The potential of inner airport horizontal transport collaboration

A case based assessment of horizontal air cargo truck transport collaboration at Schiphol airport

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Abstract

Horizontal transport collaboration is an unexplored way of organizing transport for most large air freight forwarding companies. The current difficult and more dynamic air cargo market conditions in Western Europe have recently increased the focus of forwarders on both reducing transport costs and improving transport performance. By applying horizontal transport collaboration it could result in improvements on transport performance and costs. This paper tries to justify the quantification of the potential of inner airport truck transport collaboration on a horizontal level for large freight forwarding companies. A simulation model is constructed for part of the air cargo truck transport movements within the airports surroundings and the main finding of the simulation model is that horizontal collaboration can improve both the amount of transport visits to involved forwarders facilities and reduce transport costs. Up to 40% reduction of costs and 30% reduction on transport movements to air cargo handler can be realized, compared to single company transport use. The reduction of the total amount of transport movements can only be reduced when the remaining amount of single company transport is also adapted. Thus, the application of the current simulation model is limited, as the model has been based on limited information of operation of selective number of forwarding companies. The quantified results and input data will therefore have to be further validated with more specified data of the actual transport systems in order to increase generalization of the results and usability of the model. Also, future research should be directed at validation of data the combined transport simulation model and should include other forms of transport collaboration, such as the use of variable capacity instead of solely using fixed capacity for combined transport.

Keywords: horizontal collaboration, airport logistics, air cargo, forwarders, air cargo handling, transport performance

1 Introduction

Traditionally large shippers of goods have been developing and supporting their transport needs internally (Sahay, 2003). In the last 30 years however, many shippers have started to collaborate with other companies within their own supply chain on transport organization related activities (Mason, Lalwani, & Boughton, 2007). This type of vertical supply chain collaboration has matured in many ways over the last decades; to the extent that achieving a competitive advantage by applying only vertical collaboration has been strongly reduced in highly competitive industries. Vertical supply chain collaboration has in general moved from being a differentiating strategy, to a widely and commonly applied approach that is used to support and improve the management of a specific entire supply chain. Customer preferences and transport requirements have become more challenging and demanding in recent years (Capgemini, 2010; Pyza & Golda, 2011), which has resulted in a much smaller and faster changing production flows, between major manufactures and the main consumer markets around the world (Maskell, 2001). It has therefore become increasingly difficult to improve both costs and operational performance by collaborating only with companies within a single supply chain. Increased energy costs for transport, stricter government regulations on transport use and increased focus on sustainability of transport by major costumers, have also made the effective management of supply chain more difficult by applying only vertical supply chain collaboration. In several large production industries, like the fast moving costumer goods sector (FMCG), major manufactures of goods have therefore started to collaborate with competitors, in order to able to reduce the transport cost, increase the frequency of delivery and meet other operational requirements demanded by their customers. This type of collaboration is known as horizontal collaboration. It involves the collaboration of companies that are conducting business operations on the same level of the value chain. Recent horizontal transport collaboration projects in Europe has shown that, costs savings on transport of more than 20% can be achieved by applying horizontal collaboration on transport and distribution (DHL, 2011; Vanovermeire, Sörensen, Breedam, Vannieuwenhuyse, & Verstrepen, 2011), while in the same time also improving the operational transport performance.

Collaboration on horizontal level within the air cargo transport system has been found to be non-existing in current literature, whereas this type of collaboration proved to be successfully applied in other transport systems. Previous high growth rates, between 1972 and 2005 (Worldbank, 2012), combined with healthy operations margins had limited the need and support for transport collaboration in air cargo transport system. Companies in the industry have been able either to optimize their supply chain in a cost effective way with their own means or have been able to justify inefficiency due to high operational margins. However the increased competiveness of the air cargo industry and declining operating margins (IATA, 2012) have made it more difficult for individual companies to maintain an acceptable level of transport performance and transport costs. Given this notion and the fact that a pilot project was started at Schiphol airport regarding transport collaboration in September 2012, an unique opportunity was presented for this research; to analyze a real case transport horizontal collaboration project and to analyze the potential of horizontal transport collaboration within a large air cargo system at a major European cargo airport with the use of actual data.

The objective of this paper will be: to quantify the main effects that applying horizontal transport collaboration will produce, for inner airport transport based on performance and costs. This research will contribute to support further analysis on transport collaboration in dynamic networks, by revealing results on actual case study of collaboration and pointing out the key difference of collaborative and single company transport use on set of defined key performance indicators (KPI's). Developments related to air cargo shipment transport and air cargo handling are also analyzed in order to assess how the value of collaboration on transport could change over time.

The following question will be the main question of this research paper:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and cost of truck transport at Schiphol airport?

In the following section two, the current literature on supply chain collaboration will be analyzed. Section 3 points out the most important current and future developments of air cargo industry in Western Europe in relation to the transport system inner airport transport. In section 4 the case study of transport collaboration at Schiphol will be described in order to justify the selected case study. Section 5 will explain why the simulation approach is used and will describe the key processes of model construction and validation. Section 6 will show the results of both single and combined transport performance based on the analyzed case study simulation model. Finally in section 7 the research question will be answered, limitations and directions for further research will be pointed out.

2 A state-of-the-art literature review on supply chain collaboration

Research on the subject of horizontal transport collaboration related to actual case studies has been found to be limited in current literature (Audy & D'Amours, 2008; Cruijssen & Salomon, 2004; Vanovermeire et al., 2011). The majority of the research regarding transport collaboration focuses on vertical supply chain collaboration (Holweg, Disney, Holmström, & Småros, 2005; Visser, 2009). Research is often aimed at showing the value and challenges related to applying supply chain collaboration on a vertical level and how supply chains can become more competitive by doing so (Sahay, 2003). Most of the research on supply chain collaboration does not focus specifically on transport. This can be explained by the traditional focus of supply chain management on reduction of transport costs and not on optimal of value transport costs, as has been pointed out by the research of (Mason et al., 2007). It points out in general that when only a cost focus is applied, relationships will between companies will be short term and on purely operational level. Often these types of relationships are not defined as true form of collaboration but arm's length relationships. Many challenges currently exist that have limited the actual intended impact of collaboration both on vertical and horizontal way (Barratt, 2004). Therefore recent research has looked at important variables that are related to supporting and managing supply chain collaboration in a segmented way, to improve the desired outcomes and limit the investments needed to setup and maintain effective collaboration. To realize this, segmented relationships have to be formed that reflect the ability and willingness of companies to collaborate (Rezaei & Ortt, 2012). When applying and managing transport with two or more companies operating on the same level of the value chain, this often requires longer term relationships, in order to justify and support the set up this type of transport, it can be more complex to establish and maintain such relationships (Stephens, 2006). This can be further explained by the research of (Lambert, Emmelhainz, & Gardner, 1996), which defines different levels of relationships between companies based on extent and goal of collaboration. It points out the most important aspects that define to which extent a partnership is based on the facilitators and drivers for a partnership. Key elements in the partnership model relate to organizational comparability, symmetry and trust. When companies have not collaborated before with other companies or lack the knowledge regarding the application of collaboration (Muir, 2010) it is more difficult to realize and support collaboration. Given the limited application and knowledge of horizontal transport collaboration, it is not surprising that such collaboration has seen limited development. Companies currently have more experience with application of vertical collaboration and have also more knowledge on the application of such collaboration. However the benefits of applying horizontal transport collaboration on not only transport costs or transport performance are also becoming better known, as has been pointed out by (Cruijssen, Cools, & Dullaert, 2007). The potential of horizontal transport is therefore growing, due to more dynamic markets conditions and changing customer requirements (Leitner, Meizer, Prochazka, & Sihn, 2011). The drivers to support horizontal collaboration in supply chain management are increasing in several industries, especially when vertical collaboration cannot achieve similar results or is even more difficult to realize. Collaboration in the air cargo sector has been limited and has mainly focused on collaboration between airlines (Agarwal, Ergun, Houghtalen, & Ozener, 2009), due to liberation of a key air cargo market around the globe, major airlines have started to collaborate with airline partners to share capacity and improve profitability. Within the airport system only limited collaboration has been established based on vertical collaboration regarding the coordination of transport movements to a specific air cargo handler (Franz & Stolletz, 2012a).

3 Conceptual model for air cargo airport transport collaboration

Different definitions have been found for horizontal collaboration/cooperation for example; "collaboration between parties that are at the same level between resources and final products is defined as horizontal collaboration" (Visser, 2009, p. 9) or "concerted practices between companies operating at the same level(s) in the market or logistic chain is defined horizontal cooperation"(Leitner et al., 2011, p. 333). Horizontal transport collaboration (HTC) in this paper will be defined as: all activities that can be associated with a predefined and coordinated collection and delivery of cargo involving two or more companies that are not part of the same supply chain, which operate on the same level of the value chain, to one or more destination within the supply chains of the involved companies. The conducted literature review has shown that realizing and supporting collaboration within a supply chain and between supply chains can be a challenging and difficult process, but the potential to realize performance or costs improvements by applying horizontal collaboration is growing. In order to show the potential of ground transport collaboration in the air cargo system, challenges of current single company transport will be related to opportunities of combined collaborative transport. Figure 1 below shows the way transport is now normally organized for large forwarders and how transport can be organized by collaboration between different air freight forwarders and one or more air cargo handlers. The figure shows shipments of several forwarders that are linked to one or more airlines that arrive at an air cargo handler. Currently most forwarders collect and deliver shipments linked to a specific airline individually, which produces extensive amount of transport movements between forwarders warehouse and air cargo handler.

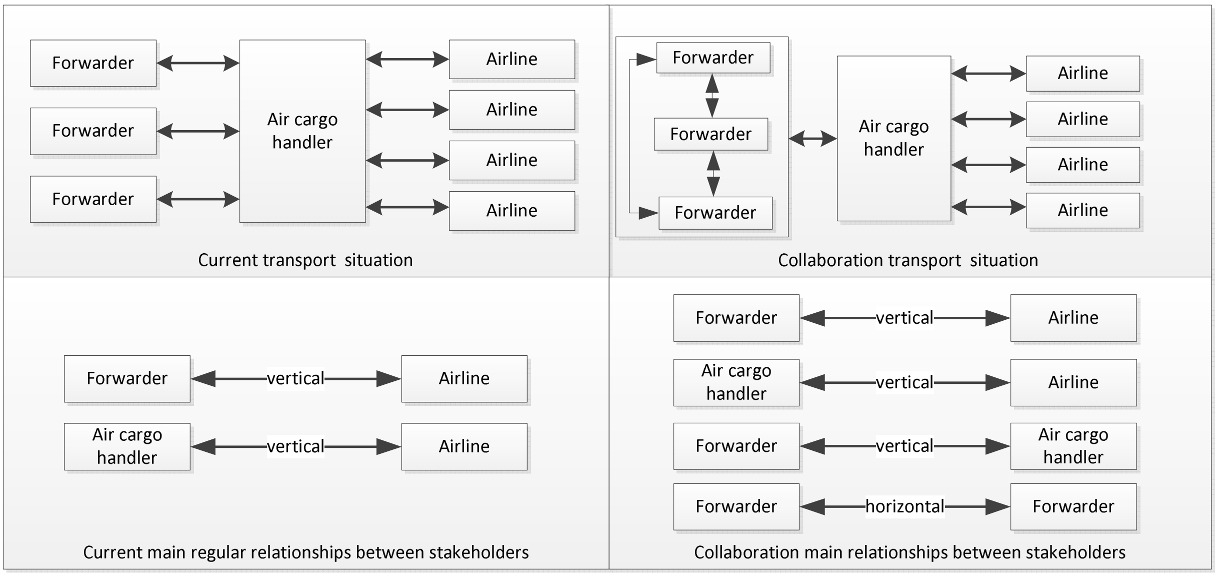

Figure 1: transport flows of air cargo shipments between forwarders, air cargo handler and airlines and main relationships between stakeholders within a general air cargo system

The number of forwarders, airline and air cargo handlers at a given major air cargo airport has increased extensively over the last few decades, due to liberation of major air transport markets (Zhang & Zhang, 2002), growth of international trade and the air cargo handling market. Previously air cargo transport system consisted of a limited amount of stakeholders and transshipment points. This combined with an average larger shipment size made it easier for freight forwarder companies, to cost effectively organize their own transport than it is now. However, increased fuel costs, changes to the supply chain of major users of air cargo transport and an increase in air cargo transport capacity both within an airport and via secondary airports have reduced the average shipment size and stability of air flows between forwarders and airport cargo handling facilities. Until recently large companies operating globally had been increasing their regular use of air transport for part of their supply chain, as a competitive advantage, in order to be able utilize their different production facilities and react to costumer demand in a more efficient way (Yuan, Low, & Ching Tang, 2010). Slower growth rate of air transport in relation to global transport shows however that the use of air transport, as preferred transport means of transport for certain large manufactures has been reduced in key markets (Loadstar, 2013). This can be explained by the use of alternative forms of transport, due to recent experiences with dependence on air transport with major disruptions (Graebel, 2012; TNO, 2012), the move of production faculties around the world (Appold & Kasarda, 2011; Eurostat, 2011) and increased attractiveness of alternative forms transport compared to air transport, based on transport costs in relation to product value. These mentioned developments have also put further pressure on the average air freight rates and operational margins of both airlines and other stakeholders involved in the operations related to the market of air cargo transport to and from Western Europe (IATA, 2012). These developments have caused an increase in the number of transport movements between forwarder facilities and the air cargo handling facilities, with similar or fewer amount of cargo transported, an increasing in the transport costs and reducing transport performance, while at the same time presenting lowered operations margins. When transport movements of several forwarders are combined, between one or more air cargo handlers, the amount of transport movements to the handling facility can be reduced, at the same time the frequency of delivery can be maintained or increased, with lower cost and higher average amount of cargo transported, which is shown in transport collaboration situation Figure 1. The current challenges and decline performance of single company transport shows that there is a large potential to practice collaboration on transport between forwarders located close to a major airport and one or more handling facilities. In order to support collaborative transport, new relationships have to be supported that currently do not (always) exists both on a vertical (forwarder/air cargo handler) and horizontal level between forwarders.

4 Case study of air cargo transport collaboration at Schiphol airport

Amsterdam airport Schiphol is one of the biggest air cargo airports in the world. It is currently positioned in the top five of largest passenger and cargo airports within Europe (Schiphol, 2012) and also ranks within the top 20 of largest airports in the world on these two aspects. Schiphol airport has recorded large growth of its air transport operations related to the amount of cargo that has been processed on yearly basis. The airport has realized an average growth rate of 6,2% a year from 1972 till 2007 (Ramaaker, 2012), also other established air cargo airports in Western Europe have previously seen similar growth rates (DT, 2009). The introduction of European Directive 96/67/EC on the liberalization of passenger and air cargo handling market in Europe has had a big impact on the amount handling companies at major European airports with most of these (new) handling companies investing in new facilities or expanded existing facilities at major airports. Schiphol is a prime example of this as currently six general handling facilities are operating at the airport. The last five years, the average growth rate at large airports like Schiphol has been negative. Based on the described developments regarding air cargo transport, in the recent past, the Western European air cargo market is expected to face a more challenging time in the future, compared to the relatively healthy growth and operating margins it has enjoyed in the last decades. This means that major stakeholders in the air cargo system that operate at existing major air cargo hubs like Schiphol airport will have to improve their system efficiency in order to stay economically viable and attractive. This also has to be realized with lower expected returns and a higher uncertainty on growth compared to other air cargo markets. Schiphol is a suitable airport for a case study analysis on horizontal transport collaboration, given the large amount of forwarders, airlines and handling facilities that operate at the airport. Also the large amount of air cargo that is processed on a yearly basis at the airport, the current over capacity, lower operating margins and declining average shipment size, make the potential of costs reductions by applying horizontal transport collaboration high at Schiphol. Many large air cargo airports in Europe have similar stakeholders and operations in relation to Schiphol and therefore results of a case study at Schiphol can also be useful for other large cargo airports.

5 Research method: simulation of horizontal transport collaboration

5.1 Simulation approach

A simulation method is chosen to reveal the potential of combined transport in relation to single company transport for this case study. Simulation can be used to show the value of changes to business processes and compare it with the current situation, which has been pointed out in research by (Khan, 2000), on an air cargo handling system. The ability to simulate air cargo handling processes that are in line with the actual situation has been proven by the researches of (Nsakanda, Turcotte, & Diaby, 2004) and (Esmemr, Ceti, & Tuna, 2010), which show that simulation can be used to obtain results of processes that are in line with the actual situation at air cargo handling facilities at major air cargo airports. This supports the applicability of using simulation to assess the impact of applying horizontal transport to air cargo systems. Actual historic data was provided by several stakeholders for this case study, thus making it possible to construct a simulation model based on actual input data and validate the results of the simulation to a certain extent based on data and observations. Besides these points, with a simulation model a different way of organizing combined transport can be assessed without actual implementation, hence without causing actual operational consequences that might not be desired. Thus, using a simulation model can also be useful for further analysis of the organization of air cargo transport systems at Schiphol or other air cargo airports.

5.2 Milkrun pilot & simulation model goal

The case study at Schiphol has been based on a selective flow of transport of three forwarding companies and one air cargo handler. Actual data of the year 2012 were used that were provided both by the analyzed companies combined with data of four other organizations, including data of Cargonaut and Schiphol Group. The suitability of the forwarding companies that have been analyzed and the extent to which they can be generalized, in relation to other handlers and forwarding companies, can be supported on several aspects. The analyzed forwarders all have a large share of 'general cargo' (CG) shipments (80 to 95%) and the analyzed companies rank in the top 15 customers for both import and export at the analyzed air cargo handler, in regards to the total weight of collected and delivered shipments over 2012. The GC shipments do not require any additional or special handling, which makes it suitable for collaboration transport, as only standard procedures are applied for handling these shipments. The analyzed air cargo handler ranks within the top three largest air cargo handlers operating at the airport and has large amount of different airline customers. This is important for the amount of cargo that is processed and the frequency of cargo shipments that arrive. Also the forwarding companies are located close to the analyzed air cargo handler and have a similar type customer base at Schiphol and at their most important other gateway stations at airports around the world. The basis for case study simulation came from increasing operational challenges that have occurred at several larger air cargo handlers at Schiphol, regarding the truck transport collection/delivery and shipment processing of loose cargo shipments. Transport performance of large forwarders operating around the airport has been reduced by these challenges; the costs of transport has increased and

reliability of transport has been reduced, as the pilot was aimed at only supporting collaboration on loose import cargo shipments transport. In order to analyze the complete potential of combined transport in relation to single company transport between the involved forwarding companies warehouses, the analyzed air cargo handler transport of ULD shipments, export transport of both loose and ULD shipments has been included in the simulation.

Goal of simulation model

The main goal of the simulation model is; to support decision making on the use and suitability of transport collaboration in relation to single company transport use. In order to realize this, the most important differences of combined and single transport are quantified on set of key performance indicators. Given that the described problem relates to transport costs, transport movements and timing, the following KPI have been defined as most crucial for the simulation:

- amount of transport movements
- amount of cargo processed
- transport costs per kilo
- average throughput time of shipments

5.3 Conceptualization of air cargo truck transport system

In order to better understand which processes and factors are relevant for the purpose of the simulation model, several tools were used to define a clear conceptual view of the transport system and its processes. The structured analysis and design technique (SADT) is one of these used and is explained in more detail below.

SADT diagrams

The highest level SADT diagrams have been defined both for forwarders and air cargo handles, which are explained below based on Figure 2. The process is defined both for import and export process, it shows that the processing of shipments relates to; document, shipment and truck processing and depends on many different resources within the analyzed facilities and information flows that is available to support the processing of shipments. Customs, security, documentation and transport also depend on and/or are influenced by other stakeholders that are involved in the air cargo supply chain. Given the extent of resources and information involved in processing are cargo shipment, this reveals that processing air cargo shipments can depend on many different elements, which are not all under control of the company in charge of the forwarding of air cargo handling facility. The process at the air cargo handler is also influenced by both airside and landside transport that can occur both to and from the involving forwarders. Transport can be conducted to and from other air cargo handlers and is also influenced by information from an additional party of the airline, on which behalf the air cargo handler has to process the shipments for a specific forwarder.

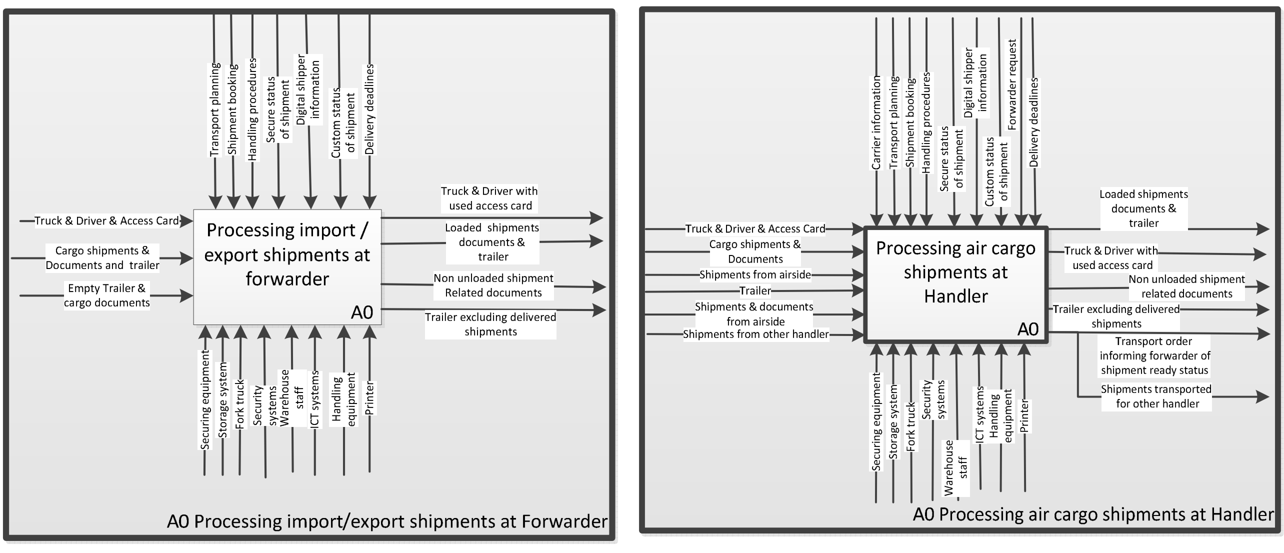

Figure 2: SADT top level diagrams process related to handling air cargo shipments at forwarder and air cargo handler

Given the extensive amount of processes that have been identified in the conceptualization, a simplified figure of the most relevant processes that will be used for the simulation model is shown below in Figure 3. It shows the different processes that an import or export shipment will go through from creation (generation) until shipment delivery at the final destination. The generation of shipments for import shipment will take place at the handling facility, whereas export shipments will be generated at the export facilities of one of the three forwarders. Import shipment are delivered at one of three import facilities of the involved forwarder and export shipments are all delivered to the handling company's export facility. Transport is generated at one of the different transport bases that have been defined, transport movements are planned by assessing the amount of shipments that are ready for collection and looking at the amount of transport that has been allocated to a specific set of shipments.

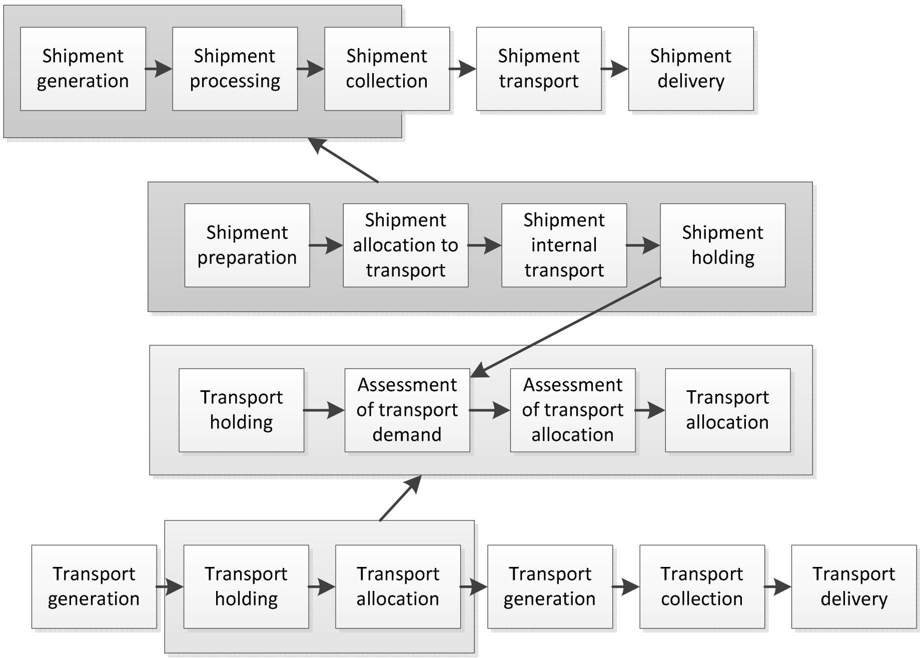

Figure 3: simplified processes of inner airport shipment transport system from generation to delivery

Based on interviews that were conducted with more than 10 different forwarders around Schiphol airport, the SADT analysis and other conceptual tools define a set of KPI's related to transport performance that are most important for air cargo inner airport truck transport system. The KPI's are shown in Figure 4 below.

Important KPI's

- Throughput times of shipments
- Transport holding time
- Transport costs per kilo
- Load factor of transport
- Amount of kilo cargo transported
- Amount of shipments on time
- Amount of shipments late
- Amount of transport visits to warehouse

Figure 4: main KPI's for transport performance of inner airport truck transport

5.4 Model specification & construction

The model has been based on the conceptual models of the previous paragraph and was specified with the use of several different data sources in order to define the input variables of the model. Actual cargo data of the year 2012 and information derived from interviews with air cargo experts have been combined in constructing the different input variables. Due to limited availability of data on detailed level, a large amount of the processes that has been defined in the previous paragraph were either simplified or not used within the simulation model. The most important input variables of the model will be discussed below.

Shipment arrivals & shipment weight

Data related to total shipment weight were provided for a certain time period regarding all shipments that were processed for each forwarder (import/export). System data related to forwarders share of cargo at the different handling facilities were used to estimate the amount of cargo that was assigned to the specific handler of this research. The general share of unit loading device (ULD) cargo and loose cargo was used to specify the total amount of ULD and loose cargo for each forwarder at the analyzed air cargo handling facility. Due to the lack of information on arrival distribution of shipments for the specific forwarders, shipment arrival was estimated using the average daily arrival and departure of flights at Schiphol (Schiphol, 2012), by using the hourly share of flights regarding the share of cargo that arrives or departs for each forwarder at a certain moment in time. The hourly arrival and departure of flights has been further simplified, by constructing three arrival periods for import and export shipments, which presented in Table 1 below. The weight distribution of loose cargo shipments was based on a lognormal distribution. A lognormal distribution was used for two reasons; several other researches regarding the simulation of air cargo shipments have used this type of distribution (Boonekamp, 2013; Huang & Chang, 2010) and a log normal distribution makes it possible to have shipments arrive spread over extensive value range. For ULD shipments, a normal distribution was used, this has been based on the assumption that all forwarders try to maximize their ULD shipment weight, therefore the spread of the weight is expected to be less and closer to the maximum possible weight.

		weight distribution import					
arrival shifts		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	6%	NORM (2300,100)	LOGNORM (350.600)	NORM (2300,100)	LOGNORM (150.400)	NORM (2300,100)	LOGNORM (310.600)
day peak	63%						
eveing peak	31%						
shipments per arrival		2	6	1	7	1	6
		weight distribution export					
depature shifts		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	2%	NORM (2300,100)	LOGNORM (390.600)	NORM (2300,100)	LOGNORM (180,400)	NORM (2300,100)	LOGNORM (330.600)
day peak	79%						
eveing peak	19%						
shipments per arrival		1	4	1	7	1	2

Table 1: arrival of shipments for ULD and loose cargo and weight distributions (shipment weight values in kilogram)

Cargo handling process

Observations at the different warehouse facilities at Schiphol, combined with information obtained at several interviews were used to define the handling times and processing of cargo shipments at Schiphol airport. Due to lack of data, processes timings for import and export were assumed to be the same for both loose and ULD cargo shipments. Given the relative high uncertainty about process times of loose cargo at a given handling facility, these processes times were based on exponential distribution. The exponential distribution seems to be the most suitable distribution for defining the processing times at the handling facility, as it has the following characteristics; values are independent of previous value, there is a large range and a variety of different values that occur with certain randomness. Also the research of (Franz & Stolletz, 2012b) uses an exponential distribution of the process times of trucks at an air cargo handling facility based on actual observed data. The main values of exponential distributions have been based on actual observed timings for single company transport and on expected values for combined transport. The defined distribution also gives maximum process times that are in line with the actual situation at the analyzed handling facilities at Schiphol. The handling times of ULD cargo at the handling facility and at forwarder for ULD and loose shipments is based on triangular distribution, as process times for these processes are much more stable and known.

Handling times (minutes)			
Handling times (un)loadingof	single loose	combined loose	ULD shipments
c1	TRIA(5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c2	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c3	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
h1	exp(8) +10	expo(4) +5	TRIA(4,6,10)
Processing import cargo at handler (hours)			
ULD shipments		TRIA (1,3,4)	
Loose cargo shipments		TRIA (3,6,10)	

Table 2: (un)loading times of shipments at different locations of transport (import/export) times in minutes and processing times of ULD and loose shipment sin hours

Transport logic & limitations of transport capacity
Transport logic and transport capacity have been based on expert judgment and interview information. Given the use of fixed capacity for transport of the involved forwarders and the lack of in depth knowledge on how transport is allocated to certain shipments, simplified transport logic was used. Transport priority was based on defined chances to export shipments ready for collection, as general export transport has higher priority than import. Besides this, another major simplification for transport generation is that at least one or more shipments should be ready for collection and that only when more shipments are waiting, which have not been assigned to a specific transport additional transport be would generated. Table 3 below shows the weight restrictions that were defined for different types of transport in relation to transport capacity for each truck. The maximum weight for transport has been set in line with the maximum shipment size. The weight limit of 10000 kilo for a specific transport has been based on the limitations that a truck has, regarding both volume and weight. In general, air cargo shipments are charged in a 1 to 6 ratio (Koning, 2012). This means that $1m^3$ of cargo equals to 166, 7 kilo of cargo. A trailer of a truck carrying 10000 kilo of actual weight therefore will use an estimated 60 m^3 of volume, while a generally used trailer for air cargo transport has a maximum capacity of 70 to 80 m^3. In order to allow for some flexibility with volume and stacking limitations of certain shipments, the maximum weight is set at 10000 kilo per trailer. Loose cargo transport is only limited by the total amount of weight, whereas for ULD transport is limited both on weight and amount of shipments that can be carried.

shipment weight	single (kilo)		combined (kilo)		trailer capacity	maximum weight	amount of shipments	
Loose	50	10000	50	2500	Loose	10000	1	∞
ULD	1800	2500	1800	2500	ULD	10000	1	4
	min	max	min	max			min	max

Table 3: shipment weight restrictions for single and combined transport and trailer capacity for loose and ULD transport

Transport resources & operating times
In reality certain freight forwarders combine ULD and loose cargo shipment. However, due to lack of information about the specific conditions under which these different types of shipments are combined, ULD and loose cargo will be transported separately in this model. This is also why specific transport units will be defined for ULD and loose transport, as decision logic regarding the allocating to either ULD or combined transport is unknown. In the model, operating times and amount of transport is defined in line with actual provided data by the analyzed forwarding companies. The operating times for both loose and ULD transport has been defined in the same way.

forwarding company single	operating times	amount transport	ULD transport	loose transport	specfic for loose import	specfic for loose
c1	24 hours a day	4	2	2	0	0
c2	from 0600 to 0200	2	1	1	0	0
c3	from 0600 to 0200	2	1	1	0	0
combined	from 0600 to 2200	4	2	2	1	1

Table 4: operating times of transport system and amount of transport resources used

5.5 Model simulation setup, verification & validation

Simulation set up
The average value key process at handling facilities during different runs were compared and statistically analyzed. The final settings selected for the simulation ,were 10 runs of 30 days, a shorter simulation run period could have been used but the a longer runtime was used, in order to easily compare simulation results with provided data of the companies.

