The Airport Choice for Scheduled Freighter Operations in Europe

Franziska Kupfer

Promotors: Prof. dr. Ann Verhetsel
Prof. dr. Eddy Van de Voorde

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PhD thesis

Promotors: Prof. dr. Ann Verhetsel

Prof. dr. Eddy Van de Voorde

University of Antwerp

Faculty of Applied Economics

Department of Transport and Regional Economics

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Abbreviations

General Abbreviations

Abbreviation	Explanation
ACI	Airport Council International
ACMI	Aircraft, Crew, Maintenance and Insurance
CASS	Cargo Accounts Settlement Systems
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
TFS	Traffic by Flight Stage
JIT	Just-in-time
UNCTAD	United Nations Conference on Trade and Development
WTO	World Trade Organization
YoY	Year on Year

IATA Airport Codes

Airport Code	Name of Airport
AMS	Amsterdam Schiphol Airport
BCN	Barcelona Airport
BRU	Brussels Airport
CDG	Paris-Roissy Charles de Gaulle Airport
CGN	Cologne/Bonn Airport
CHR	Chateauroux-Deols "Marcel Dassault" Airport
CPH	Copenhagen-Kastrup Airport
DUB	Dublin Airport
DUS	Dusseldorf Airport
EMA	East Midlands Airport
FCO	Fiumicino Leonardo da Vinci Airport
FRA	Frankfurt Airport
HHN	Frankfurt-Hahn Airport
IST	Istanbul Ataturk International Airport
LEJ	Leipzig/Halle Airport
LGG	Liège Airport
LGW	London Gatwick Airport
LHR	London Heathrow Airport

Airport Code	Name of Airport
LUX	Luxembourg-Fidel Airport
MAD	Madrid Barajas Airport
MAN	Manchester Airport
MXP	Milan-Malpensa Airport
MUC	Munich Airport
OSL	Oslo-Gardermoen Airport
STN	London Stansted Airport
VIE	Vienna Airport
XCR	Vatry Airport
ZRH	Zürich Airport

Overview of Model Names

MNL – Multinomial logit model including all six attributes as effects coded variables.

MNL mainAirports - Multinomial logit model calculated with data of airlines that mainly serve main airports, excluding parameters for passenger operations at an airport, specifying airport charges and demand as linear attributes.

MNLnoPax - Multinomial logit model including all attributes as effects coded variables excluding parameters for passenger operations at airport.

MNLnoPaxClinDlin – Multinomial logit model excluding parameter for passenger operations at an airport, specifying airport charges and demand as linear attributes and including all remaining attributes as effects coded variables.

MNL regionalAirports – Multinomial logit model calculated with data of airlines that mainly serve regional airports, excluding parameters for passenger operations at an airport, specifying airport charges and demand as linear attributes.

MNLsocio – Multinomial logit model excluding parameters for passenger operations at an airport, specifying airport charges and demand as linear attributes and including interaction variables 1) of the presence of forwarders with main airport and 2) of night-time restrictions with main airport.

PML allRandom - Panel mixed logit model including all parameters and accounting for the panel structure of the data, specifying airport charges and demand as linear attributes and assuming that the parameters are either randomly normal distributed (charges and demand) or uniform distributed (all other parameters).

PML noPaxAllRandom - Panel mixed logit model excluding parameters for passenger operations at an airport, taking into consideration the panel structure of the data, specifying airport charges and demand as linear attributes and assuming that the parameters are either randomly normal distributed (charges and demand) or uniform distributed (all other parameters).

PML noPaxRandomDExFwNight - Panel mixed logit model excluding parameters for passenger operations at an airport, taking into consideration the panel structure of the data, specifying airport charges and demand as linear attributes and assuming that all the parameters for the demand are randomly normal distributed, for experience with cargo, presence of forwarders and night-time restrictions uniform distributed and including airport charges as non-random parameter.

Acknowledgements

The acknowledgements are often one of the last parts written in a thesis. However, for me it is one of the most important parts as I could not have finished this research without the help and support of many people.

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Summary

In international freight transport, air transport plays an important role. This role was only strengthened by the process of globalization. With new production processes and a growing distance between production and consumption centers, the need for faster and more reliable transport increased. Air transport can accommodate those needs. However, research in air transport has been focussed mostly on passenger transport as has the research surrounding airport competition. Concerning the airport choice of cargo airlines, very little research has been done so far. However, with many airports competing for the same cargo, airports need a good understanding of the airport choice of cargo airlines in order to be able to attract cargo airlines. Therefore, this study was carried out as a step towards better understanding the airport choices of cargo carriers. The specific focus is set on how airlines choose their airports for scheduled freighter operations in Europe.

One of the results of this study is that different ideas could be identified concerning the process that airlines follow before deciding on an airport. While in literature, the process is described as sequential, findings from discussions with airline representatives show that it should rather be seen as a process in three different phases, which can overlap. The three phases include the economic analysis of a specific region, the analysis of restrictive factors as well as in a third phase other operational factors. During the process also financial analyses are carried out.

In the empirical part of the research, a stated preference experiment was set up using a state-of-the-art partial profile design. A total of 30 completed surveys from 26 different airlines were collected, serving as input data for the estimation of various logit models. First, a simple multinomial logit model was estimated, showing the presence of forwarders as the most important attribute for the airport choice. This result reinforces the idea that the consolidation and growth in the forwarding business during the last decennia lead to an increasing importance of the forwarders. The presence of passenger operations did not turn out to be a significant factor in the airport choice. Therefore, all-cargo airports might also be interesting for airlines.

Second, panel mixed logit models were calculated which illustrated the taste heterogeneity between the various respondents. To further point out the differences between airlines, several multinomial logit models were computed including socio-economic variables. Here, it was found that airlines mainly serving main airports especially look to the presence of forwarders at an airport while airlines that mainly serve regional airports, focus on night-time restrictions when making their decisions.

Finally, compensation indices were defined to indicate the trade-offs that airlines make when choosing an airport for freighter operations. The largest compensation indices could be found regarding the presence of forwarders.

The results of this study can support airports as well as policy makers. First, they can help airports to attract more air cargo by attracting full freighter services with the insights gained in this study. Second, they can help policy makers in dealing with increasing traffic growth at congested main airports. If it is necessary to relocate air cargo services to other less congested airports, the results can give policy makers indications which factors they have to influence in particular to facilitate the relocation for specific airline groups.

Samenvatting

In internationaal vrachtvervoer speelt luchttransport een belangrijke rol. Deze rol nam enkel maar toe door de globalisering. Met nieuwe productieprocessen en een groeiende afstand tussen de productiecentra en consumptiecentra nam de noodzaak aan sneller en betrouwbaarder transport toe. Luchtvervoer kan in deze behoefte voorzien. Toch focuste het bestaande onderzoek naar luchtvervoer, en meer specifiek ook het onderzoek rond luchthavenconcurrentie, zich vooral op passagierstransport. De luchthavenkeuze van luchtvaartmaatschappijen met betrekking tot vracht is tot op heden weinig onderzocht. Met talrijke luchthavens die om dezelfde vracht concurreren, hebben de luchthavens echter een goede kennis over het luchthavenkeuzeproces nodig om luchtvaartmaatschappijen aan te trekken. Daarom werd deze studie uitgevoerd om een beter inzicht te krijgen in de luchthavenkeuze van de luchtvaartmaatschappijen, meer specifiek hoe zij hun luchthavens voor geplande operaties (i.e. operaties volgens een vooraf vastgelegde dienstregeling) met vrachtvliegtuigen in Europa kiezen.

Eén van de resultaten van deze studie wijst op verschillende opvattingen met betrekking tot het proces dat luchtvaartmaatschappijen in hun luchthavenkeuze volgen. Terwijl dit proces in de literatuur beschreven is als sequentieel, hebben gesprekken met luchtvaartmaatschappijen aangetoond, dat de keuze eerder als een proces moet worden gezien, dat in verschillende stappen gebeurt, die niet noodzakelijk sequentieel worden doorlopen en die mekaar ook vaak kunnen overlappen. De drie stappen zijn: de economische analyse van een specifieke regio, de analyse van de restrictieve factoren en als derde de analyse van andere (operationele) factoren. Gedurende het proces worden vaak ook verschillende financiële analyses doorgevoerd.

