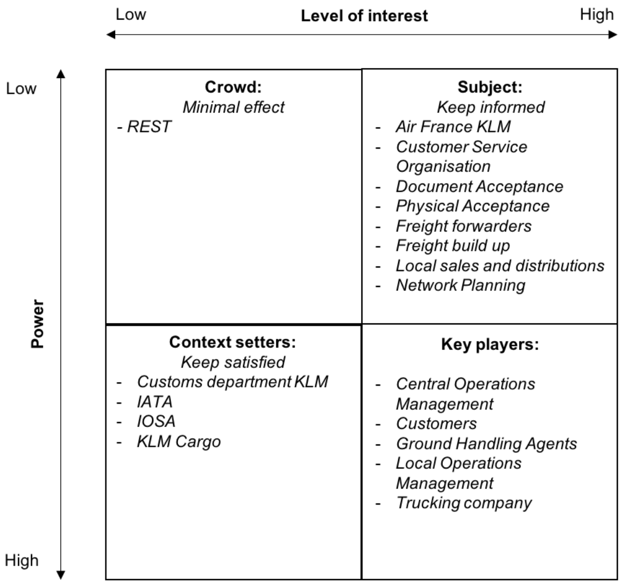


Figure C.2: Power Interest Matrix of the Stakeholders

Table C.2: Resource Dependency and Identification of Critical Actors

Actor	Important Resources	Replaceable?	Dependency Classification	Critical Actor?
Accounting	No			
Air France Cargo	No			
Air France KLM	Yes	No	High	Yes
Amsterdam Schiphol Airport	No			
Animal Hotel	No			
Central Operations Management	Yes	No	High	Yes
Customer Service Organisation	Yes	No	Medium	No
Customers	Yes	Yes / No	High	Yes
Customs Department KLM	Yes	No	High	Yes
Dangerous Goods	No			
Delta Cargo	No			
Document Acceptance	Yes	No	High	Yes
Freight Forwarders	Yes	Yes / No	Medium	No
Freight Build Up	Yes	No	Medium	No
General Goods	No			
Ground Handling Agent Outstations	Yes	Yes / No	Medium	Yes
Ground Handling Agent Schiphol	No			
IATA	Yes	No	Medium	No
IOSA	Yes	No	Low	No
KLM Cargo	Yes	No	High	Yes
Local Operations Management	Yes	No	Medium	Yes
Local Sales and Distribution	Yes	No	Low	No
Network Planning	Yes	No	Medium	Yes
Other Airlines	No			
Physical Acceptance	Yes	No	High	Yes
Procurement	No			
REST	Yes	No	Low	No
Revenue Management	No			
Security	No			
Sky Team	No			
Trucking Company	Yes	Yes / No	Medium	Yes

D In-Depth Current State Analysis

In this chapter the in-depth current state analysis will be performed. In Section D.1 the field-research performed for DTP will be described. This field-research will function as a basis for the swimlane development in Figure 5.3. Following in Section D.2 the process analysis performed at Schenker and DSV each will be presented and combined to a general process. Next, in Section D.3 the simplification from the swimlane diagram to a VSM as is done in Section 4.5.2 will be explained for the traditional model. Finally, in Section D.4 this same simplification will be done for the DTP model as explained in Section 5.3.2.

D.1 Direct Pick Up Trucking

Research regarding the DTP model has been performed by field research at 3 locations. The DTP cargo starts with a customer who requests a pick-up service to KLM customer service called the booking process. In Figure D.1 this process can be found. The booking process is divided in the one-time booking process and the structural booking process. The one-time booking process is the registration request for a direct pick-up, once the direct pick-up is known in the systems it can be booked for weekly pick-ups by operation, once the actual weight and volume of the bookings are known. The booking process has been verified with a various employees of KLM Cargo. The main stakeholders in the booking process are: customer, CSO, Operations truck department, trucking company and the hub.

Secondly, research is performed at the premises of the customer (DSV and Schenker), as will be elaborated in Section D.2. For both DSV and Schenker a separate swimlane is designed. The main processes of the swimlanes are combines and generated to a general customer swimlane as presented in Figure D.2. The main stakeholders in the customer processes and collection of cargo are: customer, trucking company, operations truck department and the hub.

Third, research is performed at the hub in Amsterdam. The trucking company collects the cargo from the customer and delivers it to the hub in Amsterdam. To improve the arrival performance as stated in the practical problem statement the processes at the hub should be investigated. In Figure D.3 the swimlane for the hub processes is illustrated. The main stakeholders are: truck driver, security, document acceptance, REST, customs, revenue management, physical acceptance.

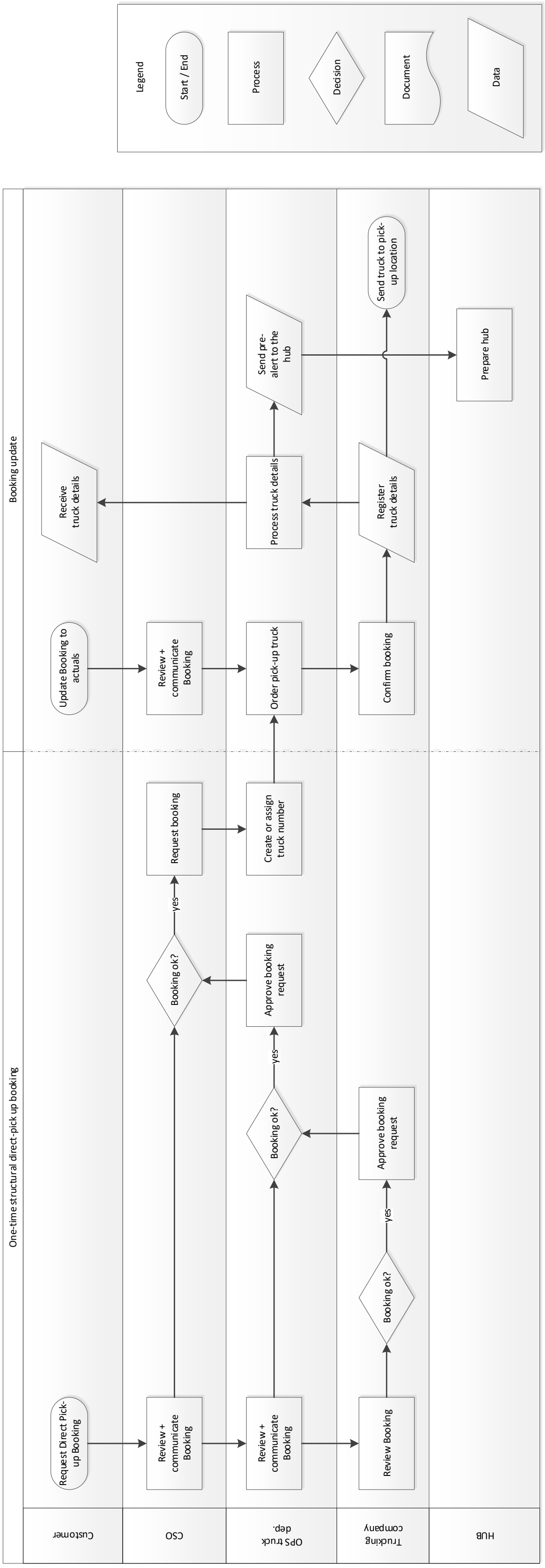


Figure D.1: Booking Swimlane

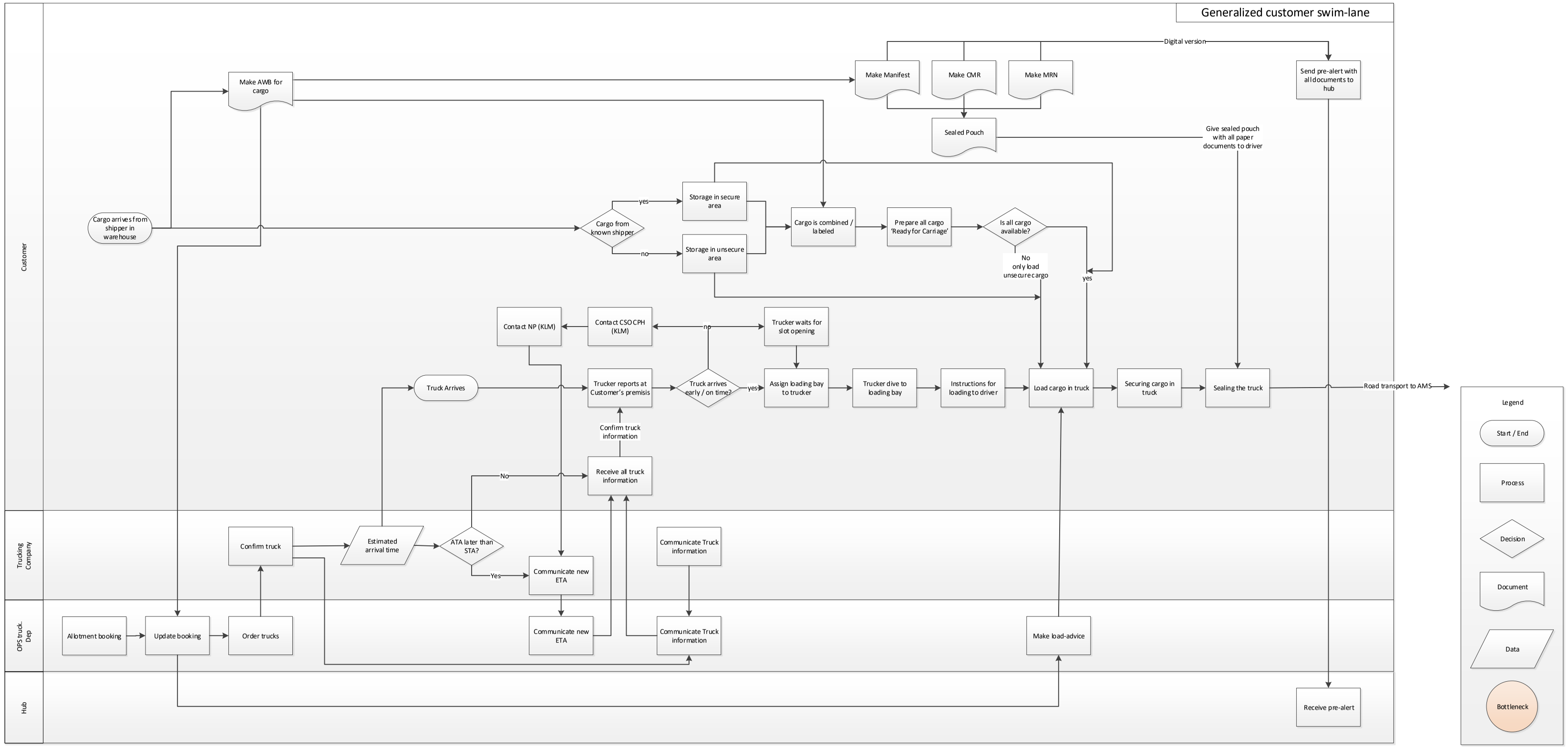


Figure D.2: Customer Swimlane

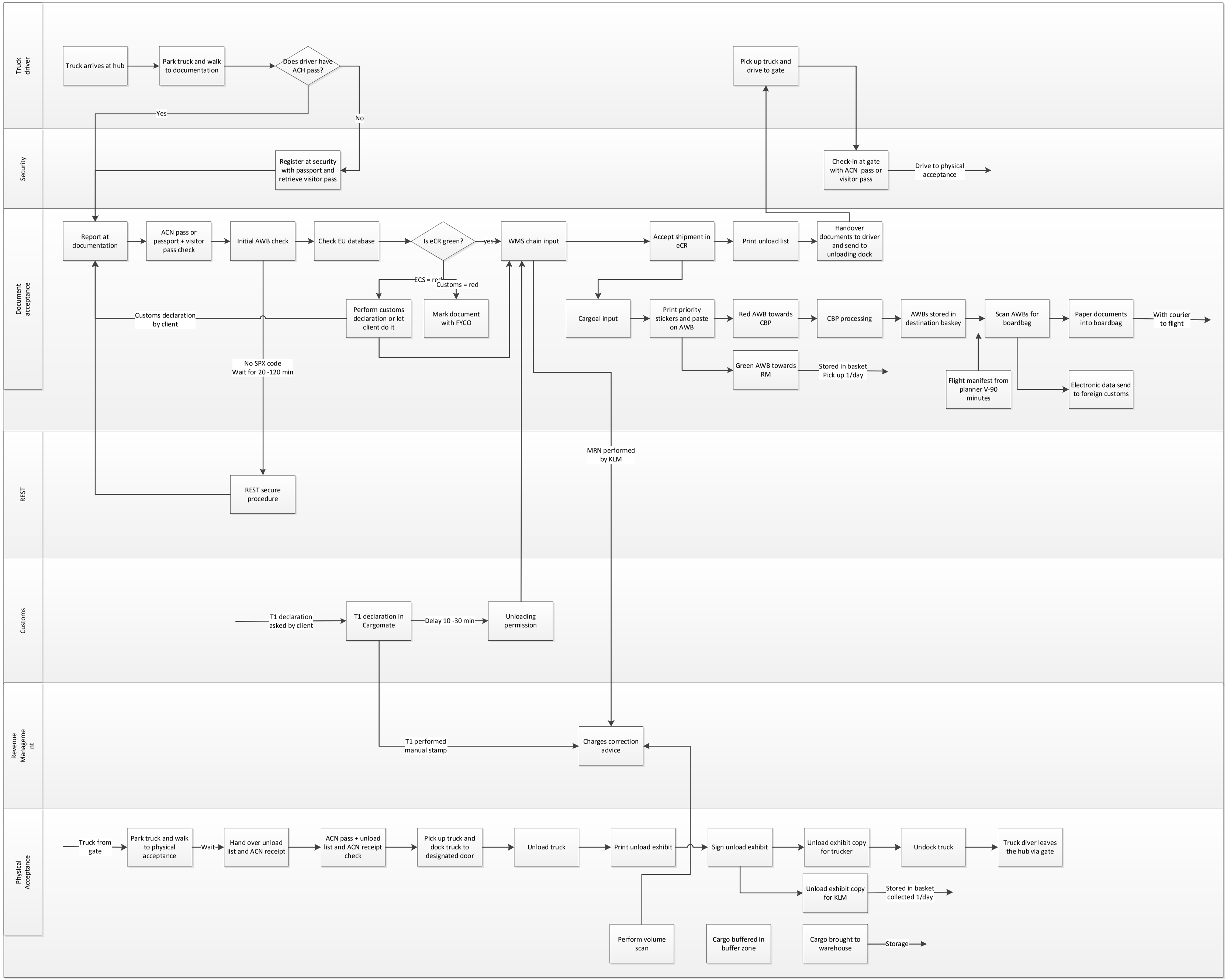


Figure D.3: KLM Cargo Hub Swimlane

D.2 Process Analysis

In the following swimlanes the current state analysis for the in-depth case study in Billund is shown. The first swim-lane is for DB Schenker and the second swim-lane for DSV. The swim-lanes have been constructed in collaboration with the customers. A visit was planned on the 14th of November 2017, in which a brown-paper session of 2 hours per customer was executed to identify the process steps and the bottlenecks experienced.

D.2.1 Process at Schenker

The result of the brown-paper session is illustrated in Figure D.4. Based on this brown paper session, discussions performed and the tour of the warehouse the specific swimlane for Schenker is designed as shown in Figure D.5. This swimlane in combination with the swimlane from DSV is generalised into a general swimlane for the customer. In the analysis the processes of the customer are not optimized as KLM has almost no influence on this party. As KLM wants to satisfy their customer, it is important that the processes of the customer are taken into account as they pose certain conditions on the system.

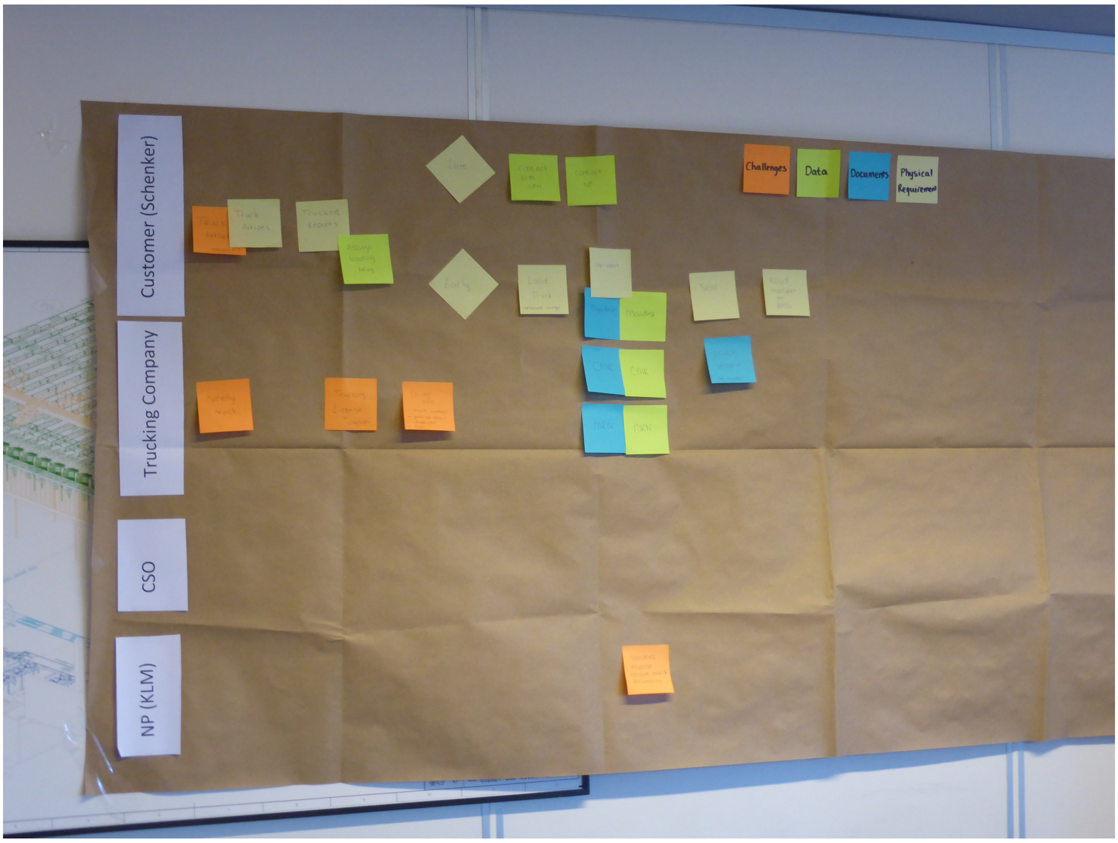


Figure D.4: Schenker Field Research

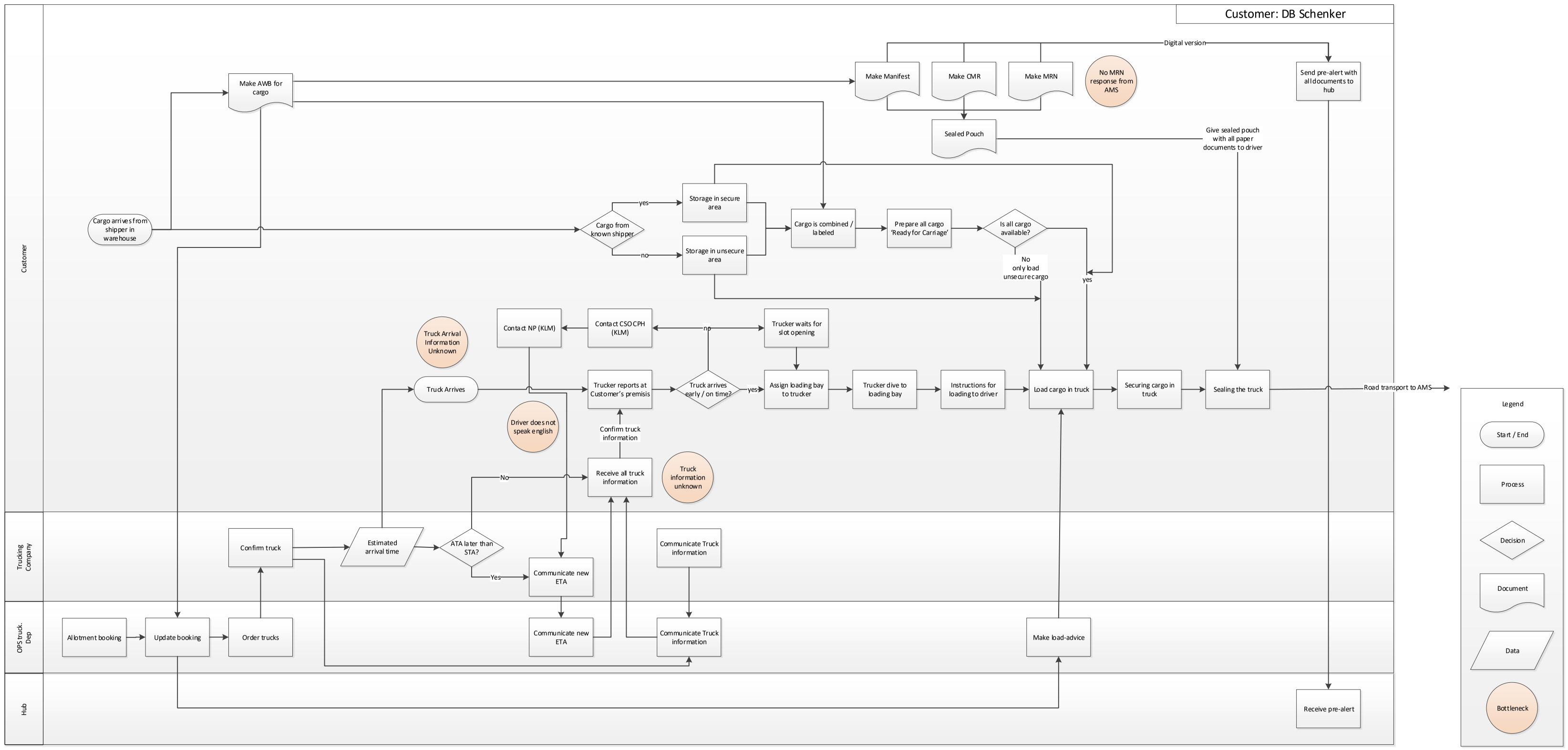


Figure D.5: Schenker Swimlane

D.2.2 Process at DSV

The result of the brown-paper session performed at DSV is illustrated in Figure D.6. Based on this brown paper session, discussions performed and a tour of the premises, the specific swimlane for DSV is designed in shown in Figure D.7. This swimlane in combination with the swimlane for Schenker are generalised into a general swimlane for the customer. In the analysis the processes of the customer are not optimized as KLM has almost no influence on this party. KLM wants to satisfy their customer, therefore it is important that the processes of the customer are taken into account as they pose certain conditions on the system.