Verification
The model has been verified by applying different verification methods. For each forwarder there are four different types of transport that can be generated for both import and export shipments

- Combined transport ULD
- Combined transport loose
- Single transport ULD
- Single transport loose

The different types of transport have been verified by creating shipments for each flow individually first and afterwards combining the different types of transport by creating shipment for more than one type of shipment. All process and decision logic for the different types of transport, from shipment generation to shipment processing at final destination within the model were analyzed in order to assess if the shipment and transport followed the right logic and sequence and in the end were either disposed of or returned to their base position. The amount of weight transport and amount of transport generated at a given time were also verified by having several variables in place that showed the amount transport that was active and the amount weight that was allocated to specific transport. While assessing these variables, the correct amount of transport was generated in relation to available amount of transport and that the total amount of weight allocated to a transport was with the possible range of weight that was accepted.

Validation

Given the lack of data it was only partly possible to validate simulation outcomes with actual data. Most of the simulation outcomes were validated based on expert judgment and observed timings during visits to handling facilities. The most important variables that were used to validate the model were:

- average company transport load factor (LF)
- average amount of transport movements per truck per shift
- average amount of shipments for loose import and export transport

In table 5 below the values show the LF of system and all companies fall within the observed average LF during visits of several facilities at Schiphol and information obtained during interviews.

30 days(imp/exp)	c1	c2	c3	system total	observed
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	1483	463	821	2767	n/a
Cargo processed [ton]	4301	985	1691	6977	within actual range
1 day (imp/exp)	c1	c2	c3	h1	
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	49	15	27	92	n/a
Cargo processed [ton]	143	33	56	233	within actual range

Table 5: LF Total transport movements for each company and amount of visits to handling company (import + export)

ULD transport movements / shipments total						uld shipments per transport				uld transport
ULD	**import**	**export**	shipments	import	export	import simulation		export simulation		company wide
c1	**349**	**384**	c1	518	574	1,5		1,5		1,5
c2	**25**	**23**	c2	26	23	1,0		1,0		1,0
c3	**171**	**203**	c3	224	254	1,3		1,3		1,3
loose transport movements / shipments total						loose shipments per transport				loose transport
loose	**import**	**export**	shipments	import	export	import sim	actual data	export	actual data	company wide
c1	**475**	**316**	c1	2240	2105	4,7		6,7		5,5
c2	**206**	**208**	c2	1418	1765	6,9		8,5		7,7
c3	**155**	**201**	c3	918	682	5,9	3 to 10	3,4	5 to 10	4,5

Table 6: Total amount of shipments transported for import/export and loose and ULD transport (30 days)

Table 5 and Table 6 above show that the amount of transport generated, cargo processed and shipments that were handled with the simulation model, can be realistically validated on basis of both information provided during interview and actual observations at different handling facilities. For ULD transport however no data was provided by the involved companies, therefore only loose cargo transport movements could be validated with actual data, which can be viewed in white blocks of the table 6 above. In order to validate extreme value of several process and throughput times of the system were also in line with the actual observed situation. The minimum, average and maximum value of several processes regarding certain shipment flows of the involved companies have been analyzed. The analyzed processes values can be found in Table 7 below and show that all values observed after 10 simulation runs of 30 days fall within the defined maximum values. These defined maximum values have been derived from interviews information with industry experts.

time unit [hours]	c1	c2	c3	c1	c2	c3	c1	c2	c3	max
transport part	average			minimum			maximum			
shipment throughput import ULD	0,8	0,7	1,5	0,4	0,4	0,4	2,1	1,5	7,8	<10
shipment throughput import loose	1,3	2,7	3,1	0,5	0,4	0,5	3,8	14,9	18,2	<30
shipment throughput export ULD	0,9	0,7	1,2	0,4	0,5	0,5	2,7	1,6	7,7	<10
shipment throughput export loose	1,5	2,2	2,1	0,7	0,5	0,6	6,9	13,2	15,4	<18
entire system time	average			minimum			maximum			
entire import time	6,8			1,8			25,9			<30
entire export time	1,7			0,4			15,4			<18
Unloading before transport	average			minimum			maximum			
Process ULD at import h1	2,7			1,0			4,0			<4
Process loose at import h1	6,3			3,0			10,0			<10
(Un)loading at transport h1	average			minimum			maximum			
Single loose cargo unloading	0,3			0,2			1,3			<2
Combined loose cargo unloading	0,2			0,1			0,6			<1
ULD unloading	0,1			0,1			0,2			<1/3
Single loose cargo loading	0,3			0,2			1,5			<2
Combined loose cargo loading	0,1			0,0			0,6			<1
ULD loading	0,1			0,1			0,2			<1/3

Table 7: system values [minimum, average & maximum] for each forwarding company related shipment transport and process related times [hours]

5.6 Limitations of the model

In the simulation model transport of export and import were not combined for the involved forwarders. Only fixed capacity was used for both single and combined transport. However, in reality large forwarders use a combination of both fixed and variable capacity. Transport combinations between different handlers for one or more forwarders have not been analyzed, due to the lack of data and knowledge about transport allocation. Weight distribution and arrival stability are based on general assumptions and generic data of Schiphol. It may the case that one or more of the analyzed companies have a different weight distributions or arrival distributions. The simulation model also does not facilitate transport collecting and delivery of both ULD's and loose cargo within one truck. This does however occur during normal operations. One important logic to improve the model that could not be proven is the information related to actual deadline of shipments for onward transport which would make this information possible to allocate shipment to either combined or single transport based on deadlines, potentially improving both the use of combined and single transport. Finally it can be expected that the use of combined transport can improve the reliability of single company transport, especially when single transport before has been combining shipment collection and delivery to multiple air cargo handlers. However given the limited scope of the model that only focus on transport movements between one air cargo handlers, the involved forwarders' potential improvement cannot be shown with this model.

6 Simulation results of air cargo transport organization at Schiphol

6.1 Single transport system performance

In order to compare the transport performance of combined transport with single transport the simulation model was first constructed for single transport movements only. Table 7 above and Table 8 below reveal the performance of single transport system for the total transport of the forwarding companies on both loose and ULD cargo transport. These tables will be used to compare the performance of single company and combined transport. The values defined in these tables already clearly shows that the different amount of transport capacity available at forwarding companies in relation to their total amount of cargo, which causes different average throughput times of both import and export transport flows of ULD and loose shipments for the involved forwarding companies.

Throughput times average of single transport [hours]	c1	c2	c3
loose import transport	7,6	9,1	9,5
loose export transport	1,5	2,2	2,1
ULD import transport	3,6	3,5	4,3
ULD export transport	0,9	0,7	1,2

Table 8: Overview of average throughput times of single company transport shipments for ULD and loose transport

Table 10 below shows the system totals and average throughput times for single company organized transport for both ULD and loose cargo transport. Not surprisingly, the average load factor of ULD transport is much higher than single company loose transport, as the average shipment weight of ULD shipments is about 7 times higher than a single loose

cargo shipment. The Table 10 below also shows that there are two different values for shipments that arrive late. This difference in these two values is based on defined deadlines for shipments and late shipment arrival based on the throughput time of shipments. In order to compare the actual performance of combined transport in relation to its operation time and the process time of shipments, the second deadline time checks if the time of creation of shipments to delivery takes longer than specified in Table 9 below for four different shipments flows. These times have been based on process times and operations times of combined transport.

deadline times	import	export
ULD	12 hours	2 hours
loose	18 hours	2 hours

Table 9: throughput time deadlines for second deadline

Transport costs per kilo

The calculation of transport costs per kilo has been based on several values that were defined for this research in relation to the amount of kilos that were transported over time. The applied values and formula used for calculating the transport costs can be found in Appendix A.

Single company transport system total between forwarder and h1 (30 days)	amount of transport via single means	System wide loose transport	system wide ULD transport	System total
Total transport movements	import movements	837	541	1378
	export movements	726	609	1335
Cargo processed in [kilo]	import cargo	1615300	1762942	3378242
	export cargo	1642339	1956700	3599039
Load factor of transport	LF (kilo/ truck)	2084	3234	2571
Amount of shipments late	import shipments late	281	0	281
	export shipments late	15	0	15
Amount of shipments later than defined time	import shipments late	12	0	12
	export shipments late	4	0	5
throughput time transport	throughput time import	8,49	3,76	8,45
	throughput time export	1,84	1,01	1,76
transport costs per kilo	all cargo (import /export)	€ 0,0383	€ 0,0336	€ 0,0358

Table 10: Overview of transport performance of ULD and loose transport on system level

6.2 Combined transport potential

Three scenarios were defined which involved a different level of collaboration, which are presented below.

Low level collaboration [60% shipment allocation for all flows for collaboration]

With low level of collaboration it would be better for loose cargo transport collaboration to accept larger shipments, in order to ensure costs effectiveness of combined loose transport, therefore the limit of shipment weight is set at 3000 kilo. Given the fact that a 1250 kilo fixed capacity had a positive impact on shipments that arrive on time for both import and export, this will also be used for the lower level of collaboration. Besides these changes, the procedure to increase the load factor due to low level of cargo collaboration, waiting until 45 minutes or 3750 kilo of loose cargo is also applied for import and 2500 kilo and 30 minutes for export. This will result in some undesired effects when more cargo is allocated to collaboration, but given the fixed capacity and lower amount of cargo it will be applied in this scenario.

Medium level collaboration [80% ULD (imp/exp), 70% loose [imp/exp] all companies' shipment allocation for collaboration transport]

Fixed capacity is added for both import and export until 1250 kilo, as this had a positive result in previous scenario analysis and also worked well in the base case scenario of collaboration. The procedure to wait for cargo is set 2500 kilo and 30 minutes for import/export flows of loose shipments, however it is not increased further for import. The 2500 kilo max weight for combined shipments is kept at 2500 kilo, as was defined in the base case, given the notion that a larger volume of cargo is already allocated to combined transport. No other settings were changed regarding shipment processing times or capacity of combined transport.

High level collaboration on small shipments [90% ULD (imp/exp), 90% loose [imp/exp] all companies shipments allocated for collaboration transport]
Other than in the previous scenario, fixed capacity is only added for export loose cargo up to 1250 kilo, and shipments are only accepted for collaboration with a maximum weight of 2000 kilo. Also holding and waiting for transport demand is increased from 1250 kilo to 2500 kilo and from 15 minutes to 30 minutes before transport only for import and not for export loose cargo, as more export cargo demand more frequent transport in order to limit the increase of throughput times and the amount of shipments that arrive late for export transport. For import shipments the increase in throughput times can be more acceptable.

6.2.1 Combined ULD transport

Table 11 below shows the performance of combined ULD transport for the previously defined collaboration scenarios. It clearly shows that the fixed capacity combined ULD transport can only support effective ULD transport up to a certain level and that when a high limited amount of ULD cargo is allocated to combined transport it does not perform as well as the average single ULD transport without any level of collaboration. The throughput time increase for export by ULD combined transport is almost double the average time of single company ULD transport, in all three scenarios, this might not make it attractive for supporting this type of transport collaboration, as ULD's for export are often only completed just before planed transport. Based on the performance of ULD transport in the three defined scenario's and relative small increase of throughput time for combined import ULD transport, supporting ULD transport up until a level similar to the medium collaboration seems to deliver the best result, as cost increase after further allocation of ULD transport to the concept. Further improvements could be made by separating the use of ULD transport for import and export flows, but this has not been analyzed in this research.

Combined transport ULD	collaboration extent	low	medium	high
Total transport movements combined	import movements ULD	316	358	365
	export movements ULD	406	490	515
Total amount of cargo processed by combined	import cargo ULD	1061039	1425047	1173913
	export cargo ULD	1165930	1582303	1739520
Average load factor of transport	LF ULD collaboration	3087	3549	3311
Amount of shipments late	import ULD combined	5	9	14
	export ULD combined	17	25	26
Amount of shipments later than defined time	import shipments late uld	4	10	17
	export shipments late uld	8	13	17
throughput time loose transport	throughput time import ULD [hours]	4,43	4,63	na
	throughput time export ULD [hours]	1,65	1,79	na
Transport costs	transport costs per kilo import uld	€ 0,023	€ 0,017	€ 0,021
	transport costs per kilo export uld	€ 0,021	€ 0,015	€ 0,014
Amount of potential reduction of movements	import movements	10	79	-5
	export movements	-43	3	27
	% of total movements loose	3%	-7%	-2%

Table 11: Overview of combined ULD transport performance in relation to different ULD allocation scenario for combined transport

6.2.2 Loose cargo transport

The analysis transport performance is based on the combination of the three simulated level of collaboration for loose cargo based on values of Table 12, which shows that the combined transport system is able to transport even a high amount of loose cargo without a significant increase in average transport throughput times, however the amount of shipments that arrive after set deadline and are late, do increase extensively. While technically possible to transport all loose cargo with the combined transport system, it is up to the preference of forwarding companies to which level they will support combined loose transport, as increased load factors and reduction in transport movements at certain point could also mean that the amount of transport visits to the forwarder warehouse comes to an unacceptable level, in relation to the way operations can be executed. It can therefore be expected that not all cargo of both import and export flows will be allocated to loose combined transport. Given the operational constrains and operational preference it will make it difficult to support all generated shipments by combined transport, this can especially be the case for export shipments were customs and security related checks could make the urgency of shipments higher than previously defined.

Combined transport loose	collaboration extent	low	medium	high	base
Total transport movements combined	import movements loose	271	313	321	346
	export movements loose	257	267	300	309
Total amount of cargo processed by combined	import cargo loose	871753	1025973	1329017	1068987
	export cargo loose	881576	1008500	1241788	1014436
Average load factor of transport	LF loose collaboration (kilo/trailer)	3323	3511	4139	3183
Amount of shipments late	import	335	402	555	431
	export	135	165	197	153
Amount of shipments later than defined time	import shipments late loose	16	21	35	24
	export shipments late loose	85	91	112	89
throughput time loose transport	throughput time import loose	9,71	9,80	9,91	9,03
	throughput time export loose	3,60	3,55	3,43	3,36
Transport costs	transport costs per kilo import loose	€ 0,028	€ 0,024	€ 0,018	€ 0,023
	transport costs per kilo export loose	€ 0,028	€ 0,024	€ 0,020	€ 0,024
Amount of potential reduction of movements	import movements	181	219	368	208
	export movements	133	179	249	140
	% of total movements loose	-20%	-25%	-39%	-22%

Table 12: Overview of combined loose transport performance in relation to different loose allocation scenario for combined transport

6.3 Performance of combined transport

In order to assess the change in performance of combined transport based on the amount of collaboration that is supported, the amount of transport movements and transport costs per kilo for the different transport flows, are shown in Figure 5 &

Figure 6 below. These figures show that allocating more shipments to combined transport, positively impacts the transport costs, as expected given the fixed amount of transport used. The decline in costs is less when the collaboration is moved to highest level of collaboration for ULD transport, but does decline even stronger for loose transport with only a limited amount of extra transport movements. It therefore can be assumed to be beneficial to support the highest level combined transport possible, however as explained before, the average throughput times keep on increasing for combined transport shipments and also results in more shipments that arrive late and after the defined deadline times, therefore it cannot be said that the performance of combined transport at the highest level of collaboration is better than other levels of collaboration. It can only be concluded that the amount of cargo that is transported and the average load factor can still increase which will give lower transport costs and less transport movements in total for combined transport. Its effects on the use of single transport can be expected to be less positive when only a limited amount of cargo can be transported by single company transport, as it will become even harder to combine the remaining single transport shipments in an effective way.

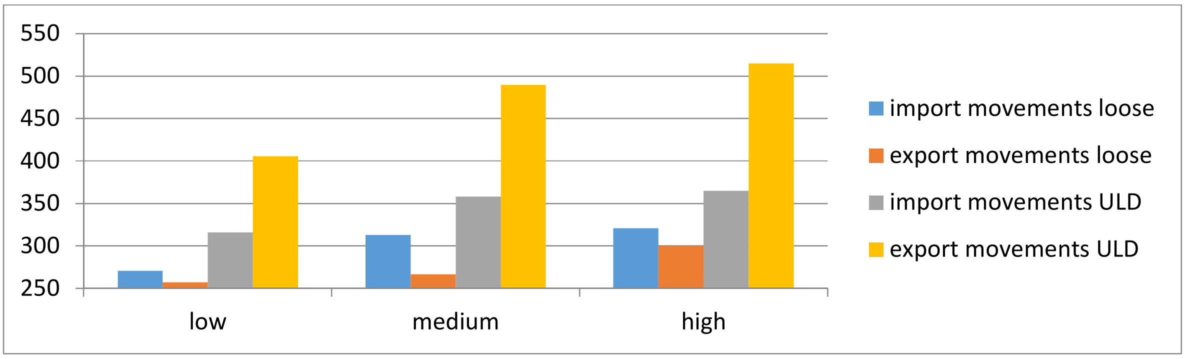

Figure 5: overview of combined transport generation in relation to different amount of shipment allocation to combined transport

Figure 6 below shows that the transport costs per kilo increase for ULD import transport when high level collaboration is supported, which can be explained by the fact that combined ULD transport between import and export is shared, with priority that is given to export transport. With a high level of combined ULD transport, more export ULD transport is realized and less import transport can therefore be generated. This shows that combing ULD transport for both import and export flows only works until a certain level with the fixed capacity has been defined.

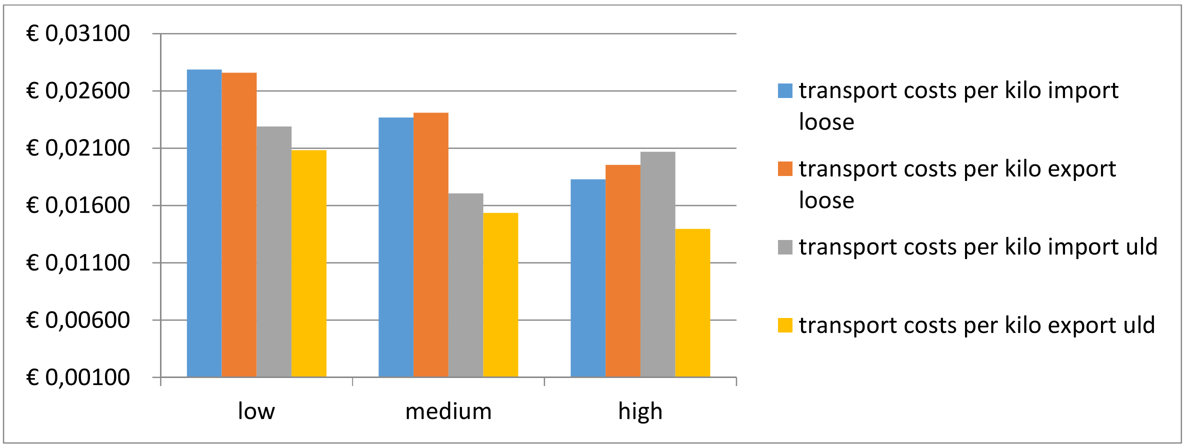

Figure 6: transport costs per kilo for the different types of combined transport in relation to the amount of shipments allocated to combined transport

7 Conclusion, discussion and future research

7.1 Conclusion

The paper has described both a qualitative analysis on air cargo transport collaboration with the air cargo industry combined with a case study analysis and simulation of horizontal collaboration for air cargo transport at Schiphol.

The main research question of this paper was:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and economics of truck transport at Schiphol airport?

The declining average shipment size combined with the ever increasing dynamics of shipment arrivals at both air cargo handlers and forwarders around Schiphol airport will make it increasingly difficult for even large forwarders to collect and deliver their shipment to a specific air cargo handler in an effective way. This especially relates to loose cargo shipments, as ULD shipments often justify single company transport based on weight and break down times for even a single shipment. The simulation model results show that supporting combined transport can be used to;

- increase the amount of cargo shipments that can be collected and delivered within a given time period
- it can reduce the total amount of truck movements between the air cargo handler and the forwarding warehouses for certain part of shipments
- it can increase the frequency of delivery of shipments for smaller forwarder companies
- it increases the average throughput time of shipments for all companies
- it can reduce the transport costs for shipments that are transported by combined transport
- it does not in all cases reduce the total amount of transport movements
- it increases the time single company transport resources are not utilized

The amount of flexibility the involved forwarders can/will expect in order to support longer average throughput times of both loose and ULD shipment for combined transport and to which extent single transport movements can be reduced, define for a large extent what possible transport improvements can be made by using combined transport. A balance will have to be found between the reduction in costs, amount of transport movements and indirect benefits that could be derived from applying combined transport, which could not all be calculated by the simulation model. Given the fact that combined transport can on average result in shipment throughput increases of between 1 to 3 hours, it can however be expected that not all of the shipments that are been offered for collecting of the involved forwarders will fall within higher throughput timings. When however forwarding companies are able to allocate a large degree of their shipment transport to combined transport and also do not significantly increase their use of single transport for the collecting of the remaining shipments, both transport costs and transport movements can be significantly reduced. Collaboration transport for both loose and ULD transport can be realized in a more cost effective way than single company transport even for the lowest level of collaboration defined scenario. However the performance and frequency of combined and

single transport after supporting combined transport will reveal if combined transport can actually be supported on the basis of lower costs alone. Not all companies that will support combined transport will be able to reduce total transport costs by only supporting combined transport at one specific air cargo handler. Indirect benefits that could be derived from applying combined transport should therefore also be analyzed in depth. Companies that are involved in horizontal collaboration at Schiphol should have sufficient scale demand on a regular basis to and from a specific handler to justify the application of combined transport with the use of fixed capacity over a limited period of time. Within the current system at Schiphol, it can be difficult to find the right number of companies based on their size and amount to support horizontal collaboration in an effective way. This is due to the fact that the amount of companies that can be considered for collaboration are limited due to the locations of warehouse and operations involved forwarding companies around Schiphol. Export collaboration does not only require similar flows or operations but also status of cargo related to security, documentation and customs in order to speed up handling processes at the handling facility. This is why it is easier to realize transport collaboration on import flow, as transport within the airport area inbound wise is less restricted. Even if collaboration on combined transport only slightly reduces the amount of trucks arriving at the handling facility it can still realize other benefits that would be important for both forwarder companies and the handler. The air cargo handler will have more control and stability over part of the trucks that come to deliver and collect shipments, which will still make it able to better plan its resources when a limited amount of cargo is allocated to combined transport systems. It can also give forwarders the ability to manage part of their transport needs with less effort and to obtain lower costs and this will make it possible for them to better utilize their organizational and transport resources for more urgent/ high care shipments. The ability and willingness of companies involved in collaboration to make the combined transport work is also highly important, when companies are more flexible and supportive regarding faster direct processing of combined transport flows the attractiveness of combined transport can further improve.

7.2 Discussion

The actual effects of using combined transport on single transport performance are currently unknown, this is why it is very difficult to state to which extent combined transport can improve both operational performance and transport costs of the each company when looking at the total transport system. The results of this research can therefore not be directly translated into actual reduction in transport costs or improvements related to amount of transport deliveries within a certain time. This research tries to show the difference of combined transport and single transport and to which extent certain use of combined or single transport have an impact on the behavior of the involved transport system. The use of fixed combined transport can be compared to the use of single transport in several situations resulting in both significant reduction of transport movements and transport cost. However, how much of these benefits remain can only be quantified once the adapted use of single transport is known. For smaller forwarding companies it can be more difficult to reduce their fixed amount of truck by supporting only a certain amount of transport with the use of combined transport. Therefore reduction in cost can only be realized when more variable capacity is used instead of fixed capacity. Given the lack of data that was at hand on which this research simulation model is based, the findings of this research is only valid to a limited extent, and which is also why the results should be only used as guidance to understand the possible differences of using single or combined transport. Forwarders and air cargo handlers around the world should use this research to assess whenever their operations can be realistically validated with the data of this model. Lack of information about the actual throughput times of forwarding companies shipments could for example reveal when companies look at the defined KPI's of this research. This can make it difficult to relate the results of this research to the actual operations of forwarding and air cargo handlers. It can however be helpful for companies to get a better understanding on which type of KPI's single and combined transport can be measured and how allocating of cargo shipments with different volumes of cargo of several companies effects the cost base and performance of combined transport. The current use of mostly fixed transport capacity for single company transport is known to be costly and often ineffective, especially with the increasing dynamics of air cargo, small shipments sizes and large amount of different handling facilities that are operating at large air cargo airport. Due to the difficulty of reducing transport costs in total for all involved forwarders assessment of indirect KPI that could not be quantified by the simulation model are crucial to ensure that combined transport can possible be supported by larger group of forwarding companies. Currently however, many forwarder companies around the airport only judge their transport system performance on direct KPI's which benefits that do not reveal all relevant organizational performance improvements that come from applying combined transport, thus making it more challenging to implement and support combined transport for companies that cannot reduce their total transport costs by applying combined transport alone.

7.3 Future research

Given the lack of data on which this research is based, the first recommendation for future research is to construct an updated simulation model on air cargo transport with the use of more detailed actual data that can be used to validate the complete simulation model. The arrival of shipments and weight distributions of both ULD and loose cargo have been

based on the average amount of cargo processed over a certain period of time. However, it not being certain to which extent the used shipment arrival distribution can be applied to forwarders active around in general or that the arrival of shipments for both import and export greatly defers between forwarders. Future research should try to assess to which extent demand stability of cargo flows both on import and export actually exists for the forwarding companies that want to collaborate. The stability of demand will be crucial to define how fixed and variable capacity for each truck transport should be used in combined transport in order to improve both the transport performance and throughput times of shipments. This is why future research should look at the impact of using either a combination of fixed or variable truck transport capacity and use. In order for this it has to be clearly defined where extra capacity should be hired and how extra costs for hiring an additional truck will be allocated to the different companies involved in the collaboration. One of the major challenges that have been described is, to which the remaining single company transport can be organized. A way to improve the remaining single transport demand is by also using a combined transport services for individual transport needs on ad hoc basis. It is likely that planning the remaining single transport demand by one specific transport company for more than one forwarder could be organized more effectively than the transport planning of three companies individually. Therefore, future research should also look at how collaborative transport can be planned jointly for both combined company shipments transport and single company 'express' shipments transport between several forwarders and a specific air cargo handler. Only when both combined and single transport can be improved and are adapted after changes are made to transport, can the full potential of using combined transport be realized both on performance and cost base.

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Appendix A: Data used for calculation of KPI's

Transport costs per kilo cargo transported

The values provided by tables (1 and 2) below are used to calculate the costs per kilo of transport for specific flow per company. For the transport flows that do not have a specific transport resources allocated to import or export transport the costs for import or export transport are assumed to be half of the total costs.

kilo cargo transported / share ULD / loose	import		export	
	uld	loose	uld	loose
	1190026	900519	1319614	891044
c1	57%	43%	60%	40%
	58615	381919	53831	490300
c2	13%	87%	10%	90%
	514299	332861	583253	260993
c3	61%	39%	69%	31%

Table 13: Amount of cargo transported by individual transport for specific flows of shipments (30 days simulation)

Transport resource use				
	truck	hours	amount of trucks	
Company	rates (hr)	operating	uld	loose
c1	€ 45,00	720	2	2
c2	€ 50,00	600	1	1
c3	€ 50,00	600	1	1
com	€ 45,00	540	2	2

Table 14: truck rates, operating hours and amount of transport (30 days operations)

- transport costs for a truck per hour (tht_e)
- amount of trucks hired for specific shipment transport (ts_a)
- amount of cargo transport by truck resources (tr_c)
- amount of hours operating transport (h)

Transport costs per kilo $(tc_k) = \left(\frac{tr_c}{ts_a * tht_e * h}\right)$

Transport movement reduction potential

Due to the fact that single transport is not rationalized in the simulation, a formula is defined that can define the potential reduction of transport movements by applying combined transport. In order to do this the transport movements and amount of cargo transport by single and combined transport for specific shipments is used. Data of table 10 and 11 is used for combined transport movements together with single company transport movement data of table 9. The reduction potential compares the amount of movements that single transport would need to transport the same amount of cargo that is transported by combined transport, the reduction in movements compared to the actual amount of combined transport is calculated and the remaining amount of cargo is assumed to be transported with the same load factor as in the single company transport situation.