In het empirische gedeelte van het onderzoek werd een discrete keuze-experiment ontwikkeld, voor hetwelke een state-of-the-art partieel profile design werd gegenereerd. Een totaal van 30 volledige enquêtes van 26 verschillende luchtvaartmaatschappijen werden verzameld als input voor de schatting van verschillende logit modellen. Als eerste werd een eenvoudig multinomial logit model geschat, die expediteurs als meest belangrijke factor in de luchthavenkeuze aantoont. Dit resultaat ondersteunt de opvatting dat de consolidatie en groei in de sector gedurende de laatste decennia tot een groter belang van de expediteurs heeft geleid. De aanwezigheid van passagiersoperaties op een luchthaven werd als een niet significante factor in het luchthavenkeuzeproces geïdentificeerd, wat de idee, vanuit het standpunt van de luchtvaartmaatschappijen, voor het bestaan van all-cargo luchthavens ondersteunt.

Daarnaast werden enkele panel mixed logit models berekend, die de heterogeniteit van de voorkeuren van de verschillende respondenten aantoont. Om deze verschillen duidelijker te maken, werden ook diverse multinomial logit modellen berekend, waarin socio-economische variabelen werden opgenomen. Deze modellen toonden aan dat luchtvaartmaatschappijen die vooral grote luchthavens bedienen in het luchthavenkeuzeproces in het bijzonder op de aanwezigheid van expediteurs letten. Luchtvaartmaatschappijen aan de andere kant, die vooral regionale luchthavens bedienen, focussen in hun beslissingen dan weer vooral op de mogelijkheid van nachtvluchten.

Tenslotte werden enkele compensatie-indices berekend om de trade-offs aan te tonen die de luchtvaartmaatschappijen in hun luchthavenkeuze maken. De grootste compensatie-indices konden gevonden worden met betrekking tot de aanwezigheid van expediteurs.

De resultaten van deze studie kunnen luchthavens alsook beleidsmakers in hun werk ondersteunen. De resultaten kunnen luchthavens helpen bij het aantrekken van meer luchtvracht door met behulp van de inzichten van deze studie meer operaties met vrachters aan te trekken. De inzichten van deze studie kunnen bovendien beleidsmakers ondersteunen, wanneer deze met een toenemende trafiek op overbelaste grote luchthavens te maken krijgen. Indien het nodig is om vrachtoperaties naar andere, niet overbelaste luchthavens af te leiden, kunnen de resultaten van deze studie beleidsmakers indicaties geven welke factoren zij in het bijzonder in acht moeten nemen om de herlokalisatie te vergemakkelijken.

1. Setting the Research Framework

In international freight transport, air transport plays an important role. This role was only strengthened by the process of globalization. With new production processes (e.g. just-in-time (JIT) production) and a growing distance between production and consumption centers, the need for faster and more reliable transport increased. Air transport can accommodate those needs, which is why it resulted in an enormous growth of air cargo traffic in the last 30 years from about 11 million tonnes in 1980 to about 49 million tonnes in 2011, an average growth of almost 4.9% per year, while seaborne trade only grew with about 2.9% annually during the same time period. (own calculations based on data from the International Civil Aviation Organization (ICAO) and the United Nations Conference on Trade and Development (UNCTAD)).

Air cargo itself has specific characteristics that lead to challenges for airlines as well as airports. First of all, in contrast to passenger transport, cargo is often transported one-way from production to consumption center. Therefore often very large imbalances in air cargo flows can be found. To accommodate this challenge, airlines often apply triangle routes to balance the imbalances. Second, the products transported by air are quite diverse and their composition differs by route. Third, the air cargo business is characterized by the volatility of its traffic. Especially all-cargo traffic is known for its volatility. This volatility of all-cargo traffic arises as in times of crisis airlines shift their cargo from all-cargo aircraft to free space in combi or passenger aircraft.

A last important characteristic of air cargo is its footloose character, which means that they do not have to deal with very important sunk costs. This arises from the fact that cargo airlines (integrators such as UPS, DHL and FedEx excluded[1]) do not have to invest greatly in infrastructure at airports. Therefore cargo airlines can relatively quickly change their routes from one airport to the other. As Starkie (2002) points out, the real market power of an airport depends on the market segment and the availability of airports in the proximity. Due to the footloose character of air cargo, airport competition for air cargo can be fierce. Especially in Western Europe where the catchment areas of the different airports overlap, where main airports are sometimes only several hours by truck from each other and where at least five European airports compete for the same freight (Messelink, 2009, p. 4), this can lead to increasing competition between airports.

[1] As integrators often have to invest in specialized infrastructure such as sorting infrastructure, they do incur more sunk costs than other airlines dealing with cargo.

While the generic idea of airport competition and airport market power has already been discussed by numerous authors[2]), often airport competition is associated with passenger transport. In passenger transport the focus has mostly been on the passengers and how they choose the airport to fly from with the hypothesis that airlines would then follow. Concerning the airport choice of cargo airlines, very little research has been done so far. However, with many airports competing for the same cargo, airports need a good understanding of the airport choice of cargo airlines in order to be able to attract cargo airlines. On the other hand, due to the strong traffic growth, airports have to increasingly deal with capacity problems. One way for airports and governments to deal with them, especially on major airports, might be to transfer some activities to other airports with more free capacity. Leisure operations as well as air cargo operations are often considered first, when discussing to relocate services to other airports. However, to be able to convince cargo carriers to transfer their activities to other airports, airports and governments need to have a good understanding of the factors that drive the airport choice of the carriers.

Therefore, this study is a step towards better understanding the airport choices of cargo carriers. The results of this study will enable airports and policy makers to better adapt their strategies to the needs of the airlines and therefore permit them to attract cargo carriers.

1.1. Research Scope

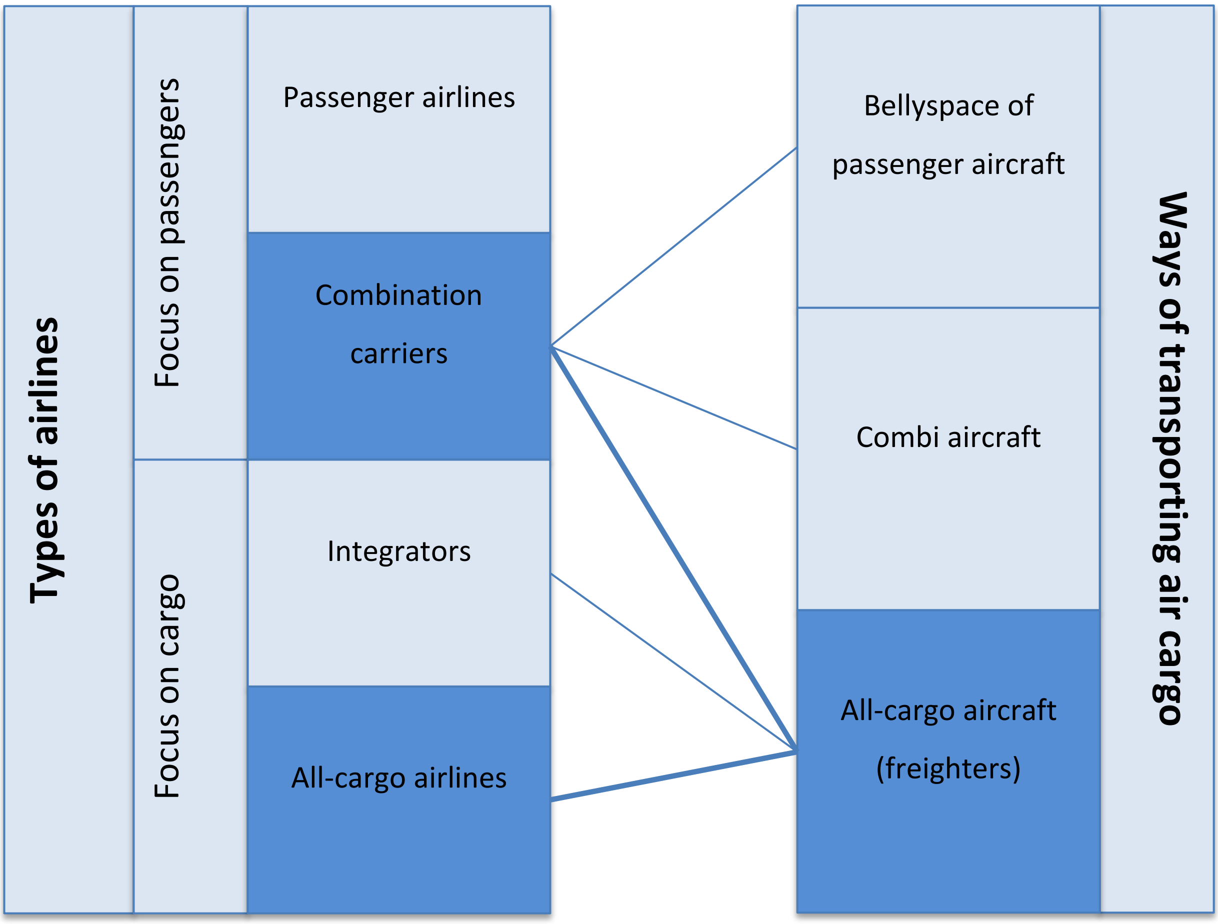
In air transport, a distinction can be made between two different types of carriers: airlines focusing on passengers and those focusing on cargo. Pure passenger airlines, such as Ryanair, deal exclusively with passengers and only organize passenger transport. Other airlines, such as Air France or British Airways focus on passengers as well, but also transport cargo, which is why they can be categorized as combination carriers. The second type of carriers includes carriers that only deal with the transport of cargo such as integrators and all-cargo airlines like Cargolux.