Figure D.6: DSV Field Research

D.2.3 Differences in Processes

The bottlenecks experienced by the customer are different in the processes for Schenker and DSV. The only corresponding bottleneck is the information communication. Both customers would like to receive truck information such as truck/trailer numbers. For DB Schenker other bottlenecks are the truck arrival information is unknown, drivers don't speak English and there is no MRN response for Amsterdam, resulting in the fact that the customer does not know if the MRN's are correct or if they have been received. The bottlenecks for DSV are that they do not load according to the loading plan send by Amsterdam. Process wise there is a difference in communication for truck arrivals. DSV contacts NP directly while Schenker first contacts CSO and following NP.

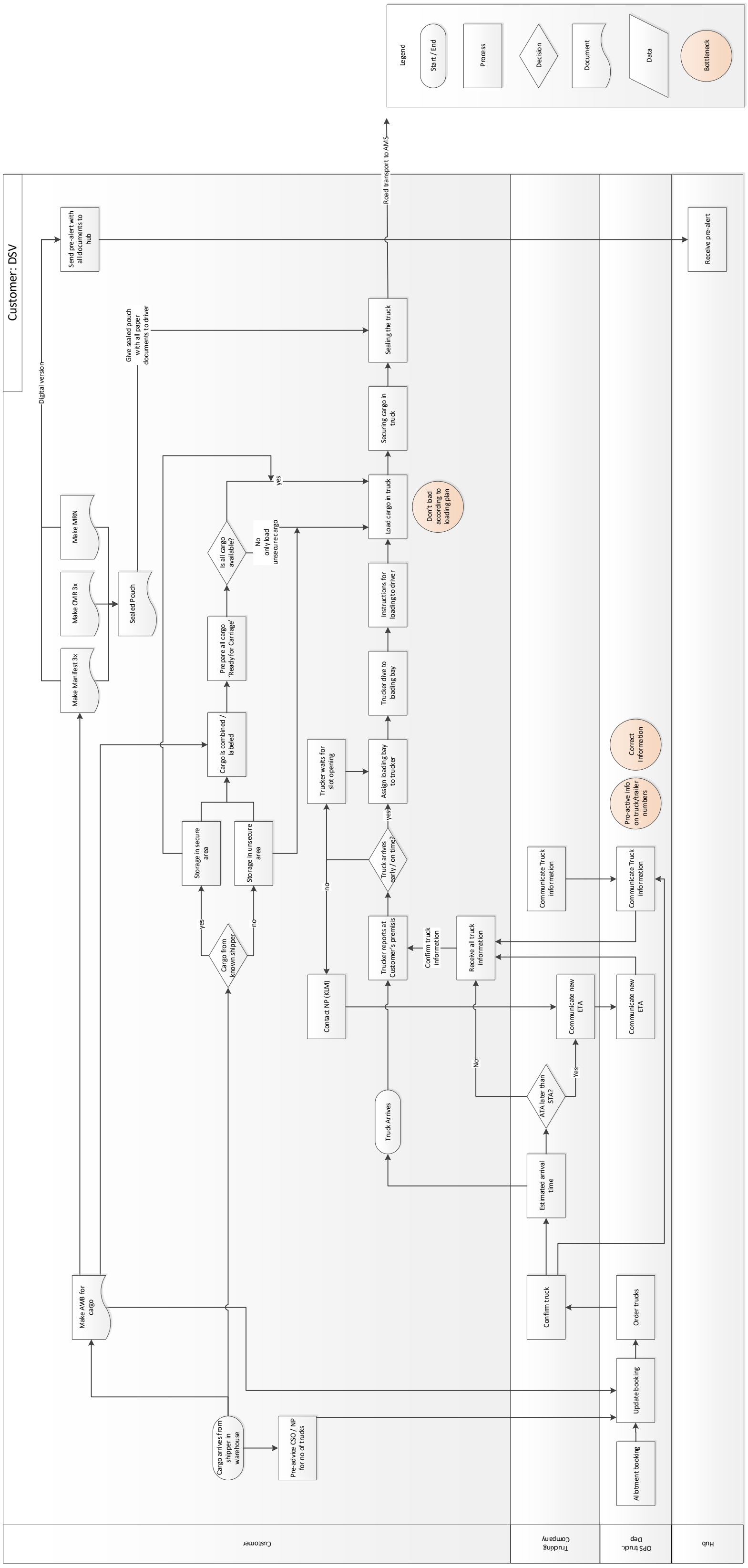


Figure D.7: DSV Swimlane

D.3 VSM Diagram Traditional

In this section the simplification of the traditional swimlane is described to generate the traditional VSM. Below each of the transactions in the traditional swimlane are discussed and which groups are simplified to which VSM process. The traditional VSM diagram will be simulated using the modelling software Simio to experiment with the traditional air cargo system.

Cargo Arrival

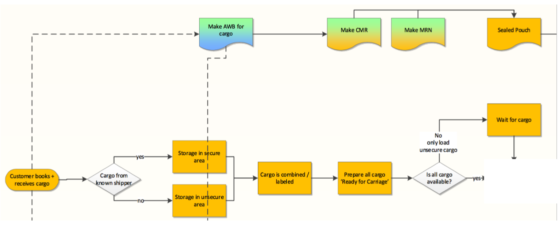


Figure D.8: [Traditional Swimlane] Process at the Customer

Cargo originates from the customer, either DSV or Schenker in Denmark. The exact arrival of the cargo is not taken into account as the optimization of the processes of the customer are not taken into account in this thesis. The corresponding swimlane processes are illustrated in Figure D.8.

Load Domestic Truck

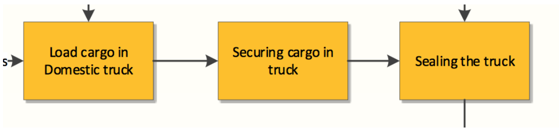


Figure D.9: [Traditional Swimlane] Load Domestic Truck

The cargo is transported from the warehouse of the customer to the GHA. The truck is loaded by the customer. The corresponding swimlane processes are illustrated in Figure D.9

Domestic Trucking

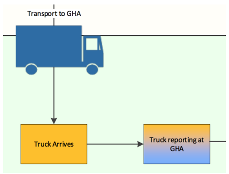


Figure D.10: [Traditional Swimlane] Domestic Trucking

The cargo is transported from the warehouse of the customer to the GHA. The transportation is arranged by the customer. The corresponding swimlane processes are illustrated in Figure D.10.

Unload Domestic Truck

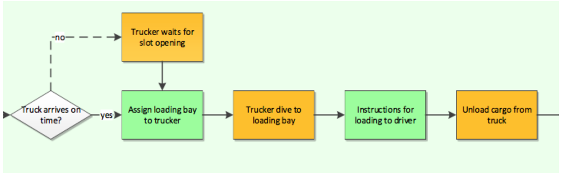


Figure D.11: [Traditional Swimlane] Unload Domestic Truck

The cargo is transported from the warehouse of the customer to the GHA. The unloading is performed by the GHA. The corresponding swimlane processes are illustrated in Figure D.11.

GHA Process

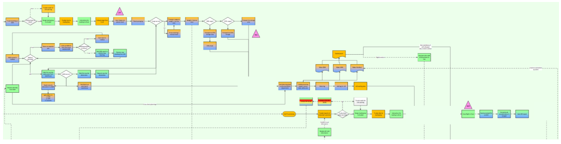


Figure D.12: [Traditional Swimlane] GHA Process

The cargo is accepted on behalf of KLM by the GHA: Cargo Center Billund. The cargo can only be accepted if all security checks are done and both the physical and documentation information is correct and checked. The corresponding swimlane processes are illustrated in Figure D.12.

Load ULD

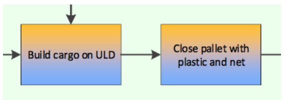


Figure D.13: [Traditional Swimlane] Load ULD

The loose cargo shipments are build up on an ULD by the GHA after all checks are performed. The ULD loading is needed for aircraft transportation. 59% of the ULDs are T-ULDs which can directly be transshipped at Schiphol to the aircraft and 41% are mix-ULDs which need to be broken down in Amsterdam.

Load JdR Truck

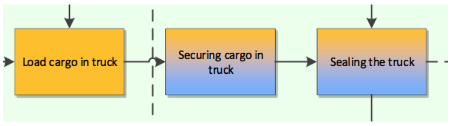


Figure D.14: [Traditional Swimlane] Load JdR Truck

The JdR truck is ordered by NP located at the hub in Amsterdam. The truck is loaded with the ULD's at the GHA in Denmark. A maximum of 4 ULD's fit in a truck. The rate payed for a truck depends on the number of ULDs.

Trucking

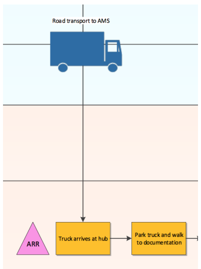


Figure D.15: [Traditional Swimlane] Truck Transit Time

The truck transit time is the time that the truck needs to drive from the warehouse in Billund to the hub in Amsterdam. The contracted truck transit time for an FTL is 14 hours and for an LTL 18 hours.

Reporting

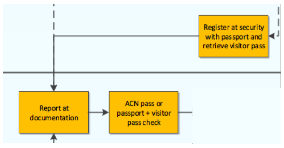


Figure D.16: [Traditional Swimlane] Reporting

After the truck arrives, the truck driver has to report and hand over the documents to check if the truck is expected and if the truck has the status secured. The corresponding swimlane processes are illustrated in Figure D.16.

Documentation Processing

After the check is performed that all documentation is complete and correct the procedure for handling the documents can be performed. The corresponding swimlane processes are illustrated in Figure D.17.

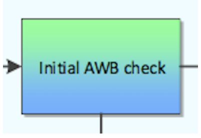


Figure D.17: [Traditional Swimlane] Documentation Processing

Incorrect Documentation Handling

If the documentation is incomplete and or incorrect and cannot be repaired by the documentation department staff, the documents are returned digitally to the GHA. The corresponding swimlane processes are illustrated in Figure D.18.

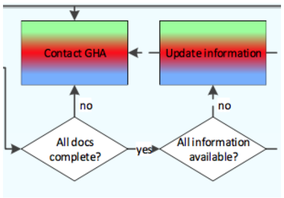


Figure D.18: [Traditional Swimlane] Incorrect Documentation Handling

GHA Correction Documentation

If the documentation is incomplete or incorrect it is send back to the GHA. As the GHA only works during opening hours and a truck can arrive at any moment at the hub, there is often a significant waiting time. The corresponding swimlane processes are illustrated in Figure D.19.

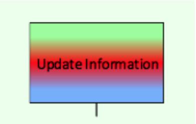


Figure D.19: [Traditional Swimlane] GHA Correction Documentation

Correct Documentation Handling

After the check is performed that all documentation is complete and correct the procedure for handling the documents can be performed. The corresponding swimlane processes are illustrated in Figure D.20.

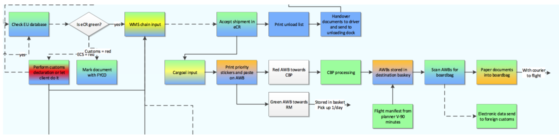


Figure D.20: [Traditional Swimlane] Correct Documentation Handling

REST

If the truck does not have the status 'secured' the truck has to go through the REST procedure as described in more detail in Appendix C. The corresponding swimlane processes are illustrated in Figure D.21.

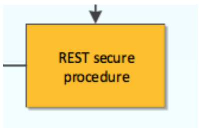


Figure D.21: [Traditional Swimlane] REST Procedure

Unload Truck

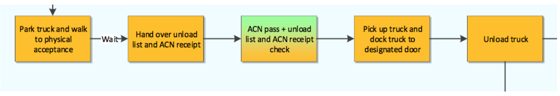


Figure D.22: [Traditional Swimlane] Unload Truck

If the truck is secured and all documentation is correct the truck can go to one of the unloading docks where the ULDs are unloaded. The ULDs are stored in the ULD storage area. The corresponding swimlane processes are illustrated in Figure D.22.

Unload ULD

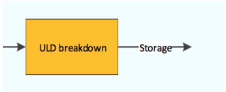


Figure D.23: [Traditional Swimlane] Unload ULD

The ULD that is needed for a certain flight is retreived from the ULD storage system and the mis-ULD is broken down. The corresponding swimlane processes are illustrated in Figure D.23.

Cargo Processing

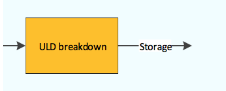


Figure D.24: [Traditional Swimlane] Cargo Processing

After the ULD is broken down the individual shipments are transported to the buffer area waiting for build up. The corresponding swimlane processes are illustrated in Figure D.24.

D.4 VSM Diagram DTP

In this section the simplification of the swimlane diagram is described to generate the DTP VSM diagram. Below each of the transactions in the DTP swimlane are discussed and which groups of transactions are simplified to a single VSM process. The DTP VSM diagram will be simulated using the modelling software Simio to experiment with the Direct Trucking Pick-up system.

Cargo Arrival

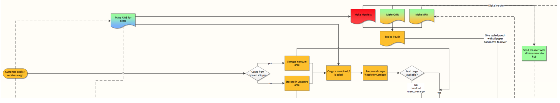


Figure D.25: [DTP Swimlane] Cargo Arrival

Cargo originates from the customer. For this specific research either from DSV or Schenker in Denmark. The exact cargo arrival is not taken into account as the optimization of the customers' processes are not taken into account in this thesis. The corresponding swimlane processes are illustrated in Figure D.25.

Load JdR Truck

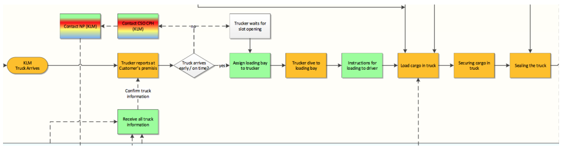


Figure D.26: [DTP Swimlane] Load JdR Truck

JdR truck is ordered by NP located at the hub in Amsterdam. The truck is loose loaded at the customer in Denmark. The rate payed for a truck depends on the distance from the nearest network point. The corresponding swimlane processes are illustrated in Figure D.26.

Trucking

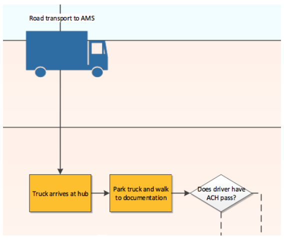


Figure D.27: [DTP Swimlane] Trucking

The truck transit time is the time that the truck needs to drive from the customer to the hub in Amsterdam. The contracted truck transit time for an FTL is 14 hours. The corresponding swimlane processes are illustrated in Figure D.27.

Reporting

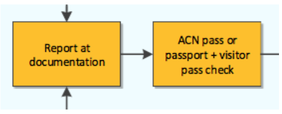


Figure D.28: [DTP Swimlane] Reporting

After the truck arrives, the truck driver has to report and hand over the documents to check if the truck is expected and if the truck has the status secured. The corresponding swimlane processes are illustrated in Figure D.28.

Documentation Processing

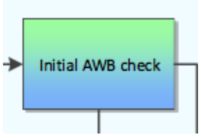


Figure D.29: [DTP Swimlane] Documentation Processing

After the check is performed that all documentation is complete and correct the procedure for handling the documents can be performed. The corresponding swimlane processes are illustrated in Figure D.29.

Incorrect Documentation Handling

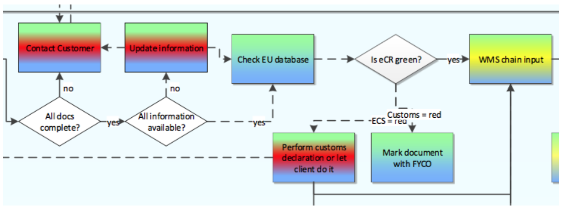


Figure D.30: [DTP Swimlane] Incorrect Documentation Handling

If the documentation is incomplete and / or incorrect and cannot be repaired by the documentation department employees, the documents are returned digitally to the customer. The corresponding swimlane processes are illustrated in Figure D.30.

Customer Documentation Correction

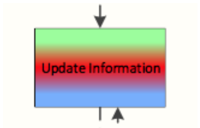


Figure D.31: [DTP Swimlane] Customer Documentation Correction

If the documentation is incomplete and / or incorrect it is send back to the customer. The customer only works during opening hours and a truck can arrive at any moment at the hub as it is open 24/7. Therefore there is often a significant waiting time for the documents return corrected to the hub. The corresponding swimlane processes are illustrated in Figure D.31.

Correct Documentation Handling

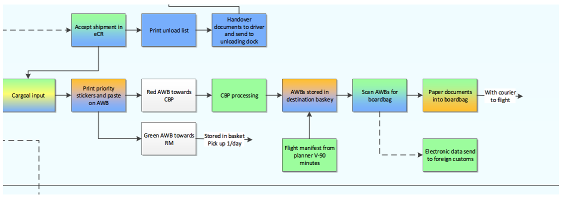


Figure D.32: [DTP Swimlane] Correct Documentation Handling

After the check is performed and all documentation is correct and complete the procedure for handling the documents can be performed. The corresponding swimlane processes are illustrated in Figure D.32.

REST

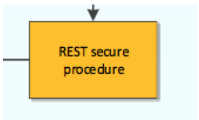


Figure D.33: [DTP Swimlane] REST

If the truck does not have the status ‘secured’, the truck has to go through the REST procedure as described in more detail in Appendix C. The corresponding swimlane processes are illustrated in Figure D.33.

Unload Truck

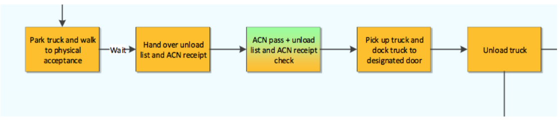


Figure D.34: [DTP Swimlane] Truck Unloading

If the truck is secured and all documentation is correct the truck can go to one of the unloading docks where the loose cargo is unloaded. The corresponding swimlane processes are illustrated in Figure D.34.

Cargo Processing

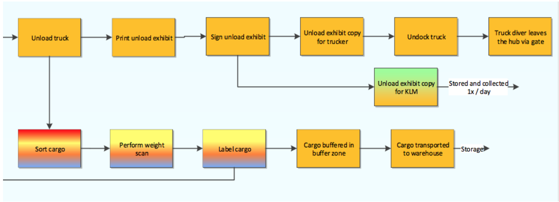


Figure D.35: [DTP Swimlane] Cargo Processing

After unloading the loose cargo has to be checked before the Ready For Carriage (RFC) milestone can be given based on weight, volume, packaging, number of pieces, etc. The corresponding swimlane processes are illustrated in Figure D.35.