- total amount of cargo transport import single company transport loose ($tisl_c$)
- total amount transport movements import single company transport loose ($tisl_t$)
- total amount of cargo transport import combined company transport loose = ($ticl_c$)
- total amount transport movements import combined company transport loose ($ticl_t$)
- total amount of cargo transport export single company transport loose ($tisl_c$)
- total amount transport movements export single company transport loose ($tisl_t$)
- total amount of cargo transport export combined company transport loose ($ticl_c$)
- total amount transport movements export combined company transport loose ($ticl_t$)

Import reduction potential $(tpci_t) = tisl_t - ((1 - \left(\frac{ticl_c}{tisl_c}\right) * tisl_{t)}) + ticl_t)$

Export reduction potential $(tpce_t) = tesl_t - ((1 - \left(\frac{tecl_c}{tesl_c}\right) * tesl_{t)}) + tecl_t)$

The potential of inner airport horizontal transport collaboration

A case based assessment of horizontal air cargo truck transport collaboration at Schiphol airport

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Abstract

Horizontal transport collaboration is an unexplored way of organizing transport for most large air freight forwarding companies. The current difficult and more dynamic air cargo market conditions in Western Europe have recently increased the focus of forwarders on both reducing transport costs and improving transport performance. By applying horizontal transport collaboration it could result in improvements on transport performance and costs. This paper tries to justify the quantification of the potential of inner airport truck transport collaboration on a horizontal level for large freight forwarding companies. A simulation model is constructed for part of the air cargo truck transport movements within the airports surroundings and the main finding of the simulation model is that horizontal collaboration can improve both the amount of transport visits to involved forwarders facilities and reduce transport costs. Up to 40% reduction of costs and 30% reduction on transport movements to air cargo handler can be realized, compared to single company transport use. The reduction of the total amount of transport movements can only be reduced when the remaining amount of single company transport is also adapted. Thus, the application of the current simulation model is limited, as the model has been based on limited information of operation of selective number of forwarding companies. The quantified results and input data will therefore have to be further validated with more specified data of the actual transport systems in order to increase generalization of the results and usability of the model. Also, future research should be directed at validation of data the combined transport simulation model and should include other forms of transport collaboration, such as the use of variable capacity instead of solely using fixed capacity for combined transport.

Keywords: horizontal collaboration, airport logistics, air cargo, forwarders, air cargo handling, transport performance

1 Introduction

Traditionally large shippers of goods have been developing and supporting their transport needs internally (Sahay, 2003). In the last 30 years however, many shippers have started to collaborate with other companies within their own supply chain on transport organization related activities (Mason, Lalwani, & Boughton, 2007). This type of vertical supply chain collaboration has matured in many ways over the last decades; to the extent that achieving a competitive advantage by applying only vertical collaboration has been strongly reduced in highly competitive industries. Vertical supply chain collaboration has in general moved from being a differentiating strategy, to a widely and commonly applied approach that is used to support and improve the management of a specific entire supply chain. Customer preferences and transport requirements have become more challenging and demanding in recent years (Capgemini, 2010; Pyza & Golda, 2011), which has resulted in a much smaller and faster changing production flows, between major manufactures and the main consumer markets around the world (Maskell, 2001). It has therefore become increasingly difficult to improve both costs and operational performance by collaborating only with companies within a single supply chain. Increased energy costs for transport, stricter government regulations on transport use and increased focus on sustainability of transport by major costumers, have also made the effective management of supply chain more difficult by applying only vertical supply chain collaboration. In several large production industries, like the fast moving costumer goods sector (FMCG), major manufactures of goods have therefore started to collaborate with competitors, in order to able to reduce the transport cost, increase the frequency of delivery and meet other operational requirements demanded by their customers. This type of collaboration is known as horizontal collaboration. It involves the collaboration of companies that are conducting business operations on the same level of the value chain. Recent horizontal transport collaboration projects in Europe has shown that, costs savings on transport of more than 20% can be achieved by applying horizontal collaboration on transport and distribution (DHL, 2011; Vanovermeire, Sörensen, Breedam, Vannieuwenhuyse, & Verstrepen, 2011), while in the same time also improving the operational transport performance.

Collaboration on horizontal level within the air cargo transport system has been found to be non-existing in current literature, whereas this type of collaboration proved to be successfully applied in other transport systems. Previous high growth rates, between 1972 and 2005 (Worldbank, 2012), combined with healthy operations margins had limited the need and support for transport collaboration in air cargo transport system. Companies in the industry have been able either to optimize their supply chain in a cost effective way with their own means or have been able to justify inefficiency due to high operational margins. However the increased competiveness of the air cargo industry and declining operating margins (IATA, 2012) have made it more difficult for individual companies to maintain an acceptable level of transport performance and transport costs. Given this notion and the fact that a pilot project was started at Schiphol airport regarding transport collaboration in September 2012, an unique opportunity was presented for this research; to analyze a real case transport horizontal collaboration project and to analyze the potential of horizontal transport collaboration within a large air cargo system at a major European cargo airport with the use of actual data.

The objective of this paper will be: to quantify the main effects that applying horizontal transport collaboration will produce, for inner airport transport based on performance and costs. This research will contribute to support further analysis on transport collaboration in dynamic networks, by revealing results on actual case study of collaboration and pointing out the key difference of collaborative and single company transport use on set of defined key performance indicators (KPI's). Developments related to air cargo shipment transport and air cargo handling are also analyzed in order to assess how the value of collaboration on transport could change over time.

The following question will be the main question of this research paper:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and cost of truck transport at Schiphol airport?

In the following section two, the current literature on supply chain collaboration will be analyzed. Section 3 points out the most important current and future developments of air cargo industry in Western Europe in relation to the transport system inner airport transport. In section 4 the case study of transport collaboration at Schiphol will be described in order to justify the selected case study. Section 5 will explain why the simulation approach is used and will describe the key processes of model construction and validation. Section 6 will show the results of both single and combined transport performance based on the analyzed case study simulation model. Finally in section 7 the research question will be answered, limitations and directions for further research will be pointed out.

2 A state-of-the-art literature review on supply chain collaboration

Research on the subject of horizontal transport collaboration related to actual case studies has been found to be limited in current literature (Audy & D'Amours, 2008; Cruijssen & Salomon, 2004; Vanovermeire et al., 2011). The majority of the research regarding transport collaboration focuses on vertical supply chain collaboration (Holweg, Disney, Holmström, & Småros, 2005; Visser, 2009). Research is often aimed at showing the value and challenges related to applying supply chain collaboration on a vertical level and how supply chains can become more competitive by doing so (Sahay, 2003). Most of the research on supply chain collaboration does not focus specifically on transport. This can be explained by the traditional focus of supply chain management on reduction of transport costs and not on optimal of value transport costs, as has been pointed out by the research of (Mason et al., 2007). It points out in general that when only a cost focus is applied, relationships will between companies will be short term and on purely operational level. Often these types of relationships are not defined as true form of collaboration but arm's length relationships. Many challenges currently exist that have limited the actual intended impact of collaboration both on vertical and horizontal way (Barratt, 2004). Therefore recent research has looked at important variables that are related to supporting and managing supply chain collaboration in a segmented way, to improve the desired outcomes and limit the investments needed to setup and maintain effective collaboration. To realize this, segmented relationships have to be formed that reflect the ability and willingness of companies to collaborate (Rezaei & Ortt, 2012). When applying and managing transport with two or more companies operating on the same level of the value chain, this often requires longer term relationships, in order to justify and support the set up this type of transport, it can be more complex to establish and maintain such relationships (Stephens, 2006). This can be further explained by the research of (Lambert, Emmelhainz, & Gardner, 1996), which defines different levels of relationships between companies based on extent and goal of collaboration. It points out the most important aspects that define to which extent a partnership is based on the facilitators and drivers for a partnership. Key elements in the partnership model relate to organizational comparability, symmetry and trust. When companies have not collaborated before with other companies or lack the knowledge regarding the application of collaboration (Muir, 2010) it is more difficult to realize and support collaboration. Given the limited application and knowledge of horizontal transport collaboration, it is not surprising that such collaboration has seen limited development. Companies currently have more experience with application of vertical collaboration and have also more knowledge on the application of such collaboration. However the benefits of applying horizontal transport collaboration on not only transport costs or transport performance are also becoming better known, as has been pointed out by (Cruijssen, Cools, & Dullaert, 2007). The potential of horizontal transport is therefore growing, due to more dynamic markets conditions and changing customer requirements (Leitner, Meizer, Prochazka, & Sihn, 2011). The drivers to support horizontal collaboration in supply chain management are increasing in several industries, especially when vertical collaboration cannot achieve similar results or is even more difficult to realize. Collaboration in the air cargo sector has been limited and has mainly focused on collaboration between airlines (Agarwal, Ergun, Houghtalen, & Ozener, 2009), due to liberation of a key air cargo market around the globe, major airlines have started to collaborate with airline partners to share capacity and improve profitability. Within the airport system only limited collaboration has been established based on vertical collaboration regarding the coordination of transport movements to a specific air cargo handler (Franz & Stolletz, 2012a).

3 Conceptual model for air cargo airport transport collaboration

Different definitions have been found for horizontal collaboration/cooperation for example; "collaboration between parties that are at the same level between resources and final products is defined as horizontal collaboration" (Visser, 2009, p. 9) or "concerted practices between companies operating at the same level(s) in the market or logistic chain is defined horizontal cooperation"(Leitner et al., 2011, p. 333). Horizontal transport collaboration (HTC) in this paper will be defined as: all activities that can be associated with a predefined and coordinated collection and delivery of cargo involving two or more companies that are not part of the same supply chain, which operate on the same level of the value chain, to one or more destination within the supply chains of the involved companies. The conducted literature review has shown that realizing and supporting collaboration within a supply chain and between supply chains can be a challenging and difficult process, but the potential to realize performance or costs improvements by applying horizontal collaboration is growing. In order to show the potential of ground transport collaboration in the air cargo system, challenges of current single company transport will be related to opportunities of combined collaborative transport. Figure 1 below shows the way transport is now normally organized for large forwarders and how transport can be organized by collaboration between different air freight forwarders and one or more air cargo handlers. The figure shows shipments of several forwarders that are linked to one or more airlines that arrive at an air cargo handler. Currently most forwarders collect and deliver shipments linked to a specific airline individually, which produces extensive amount of transport movements between forwarders warehouse and air cargo handler.

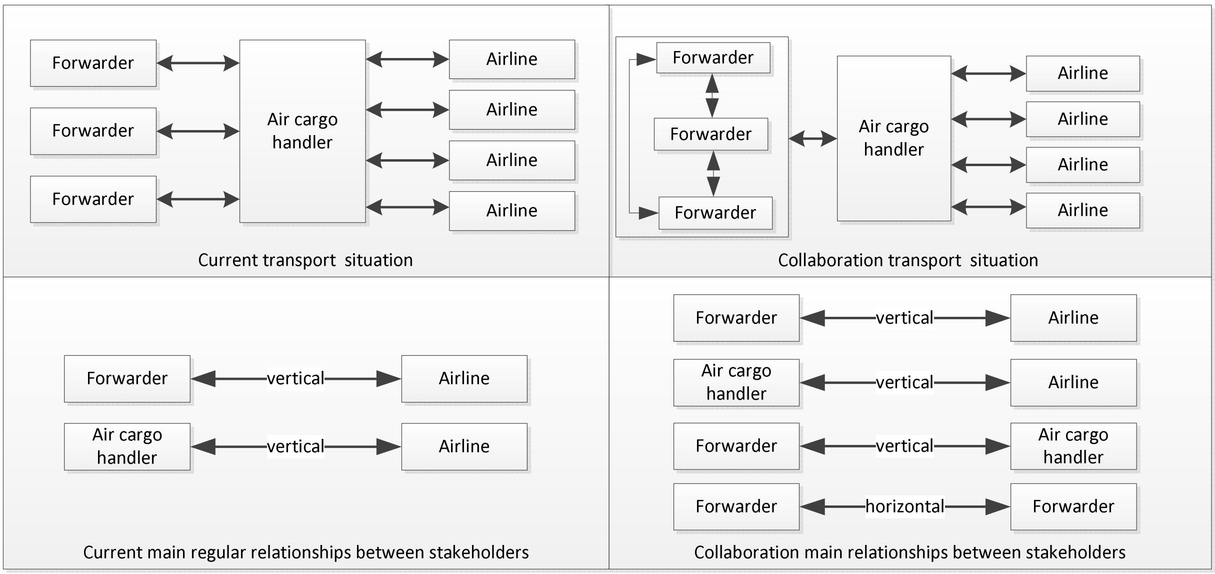

Figure 1: transport flows of air cargo shipments between forwarders, air cargo handler and airlines and main relationships between stakeholders within a general air cargo system

The number of forwarders, airline and air cargo handlers at a given major air cargo airport has increased extensively over the last few decades, due to liberation of major air transport markets (Zhang & Zhang, 2002), growth of international trade and the air cargo handling market. Previously air cargo transport system consisted of a limited amount of stakeholders and transshipment points. This combined with an average larger shipment size made it easier for freight forwarder companies, to cost effectively organize their own transport than it is now. However, increased fuel costs, changes to the supply chain of major users of air cargo transport and an increase in air cargo transport capacity both within an airport and via secondary airports have reduced the average shipment size and stability of air flows between forwarders and airport cargo handling facilities. Until recently large companies operating globally had been increasing their regular use of air transport for part of their supply chain, as a competitive advantage, in order to be able utilize their different production facilities and react to costumer demand in a more efficient way (Yuan, Low, & Ching Tang, 2010). Slower growth rate of air transport in relation to global transport shows however that the use of air transport, as preferred transport means of transport for certain large manufactures has been reduced in key markets (Loadstar, 2013). This can be explained by the use of alternative forms of transport, due to recent experiences with dependence on air transport with major disruptions (Graebel, 2012; TNO, 2012), the move of production faculties around the world (Appold & Kasarda, 2011; Eurostat, 2011) and increased attractiveness of alternative forms transport compared to air transport, based on transport costs in relation to product value. These mentioned developments have also put further pressure on the average air freight rates and operational margins of both airlines and other stakeholders involved in the operations related to the market of air cargo transport to and from Western Europe (IATA, 2012). These developments have caused an increase in the number of transport movements between forwarder facilities and the air cargo handling facilities, with similar or fewer amount of cargo transported, an increasing in the transport costs and reducing transport performance, while at the same time presenting lowered operations margins. When transport movements of several forwarders are combined, between one or more air cargo handlers, the amount of transport movements to the handling facility can be reduced, at the same time the frequency of delivery can be maintained or increased, with lower cost and higher average amount of cargo transported, which is shown in transport collaboration situation Figure 1. The current challenges and decline performance of single company transport shows that there is a large potential to practice collaboration on transport between forwarders located close to a major airport and one or more handling facilities. In order to support collaborative transport, new relationships have to be supported that currently do not (always) exists both on a vertical (forwarder/air cargo handler) and horizontal level between forwarders.

4 Case study of air cargo transport collaboration at Schiphol airport

Amsterdam airport Schiphol is one of the biggest air cargo airports in the world. It is currently positioned in the top five of largest passenger and cargo airports within Europe (Schiphol, 2012) and also ranks within the top 20 of largest airports in the world on these two aspects. Schiphol airport has recorded large growth of its air transport operations related to the amount of cargo that has been processed on yearly basis. The airport has realized an average growth rate of 6,2% a year from 1972 till 2007 (Ramaaker, 2012), also other established air cargo airports in Western Europe have previously seen similar growth rates (DT, 2009). The introduction of European Directive 96/67/EC on the liberalization of passenger and air cargo handling market in Europe has had a big impact on the amount handling companies at major European airports with most of these (new) handling companies investing in new facilities or expanded existing facilities at major airports. Schiphol is a prime example of this as currently six general handling facilities are operating at the airport. The last five years, the average growth rate at large airports like Schiphol has been negative. Based on the described developments regarding air cargo transport, in the recent past, the Western European air cargo market is expected to face a more challenging time in the future, compared to the relatively healthy growth and operating margins it has enjoyed in the last decades. This means that major stakeholders in the air cargo system that operate at existing major air cargo hubs like Schiphol airport will have to improve their system efficiency in order to stay economically viable and attractive. This also has to be realized with lower expected returns and a higher uncertainty on growth compared to other air cargo markets. Schiphol is a suitable airport for a case study analysis on horizontal transport collaboration, given the large amount of forwarders, airlines and handling facilities that operate at the airport. Also the large amount of air cargo that is processed on a yearly basis at the airport, the current over capacity, lower operating margins and declining average shipment size, make the potential of costs reductions by applying horizontal transport collaboration high at Schiphol. Many large air cargo airports in Europe have similar stakeholders and operations in relation to Schiphol and therefore results of a case study at Schiphol can also be useful for other large cargo airports.

5 Research method: simulation of horizontal transport collaboration

5.1 Simulation approach

A simulation method is chosen to reveal the potential of combined transport in relation to single company transport for this case study. Simulation can be used to show the value of changes to business processes and compare it with the current situation, which has been pointed out in research by (Khan, 2000), on an air cargo handling system. The ability to simulate air cargo handling processes that are in line with the actual situation has been proven by the researches of (Nsakanda, Turcotte, & Diaby, 2004) and (Esmemr, Ceti, & Tuna, 2010), which show that simulation can be used to obtain results of processes that are in line with the actual situation at air cargo handling facilities at major air cargo airports. This supports the applicability of using simulation to assess the impact of applying horizontal transport to air cargo systems. Actual historic data was provided by several stakeholders for this case study, thus making it possible to construct a simulation model based on actual input data and validate the results of the simulation to a certain extent based on data and observations. Besides these points, with a simulation model a different way of organizing combined transport can be assessed without actual implementation, hence without causing actual operational consequences that might not be desired. Thus, using a simulation model can also be useful for further analysis of the organization of air cargo transport systems at Schiphol or other air cargo airports.

5.2 Milkrun pilot & simulation model goal

The case study at Schiphol has been based on a selective flow of transport of three forwarding companies and one air cargo handler. Actual data of the year 2012 were used that were provided both by the analyzed companies combined with data of four other organizations, including data of Cargonaut and Schiphol Group. The suitability of the forwarding companies that have been analyzed and the extent to which they can be generalized, in relation to other handlers and forwarding companies, can be supported on several aspects. The analyzed forwarders all have a large share of 'general cargo' (CG) shipments (80 to 95%) and the analyzed companies rank in the top 15 customers for both import and export at the analyzed air cargo handler, in regards to the total weight of collected and delivered shipments over 2012. The GC shipments do not require any additional or special handling, which makes it suitable for collaboration transport, as only standard procedures are applied for handling these shipments. The analyzed air cargo handler ranks within the top three largest air cargo handlers operating at the airport and has large amount of different airline customers. This is important for the amount of cargo that is processed and the frequency of cargo shipments that arrive. Also the forwarding companies are located close to the analyzed air cargo handler and have a similar type customer base at Schiphol and at their most important other gateway stations at airports around the world. The basis for case study simulation came from increasing operational challenges that have occurred at several larger air cargo handlers at Schiphol, regarding the truck transport collection/delivery and shipment processing of loose cargo shipments. Transport performance of large forwarders operating around the airport has been reduced by these challenges; the costs of transport has increased and

reliability of transport has been reduced, as the pilot was aimed at only supporting collaboration on loose import cargo shipments transport. In order to analyze the complete potential of combined transport in relation to single company transport between the involved forwarding companies warehouses, the analyzed air cargo handler transport of ULD shipments, export transport of both loose and ULD shipments has been included in the simulation.

Goal of simulation model

The main goal of the simulation model is; to support decision making on the use and suitability of transport collaboration in relation to single company transport use. In order to realize this, the most important differences of combined and single transport are quantified on set of key performance indicators. Given that the described problem relates to transport costs, transport movements and timing, the following KPI have been defined as most crucial for the simulation:

- amount of transport movements
- amount of cargo processed
- transport costs per kilo
- average throughput time of shipments

5.3 Conceptualization of air cargo truck transport system

In order to better understand which processes and factors are relevant for the purpose of the simulation model, several tools were used to define a clear conceptual view of the transport system and its processes. The structured analysis and design technique (SADT) is one of these used and is explained in more detail below.

SADT diagrams

The highest level SADT diagrams have been defined both for forwarders and air cargo handles, which are explained below based on Figure 2. The process is defined both for import and export process, it shows that the processing of shipments relates to; document, shipment and truck processing and depends on many different resources within the analyzed facilities and information flows that is available to support the processing of shipments. Customs, security, documentation and transport also depend on and/or are influenced by other stakeholders that are involved in the air cargo supply chain. Given the extent of resources and information involved in processing are cargo shipment, this reveals that processing air cargo shipments can depend on many different elements, which are not all under control of the company in charge of the forwarding of air cargo handling facility. The process at the air cargo handler is also influenced by both airside and landside transport that can occur both to and from the involving forwarders. Transport can be conducted to and from other air cargo handlers and is also influenced by information from an additional party of the airline, on which behalf the air cargo handler has to process the shipments for a specific forwarder.

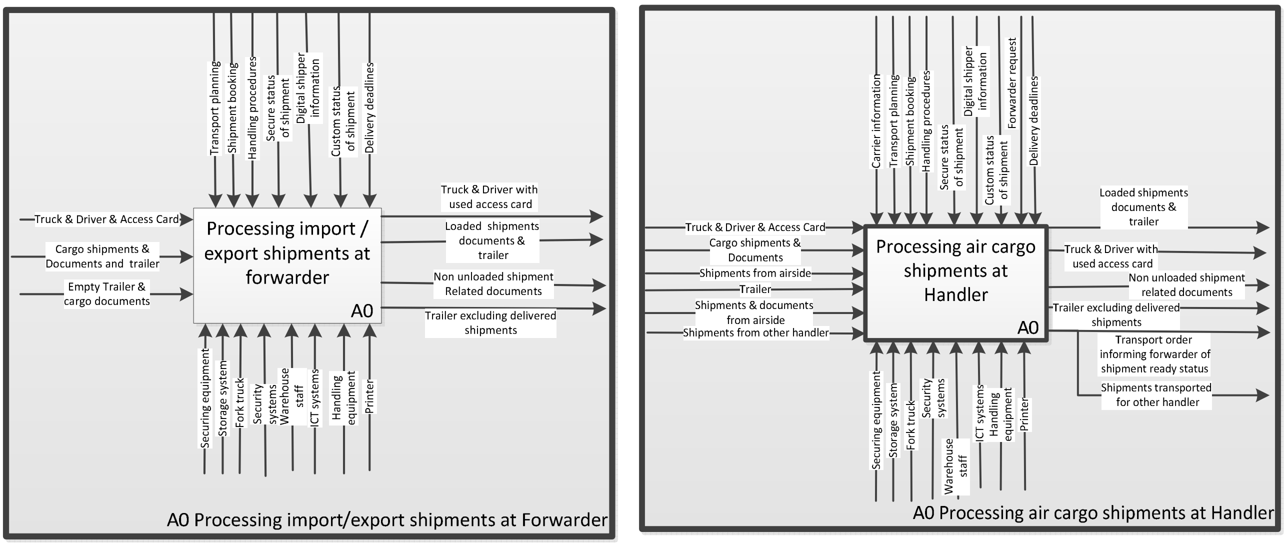

Figure 2: SADT top level diagrams process related to handling air cargo shipments at forwarder and air cargo handler

Given the extensive amount of processes that have been identified in the conceptualization, a simplified figure of the most relevant processes that will be used for the simulation model is shown below in Figure 3. It shows the different processes that an import or export shipment will go through from creation (generation) until shipment delivery at the final destination. The generation of shipments for import shipment will take place at the handling facility, whereas export shipments will be generated at the export facilities of one of the three forwarders. Import shipment are delivered at one of three import facilities of the involved forwarder and export shipments are all delivered to the handling company's export facility. Transport is generated at one of the different transport bases that have been defined, transport movements are planned by assessing the amount of shipments that are ready for collection and looking at the amount of transport that has been allocated to a specific set of shipments.

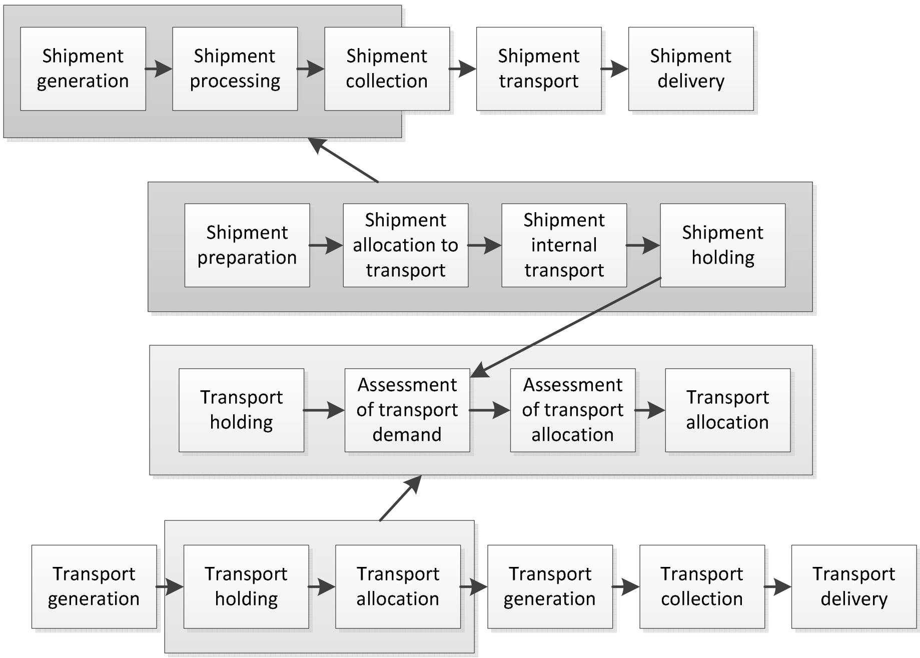

Figure 3: simplified processes of inner airport shipment transport system from generation to delivery

Based on interviews that were conducted with more than 10 different forwarders around Schiphol airport, the SADT analysis and other conceptual tools define a set of KPI's related to transport performance that are most important for air cargo inner airport truck transport system. The KPI's are shown in Figure 4 below.

Important KPI's

- Throughput times of shipments
- Transport holding time
- Transport costs per kilo
- Load factor of transport
- Amount of kilo cargo transported
- Amount of shipments on time
- Amount of shipments late
- Amount of transport visits to warehouse

Figure 4: main KPI's for transport performance of inner airport truck transport

5.4 Model specification & construction

The model has been based on the conceptual models of the previous paragraph and was specified with the use of several different data sources in order to define the input variables of the model. Actual cargo data of the year 2012 and information derived from interviews with air cargo experts have been combined in constructing the different input variables. Due to limited availability of data on detailed level, a large amount of the processes that has been defined in the previous paragraph were either simplified or not used within the simulation model. The most important input variables of the model will be discussed below.

Shipment arrivals & shipment weight

Data related to total shipment weight were provided for a certain time period regarding all shipments that were processed for each forwarder (import/export). System data related to forwarders share of cargo at the different handling facilities were used to estimate the amount of cargo that was assigned to the specific handler of this research. The general share of unit loading device (ULD) cargo and loose cargo was used to specify the total amount of ULD and loose cargo for each forwarder at the analyzed air cargo handling facility. Due to the lack of information on arrival distribution of shipments for the specific forwarders, shipment arrival was estimated using the average daily arrival and departure of flights at Schiphol (Schiphol, 2012), by using the hourly share of flights regarding the share of cargo that arrives or departs for each forwarder at a certain moment in time. The hourly arrival and departure of flights has been further simplified, by constructing three arrival periods for import and export shipments, which presented in Table 1 below. The weight distribution of loose cargo shipments was based on a lognormal distribution. A lognormal distribution was used for two reasons; several other researches regarding the simulation of air cargo shipments have used this type of distribution (Boonekamp, 2013; Huang & Chang, 2010) and a log normal distribution makes it possible to have shipments arrive spread over extensive value range. For ULD shipments, a normal distribution was used, this has been based on the assumption that all forwarders try to maximize their ULD shipment weight, therefore the spread of the weight is expected to be less and closer to the maximum possible weight.

		weight distribution import					
arrival shifts		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	6%	NORM (2300,100)	LOGNORM (350.600)	NORM (2300,100)	LOGNORM (150.400)	NORM (2300,100)	LOGNORM (310.600)
day peak	63%						
eveing peak	31%						
shipments per arrival		2	6	1	7	1	6
		weight distribution export					
depature shifts		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	2%	NORM (2300,100)	LOGNORM (390.600)	NORM (2300,100)	LOGNORM (180,400)	NORM (2300,100)	LOGNORM (330.600)
day peak	79%						
eveing peak	19%						
shipments per arrival		1	4	1	7	1	2

Table 1: arrival of shipments for ULD and loose cargo and weight distributions (shipment weight values in kilogram)

Cargo handling process

Observations at the different warehouse facilities at Schiphol, combined with information obtained at several interviews were used to define the handling times and processing of cargo shipments at Schiphol airport. Due to lack of data, processes timings for import and export were assumed to be the same for both loose and ULD cargo shipments. Given the relative high uncertainty about process times of loose cargo at a given handling facility, these processes times were based on exponential distribution. The exponential distribution seems to be the most suitable distribution for defining the processing times at the handling facility, as it has the following characteristics; values are independent of previous value, there is a large range and a variety of different values that occur with certain randomness. Also the research of (Franz & Stolletz, 2012b) uses an exponential distribution of the process times of trucks at an air cargo handling facility based on actual observed data. The main values of exponential distributions have been based on actual observed timings for single company transport and on expected values for combined transport. The defined distribution also gives maximum process times that are in line with the actual situation at the analyzed handling facilities at Schiphol. The handling times of ULD cargo at the handling facility and at forwarder for ULD and loose shipments is based on triangular distribution, as process times for these processes are much more stable and known.

Handling times (minutes)			
Handling times (un)loadingof	single loose	combined loose	ULD shipments
c1	TRIA(5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c2	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c3	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
h1	exp(8) +10	expo(4) +5	TRIA(4,6,10)
Processing import cargo at handler (hours)			
ULD shipments		TRIA (1,3,4)	
Loose cargo shipments		TRIA (3,6,10)	

Table 2: (un)loading times of shipments at different locations of transport (import/export) times in minutes and processing times of ULD and loose shipment sin hours

Transport logic & limitations of transport capacity
Transport logic and transport capacity have been based on expert judgment and interview information. Given the use of fixed capacity for transport of the involved forwarders and the lack of in depth knowledge on how transport is allocated to certain shipments, simplified transport logic was used. Transport priority was based on defined chances to export shipments ready for collection, as general export transport has higher priority than import. Besides this, another major simplification for transport generation is that at least one or more shipments should be ready for collection and that only when more shipments are waiting, which have not been assigned to a specific transport additional transport be would generated. Table 3 below shows the weight restrictions that were defined for different types of transport in relation to transport capacity for each truck. The maximum weight for transport has been set in line with the maximum shipment size. The weight limit of 10000 kilo for a specific transport has been based on the limitations that a truck has, regarding both volume and weight. In general, air cargo shipments are charged in a 1 to 6 ratio (Koning, 2012). This means that $1m^3$ of cargo equals to 166, 7 kilo of cargo. A trailer of a truck carrying 10000 kilo of actual weight therefore will use an estimated 60 m^3 of volume, while a generally used trailer for air cargo transport has a maximum capacity of 70 to 80 m^3. In order to allow for some flexibility with volume and stacking limitations of certain shipments, the maximum weight is set at 10000 kilo per trailer. Loose cargo transport is only limited by the total amount of weight, whereas for ULD transport is limited both on weight and amount of shipments that can be carried.

shipment weight	single (kilo)		combined (kilo)		trailer capacity	maximum weight	amount of shipments	
Loose	50	10000	50	2500	Loose	10000	1	∞
ULD	1800	2500	1800	2500	ULD	10000	1	4
	min	max	min	max			min	max

Table 3: shipment weight restrictions for single and combined transport and trailer capacity for loose and ULD transport

Transport resources & operating times
In reality certain freight forwarders combine ULD and loose cargo shipment. However, due to lack of information about the specific conditions under which these different types of shipments are combined, ULD and loose cargo will be transported separately in this model. This is also why specific transport units will be defined for ULD and loose transport, as decision logic regarding the allocating to either ULD or combined transport is unknown. In the model, operating times and amount of transport is defined in line with actual provided data by the analyzed forwarding companies. The operating times for both loose and ULD transport has been defined in the same way.

forwarding company single	operating times	amount transport	ULD transport	loose transport	specfic for loose import	specfic for loose
c1	24 hours a day	4	2	2	0	0
c2	from 0600 to 0200	2	1	1	0	0
c3	from 0600 to 0200	2	1	1	0	0
combined	from 0600 to 2200	4	2	2	1	1

Table 4: operating times of transport system and amount of transport resources used

5.5 Model simulation setup, verification & validation

Simulation set up
The average value key process at handling facilities during different runs were compared and statistically analyzed. The final settings selected for the simulation ,were 10 runs of 30 days, a shorter simulation run period could have been used but the a longer runtime was used, in order to easily compare simulation results with provided data of the companies.