Furthermore, cargo can be transported by air in different ways. First, cargo can be transported in the bellyspace of an aircraft, where also the baggage of the passengers is stored. Second, cargo can be transported in combi aircraft, which are aircraft in which cargo as well as passengers are transported on the main deck. Third, airlines can transport cargo in aircraft especially designed or converted for

[2] For an overview of studies on airport competition please see Forsyth et al. (2010), for a study concerning the airport market power I refer to e.g. Starkie (2008).

the transport of air cargo, so-called all-cargo aircraft or freighters. An overview over the distinctions previously made can be found in Figure 1.1.

Figure 1.1 - Research scope



During the last 40 years an increase in the share of all-cargo traffic[3] could be noticed. Studies (see for example Kupfer et al. (2011)) have shown that all-cargo traffic and combi traffic[4] behave in a different way and therefore should be studied separately. This will have implications for this research as due to those differences also the airport choice will differ between freighter operators and operators of combi- or passenger aircraft. However, to focus the study of airport choice only on all-cargo carriers would be too restricted, as the combination carriers form an important part of the air cargo environment and sometimes also use freighters for their operations. Therefore the research will be centered around the airport choice of combination carriers and all-cargo airlines with regard to their freighter operations. Integrators will be excluded in this study, due to their different business model. Integrators often offer fast door-to-door services for small cargo, while other freighter

[3] All-cargo traffic is defined as cargo traffic generated by freighter aircraft.
[4] Combi traffic is defined as the traffic generated by passenger aircraft in the belly and/or on the main deck.

operators transport mainly general cargo on an airport-to-airport basis. Figure 1.1 graphically shows the scope of the research.

Furthermore, in air transport ad-hoc and scheduled operations can be distinguished. Ad hoc or non-scheduled operations are often carried out due to, for example, sudden extra demand and in agreement with the customer. As a result, the customer also decides the route of the cargo and the airport it is flown to. The scope of this research is therefore limited to scheduled operations as they are set up before the specific demand for the operations is known and decisions concerning airports are taken more independently. Because of this reason, also ACMI carriers[5], which lease aircraft to other airlines, are excluded as they do not make the airport choice decisions themselves. On the other hand, airlines that lease freighters which are operated by another carrier are included in the study. British Airline for example is included in the scope of this study as the airline schedules freighter operations and makes the airport choice decisions. The ACMI carrier Atlas Air, on the other hand, which merely carries out the flights for British Airways, is not included in the scope of this study.

1.2. Aim and Objectives

The overall aim and objective of this research is to deepen the understanding of the airport choice of cargo airlines. In this overall objective, the focus is set on how cargo airlines choose their airports for scheduled freighter operations in Europe. It is important to understand that the objective of this research is to gain information on the general airport choice and not to compare specific European airports concerning their attractiveness to airlines.

[5] ACMI stands for Aircraft, Crew, Maintenance and Insurance. ACMI carriers lease-out aircraft together with its crew. With this type of lease also maintenance and insurance is covered.

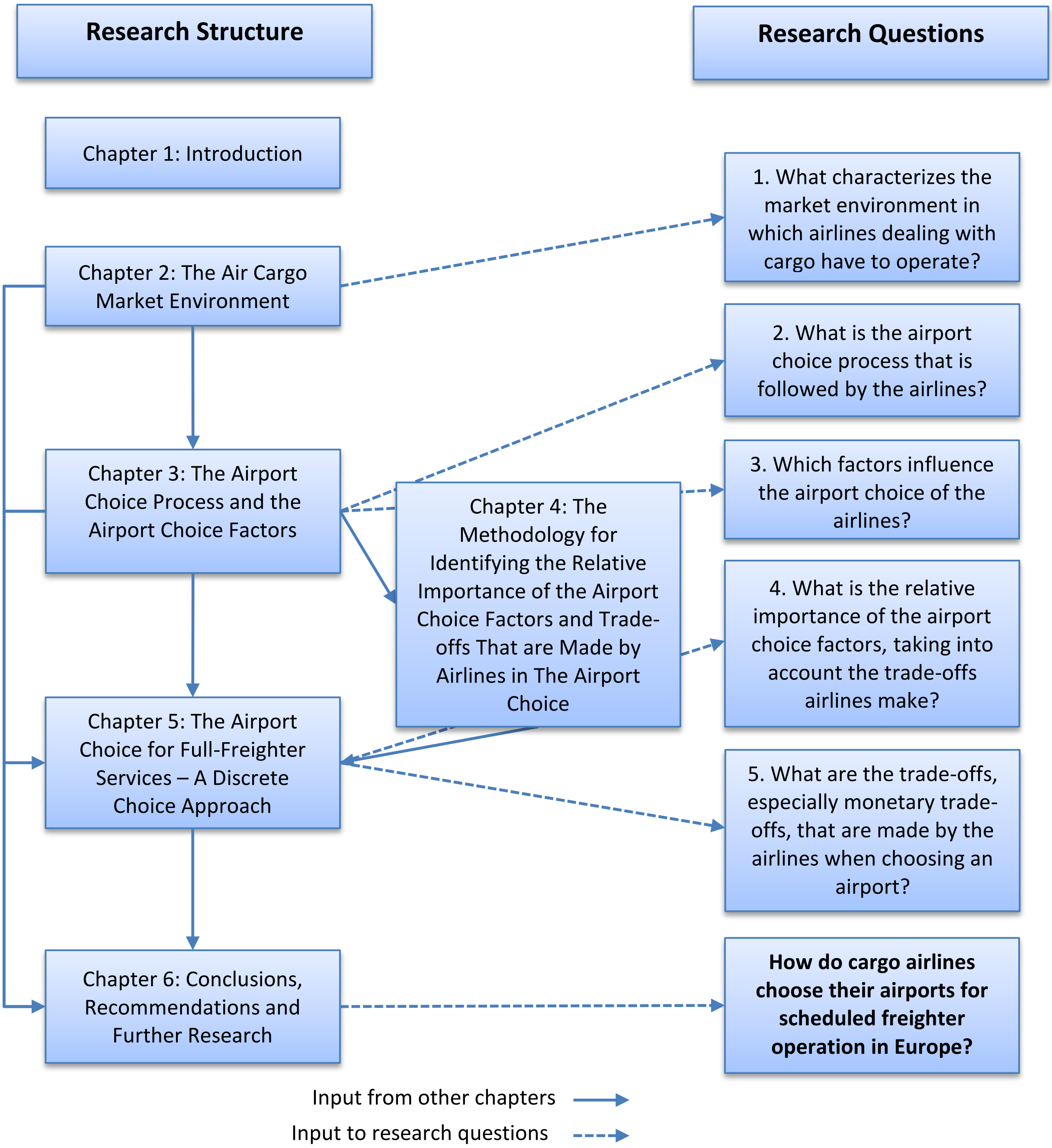
In order to achieve the overall aim, the following sub-questions were formulated and will be addressed during the research:

1. What characterizes the market environment in which airlines dealing with cargo have to operate?
2. What is the airport choice process that is followed by the airlines?
3. Which factors influence the airport choice of the airlines?
4. What is the relative importance of the airport choice factors, taking into account the trade-offs airlines make?
5. What are the trade-offs, especially monetary trade-offs, that are made by the airlines when choosing an airport?