E In-Depth Electronic Data Interchange

In this appendix the details of the current state of Electronic Data Interchange (EDI) is examined. In Section E.1 the communication between the different parties in the traditional supply chain is illustrated. In Section E.2 the communication manners between the different parties in the DTP supply chain is illustrated. In Section E.3 the current EDI is adapted to suggest a future EDI DTP scenario. This scenario is in accordance with design option 4 and 5 as presented in Chapter 7.

E.1 EDI in Current Traditional Supply Chain

The high-level traditional supply chain is illustrated in Figure 1.3. The physical and information flow in the current state as available in theory for the traditional supply chain is illustrated in Figure E.1.

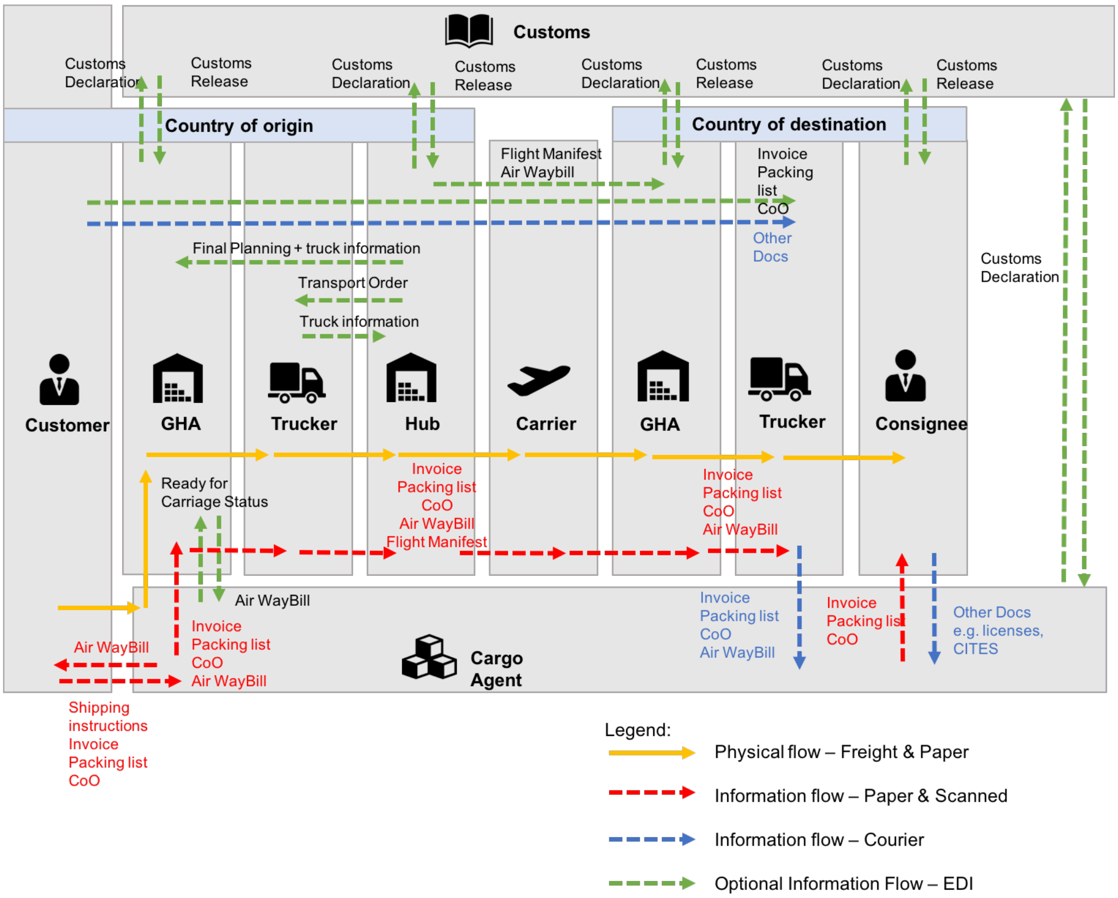


Figure E.1: EDI Traditional Air Cargo Supply Chain

From Figure E.1 it can be determined that there remains paperwork in the supply chain, which is transferred from party to party. It can also be observed that already some EDI is present in the system, especially with regard to customs declarations.

E.2 EDI in Current Direct Trucking Pick-up

Currently the high-level as-is business process as illustrated in Figure E.2 can be found in literature (International Air Transport Association, 2010). Below a short description of the as-is business process is provided:

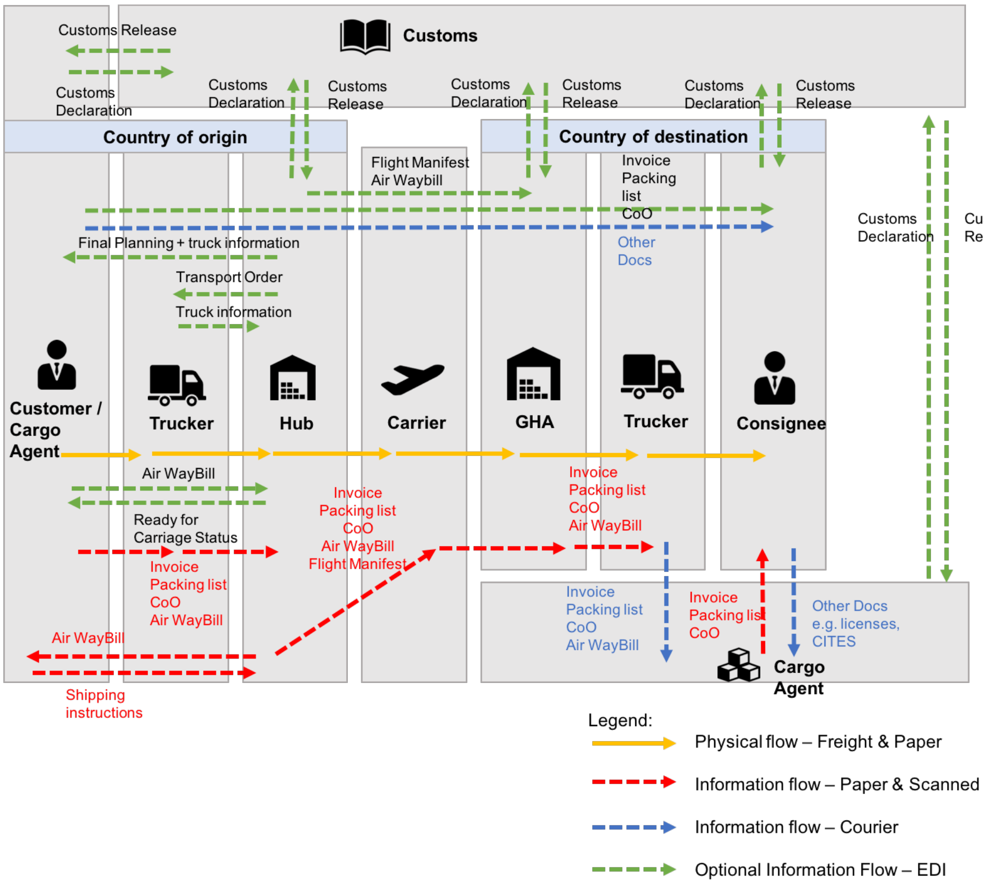


Figure E.2: EDI DTP Air Cargo Supply Chain

1. Customer
    - Provides the cargo agent with hard copies of the shipping instruction and possibly scanned images or electronic versions of trade documents.
    - In some cases provides the consignee and customs with electronic version of the trade documents. Customs or consignee may also be provided with electronic access to the trade documents.
    - Provides consignee with hard copies of other paper documents legally required in paper format at destination via courier or by sending with the shipment.
    - Submits the customs export goods declaration to clear the goods for export.
2. Cargo Agent (origin)
    - Creates and submits the Air Waybill as instructed by the customer including the customer's name in the Air Waybill (FWB) message information and arranges the booking.
    - Places the Air WayBill, Invoice, Packing List and Certificate of Origin on Freight Invoice in the "pouch" that ravels with the shipment.
    - Provides the customer with the Air WayBill, which may be a scanned PDF copy or a signed paper copy of the original.
3. Carrier
    - Receives the shipment with the "pouch" from the cargo agent, makes it available at destination airport and notifies customs / agent / consignee.
    - Provides, if need be, a warehouse receipt to the cargo agent to confirm the freight weight, volume and number of pieces that he has received.

- Lodges the customs export cargo declaration at origin and the customs import cargo declaration at destination to clear the cargo providing any additional paper documents if requested.
- Delivers to destination airport and notifies customs / agent / consignee.
- Provides, if need be, a delivery note to the consignee at destination to confirm the freight weight, volume and number of pieces that he has delivered.

4. Consignee
    - Provides customs / agent with the paper or scanned invoice, packing list and where legally feasible the certificate of origin as well as with hard copies of other documents via courier / post / hand prior to reception of the shipment.
    - Receives arrival notification from the carrier at destination, when no notify part is shown in the Air WayBill.
    - Arranges pick up and delivery of the shipment.
5. Cargo Agent (destination)
    - Receives from the consignee other paper documents that are legally required in paper format.
    - Receives from the carrier at destination the arrival notification as well as the Air WayBill together with the trade documents.
    - Prepares the customs import goods declaration prior to the reception of the shipment by consignee. Lodges the customs import goods declaration to clear the shipment providing any additional paper documents if requested.
    - Undertakes ancillary services as instructed by the consignee, such as pick-up and delivery of the shipment.

E.3 EDI for Future Direct Trucking Pick-up

In Figure E.3 the future EDI communications between the different parties in the DTP supply chain is suggested. This Figure is adapted based on the current state EDI and description as presented in Section E.2

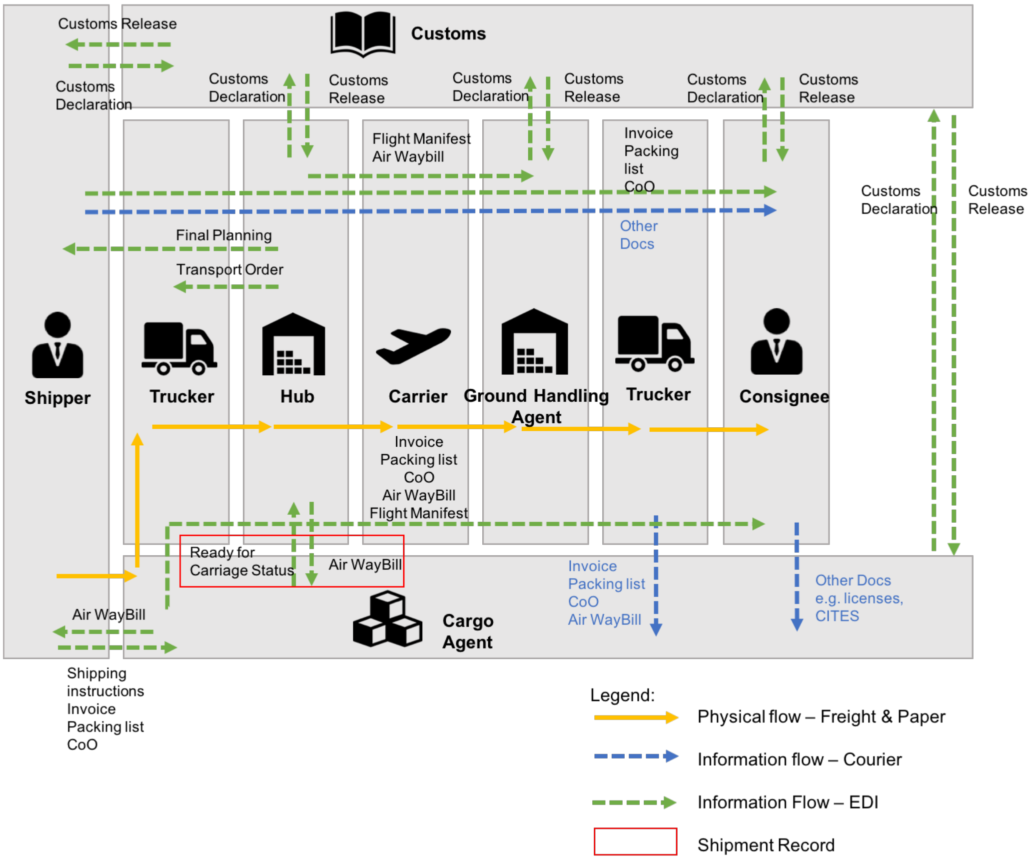


Figure E.3: Future EDI DTP

F In-Depth Model

In this appendix more background information is provided with regard to the development of the simulation model. A simulation model is developed to function as test platform for the various improvement scenarios suggested in Chapter 7. In Section F.1 the simulation project plan will be presented. Following in Section F.2 the various distributions that can be used in modelling will be presented, both discrete and continuous distributions. Next, in Section F.3 the theory behind the boxplots used to analyse the data will be explained. In Section F.4 the boxplot distributions and the distribution variable as entered in the traditional model are shown and in Section F.5 this is done for the DTP model.

F.1 Modelling Approach

In Figure F.1 the simulation project plan is presented. On the left side of Figure F.1, the ‘as-is’ model is presented. To understand the current situation, a description of the system should be made in such a way, that the kind and the behaviour of the system can be studied and understood. This is particularly useful for; specification, analysis and diagnosis. On the right side of Figure F.1, the ‘to-be’ model is presented. To understand new situations, a description of a new situation for the system needs to be made before modelling. This is particularly useful to specify alternative solutions to problems perceived, to analyse potential solutions and to explain and demonstrate favourable alternatives to the problem owner.

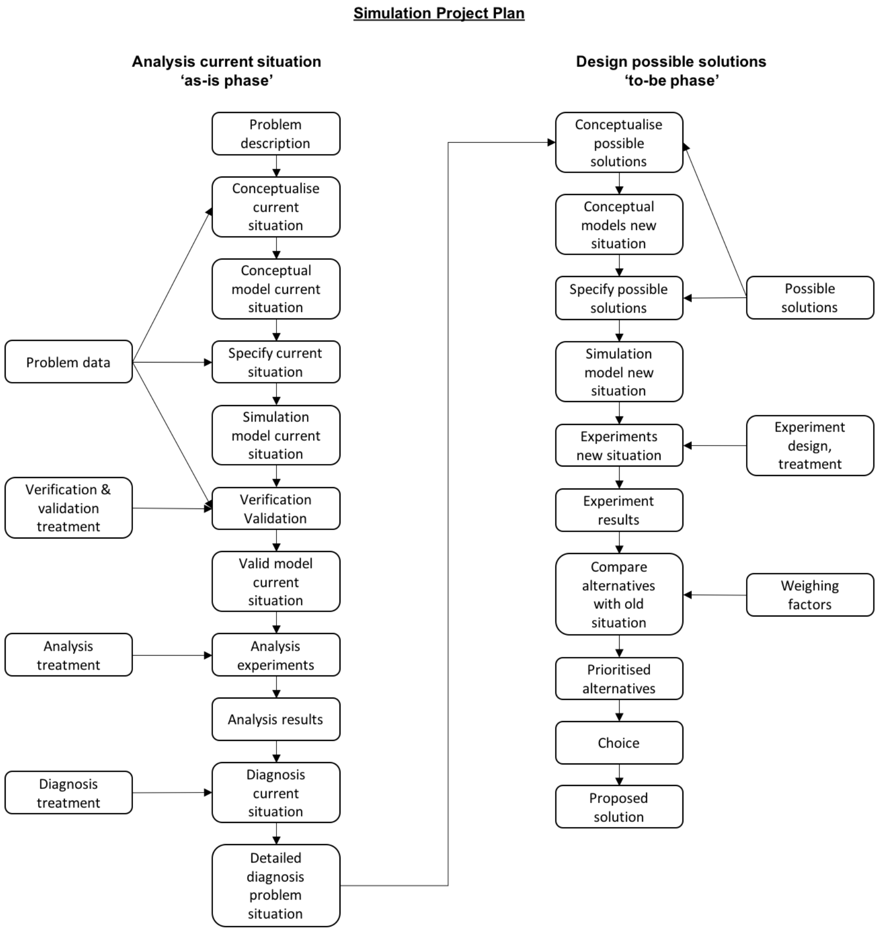


Figure F.1: Simulation Project Plan - adapted from (Verbreak, 2015)

F.2 Distributions

In this section, a small explanation is provided on the different types of distributions that are used in the discrete even simulation model. There are two types of distributions, firstly discrete probability distributions and secondly continuous probability distributions. Discrete probability distributions are used when an experiment only has integer (whole number) outcomes, such as the number of customers that arrive or a number of products that a machine can make per hour. Continuous probability distributions are used when an experiment can have all values in a certain interval. Outcomes such as the production time to make a product or the arrival time between two customers are two examples. Continuous distributions are used in modelling random events in which the variable can have any value in a particular interval.

F.2.1 Discrete Probability Distributions

For discrete probability distributions there are several types of distributions possible. A discrete random variable can be used to describe random events, in which only integer values can occur or values that are countable. Below the equations are shown for several types of distributions.

Bernoulli distribution

A Bernoulli distribution can be used to model the outcome of an experiment with only two outcomes yes or no.

$$\begin{aligned} p_j(x_j) = p(x_j) &= p, x_j = 1, j = 1,2,...,n \\ &= 1-p = q, x_j = 0, j = 1,2,...,n \\ &= 0, otherwise \end{aligned} \tag{F.1}$$

Binomial distribution

The Binomial distribution is used to model the number of successes in x number of Bernoulli experiments.

$$\begin{aligned} p(x) &= (\frac{n}{x})p^x q^{n-x}, x = 0,1,2,...,n \\ &= 0, otherwise \end{aligned} \tag{F.2}$$

Geometric distribution

A geometric distribution can be used to model the number of Bernoulli experiments up till the first success and the Poisson distribution to model the number of events in a certain time interval.

$$\begin{aligned} p(x) &= q^{x-1}p, x = 1,2,... \\ &= 0, otherwise \end{aligned} \tag{F.3}$$

Poisson distribution

The Poisson distribution is used to model a number of random events within a particular time interval. If the time between events has been distributed exponentially, the number of events in a time interval has the Poisson distribution. The probability density function is:

$$\begin{aligned} p(x) &= \frac{e^{-\alpha}\alpha^x}{x!}, x = 0,1,... \\ &= 0, otherwise \end{aligned} \tag{F.4}$$

F.2.2 Continuous Distributions

Continuous distributions are used in modelling random events in which the variable can have any value in a particular interval. Below the equations are shown for several types of continuous distributions.

Uniform distribution

A uniform distribution can be used to model the outcome of an experiment in which all outcomes have the same probability. A random variable X is distributed uniformly at interval [a,b] if the probability density function is expressed by:

$$\begin{aligned} f(x) &= \frac{1}{(b-a)}, a < x \leq b \\ &= 0, otherwise \end{aligned} \tag{F.5}$$

Triangular distribution

A random variable X has a triangular distribution if the probability density function is as follows:

$$\begin{aligned} f(x) &= \frac{2(x-a)}{(b-a)(c-a)}, a \leq x \leq b \\ &= \frac{2(c-x)}{(c-b)(c-a)}, b < x \leq c \\ 1, x > c & \end{aligned} \tag{F.6}$$

Exponential distribution

A random variable X is distributed exponentially with parameter $\lambda > 0$ specified if the probability density function is expressed by:

$$\begin{aligned} f(x) &= \lambda e^{-\lambda \cdot x}, x \geq 0 \\ &= 0, otherwise \end{aligned} \tag{F.7}$$

Gamma distribution

The exponential distribution has only one parameter, the gamma distribution has two parameters. The gamma distribution is defined using β and α, which can be used to generate a large variety of forms of probability density functions. The probability density function for the gamma distribution is:

$$f(x) = \frac{x^{\beta-1}}{\theta^{\beta}\Gamma(\beta)} e^{-\frac{x}{\theta}}, x > 0 \tag{F.8}$$

Lognormal distribution

The lognormal distribution has a random variable whose logarithm is normally distributed. If the random variable X is log-normally distributed then Y = ln(X) has a normal distribution. Likewise, if Y has a normal distribution, then the exponential function of Y, X = exp(Y) has a log-normal distribution. The probability density function for the lognormal distribution is:

$$f(x) = \frac{1}{2} \cdot \frac{1}{\sigma\sqrt{2\pi}} e^{(} - \frac{(lnx-\mu)^2}{2\sigma^2} \tag{F.9}$$

The mean can be calculated using equation:

$$exp(\mu + \frac{\sigma^2}{2}) \tag{F.10}$$

F.3 Box plot Analysis

While analyzing data, means can be used, to compare results. However, as explained in Chapter 3, means are important but do not display the entire range of possibilities. Mean is the average of (an infinite) number of replications of the random variable of interest (Kelton et al., 2011). They don't inform about the spread or what values are likely or unlikely. A box plot displays the minimum and maximum observed values, the sample mean, sample median and lower and upper percentile values. The box plot was first introduced by (Tukey, 1977). In Figure F.2 an example of a box plot can be found.