Verification
The model has been verified by applying different verification methods. For each forwarder there are four different types of transport that can be generated for both import and export shipments

- Combined transport ULD
- Combined transport loose
- Single transport ULD
- Single transport loose

The different types of transport have been verified by creating shipments for each flow individually first and afterwards combining the different types of transport by creating shipment for more than one type of shipment. All process and decision logic for the different types of transport, from shipment generation to shipment processing at final destination within the model were analyzed in order to assess if the shipment and transport followed the right logic and sequence and in the end were either disposed of or returned to their base position. The amount of weight transport and amount of transport generated at a given time were also verified by having several variables in place that showed the amount transport that was active and the amount weight that was allocated to specific transport. While assessing these variables, the correct amount of transport was generated in relation to available amount of transport and that the total amount of weight allocated to a transport was with the possible range of weight that was accepted.

Validation

Given the lack of data it was only partly possible to validate simulation outcomes with actual data. Most of the simulation outcomes were validated based on expert judgment and observed timings during visits to handling facilities. The most important variables that were used to validate the model were:

- average company transport load factor (LF)
- average amount of transport movements per truck per shift
- average amount of shipments for loose import and export transport

In table 5 below the values show the LF of system and all companies fall within the observed average LF during visits of several facilities at Schiphol and information obtained during interviews.

30 days(imp/exp)	c1	c2	c3	system total	observed
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	1483	463	821	2767	n/a
Cargo processed [ton]	4301	985	1691	6977	within actual range
1 day (imp/exp)	c1	c2	c3	h1	
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	49	15	27	92	n/a
Cargo processed [ton]	143	33	56	233	within actual range

Table 5: LF Total transport movements for each company and amount of visits to handling company (import + export)

ULD transport movements / shipments total						uld shipments per transport				uld transport
ULD	**import**	**export**	shipments	import	export	import simulation		export simulation		company wide
c1	**349**	**384**	c1	518	574	1,5		1,5		1,5
c2	**25**	**23**	c2	26	23	1,0		1,0		1,0
c3	**171**	**203**	c3	224	254	1,3		1,3		1,3
loose transport movements / shipments total						loose shipments per transport				loose transport
loose	**import**	**export**	shipments	import	export	import sim	actual data	export	actual data	company wide
c1	**475**	**316**	c1	2240	2105	4,7		6,7		5,5
c2	**206**	**208**	c2	1418	1765	6,9		8,5		7,7
c3	**155**	**201**	c3	918	682	5,9	3 to 10	3,4	5 to 10	4,5

Table 6: Total amount of shipments transported for import/export and loose and ULD transport (30 days)

Table 5 and Table 6 above show that the amount of transport generated, cargo processed and shipments that were handled with the simulation model, can be realistically validated on basis of both information provided during interview and actual observations at different handling facilities. For ULD transport however no data was provided by the involved companies, therefore only loose cargo transport movements could be validated with actual data, which can be viewed in white blocks of the table 6 above. In order to validate extreme value of several process and throughput times of the system were also in line with the actual observed situation. The minimum, average and maximum value of several processes regarding certain shipment flows of the involved companies have been analyzed. The analyzed processes values can be found in Table 7 below and show that all values observed after 10 simulation runs of 30 days fall within the defined maximum values. These defined maximum values have been derived from interviews information with industry experts.

time unit [hours]	c1	c2	c3	c1	c2	c3	c1	c2	c3	max
transport part	average			minimum			maximum			
shipment throughput import ULD	0,8	0,7	1,5	0,4	0,4	0,4	2,1	1,5	7,8	<10
shipment throughput import loose	1,3	2,7	3,1	0,5	0,4	0,5	3,8	14,9	18,2	<30
shipment throughput export ULD	0,9	0,7	1,2	0,4	0,5	0,5	2,7	1,6	7,7	<10
shipment throughput export loose	1,5	2,2	2,1	0,7	0,5	0,6	6,9	13,2	15,4	<18
entire system time	average			minimum			maximum			
entire import time	6,8			1,8			25,9			<30
entire export time	1,7			0,4			15,4			<18
Unloading before transport	average			minimum			maximum			
Process ULD at import h1	2,7			1,0			4,0			<4
Process loose at import h1	6,3			3,0			10,0			<10
(Un)loading at transport h1	average			minimum			maximum			
Single loose cargo unloading	0,3			0,2			1,3			<2
Combined loose cargo unloading	0,2			0,1			0,6			<1
ULD unloading	0,1			0,1			0,2			<1/3
Single loose cargo loading	0,3			0,2			1,5			<2
Combined loose cargo loading	0,1			0,0			0,6			<1
ULD loading	0,1			0,1			0,2			<1/3

Table 7: system values [minimum, average & maximum] for each forwarding company related shipment transport and process related times [hours]

5.6 Limitations of the model

In the simulation model transport of export and import were not combined for the involved forwarders. Only fixed capacity was used for both single and combined transport. However, in reality large forwarders use a combination of both fixed and variable capacity. Transport combinations between different handlers for one or more forwarders have not been analyzed, due to the lack of data and knowledge about transport allocation. Weight distribution and arrival stability are based on general assumptions and generic data of Schiphol. It may the case that one or more of the analyzed companies have a different weight distributions or arrival distributions. The simulation model also does not facilitate transport collecting and delivery of both ULD's and loose cargo within one truck. This does however occur during normal operations. One important logic to improve the model that could not be proven is the information related to actual deadline of shipments for onward transport which would make this information possible to allocate shipment to either combined or single transport based on deadlines, potentially improving both the use of combined and single transport. Finally it can be expected that the use of combined transport can improve the reliability of single company transport, especially when single transport before has been combining shipment collection and delivery to multiple air cargo handlers. However given the limited scope of the model that only focus on transport movements between one air cargo handlers, the involved forwarders' potential improvement cannot be shown with this model.

6 Simulation results of air cargo transport organization at Schiphol

6.1 Single transport system performance

In order to compare the transport performance of combined transport with single transport the simulation model was first constructed for single transport movements only. Table 7 above and Table 8 below reveal the performance of single transport system for the total transport of the forwarding companies on both loose and ULD cargo transport. These tables will be used to compare the performance of single company and combined transport. The values defined in these tables already clearly shows that the different amount of transport capacity available at forwarding companies in relation to their total amount of cargo, which causes different average throughput times of both import and export transport flows of ULD and loose shipments for the involved forwarding companies.

Throughput times average of single transport [hours]	c1	c2	c3
loose import transport	7,6	9,1	9,5
loose export transport	1,5	2,2	2,1
ULD import transport	3,6	3,5	4,3
ULD export transport	0,9	0,7	1,2

Table 8: Overview of average throughput times of single company transport shipments for ULD and loose transport

Table 10 below shows the system totals and average throughput times for single company organized transport for both ULD and loose cargo transport. Not surprisingly, the average load factor of ULD transport is much higher than single company loose transport, as the average shipment weight of ULD shipments is about 7 times higher than a single loose

cargo shipment. The Table 10 below also shows that there are two different values for shipments that arrive late. This difference in these two values is based on defined deadlines for shipments and late shipment arrival based on the throughput time of shipments. In order to compare the actual performance of combined transport in relation to its operation time and the process time of shipments, the second deadline time checks if the time of creation of shipments to delivery takes longer than specified in Table 9 below for four different shipments flows. These times have been based on process times and operations times of combined transport.

deadline times	import	export
ULD	12 hours	2 hours
loose	18 hours	2 hours

Table 9: throughput time deadlines for second deadline

<u>Transport costs per kilo</u>
The calculation of transport costs per kilo has been based on several values that were defined for this research in relation to the amount of kilos that were transported over time. The applied values and formula used for calculating the transport costs can be found in Appendix A.

Single company transport system total between forwarder and h1 (30 days)	amount of transport via single means	System wide loose transport	system wide ULD transport	System total
Total transport movements	import movements	837	541	1378
	export movements	726	609	1335
Cargo processed in [kilo]	import cargo	1615300	1762942	3378242
	export cargo	1642339	1956700	3599039
Load factor of transport	LF (kilo/ truck)	2084	3234	2571
Amount of shipments late	import shipments late	281	0	281
	export shipments late	15	0	15
Amount of shipments later than defined time	import shipments late	12	0	12
	export shipments late	4	0	5
throughput time transport	throughput time import	8,49	3,76	8,45
	throughput time export	1,84	1,01	1,76
transport costs per kilo	all cargo (import /export)	€ 0,0383	€ 0,0336	€ 0,0358

Table 10: Overview of transport performance of ULD and loose transport on system level

6.2 Combined transport potential

Three scenarios were defined which involved a different level of collaboration, which are presented below.

Low level collaboration [60% shipment allocation for all flows for collaboration]
With low level of collaboration it would be better for loose cargo transport collaboration to accept larger shipments, in order to ensure costs effectiveness of combined loose transport, therefore the limit of shipment weight is set at 3000 kilo. Given the fact that a 1250 kilo fixed capacity had a positive impact on shipments that arrive on time for both import and export, this will also be used for the lower level of collaboration. Besides these changes, the procedure to increase the load factor due to low level of cargo collaboration, waiting until 45 minutes or 3750 kilo of loose cargo is also applied for import and 2500 kilo and 30 minutes for export. This will result in some undesired effects when more cargo is allocated to collaboration, but given the fixed capacity and lower amount of cargo it will be applied in this scenario.

Medium level collaboration [80% ULD (imp/exp), 70% loose [imp/exp] all companies' shipment allocation for collaboration transport]
Fixed capacity is added for both import and export until 1250 kilo, as this had a positive result in previous scenario analysis and also worked well in the base case scenario of collaboration. The procedure to wait for cargo is set 2500 kilo and 30 minutes for import/export flows of loose shipments, however it is not increased further for import. The 2500 kilo max weight for combined shipments is kept at 2500 kilo, as was defined in the base case, given the notion that a larger volume of cargo is already allocated to combined transport. No other settings were changed regarding shipment processing times or capacity of combined transport.

High level collaboration on small shipments [90% ULD (imp/exp), 90% loose [imp/exp] all companies shipments allocated for collaboration transport]
Other than in the previous scenario, fixed capacity is only added for export loose cargo up to 1250 kilo, and shipments are only accepted for collaboration with a maximum weight of 2000 kilo. Also holding and waiting for transport demand is increased from 1250 kilo to 2500 kilo and from 15 minutes to 30 minutes before transport only for import and not for export loose cargo, as more export cargo demand more frequent transport in order to limit the increase of throughput times and the amount of shipments that arrive late for export transport. For import shipments the increase in throughput times can be more acceptable.

6.2.1 Combined ULD transport

Table 11 below shows the performance of combined ULD transport for the previously defined collaboration scenarios. It clearly shows that the fixed capacity combined ULD transport can only support effective ULD transport up to a certain level and that when a high limited amount of ULD cargo is allocated to combined transport it does not perform as well as the average single ULD transport without any level of collaboration. The throughput time increase for export by ULD combined transport is almost double the average time of single company ULD transport, in all three scenarios, this might not make it attractive for supporting this type of transport collaboration, as ULD's for export are often only completed just before planed transport. Based on the performance of ULD transport in the three defined scenario's and relative small increase of throughput time for combined import ULD transport, supporting ULD transport up until a level similar to the medium collaboration seems to deliver the best result, as cost increase after further allocation of ULD transport to the concept. Further improvements could be made by separating the use of ULD transport for import and export flows, but this has not been analyzed in this research.

Combined transport ULD	collaboration extent	low	medium	high
Total transport movements combined	import movements ULD	316	358	365
	export movements ULD	406	490	515
Total amount of cargo processed by combined	import cargo ULD	1061039	1425047	1173913
	export cargo ULD	1165930	1582303	1739520
Average load factor of transport	LF ULD collaboration	3087	3549	3311
Amount of shipments late	import ULD combined	5	9	14
	export ULD combined	17	25	26
Amount of shipments later than defined time	import shipments late uld	4	10	17
	export shipments late uld	8	13	17
throughput time loose transport	throughput time import ULD [hours]	4,43	4,63	na
	throughput time export ULD [hours]	1,65	1,79	na
Transport costs	transport costs per kilo import uld	€ 0,023	€ 0,017	€ 0,021
	transport costs per kilo export uld	€ 0,021	€ 0,015	€ 0,014
Amount of potential reduction of movements	import movements	10	79	-5
	export movements	-43	3	27
	% of total movements loose	3%	-7%	-2%

Table 11: Overview of combined ULD transport performance in relation to different ULD allocation scenario for combined transport

6.2.2 Loose cargo transport

The analysis transport performance is based on the combination of the three simulated level of collaboration for loose cargo based on values of Table 12, which shows that the combined transport system is able to transport even a high amount of loose cargo without a significant increase in average transport throughput times, however the amount of shipments that arrive after set deadline and are late, do increase extensively. While technically possible to transport all loose cargo with the combined transport system, it is up to the preference of forwarding companies to which level they will support combined loose transport, as increased load factors and reduction in transport movements at certain point could also mean that the amount of transport visits to the forwarder warehouse comes to an unacceptable level, in relation to the way operations can be executed. It can therefore be expected that not all cargo of both import and export flows will be allocated to loose combined transport. Given the operational constrains and operational preference it will make it difficult to support all generated shipments by combined transport, this can especially be the case for export shipments were customs and security related checks could make the urgency of shipments higher than previously defined.

Combined transport loose	collaboration extent	low	medium	high	base
Total transport movements combined	import movements loose	271	313	321	346
	export movements loose	257	267	300	309
Total amount of cargo processed by combined	import cargo loose	871753	1025973	1329017	1068987
	export cargo loose	881576	1008500	1241788	1014436
Average load factor of transport	LF loose collaboration (kilo/trailer)	3323	3511	4139	3183
Amount of shipments late	import	335	402	555	431
	export	135	165	197	153
Amount of shipments later than defined time	import shipments late loose	16	21	35	24
	export shipments late loose	85	91	112	89
throughput time loose transport	throughput time import loose	9,71	9,80	9,91	9,03
	throughput time export loose	3,60	3,55	3,43	3,36
Transport costs	transport costs per kilo import loose	€ 0,028	€ 0,024	€ 0,018	€ 0,023
	transport costs per kilo export loose	€ 0,028	€ 0,024	€ 0,020	€ 0,024
Amount of potential reduction of movements	import movements	181	219	368	208
	export movements	133	179	249	140
	% of total movements loose	-20%	-25%	-39%	-22%

Table 12: Overview of combined loose transport performance in relation to different loose allocation scenario for combined transport

6.3 Performance of combined transport

In order to assess the change in performance of combined transport based on the amount of collaboration that is supported, the amount of transport movements and transport costs per kilo for the different transport flows, are shown in Figure 5 &

Figure 6 below. These figures show that allocating more shipments to combined transport, positively impacts the transport costs, as expected given the fixed amount of transport used. The decline in costs is less when the collaboration is moved to highest level of collaboration for ULD transport, but does decline even stronger for loose transport with only a limited amount of extra transport movements. It therefore can be assumed to be beneficial to support the highest level combined transport possible, however as explained before, the average throughput times keep on increasing for combined transport shipments and also results in more shipments that arrive late and after the defined deadline times, therefore it cannot be said that the performance of combined transport at the highest level of collaboration is better than other levels of collaboration. It can only be concluded that the amount of cargo that is transported and the average load factor can still increase which will give lower transport costs and less transport movements in total for combined transport. Its effects on the use of single transport can be expected to be less positive when only a limited amount of cargo can be transported by single company transport, as it will become even harder to combine the remaining single transport shipments in an effective way.

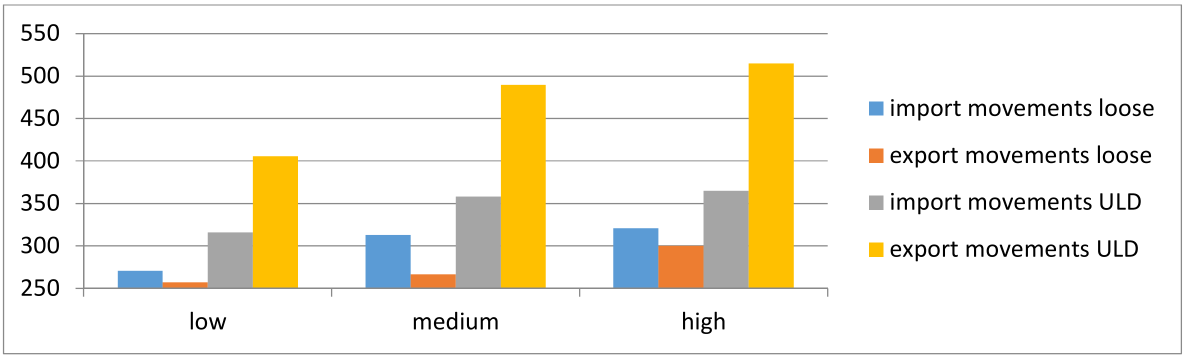

Figure 5: overview of combined transport generation in relation to different amount of shipment allocation to combined transport

Figure 6 below shows that the transport costs per kilo increase for ULD import transport when high level collaboration is supported, which can be explained by the fact that combined ULD transport between import and export is shared, with priority that is given to export transport. With a high level of combined ULD transport, more export ULD transport is realized and less import transport can therefore be generated. This shows that combing ULD transport for both import and export flows only works until a certain level with the fixed capacity has been defined.

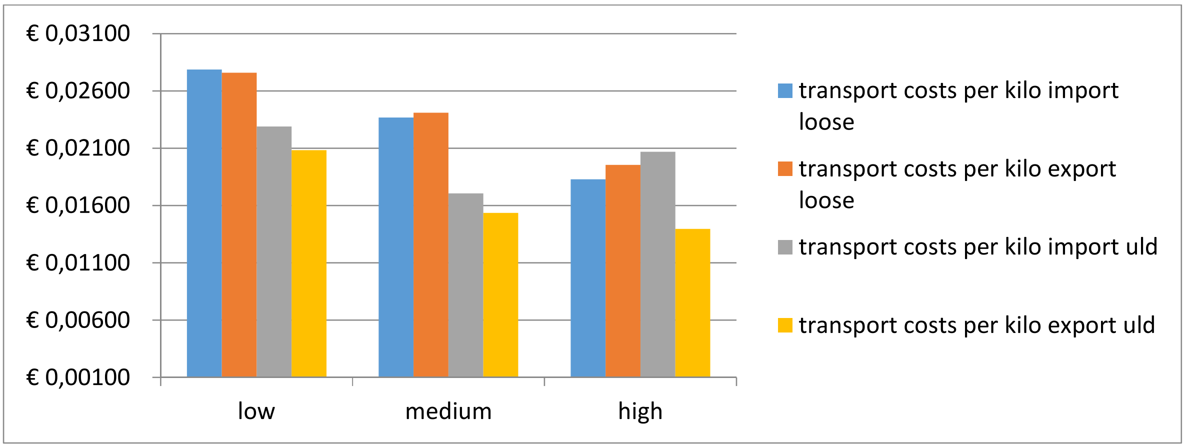

Figure 6: transport costs per kilo for the different types of combined transport in relation to the amount of shipments allocated to combined transport

7 Conclusion, discussion and future research

7.1 Conclusion

The paper has described both a qualitative analysis on air cargo transport collaboration with the air cargo industry combined with a case study analysis and simulation of horizontal collaboration for air cargo transport at Schiphol.

The main research question of this paper was:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and economics of truck transport at Schiphol airport?

The declining average shipment size combined with the ever increasing dynamics of shipment arrivals at both air cargo handlers and forwarders around Schiphol airport will make it increasingly difficult for even large forwarders to collect and deliver their shipment to a specific air cargo handler in an effective way. This especially relates to loose cargo shipments, as ULD shipments often justify single company transport based on weight and break down times for even a single shipment. The simulation model results show that supporting combined transport can be used to;

- increase the amount of cargo shipments that can be collected and delivered within a given time period
- it can reduce the total amount of truck movements between the air cargo handler and the forwarding warehouses for certain part of shipments
- it can increase the frequency of delivery of shipments for smaller forwarder companies
- it increases the average throughput time of shipments for all companies
- it can reduce the transport costs for shipments that are transported by combined transport
- it does not in all cases reduce the total amount of transport movements
- it increases the time single company transport resources are not utilized

The amount of flexibility the involved forwarders can/will expect in order to support longer average throughput times of both loose and ULD shipment for combined transport and to which extent single transport movements can be reduced, define for a large extent what possible transport improvements can be made by using combined transport. A balance will have to be found between the reduction in costs, amount of transport movements and indirect benefits that could be derived from applying combined transport, which could not all be calculated by the simulation model. Given the fact that combined transport can on average result in shipment throughput increases of between 1 to 3 hours, it can however be expected that not all of the shipments that are been offered for collecting of the involved forwarders will fall within higher throughput timings. When however forwarding companies are able to allocate a large degree of their shipment transport to combined transport and also do not significantly increase their use of single transport for the collecting of the remaining shipments, both transport costs and transport movements can be significantly reduced. Collaboration transport for both loose and ULD transport can be realized in a more cost effective way than single company transport even for the lowest level of collaboration defined scenario. However the performance and frequency of combined and

single transport after supporting combined transport will reveal if combined transport can actually be supported on the basis of lower costs alone. Not all companies that will support combined transport will be able to reduce total transport costs by only supporting combined transport at one specific air cargo handler. Indirect benefits that could be derived from applying combined transport should therefore also be analyzed in depth. Companies that are involved in horizontal collaboration at Schiphol should have sufficient scale demand on a regular basis to and from a specific handler to justify the application of combined transport with the use of fixed capacity over a limited period of time. Within the current system at Schiphol, it can be difficult to find the right number of companies based on their size and amount to support horizontal collaboration in an effective way. This is due to the fact that the amount of companies that can be considered for collaboration are limited due to the locations of warehouse and operations involved forwarding companies around Schiphol. Export collaboration does not only require similar flows or operations but also status of cargo related to security, documentation and customs in order to speed up handling processes at the handling facility. This is why it is easier to realize transport collaboration on import flow, as transport within the airport area inbound wise is less restricted. Even if collaboration on combined transport only slightly reduces the amount of trucks arriving at the handling facility it can still realize other benefits that would be important for both forwarder companies and the handler. The air cargo handler will have more control and stability over part of the trucks that come to deliver and collect shipments, which will still make it able to better plan its resources when a limited amount of cargo is allocated to combined transport systems. It can also give forwarders the ability to manage part of their transport needs with less effort and to obtain lower costs and this will make it possible for them to better utilize their organizational and transport resources for more urgent/ high care shipments. The ability and willingness of companies involved in collaboration to make the combined transport work is also highly important, when companies are more flexible and supportive regarding faster direct processing of combined transport flows the attractiveness of combined transport can further improve.

7.2 Discussion

The actual effects of using combined transport on single transport performance are currently unknown, this is why it is very difficult to state to which extent combined transport can improve both operational performance and transport costs of the each company when looking at the total transport system. The results of this research can therefore not be directly translated into actual reduction in transport costs or improvements related to amount of transport deliveries within a certain time. This research tries to show the difference of combined transport and single transport and to which extent certain use of combined or single transport have an impact on the behavior of the involved transport system. The use of fixed combined transport can be compared to the use of single transport in several situations resulting in both significant reduction of transport movements and transport cost. However, how much of these benefits remain can only be quantified once the adapted use of single transport is known. For smaller forwarding companies it can be more difficult to reduce their fixed amount of truck by supporting only a certain amount of transport with the use of combined transport. Therefore reduction in cost can only be realized when more variable capacity is used instead of fixed capacity. Given the lack of data that was at hand on which this research simulation model is based, the findings of this research is only valid to a limited extent, and which is also why the results should be only used as guidance to understand the possible differences of using single or combined transport. Forwarders and air cargo handlers around the world should use this research to assess whenever their operations can be realistically validated with the data of this model. Lack of information about the actual throughput times of forwarding companies shipments could for example reveal when companies look at the defined KPI's of this research. This can make it difficult to relate the results of this research to the actual operations of forwarding and air cargo handlers. It can however be helpful for companies to get a better understanding on which type of KPI's single and combined transport can be measured and how allocating of cargo shipments with different volumes of cargo of several companies effects the cost base and performance of combined transport. The current use of mostly fixed transport capacity for single company transport is known to be costly and often ineffective, especially with the increasing dynamics of air cargo, small shipments sizes and large amount of different handling facilities that are operating at large air cargo airport. Due to the difficulty of reducing transport costs in total for all involved forwarders assessment of indirect KPI that could not be quantified by the simulation model are crucial to ensure that combined transport can possible be supported by larger group of forwarding companies. Currently however, many forwarder companies around the airport only judge their transport system performance on direct KPI's which benefits that do not reveal all relevant organizational performance improvements that come from applying combined transport, thus making it more challenging to implement and support combined transport for companies that cannot reduce their total transport costs by applying combined transport alone.

7.3 Future research

Given the lack of data on which this research is based, the first recommendation for future research is to construct an updated simulation model on air cargo transport with the use of more detailed actual data that can be used to validate the complete simulation model. The arrival of shipments and weight distributions of both ULD and loose cargo have been

based on the average amount of cargo processed over a certain period of time. However, it not being certain to which extent the used shipment arrival distribution can be applied to forwarders active around in general or that the arrival of shipments for both import and export greatly defers between forwarders. Future research should try to assess to which extent demand stability of cargo flows both on import and export actually exists for the forwarding companies that want to collaborate. The stability of demand will be crucial to define how fixed and variable capacity for each truck transport should be used in combined transport in order to improve both the transport performance and throughput times of shipments. This is why future research should look at the impact of using either a combination of fixed or variable truck transport capacity and use. In order for this it has to be clearly defined where extra capacity should be hired and how extra costs for hiring an additional truck will be allocated to the different companies involved in the collaboration. One of the major challenges that have been described is, to which the remaining single company transport can be organized. A way to improve the remaining single transport demand is by also using a combined transport services for individual transport needs on ad hoc basis. It is likely that planning the remaining single transport demand by one specific transport company for more than one forwarder could be organized more effectively than the transport planning of three companies individually. Therefore, future research should also look at how collaborative transport can be planned jointly for both combined company shipments transport and single company 'express' shipments transport between several forwarders and a specific air cargo handler. Only when both combined and single transport can be improved and are adapted after changes are made to transport, can the full potential of using combined transport be realized both on performance and cost base.

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Appendix A: Data used for calculation of KPI's

Transport costs per kilo cargo transported

The values provided by tables (1 and 2) below are used to calculate the costs per kilo of transport for specific flow per company. For the transport flows that do not have a specific transport resources allocated to import or export transport the costs for import or export transport are assumed to be half of the total costs.

kilo cargo transported / share ULD / loose	import		export	
	uld	loose	uld	loose
c1	1190026	900519	1319614	891044
	57%	43%	60%	40%
c2	58615	381919	53831	490300
	13%	87%	10%	90%
c3	514299	332861	583253	260993
	61%	39%	69%	31%

Table 13: Amount of cargo transported by individual transport for specific flows of shipments (30 days simulation)

Transport resource use				
Company	truck rates (hr)	hours operating	amount of trucks uld	amount of trucks loose
c1	€ 45,00	720	2	2
c2	€ 50,00	600	1	1
c3	€ 50,00	600	1	1
com	€ 45,00	540	2	2

Table 14: truck rates, operating hours and amount of transport (30 days operations)

- transport costs for a truck per hour (tht_e)
- amount of trucks hired for specific shipment transport (ts_a)
- amount of cargo transport by truck resources (tr_c)
- amount of hours operating transport (h)

Transport costs per kilo $(tc_k) = \left(\frac{tr_c}{ts_a * tht_e * h}\right)$

Transport movement reduction potential

Due to the fact that single transport is not rationalized in the simulation, a formula is defined that can define the potential reduction of transport movements by applying combined transport. In order to do this the transport movements and amount of cargo transport by single and combined transport for specific shipments is used. Data of table 10 and 11 is used for combined transport movements together with single company transport movement data of table 9. The reduction potential compares the amount of movements that single transport would need to transport the same amount of cargo that is transported by combined transport, the reduction in movements compared to the actual amount of combined transport is calculated and the remaining amount of cargo is assumed to be transported with the same load factor as in the single company transport situation.