1.3. Research Structure

The relevance of the chapters for the research questions is shown in Figure 1.2. The first chapter includes some introductory remarks as well as the objective and motivation for the research. In the second chapter the air cargo market environment is presented to get a better view about the market environment in which cargo airlines operate. Chapter 3 will give more insights into the choice process of an airline, on the one hand from literature and on the other hand from discussions with airline representatives. Furthermore, the chapter includes a literature review about the factors that influence the airlines in their airport choice decision. The results from the literature review as well as the information on the airport choice process will be used as input for Chapter 4, a chapter that focusses on finding the best method to analyze research questions four and five as well as explaining the application of the method chosen. Chapter 5 is the core of the original research with which I hope to expand the knowledge concerning the airport choice of freighter operators in Europe. The chapter will answer the research question about the relative importance of the airport choice factors, taking into account the trade-offs airlines make. Moreover, the trade-offs, especially the monetary trade-offs, that are made by cargo airlines when choosing an airport are analyzed. In the last chapter, the conclusions will be drawn to answer the main research question. Moreover, some recommendations for airports and governments on which strategy to follow in order to attract air cargo carriers and recommendations concerning future research will be given.

Figure 1.2 - Research structure



2. The Air Cargo Market Environment

During the last decades, air cargo has developed from a by-product of air transport to an important part of business for airlines as well as airports. Traffic growth has been strong and more and more airlines pay particular attention to air cargo and even formulate their own strategies regarding this part of the air transport sector. Moreover, the number of airports focusing on air cargo is increasing.

This chapter introduces the air cargo sector in order to position the research in the general field of air transport. Furthermore, it is a guidance to the environment in which airlines that deal with cargo operate. In order to reach this aim, the peculiarities of air cargo are shown. Also fields of interest connected to the airport choice of airlines are pointed out.

The first chapter begins with a comparison of the evolution of air cargo and passenger traffic to underline the growing importance of the air cargo sector[6]. A general difference between passenger and cargo transport is that passengers typically book a return trip, while cargo is transported one-way from production center to consumption center. This leads to worldwide imbalances in air cargo flows. Those imbalances are analyzed in Section 2.2. The third section presents an overview of air cargo. First, the different categories of air cargo are defined. Special attention is given to the difference of the evolutions of cargo transported in freighter aircraft and passenger aircraft. Furthermore, the customer motivation for shipping cargo by air is given.

The main actors in the air cargo business are introduced in Section 2.4. Moreover, also the air cargo transport network is presented. In the remainder of the chapter the most important actors are further analyzed. The section about cargo airlines is structured as follows: First, integrators, non-integrated freight carriers and combination carriers are initiated. Special attention is given to the cargo revenue share of combination carriers. Second, the position of strategic alliances in the air cargo sector is sketched. Last, the largest cargo airlines are illustrated.

The section about airlines is pursued by an introduction to cargo airports. The different categorizations of airports are described, followed by a discussion of the biggest air cargo airports in the world. Airports handling cargo in Europe are also dealt with as the research is focusing on the European continent. At last, the airport quality of the European airports is looked at, to have a better idea about which airports perform well and which do not.

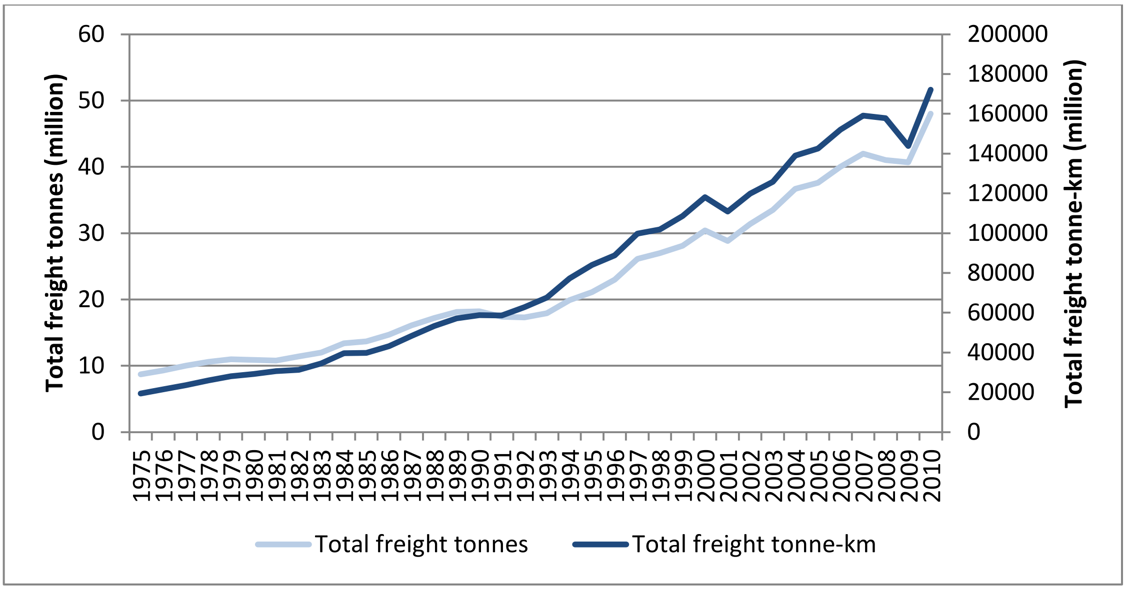
[6] The data of this chapter were last updated on 27 March 2012.

To complete the introduction of the actors in air cargo, the seventh section of the chapter is dedicated to the freight forwarders and their importance in the air cargo network. Finally, the conclusions of the chapter are drawn and suggestions formulated for the continuation of the research.

2.1. Traffic Development

During the last 35 years, air cargo has known a tremendous growth. Figure 2.1 shows the increase in air cargo traffic from 9 million tonnes in 1975 to about 48 million tonnes in 2010, a growth of more than 4.8% per year. This growth can be attributed to amongst others increasing international trade, changes in production processes, and deregulation in numerous regions. An increasing trend can also be seen in the freight-tonne kilometers, where an annual growth of about 6.4% took place in the same period. The reason for the strong increase in freight tonne-kilometer is the globalization process which lead to decreasing trade restrictions and therefore increasing global trade which stimulated not only the growth of transport but also lead to increasing transport distances.

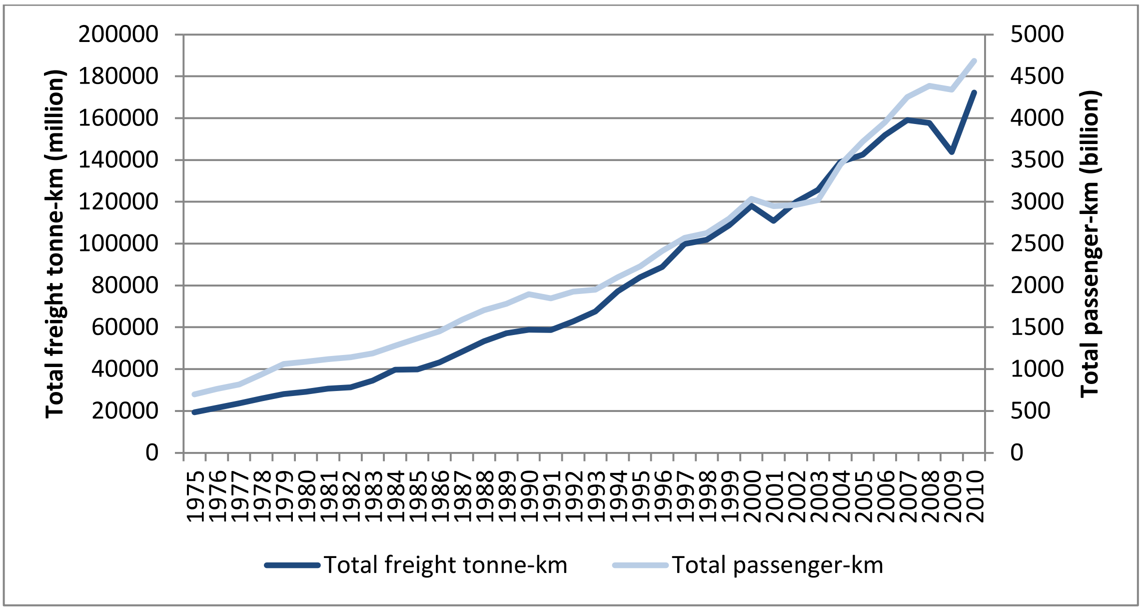
Figure 2.1 - Evolution of worldwide air freight (1975-2010)



Source: Based on ICAO data

Comparing the evolution of freight traffic with the evolution of passenger traffic (see Figure 2.2) it can be seen that passenger-kilometers increased annually with about 5.3%, therefore less than freight kilometers. Especially in the 90s, the cargo traffic knew a stronger growth than passenger traffic.