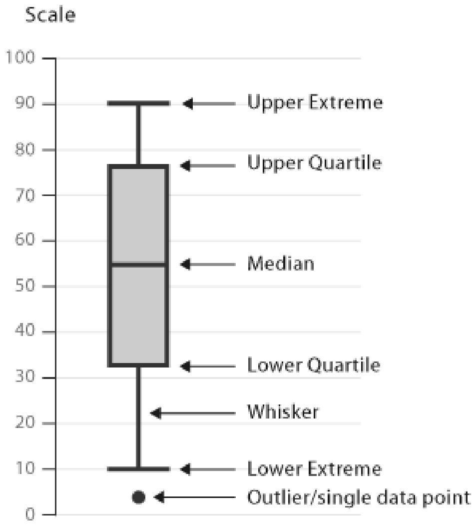


Figure F.2: Boxplot

The data gathered from (KLM) systems, for the analysis of the current state, will be analysed using box plots. To summarize the results the following abbreviations will be used:

1. Upper Extreme (UE)
2. Upper Quartile (UQ)
3. Median (Med.)
4. Lower Quartile (LQ)
5. Lower Extreme (LE)

F.4 Traditional Line-haul Trucking

[Traditional] Number of Cargo per Truck

To simulate the amount of cargo on a traditional line-haul truck, the number of cargo pieces used, is the same as in the DTP model, to make comparison for same amount of cargo. As the seed of the simulation is the same it will take the same random distribution every time.

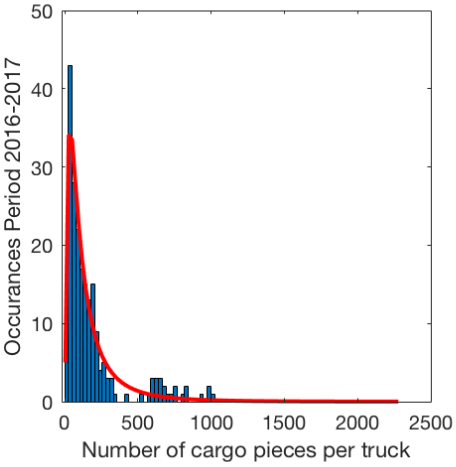


Figure F.3: [Traditional] Number of Cargo per Truck

Table F.1: [Traditional] Truck Transit Time

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
Minutes	35.32	24.49	104.00	14.85	13.12	Lognormal(177.341 , 1.027)

[Traditional] Truck Transit Time from GHA to Schiphol

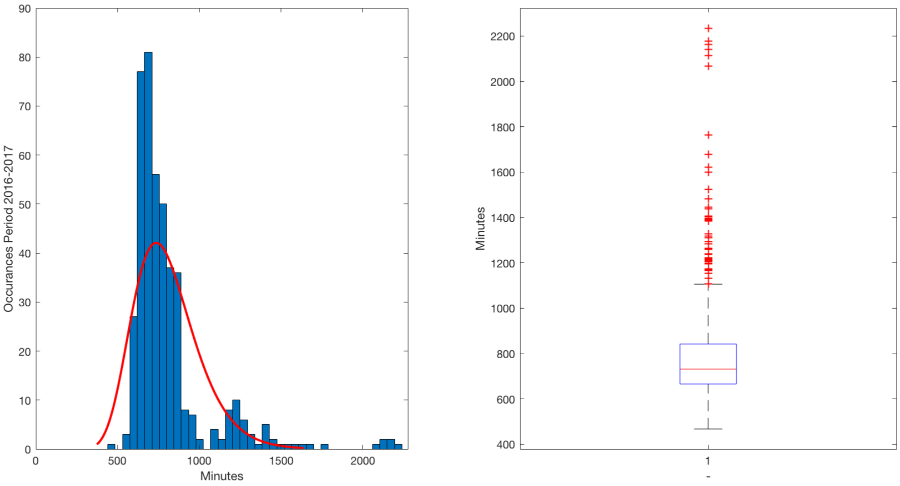


Figure F.4: [Traditional] Truck Transit Time

Based on data from the KLM database, a fit has been made. This fit is a lognormal distribution, the notation of lognormal distribution is $Lognormal(\mu, \sigma^2)$. The mean of the lognormal distribution can be calculated using equation F.11. This fit will be used in the simulation model to generate a random sample from this distribution for the duration of the trucking time.

$$Mean = exp(\mu_{normal} + \frac{\sigma^2}{2}) \tag{F.11}$$

Rewriting equation F.11 results in equation F.12. The distribution for lognormal is determined by using this equation.

$$\mu_{normal} = ln(\mu_{logn}) - \frac{\sigma^2}{2} \tag{F.12}$$

Table F.2: [Traditional] Truck Transit Time

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
Minutes	1106	842	732	666	467	Lognormal(806 , 0.245)

[Traditional] REST Time

The distribution of the REST time for the traditional model can be found on the left side in Figure F.5 and the corresponding box-plot can be found on the right side. The upper extreme is 35 minutes and the lower extreme 13 minutes as displayed in Table F.3. These values are in correspondence with the current state measurements.

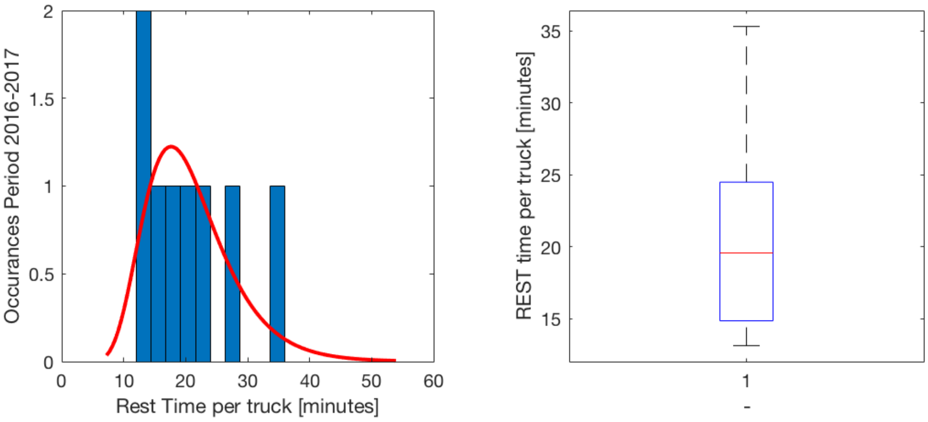


Figure F.5: [Traditional] REST per Truck

Table F.3: [Traditional] REST Time

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
Minutes	35.32	24.49	19.56	14.85	13.12	Lognormal(20.885 , 0.335)

[Traditional] Unloading Time

The distribution of the unloading time for a truck in the traditional model can be found on the left side of Figure F.6. The corresponding boxplot can be found on the right side. As displayed in Table F.4 the maximum time for unloading an entire truck with ULDs is 15 minutes and the lowest is 0.05 minutes. This depends on the number of ULDs that are loaded in the truck. For this research however, the assumption is made that only FTL trucks are transported. Therefore in Figure F.7 the unloadingtime per ULD is calculated.

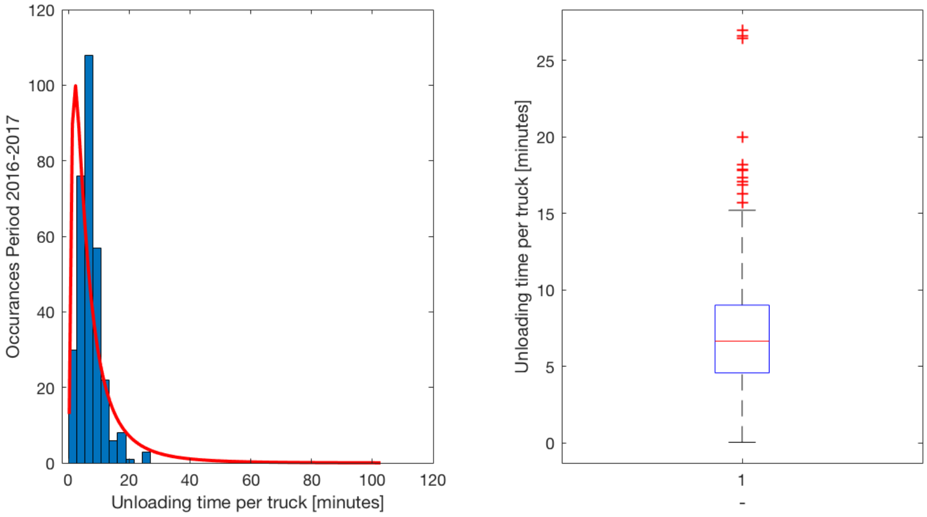


Figure F.6: [Traditional] Unloading Time per Truck

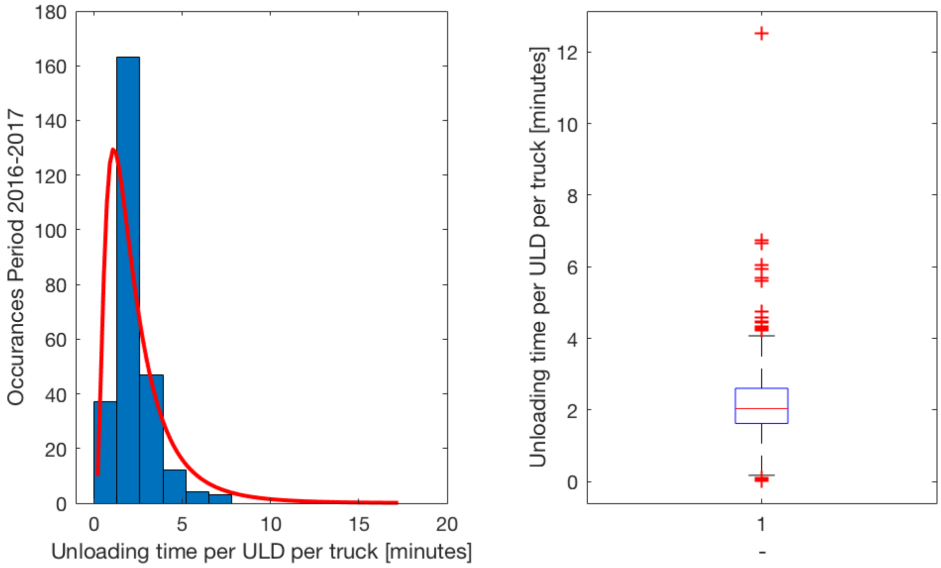


Figure F.7: [Traditional] Unloading Time per ULD on a Truck

Table F.4: [Traditional] Truck Unloading Time

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
Truck	15.22	9.02	6.67	4.59	0.05	Lognormal(8.849 , 0.976)
ULD	4.07	2.60	2.04	1.62	0.17	Lognormal(2.495 , 0.734)

F.5 Direct Trucking Pick-up

[DTP] Cargo Generation

In this section the distribution for generation of cargo is calculated based on data entries from the KLM systems. A case study is performed for both Schenker and DSV.

Case Study - Schenker

The distribution for the number of cargo pieces per truck for a Schenker truck can be found on the left side of Figure F.8. On the right side the corresponding boxplot can be found. In Table F.5 the upper extreme for Schenker is 245 pieces of cargo per truck. The lower extreme is 3 pieces of cargo per truck. As only FTL trucks are ordered for DTP transportation it can be concluded that the number of pieces does not indicate anything, but the size of the cargo does. For example the unloading time does not depend on the number of cargo pieces, it also depends on the size and how easy it is to handle the cargo. On average there are 94 cargo pieces for Schenker in a truck.

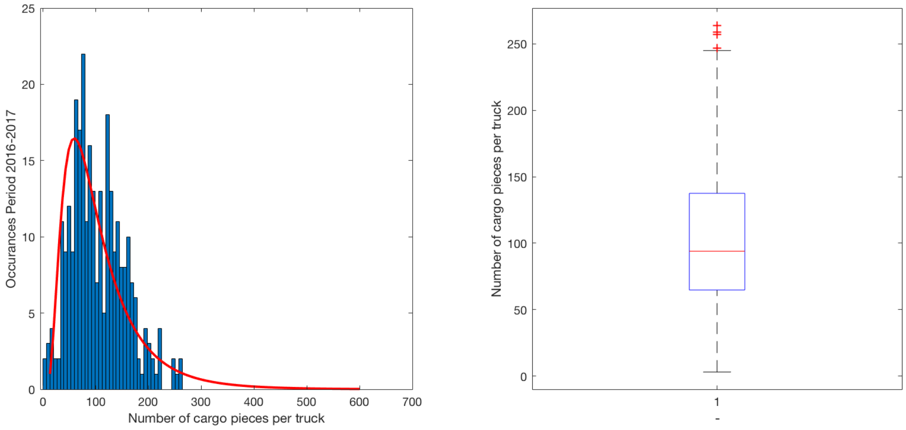


Figure F.8: [DTP] Schenker Number of Cargo Pieces Per Truck

Case Study - DSV

The distribution for the number of cargo pieces per truck for a DSV truck can be found on the left side of Figure F.9. On the right side the corresponding boxplot can be found. In Table F.5 the upper extreme for DSV is 212 pieces of cargo per truck. The lower extreme is 1 pieces of cargo per truck. On average there are 80 cargo pieces for Schenker in a truck. As shown in this Table all cargo pieces are integer numbers as is expected.

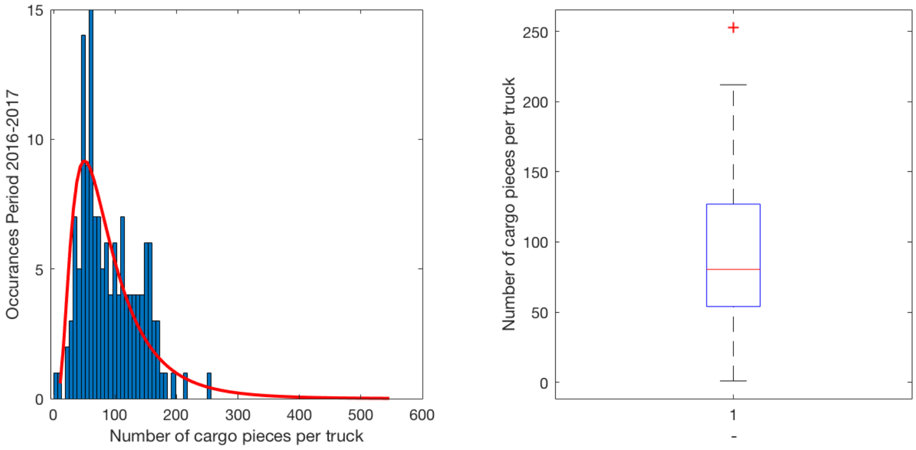


Figure F.9: [DTP] DSV Number of Cargo Pieces Per Truck

Table F.5: [DTP] Cargo per Truck

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
Schenker	245	137	94	65	3	Lognormal(108.8 , 0.637)
DSV	212	127	80	54	1	Lognormal(95.293 , 0.653)

[DTP] Truck Loading

This process takes place at the customer and as no field data is available, this data is gathered using the interview technique. According to an interview with (Mauritzen, 2017) and (Maansson & Madsen, 2017), loading the truck takes between 1 - 2 hours. Therefore, the loading time is simulated as a uniform distribution with a minimum of 1 hour and a maximum of 2 hours as shown in Figure F.10.

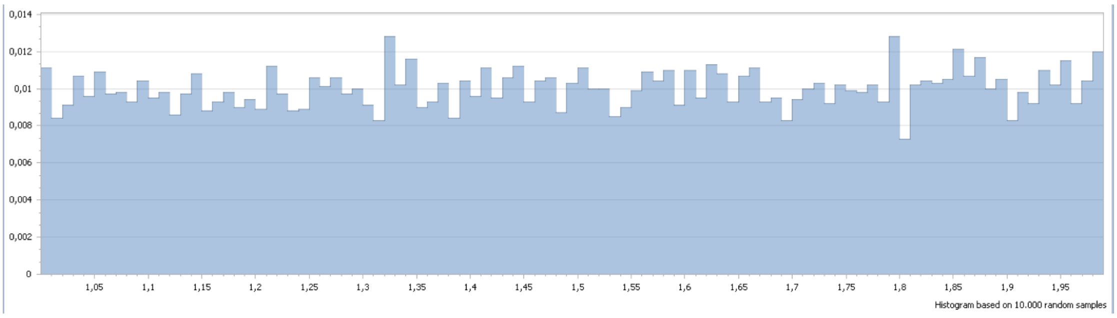


Figure F.10: [DTP] Truck Loading

[DTP] Truck Transit Time

The distribution for the truck transit time is shown on the left of Figure F.11. On the right side the corresponding boxplot can be found. In this Figure the data deviates from what is expected. After in-depth research it is determined that these bars represent the default values that are entered in the system. Therefore it is recommended to KLM Cargo that the data entries are improved to make solid analysis. For now, this data will be used for the model, as no other data is available. Based on interviews with KLM management employees it is validated that this data falls within the boundaries of what is expected for the truck transit time. In Table F.6 the upper extreme for the transit time is 826 minutes, equivalent to 13,77 hours. The lower extreme is 585 minutes, equivalent to 9,75 hours. These results are as expected as on google maps an average transportation time from Amsterdam to Billund is around 8 hours.

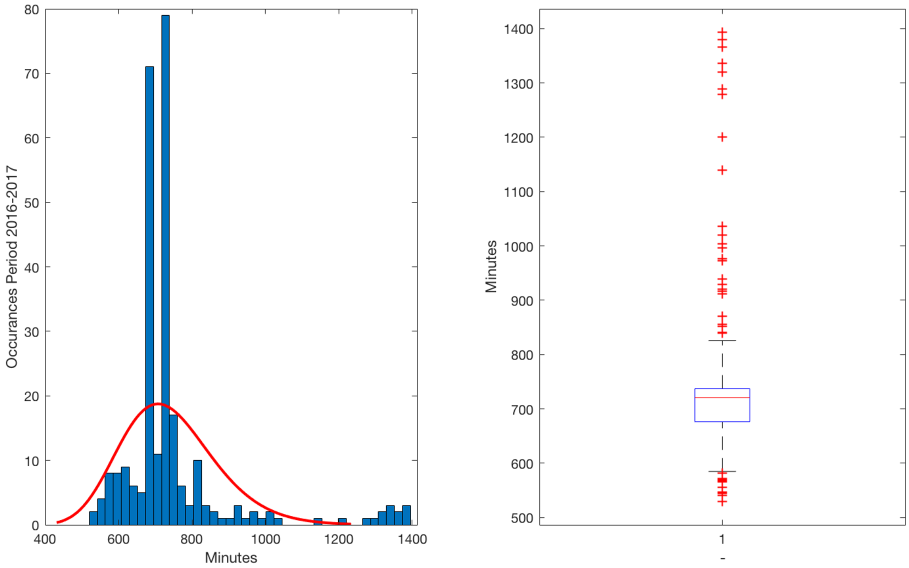


Figure F.11: [DTP] Truck Transit Times

Table F.6: [DTP] Truck Transit Time

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
Minutes	826	737	721	676	585	Lognormal(740.8 , 0.175)

[DTP] Document Creation

In this section the distribution for the creation of documentation to be used in the Simio model is determined. A case study is performed both for DSV and Schenker, as presented below. Below in Figure F.12 the number of AWBs per truck have been determined. The available data entries for DSV and Schenker were combines and a distribution for both is plotted. On the right side the corresponding boxplot can be found. In Table F.7 the upper extreme is 19 AWBs per truck and the lower extreme is just 1 AWB per truck. For the modelling this distribution can not be used as the number of AWBs also depends on the number of cargo. As displayed in Table F.5 the lower extreme for Schenker cargo pieces is 3 and for DSV cargo pieces 1. It would not match if the random number generator would generate 19 AWBs for 1 piece of cargo. Therefore the number of cargo pieces per AWB is determined for a case study of Schenker and DSV below.