- total amount of cargo transport import single company transport loose ($tisl_c$)
- total amount transport movements import single company transport loose ($tisl_t$)
- total amount of cargo transport import combined company transport loose = ($ticl_c$)
- total amount transport movements import combined company transport loose ($ticl_t$)
- total amount of cargo transport export single company transport loose ($tisl_c$)
- total amount transport movements export single company transport loose ($tisl_t$)
- total amount of cargo transport export combined company transport loose ($ticl_c$)
- total amount transport movements export combined company transport loose ($ticl_t$)

Import reduction potential $(tpci_t) = tisl_t - (\left(1 - \left(\frac{ticl_c}{tisl_c}\right) * tisl_{t)}\right) + ticl_t)$

Export reduction potential $(tpce_t) = tesl_t - (\left(1 - \left(\frac{tecl_c}{tesl_c}\right) * tesl_{t)}\right) + tecl_t)$

The potential of inner airport horizontal transport collaboration

A case based assessment of horizontal air cargo truck transport collaboration at Schiphol airport

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Abstract

Horizontal transport collaboration is an unexplored way of organizing transport for most large air freight forwarding companies. The current difficult and more dynamic air cargo market conditions in Western Europe have recently increased the focus of forwarders on both reducing transport costs and improving transport performance. By applying horizontal transport collaboration it could result in improvements on transport performance and costs. This paper tries to justify the quantification of the potential of inner airport truck transport collaboration on a horizontal level for large freight forwarding companies. A simulation model is constructed for part of the air cargo truck transport movements within the airports surroundings and the main finding of the simulation model is that horizontal collaboration can improve both the amount of transport visits to involved forwarders facilities and reduce transport costs. Up to 40% reduction of costs and 30% reduction on transport movements to air cargo handler can be realized, compared to single company transport use. The reduction of the total amount of transport movements can only be reduced when the remaining amount of single company transport is also adapted. Thus, the application of the current simulation model is limited, as the model has been based on limited information of operation of selective number of forwarding companies. The quantified results and input data will therefore have to be further validated with more specified data of the actual transport systems in order to increase generalization of the results and usability of the model. Also, future research should be directed at validation of data the combined transport simulation model and should include other forms of transport collaboration, such as the use of variable capacity instead of solely using fixed capacity for combined transport.

Keywords: horizontal collaboration, airport logistics, air cargo, forwarders, air cargo handling, transport performance

1 Introduction

Traditionally large shippers of goods have been developing and supporting their transport needs internally (Sahay, 2003). In the last 30 years however, many shippers have started to collaborate with other companies within their own supply chain on transport organization related activities (Mason, Lalwani, & Boughton, 2007). This type of vertical supply chain collaboration has matured in many ways over the last decades; to the extent that achieving a competitive advantage by applying only vertical collaboration has been strongly reduced in highly competitive industries. Vertical supply chain collaboration has in general moved from being a differentiating strategy, to a widely and commonly applied approach that is used to support and improve the management of a specific entire supply chain. Customer preferences and transport requirements have become more challenging and demanding in recent years (Capgemini, 2010; Pyza & Golda, 2011), which has resulted in a much smaller and faster changing production flows, between major manufactures and the main consumer markets around the world (Maskell, 2001). It has therefore become increasingly difficult to improve both costs and operational performance by collaborating only with companies within a single supply chain. Increased energy costs for transport, stricter government regulations on transport use and increased focus on sustainability of transport by major costumers, have also made the effective management of supply chain more difficult by applying only vertical supply chain collaboration. In several large production industries, like the fast moving costumer goods sector (FMCG), major manufactures of goods have therefore started to collaborate with competitors, in order to able to reduce the transport cost, increase the frequency of delivery and meet other operational requirements demanded by their customers. This type of collaboration is known as horizontal collaboration. It involves the collaboration of companies that are conducting business operations on the same level of the value chain. Recent horizontal transport collaboration projects in Europe has shown that, costs savings on transport of more than 20% can be achieved by applying horizontal collaboration on transport and distribution (DHL, 2011; Vanovermeire, Sörensen, Breedam, Vannieuwenhuyse, & Verstrepen, 2011), while in the same time also improving the operational transport performance.

Collaboration on horizontal level within the air cargo transport system has been found to be non-existing in current literature, whereas this type of collaboration proved to be successfully applied in other transport systems. Previous high growth rates, between 1972 and 2005 (Worldbank, 2012), combined with healthy operations margins had limited the need and support for transport collaboration in air cargo transport system. Companies in the industry have been able either to optimize their supply chain in a cost effective way with their own means or have been able to justify inefficiency due to high operational margins. However the increased competiveness of the air cargo industry and declining operating margins (IATA, 2012) have made it more difficult for individual companies to maintain an acceptable level of transport performance and transport costs. Given this notion and the fact that a pilot project was started at Schiphol airport regarding transport collaboration in September 2012, an unique opportunity was presented for this research; to analyze a real case transport horizontal collaboration project and to analyze the potential of horizontal transport collaboration within a large air cargo system at a major European cargo airport with the use of actual data.

The objective of this paper will be: to quantify the main effects that applying horizontal transport collaboration will produce, for inner airport transport based on performance and costs. This research will contribute to support further analysis on transport collaboration in dynamic networks, by revealing results on actual case study of collaboration and pointing out the key difference of collaborative and single company transport use on set of defined key performance indicators (KPI's). Developments related to air cargo shipment transport and air cargo handling are also analyzed in order to assess how the value of collaboration on transport could change over time.

The following question will be the main question of this research paper:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and cost of truck transport at Schiphol airport?

In the following section two, the current literature on supply chain collaboration will be analyzed. Section 3 points out the most important current and future developments of air cargo industry in Western Europe in relation to the transport system inner airport transport. In section 4 the case study of transport collaboration at Schiphol will be described in order to justify the selected case study. Section 5 will explain why the simulation approach is used and will describe the key processes of model construction and validation. Section 6 will show the results of both single and combined transport performance based on the analyzed case study simulation model. Finally in section 7 the research question will be answered, limitations and directions for further research will be pointed out.

2 A state-of-the-art literature review on supply chain collaboration

Research on the subject of horizontal transport collaboration related to actual case studies has been found to be limited in current literature (Audy & D'Amours, 2008; Cruijssen & Salomon, 2004; Vanovermeire et al., 2011). The majority of the research regarding transport collaboration focuses on vertical supply chain collaboration (Holweg, Disney, Holmström, & Småros, 2005; Visser, 2009). Research is often aimed at showing the value and challenges related to applying supply chain collaboration on a vertical level and how supply chains can become more competitive by doing so (Sahay, 2003). Most of the research on supply chain collaboration does not focus specifically on transport. This can be explained by the traditional focus of supply chain management on reduction of transport costs and not on optimal of value transport costs, as has been pointed out by the research of (Mason et al., 2007). It points out in general that when only a cost focus is applied, relationships will between companies will be short term and on purely operational level. Often these types of relationships are not defined as true form of collaboration but arm's length relationships. Many challenges currently exist that have limited the actual intended impact of collaboration both on vertical and horizontal way (Barratt, 2004). Therefore recent research has looked at important variables that are related to supporting and managing supply chain collaboration in a segmented way, to improve the desired outcomes and limit the investments needed to setup and maintain effective collaboration. To realize this, segmented relationships have to be formed that reflect the ability and willingness of companies to collaborate (Rezaei & Ortt, 2012). When applying and managing transport with two or more companies operating on the same level of the value chain, this often requires longer term relationships, in order to justify and support the set up this type of transport, it can be more complex to establish and maintain such relationships (Stephens, 2006). This can be further explained by the research of (Lambert, Emmelhainz, & Gardner, 1996), which defines different levels of relationships between companies based on extent and goal of collaboration. It points out the most important aspects that define to which extent a partnership is based on the facilitators and drivers for a partnership. Key elements in the partnership model relate to organizational comparability, symmetry and trust. When companies have not collaborated before with other companies or lack the knowledge regarding the application of collaboration (Muir, 2010) it is more difficult to realize and support collaboration. Given the limited application and knowledge of horizontal transport collaboration, it is not surprising that such collaboration has seen limited development. Companies currently have more experience with application of vertical collaboration and have also more knowledge on the application of such collaboration. However the benefits of applying horizontal transport collaboration on not only transport costs or transport performance are also becoming better known, as has been pointed out by (Cruijssen, Cools, & Dullaert, 2007). The potential of horizontal transport is therefore growing, due to more dynamic markets conditions and changing customer requirements (Leitner, Meizer, Prochazka, & Sihn, 2011). The drivers to support horizontal collaboration in supply chain management are increasing in several industries, especially when vertical collaboration cannot achieve similar results or is even more difficult to realize. Collaboration in the air cargo sector has been limited and has mainly focused on collaboration between airlines (Agarwal, Ergun, Houghtalen, & Ozener, 2009), due to liberation of a key air cargo market around the globe, major airlines have started to collaborate with airline partners to share capacity and improve profitability. Within the airport system only limited collaboration has been established based on vertical collaboration regarding the coordination of transport movements to a specific air cargo handler (Franz & Stolletz, 2012a).

3 Conceptual model for air cargo airport transport collaboration

Different definitions have been found for horizontal collaboration/cooperation for example; "collaboration between parties that are at the same level between resources and final products is defined as horizontal collaboration" (Visser, 2009, p. 9) or "concerted practices between companies operating at the same level(s) in the market or logistic chain is defined horizontal cooperation"(Leitner et al., 2011, p. 333). Horizontal transport collaboration (HTC) in this paper will be defined as: all activities that can be associated with a predefined and coordinated collection and delivery of cargo involving two or more companies that are not part of the same supply chain, which operate on the same level of the value chain, to one or more destination within the supply chains of the involved companies. The conducted literature review has shown that realizing and supporting collaboration within a supply chain and between supply chains can be a challenging and difficult process, but the potential to realize performance or costs improvements by applying horizontal collaboration is growing. In order to show the potential of ground transport collaboration in the air cargo system, challenges of current single company transport will be related to opportunities of combined collaborative transport. Figure 1 below shows the way transport is now normally organized for large forwarders and how transport can be organized by collaboration between different air freight forwarders and one or more air cargo handlers. The figure shows shipments of several forwarders that are linked to one or more airlines that arrive at an air cargo handler. Currently most forwarders collect and deliver shipments linked to a specific airline individually, which produces extensive amount of transport movements between forwarders warehouse and air cargo handler.

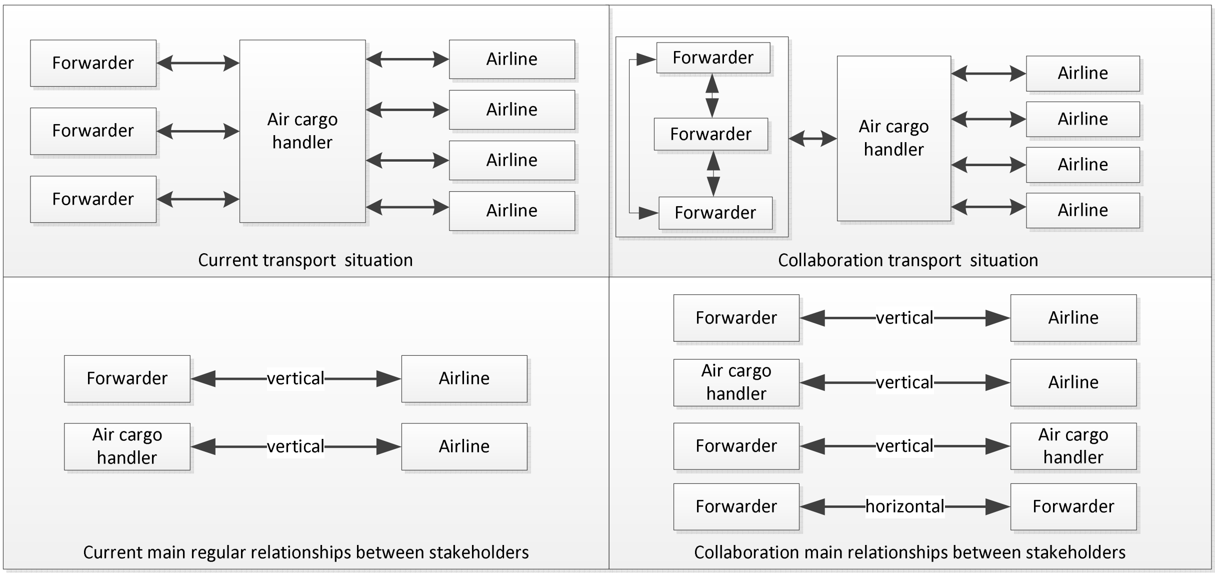

Figure 1: transport flows of air cargo shipments between forwarders, air cargo handler and airlines and main relationships between stakeholders within a general air cargo system

The number of forwarders, airline and air cargo handlers at a given major air cargo airport has increased extensively over the last few decades, due to liberation of major air transport markets (Zhang & Zhang, 2002), growth of international trade and the air cargo handling market. Previously air cargo transport system consisted of a limited amount of stakeholders and transshipment points. This combined with an average larger shipment size made it easier for freight forwarder companies, to cost effectively organize their own transport than it is now. However, increased fuel costs, changes to the supply chain of major users of air cargo transport and an increase in air cargo transport capacity both within an airport and via secondary airports have reduced the average shipment size and stability of air flows between forwarders and airport cargo handling facilities. Until recently large companies operating globally had been increasing their regular use of air transport for part of their supply chain, as a competitive advantage, in order to be able utilize their different production facilities and react to costumer demand in a more efficient way (Yuan, Low, & Ching Tang, 2010). Slower growth rate of air transport in relation to global transport shows however that the use of air transport, as preferred transport means of transport for certain large manufactures has been reduced in key markets (Loadstar, 2013). This can be explained by the use of alternative forms of transport, due to recent experiences with dependence on air transport with major disruptions (Graebel, 2012; TNO, 2012), the move of production faculties around the world (Appold & Kasarda, 2011; Eurostat, 2011) and increased attractiveness of alternative forms transport compared to air transport, based on transport costs in relation to product value. These mentioned developments have also put further pressure on the average air freight rates and operational margins of both airlines and other stakeholders involved in the operations related to the market of air cargo transport to and from Western Europe (IATA, 2012). These developments have caused an increase in the number of transport movements between forwarder facilities and the air cargo handling facilities, with similar or fewer amount of cargo transported, an increasing in the transport costs and reducing transport performance, while at the same time presenting lowered operations margins. When transport movements of several forwarders are combined, between one or more air cargo handlers, the amount of transport movements to the handling facility can be reduced, at the same time the frequency of delivery can be maintained or increased, with lower cost and higher average amount of cargo transported, which is shown in transport collaboration situation Figure 1. The current challenges and decline performance of single company transport shows that there is a large potential to practice collaboration on transport between forwarders located close to a major airport and one or more handling facilities. In order to support collaborative transport, new relationships have to be supported that currently do not (always) exists both on a vertical (forwarder/air cargo handler) and horizontal level between forwarders.

4 Case study of air cargo transport collaboration at Schiphol airport

Amsterdam airport Schiphol is one of the biggest air cargo airports in the world. It is currently positioned in the top five of largest passenger and cargo airports within Europe (Schiphol, 2012) and also ranks within the top 20 of largest airports in the world on these two aspects. Schiphol airport has recorded large growth of its air transport operations related to the amount of cargo that has been processed on yearly basis. The airport has realized an average growth rate of 6,2% a year from 1972 till 2007 (Ramaaker, 2012), also other established air cargo airports in Western Europe have previously seen similar growth rates (DT, 2009). The introduction of European Directive 96/67/EC on the liberalization of passenger and air cargo handling market in Europe has had a big impact on the amount handling companies at major European airports with most of these (new) handling companies investing in new facilities or expanded existing facilities at major airports. Schiphol is a prime example of this as currently six general handling facilities are operating at the airport. The last five years, the average growth rate at large airports like Schiphol has been negative. Based on the described developments regarding air cargo transport, in the recent past, the Western European air cargo market is expected to face a more challenging time in the future, compared to the relatively healthy growth and operating margins it has enjoyed in the last decades. This means that major stakeholders in the air cargo system that operate at existing major air cargo hubs like Schiphol airport will have to improve their system efficiency in order to stay economically viable and attractive. This also has to be realized with lower expected returns and a higher uncertainty on growth compared to other air cargo markets. Schiphol is a suitable airport for a case study analysis on horizontal transport collaboration, given the large amount of forwarders, airlines and handling facilities that operate at the airport. Also the large amount of air cargo that is processed on a yearly basis at the airport, the current over capacity, lower operating margins and declining average shipment size, make the potential of costs reductions by applying horizontal transport collaboration high at Schiphol. Many large air cargo airports in Europe have similar stakeholders and operations in relation to Schiphol and therefore results of a case study at Schiphol can also be useful for other large cargo airports.

5 Research method: simulation of horizontal transport collaboration

5.1 Simulation approach

A simulation method is chosen to reveal the potential of combined transport in relation to single company transport for this case study. Simulation can be used to show the value of changes to business processes and compare it with the current situation, which has been pointed out in research by (Khan, 2000), on an air cargo handling system. The ability to simulate air cargo handling processes that are in line with the actual situation has been proven by the researches of (Nsakanda, Turcotte, & Diaby, 2004) and (Esmemr, Ceti, & Tuna, 2010), which show that simulation can be used to obtain results of processes that are in line with the actual situation at air cargo handling facilities at major air cargo airports. This supports the applicability of using simulation to assess the impact of applying horizontal transport to air cargo systems. Actual historic data was provided by several stakeholders for this case study, thus making it possible to construct a simulation model based on actual input data and validate the results of the simulation to a certain extent based on data and observations. Besides these points, with a simulation model a different way of organizing combined transport can be assessed without actual implementation, hence without causing actual operational consequences that might not be desired. Thus, using a simulation model can also be useful for further analysis of the organization of air cargo transport systems at Schiphol or other air cargo airports.

5.2 Milkrun pilot & simulation model goal

The case study at Schiphol has been based on a selective flow of transport of three forwarding companies and one air cargo handler. Actual data of the year 2012 were used that were provided both by the analyzed companies combined with data of four other organizations, including data of Cargonaut and Schiphol Group. The suitability of the forwarding companies that have been analyzed and the extent to which they can be generalized, in relation to other handlers and forwarding companies, can be supported on several aspects. The analyzed forwarders all have a large share of 'general cargo' (CG) shipments (80 to 95%) and the analyzed companies rank in the top 15 customers for both import and export at the analyzed air cargo handler, in regards to the total weight of collected and delivered shipments over 2012. The GC shipments do not require any additional or special handling, which makes it suitable for collaboration transport, as only standard procedures are applied for handling these shipments. The analyzed air cargo handler ranks within the top three largest air cargo handlers operating at the airport and has large amount of different airline customers. This is important for the amount of cargo that is processed and the frequency of cargo shipments that arrive. Also the forwarding companies are located close to the analyzed air cargo handler and have a similar type customer base at Schiphol and at their most important other gateway stations at airports around the world. The basis for case study simulation came from increasing operational challenges that have occurred at several larger air cargo handlers at Schiphol, regarding the truck transport collection/delivery and shipment processing of loose cargo shipments. Transport performance of large forwarders operating around the airport has been reduced by these challenges; the costs of transport has increased and

reliability of transport has been reduced, as the pilot was aimed at only supporting collaboration on loose import cargo shipments transport. In order to analyze the complete potential of combined transport in relation to single company transport between the involved forwarding companies warehouses, the analyzed air cargo handler transport of ULD shipments, export transport of both loose and ULD shipments has been included in the simulation.

Goal of simulation model
The main goal of the simulation model is; to support decision making on the use and suitability of transport collaboration in relation to single company transport use. In order to realize this, the most important differences of combined and single transport are quantified on set of key performance indicators. Given that the described problem relates to transport costs, transport movements and timing, the following KPI have been defined as most crucial for the simulation:

- amount of transport movements
- amount of cargo processed
- transport costs per kilo
- average throughput time of shipments

5.3 Conceptualization of air cargo truck transport system

In order to better understand which processes and factors are relevant for the purpose of the simulation model, several tools were used to define a clear conceptual view of the transport system and its processes. The structured analysis and design technique (SADT) is one of these used and is explained in more detail below.

SADT diagrams
The highest level SADT diagrams have been defined both for forwarders and air cargo handles, which are explained below based on Figure 2. The process is defined both for import and export process, it shows that the processing of shipments relates to; document, shipment and truck processing and depends on many different resources within the analyzed facilities and information flows that is available to support the processing of shipments. Customs, security, documentation and transport also depend on and/or are influenced by other stakeholders that are involved in the air cargo supply chain. Given the extent of resources and information involved in processing are cargo shipment, this reveals that processing air cargo shipments can depend on many different elements, which are not all under control of the company in charge of the forwarding of air cargo handling facility. The process at the air cargo handler is also influenced by both airside and landside transport that can occur both to and from the involving forwarders. Transport can be conducted to and from other air cargo handlers and is also influenced by information from an additional party of the airline, on which behalf the air cargo handler has to process the shipments for a specific forwarder.

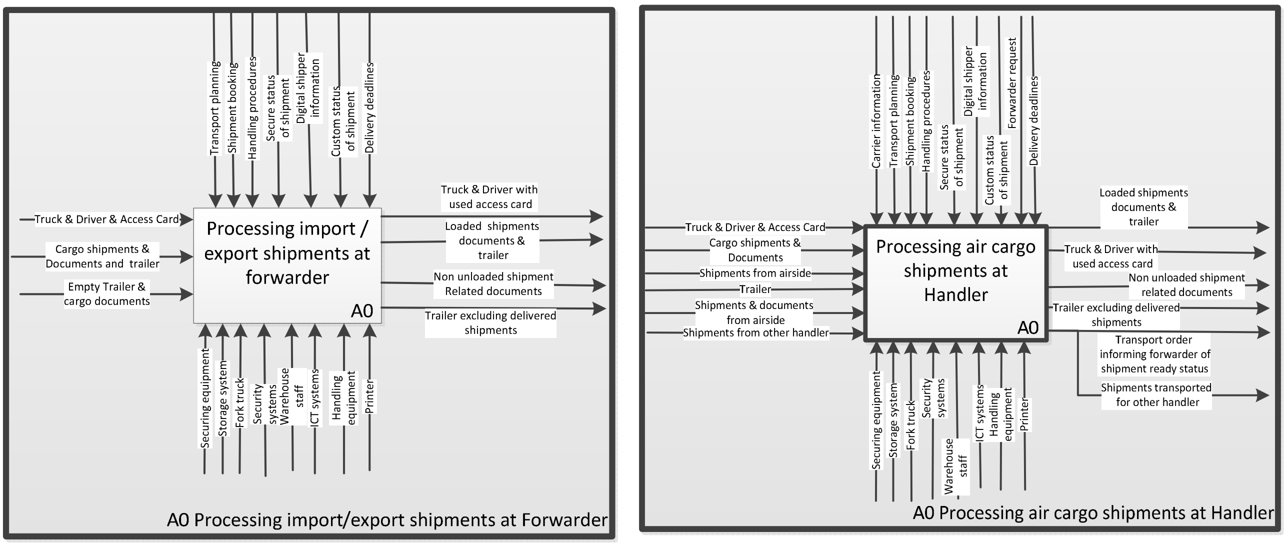

Figure 2: SADT top level diagrams process related to handling air cargo shipments at forwarder and air cargo handler

Given the extensive amount of processes that have been identified in the conceptualization, a simplified figure of the most relevant processes that will be used for the simulation model is shown below in Figure 3. It shows the different processes that an import or export shipment will go through from creation (generation) until shipment delivery at the final destination. The generation of shipments for import shipment will take place at the handling facility, whereas export shipments will be generated at the export facilities of one of the three forwarders. Import shipment are delivered at one of three import facilities of the involved forwarder and export shipments are all delivered to the handling company's export facility. Transport is generated at one of the different transport bases that have been defined, transport movements are planned by assessing the amount of shipments that are ready for collection and looking at the amount of transport that has been allocated to a specific set of shipments.

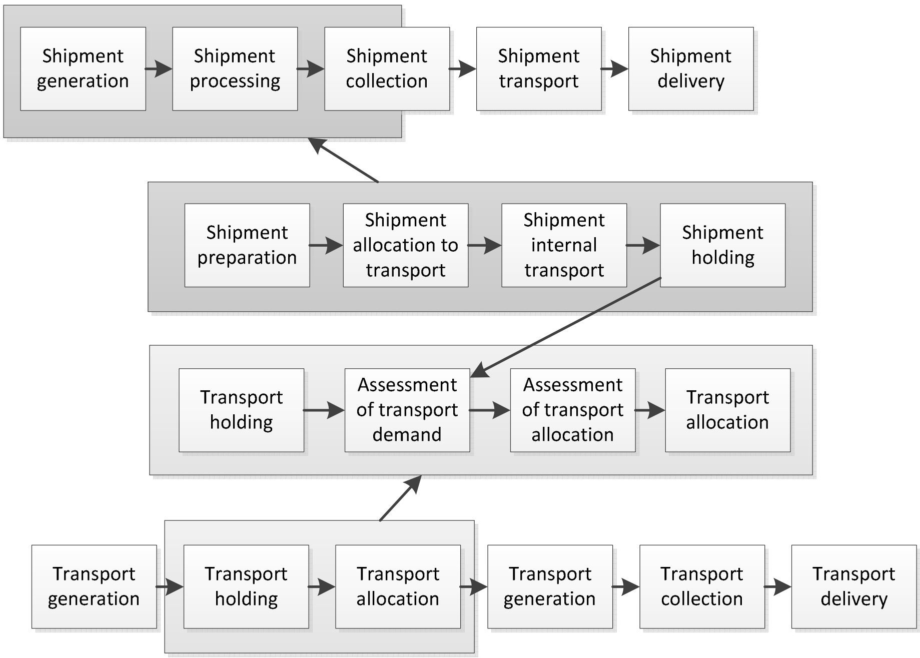

Figure 3: simplified processes of inner airport shipment transport system from generation to delivery

Based on interviews that were conducted with more than 10 different forwarders around Schiphol airport, the SADT analysis and other conceptual tools define a set of KPI's related to transport performance that are most important for air cargo inner airport truck transport system. The KPI's are shown in Figure 4 below.

Important KPI's

- Throughput times of shipments
- Transport holding time
- Transport costs per kilo
- Load factor of transport
- Amount of kilo cargo transported
- Amount of shipments on time
- Amount of shipments late
- Amount of transport visits to warehouse

Figure 4: main KPI's for transport performance of inner airport truck transport

5.4 Model specification & construction

The model has been based on the conceptual models of the previous paragraph and was specified with the use of several different data sources in order to define the input variables of the model. Actual cargo data of the year 2012 and information derived from interviews with air cargo experts have been combined in constructing the different input variables. Due to limited availability of data on detailed level, a large amount of the processes that has been defined in the previous paragraph were either simplified or not used within the simulation model. The most important input variables of the model will be discussed below.

Shipment arrivals & shipment weight

Data related to total shipment weight were provided for a certain time period regarding all shipments that were processed for each forwarder (import/export). System data related to forwarders share of cargo at the different handling facilities were used to estimate the amount of cargo that was assigned to the specific handler of this research. The general share of unit loading device (ULD) cargo and loose cargo was used to specify the total amount of ULD and loose cargo for each forwarder at the analyzed air cargo handling facility. Due to the lack of information on arrival distribution of shipments for the specific forwarders, shipment arrival was estimated using the average daily arrival and departure of flights at Schiphol (Schiphol, 2012), by using the hourly share of flights regarding the share of cargo that arrives or departs for each forwarder at a certain moment in time. The hourly arrival and departure of flights has been further simplified, by constructing three arrival periods for import and export shipments, which presented in Table 1 below. The weight distribution of loose cargo shipments was based on a lognormal distribution. A lognormal distribution was used for two reasons; several other researches regarding the simulation of air cargo shipments have used this type of distribution (Boonekamp, 2013; Huang & Chang, 2010) and a log normal distribution makes it possible to have shipments arrive spread over extensive value range. For ULD shipments, a normal distribution was used, this has been based on the assumption that all forwarders try to maximize their ULD shipment weight, therefore the spread of the weight is expected to be less and closer to the maximum possible weight.

		weight distribution import					
arrival shifts		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	6%	NORM (2300,100)	LOGNORM (350.600)	NORM (2300,100)	LOGNORM (150.400)	NORM (2300,100)	LOGNORM (310.600)
day peak	63%						
eveing peak	31%						
shipments per arrival		2	6	1	7	1	6
		weight distribution export					
depature shifts		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	2%	NORM (2300,100)	LOGNORM (390.600)	NORM (2300,100)	LOGNORM (180,400)	NORM (2300,100)	LOGNORM (330.600)
day peak	79%						
eveing peak	19%						
shipments per arrival		1	4	1	7	1	2

Table 1: arrival of shipments for ULD and loose cargo and weight distributions (shipment weight values in kilogram)

Cargo handling process

Observations at the different warehouse facilities at Schiphol, combined with information obtained at several interviews were used to define the handling times and processing of cargo shipments at Schiphol airport. Due to lack of data, processes timings for import and export were assumed to be the same for both loose and ULD cargo shipments. Given the relative high uncertainty about process times of loose cargo at a given handling facility, these processes times were based on exponential distribution. The exponential distribution seems to be the most suitable distribution for defining the processing times at the handling facility, as it has the following characteristics; values are independent of previous value, there is a large range and a variety of different values that occur with certain randomness. Also the research of (Franz & Stolletz, 2012b) uses an exponential distribution of the process times of trucks at an air cargo handling facility based on actual observed data. The main values of exponential distributions have been based on actual observed timings for single company transport and on expected values for combined transport. The defined distribution also gives maximum process times that are in line with the actual situation at the analyzed handling facilities at Schiphol. The handling times of ULD cargo at the handling facility and at forwarder for ULD and loose shipments is based on triangular distribution, as process times for these processes are much more stable and known.

Handling times (minutes)			
Handling times (un)loadingof	single loose	combined loose	ULD shipments
c1	TRIA(5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c2	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c3	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
h1	exp(8) +10	expo(4) +5	TRIA(4,6,10)
Processing import cargo at handler (hours)			
ULD shipments		TRIA (1,3,4)	
Loose cargo shipments		TRIA (3,6,10)	

Table 2: (un)loading times of shipments at different locations of transport (import/export) times in minutes and processing times of ULD and loose shipment sin hours

Transport logic & limitations of transport capacity

Transport logic and transport capacity have been based on expert judgment and interview information. Given the use of fixed capacity for transport of the involved forwarders and the lack of in depth knowledge on how transport is allocated to certain shipments, simplified transport logic was used. Transport priority was based on defined chances to export shipments ready for collection, as general export transport has higher priority than import. Besides this, another major simplification for transport generation is that at least one or more shipments should be ready for collection and that only when more shipments are waiting, which have not been assigned to a specific transport additional transport be would generated. Table 3 below shows the weight restrictions that were defined for different types of transport in relation to transport capacity for each truck. The maximum weight for transport has been set in line with the maximum shipment size. The weight limit of 10000 kilo for a specific transport has been based on the limitations that a truck has, regarding both volume and weight. In general, air cargo shipments are charged in a 1 to 6 ratio (Koning, 2012). This means that $1m^3$ of cargo equals to 166, 7 kilo of cargo. A trailer of a truck carrying 10000 kilo of actual weight therefore will use an estimated 60 m^3 of volume, while a generally used trailer for air cargo transport has a maximum capacity of 70 to 80 m^3. In order to allow for some flexibility with volume and stacking limitations of certain shipments, the maximum weight is set at 10000 kilo per trailer. Loose cargo transport is only limited by the total amount of weight, whereas for ULD transport is limited both on weight and amount of shipments that can be carried.

shipment weight	single (kilo)		combined (kilo)		trailer capacity	maximum weight	amount of shipments	
Loose	50	10000	50	2500	Loose	10000	1	∞
ULD	1800	2500	1800	2500	ULD	10000	1	4
	min	max	min	max			min	max

Table 3: shipment weight restrictions for single and combined transport and trailer capacity for loose and ULD transport

Transport resources & operating times

In reality certain freight forwarders combine ULD and loose cargo shipment. However, due to lack of information about the specific conditions under which these different types of shipments are combined, ULD and loose cargo will be transported separately in this model. This is also why specific transport units will be defined for ULD and loose transport, as decision logic regarding the allocating to either ULD or combined transport is unknown. In the model, operating times and amount of transport is defined in line with actual provided data by the analyzed forwarding companies. The operating times for both loose and ULD transport has been defined in the same way.

forwarding company single	operating times	amount transport	ULD transport	loose transport	specfic for loose import	specfic for loose
c1	24 hours a day	4	2	2	0	0
c2	from 0600 to 0200	2	1	1	0	0
c3	from 0600 to 0200	2	1	1	0	0
combined	from 0600 to 2200	4	2	2	1	1

Table 4: operating times of transport system and amount of transport resources used

5.5 Model simulation setup, verification & validation

Simulation set up

The average value key process at handling facilities during different runs were compared and statistically analyzed. The final settings selected for the simulation ,were 10 runs of 30 days, a shorter simulation run period could have been used but the a longer runtime was used, in order to easily compare simulation results with provided data of the companies.