Figure 2.2 - Evolution of worldwide freight traffic vs. passenger traffic (1975-2010)

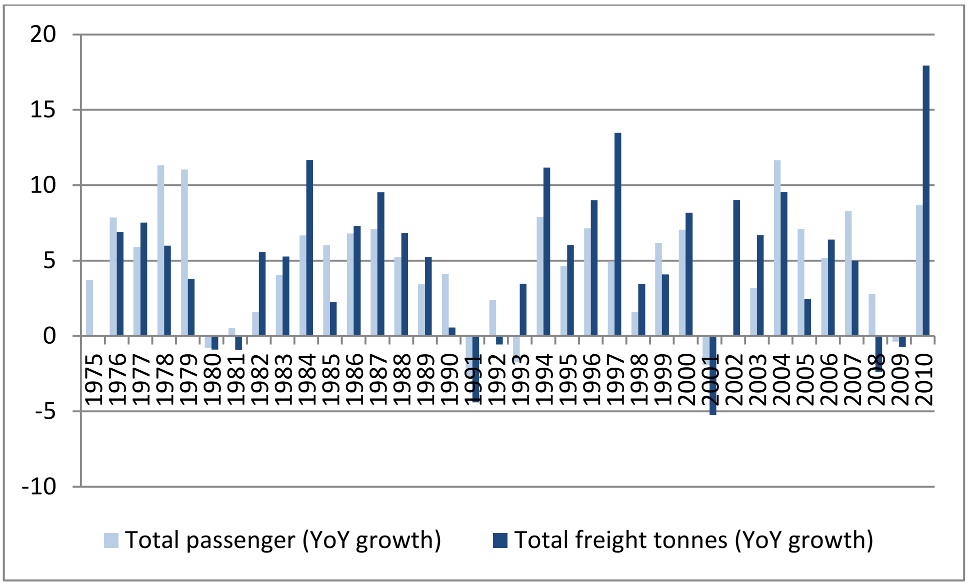


Source: Based on ICAO data

Figure 2.1 and Figure 2.2 both show the decrease in traffic in 2001, due to the 9/11 terrorist attacks, and in 2008/2009, due to the worldwide economic downturn. It can also be seen that freight traffic was much more impacted by the economic crisis than passenger traffic. The reason for the strong impact is that in times of economic crisis, companies often first decrease stock, before ordering more products. This leads to a decrease in the transport of goods. Furthermore, in times of crisis, shippers will often shift transport to less expensive modes. In general, air cargo traffic often reacts more dramatically to crisis situations than passenger traffic but on the other hand also rebounds faster as is shown in Figure 2.3. Since 1975, air cargo has suffered from a negative growth in six years. The first negative growth years in 1980 and 1981 can be attributed to the worsening economic climate, the increasing oil prices and decreasing demand during the second oil crisis. In 1991 and 1992, growth rates again dropped below zero because of high oil prices and the worldwide recession in the early 1990s. The last two times when negative growth numbers can be seen this was due to the 9/11 attacks in 2001 and the worldwide economic recession in 2008/2009.

During those four periods we can see a negative growth which is stronger than that of air passenger transport. However, when the traffic numbers improved, the growth of air cargo was always higher than that of passenger transport. Also in 2010 a higher growth of air cargo than of passenger traffic can be seen. Another reason for the high volatility of air cargo traffic in comparison to passenger traffic is that as previously mentioned in times of crisis shippers often decide to ship their goods via less expensive transport modes, while for passengers often no alternative for e.g. intercontinental transport is available.

Figure 2.3 - Year on Year (YoY) growth of freight tonnes vs. passenger (1975-2010)



Source: Based on ICAO data

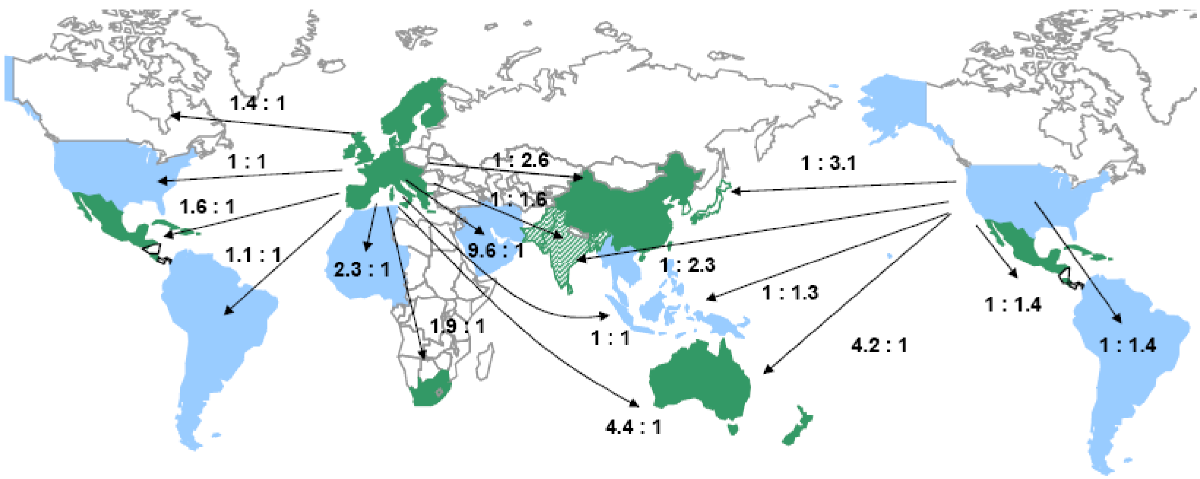
2.2. Imbalances in Air Cargo Flows

Although cargo traffic growth was strong throughout the last decennia, air cargo traffic is not distributed evenly between the continents. Out of the 28 route areas defined by IATA, the biggest 6 routes amount for about 70% of the total traffic in tonnes. Those routes include Domestic North America, Domestic Asia, Asia International, Europe-Asia, North and Mid Pacific and North Atlantic. (IATA, 2011)

One of the differences between passenger transport and cargo transport is that passengers most of the times book a return trip, while cargo is only travelling one way, from production center to consumption center. This characteristic of air cargo leads to large imbalances in the demand for cargo transport by air, while it also brings very different cargo rates depending on the routes and directions (Zhang & Zhang, 2002). Due to those demand imbalances, airlines often develop circular or triangle routes, to adapt their supply. Some airlines, such as Cathay even introduced round-the-world routes to balance their traffic.

The world air cargo flow imbalances of 2008 can be seen in Figure 2.4 and for the major routes between continents in Figure 2.5, as an indication for the size of the imbalance.