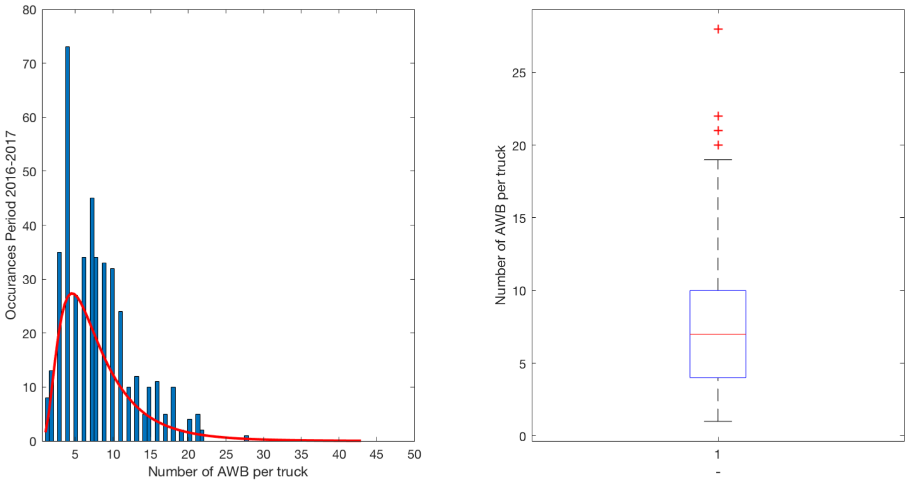


Figure F.12: [DTP] AWB per Truck

Case Study - DSV

The distribution for the number of cargo pieces per AWB for cargo originating from DSV can be found in Figure F.13. On the left side the distribution is shown and on the right side the corresponding box plot. From Table F.7 it can be concluded that the upper extreme is 18 AWBs and the lower extreme is 1. This is as expected, because if a truck has no AWB, the cargo does not have a booking, so is not allowed on KLM premises.

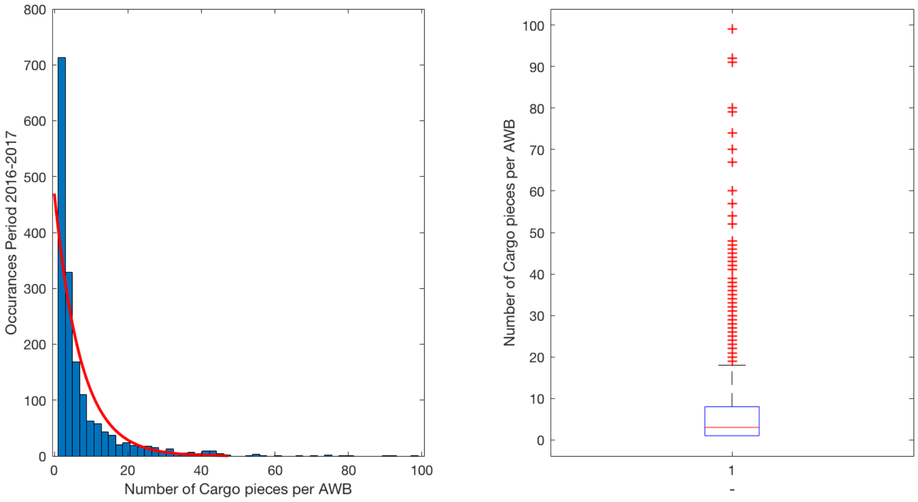


Figure F.13: [DTP] DSV Cargo per AWB

Case Study - Schenker

The distribution for the number of cargo pieces per AWB for cargo originating from Schenker can be found in Figure F.14. On the left side the distribution is shown and on the right side the corresponding box plot. From Table F.7 it can be concluded that the upper extreme is 59 cargo pieces per AWB. This number of much higher than the DSV average. From this comparison it can be concluded that this value depends on the type of company and the type of goods they are transporting.

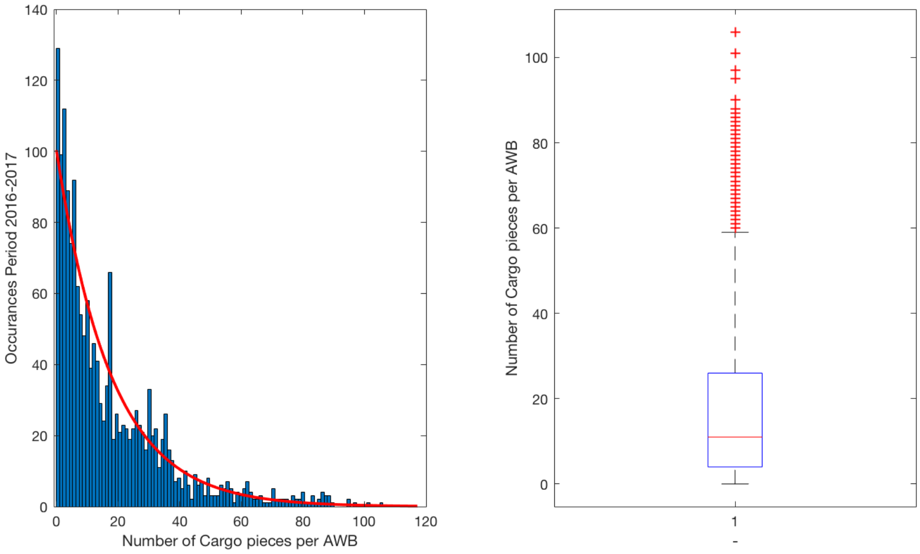


Figure F.14: [DTP] Schenker Cargo per AWB

Table F.7: [DTP] Document Creation

Transit Time	UE	UQ	Med.	LQ Quartile	LE	Distribution
AWB/Truck	19	10	7	4	1	Lognormal(8.111 , 0.619)
DSV Cargo/AWB	18	8	3	1	1	Exponential(7.151)
Sch. Cargo/AWB	59	26	11	4	1	Exponential(17.732)

[DTP] REST Procedure

In this section the distribution for the REST procedure used in the Simio model is determined. As limited data entries are available the trucks originating from Schenker and DSV are combined in the data set. On the left side of Figure F.15 the distribution is shown and on the right side the corresponding boxplot. According to Table F.8 the upper extreme is 45 minutes and the lower extreme 7,5 minutes. This is in accordance with the interviews that were performed to validate the data.

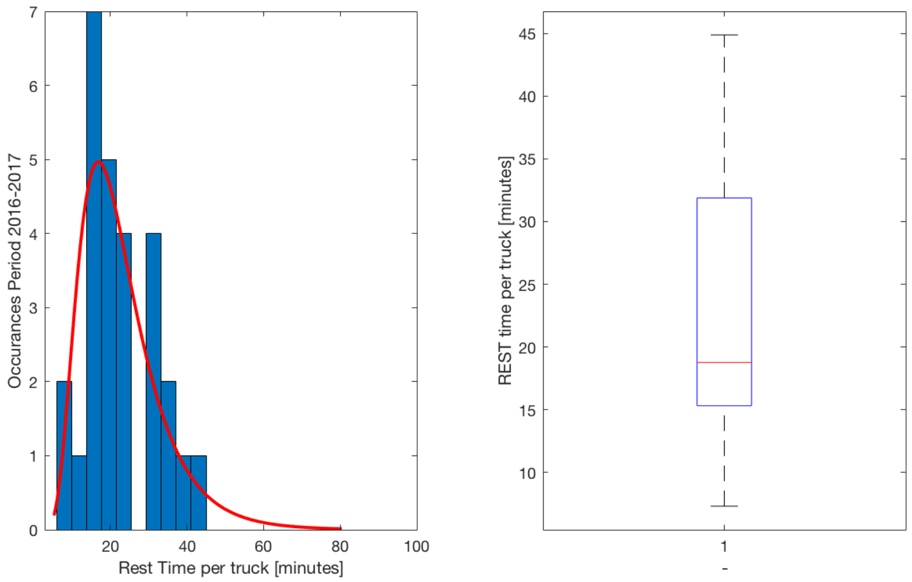


Figure F.15: [DTP] REST per Truck

Table F.8: [DTP] REST Time

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
Minutes	44.89	31.89	18.76	15.31	7.30	Lognormal(22.936 , 0.452)

[DTP] Unloading

The unloading time of DTPs is, from the point of view of the hub, not related to the country of origin. The employees receive a truck with loose loaded cargo which has to be unloaded followed by the ‘ready for carriage’ check. The duration of unloading cargo from different origins, was compared in order to investigate any irregularities. In Figure F.16 the unloading time, in minutes, for 6 different origins can be found. An immediate observation is, that the unloading time for cargo from Billund (BLL), first boxplot on the right, takes the most time. The corresponding values are displayed in Table F.9.

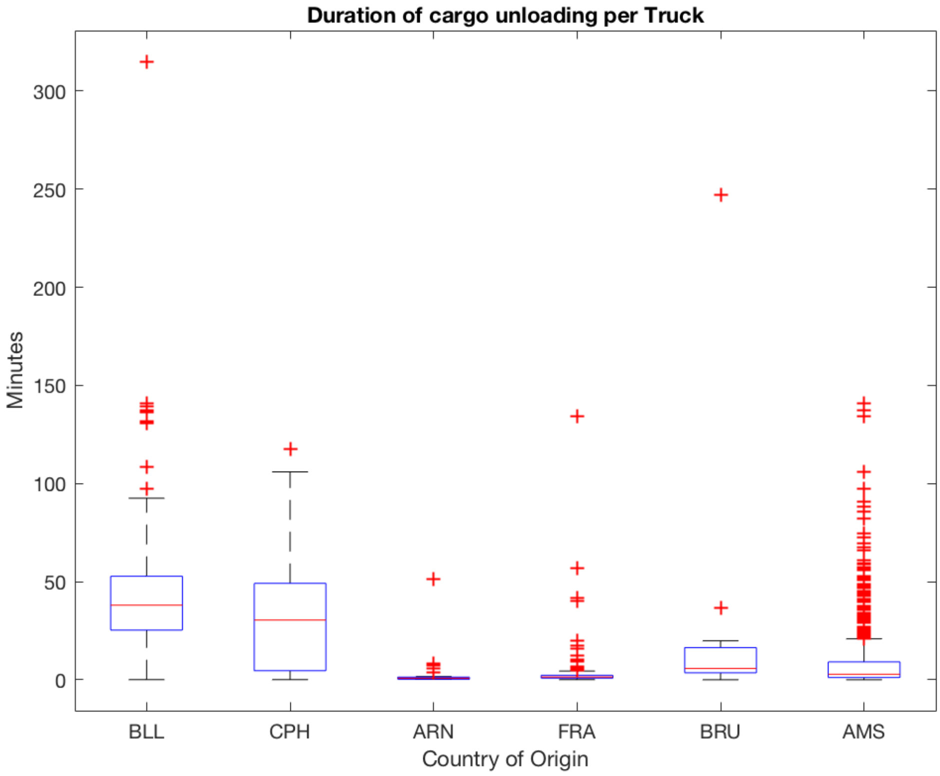


Figure F.16: [DTP] Unloading Time per Truck per Country

Table F.9: [DTP] Unloading Time per Truck per Country

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
BLL	92.55	52.82	38.02	25.23	0.08	Lognormal(52.88 , 1.017)
CPH	105.95	49.15	30.43	4.68	0.08	Lognormal(54.32 , 1.634)
ARN	1.70	1.37	0.80	0.32	0.22	Lognormal(2.36 , 1.337)
FRA	4.48	2.34	1.43	0.88	0.08	Lognormal(2.33 , 0.968)
BRU	19.92	16.43	5.78	3.57	0.05	Lognormal(35.30 , 2.042)
AMS	20.93	9.12	2.80	1.18	0.05	Lognormal(10.88 , 1.549)

[DTP] Cargo Processing

In this section the cargo processing time of cargo from DTP trucks is analysed. The cargo processing time of DTPs is, from the point of view of the hub, not related to the country of origin. The employees receive a truck with cargo which has to be processed. The duration of cargo processing of cargo from different origins, was compared in order to investigate any irregularities. In Figure F.17 the processing time, in minutes, for 6 different origins can be found. The corresponding values are displayed in Table F.10.

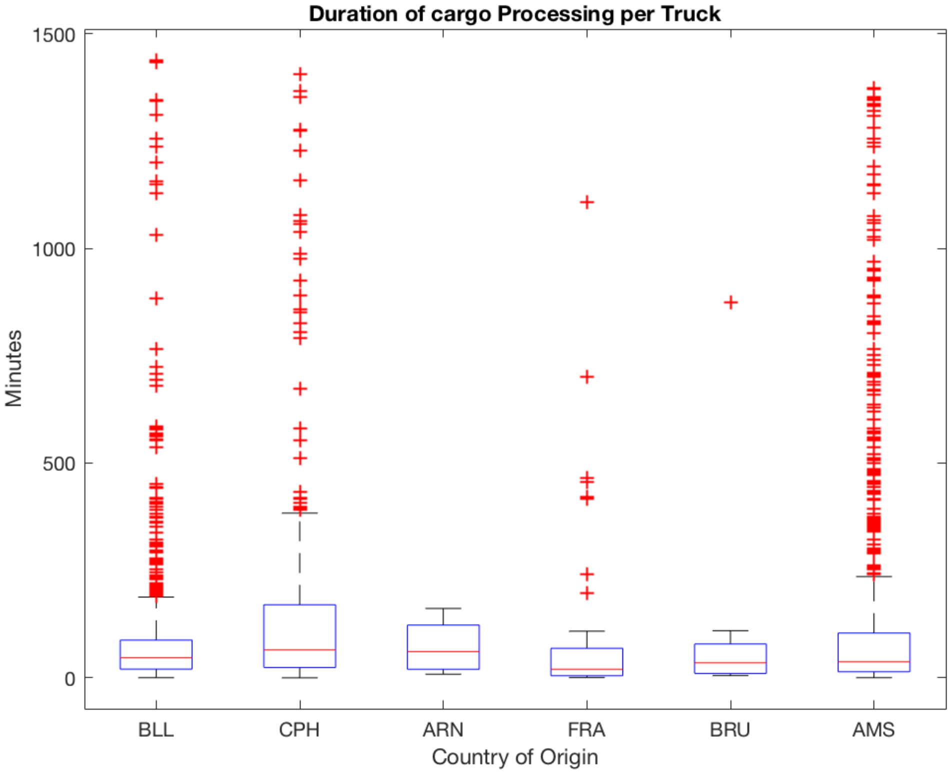


Figure F.17: [DTP] Cargo Process Time per Truck per Country

Table F.10: [DTP] Processing Time per Truck per Country

Transit Time	UE	UQ	Med.	LQ	LE	Distribution
BLL	187.92	87.70	46.67	20.15	0.30	Lognormal(96.596 , 1.275)
CPH	383.50	170.20	65.08	23.99	0.05	Lognormal(193.84 , 1.492)
ARN	161.40	122.65	61.37	20.00	8.35	Lognormal(89.000 , 1.154)
FRA	108.65	68.65	19.98	4.83	0.683	Lognormal(147.905 , 1.973)
BRU	109.67	78.94	34.96	10.06	5.15	Lognormal(66.006 , 1.211)
AMS	235.67	104.29	37.40	14.04	0.40	Lognormal(144.444 , 1.592)

G Research Paper

Exploring the possibility to design a seamless air cargo supply chain for Direct Trucking Pick-ups

F. M. Sickler *, W.W.A. Beelaerts van Blokland, R.R. Negenborn, J.H. Baggen,
J. Razei, S. Mravik, G.F.J. Camoenie

Delft University of Technology
KLM Cargo
ME2190 TEL Graduation Thesis
Student number: 4094085
March 20, 2018

Abstract

The air cargo market is experiencing momentous developments that may impact strongly on future trends. A consolidation shift has been observed, by more integration of the supply chain. Integrators engage in forwarding, forwarding agents operate their own aircraft and airlines bypass the forwarding agents, by striking direct structural deals with major customers. This last development in the field of the air cargo road feeder service (RFS) is also known as Direct Trucking Pick-up (DTP). In the current air cargo business models, all cargo is delivered via a freight forwarder to combination carriers (carrying both passengers and cargo). In the existing organizational cargo structures, there is no direct link from customer to combination carriers. The traditional model of air-cargo transportation, has been challenged in recent years. This stresses the need for research regarding the green field of the DTP model, researched in this thesis. It is important for the combination air cargo carriers to consider how to deal with future competition. Using several theories, such as lean manufacturing and transaction cost economics (TCE), the performance of the current state of an in-depth case study for KLM Cargo was analysed. Based on the measurements and analysis, several problems were identified and a framework had to be developed as a test platform to test several improvement scenarios. Using the discrete event simulation tool Simio, a model was created serving as a test platform. Simulation was used to explore various opportunities of process improvements and the impact of the proposed changes before implementation. The 5 proposed improvement scenarios were tested using the test platform. It can be concluded that all scenarios improve / enhance the DTP supply chain.

Keywords: Air Cargo, Direct Trucking Pick-up, Road Feeder Service, Line-haul Trucking, Transaction Cost Economics, Seamless Supply Chain, Discrete Event Simulation, KLM Cargo

I. INTRODUCTION

The air cargo industry has grown significantly over the past years. In 2014 the world air cargo industry increased with 4.8% and in 2015 with 1.9% (Boeing World Air Cargo Forecast Team, 2017). In 2016, the air cargo industry was responsible for transporting goods equivalent to 5.5 trillion U.S. dollars (International Air Transport Association, 2017). Of the total value of trade, 35% was transported by air, while this was less than 1% of the world trade volume. The air cargo industry is critical for serving markets that demand high speed, where the goods are often of high value, time

---

*E-mail f.m.sickler@student.tudelft.nl

sensitive, perishable and require reliability for the transportation of goods. It is predicted that over the next 20 years, the air cargo industry worldwide will grow with another 4.2%.

The air cargo market is experiencing momentous developments that may impact strongly on future trends (Merkert et al., 2017). An important growing phenomenon is the road feeder service (RFS) of freight towards large intercontinental hubs (examples in Europe; Schiphol, Paris CDG). In recent years, a consolidation shift has been observed in the air cargo industry by more integration of the supply chain. Integrators engage in forwarding, forwarding agents operate their own aircraft and airlines bypass the forwarding agents, by striking direct structural deals with major customers (Merkert et al., 2017). This last development in the field of the air cargo RFS is also known as Direct Trucking Pick-up (DTP).

A. Research Field

This research is conducted for the cargo department of the company Air France - KLM (from now on referred to as KLM Cargo). KLM Cargo is responsible for the transportation of 1.2 million tons of cargo over 2016, resulting in a combined revenue on 2.5 billion euros with Air-France. Cargo is transported to 457 destinations across 157 countries (including trucking) (Air France KLM Cargo, 2017). KLM Cargo is responsible for the handling and transportation of cargo by road and air from 83 stations in Europe to the hub at Amsterdam Schiphol Airport and vice versa.

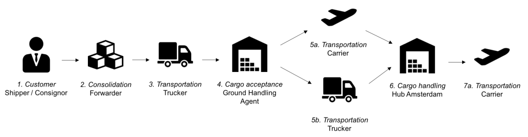


Figure 1: Traditional air cargo supply chain

KLM Cargo strives for becoming a competitive and qualitative carrier for air cargo. With the aim to transport the cargo as promised to the consignee. Export cargo can be delivered in several ways to the hub. Customers can deliver their cargo directly to the hub in Amsterdam, called export delivery. Cargo from the stations in Europe (outstations) can be transported either by flight, line-haul truck and / or DTP truck. In the latter case it is called export delivery, as acceptance is performed in Amsterdam. A line-haul truck allows for regular and scheduled transportation of cargo between two major cities or locations, also known in literature as a hub and spoke structure. The line-haul truck operates from the ground handling agent (GHA) who is contracted by the carrier to handle their cargo and update information on behalf of the carrier. This traditional line-haul model operates a truck that transports cargo from the ground handling agent (GHA) to the hub as illustrated in Figure 1. The GHA is contracted by the carrier to handle their cargo and update information on behalf of the carrier. Therefore the cargo arrives 'Ready for Carriage' (RFC) at the hub and only needs to be re-located to the designated destination buffer at the hub in Amsterdam.

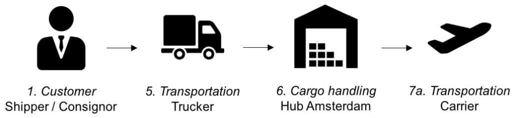


Figure 2: DTP air cargo supply chain

In literature DTP is defined as: "a carrier-operated truck (that is under carriers designation) that transports freight to or from a specific customer / forwarder at a location without the freight being handled at the carrier's (of their designated service provider's) origin and / or destination airport location" (International Air Transport Association, 2008). The DTP truck allows for direct cargo collection from the customer as illustrated in Figure 2. There exist two types of DTP; ad-hoc and structural DTPs. The main difference between the line-haul truck and DTP truck is that the line-haul truck often transports cargo from different customers consolidated at an outstation by a GHA, while the DTP truck collects the cargo directly from the customer, thus only transporting the cargo of this one customer. As DTPs arrive un-checked at the hub, all RFC checks still need to be performed upon arrival at the hub.