Verification

The model has been verified by applying different verification methods. For each forwarder there are four different types of transport that can be generated for both import and export shipments

- Combined transport ULD
- Combined transport loose
- Single transport ULD
- Single transport loose

The different types of transport have been verified by creating shipments for each flow individually first and afterwards combining the different types of transport by creating shipment for more than one type of shipment. All process and decision logic for the different types of transport, from shipment generation to shipment processing at final destination within the model were analyzed in order to assess if the shipment and transport followed the right logic and sequence and in the end were either disposed of or returned to their base position. The amount of weight transport and amount of transport generated at a given time were also verified by having several variables in place that showed the amount transport that was active and the amount weight that was allocated to specific transport. While assessing these variables, the correct amount of transport was generated in relation to available amount of transport and that the total amount of weight allocated to a transport was with the possible range of weight that was accepted.

Validation

Given the lack of data it was only partly possible to validate simulation outcomes with actual data. Most of the simulation outcomes were validated based on expert judgment and observed timings during visits to handling facilities. The most important variables that were used to validate the model were:

- average company transport load factor (LF)
- average amount of transport movements per truck per shift
- average amount of shipments for loose import and export transport

In table 5 below the values show the LF of system and all companies fall within the observed average LF during visits of several facilities at Schiphol and information obtained during interviews.

30 days(imp/exp)	c1	c2	c3	system total	observed
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	1483	463	821	2767	n/a
Cargo processed [ton]	4301	985	1691	6977	within actual range
1 day (imp/exp)	c1	c2	c3	h1	
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	49	15	27	92	n/a
Cargo processed [ton]	143	33	56	233	within actual range

Table 5: LF Total transport movements for each company and amount of visits to handling company (import + export)

ULD transport movements / shipments total						uld shipments per transport				uld transport
ULD	import	export	shipments	import	export	import simulation		export simulation		company wide
c1	349	384	c1	518	574	1,5		1,5		1,5
c2	25	23	c2	26	23	1,0		1,0		1,0
c3	171	203	c3	224	254	1,3		1,3		1,3
loose transport movements / shipments total						loose shipments per transport				loose transport
loose	import	export	shipments	import	export	import sim	actual data	export	actual data	company wide
c1	475	316	c1	2240	2105	4,7		6,7		5,5
c2	206	208	c2	1418	1765	6,9		8,5		7,7
c3	155	201	c3	918	682	5,9	3 to 10	3,4	5 to 10	4,5

Table 6: Total amount of shipments transported for import/export and loose and ULD transport (30 days)

Table 5 and Table 6 above show that the amount of transport generated, cargo processed and shipments that were handled with the simulation model, can be realistically validated on basis of both information provided during interview and actual observations at different handling facilities. For ULD transport however no data was provided by the involved companies, therefore only loose cargo transport movements could be validated with actual data, which can be viewed in white blocks of the table 6 above. In order to validate extreme value of several process and throughput times of the system were also in line with the actual observed situation. The minimum, average and maximum value of several processes regarding certain shipment flows of the involved companies have been analyzed. The analyzed processes values can be found in Table 7 below and show that all values observed after 10 simulation runs of 30 days fall within the defined maximum values. These defined maximum values have been derived from interviews information with industry experts.

time unit [hours]	c1	c2	c3	c1	c2	c3	c1	c2	c3	max
transport part	average			minimum			maximum			
shipment throughput import ULD	0,8	0,7	1,5	0,4	0,4	0,4	2,1	1,5	7,8	<10
shipment throughput import loose	1,3	2,7	3,1	0,5	0,4	0,5	3,8	14,9	18,2	<30
shipment throughput export ULD	0,9	0,7	1,2	0,4	0,5	0,5	2,7	1,6	7,7	<10
shipment throughput export loose	1,5	2,2	2,1	0,7	0,5	0,6	6,9	13,2	15,4	<18
entire system time	average			minimum			maximum			
entire import time	6,8			1,8			25,9			<30
entire export time	1,7			0,4			15,4			<18
Unloading before transport	average			minimum			maximum			
Process ULD at import h1	2,7			1,0			4,0			<4
Process loose at import h1	6,3			3,0			10,0			<10
(Un)loading at transport h1	average			minimum			maximum			
Single loose cargo unloading	0,3			0,2			1,3			<2
Combined loose cargo unloading	0,2			0,1			0,6			<1
ULD unloading	0,1			0,1			0,2			<1/3
Single loose cargo loading	0,3			0,2			1,5			<2
Combined loose cargo loading	0,1			0,0			0,6			<1
ULD loading	0,1			0,1			0,2			<1/3

Table 7: system values [minimum, average & maximum] for each forwarding company related shipment transport and process related times [hours]

5.6 Limitations of the model

In the simulation model transport of export and import were not combined for the involved forwarders. Only fixed capacity was used for both single and combined transport. However, in reality large forwarders use a combination of both fixed and variable capacity. Transport combinations between different handlers for one or more forwarders have not been analyzed, due to the lack of data and knowledge about transport allocation. Weight distribution and arrival stability are based on general assumptions and generic data of Schiphol. It may the case that one or more of the analyzed companies have a different weight distributions or arrival distributions. The simulation model also does not facilitate transport collecting and delivery of both ULD's and loose cargo within one truck. This does however occur during normal operations. One important logic to improve the model that could not be proven is the information related to actual deadline of shipments for onward transport which would make this information possible to allocate shipment to either combined or single transport based on deadlines, potentially improving both the use of combined and single transport. Finally it can be expected that the use of combined transport can improve the reliability of single company transport, especially when single transport before has been combining shipment collection and delivery to multiple air cargo handlers. However given the limited scope of the model that only focus on transport movements between one air cargo handlers, the involved forwarders' potential improvement cannot be shown with this model.

6 Simulation results of air cargo transport organization at Schiphol

6.1 Single transport system performance

In order to compare the transport performance of combined transport with single transport the simulation model was first constructed for single transport movements only. Table 7 above and Table 8 below reveal the performance of single transport system for the total transport of the forwarding companies on both loose and ULD cargo transport. These tables will be used to compare the performance of single company and combined transport. The values defined in these tables already clearly shows that the different amount of transport capacity available at forwarding companies in relation to their total amount of cargo, which causes different average throughput times of both import and export transport flows of ULD and loose shipments for the involved forwarding companies.

Throughput times average of single transport [hours]	c1	c2	c3
loose import transport	7,6	9,1	9,5
loose export transport	1,5	2,2	2,1
ULD import transport	3,6	3,5	4,3
ULD export transport	0,9	0,7	1,2

Table 8: Overview of average throughput times of single company transport shipments for ULD and loose transport

Table 10 below shows the system totals and average throughput times for single company organized transport for both ULD and loose cargo transport. Not surprisingly, the average load factor of ULD transport is much higher than single company loose transport, as the average shipment weight of ULD shipments is about 7 times higher than a single loose

cargo shipment. The Table 10 below also shows that there are two different values for shipments that arrive late. This difference in these two values is based on defined deadlines for shipments and late shipment arrival based on the throughput time of shipments. In order to compare the actual performance of combined transport in relation to its operation time and the process time of shipments, the second deadline time checks if the time of creation of shipments to delivery takes longer than specified in Table 9 below for four different shipments flows. These times have been based on process times and operations times of combined transport.

deadline times	import	export
ULD	12 hours	2 hours
loose	18 hours	2 hours

Table 9: throughput time deadlines for second deadline

Transport costs per kilo

The calculation of transport costs per kilo has been based on several values that were defined for this research in relation to the amount of kilos that were transported over time. The applied values and formula used for calculating the transport costs can be found in Appendix A.

Single company transport system total between forwarder and h1 (30 days)	amount of transport via single means	System wide loose transport	system wide ULD transport	System total
Total transport movements	import movements	837	541	1378
	export movements	726	609	1335
Cargo processed in [kilo]	import cargo	1615300	1762942	3378242
	export cargo	1642339	1956700	3599039
Load factor of transport	LF (kilo/ truck)	2084	3234	2571
Amount of shipments late	import shipments late	281	0	281
	export shipments late	15	0	15
Amount of shipments later than defined time	import shipments late	12	0	12
	export shipments late	4	0	5
throughput time transport	throughput time import	8,49	3,76	8,45
	throughput time export	1,84	1,01	1,76
transport costs per kilo	all cargo (import /export)	€ 0,0383	€ 0,0336	€ 0,0358

Table 10: Overview of transport performance of ULD and loose transport on system level

6.2 Combined transport potential

Three scenarios were defined which involved a different level of collaboration, which are presented below.

Low level collaboration [60% shipment allocation for all flows for collaboration]

With low level of collaboration it would be better for loose cargo transport collaboration to accept larger shipments, in order to ensure costs effectiveness of combined loose transport, therefore the limit of shipment weight is set at 3000 kilo. Given the fact that a 1250 kilo fixed capacity had a positive impact on shipments that arrive on time for both import and export, this will also be used for the lower level of collaboration. Besides these changes, the procedure to increase the load factor due to low level of cargo collaboration, waiting until 45 minutes or 3750 kilo of loose cargo is also applied for import and 2500 kilo and 30 minutes for export. This will result in some undesired effects when more cargo is allocated to collaboration, but given the fixed capacity and lower amount of cargo it will be applied in this scenario.

Medium level collaboration [80% ULD (imp/exp), 70% loose [imp/exp] all companies' shipment allocation for collaboration transport]

Fixed capacity is added for both import and export until 1250 kilo, as this had a positive result in previous scenario analysis and also worked well in the base case scenario of collaboration. The procedure to wait for cargo is set 2500 kilo and 30 minutes for import/export flows of loose shipments, however it is not increased further for import. The 2500 kilo max weight for combined shipments is kept at 2500 kilo, as was defined in the base case, given the notion that a larger volume of cargo is already allocated to combined transport. No other settings were changed regarding shipment processing times or capacity of combined transport.

High level collaboration on small shipments [90% ULD (imp/exp), 90% loose [imp/exp] all companies shipments allocated for collaboration transport]
Other than in the previous scenario, fixed capacity is only added for export loose cargo up to 1250 kilo, and shipments are only accepted for collaboration with a maximum weight of 2000 kilo. Also holding and waiting for transport demand is increased from 1250 kilo to 2500 kilo and from 15 minutes to 30 minutes before transport only for import and not for export loose cargo, as more export cargo demand more frequent transport in order to limit the increase of throughput times and the amount of shipments that arrive late for export transport. For import shipments the increase in throughput times can be more acceptable.

6.2.1 Combined ULD transport

Table 11 below shows the performance of combined ULD transport for the previously defined collaboration scenarios. It clearly shows that the fixed capacity combined ULD transport can only support effective ULD transport up to a certain level and that when a high limited amount of ULD cargo is allocated to combined transport it does not perform as well as the average single ULD transport without any level of collaboration. The throughput time increase for export by ULD combined transport is almost double the average time of single company ULD transport, in all three scenarios, this might not make it attractive for supporting this type of transport collaboration, as ULD's for export are often only completed just before planed transport. Based on the performance of ULD transport in the three defined scenario's and relative small increase of throughput time for combined import ULD transport, supporting ULD transport up until a level similar to the medium collaboration seems to deliver the best result, as cost increase after further allocation of ULD transport to the concept. Further improvements could be made by separating the use of ULD transport for import and export flows, but this has not been analyzed in this research.

Combined transport ULD	collaboration extent	low	medium	high
Total transport movements combined	import movements ULD	316	358	365
	export movements ULD	406	490	515
Total amount of cargo processed by combined	import cargo ULD	1061039	1425047	1173913
	export cargo ULD	1165930	1582303	1739520
Average load factor of transport	LF ULD collaboration	3087	3549	3311
Amount of shipments late	import ULD combined	5	9	14
	export ULD combined	17	25	26
Amount of shipments later than defined time	import shipments late uld	4	10	17
	export shipments late uld	8	13	17
throughput time loose transport	throughput time import ULD [hours]	4,43	4,63	na
	throughput time export ULD [hours]	1,65	1,79	na
Transport costs	transport costs per kilo import uld	€ 0,023	€ 0,017	€ 0,021
	transport costs per kilo export uld	€ 0,021	€ 0,015	€ 0,014
Amount of potential reduction of movements	import movements	10	79	-5
	export movements	-43	3	27
	% of total movements loose	3%	-7%	-2%

Table 11: Overview of combined ULD transport performance in relation to different ULD allocation scenario for combined transport

6.2.2 Loose cargo transport

The analysis transport performance is based on the combination of the three simulated level of collaboration for loose cargo based on values of Table 12, which shows that the combined transport system is able to transport even a high amount of loose cargo without a significant increase in average transport throughput times, however the amount of shipments that arrive after set deadline and are late, do increase extensively. While technically possible to transport all loose cargo with the combined transport system, it is up to the preference of forwarding companies to which level they will support combined loose transport, as increased load factors and reduction in transport movements at certain point could also mean that the amount of transport visits to the forwarder warehouse comes to an unacceptable level, in relation to the way operations can be executed. It can therefore be expected that not all cargo of both import and export flows will be allocated to loose combined transport. Given the operational constrains and operational preference it will make it difficult to support all generated shipments by combined transport, this can especially be the case for export shipments were customs and security related checks could make the urgency of shipments higher than previously defined.

Combined transport loose	collaboration extent	low	medium	high	base
Total transport movements combined	import movements loose	271	313	321	346
	export movements loose	257	267	300	309
Total amount of cargo processed by combined	import cargo loose	871753	1025973	1329017	1068987
	export cargo loose	881576	1008500	1241788	1014436
Average load factor of transport	LF loose collaboration (kilo/trailer)	3323	3511	4139	3183
Amount of shipments late	import	335	402	555	431
	export	135	165	197	153
Amount of shipments later than defined time	import shipments late loose	16	21	35	24
	export shipments late loose	85	91	112	89
throughput time loose transport	throughput time import loose	9,71	9,80	9,91	9,03
	throughput time export loose	3,60	3,55	3,43	3,36
Transport costs	transport costs per kilo import loose	€ 0,028	€ 0,024	€ 0,018	€ 0,023
	transport costs per kilo export loose	€ 0,028	€ 0,024	€ 0,020	€ 0,024
Amount of potential reduction of movements	import movements	181	219	368	208
	export movements	133	179	249	140
	% of total movements loose	-20%	-25%	-39%	-22%

Table 12: Overview of combined loose transport performance in relation to different loose allocation scenario for combined transport

6.3 Performance of combined transport

In order to assess the change in performance of combined transport based on the amount of collaboration that is supported, the amount of transport movements and transport costs per kilo for the different transport flows, are shown in Figure 5 &

Figure 6 below. These figures show that allocating more shipments to combined transport, positively impacts the transport costs, as expected given the fixed amount of transport used. The decline in costs is less when the collaboration is moved to highest level of collaboration for ULD transport, but does decline even stronger for loose transport with only a limited amount of extra transport movements. It therefore can be assumed to be beneficial to support the highest level combined transport possible, however as explained before, the average throughput times keep on increasing for combined transport shipments and also results in more shipments that arrive late and after the defined deadline times, therefore it cannot be said that the performance of combined transport at the highest level of collaboration is better than other levels of collaboration. It can only be concluded that the amount of cargo that is transported and the average load factor can still increase which will give lower transport costs and less transport movements in total for combined transport. Its effects on the use of single transport can be expected to be less positive when only a limited amount of cargo can be transported by single company transport, as it will become even harder to combine the remaining single transport shipments in an effective way.

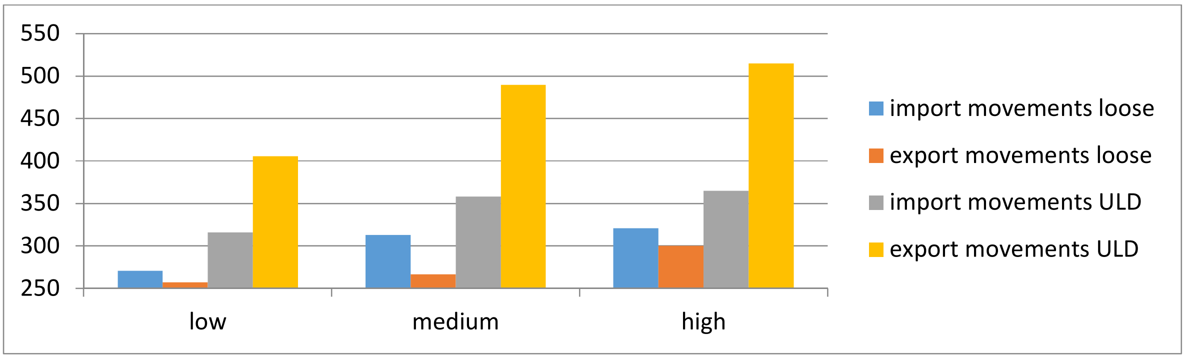

Figure 5: overview of combined transport generation in relation to different amount of shipment allocation to combined transport

Figure 6 below shows that the transport costs per kilo increase for ULD import transport when high level collaboration is supported, which can be explained by the fact that combined ULD transport between import and export is shared, with priority that is given to export transport. With a high level of combined ULD transport, more export ULD transport is realized and less import transport can therefore be generated. This shows that combing ULD transport for both import and export flows only works until a certain level with the fixed capacity has been defined.

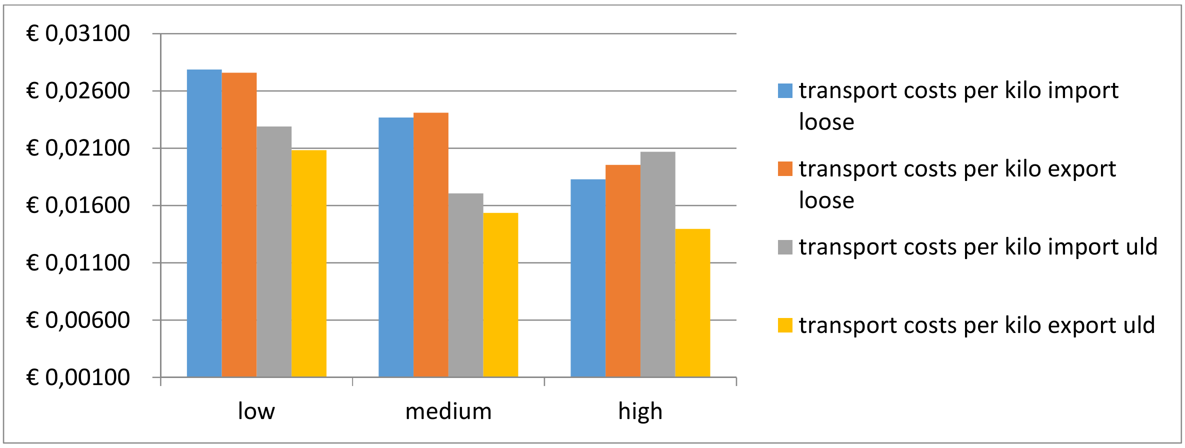

Figure 6: transport costs per kilo for the different types of combined transport in relation to the amount of shipments allocated to combined transport

7 Conclusion, discussion and future research

7.1 Conclusion

The paper has described both a qualitative analysis on air cargo transport collaboration with the air cargo industry combined with a case study analysis and simulation of horizontal collaboration for air cargo transport at Schiphol.

The main research question of this paper was:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and economics of truck transport at Schiphol airport?

The declining average shipment size combined with the ever increasing dynamics of shipment arrivals at both air cargo handlers and forwarders around Schiphol airport will make it increasingly difficult for even large forwarders to collect and deliver their shipment to a specific air cargo handler in an effective way. This especially relates to loose cargo shipments, as ULD shipments often justify single company transport based on weight and break down times for even a single shipment. The simulation model results show that supporting combined transport can be used to;

- increase the amount of cargo shipments that can be collected and delivered within a given time period
- it can reduce the total amount of truck movements between the air cargo handler and the forwarding warehouses for certain part of shipments
- it can increase the frequency of delivery of shipments for smaller forwarder companies
- it increases the average throughput time of shipments for all companies
- it can reduce the transport costs for shipments that are transported by combined transport
- it does not in all cases reduce the total amount of transport movements
- it increases the time single company transport resources are not utilized

The amount of flexibility the involved forwarders can/will expect in order to support longer average throughput times of both loose and ULD shipment for combined transport and to which extent single transport movements can be reduced, define for a large extent what possible transport improvements can be made by using combined transport. A balance will have to be found between the reduction in costs, amount of transport movements and indirect benefits that could be derived from applying combined transport, which could not all be calculated by the simulation model. Given the fact that combined transport can on average result in shipment throughput increases of between 1 to 3 hours, it can however be expected that not all of the shipments that are been offered for collecting of the involved forwarders will fall within higher throughput timings. When however forwarding companies are able to allocate a large degree of their shipment transport to combined transport and also do not significantly increase their use of single transport for the collecting of the remaining shipments, both transport costs and transport movements can be significantly reduced. Collaboration transport for both loose and ULD transport can be realized in a more cost effective way than single company transport even for the lowest level of collaboration defined scenario. However the performance and frequency of combined and

single transport after supporting combined transport will reveal if combined transport can actually be supported on the basis of lower costs alone. Not all companies that will support combined transport will be able to reduce total transport costs by only supporting combined transport at one specific air cargo handler. Indirect benefits that could be derived from applying combined transport should therefore also be analyzed in depth. Companies that are involved in horizontal collaboration at Schiphol should have sufficient scale demand on a regular basis to and from a specific handler to justify the application of combined transport with the use of fixed capacity over a limited period of time. Within the current system at Schiphol, it can be difficult to find the right number of companies based on their size and amount to support horizontal collaboration in an effective way. This is due to the fact that the amount of companies that can be considered for collaboration are limited due to the locations of warehouse and operations involved forwarding companies around Schiphol. Export collaboration does not only require similar flows or operations but also status of cargo related to security, documentation and customs in order to speed up handling processes at the handling facility. This is why it is easier to realize transport collaboration on import flow, as transport within the airport area inbound wise is less restricted. Even if collaboration on combined transport only slightly reduces the amount of trucks arriving at the handling facility it can still realize other benefits that would be important for both forwarder companies and the handler. The air cargo handler will have more control and stability over part of the trucks that come to deliver and collect shipments, which will still make it able to better plan its resources when a limited amount of cargo is allocated to combined transport systems. It can also give forwarders the ability to manage part of their transport needs with less effort and to obtain lower costs and this will make it possible for them to better utilize their organizational and transport resources for more urgent/ high care shipments. The ability and willingness of companies involved in collaboration to make the combined transport work is also highly important, when companies are more flexible and supportive regarding faster direct processing of combined transport flows the attractiveness of combined transport can further improve.

7.2 Discussion

The actual effects of using combined transport on single transport performance are currently unknown, this is why it is very difficult to state to which extent combined transport can improve both operational performance and transport costs of the each company when looking at the total transport system. The results of this research can therefore not be directly translated into actual reduction in transport costs or improvements related to amount of transport deliveries within a certain time. This research tries to show the difference of combined transport and single transport and to which extent certain use of combined or single transport have an impact on the behavior of the involved transport system. The use of fixed combined transport can be compared to the use of single transport in several situations resulting in both significant reduction of transport movements and transport cost. However, how much of these benefits remain can only be quantified once the adapted use of single transport is known. For smaller forwarding companies it can be more difficult to reduce their fixed amount of truck by supporting only a certain amount of transport with the use of combined transport. Therefore reduction in cost can only be realized when more variable capacity is used instead of fixed capacity. Given the lack of data that was at hand on which this research simulation model is based, the findings of this research is only valid to a limited extent, and which is also why the results should be only used as guidance to understand the possible differences of using single or combined transport. Forwarders and air cargo handlers around the world should use this research to assess whenever their operations can be realistically validated with the data of this model. Lack of information about the actual throughput times of forwarding companies shipments could for example reveal when companies look at the defined KPI's of this research. This can make it difficult to relate the results of this research to the actual operations of forwarding and air cargo handlers. It can however be helpful for companies to get a better understanding on which type of KPI's single and combined transport can be measured and how allocating of cargo shipments with different volumes of cargo of several companies effects the cost base and performance of combined transport. The current use of mostly fixed transport capacity for single company transport is known to be costly and often ineffective, especially with the increasing dynamics of air cargo, small shipments sizes and large amount of different handling facilities that are operating at large air cargo airport. Due to the difficulty of reducing transport costs in total for all involved forwarders assessment of indirect KPI that could not be quantified by the simulation model are crucial to ensure that combined transport can possible be supported by larger group of forwarding companies. Currently however, many forwarder companies around the airport only judge their transport system performance on direct KPI's which benefits that do not reveal all relevant organizational performance improvements that come from applying combined transport, thus making it more challenging to implement and support combined transport for companies that cannot reduce their total transport costs by applying combined transport alone.

7.3 Future research

Given the lack of data on which this research is based, the first recommendation for future research is to construct an updated simulation model on air cargo transport with the use of more detailed actual data that can be used to validate the complete simulation model. The arrival of shipments and weight distributions of both ULD and loose cargo have been

based on the average amount of cargo processed over a certain period of time. However, it not being certain to which extent the used shipment arrival distribution can be applied to forwarders active around in general or that the arrival of shipments for both import and export greatly defers between forwarders. Future research should try to assess to which extent demand stability of cargo flows both on import and export actually exists for the forwarding companies that want to collaborate. The stability of demand will be crucial to define how fixed and variable capacity for each truck transport should be used in combined transport in order to improve both the transport performance and throughput times of shipments. This is why future research should look at the impact of using either a combination of fixed or variable truck transport capacity and use. In order for this it has to be clearly defined where extra capacity should be hired and how extra costs for hiring an additional truck will be allocated to the different companies involved in the collaboration. One of the major challenges that have been described is, to which the remaining single company transport can be organized. A way to improve the remaining single transport demand is by also using a combined transport services for individual transport needs on ad hoc basis. It is likely that planning the remaining single transport demand by one specific transport company for more than one forwarder could be organized more effectively than the transport planning of three companies individually. Therefore, future research should also look at how collaborative transport can be planned jointly for both combined company shipments transport and single company 'express' shipments transport between several forwarders and a specific air cargo handler. Only when both combined and single transport can be improved and are adapted after changes are made to transport, can the full potential of using combined transport be realized both on performance and cost base.

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Appendix A: Data used for calculation of KPI's

Transport costs per kilo cargo transported

The values provided by tables (1 and 2) below are used to calculate the costs per kilo of transport for specific flow per company. For the transport flows that do not have a specific transport resources allocated to import or export transport the costs for import or export transport are assumed to be half of the total costs.

kilo cargo transported / share ULD / loose	import		export	
	uld	loose	uld	loose
c1	1190026	900519	1319614	891044
	57%	43%	60%	40%
c2	58615	381919	53831	490300
	13%	87%	10%	90%
c3	514299	332861	583253	260993
	61%	39%	69%	31%

Table 13: Amount of cargo transported by individual transport for specific flows of shipments (30 days simulation)

Transport resource use				
Company	truck rates (hr)	hours operating	amount of trucks uld	amount of trucks loose
c1	€ 45,00	720	2	2
c2	€ 50,00	600	1	1
c3	€ 50,00	600	1	1
com	€ 45,00	540	2	2

Table 14: truck rates, operating hours and amount of transport (30 days operations)

- transport costs for a truck per hour (tht_e)
- amount of trucks hired for specific shipment transport (ts_a)
- amount of cargo transport by truck resources (tr_c)
- amount of hours operating transport (h)

Transport costs per kilo $(tc_k) = \left(\frac{tr_c}{ts_a * tht_e * h}\right)$

Transport movement reduction potential

Due to the fact that single transport is not rationalized in the simulation, a formula is defined that can define the potential reduction of transport movements by applying combined transport. In order to do this the transport movements and amount of cargo transport by single and combined transport for specific shipments is used. Data of table 10 and 11 is used for combined transport movements together with single company transport movement data of table 9. The reduction potential compares the amount of movements that single transport would need to transport the same amount of cargo that is transported by combined transport, the reduction in movements compared to the actual amount of combined transport is calculated and the remaining amount of cargo is assumed to be transported with the same load factor as in the single company transport situation.

- total amount of cargo transport import single company transport loose ($tisl_c$)
- total amount transport movements import single company transport loose ($tisl_t$)
- total amount of cargo transport import combined company transport loose = ($ticl_c$)
- total amount transport movements import combined company transport loose ($ticl_t$)
- total amount of cargo transport export single company transport loose ($tisl_c$)
- total amount transport movements export single company transport loose ($tisl_t$)
- total amount of cargo transport export combined company transport loose ($ticl_c$)
- total amount transport movements export combined company transport loose ($ticl_t$)

Import reduction potential $(tpci_t) = tisl_t - (\left(1 - \left(\frac{ticl_c}{tisl_c}\right) * tisl_{t)}\right) + ticl_t)$

Export reduction potential $(tpce_t) = tesl_t - (\left(1 - \left(\frac{tecl_c}{tesl_c}\right) * tesl_{t)}\right) + tecl_t)$

The potential of inner airport horizontal transport collaboration

A case based assessment of horizontal air cargo truck transport collaboration at Schiphol airport

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Abstract

Horizontal transport collaboration is an unexplored way of organizing transport for most large air freight forwarding companies. The current difficult and more dynamic air cargo market conditions in Western Europe have recently increased the focus of forwarders on both reducing transport costs and improving transport performance. By applying horizontal transport collaboration it could result in improvements on transport performance and costs. This paper tries to justify the quantification of the potential of inner airport truck transport collaboration on a horizontal level for large freight forwarding companies. A simulation model is constructed for part of the air cargo truck transport movements within the airports surroundings and the main finding of the simulation model is that horizontal collaboration can improve both the amount of transport visits to involved forwarders facilities and reduce transport costs. Up to 40% reduction of costs and 30% reduction on transport movements to air cargo handler can be realized, compared to single company transport use. The reduction of the total amount of transport movements can only be reduced when the remaining amount of single company transport is also adapted. Thus, the application of the current simulation model is limited, as the model has been based on limited information of operation of selective number of forwarding companies. The quantified results and input data will therefore have to be further validated with more specified data of the actual transport systems in order to increase generalization of the results and usability of the model. Also, future research should be directed at validation of data the combined transport simulation model and should include other forms of transport collaboration, such as the use of variable capacity instead of solely using fixed capacity for combined transport.