Figure 2.4 - Air cargo imbalances (2008)

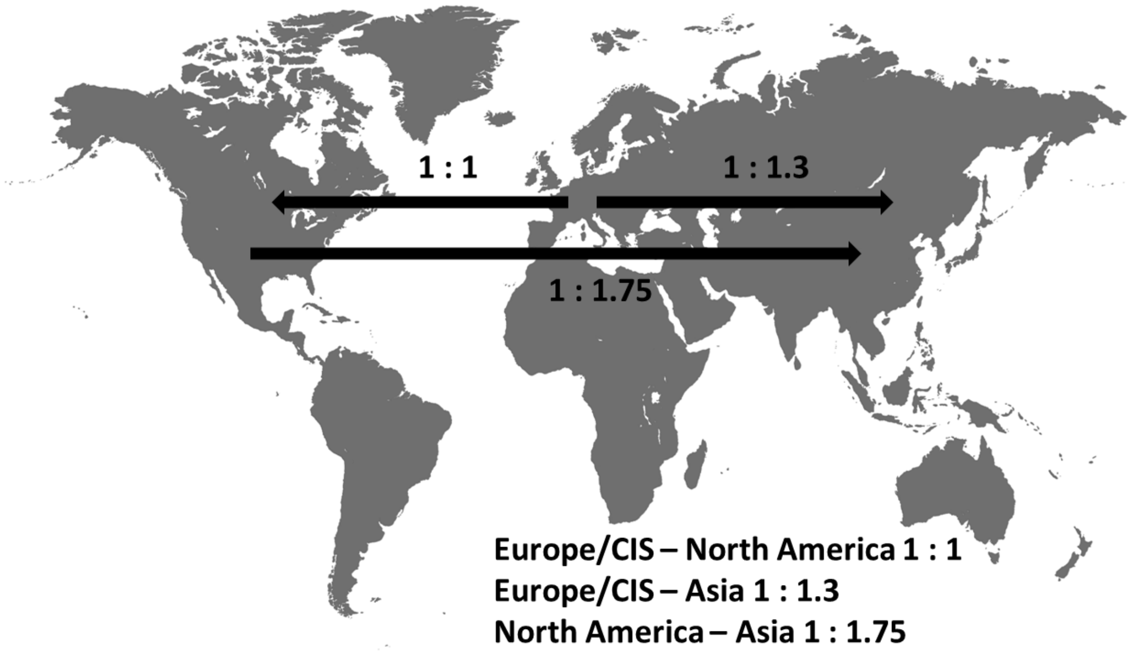


USA to:		*Europe to:*	
Africa	2.6 : 1	East Africa	1 : 3.4
Middle East excl. Israel	14.2 : 1	North Africa	1.2 : 1

Source: YDL Management Consultants (Van de Weg, 2009, p. 4)

The largest imbalance could be seen between the US and the Middle East and Europe as well as between the Middle East. For every tonne of air cargo that was exported from the Middle East to the USA, 14.2 tonnes were imported. The main reason for this imbalance is the nature of goods transported by air. While the USA exports high valued goods to the Middle East, the main export product of the Middle East is oil, which is transported by vessel. Furthermore it can be seen in Figure 2.5 that concerning air freight, the flows between North America[7] and Europe are in balance. On the other hand, on routes from and to Asia, an imbalance of 1:1.3 for Europe and 1:1.75 for North America can be found.

Figure 2.5 - Air cargo imbalances on major routes (2008)



Source: own calculations based on ICAO Traffic by Flight Stage (TFS) data

[7] For the imbalances based on ICAO TFS date, regional aggregation is used as defined by the WTO. For an example of the definition of regions for 2008, see http://www.wto.org/english/res_e/statis_e/its2009_e/its09_metadata_e.pdf

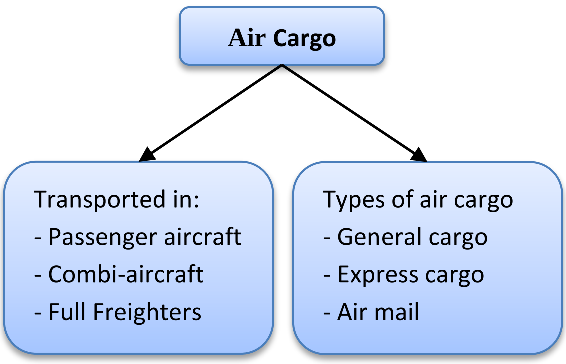
2.3. The Nature of Air Cargo

To understand the character of the air cargo product, its different characteristics are illustrated in this section. In Section 2.3.1 the different types of air cargo are explained with emphasis on the differences between cargo transported in passenger aircraft and in cargo aircraft, while in the second section the motivation of a shipper to use aircraft for cargo transport is outlined.

2.3.1. Categories of Air Cargo

Air cargo can be looked at from two different perspectives. First, a difference can be made regarding the transport of air cargo: air cargo can be transported in passenger aircraft (in the belly), in combi-aircraft or in full freighters. Combi-aircraft are defined as aircraft that next to passengers can transport cargo on the main deck. On the other hand, air cargo can be divided into general cargo, express cargo or postal cargo.

Figure 2.6 - Categories of air cargo



Source: own composition

Of those three different kinds of cargo, general cargo is the most important worldwide, with the highest share of revenue tonne-kilometer (about 84%). General cargo was first introduced in the US in 1931 (Wensveen, 2007, p. 323) and can be defined as cargo on pallets as well as in containers and which is less time-sensitive than express cargo .

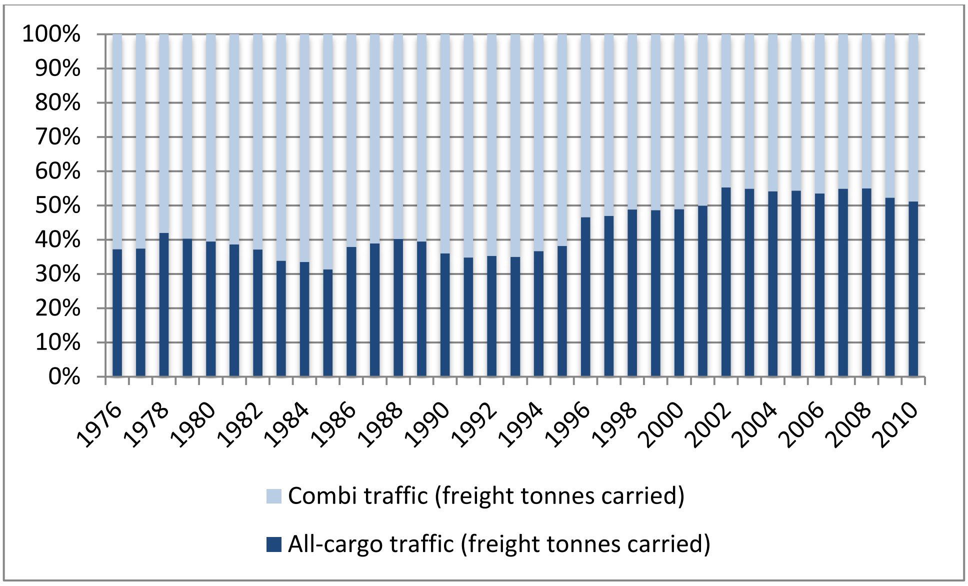
Express cargo on the other hand includes very time-sensitive cargo that is often transported in small packages. In the last decennia, express cargo has grown at almost triple the rate of total worldwide air cargo traffic, with an average annual growth of 22% from 1992 to 2000 and 6.8% between 2000 and 2008. Its share in world air cargo has also grown from 4.1% in 1992 to 12.6% in 2009. (Boeing, 2010a) The growth of Just-in-Time (JIT) concepts is one of the reasons for the growth of express cargo. (Zhang & Zhang, 2002)

Although one of the pioneers of air cargo, air mail nowadays has the smallest share worldwide. In the last years its share decreased from 4.5% in 2000 to 2.5% in 2010. (own calculations based on IATA 2009, p.11) While general cargo and express cargo increased in the aforementioned timeframe, air mail decreased with about 16.4%. This decrease can be attributed to the still increasing trend of digitalization of written documents which, in numerous cases, makes the transport of documents obsolete.

Air cargo, either general, express or air mail, can be transported in the in combi-aircraft, the belly space of a passenger aircraft or in full-freighters. Here full-freighters or "dedicated freighters" are defined as airplanes dedicated to cargo in contrast to combi-aircraft which also transport passengers. However, full-freighters are not to be confused with all-cargo carriers, as combination carriers can also operate full-freighters. During the last 30 years, decreasing capacity on passenger airplanes, more stringent security measures, differences in the flows of passengers and cargo as well as the tendency towards consolidation and growing demand for air cargo led towards a growing share of all-cargo traffic. (Herman & Van de Voorde, 2006) This phenomenon can be found in the number of tonne-kilometres as well as in the freight tonnes carried. Figure 2.7 shows the proportion of freight tonnes changing from about 40% all-cargo traffic and 60% combination traffic (air cargo transported in the belly space or combi-aircraft) to 50% all-cargo traffic and combi-traffic[8]. Between 2002 and 2008, all-cargo traffic in tonnes even had a slightly larger share than combination traffic. However, also the share of all-cargo traffic and combi-traffic differs between routes. While wide-body airplanes with sufficient capacity for cargo dominate the domestic Asian market, narrow-bodies with less cargo capacity are deployed in the domestic US market, which makes the use of full-freighters more popular.