B. Research Problem

In the current air cargo business models, all cargo is delivered via a freight forwarder to combination carriers (carrying both passengers and cargo). Forwarders control around >85% of the retail channels for general cargo (Reis & Silva, 2016), (Azadian et al., 2017) and (Hellberg & Sannes, 1991). In the existing organizational cargo structures there is no direct link from customer to combination carriers (Huang & Hsu, 2016) and (Onghena et al., 2014). The traditional model of air-cargo transportation, has been challenged in recent years. The boundaries between the different segments of the cargo industry are blurring (Onghena et al., 2014). This shows the need for research regarding the green field of the DTP model, researched in this thesis. It is important for the combination air cargo carriers to consider how to deal with future competition. Integrators, performing direct deliveries, currently account for 5 - 10% of the air cargo freight volume (Azadian et al., 2012). In an era where time is money, customers want their cargo to be transported as fast as possible. Every day extra transit represents an ad-volorem tariff of 0.6 - 2.3% (Hummels & Schaur, 2012). KLM Cargo strives to become a competitive (speed at affordable cost), reliable and quality carrier for air cargo. With DTP, KLM Cargo wants to compete with the integrators gaining market share and monetary advantages.

C. Scientific Problem Statement

The scientific gap comprises that limited scientific research has been performed regarding air cargo in general, as identified by several scholars. Carriers used to focus primarily on passenger transport, as this was the most profitable industry. However, over the past years, air freight has developed from a by-product to a crucial element in the competitive struggle for market share (Merkert et al., 2017). From (Feng et al., 2015)'s research it can be concluded that little to no scientific research has been performed regarding DTP. Often the existence of RFS offered by the carriers are acknowledged, but omitted from (further) research such as the connectivity model by (Boonekamp & Burghouwt, 2017). (Walcott & Fan, 2017) state that research regarding cargo transport systems remains under-examined in both theory and case study. According to (Heinitz et al., 2013) there is a lack of publicly available data, differentiating between freighter and truck operations. Therefore it can be concluded that the research regarding DTPs is a green field and further academic research is needed (Merkert et al., 2017).

D. Practical Problem Statement

Currently, the DTP supply chain is characterized by overtime, firefighting and blindness. Information is often unavailable, resulting in problems such as unexpected arrival times at the hub, CIQ milestones (as defined in Definitions) are not triggered, accounting does not have a manifest etc. etc. This results in cargo arriving too late at the hub in Amsterdam accompanied with limited available information about the cargo, resulting in rework and correction time. Furthermore, the involved parties in the supply chain feel a lot of pressure and are unable to oversee the supply chain. The pressure is mainly caused by the criticality of shipments making their connecting flights in Amsterdam. Currently, it is unclear how to improve, manage and control the DTP supply chain to prevent the issues of overtime, firefighting and blindness. Finally it is unclear what key performance indicators (KPIs) influence the performance in this supply chain, how the KPIs can be improved and what the theoretical optimal performance could be by designing a seamless supply chain. The practical problem statement is formulated as follows:

"There is a gap between the desired performance and the current performance and it is not clear what KPIs influence this gap. Furthermore, it is not known how the KPIs can be improved and what the theoretical performance could be in terms of arrival performance at the hub in Amsterdam."

E. Research Scope

This research will focus on export cargo. Export cargo is cargo that arrives at the hub at Amsterdam Schiphol Airport from other locations in Europe (including the Netherlands) that has a destination other than the Netherlands. The traditional line-haul business model will be compared with the innovative DTP model.

The case that was studied was determined based on the largest DTP volume in Europe during the year 2016 - 2017. This was for the single trade lane Billund (Denmark) - Amsterdam (The Netherlands). The intention was to focus on the DTPs and how this could have additional value for KLM Cargo, opposed to the traditional route via a GHA. The seamless supply chain for this research is defined from customer until it arrives at the hub in Amsterdam. The time frame for the measurements in the current state was 1 year from September 2016 until September 2017. This research period was chosen as enough data points were available during the period of 1 year, additional seasonal influences will be averaged when simulating the data.

The analysis can be performed on several levels. It is important to consider the larger processes on a higher level as well as the in depth processes. In depth processes can be processes that are necessary to execute single transactions. When the execution of processes of one level influence the execution of processes on another level this could result in problematic inter-dependencies (**?**). The various levels of analysis are displayed in Figure 3. Below, each level is explained in more detail.

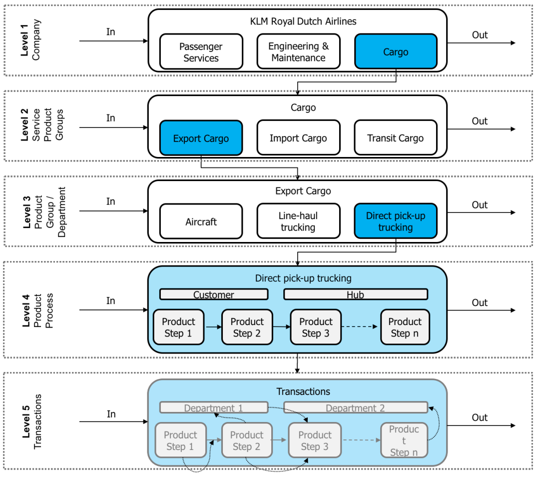


Figure 3: Levels of Analysis

1. Level 1: Company: The company has three major divisions; passenger services, engineering & maintenance and cargo.
2. Level 2: Cargo: The division under study is Cargo. Cargo consists of; export cargo, import cargo and transit cargo. The focus is on export DTP cargo.
3. Level 3: Export Cargo: One specific product and its associated processes will be analysed. The export cargo has been chosen as this type of cargo imposes the most problems for KLM Cargo's operations. Export cargo has to be screened and checked in Amsterdam and creates the most work.
4. Level 4: DTP: The different process steps in DTP are investigated. DTP was compared to the traditional model. The methods used to analyse this level are; case studies, interviews, swimlane mapping, value stream mapping and discrete event simulations.
5. Level 5: Transactions: The transactions between specific product related processes are investigated. The changes and improvements for the DTP model would need to be implemented on this level. Scenarios were run using simulations, to discover the effects of proposed changes and improvements.

F. Research Objective

This research focused on the development of a theory-oriented framework to design and improve the DTP supply chain. The case study at KLM Cargo was used to test the framework. The research objective is stated as followed: *"Determine the criteria to propose a framework for a seamless air cargo supply chain, from a transaction cost perspective, focusing on the DTP supply chain and apply this framework at KLM Cargo to improve the DTP performance"*.

G. Research Question

The research question answered in this research is:
"What are the criteria to design a seamless supply chain for the Direct Trucking Pick-up cargo flow for KLM Cargo? "

H. Research Structure

The DMAIC cycle is an approach adapted from the Six Sigma methodology (Reid & Sanders, 2011) and is the inspiration for the DMADE cycle, which was used for answering the main research question. This approach is used as it is applicable to an operations case-study as defined by (Dul & Hak, 2008) with their intervention cycle for solving a practical problem. The five-step plan stands for Define, Measure, Analyse, Improve and Control. DMAIC is a widely used tool to structure, research, improve and optimize processes. The DMAIC approach has the ability to find methods for continuous improvement in a systematic way. This tool is taken from Lean Six Sigma methodology. In scope of this research, the traditional 'Improve' phase has been replaced with a 'Design' phase. During this phase, design options are introduced that can improve the process, but are not implemented. In addition the 'Control' phase has been replaced by 'Evaluate'. During this phase, the design options are evaluated. This changes the DMAIC cycle to DMADE.

Section II will present a literature study on the topics; the air cargo industry, air cargo business models, supply chains, hub-and-spoke structures and electronic data interchange (EDI). Consecutively, section III introduces the different theories and methodologies during this research. The current state of the traditional air cargo model is described in section IV and the current state of the DTP air cargo model in section V. Next, discrete event simulation is introduced in section VI and improvement design options are suggested in section VII. Finally this research will be concluded and several recommendations suggested in section VIII.

II. Literature Background

A literature review was conducted, entailing that books, articles, conference papers and other publications were reviewed. In addition, also secondary data was used. Using the data, gained from the above mentioned reviews can save time and effort as a literature review is a quick way to obtain a large amount of data. First literature regarding the air cargo industry is presented, followed by literature the air cargo business model. Next a study is performed on supply chains, focusing on integrated and seamless supply chains. Finally the hub-and-spoke structure including RFS and EDI are discussed.

A. Air Cargo Industry

Historically, most combination carriers (transporting both passengers and cargo) main business was passenger transportation, consigning the air cargo business to a secondary role (Rhoades, 2016). Over the years the market developed and the air cargo service providers began occupying the space left in the belly of the combination carriers. To be competitive, combination carriers need to invest in the cargo division. However, due to the secondary importance of the cargo division to combination carriers, such investments may not be affordable. Wide-bodied passenger aircraft, have considerable spare hold space which, if used to carry freight can provide an additional source of revenue at marginal cost (Reis & Silva, 2016). Due to the small margins, combination carriers face the big challenge of managing their cargo operations efficiently. Strategic operation plans need to be developed to be able to adapt and respond in a timely manner to changes in the competitive environment (Nobert & Roy, 1998).

The transportation of large amounts of freight, both in volume and weight, over great distances is a complex business that involves many companies in the supply chain. This requires ongoing coordination between the various parties both for the physical movement of goods and for the management and exchange of information regarding the goods. To transport freight cross-border (internationally) adds an additional layer of complexity as additional regulations have to be taken into account, ranging from licensing requirements to customs and security regulations (Schwarz, 2006). Traditionally the core function of a freight forwarder is to function as the intermediaries between the customer and the carrier.

As mentioned above, the air cargo industry operates in one of the more heavily regulated sectors of the global economy, for flight safety reasons. These regulatory restrictions prevent quick adaptations in the form and scope of the business models in the air cargo industry, as well as restructuring the industry itself. Many players in the industry view the restrictions as a major barrier to further global consolidation of the air-cargo industry and require carriers and integrated express carriers to outsource many functions to local firms (Schwarz, 2006). The traditional model of air-cargo transportation, has been challenged in recent years. The most visible change is that the freight forwarders, which traditionally have been in a highly fragmented industry, have started to evolve from a pure non-asset model to operating their own trucking fleet and warehouses, to handle goods on the way to and from the airports (Bowen & Leinbach, 2004).

B. Air Cargo Business Models

For air freight, the carriers can be classified in 3 categories, the combination carriers, conventional all-cargo carriers and the integrated carriers. The organizational structure designed by (Huang & Hsu, 2016) is similar to the structure designed by (Onghena et al., 2014). These two structures are adapted and combined and can be found in Figure 4. In the current models of air freight networks it can be seen that for combination carriers, all cargo must flow through the supply chain using the freight forwarder (indicated in orange) as a middle man.

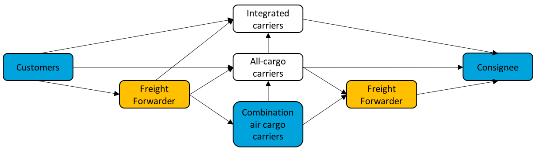


Figure 4: Organizational Structure of Air Freight - adapted from (Huang & Hsu, 2016) and (Onghena et al., 2014)

The integrated carriers can provide door-to-door service independently. The integrated carriers have established an integral supply chain system by which they can provide a complete and prompt service for customers (Huang & Hsu, 2016). The non-integrated service providers, such as the conventional all-cargo carriers and combination carriers have to cooperate in order to deliver air cargo services from customer to consignee. The main reason why 90% is transported via freight forwarders while integrators have the experience and know-how to deliver door-to-door, is the fact that this is only cost effective for shipments less than 70 - 150 lbs (Azadian et al., 2012). Currently, integrators only account for a small fraction of the total airfreight volume (5 - 10%) (Azadian et al., 2012). They are able to deliver door-to-door and therefore are inspirational for the DTP design.

C. Supply Chains

The non-integrated service providers, such as the conventional all-cargo carriers and combination carriers have to cooperate with freight forwarders in order to deliver air cargo services from customer to consignee. As KLM Cargo (a combination carrier), relies on collaboration through the supply chain, this chain must be investigated. (Laseter & Oliver, 2003) aims to develop a vision which can penetrate the functional silos within the various departments of the company.

Supply chain and supply chain management have been defined by many scholars (Monde la & Masters, 1994), (Stevens, 1989), (Houlihan, 1988), (Cooper et al., 1997) and (Arnold, 2000). The definition of a supply chain used in this research will be: *"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer"* (Mentzer et al., 2001).

The air cargo is heavily influenced by its international regulatory environment. (Schwarz, 2006) described it as a complex business that involves complex transportation systems. These systems require coordination, information exchange and information processing on a high level. To make the system work, the virtual networks of information exchange between air-cargo firms are as important as the physical networks of airports, warehouses, trucks and airplanes. Therefore air cargo supply chain can be characterized by being highly asset specific (Jong de & Beelaerts van Blokland, 2016). The actions performed in the supply chain are a combination of physical (technical) and information (administrative, such as certification, registration, regulation, compliance) actions. Due to the fact that the air cargo industry has to comply with all IATA set regulations (International Air Transport Association, 2016), the processes, assets and components are asset specific for reasons of safety. (Williamson, 1981) identifies three kinds of asset specificity.

For creating a seamless supply chain, supply chain management is needed. (Lambert & Cooper, 2000) identify that supply chain management is a new way of managing the business and its relationships. The main business processes in the supply chain must penetrate the functional silos within the individual companies and the various corporate silos in the supply chain. This results in business processes evolving to supply chain processes that are linked across intra- and inter-company boundaries. According to (Thomson, 2016) silos happen when departments either can't or won't easily share information with other departments. Impaired communication between suppliers and the business leads to poor supply chain visibility, slow or stalled innovation, weak collaboration and increased risk of unexpected events such as missing delivery deadlines. This phenomenon is also known as the 'silo-mentality'.

The supply chain orientation mentality can be enhanced by cooperation, focus, information sharing, integration of key processes, inter functional coordination, long-term relationships, shared risks / rewards and similar customer service goals. If all this is in place, this can lead to lower costs, improved customer value, customer satisfaction and a competitive advantage. In this research this is defined as a "seamless supply chain". Where the flow of goods and information flows seamless between the different parties and / or individuals in the cargo value chain.

D. Hub-and-Spoke Structure

Large carriers often operate their cargo network via hub-and-spoke network structures, meaning that cargo is consolidated in a location other than the hub (called outstation) and transported via a direct link to the hub. An outstation is defined as a point of pick-up and delivery while a hub is a point of consolidation.

In recent years, air freight is also transported by road. This is called "forwarder trucking", "line-haul" or "direct-delivery". Often the road-transportation is a substitution for freighter or combined flights, also called "airline trucking", "road feeder service" or "trucked flights" (Heinitz et al., 2013). The trucks are operating under a published flight number. Trucking air freight is often performed for secondary airports or fragmented markets, where the weekly amount of consignments may not reach the quantity threshold justifying the costs of (extra) aircraft operations. These markets are therefore dependent on stable, cost-effective, frequent trucking connections to an air cargo hub (Heinitz et al., 2013). Often carriers perform both flights and trucks, with trucks being able to transport the (over-)capacities, and customers wanting to pay a lower kilogram rate for their freight. According to the Boeing World Air Cargo Forecast Team, the truck flight frequencies in Europe have grown steadily at a 2.2% increase each year over the past 10 years and is expected to keep this pace for the next 15 years (Boeing World Air Cargo Forecast Team, 2017).

Another difference is that RFS operates as carrier-exclusive, as an integral part of the carriers' timetable and will thus become part of the route-search on time space graphs (Heinitz et al., 2013). According to (Selinka et al., 2016) the movements by service can be divided as shown in Table 1. One of the scientific gaps identified by (Heinitz et al., 2013) is that there is a "lack of publicly available data, differentiating between freighter and truck operations", to be able to perform an in depth study on RFS.

Table 1: Air Freight Breakdown by Movements by Service (Selinka et al., 2016)

Service	% of truck movements
RFS Scheduled	58.5
RFS Ad-hoc	21.4
Export by forwarder	7.5
Import by forwarder	12.6

(Azadian et al., 2017) mentions that when the load to be collected at the customer is less-than-truck-load (LTL), which is a common case for air cargo, consolidating loads of multiple customers in a single truck trip provides an opportunity to reduce logistics costs. When a LTL truck load is needed, carriers often use the traditional supply chain via the GHA, who consolidates all cargo on behalf of the carrier. However, if a full-truck-load (FTL) can be shipped directly from the customer, it is more cost effective to directly ship the cargo to the hub, to eliminate the 'external' handling cost to be paid to the GHA and reduce the number of transactions performed.

E. Electronic Data Interchange

EDI is developing at a fast pace in the air cargo industry. The introduction of internet and implementation of modern information systems have a great effect on the way the air cargo industry operates (Lobo & Zairi, 1999). Traditional faxes and paper documentation is replaced by business-to-business e-commerce and EDI systems (Schwarz, 2006). For integrators such as UPS or FedEx, the internet has enabled a seamless integration of information flows into the transportation process. EDI allows for customers to receive real-time booking, pricing and tracking information. Real-time allows for information updates when irregularities and / or delays occur. In an era where time is money, customers increasingly demand visibility from their logistic provider. Many companies are working with just-in-time systems and lean operations, which requires them to react quickly to unforeseen events. Some important characteristics of EDI are:

- An electronic transmission medium (e.g. e-AWBs) is used rather than physical media (e.g. paper AWBs).
- Standards, structures and formats for messages can be determined such that all messages can be translated, interpreted and checked for compliance by different systems of various companies.
- The time between sending and receiving decreases significantly for electronic documents.
- Information does not have to be manually re-entered in the system, reducing the error-rates and manual labour (first-time-right).
- The information can be directly processed by the application software.

III. Theory Analysis

In this section, the theories used in the research are explained. First the process improvement theories are presented, second, the research methodologies.

A. Process Improvement Theories

This section aims to explore different methods to create solution alternatives that can lead to improvements in the air cargo supply chain and identify the main elements used in these methodologies. First a definition of a process is stated as: *"Processes are relationships between inputs and outputs, where inputs are transformed into outputs using a series of activities,* *which add value to the inputs"* (Aguilar-Saven, 2004). The most popular process improvement methodologies include; Business Process Re-engineering, Continuous Process Improvement, Total Quality Management and Organizational Transformation. These process improvement methodologies are often used in the manufacturing industry, service industry and medical industry (Cima et al., 2011). (Mason et al., 2014) also mentioned for for aviation in the engineering & maintenance department. For the air cargo industry, especially with regard to the information flow, the implementation and the effect of process improvement theories studied, are limited.

1. Lean Manufacturing

Lean manufacturing emerged from the Ford production plants. Henry Ford started with focusing on activities that are of value for the customer and therefore eliminating all non-value adding actions to the customer. Lean became famous by Toyota in Japan and the Toyota Production Systems. (Bendell, 2005) provides a clear definition of what it means to use lean: *"Lean (...) is the systematic pursuit of perfect value through the elimination of waste in all aspects of the organization's business process. It requires a very clear focus on the value element of all products and services and a thorough understanding of the Value Stream"*. Overall, lean is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and should therefore be eliminated. Value is defined as any action or process that a customer would be willing to pay for.

2. Transaction Cost Economics

TCE originates from John R. Commons in 1934 who proposed that the transaction is a basic unit of economic analysis (Williamson, 1981). Commons identified that the exchange of goods and services between technologically separable entities can be influenced by it's governance. Following Ronald Coase in 1937 recognized that the boundary of the firm is a decision variable for which an economic assessment is needed. Williamson defines a transaction as: *"A transaction occurs when a good or service is transferred across a technologically separable interface"*.

In accordance with the stated definition of a transaction, in this thesis the practical definition of a transaction used is when one stage of activity terminates and another activity begins. An economic transaction can best be explained by the comparison with mechanical systems. Efficient mechanical systems are systems where friction and loss of energy are minimized. The economic counterpart is to ensure that parties involved in the exchange operate harmoniously (Williamson, 1986). It is important to minimize misunderstandings and / or conflicts in transactions that can lead to delays, breakdowns and other malfunctions in the system. (Williamson, 1988) identifies three critical dimensions for transactions; uncertainty, frequency with which the transactions recur and the degree to which durable transaction specific investments (asset specificity) are required to the least cost supply. The TCE theory focuses on these dimensions by studying the comparative costs of supply chain management (planning, adapting, monitoring tasks) under alternative governance structures.