Keywords: horizontal collaboration, airport logistics, air cargo, forwarders, air cargo handling, transport performance

1 Introduction

Traditionally large shippers of goods have been developing and supporting their transport needs internally (Sahay, 2003). In the last 30 years however, many shippers have started to collaborate with other companies within their own supply chain on transport organization related activities (Mason, Lalwani, & Boughton, 2007). This type of vertical supply chain collaboration has matured in many ways over the last decades; to the extent that achieving a competitive advantage by applying only vertical collaboration has been strongly reduced in highly competitive industries. Vertical supply chain collaboration has in general moved from being a differentiating strategy, to a widely and commonly applied approach that is used to support and improve the management of a specific entire supply chain. Customer preferences and transport requirements have become more challenging and demanding in recent years (Capgemini, 2010; Pyza & Golda, 2011), which has resulted in a much smaller and faster changing production flows, between major manufactures and the main consumer markets around the world (Maskell, 2001). It has therefore become increasingly difficult to improve both costs and operational performance by collaborating only with companies within a single supply chain. Increased energy costs for transport, stricter government regulations on transport use and increased focus on sustainability of transport by major costumers, have also made the effective management of supply chain more difficult by applying only vertical supply chain collaboration. In several large production industries, like the fast moving costumer goods sector (FMCG), major manufactures of goods have therefore started to collaborate with competitors, in order to able to reduce the transport cost, increase the frequency of delivery and meet other operational requirements demanded by their customers. This type of collaboration is known as horizontal collaboration. It involves the collaboration of companies that are conducting business operations on the same level of the value chain. Recent horizontal transport collaboration projects in Europe has shown that, costs savings on transport of more than 20% can be achieved by applying horizontal collaboration on transport and distribution (DHL, 2011; Vanovermeire, Sörensen, Breedam, Vannieuwenhuyse, & Verstrepen, 2011), while in the same time also improving the operational transport performance.

Collaboration on horizontal level within the air cargo transport system has been found to be non-existing in current literature, whereas this type of collaboration proved to be successfully applied in other transport systems. Previous high growth rates, between 1972 and 2005 (Worldbank, 2012), combined with healthy operations margins had limited the need and support for transport collaboration in air cargo transport system. Companies in the industry have been able either to optimize their supply chain in a cost effective way with their own means or have been able to justify inefficiency due to high operational margins. However the increased competiveness of the air cargo industry and declining operating margins (IATA, 2012) have made it more difficult for individual companies to maintain an acceptable level of transport performance and transport costs. Given this notion and the fact that a pilot project was started at Schiphol airport regarding transport collaboration in September 2012, an unique opportunity was presented for this research; to analyze a real case transport horizontal collaboration project and to analyze the potential of horizontal transport collaboration within a large air cargo system at a major European cargo airport with the use of actual data.

The objective of this paper will be: to quantify the main effects that applying horizontal transport collaboration will produce, for inner airport transport based on performance and costs. This research will contribute to support further analysis on transport collaboration in dynamic networks, by revealing results on actual case study of collaboration and pointing out the key difference of collaborative and single company transport use on set of defined key performance indicators (KPI's). Developments related to air cargo shipment transport and air cargo handling are also analyzed in order to assess how the value of collaboration on transport could change over time.

The following question will be the main question of this research paper:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and cost of truck transport at Schiphol airport?

In the following section two, the current literature on supply chain collaboration will be analyzed. Section 3 points out the most important current and future developments of air cargo industry in Western Europe in relation to the transport system inner airport transport. In section 4 the case study of transport collaboration at Schiphol will be described in order to justify the selected case study. Section 5 will explain why the simulation approach is used and will describe the key processes of model construction and validation. Section 6 will show the results of both single and combined transport performance based on the analyzed case study simulation model. Finally in section 7 the research question will be answered, limitations and directions for further research will be pointed out.

2 A state-of-the-art literature review on supply chain collaboration

Research on the subject of horizontal transport collaboration related to actual case studies has been found to be limited in current literature (Audy & D'Amours, 2008; Cruijssen & Salomon, 2004; Vanovermeire et al., 2011). The majority of the research regarding transport collaboration focuses on vertical supply chain collaboration (Holweg, Disney, Holmström, & Småros, 2005; Visser, 2009). Research is often aimed at showing the value and challenges related to applying supply chain collaboration on a vertical level and how supply chains can become more competitive by doing so (Sahay, 2003). Most of the research on supply chain collaboration does not focus specifically on transport. This can be explained by the traditional focus of supply chain management on reduction of transport costs and not on optimal of value transport costs, as has been pointed out by the research of (Mason et al., 2007). It points out in general that when only a cost focus is applied, relationships will between companies will be short term and on purely operational level. Often these types of relationships are not defined as true form of collaboration but arm's length relationships. Many challenges currently exist that have limited the actual intended impact of collaboration both on vertical and horizontal way (Barratt, 2004). Therefore recent research has looked at important variables that are related to supporting and managing supply chain collaboration in a segmented way, to improve the desired outcomes and limit the investments needed to setup and maintain effective collaboration. To realize this, segmented relationships have to be formed that reflect the ability and willingness of companies to collaborate (Rezaei & Ortt, 2012). When applying and managing transport with two or more companies operating on the same level of the value chain, this often requires longer term relationships, in order to justify and support the set up this type of transport, it can be more complex to establish and maintain such relationships (Stephens, 2006). This can be further explained by the research of (Lambert, Emmelhainz, & Gardner, 1996), which defines different levels of relationships between companies based on extent and goal of collaboration. It points out the most important aspects that define to which extent a partnership is based on the facilitators and drivers for a partnership. Key elements in the partnership model relate to organizational comparability, symmetry and trust. When companies have not collaborated before with other companies or lack the knowledge regarding the application of collaboration (Muir, 2010) it is more difficult to realize and support collaboration. Given the limited application and knowledge of horizontal transport collaboration, it is not surprising that such collaboration has seen limited development. Companies currently have more experience with application of vertical collaboration and have also more knowledge on the application of such collaboration. However the benefits of applying horizontal transport collaboration on not only transport costs or transport performance are also becoming better known, as has been pointed out by (Cruijssen, Cools, & Dullaert, 2007). The potential of horizontal transport is therefore growing, due to more dynamic markets conditions and changing customer requirements (Leitner, Meizer, Prochazka, & Sihn, 2011). The drivers to support horizontal collaboration in supply chain management are increasing in several industries, especially when vertical collaboration cannot achieve similar results or is even more difficult to realize. Collaboration in the air cargo sector has been limited and has mainly focused on collaboration between airlines (Agarwal, Ergun, Houghtalen, & Ozener, 2009), due to liberation of a key air cargo market around the globe, major airlines have started to collaborate with airline partners to share capacity and improve profitability. Within the airport system only limited collaboration has been established based on vertical collaboration regarding the coordination of transport movements to a specific air cargo handler (Franz & Stolletz, 2012a).

3 Conceptual model for air cargo airport transport collaboration

Different definitions have been found for horizontal collaboration/cooperation for example; "collaboration between parties that are at the same level between resources and final products is defined as horizontal collaboration" (Visser, 2009, p. 9) or "concerted practices between companies operating at the same level(s) in the market or logistic chain is defined horizontal cooperation"(Leitner et al., 2011, p. 333). Horizontal transport collaboration (HTC) in this paper will be defined as: all activities that can be associated with a predefined and coordinated collection and delivery of cargo involving two or more companies that are not part of the same supply chain, which operate on the same level of the value chain, to one or more destination within the supply chains of the involved companies. The conducted literature review has shown that realizing and supporting collaboration within a supply chain and between supply chains can be a challenging and difficult process, but the potential to realize performance or costs improvements by applying horizontal collaboration is growing. In order to show the potential of ground transport collaboration in the air cargo system, challenges of current single company transport will be related to opportunities of combined collaborative transport. Figure 1 below shows the way transport is now normally organized for large forwarders and how transport can be organized by collaboration between different air freight forwarders and one or more air cargo handlers. The figure shows shipments of several forwarders that are linked to one or more airlines that arrive at an air cargo handler. Currently most forwarders collect and deliver shipments linked to a specific airline individually, which produces extensive amount of transport movements between forwarders warehouse and air cargo handler.

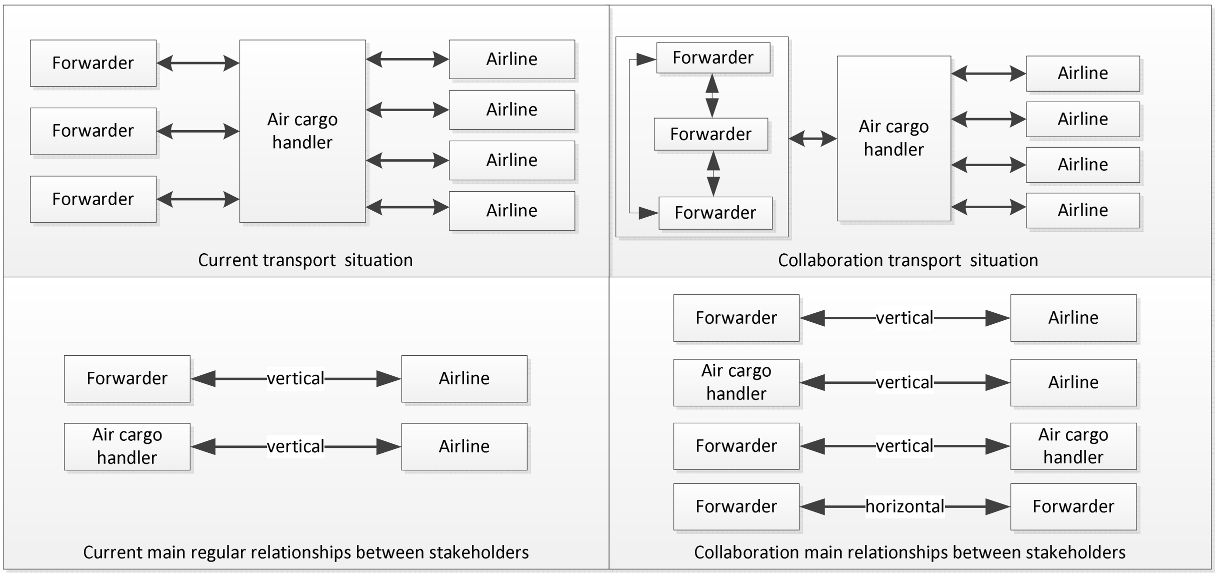

Figure 1: transport flows of air cargo shipments between forwarders, air cargo handler and airlines and main relationships between stakeholders within a general air cargo system

The number of forwarders, airline and air cargo handlers at a given major air cargo airport has increased extensively over the last few decades, due to liberation of major air transport markets (Zhang & Zhang, 2002), growth of international trade and the air cargo handling market. Previously air cargo transport system consisted of a limited amount of stakeholders and transshipment points. This combined with an average larger shipment size made it easier for freight forwarder companies, to cost effectively organize their own transport than it is now. However, increased fuel costs, changes to the supply chain of major users of air cargo transport and an increase in air cargo transport capacity both within an airport and via secondary airports have reduced the average shipment size and stability of air flows between forwarders and airport cargo handling facilities. Until recently large companies operating globally had been increasing their regular use of air transport for part of their supply chain, as a competitive advantage, in order to be able utilize their different production facilities and react to costumer demand in a more efficient way (Yuan, Low, & Ching Tang, 2010). Slower growth rate of air transport in relation to global transport shows however that the use of air transport, as preferred transport means of transport for certain large manufactures has been reduced in key markets (Loadstar, 2013). This can be explained by the use of alternative forms of transport, due to recent experiences with dependence on air transport with major disruptions (Graebel, 2012; TNO, 2012), the move of production faculties around the world (Appold & Kasarda, 2011; Eurostat, 2011) and increased attractiveness of alternative forms transport compared to air transport, based on transport costs in relation to product value. These mentioned developments have also put further pressure on the average air freight rates and operational margins of both airlines and other stakeholders involved in the operations related to the market of air cargo transport to and from Western Europe (IATA, 2012). These developments have caused an increase in the number of transport movements between forwarder facilities and the air cargo handling facilities, with similar or fewer amount of cargo transported, an increasing in the transport costs and reducing transport performance, while at the same time presenting lowered operations margins. When transport movements of several forwarders are combined, between one or more air cargo handlers, the amount of transport movements to the handling facility can be reduced, at the same time the frequency of delivery can be maintained or increased, with lower cost and higher average amount of cargo transported, which is shown in transport collaboration situation Figure 1. The current challenges and decline performance of single company transport shows that there is a large potential to practice collaboration on transport between forwarders located close to a major airport and one or more handling facilities. In order to support collaborative transport, new relationships have to be supported that currently do not (always) exists both on a vertical (forwarder/air cargo handler) and horizontal level between forwarders.

4 Case study of air cargo transport collaboration at Schiphol airport

Amsterdam airport Schiphol is one of the biggest air cargo airports in the world. It is currently positioned in the top five of largest passenger and cargo airports within Europe (Schiphol, 2012) and also ranks within the top 20 of largest airports in the world on these two aspects. Schiphol airport has recorded large growth of its air transport operations related to the amount of cargo that has been processed on yearly basis. The airport has realized an average growth rate of 6,2% a year from 1972 till 2007 (Ramaaker, 2012), also other established air cargo airports in Western Europe have previously seen similar growth rates (DT, 2009). The introduction of European Directive 96/67/EC on the liberalization of passenger and air cargo handling market in Europe has had a big impact on the amount handling companies at major European airports with most of these (new) handling companies investing in new facilities or expanded existing facilities at major airports. Schiphol is a prime example of this as currently six general handling facilities are operating at the airport. The last five years, the average growth rate at large airports like Schiphol has been negative. Based on the described developments regarding air cargo transport, in the recent past, the Western European air cargo market is expected to face a more challenging time in the future, compared to the relatively healthy growth and operating margins it has enjoyed in the last decades. This means that major stakeholders in the air cargo system that operate at existing major air cargo hubs like Schiphol airport will have to improve their system efficiency in order to stay economically viable and attractive. This also has to be realized with lower expected returns and a higher uncertainty on growth compared to other air cargo markets. Schiphol is a suitable airport for a case study analysis on horizontal transport collaboration, given the large amount of forwarders, airlines and handling facilities that operate at the airport. Also the large amount of air cargo that is processed on a yearly basis at the airport, the current over capacity, lower operating margins and declining average shipment size, make the potential of costs reductions by applying horizontal transport collaboration high at Schiphol. Many large air cargo airports in Europe have similar stakeholders and operations in relation to Schiphol and therefore results of a case study at Schiphol can also be useful for other large cargo airports.

5 Research method: simulation of horizontal transport collaboration

5.1 Simulation approach

A simulation method is chosen to reveal the potential of combined transport in relation to single company transport for this case study. Simulation can be used to show the value of changes to business processes and compare it with the current situation, which has been pointed out in research by (Khan, 2000), on an air cargo handling system. The ability to simulate air cargo handling processes that are in line with the actual situation has been proven by the researches of (Nsakanda, Turcotte, & Diaby, 2004) and (Esmemr, Ceti, & Tuna, 2010), which show that simulation can be used to obtain results of processes that are in line with the actual situation at air cargo handling facilities at major air cargo airports. This supports the applicability of using simulation to assess the impact of applying horizontal transport to air cargo systems. Actual historic data was provided by several stakeholders for this case study, thus making it possible to construct a simulation model based on actual input data and validate the results of the simulation to a certain extent based on data and observations. Besides these points, with a simulation model a different way of organizing combined transport can be assessed without actual implementation, hence without causing actual operational consequences that might not be desired. Thus, using a simulation model can also be useful for further analysis of the organization of air cargo transport systems at Schiphol or other air cargo airports.

5.2 Milkrun pilot & simulation model goal

The case study at Schiphol has been based on a selective flow of transport of three forwarding companies and one air cargo handler. Actual data of the year 2012 were used that were provided both by the analyzed companies combined with data of four other organizations, including data of Cargonaut and Schiphol Group. The suitability of the forwarding companies that have been analyzed and the extent to which they can be generalized, in relation to other handlers and forwarding companies, can be supported on several aspects. The analyzed forwarders all have a large share of 'general cargo' (CG) shipments (80 to 95%) and the analyzed companies rank in the top 15 customers for both import and export at the analyzed air cargo handler, in regards to the total weight of collected and delivered shipments over 2012. The GC shipments do not require any additional or special handling, which makes it suitable for collaboration transport, as only standard procedures are applied for handling these shipments. The analyzed air cargo handler ranks within the top three largest air cargo handlers operating at the airport and has large amount of different airline customers. This is important for the amount of cargo that is processed and the frequency of cargo shipments that arrive. Also the forwarding companies are located close to the analyzed air cargo handler and have a similar type customer base at Schiphol and at their most important other gateway stations at airports around the world. The basis for case study simulation came from increasing operational challenges that have occurred at several larger air cargo handlers at Schiphol, regarding the truck transport collection/delivery and shipment processing of loose cargo shipments. Transport performance of large forwarders operating around the airport has been reduced by these challenges; the costs of transport has increased and

reliability of transport has been reduced, as the pilot was aimed at only supporting collaboration on loose import cargo shipments transport. In order to analyze the complete potential of combined transport in relation to single company transport between the involved forwarding companies warehouses, the analyzed air cargo handler transport of ULD shipments, export transport of both loose and ULD shipments has been included in the simulation.

Goal of simulation model
The main goal of the simulation model is; to support decision making on the use and suitability of transport collaboration in relation to single company transport use. In order to realize this, the most important differences of combined and single transport are quantified on set of key performance indicators. Given that the described problem relates to transport costs, transport movements and timing, the following KPI have been defined as most crucial for the simulation:

- amount of transport movements
- amount of cargo processed
- transport costs per kilo
- average throughput time of shipments

5.3 Conceptualization of air cargo truck transport system
In order to better understand which processes and factors are relevant for the purpose of the simulation model, several tools were used to define a clear conceptual view of the transport system and its processes. The structured analysis and design technique (SADT) is one of these used and is explained in more detail below.

SADT diagrams
The highest level SADT diagrams have been defined both for forwarders and air cargo handles, which are explained below based on Figure 2. The process is defined both for import and export process, it shows that the processing of shipments relates to; document, shipment and truck processing and depends on many different resources within the analyzed facilities and information flows that is available to support the processing of shipments. Customs, security, documentation and transport also depend on and/or are influenced by other stakeholders that are involved in the air cargo supply chain. Given the extent of resources and information involved in processing are cargo shipment, this reveals that processing air cargo shipments can depend on many different elements, which are not all under control of the company in charge of the forwarding of air cargo handling facility. The process at the air cargo handler is also influenced by both airside and landside transport that can occur both to and from the involving forwarders. Transport can be conducted to and from other air cargo handlers and is also influenced by information from an additional party of the airline, on which behalf the air cargo handler has to process the shipments for a specific forwarder.

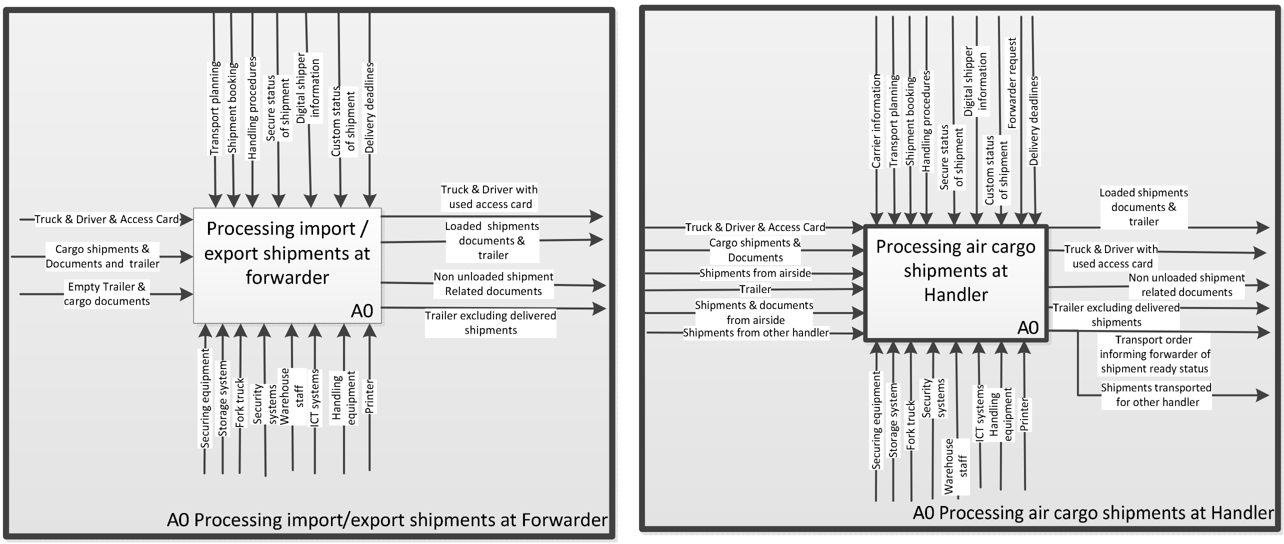

Figure 2: SADT top level diagrams process related to handling air cargo shipments at forwarder and air cargo handler

Given the extensive amount of processes that have been identified in the conceptualization, a simplified figure of the most relevant processes that will be used for the simulation model is shown below in Figure 3. It shows the different processes that an import or export shipment will go through from creation (generation) until shipment delivery at the final destination. The generation of shipments for import shipment will take place at the handling facility, whereas export shipments will be generated at the export facilities of one of the three forwarders. Import shipment are delivered at one of three import facilities of the involved forwarder and export shipments are all delivered to the handling company's export facility. Transport is generated at one of the different transport bases that have been defined, transport movements are planned by assessing the amount of shipments that are ready for collection and looking at the amount of transport that has been allocated to a specific set of shipments.

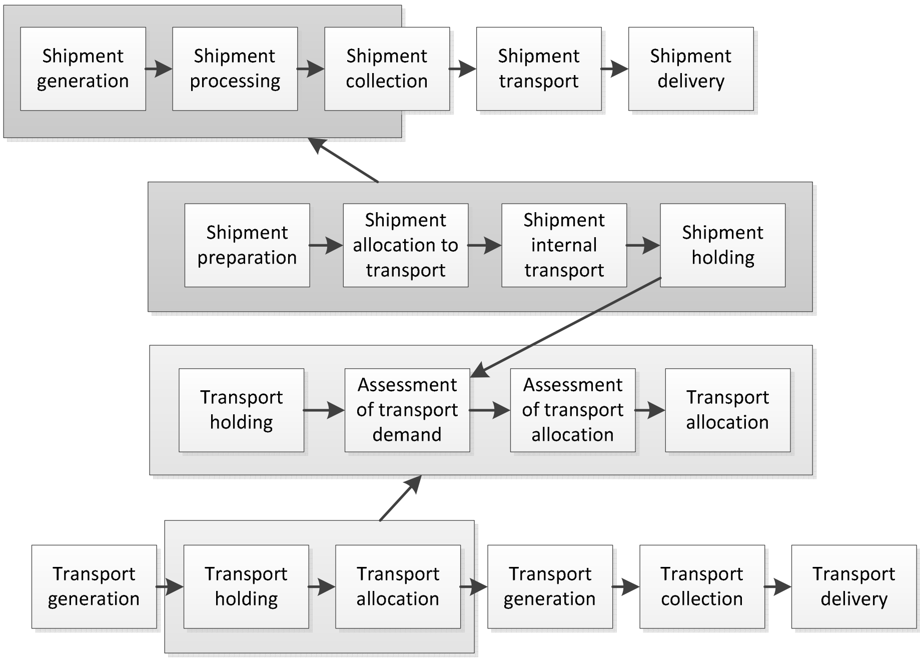

Figure 3: simplified processes of inner airport shipment transport system from generation to delivery

Based on interviews that were conducted with more than 10 different forwarders around Schiphol airport, the SADT analysis and other conceptual tools define a set of KPI's related to transport performance that are most important for air cargo inner airport truck transport system. The KPI's are shown in Figure 4 below.

Important KPI's

- Throughput times of shipments
- Transport holding time
- Transport costs per kilo
- Load factor of transport
- Amount of kilo cargo transported
- Amount of shipments on time
- Amount of shipments late
- Amount of transport visits to warehouse

Figure 4: main KPI's for transport performance of inner airport truck transport

5.4 Model specification & construction

The model has been based on the conceptual models of the previous paragraph and was specified with the use of several different data sources in order to define the input variables of the model. Actual cargo data of the year 2012 and information derived from interviews with air cargo experts have been combined in constructing the different input variables. Due to limited availability of data on detailed level, a large amount of the processes that has been defined in the previous paragraph were either simplified or not used within the simulation model. The most important input variables of the model will be discussed below.

Shipment arrivals & shipment weight

Data related to total shipment weight were provided for a certain time period regarding all shipments that were processed for each forwarder (import/export). System data related to forwarders share of cargo at the different handling facilities were used to estimate the amount of cargo that was assigned to the specific handler of this research. The general share of unit loading device (ULD) cargo and loose cargo was used to specify the total amount of ULD and loose cargo for each forwarder at the analyzed air cargo handling facility. Due to the lack of information on arrival distribution of shipments for the specific forwarders, shipment arrival was estimated using the average daily arrival and departure of flights at Schiphol (Schiphol, 2012), by using the hourly share of flights regarding the share of cargo that arrives or departs for each forwarder at a certain moment in time. The hourly arrival and departure of flights has been further simplified, by constructing three arrival periods for import and export shipments, which presented in Table 1 below. The weight distribution of loose cargo shipments was based on a lognormal distribution. A lognormal distribution was used for two reasons; several other researches regarding the simulation of air cargo shipments have used this type of distribution (Boonekamp, 2013; Huang & Chang, 2010) and a log normal distribution makes it possible to have shipments arrive spread over extensive value range. For ULD shipments, a normal distribution was used, this has been based on the assumption that all forwarders try to maximize their ULD shipment weight, therefore the spread of the weight is expected to be less and closer to the maximum possible weight.

arrival shifts		weight distribution import					
		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	6%	NORM (2300,100)	LOGNORM (350.600)	NORM (2300,100)	LOGNORM (150.400)	NORM (2300,100)	LOGNORM (310.600)
day peak	63%						
eveing peak	31%						
shipments per arrival		2	6	1	7	1	6
depature shifts		weight distribution export					
		ULD	Loose	ULD	Loose	ULD	Loose
arrival block	%	c1	c1	c2	c2	c3	c3
early morning	2%	NORM (2300,100)	LOGNORM (390.600)	NORM (2300,100)	LOGNORM (180,400)	NORM (2300,100)	LOGNORM (330.600)
day peak	79%						
eveing peak	19%						
shipments per arrival		1	4	1	7	1	2

Table 1: arrival of shipments for ULD and loose cargo and weight distributions (shipment weight values in kilogram)

Cargo handling process

Observations at the different warehouse facilities at Schiphol, combined with information obtained at several interviews were used to define the handling times and processing of cargo shipments at Schiphol airport. Due to lack of data, processes timings for import and export were assumed to be the same for both loose and ULD cargo shipments. Given the relative high uncertainty about process times of loose cargo at a given handling facility, these processes times were based on exponential distribution. The exponential distribution seems to be the most suitable distribution for defining the processing times at the handling facility, as it has the following characteristics; values are independent of previous value, there is a large range and a variety of different values that occur with certain randomness. Also the research of (Franz & Stolletz, 2012b) uses an exponential distribution of the process times of trucks at an air cargo handling facility based on actual observed data. The main values of exponential distributions have been based on actual observed timings for single company transport and on expected values for combined transport. The defined distribution also gives maximum process times that are in line with the actual situation at the analyzed handling facilities at Schiphol. The handling times of ULD cargo at the handling facility and at forwarder for ULD and loose shipments is based on triangular distribution, as process times for these processes are much more stable and known.

Handling times (minutes)			
Handling times (un)loadingof	single loose	combined loose	ULD shipments
c1	TRIA(5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c2	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
c3	TRIA (5,7,20)	TRIA(3,7,15)	TRIA(2,5,7)
h1	exp(8) +10	expo(4) +5	TRIA(4,6,10)
Processing import cargo at handler (hours)			
ULD shipments		TRIA (1,3,4)	
Loose cargo shipments		TRIA (3,6,10)	

Table 2: (un)loading times of shipments at different locations of transport (import/export) times in minutes and processing times of ULD and loose shipment sin hours

Transport logic & limitations of transport capacity
Transport logic and transport capacity have been based on expert judgment and interview information. Given the use of fixed capacity for transport of the involved forwarders and the lack of in depth knowledge on how transport is allocated to certain shipments, simplified transport logic was used. Transport priority was based on defined chances to export shipments ready for collection, as general export transport has higher priority than import. Besides this, another major simplification for transport generation is that at least one or more shipments should be ready for collection and that only when more shipments are waiting, which have not been assigned to a specific transport additional transport be would generated. Table 3 below shows the weight restrictions that were defined for different types of transport in relation to transport capacity for each truck. The maximum weight for transport has been set in line with the maximum shipment size. The weight limit of 10000 kilo for a specific transport has been based on the limitations that a truck has, regarding both volume and weight. In general, air cargo shipments are charged in a 1 to 6 ratio (Koning, 2012). This means that $1m^3$ of cargo equals to 166, 7 kilo of cargo. A trailer of a truck carrying 10000 kilo of actual weight therefore will use an estimated 60 m^3 of volume, while a generally used trailer for air cargo transport has a maximum capacity of 70 to 80 m^3. In order to allow for some flexibility with volume and stacking limitations of certain shipments, the maximum weight is set at 10000 kilo per trailer. Loose cargo transport is only limited by the total amount of weight, whereas for ULD transport is limited both on weight and amount of shipments that can be carried.

shipment weight	single (kilo)		combined (kilo)		trailer capacity	maximum weight	amount of shipments	
Loose	50	10000	50	2500	Loose	10000	1	∞
ULD	1800	2500	1800	2500	ULD	10000	1	4
	min	max	min	max			min	max

Table 3: shipment weight restrictions for single and combined transport and trailer capacity for loose and ULD transport

Transport resources & operating times
In reality certain freight forwarders combine ULD and loose cargo shipment. However, due to lack of information about the specific conditions under which these different types of shipments are combined, ULD and loose cargo will be transported separately in this model. This is also why specific transport units will be defined for ULD and loose transport, as decision logic regarding the allocating to either ULD or combined transport is unknown. In the model, operating times and amount of transport is defined in line with actual provided data by the analyzed forwarding companies. The operating times for both loose and ULD transport has been defined in the same way.

forwarding company single	operating times	amount transport	ULD transport	loose transport	specfic for loose import	specfic for loose
c1	24 hours a day	4	2	2	0	0
c2	from 0600 to 0200	2	1	1	0	0
c3	from 0600 to 0200	2	1	1	0	0
combined	from 0600 to 2200	4	2	2	1	1

Table 4: operating times of transport system and amount of transport resources used

5.5 Model simulation setup, verification & validation

Simulation set up
The average value key process at handling facilities during different runs were compared and statistically analyzed. The final settings selected for the simulation ,were 10 runs of 30 days, a shorter simulation run period could have been used but the a longer runtime was used, in order to easily compare simulation results with provided data of the companies.