[8] The proportions are calculated based on IATA data, which includes only IATA members in contrast to ICAO data.

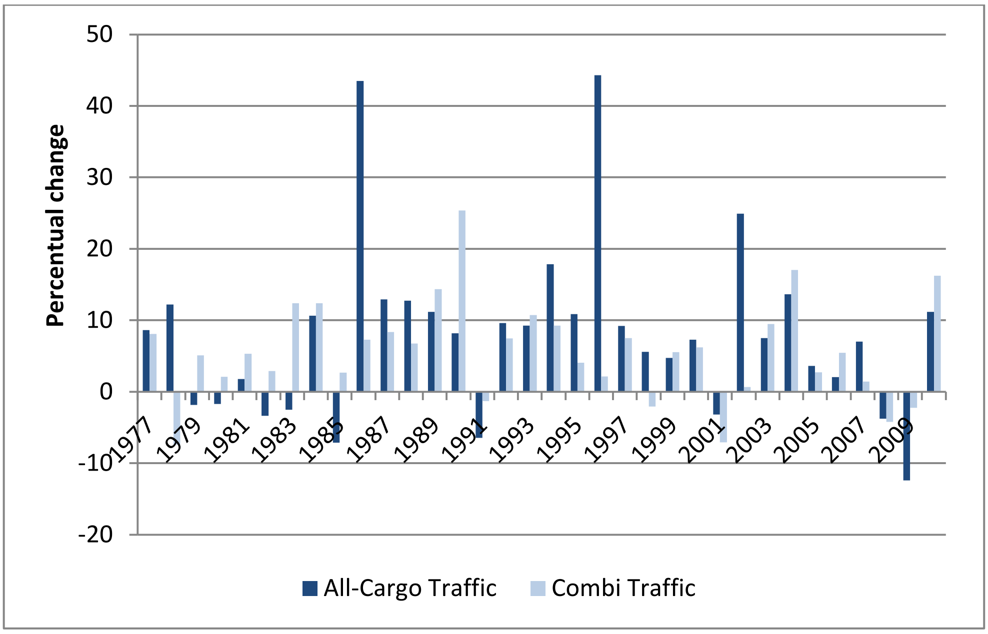
Figure 2.7 - Evolution of the share of all-cargo and combi traffic international and domestic (scheduled services)



Source: IATA (1981-2011), IATA Members' Air Transport Operations

In order to gain insight into the development of all-cargo and combi traffic, the annual changes of both are depicted in Figure 2.8. As already shown in Figure 2.2, the effects of the second oil crisis in 1979, the Gulf War and economic recession at the beginning of the 90s, the terrorist attack on 9/11/2001 and the economic crisis beginning in 2008 can be seen in the evolution of freight traffic. It can be seen however, that all-cargo traffic is much more volatile than combi traffic. The reason for this is that in times of crisis, airlines often first cut back on their freighter capacity and more intensely use their belly-space capacity. Take for example the beginning of the 1990's: while combi traffic still shows a growth in 1990, all-cargo traffic already decreased due to high oil prices and stagnating demand. In 1991, also combi-traffic shows negative growth numbers, still less serious than for all-cargo traffic. On the other hand, once the economic situation improved, all-cargo traffic shows a much higher growth as can be seen in 1992 and especially 1994.

Figure 2.8 - Annual % change of freight tonnes of all-cargo and combi traffic



Source: IATA (1981-2011), IATA Members' Air Transport Operations

2.3.2. Customer Motivation for the Choice of Air Transport

Air cargo is often seen as a premium-cost transportation mode, a mode in which the extra cost compared to other modes is justified by the special advantages of shipping by air. The most important reason to ship by air is the speed of transport. Speed can be especially important for the transport of perishable goods, goods with short live cycles as well as for shipping in emergency situations. In 2008, about 6% of the transported goods by air were foods and therefore perishables. On the route from Latin America to North America this percentage amounted to 49%. (MergeGlobal Value Creation Initiative, 2008) Next to food items, also flowers are counted as perishables. Other good categories that are transported by air due to the speed of transport include electronics and consumer goods such as textiles. Those product groups can have very short live cycles as they follow special trends. An example of the importance of air transport for those goods is the seasonal peak of air transport in the months before Christmas. Between September and November, many producers want to bring their newest products very fast to the market, so the consumer can buy them just in time for Christmas. During this peak also cheaper consumer goods are transported by air, only so that they can lay in the shelves during the Christmas shopping time. The third reason to ship goods by air because of its transport speed are emergency deliveries. By shipping for example repair parts by air, the shipper minimizes the time that equipment is shut down and therefore avoids manufacturing delays.

Another important reason to transport goods by air is that companies can reduce inventory. Customers can choose from a wide pallet of products, but the product itself is only shipped when ordered or sometimes even just made before it is shipped. The most common example for such a way of operating is Dell. Customers can select the components of the computer they would like to by online and thus create a computer that fits their individual needs. After the order is send to Dell, the computer is assembled and shipped to the customer. Because Dell does only have to stock the computer parts and not a high number of computers of different configurations, they save a lot on inventory cost. They also prevent losses from assembled computers with specific configurations that become obsolete due to technical changes and changes in demand.

To transport products by air and with it, save on warehousing, can also be convenient for a company that wishes to start operations in a new market. As, due to airfreight, no large investments for warehouses or distribution centers have to be made in the new market, it is relatively easy to expand the business into new markets. (Lumsden & Stefansson, 2007, p. 7) The use of air cargo can also increase an existing market as in for example 1 hour, a wider market can be reached by air than by road.

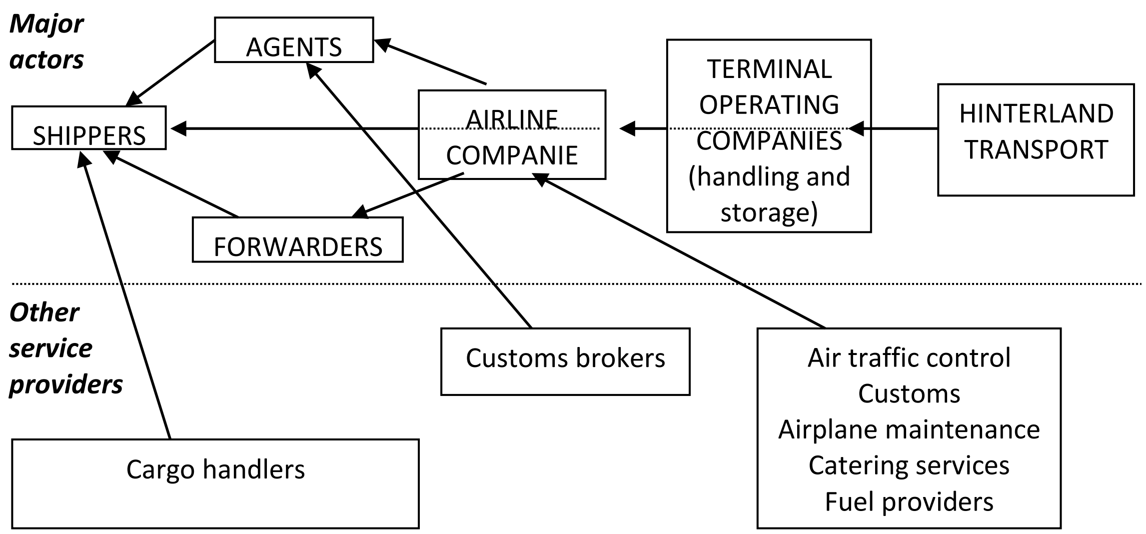
Another advantage of shipping by air is that insurance costs are considerably lower than for other transport modes as the risk of damage is lower and because the transit time is shorter. This is especially important for companies with a high expenditure for insurance. (Wensveen, 2007, p. 330) Also other costs can be lower when using air transport, for example when duty at the destination has to be paid by the gross weight. As the risk of damage is lower, the packaging of the products does not have to be very heavy, which can save out on duties. (Wood, 1995, p. 135)

Furthermore, products are often shipped by air to destinations that do not have good transport infrastructure at their disposal. Such destinations are for example third world countries where road and rail infrastructure is poorly developed.