The issue with asset specificity is that large fixed investments are needed, but also that these investments are specialized to a particular transaction (called transaction idiosyncrasy). According to (Williamson, 1981) there are three types of asset specificities namely; site specificity, physical asset specificity and human asset specificity. Asset specificity in the air cargo supply chain is present in the site specificity, buildings and special tooling. These are all directly related to the quality and safety standards of the product set by the air cargo industry. A transaction can have low or high asset specificity. If a transaction has low specificity, it is often for a simple transaction, little information has to be exchanged (Arnold, 2000). In case of high asset specificity, much and complex information and / or products have to be exchanged, before, during and after the exchange of goods (Arnold, 2000). This results in high market transaction costs. Goods and services with high specificity cannot be used on other transactions without huge additional costs. For the air cargo industry the processes and services are highly regulated by the airline and air cargo authorities for safety reasons and can therefore be classified as having high specificity.

B. Research Methodologies

In this section the research methodologies are explained. For the case study a swimlane, value stream map and discrete event simulation is used.

1. Case Study

For the exploratory case study, the research methodology of (Verschuren & Doorewaard, 2010) is used in combination with the research methodology of (Dul & Hak, 2008). The case study is performed using several methods, such as questioning (interviews), field research (observations of transport / handling processes as well as the study of documents handling). Using a case study, gives great insight into the problem at hand, taking all aspects into consideration.

2. Swimlane Diagram

A swimlane is a flowchart, which shows a process from start to finish. At the same time the swimlane divides the steps into functional areas to distinguish which departments or employees are responsible for each set of actions. Each lane represents a different area of responsibilities or department. Each step or process in the swimlane is indicated by a block, which is listed in chronological order in its appropriate lane. In order to speed up the process of correcting inefficiencies and eliminate delays, it is important to gain knowledge about processes and responsibilities of each party in the chain. A swimlane can help to gain this knowledge and insight.

3. Value Stream Mapping

Within value stream mapping (VSM), "value" is defined as a capability provided to a customer of the highest quality, at the right time and at an appropriate price (thus what the customer buys) (Atieh et al., 2016). VSM is a planning tool to optimize results and eliminate waste. VSM is used for a quick analysis of product flows through a manufacturing system from raw material to delivery. VSM is a tool for visualization, analysis and redesign of the supply chain. The end product is a single-page map that graphically illustrates all processes in the current state of the system under study (Hines & Rich, 1997).

VSM is a tool for analysing the value flows. It's strengths are: fast, easy to perform, cheap, no special tools or computer programs required, simple, easy to learn, easy to understand, solid basis for discussions and decisions, increases understanding of the customer and can often be performed directly with the people involved in the system (Solding & Gullander, 2009). However, VSM also has some weaknesses, starting with it's manual nature. A VSM creates a static model out of observations and evaluations of the processes within a system. It only gives a snapshot of the situation at one specific moment in time. Therefore a VSM can not be used to study a dynamic problem. VSM is a simplification of the real situation and can only be generated for one flow at a time. Finally, due to it's static nature, it is difficult to experiment with new systems and layouts when designing improvements.

Therefore, many researchers aim to enhance a VSM with a complementary tool, to handle uncertainty and the model dynamics. Many researchers used simulation to enhance VSM. Using this combination, more than one product can be analysed at a time and a real-time view of the system can be generated. Simulation can be used to make VSM dynamic and provide a way to explore various opportunities of process improvements and the impact of the proposed changes before implementation. A dynamic VSM can assess the differences between the current state and future state but can also identify all areas that need improvement.

4. Discrete Event Simulation

The objective of this research was to: *"Determine the criteria to propose a framework for a seamless air cargo supply chain, from a transaction cost perspective, focusing on the DTP supply chain and apply this framework at KLM Cargo to improve the DTP performance"*. The proposed framework had to be tested using a test platform. This was done using Simio as a modelling tool.

A simulation modelling approach is selected to make it possible to experiment (easily) with the air cargo system. If the experiments are to be implemented in the real operation, the disturbances for the processes of the hub will cause large impositions. In addition it will be very expensive and time consuming to experiment in real life example as all the personnel and operations need to be informed when to perform which activity. Also, it may not always be possible to describe the system mathematically. A system is a set of related components that work toward some purpose (Kelton et al., 2011). To gain understanding of the system a model of the system is used.

IV. Current State

In this section the case study selection is explained, the current state of the traditional model and DTP model elaborated and the key performance indicators (KPIs) are identified.

A. Case Study Selection

Currently, KLM Cargo transports most cargo from Europe towards the hub in Amsterdam, using the traditional supply chain business model. DTP is only performed when convenient for the customer. First, all locations from which both traditional flows and DTP flows are employed were mapped. KLM has 84 locations from where DTP was performed in 2016, either structurally or ad-hoc as shown in Figure 5.

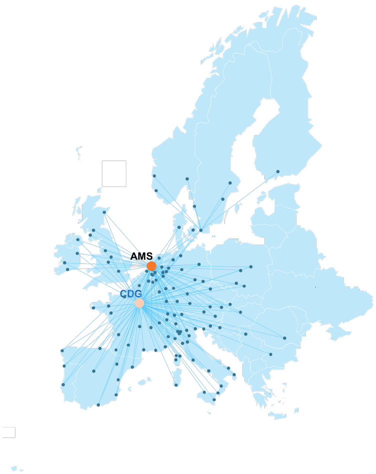


Figure 5: KLM Cargo DTP Trade Lanes

For the case study selection, several criteria were taken into account:

1. Station must have both traditional and DTP flow.
2. DTP must be a structural DTP flow.
3. A significant amount of cargo must be transported to have sufficient data points.
4. For KLM Cargo the origin is stated as the nearest network point, however, the pick-up address must be situated within 25 km range from the network point. Therefore the origin must be from 1 or 2 large customers and not from numerous smaller customers.
5. Collaboration of customer to participate in this research.

Based on these criteria, the station Billund (BLL) was selected. The traditional cargo flow from Billund goes through the GHA: Cargo Center Billund. For the DTP flow, Billund has the most transported weight in tons over the measurement period, originating from two major customers located near Billund. The two major customers in Billund are 'DSV Air and Sea' (from this moment onward referred to as DSV) and 'Schenker Air and Sea' (from this moment onward referred to as Schenker).

B. Traditional Model

The air cargo value chain in the traditional perspective can be divided into 6 high level steps as shown in Figure 1. First, the customer wants to transport a piece of cargo. Secondly, the freight forwarder consolidates the various pieces of cargo from different customers and makes a booking with a carrier. Thirdly, the freight forwarder transports the consolidated cargo to the GHA. Forthly, the GHA accepts on behalf of the carrier the cargo. Fifthly the carrier sends a truck to collect the cargo at the GHA. Sixthly, the carrier transports the cargo towards the hub and loads it on the connecting flight.

For this research, the research parties are: DSV, Schenker and CCB in Denmark, Jan de Rijk logistics and the KLM Cargo hub at Amsterdam Schiphol Airport. The entire "as-is", current state flow processes have been identified and were presented, using a swimlane. Based on this swimlane, measurements were performed by field-research, data gathering from systems and interviews. Observations based on the swimlane include; there are many double, rework, manual transactions in the system, both from a physical and information perspective, making the product susceptible to damage and human errors. Next, the swimlane was simplified to a VSM incorporating the duration of each transaction. Following measurements were performed on the traditional system. From the measurements performed, the following physical challenges can be observed:

- The waiting time increases significantly as the product goes through various parties, each performing their own checks and processes.
- The current process is strongly human-driven and human-dependent.
- Many deviations occur from the standardized process.
- Truck arrivals not leveled over the week. As a consequence there is a high work load on weekends especially in the evenings.
- Truck slots in Amsterdam not according to schedule, random serving of trucks.

For the measurements performed in the traditional model, the following information related challenges can be observed:

- No structural internal feedback on the work performed, resulting in repair actions needed.

Involves a lot of paperwork, EDI is slowly adopted.
- No structural feedback provided to GHA.
- Duplication effort as the (same) inputs have to be done in different systems.
- No differentiation is currently made between handling a paper AWB or an e-AWB.

Summarizing, the bottlenecks for the current traditional export cargo flow are many double or non-value adding actions, many human actions, lack of information in the chain and long waiting times.

C. DTP Model

The main difference between a traditional line-haul truck and a DTP is that with the traditional flow, an extra party is omitted from the value chain, namely the GHA. The GHA performs actions on behalf of the hub, decreasing the workload at the airline. However, a GHA needs to be paid for their services, increasing the cost of the operation. By omitting the GHA, the documentation department at the hub has to accept the documents accompanying the cargo and the warehouse has to do the physical acceptance and the check of the cargo. The cargo has to be accepted in the KLM system as RFC with all compliance checks included before being handled / transportation on an aircraft. The business structure for the DTP model is illustrated in Figure 2.

A swimlane was also designed for the current DTP flow. Based on this swimlane, measurements were performed by doing field-research, gathering data from systems and interviews. Observations based on the swimlane diagram include: compared to the traditional flow, the number of transactions reduced. However, because the GHA is omitted from the system, milestones in the supply chain are no longer triggered and information is not communicated. Therefore, re-work and manual transactions from both a physical and information aspect, increase. Next, the swimlane was also simplified to a VSM, incorporating the duration of each transaction. Following, measurements were performed on the DTP system. From the measurements performed, the following physical challenges can be observed: observed that:

- The throughput time is decreased significantly as parties are omitted from the supply chain.
- The current process is strongly human-driven and human-dependent.
- Many deviations occur from the standardized process.
- Trucks are loose loaded.
- Parcels are scattered through trucks.
- Weighing / volume checks are incorrectly performed.
- Unloading time increases.
- Acceptance time increases.
- Trucks are not leveled over the week.
- No clear awareness of what the DTP standards should be.
- High risk of cargo (data) discrepancies

For the measurements performed in the DTP model, the following information related challenges can be observed:

- No FFM is sent.
- Milestones in the supply chain are not triggered.
- Customs documents are incorrectly delivered.
- No internal feedback on the work performed, resulting in repair actions needed.
- Involves a lot of paperwork and paper handling, EDI is slowly adopted.
- Duplication effort as the (same) inputs have to be done in different systems.
- No feedback provided to customers.
- No differentiation is currently made between handling a paper AWB or an e-AWB.
- Information is not digitally available.
- Information is not accessible for all parties.
- Too much data entry and opportunities for mistakes.
- Many ways to communicate the same information (paper, courier, e-mail).
- Limited EDI capabilities & options available.
- No clear awareness of what EDI standards should be.
- High risk of data discrepancies.
- Many different systems.

Summarizing, the bottlenecks for the DTP cargo flow are visibility in the supply chain, limited access to EDI, inducing high risks of data discrepancies and no collaboration in the supply chain.

D. Key Performance Indicators

The key performance indicators for this research are: throughput time (from a supply chain perspective), costs (from a company perspective) and transactions (from a TCE perspective). The KPIs for throughput time comprises of an information aspect (documentation processing) and a physical aspect (physical acceptance time and unloading time). The costs can be divided in transportation costs and handling costs. The transactions KPI is also divided in an information perspective and a physical perspective. The framework was developed in the form of a discrete event model, in which the proposed design options can be tested.

V. Discrete Event Modelling

A discrete event simulation model is developed for both the traditional supply chain and the DTP supply chain, using the methodology of (Kelton et al., 2011), (Law & McComas, 1990) and (Law, 2011). The model characteristics of both models can be found in Table 2 on page 14.

Table 2: Model Characteristics

Model Characteristics	
Length of Simulation	Terminating System 48 hours
Warm-up Period	Terminating System 0 minutes
Output Type	Transient Outputs
Number of Replications	100

The results of the simulation model are presented in Table 3.

Regarding the KPI 'Total Throughput Time', it can be observed that for DTP it is almost half (15.75 hours), compared to the traditional model (29.49 hours). When looking at the individual transactions in the traditional model, it could be concluded that the different processes are shorter than the same steps in the DTP supply chain. However, when looking at the total throughput time of cargo, the DTP supply chain is 40% faster than the traditional supply chain. Evaluating the current trucking schedule could help reduce the throughput time in the traditional supply chain.

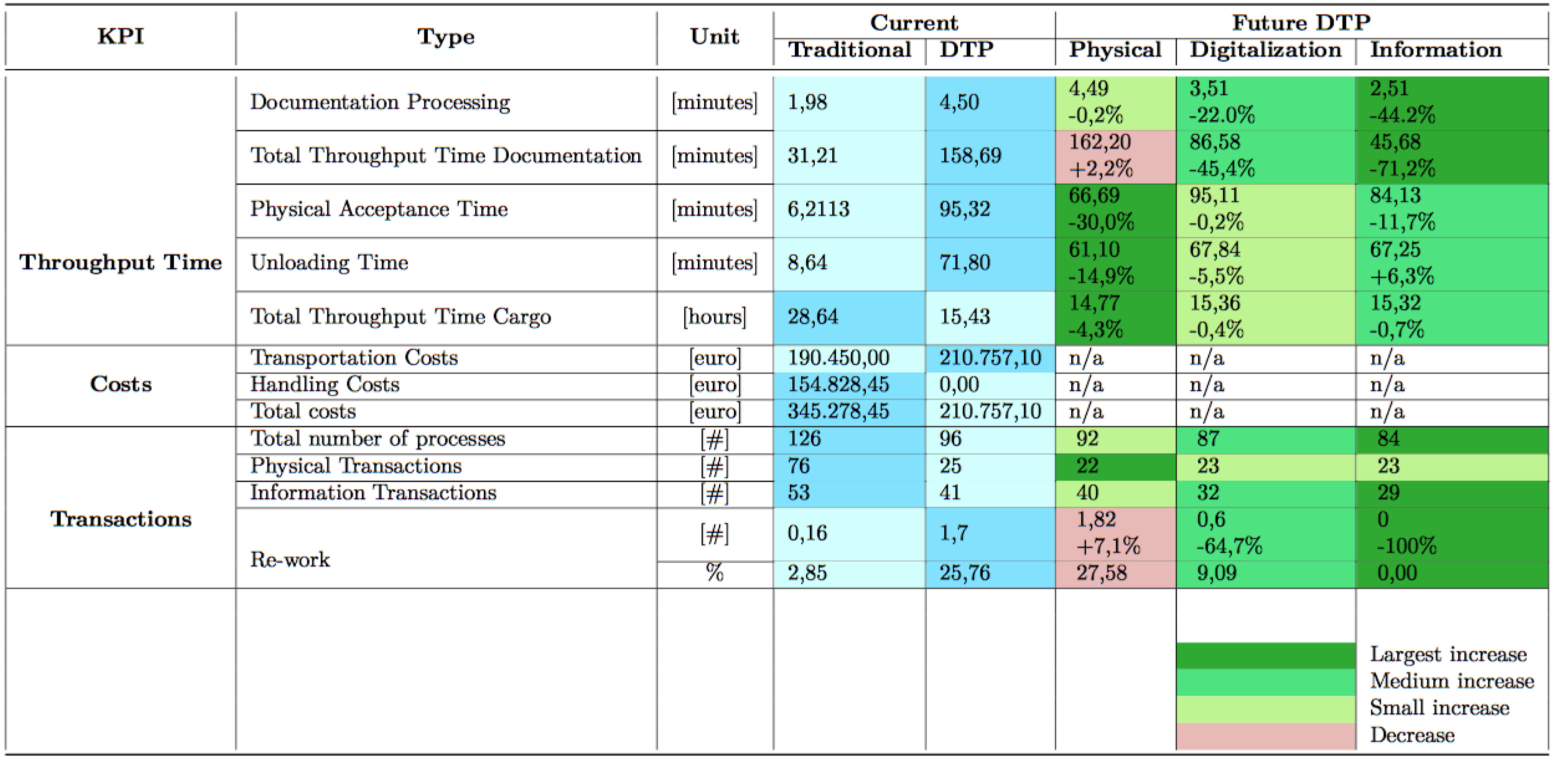
As illustrated in Table 3, the savings gained by transporting cargo directly to the hub, bypassing the GHA are significant. However, as the acceptance process and handling of cargo is now moved to Amsterdam, the internal costs per cargo handling have to be taken into account. Although, currently, this value is unknown at the hub. It can be argued whether the handling of the cargo internally is preferred, as the specific assets are available already, investments have been made, building and electricity bill paid and knowledge is available in-house (human asset-specificity). This asset specificity means, that it can only be used for cargo handling. Therefore it is beneficial to utilize the hub's means for cargo handling as much as possible instead of outsourcing the activities. The price paid to the GHA in Billund, Denmark is €0,07 per kg. If KLM is able to process the cargo for €0,06 euro per kg, they will play even as the trucking costs for the DTP model are higher. Only if they can reduce the handling costs below €0,06 euro per kg, a profit can be made by transporting cargo by DTP.

From Table 3 it can be clearly seen that the total number of transactions is significantly lower for DTP, when comparing to the traditional model. Especially the physical transactions are reduced with DTP. In case a customer has a fragile shipment, it could be beneficial to transport the shipment by DTP, reducing risk of damage due to decreased physical handling. The information transactions are also reduced when using DTP, these transactions are reduced significantly less due to the fact that a lot of information still has to be exchanged in Amsterdam with third parties such as customs. The amount of re-work in the DTP model is significantly higher than for the traditional model. Due to the fact that the GHA is omitted as middle-man, the cargo and information delivered by the customer is not checked and directly delivered to KLM Cargo. Resulting in the fact that, the physical acceptance department and document department of KLM Cargo encounter an increased workload in case the DTP model is employed.

VI. Design

As stated before, the total throughput time of the DTP business model (15.75 hours) is almost half of the throughput time of the traditional business model (29.49 hours). However, the throughput time of the DTP model can still be decreased. Based on the observations, several design options were proposed. KLM Cargo selected the following five design options as the most promising:

1. Introducing new / additional measurement points in the DTP supply chain.
2. Building a simulation model to facilitate the comparison between the traditional and DTP supply chain.
3. Collaboration in the DTP supply chain.



KPI	Type	Unit	Current		Future DTP		
			Traditional	DTP	Physical	Digitalization	Information
Throughput Time	Documentation Processing	[minutes]	1,98	4,50	4,49 -0,2%	3,51 -22.0%	2,51 -44.2%
	Total Throughput Time Documentation	[minutes]	31,21	158,69	162,20 +2,2%	86,58 -45,4%	45,68 -71,2%
	Physical Acceptance Time	[minutes]	6,2113	95,32	66,69 -30,0%	95,11 -0,2%	84,13 -11,7%
	Unloading Time	[minutes]	8,64	71,80	61,10 -14,9%	67,84 -5,5%	67,25 +6,3%
	Total Throughput Time Cargo	[hours]	28,64	15,43	14,77 -4,3%	15,36 -0,4%	15,32 -0,7%
Costs	Transportation Costs	[euro]	190.450,00	210.757,10	n/a	n/a	n/a
	Handling Costs	[euro]	154.828,45	0,00	n/a	n/a	n/a
	Total costs	[euro]	345.278,45	210.757,10	n/a	n/a	n/a
Transactions	Total number of processes	[#]	126	96	92	87	84
	Physical Transactions	[#]	76	25	22	23	23
	Information Transactions	[#]	53	41	40	32	29
	Re-work	[#]	0,16	1,7	1,82 +7,1%	0,6 -64,7%	0 -100%
		%	2,85	25,76	27,58	9,09	0,00

Largest increase
Medium increase
Small increase
Decrease

Figure 6: Results

Table 3: KPI Traditional vs. DTP

KPI	Type	Unit	Current	
			Traditional	**DTP**
Throughput Time	Documentation Processing	[minutes]	1,98	4,50
	Total Throughput Time Documentation	[minutes]	31,21	158,69
	Physical Acceptance Time	[minutes]	6,2113	95,32
	Unloading Time	[minutes]	8,64	71,80
	Total Throughput Time Cargo	[hours]	28,64	15,43
Costs	Transportation Costs	[euro]	€190.450,00	€210.757,10
	Handling Costs	[euro]	€154.828,45	€0,00
	Total costs	[euro]	€345.278,45	€210.757,10
Transactions	Total number of Processes	[#]	126	96
	Physical Transactions	[#]	76	25
	Information Transactions	[#]	53	41
	Re-work	[#]	0,16	1,7
		%	2,85	25,76

4. Digitalization in the DTP supply chain.
5. Correct information in the DTP supply chain.

To analyse the five designs, they were integrated into a framework, which was used as a test platform. This platform was built using discrete event simulation modelling. In this model, the traditional and the DTP supply chain models were tested using identical KPIs. The impact of each of the three improvement designs for the DTP supply chain (no. 3-5) was obtained by comparing the results with the current state KPI performance as displayed in Figure 6 on page 13. It can be concluded that all designs, tested with the discrete event model improve / enhance the DTP supply chain.