Verification
The model has been verified by applying different verification methods. For each forwarder there are four different types of transport that can be generated for both import and export shipments

- Combined transport ULD
- Combined transport loose
- Single transport ULD
- Single transport loose

The different types of transport have been verified by creating shipments for each flow individually first and afterwards combining the different types of transport by creating shipment for more than one type of shipment. All process and decision logic for the different types of transport, from shipment generation to shipment processing at final destination within the model were analyzed in order to assess if the shipment and transport followed the right logic and sequence and in the end were either disposed of or returned to their base position. The amount of weight transport and amount of transport generated at a given time were also verified by having several variables in place that showed the amount transport that was active and the amount weight that was allocated to specific transport. While assessing these variables, the correct amount of transport was generated in relation to available amount of transport and that the total amount of weight allocated to a transport was with the possible range of weight that was accepted.

Validation

Given the lack of data it was only partly possible to validate simulation outcomes with actual data. Most of the simulation outcomes were validated based on expert judgment and observed timings during visits to handling facilities. The most important variables that were used to validate the model were:

- average company transport load factor (LF)
- average amount of transport movements per truck per shift
- average amount of shipments for loose import and export transport

In table 5 below the values show the LF of system and all companies fall within the observed average LF during visits of several facilities at Schiphol and information obtained during interviews.

30 days(imp/exp)	c1	c2	c3	system total	observed
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	1483	463	821	2767	n/a
Cargo processed [ton]	4301	985	1691	6977	within actual range
1 day (imp/exp)	c1	c2	c3	h1	
Load factor	29%	21%	21%	25%	20 to 40%
Transport movements	49	15	27	92	n/a
Cargo processed [ton]	143	33	56	233	within actual range

Table 5: LF Total transport movements for each company and amount of visits to handling company (import + export)

ULD transport movements / shipments total						uld shipments per transport				uld transport
ULD	**import**	**export**	shipments	import	export	import simulation		export simulation		company wide
c1	**349**	**384**	c1	518	574	1,5		1,5		1,5
c2	**25**	**23**	c2	26	23	1,0		1,0		1,0
c3	**171**	**203**	c3	224	254	1,3		1,3		1,3
loose transport movements / shipments total						loose shipments per transport				loose transport
loose	**import**	**export**	shipments	import	export	import sim	actual data	export	actual data	company wide
c1	**475**	**316**	c1	2240	2105	4,7		6,7		5,5
c2	**206**	**208**	c2	1418	1765	6,9		8,5		7,7
c3	**155**	**201**	c3	918	682	5,9	3 to 10	3,4	5 to 10	4,5

Table 6: Total amount of shipments transported for import/export and loose and ULD transport (30 days)

Table 5 and Table 6 above show that the amount of transport generated, cargo processed and shipments that were handled with the simulation model, can be realistically validated on basis of both information provided during interview and actual observations at different handling facilities. For ULD transport however no data was provided by the involved companies, therefore only loose cargo transport movements could be validated with actual data, which can be viewed in white blocks of the table 6 above. In order to validate extreme value of several process and throughput times of the system were also in line with the actual observed situation. The minimum, average and maximum value of several processes regarding certain shipment flows of the involved companies have been analyzed. The analyzed processes values can be found in Table 7 below and show that all values observed after 10 simulation runs of 30 days fall within the defined maximum values. These defined maximum values have been derived from interviews information with industry experts.

time unit [hours]	c1	c2	c3	c1	c2	c3	c1	c2	c3	max
transport part	average			minimum			maximum			
shipment throughput import ULD	0,8	0,7	1,5	0,4	0,4	0,4	2,1	1,5	7,8	<10
shipment throughput import loose	1,3	2,7	3,1	0,5	0,4	0,5	3,8	14,9	18,2	<30
shipment throughput export ULD	0,9	0,7	1,2	0,4	0,5	0,5	2,7	1,6	7,7	<10
shipment throughput export loose	1,5	2,2	2,1	0,7	0,5	0,6	6,9	13,2	15,4	<18
entire system time	average			minimum			maximum			
entire import time	6,8			1,8			25,9			<30
entire export time	1,7			0,4			15,4			<18
Unloading before transport	average			minimum			maximum			
Process ULD at import h1	2,7			1,0			4,0			<4
Process loose at import h1	6,3			3,0			10,0			<10
(Un)loading at transport h1	average			minimum			maximum			
Single loose cargo unloading	0,3			0,2			1,3			<2
Combined loose cargo unloading	0,2			0,1			0,6			<1
ULD unloading	0,1			0,1			0,2			<1/3
Single loose cargo loading	0,3			0,2			1,5			<2
Combined loose cargo loading	0,1			0,0			0,6			<1
ULD loading	0,1			0,1			0,2			<1/3

Table 7: system values [minimum, average & maximum] for each forwarding company related shipment transport and process related times [hours]

5.6 Limitations of the model

In the simulation model transport of export and import were not combined for the involved forwarders. Only fixed capacity was used for both single and combined transport. However, in reality large forwarders use a combination of both fixed and variable capacity. Transport combinations between different handlers for one or more forwarders have not been analyzed, due to the lack of data and knowledge about transport allocation. Weight distribution and arrival stability are based on general assumptions and generic data of Schiphol. It may the case that one or more of the analyzed companies have a different weight distributions or arrival distributions. The simulation model also does not facilitate transport collecting and delivery of both ULD's and loose cargo within one truck. This does however occur during normal operations. One important logic to improve the model that could not be proven is the information related to actual deadline of shipments for onward transport which would make this information possible to allocate shipment to either combined or single transport based on deadlines, potentially improving both the use of combined and single transport. Finally it can be expected that the use of combined transport can improve the reliability of single company transport, especially when single transport before has been combining shipment collection and delivery to multiple air cargo handlers. However given the limited scope of the model that only focus on transport movements between one air cargo handlers, the involved forwarders' potential improvement cannot be shown with this model.

6 Simulation results of air cargo transport organization at Schiphol

6.1 Single transport system performance

In order to compare the transport performance of combined transport with single transport the simulation model was first constructed for single transport movements only. Table 7 above and Table 8 below reveal the performance of single transport system for the total transport of the forwarding companies on both loose and ULD cargo transport. These tables will be used to compare the performance of single company and combined transport. The values defined in these tables already clearly shows that the different amount of transport capacity available at forwarding companies in relation to their total amount of cargo, which causes different average throughput times of both import and export transport flows of ULD and loose shipments for the involved forwarding companies.

Throughput times average of single transport [hours]	c1	c2	c3
loose import transport	7,6	9,1	9,5
loose export transport	1,5	2,2	2,1
ULD import transport	3,6	3,5	4,3
ULD export transport	0,9	0,7	1,2

Table 8: Overview of average throughput times of single company transport shipments for ULD and loose transport

Table 10 below shows the system totals and average throughput times for single company organized transport for both ULD and loose cargo transport. Not surprisingly, the average load factor of ULD transport is much higher than single company loose transport, as the average shipment weight of ULD shipments is about 7 times higher than a single loose

cargo shipment. The Table 10 below also shows that there are two different values for shipments that arrive late. This difference in these two values is based on defined deadlines for shipments and late shipment arrival based on the throughput time of shipments. In order to compare the actual performance of combined transport in relation to its operation time and the process time of shipments, the second deadline time checks if the time of creation of shipments to delivery takes longer than specified in Table 9 below for four different shipments flows. These times have been based on process times and operations times of combined transport.

deadline times	import	export
ULD	12 hours	2 hours
loose	18 hours	2 hours

Table 9: throughput time deadlines for second deadline

<u>Transport costs per kilo</u>
The calculation of transport costs per kilo has been based on several values that were defined for this research in relation to the amount of kilos that were transported over time. The applied values and formula used for calculating the transport costs can be found in Appendix A.

Single company transport system total between forwarder and h1 (30 days)	amount of transport via single means	System wide loose transport	system wide ULD transport	System total
Total transport movements	import movements	837	541	1378
	export movements	726	609	1335
Cargo processed in [kilo]	import cargo	1615300	1762942	3378242
	export cargo	1642339	1956700	3599039
Load factor of transport	LF (kilo/ truck)	2084	3234	2571
Amount of shipments late	import shipments late	281	0	281
	export shipments late	15	0	15
Amount of shipments later than defined time	import shipments late	12	0	12
	export shipments late	4	0	5
throughput time transport	throughput time import	8,49	3,76	8,45
	throughput time export	1,84	1,01	1,76
transport costs per kilo	all cargo (import /export)	€ 0,0383	€ 0,0336	€ 0,0358

Table 10: Overview of transport performance of ULD and loose transport on system level

6.2 Combined transport potential

Three scenarios were defined which involved a different level of collaboration, which are presented below.

Low level collaboration [60% shipment allocation for all flows for collaboration]
With low level of collaboration it would be better for loose cargo transport collaboration to accept larger shipments, in order to ensure costs effectiveness of combined loose transport, therefore the limit of shipment weight is set at 3000 kilo. Given the fact that a 1250 kilo fixed capacity had a positive impact on shipments that arrive on time for both import and export, this will also be used for the lower level of collaboration. Besides these changes, the procedure to increase the load factor due to low level of cargo collaboration, waiting until 45 minutes or 3750 kilo of loose cargo is also applied for import and 2500 kilo and 30 minutes for export. This will result in some undesired effects when more cargo is allocated to collaboration, but given the fixed capacity and lower amount of cargo it will be applied in this scenario.

Medium level collaboration [80% ULD (imp/exp), 70% loose [imp/exp] all companies' shipment allocation for collaboration transport]
Fixed capacity is added for both import and export until 1250 kilo, as this had a positive result in previous scenario analysis and also worked well in the base case scenario of collaboration. The procedure to wait for cargo is set 2500 kilo and 30 minutes for import/export flows of loose shipments, however it is not increased further for import. The 2500 kilo max weight for combined shipments is kept at 2500 kilo, as was defined in the base case, given the notion that a larger volume of cargo is already allocated to combined transport. No other settings were changed regarding shipment processing times or capacity of combined transport.

High level collaboration on small shipments [90% ULD (imp/exp), 90% loose [imp/exp] all companies shipments allocated for collaboration transport]
Other than in the previous scenario, fixed capacity is only added for export loose cargo up to 1250 kilo, and shipments are only accepted for collaboration with a maximum weight of 2000 kilo. Also holding and waiting for transport demand is increased from 1250 kilo to 2500 kilo and from 15 minutes to 30 minutes before transport only for import and not for export loose cargo, as more export cargo demand more frequent transport in order to limit the increase of throughput times and the amount of shipments that arrive late for export transport. For import shipments the increase in throughput times can be more acceptable.

6.2.1 Combined ULD transport

Table 11 below shows the performance of combined ULD transport for the previously defined collaboration scenarios. It clearly shows that the fixed capacity combined ULD transport can only support effective ULD transport up to a certain level and that when a high limited amount of ULD cargo is allocated to combined transport it does not perform as well as the average single ULD transport without any level of collaboration. The throughput time increase for export by ULD combined transport is almost double the average time of single company ULD transport, in all three scenarios, this might not make it attractive for supporting this type of transport collaboration, as ULD's for export are often only completed just before planed transport. Based on the performance of ULD transport in the three defined scenario's and relative small increase of throughput time for combined import ULD transport, supporting ULD transport up until a level similar to the medium collaboration seems to deliver the best result, as cost increase after further allocation of ULD transport to the concept. Further improvements could be made by separating the use of ULD transport for import and export flows, but this has not been analyzed in this research.

Combined transport ULD	collaboration extent	low	medium	high
Total transport movements combined	import movements ULD	316	358	365
	export movements ULD	406	490	515
Total amount of cargo processed by combined	import cargo ULD	1061039	1425047	1173913
	export cargo ULD	1165930	1582303	1739520
Average load factor of transport	LF ULD collaboration	3087	3549	3311
Amount of shipments late	import ULD combined	5	9	14
	export ULD combined	17	25	26
Amount of shipments later than defined time	import shipments late uld	4	10	17
	export shipments late uld	8	13	17
throughput time loose transport	throughput time import ULD [hours]	4,43	4,63	na
	throughput time export ULD [hours]	1,65	1,79	na
Transport costs	transport costs per kilo import uld	€ 0,023	€ 0,017	€ 0,021
	transport costs per kilo export uld	€ 0,021	€ 0,015	€ 0,014
Amount of potential reduction of movements	import movements	10	79	-5
	export movements	-43	3	27
	% of total movements loose	3%	-7%	-2%

Table 11: Overview of combined ULD transport performance in relation to different ULD allocation scenario for combined transport

6.2.2 Loose cargo transport

The analysis transport performance is based on the combination of the three simulated level of collaboration for loose cargo based on values of Table 12, which shows that the combined transport system is able to transport even a high amount of loose cargo without a significant increase in average transport throughput times, however the amount of shipments that arrive after set deadline and are late, do increase extensively. While technically possible to transport all loose cargo with the combined transport system, it is up to the preference of forwarding companies to which level they will support combined loose transport, as increased load factors and reduction in transport movements at certain point could also mean that the amount of transport visits to the forwarder warehouse comes to an unacceptable level, in relation to the way operations can be executed. It can therefore be expected that not all cargo of both import and export flows will be allocated to loose combined transport. Given the operational constrains and operational preference it will make it difficult to support all generated shipments by combined transport, this can especially be the case for export shipments were customs and security related checks could make the urgency of shipments higher than previously defined.

Combined transport loose	collaboration extent	low	medium	high	base
Total transport movements combined	import movements loose	271	313	321	346
	export movements loose	257	267	300	309
Total amount of cargo processed by combined	import cargo loose	871753	1025973	1329017	1068987
	export cargo loose	881576	1008500	1241788	1014436
Average load factor of transport	LF loose collaboration (kilo/trailer)	3323	3511	4139	3183
Amount of shipments late	import	335	402	555	431
	export	135	165	197	153
Amount of shipments later than defined time	import shipments late loose	16	21	35	24
	export shipments late loose	85	91	112	89
throughput time loose transport	throughput time import loose	9,71	9,80	9,91	9,03
	throughput time export loose	3,60	3,55	3,43	3,36
Transport costs	transport costs per kilo import loose	€ 0,028	€ 0,024	€ 0,018	€ 0,023
	transport costs per kilo export loose	€ 0,028	€ 0,024	€ 0,020	€ 0,024
Amount of potential reduction of movements	import movements	181	219	368	208
	export movements	133	179	249	140
	% of total movements loose	-20%	-25%	-39%	-22%

Table 12: Overview of combined loose transport performance in relation to different loose allocation scenario for combined transport

6.3 Performance of combined transport

In order to assess the change in performance of combined transport based on the amount of collaboration that is supported, the amount of transport movements and transport costs per kilo for the different transport flows, are shown in Figure 5 &

Figure 6 below. These figures show that allocating more shipments to combined transport, positively impacts the transport costs, as expected given the fixed amount of transport used. The decline in costs is less when the collaboration is moved to highest level of collaboration for ULD transport, but does decline even stronger for loose transport with only a limited amount of extra transport movements. It therefore can be assumed to be beneficial to support the highest level combined transport possible, however as explained before, the average throughput times keep on increasing for combined transport shipments and also results in more shipments that arrive late and after the defined deadline times, therefore it cannot be said that the performance of combined transport at the highest level of collaboration is better than other levels of collaboration. It can only be concluded that the amount of cargo that is transported and the average load factor can still increase which will give lower transport costs and less transport movements in total for combined transport. Its effects on the use of single transport can be expected to be less positive when only a limited amount of cargo can be transported by single company transport, as it will become even harder to combine the remaining single transport shipments in an effective way.

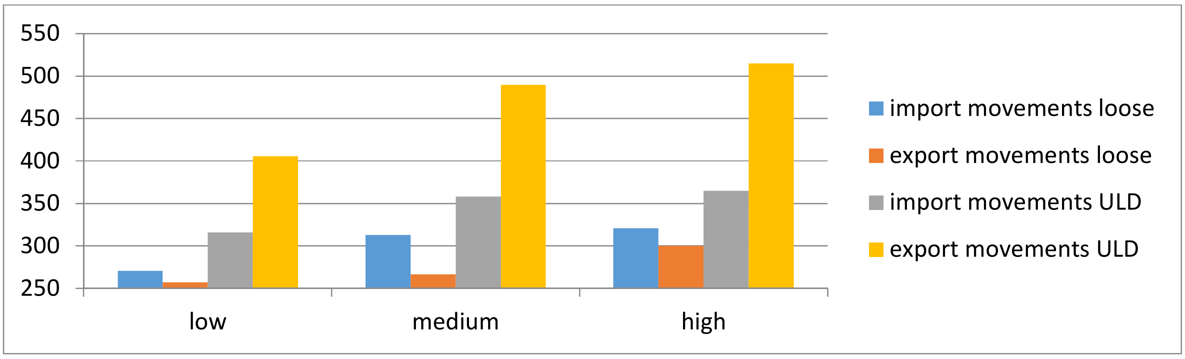

Figure 5: overview of combined transport generation in relation to different amount of shipment allocation to combined transport

Figure 6 below shows that the transport costs per kilo increase for ULD import transport when high level collaboration is supported, which can be explained by the fact that combined ULD transport between import and export is shared, with priority that is given to export transport. With a high level of combined ULD transport, more export ULD transport is realized and less import transport can therefore be generated. This shows that combing ULD transport for both import and export flows only works until a certain level with the fixed capacity has been defined.

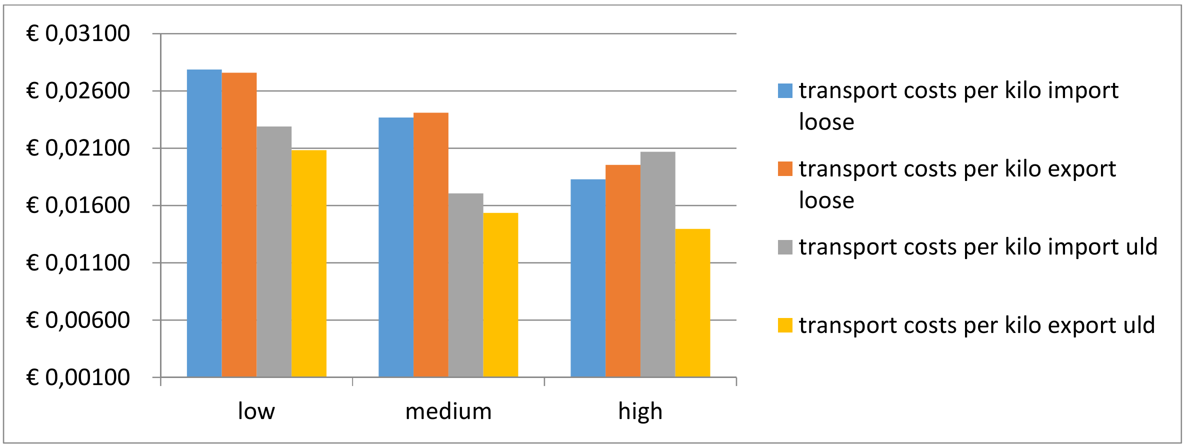

Figure 6: transport costs per kilo for the different types of combined transport in relation to the amount of shipments allocated to combined transport

7 Conclusion, discussion and future research

7.1 Conclusion

The paper has described both a qualitative analysis on air cargo transport collaboration with the air cargo industry combined with a case study analysis and simulation of horizontal collaboration for air cargo transport at Schiphol.

The main research question of this paper was:

To which extent can the application of horizontal truck transport collaboration for inner airport transport of air cargo shipments improve the performance and economics of truck transport at Schiphol airport?

The declining average shipment size combined with the ever increasing dynamics of shipment arrivals at both air cargo handlers and forwarders around Schiphol airport will make it increasingly difficult for even large forwarders to collect and deliver their shipment to a specific air cargo handler in an effective way. This especially relates to loose cargo shipments, as ULD shipments often justify single company transport based on weight and break down times for even a single shipment. The simulation model results show that supporting combined transport can be used to;

- increase the amount of cargo shipments that can be collected and delivered within a given time period
- it can reduce the total amount of truck movements between the air cargo handler and the forwarding warehouses for certain part of shipments
- it can increase the frequency of delivery of shipments for smaller forwarder companies
- it increases the average throughput time of shipments for all companies
- it can reduce the transport costs for shipments that are transported by combined transport
- it does not in all cases reduce the total amount of transport movements
- it increases the time single company transport resources are not utilized

The amount of flexibility the involved forwarders can/will expect in order to support longer average throughput times of both loose and ULD shipment for combined transport and to which extent single transport movements can be reduced, define for a large extent what possible transport improvements can be made by using combined transport. A balance will have to be found between the reduction in costs, amount of transport movements and indirect benefits that could be derived from applying combined transport, which could not all be calculated by the simulation model. Given the fact that combined transport can on average result in shipment throughput increases of between 1 to 3 hours, it can however be expected that not all of the shipments that are been offered for collecting of the involved forwarders will fall within higher throughput timings. When however forwarding companies are able to allocate a large degree of their shipment transport to combined transport and also do not significantly increase their use of single transport for the collecting of the remaining shipments, both transport costs and transport movements can be significantly reduced. Collaboration transport for both loose and ULD transport can be realized in a more cost effective way than single company transport even for the lowest level of collaboration defined scenario. However the performance and frequency of combined and

single transport after supporting combined transport will reveal if combined transport can actually be supported on the basis of lower costs alone. Not all companies that will support combined transport will be able to reduce total transport costs by only supporting combined transport at one specific air cargo handler. Indirect benefits that could be derived from applying combined transport should therefore also be analyzed in depth. Companies that are involved in horizontal collaboration at Schiphol should have sufficient scale demand on a regular basis to and from a specific handler to justify the application of combined transport with the use of fixed capacity over a limited period of time. Within the current system at Schiphol, it can be difficult to find the right number of companies based on their size and amount to support horizontal collaboration in an effective way. This is due to the fact that the amount of companies that can be considered for collaboration are limited due to the locations of warehouse and operations involved forwarding companies around Schiphol. Export collaboration does not only require similar flows or operations but also status of cargo related to security, documentation and customs in order to speed up handling processes at the handling facility. This is why it is easier to realize transport collaboration on import flow, as transport within the airport area inbound wise is less restricted. Even if collaboration on combined transport only slightly reduces the amount of trucks arriving at the handling facility it can still realize other benefits that would be important for both forwarder companies and the handler. The air cargo handler will have more control and stability over part of the trucks that come to deliver and collect shipments, which will still make it able to better plan its resources when a limited amount of cargo is allocated to combined transport systems. It can also give forwarders the ability to manage part of their transport needs with less effort and to obtain lower costs and this will make it possible for them to better utilize their organizational and transport resources for more urgent/ high care shipments. The ability and willingness of companies involved in collaboration to make the combined transport work is also highly important, when companies are more flexible and supportive regarding faster direct processing of combined transport flows the attractiveness of combined transport can further improve.

7.2 Discussion

The actual effects of using combined transport on single transport performance are currently unknown, this is why it is very difficult to state to which extent combined transport can improve both operational performance and transport costs of the each company when looking at the total transport system. The results of this research can therefore not be directly translated into actual reduction in transport costs or improvements related to amount of transport deliveries within a certain time. This research tries to show the difference of combined transport and single transport and to which extent certain use of combined or single transport have an impact on the behavior of the involved transport system. The use of fixed combined transport can be compared to the use of single transport in several situations resulting in both significant reduction of transport movements and transport cost. However, how much of these benefits remain can only be quantified once the adapted use of single transport is known. For smaller forwarding companies it can be more difficult to reduce their fixed amount of truck by supporting only a certain amount of transport with the use of combined transport. Therefore reduction in cost can only be realized when more variable capacity is used instead of fixed capacity. Given the lack of data that was at hand on which this research simulation model is based, the findings of this research is only valid to a limited extent, and which is also why the results should be only used as guidance to understand the possible differences of using single or combined transport. Forwarders and air cargo handlers around the world should use this research to assess whenever their operations can be realistically validated with the data of this model. Lack of information about the actual throughput times of forwarding companies shipments could for example reveal when companies look at the defined KPI's of this research. This can make it difficult to relate the results of this research to the actual operations of forwarding and air cargo handlers. It can however be helpful for companies to get a better understanding on which type of KPI's single and combined transport can be measured and how allocating of cargo shipments with different volumes of cargo of several companies effects the cost base and performance of combined transport. The current use of mostly fixed transport capacity for single company transport is known to be costly and often ineffective, especially with the increasing dynamics of air cargo, small shipments sizes and large amount of different handling facilities that are operating at large air cargo airport. Due to the difficulty of reducing transport costs in total for all involved forwarders assessment of indirect KPI that could not be quantified by the simulation model are crucial to ensure that combined transport can possible be supported by larger group of forwarding companies. Currently however, many forwarder companies around the airport only judge their transport system performance on direct KPI's which benefits that do not reveal all relevant organizational performance improvements that come from applying combined transport, thus making it more challenging to implement and support combined transport for companies that cannot reduce their total transport costs by applying combined transport alone.

7.3 Future research

Given the lack of data on which this research is based, the first recommendation for future research is to construct an updated simulation model on air cargo transport with the use of more detailed actual data that can be used to validate the complete simulation model. The arrival of shipments and weight distributions of both ULD and loose cargo have been

based on the average amount of cargo processed over a certain period of time. However, it not being certain to which extent the used shipment arrival distribution can be applied to forwarders active around in general or that the arrival of shipments for both import and export greatly defers between forwarders. Future research should try to assess to which extent demand stability of cargo flows both on import and export actually exists for the forwarding companies that want to collaborate. The stability of demand will be crucial to define how fixed and variable capacity for each truck transport should be used in combined transport in order to improve both the transport performance and throughput times of shipments. This is why future research should look at the impact of using either a combination of fixed or variable truck transport capacity and use. In order for this it has to be clearly defined where extra capacity should be hired and how extra costs for hiring an additional truck will be allocated to the different companies involved in the collaboration. One of the major challenges that have been described is, to which the remaining single company transport can be organized. A way to improve the remaining single transport demand is by also using a combined transport services for individual transport needs on ad hoc basis. It is likely that planning the remaining single transport demand by one specific transport company for more than one forwarder could be organized more effectively than the transport planning of three companies individually. Therefore, future research should also look at how collaborative transport can be planned jointly for both combined company shipments transport and single company 'express' shipments transport between several forwarders and a specific air cargo handler. Only when both combined and single transport can be improved and are adapted after changes are made to transport, can the full potential of using combined transport be realized both on performance and cost base.

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Appendix A: Data used for calculation of KPI's

Transport costs per kilo cargo transported

The values provided by tables (1 and 2) below are used to calculate the costs per kilo of transport for specific flow per company. For the transport flows that do not have a specific transport resources allocated to import or export transport the costs for import or export transport are assumed to be half of the total costs.

kilo cargo transported / share ULD / loose	import		export	
	uld	loose	uld	loose
c1	1190026	900519	1319614	891044
	57%	43%	60%	40%
c2	58615	381919	53831	490300
	13%	87%	10%	90%
c3	514299	332861	583253	260993
	61%	39%	69%	31%

Table 13: Amount of cargo transported by individual transport for specific flows of shipments (30 days simulation)

Transport resource use				
Company	truck rates (hr)	hours operating	amount of trucks uld	amount of trucks loose
c1	€ 45,00	720	2	2
c2	€ 50,00	600	1	1
c3	€ 50,00	600	1	1
com	€ 45,00	540	2	2

Table 14: truck rates, operating hours and amount of transport (30 days operations)

- transport costs for a truck per hour (tht_e)
- amount of trucks hired for specific shipment transport (ts_a)
- amount of cargo transport by truck resources (tr_c)
- amount of hours operating transport (h)

Transport costs per kilo $(tc_k) = \left(\frac{tr_c}{ts_a * tht_e * h}\right)$

Transport movement reduction potential

Due to the fact that single transport is not rationalized in the simulation, a formula is defined that can define the potential reduction of transport movements by applying combined transport. In order to do this the transport movements and amount of cargo transport by single and combined transport for specific shipments is used. Data of table 10 and 11 is used for combined transport movements together with single company transport movement data of table 9. The reduction potential compares the amount of movements that single transport would need to transport the same amount of cargo that is transported by combined transport, the reduction in movements compared to the actual amount of combined transport is calculated and the remaining amount of cargo is assumed to be transported with the same load factor as in the single company transport situation.

- total amount of cargo transport import single company transport loose ($tisl_c$)
- total amount transport movements import single company transport loose ($tisl_t$)
- total amount of cargo transport import combined company transport loose = ($ticl_c$)
- total amount transport movements import combined company transport loose ($ticl_t$)
- total amount of cargo transport export single company transport loose ($tisl_c$)
- total amount transport movements export single company transport loose ($tisl_t$)
- total amount of cargo transport export combined company transport loose ($ticl_c$)
- total amount transport movements export combined company transport loose ($ticl_t$)

Import reduction potential $(tpci_t) = tisl_t - (\left(1 - \left(\frac{ticl_c}{tisl_c}\right) * tisl_{t)}\right) + ticl_t)$

Export reduction potential $(tpce_t) = tesl_t - (\left(1 - \left(\frac{tecl_c}{tesl_c}\right) * tesl_{t)}\right) + tecl_t)$