Below, each scenario is explained in more detail, the suggested improvements are key to improve one or both supply chains. For scenario 1, several measurement points should be implemented in the DTP supply chain, to create visibility and allow future analysis. The CIQ (industry standard) milestones should be re-designed, or a functionality should be created to make customization of the milestone order possible, to allow for structural feedback between the different parties in the supply chain. Scenario 2, is described above in the discrete model output. Scenario 3, 4 and 5 suggest improvements for the current DTP setup. The total throughput time of Scenario 3,4 and 5 are compared to the current DTP state in the spider diagram presented in Figure 7. Regarding design option 3, by improving the physical collaboration between all parties in the DTP supply chain, the acceptance time would be reduced with 30%. In addition, with this scenario the unloading time is the lowest compared to all other scenarios. It shows a reduction of 14.9% compared to the current state. Regarding, design option 4, by digitizing the DTP supply chain, a severe reduction was observed in the documentation processing time, total throughput time for documentation and a small reduction in unloading time. Regarding design option 5 represents an ideal situation, where the information should be made digitally available and correct. The documentation processing, total throughput time documentation and unloading time reduce significantly. However, this is a situation to be aimed for in the future. Realistically, design option 4, digitalization, will be more feasible in the near future rather than immediately.

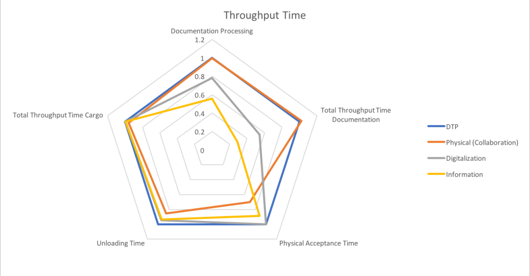


Figure 7: Comparison of DTP Design Options for the KPI Total Throughput Time

When considering the cost and time aspects of the supply chain, it could be concluded that the DTP business model looks more favourable, compared to the traditional business model. However, these five scenarios should be interpreted with caution. Many other factors need to be taken into account when comparing the two business models. Examples of these factors are; amount and type of cargo, proximity to a network point, customs, liability and safety (compliance issues), information and communication issues. To employ the DTP business model, first these factors should be discussed and agreed upon by all parties in the supply chain.

VII. Conclusion

This thesis studied the traditional air cargo flow and the DTP flow for a case study from Billund (Denmark) towards Amsterdam (The Netherlands). DTP is often performed as a special offer to the customers, with the intention to transport cargo faster and cheaper. However, this has never been studied properly. To recapitulate the main research question is:

"What are the criteria to design a seamless supply chain for the Direct Trucking Pick-up cargo flow for KLM Cargo?"

To design a seamless supply chain, an in-depth case study was executed for both the traditional and the DTP cargo flow. Using several theories, such as lean manufacturing and TCE, the current state performance was analysed. The air cargo industry can be defined as a consecutive stream of (physical and / or information) transactions. Current academic research does not provide a TCE perspective on the air cargo industry, studying the number of goods or services transferred across a technologically separable interface. Based on the measurements and analysis of the current state, several problems were identified and a framework had to be developed as a test platform to test several improvement scenarios. Currently, the air cargo industry is characterized by overtime, firefighting and blindness. Using the discrete event simulation tool Simio, a model was created serving as a test platform for the air cargo industry. Simulation can be used to explore various opportunities of process improvements and the impact of the proposed changes before implementation. Based on the simulation results the main research question can be answered. The criteria to design a seamless supply chain for the DTP cargo flow for KLM Cargo are:

1. Minimize the number of physical and information (re-work, double, manual) transactions.
2. Introduce electronic data interchange.
3. Ensure collaboration between the different parties in the supply chain.

VIII. Recommendation

In this section the recommendations with regard to scientific research and for the case study performed at KLM Cargo are presented.

A. Recommendation Scientific Research

This case-study has been performed for the trade lane Billund - Amsterdam, therefore only representing one trade lane in the area of the Nordics. Additional case studies have to be performed to gain insight in all bottlenecks present in the air cargo industry. It is recommended to perform numerous case studies on different trade lanes in different markets. In addition, it is recommended that various air cargo business models, such as co-loading, multiple contracted GHA's and multiple contracted trucking companies are studied. Also other industries working with DTP can be studied, such as; (sea) port communities, health care, fast moving consumer goods, flower trade, pharmaceutical industry, chemistry and /or road transportation industry.

Several other recommendations are; in scenario 1 it was suggested to implement measurement points in the DTP supply chain. Using these measurements points, detailed data can be gathered and analysed, providing input for future development of an in-depth dynamic model. Focusing on the methods used to analyse the supply chain, it can be recommended that with respect to the TCE theory, the number of transactions is recommended to be introduced as a parameter in the air cargo supply chain. This would be complementary to the already existing parameters, gained from the lean manufacturing theory. Data sharing is a key improvement point in the industry. One of the main developments to be researched, is the possibilities to use blockchain technology to control information sharing among different parties. It is recommended to study this possibility in future research. The same principle (DTP) can be applied for delivery to the customer, known as direct to agent (DTA). For further research the current developed framework can be mirrored and with slight adaptations, it can be used for DTA in the air cargo industry.

B. Recommendations KLM Cargo

Before implementing DTP, taking into account the complexity of the industry, first a solid proof of concept should be generated. Based on this proof of concept, strict rules should be set with the customer. Since DTP is an exclusive service, customers gain a faster and personalized service, risks are reduced, less transactions are executed and the costs are reduced since the GHA is bypassed, it should be considered to have customers pay for that service. However, in the current state there are limited benefits for KLM Cargo, since the supply chain is polluted due to lacking or unclear processes. The DTP service should be exclusively offered to premium customers, who are willing to collaborate and provide all the needed information. Essential elements have to be identified to create a culture of continuous feedback in a seamless supply chain. It is recommended to set the culture to strive to excellence. To set a price on the premium DTP service, offering less transactions on both a physical and information level to the customer, the currently unknown, internal transaction costs of KLM Cargo have to be determined.

On hub operation level it is recommended that a policy should be designed concerning the order in which trucks and documents are handled, but also regarding cargo processing further in the chain. Regarding the cargo processing, it can occur that the 'easy' trucks (carrying ULDs) are handled first, resulting in delays for the 'difficult' trucks (carrying loose cargo), even if they arrived first at the hub. Since the DTP trucks are considered as 'difficult' trucks, the current DTP schedule should be redesigned, looking at the best days of the week and the best time slots in order to ensure quick handling at the hub. Currently, shipments with long connection times are booked on the DTP trucks, resulting waiting time and storage at the hub, creating inventory and pollution at the limited storage space at the hub. The hub should strive for operational excellence. In passenger services, all operations are digitalized. Personnel works with apps, while in the cargo division paper AWBs are still every day practice. Finally, the legal and compliance aspect of the DTP model should be studied in more detail.

IX. Reflection

In this section the limitations, scientific contribution and practical contribution are presented.

A. Limitations

For the current case study, performed for KLM Cargo, a data set of 1 year is used. However, for future research it is recommended to study the performance of a larger data set. Using a larger data set, external influences can be identified and prediction models can be generated to predict future cargo trends. In addition, this research is limited as only non-exceptional export goods were studied. Exception handling introduces the most constraints on the hub's acceptance system. Therefore for future research it is recommended to take into account the exceptional cargo. Moreover, the availability of the complete, right and reliable data has been limited. Often, this was not a system and / or analysis tool related problem, but due to manual input of data prone to human-error and therefore not available or incorrectly entered. Combining the previous with the numerous available legacy systems, resulted in scattered data from which intelligence could only be gained after careful pre-processing. The largest limitation of this research is, that it was limited to one country. For future research, it is recommended to study other markets in other regions and compare results.

B. Scientific Contribution

Limited scientific research has been performed on air cargo in general (Feng et al., 2015) as until recent, carriers regarded air cargo as a by-product to the core-business, passenger services. Especially research regarding the RFS aspect of air cargo transportation is neglected. Research regarding DTPs is a green field and further academic research is needed (Merkert et al., 2017). This research therefore contributes to the air cargo literature with a focus on RFS and DTP. This research has presented several contributions to scientific literature. The first contribution is additional scientific research to the currently limited existing research in the air cargo industry. The second contribution is a pioneering exploratory case-study research, regarding DTPs. The third contribution, a framework is proposed on how to design and improve a seamless supply chain for the DTP service. Final contribution, a simulation is generated exemplifying the functionality of the proposed framework.

The air cargo industry can be characterized by rules, regulations and certifications due to government laws for safety of the passengers on board of combi-aircraft. As a result, the products and services are highly complex in nature, in combination with high asset and human specificity. Therefore TCE developed by (Williamson, 1981) can be used to analyse the industry, complementary to the already known Lean Six Sigma key performance indicators. TCE has not been used previously, to study the air cargo industry and therefore this is a greenfield, contributing to scientific knowledge. The separation of the transactions in a physical influence and information influence is also a new development regarding TCE. The discrete event simulation models provide an air cargo logistics company, the capability to simulate the effects of process improvements on the operational performance, prior to implementation. By means of three transaction alterations to a simulated DTP air cargo supply chain process, it is shown that the operational performance on the KPIs is useful to determine the boundaries of the system.

C. Practical Contribution

This research has contributed to the practical understanding of the air cargo supply chain, both for the traditional model and the DTP model. First of all, an insight in the entire cargo supply chain has been provided and the difference between the two models was identified. The case study has been performed for KLM Cargo, who until now, did not have a qualitative insight in the differences between the two models. Based on the performance of the two models, a substantiated consideration can be made between the traditional model and the DTP model. Secondly, it has been identified what the contributing factors to the variation in the throughput time and re-work are, and how these variations can be omitted. This has resulted in a more stable process and a reduced throughput time. Thirdly, several improved design options are suggested to improve the current DTP performance.

References

Aguilar-Saven, R. S. (2004). Business process modelling: Review and framework. *International Journal of Production Economics*, *90*, 129–149. doi: 10.1016/S0925-5273(03)00102-6

Arnold, U. (2000). New dimensions of outsourcing: a combination of transaction cost economics and the core competencies concept. *European Journal of Purchasing and Supply Management*, *6*, 23–29.

Atieh, A. M., Kaylani, H., Almuhtady, A., & Altamimi, O. (2016). A value stream mapping and simulation hybrid approach: application to glass industry. *International Journal of Advanced Manufacturing Technology*, *84*, 1573–1586. doi: 10.1007/s00170-015-7805-8

Azadian, F., Murat, A., & Babu, R. (2017). An unpaired pickup and delivery problem with time dependent assignment costs: Application in air cargo transportation. *European Journal of Operational Research*, *263*, 188–202. doi: 10.1016/j.ejor.2017.04.033

Azadian, F., Murat, A. E., & Chinnam, R. B. (2012). Dynamic routing of time-sensitive air cargo using real-time information. *Transportation Research Part E*, *48*(1), 355–372. Retrieved from `http://dx.doi.org/10.1016/j.tre.2011.07.004` doi: 10.1016/j.tre.2011.07.004

Bendell, T. (2005). Structuring business process improvement methodologies. *Total Quality Management & Business Excellence*, *16*(8-9), 969–978. Retrieved from `http://www.tandfonline.com/doi/abs/10.1080/14783360500163110` doi: 10.1080/14783360500163110

Boeing World Air Cargo Forecast Team. (2017). *World Air Cargo Forecast* (Tech. Rep.). Retrieved from `http://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/cargo-market-detail-wacf/download-report/assets/pdfs/wacf.pdf`

Boonekamp, T., & Burghouwt, G. (2017). Measuring connectivity in the air freight industry. *Journal of Air Transport Management*, *61*, 81–94. Retrieved from `http://dx.doi.org/10.1016/j.jairtraman.2016.05.003` doi: 10.1016/j.jairtraman.2016.05.003

Bowen, J., & Leinbach, T. (2004). Market concentration in the air freight forwarding industry. *Tijdschrift voor Economische en Sociale Geografie*, *95*(2), 174–188.

Cima, R. R., Brown, M. J., Hebl, J. R., Moore, R., Rogers, J. C., Kollengode, A., . . . Deschamps, C. (2011). Use of Lean and Six Sigma Methodology to Improve Operating Room Efficiency in a High-Volume Tertiary-Care Academic Medical Center. *American College of Surgeons*, *213*(1), 83–92. Retrieved from `http://dx.doi.org/10.1016/j.jamcollsurg.2011.02.009` doi: 10.1016/j.jamcollsurg.2011.02.009

Cooper, M. C., Lambert, D. M., & Pagh, J. D. (1997). Supply Chain Management: More Than a New Name for Logistics. *The International Journal of Logistics Management*, *8*(1), 1–14. Retrieved from `http://www.emeraldinsight.com/doi/abs/10.1108/09574099710805556`

Dul, J., & Hak, T. (2008). *Case Study Methodology in Business Research* (First Edit ed.). Butterworth - Heinemann.

Feng, B., Li, Y., & Shen, Z. J. M. (2015). Air cargo operations: Literature review and comparison with practices. *Transportation Research Part C: Emerging Technologies*, *56*, 263–280. Retrieved from `http://dx.doi.org/10.1016/j.trc.2015.03.028` doi: 10.1016/j.trc.2015.03.028

Heinitz, F., Hirschberger, M., & Werstat, C. (2013). The Role of Road Transport in Scheduled Air Cargo Networks. *Procedia - Social and Behavioral Sciences*, *104*, 1198–1207. Retrieved from `http://dx.doi.org/10.1016/j.sbspro.2013.11.216` doi: 10.1016/j.sbspro.2013.11.216

Hellberg, R., & Sannes, R. (1991). Customs clearance and electronic data interchange - A study of Norwegian freight forwarders using EDI. *International Journal of Production Economics*, *24*, 91–101.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International Journal of Operations & Production Management*, *17*(1), 46–64.

Houlihan, J. B. (1988). International Supply Chains: A New Approach. *International Journal of Physical Distribution & Materials Management*, *26*(3), 13–19. Retrieved from `http://www.emeraldinsight.com/doi/abs/10.1108/eb001493`

Huang, S.-H. S., & Hsu, W.-K. K. (2016). Evaluating the service requirements of combination air cargo carriers. *Asia Pacific Management Review*, *21*(1), 1–8. Retrieved from `http://dx.doi.org/10.1016/j.apmrv.2015.05.001` doi: 10.1016/j.apmrv.2015.05.001

Hummels, D., & Schaur, G. (2012). *Time as a Trade Barrier.* Cambridge. Retrieved from `http://www.nber.org/papers/w17758.pdf`

International Air Transport Association. (2008). *Cargo 2000* (Tech. Rep. No. April). International Air Transport Association.

International Air Transport Association. (2016). *Air Cargo Industry Master Operating Plan* (Tech. Rep. No. March).

International Air Transport Association. (2017). *IATA Cargo Strategy* (Tech. Rep. No. July). Retrieved from `http://www.iata.org/whatwedo/cargo/Documents/cargo-strategy.pdf`

Jong de, S. J., & Beelaerts van Blokland, W. A. (2016). Measuring lean implementation for maintenance service companies. *International Journal of Lean Six Sigma*, *7*(1), 35–61. Retrieved from `www.emeraldinsight.com/2040-4166.htm` doi: 10.1108/IJLSS-12-2014-0039

Kelton, W., Smith, J., & Sturrock, D. (2011). *Simio and Simulation - Modeling, Analysis, Applications* (2nd editio ed.). Simio LLC.

Lambert, D. M., & Cooper, M. C. (2000). Issues in Supply Chain Management. *Industrial Marketing Management*, *29*, 65–83.

Laseter, T., & Oliver, K. (2003). When Will Supply Chain Management Grow Up? *Strategy + Business*, *Operating*(32), 1–5. Retrieved from `https://www.strategy-business.com/article/03304?gko=54182`

Law, A. M. (2011). How to select simulation input probability distributions. In *Proceedings of the 2011 winter simulation conference* (pp. 1394–1407). Tucson, USA: Avrill M. Law & Associates, Inc.

Law, A. M., & McComas, M. G. (1990). Secrets of Successful Simulation Studies. *Journal of Industrial Engineering*, *25*.

Lobo, I., & Zairi, M. (1999). Competitive benchmarking in the air cargo industry: Part I. *Benchmarking: An International Journal*, *6*(2), 164–191. Retrieved from `https://doi.org/10.1108/14635779910269768`

Mason, S. E., Nicolay, C. R., & Darzi, A. (2014). The use of Lean and Six Sigma methodologies in surgery: A systematic review. *Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland*, *13*(2), 91–100. Retrieved from `http://dx.doi.org/10.1016/j.surge.2014.08.002` doi: 10.1016/j.surge.2014.08.002

Mentzer, J. T., Dewitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). Defining Supply Chain Management. *Journal of Business Logistics*, *22*(2), 1–25. Retrieved from `http://www.aui.ma/personal/{~}A.Berrado/MGT5309/DEFININGSUPPLYCHAINMANAGEMENT{_}Metznereta1.2001.pdf`

Merkert, R., van de Voorde, E., & de Wit, J. (2017). Making or breaking - Key success factors in the air cargo market. *Journal of Air Transport Management*, *61*, 1–5. doi: 10.1016/j.jairtraman.2017.02.001

Monde la, B. J., & Masters, J. M. (1994). Emerging Logistics Strategies: Blueprints for the Next Century. *International Journal of Physical Distribution & Logistics Management*, *24*(7), 35–47. Retrieved from `https://doi.org/10.1108/09600039410070975Downloaded`

Nobert, Y., & Roy, J. (1998). Freight Handling Personnel Scheduling at Air Cargo Terminals. *Transportation Science*, *32*(2), 295–301. Retrieved from `https://pubsonline.informs.org/doi/abs/10.1287/trsc.32.3.295`

Onghena, E., Meersman, H., & Voorde, E. V. D. (2014). A translog cost function of the integrated air freight business: The case of FedEx and UPS. *Transportation Research Part A*, *62*, 81–97. Retrieved from `http://dx.doi.org/10.1016/j.tra.2014.02.002` doi: 10.1016/j.tra.2014.02.002

Reid, R., & Sanders, N. (2011). *Operations Management - An Integrated Approach* (4th ed.). Hoboken: John Wiley & Sons Inc.

Reis, V., & Silva, J. (2016). Assessing the air cargo business models of combination airlines. *Journal of Air Transport Management*, *57*, 250–259. doi: 10.1016/j.jairtraman.2016.08.011

Rhoades, D. L. (2016). *Evolution of International Aviation: Phoenix Rising*. Taylor & Francis. Retrieved from `https://books.google.nl/books?id=Cv8FDAAAQBAJ`

Schwarz, G. (2006). Enabling global trade above the clouds: restructuring processes and information technology in the transatlantic air-cargo industry. *Journal of Environment and Planning A*, *38*, 1463–1485. doi: 10.1068/a3852

Selinka, G., Franz, A., & Stolletz, R. (2016). Time-dependent performance approximation of truck handling operations at an air cargo terminal. *Computers and Operations Research*, *65*, 164–173. Retrieved from `http://dx.doi.org/10.1016/j.cor.2014.06.005` doi: 10.1016/j.cor.2014.06.005

Solding, P., & Gullander, P. (2009). Concepts for simulation based value stream mapping. In *Proceedings of the 2009 winter simulation conference* (pp. 2231–2237).

Stevens, G. C. (1989). Integrating the Supply Chain. *International Journal of Physical Distribution & Materials Management*, *19*(8), 3–8. Retrieved from `http://www.emeraldinsight.com/doi/abs/10.1108/EUM0000000000329`

Thomson, C. (2016). *Three silos in your supply chain and what to do about them.* Retrieved 24-01-2018, from `http://www.supplychaindigital.com/scm/three-silos{\protect.\kern\fontdimen3\font.\kern\fontdimen3\font.\kern\fontdimen3\font}`

Verschuren, P., & Doorewaard, H. (2010). *Designing a Research Project* (second ed.). The Hague: Eleven International Publishing.

Walcott, S. M., & Fan, Z. (2017). Comparison of major air freight network hubs in the U.S. and China. *Journal of Air Transport Management*, *61*, 64–72. Retrieved from `http://dx.doi.org/10.1016/j.jairtraman.2016.06.006` doi: 10.1016/j.jairtraman.2016.06.006

Williamson, O. E. (1981). The Economics of Organization: The Transaction Cost Approach. *American Journal of Sociology*, *87*(3), 548–577.

Williamson, O. E. (1986). Transaction Cost Economics - The Comparative Contracting Perspective. *Journal of Economic Behavior and Organization*, *8*, 617–625.

Williamson, O. E. (1988). Technology and Transaction Cost Economics - A reply. *Journal of Economic Behavior and Organisation*, *10*, 355–363.