2.4. Actors in the Air Cargo Business and the Air Cargo Transport Network

Many actors will have to work together in order to transport a good from origin to destination. Figure 2.9 shows the actors in the air cargo business and their relations. In the center of the graph, the airline is shown as it is the main service provider, offering its services to agents, forwarders and shippers. The airlines themselves are supported by the terminal operating companies (often the airports themselves) as well as indirectly by the hinterland transport companies. Furthermore, other actors such as air traffic control, cargo handlers and customs are shown that support the major actors.

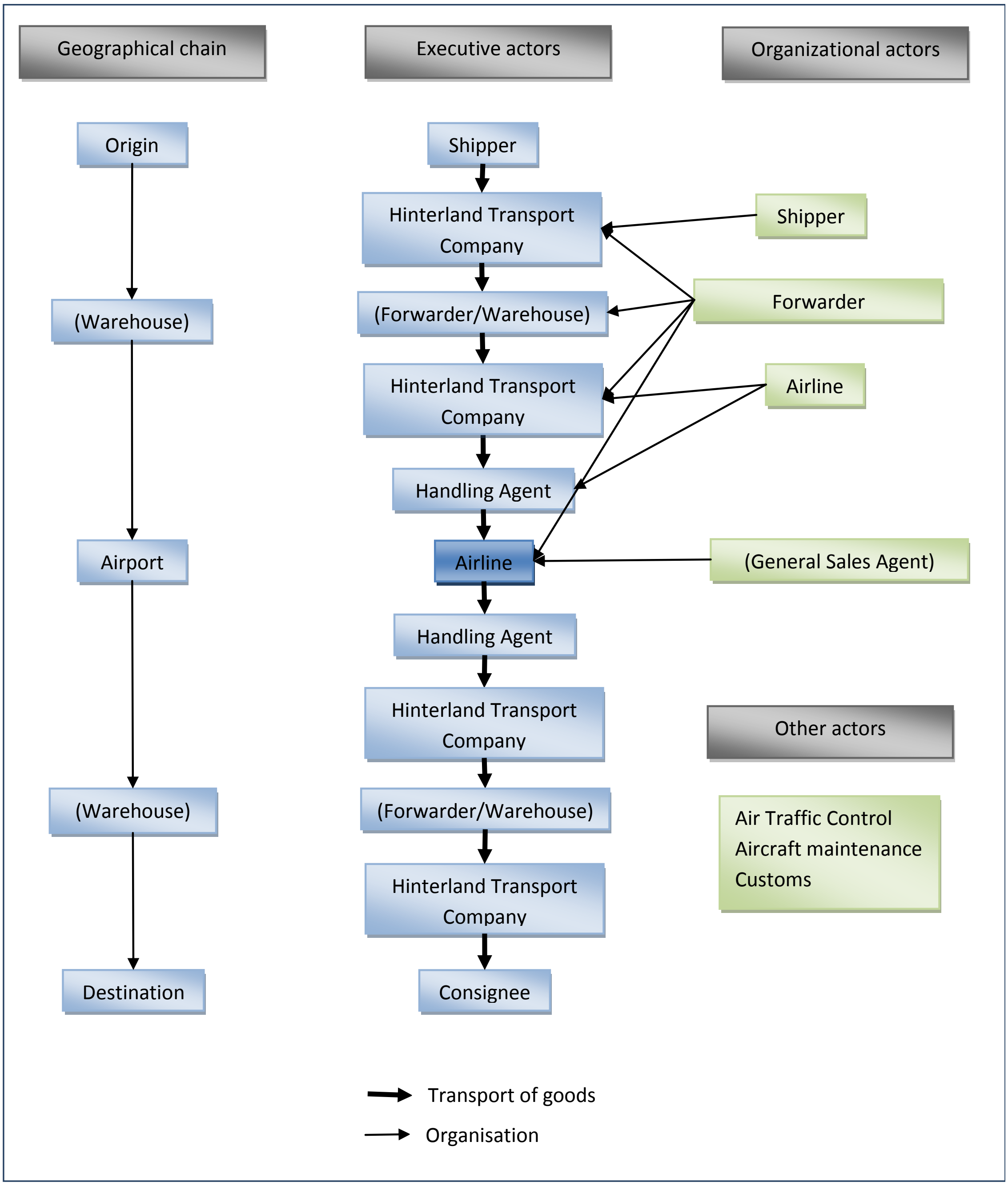
Figure 2.9 - Service providers in the air cargo business



Source: Meersman et al. (2008, p. 77)

When looking at the actors from a transport chain perspective, one can see that again, airlines occupy a central position (see Figure 2.10.). Geographically the goods are transported from the origin, eventually via warehouses and via different airports, to the destination. The transport from the shipper to the airport is often carried out by hinterland transport companies and organized by the shipper itself, the forwarder or the airline. Most of the times, however, this transport is organized by the forwarders. Once at the airport the goods are handled by handling agents and put onto the aircraft to be carried to the destination airport. From the destination airport, the goods will follow the opposite direction via handling agents and hinterland transport companies to the consignee. Other actors that are directly or indirectly involved in the transport of the goods in the air cargo transport chain are general sales agents, which sell the capacity of airlines, air traffic control, aircraft maintenance and customs.

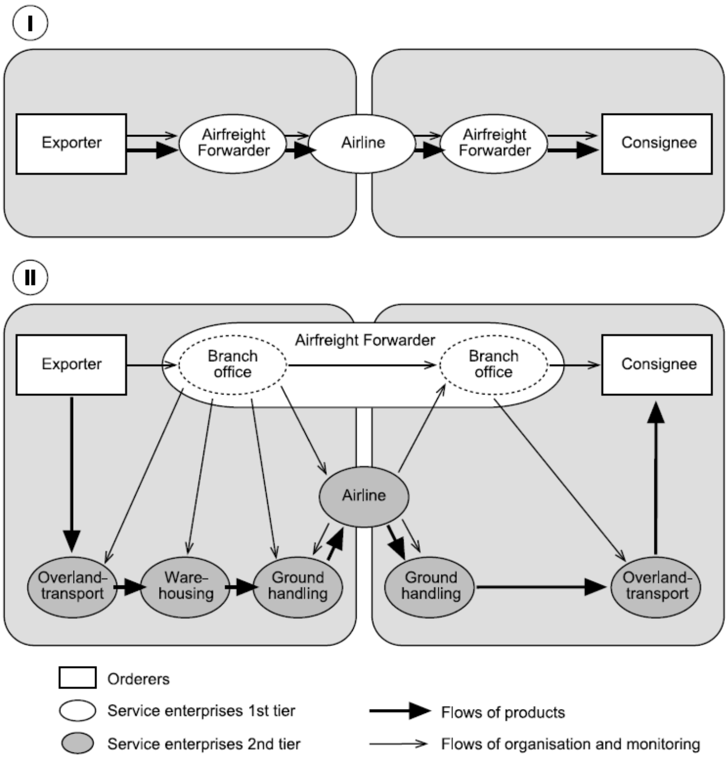
Figure 2.10 - The air cargo transport chain



Source: own composition based on Meersman et al. (2010)

Although Figure 2.10 is very illustrative, it is only a simplified approach to show the way of a good transported from shipper to consignee. Since the deregulation of the transport market, transport companies developed more and more into logistic service providers. As a result of this, the air transport chain as shown in Figure 2.10 developed in time into an air transport network. This structural change can be seen in Figure 2.11, where the airlines seem to play a subordinate role, while the central role of the forwarder becomes apparent. As the forwarders took over the task of organizing all aspects of the organization of transport, they gained control of the transport chain. While they do not carry out all the tasks himself, the forwarders often outsource services as the physical transport, warehousing and ground handling. In Section 2.7 the importance of the forwarders will be explained more in detail.

Figure 2.11 - Air freight: towards a global network



Source: Neiberger (2008, p. 249)

2.5. Cargo Airlines – An Overview

Airlines are the core actors of the air transport chain. Therefore, to be able to understand the air cargo business, it is good to have a closer look at the different kinds of airlines. Furthermore, strategic alliances in the air cargo business are discussed and the world's biggest airlines introduced.

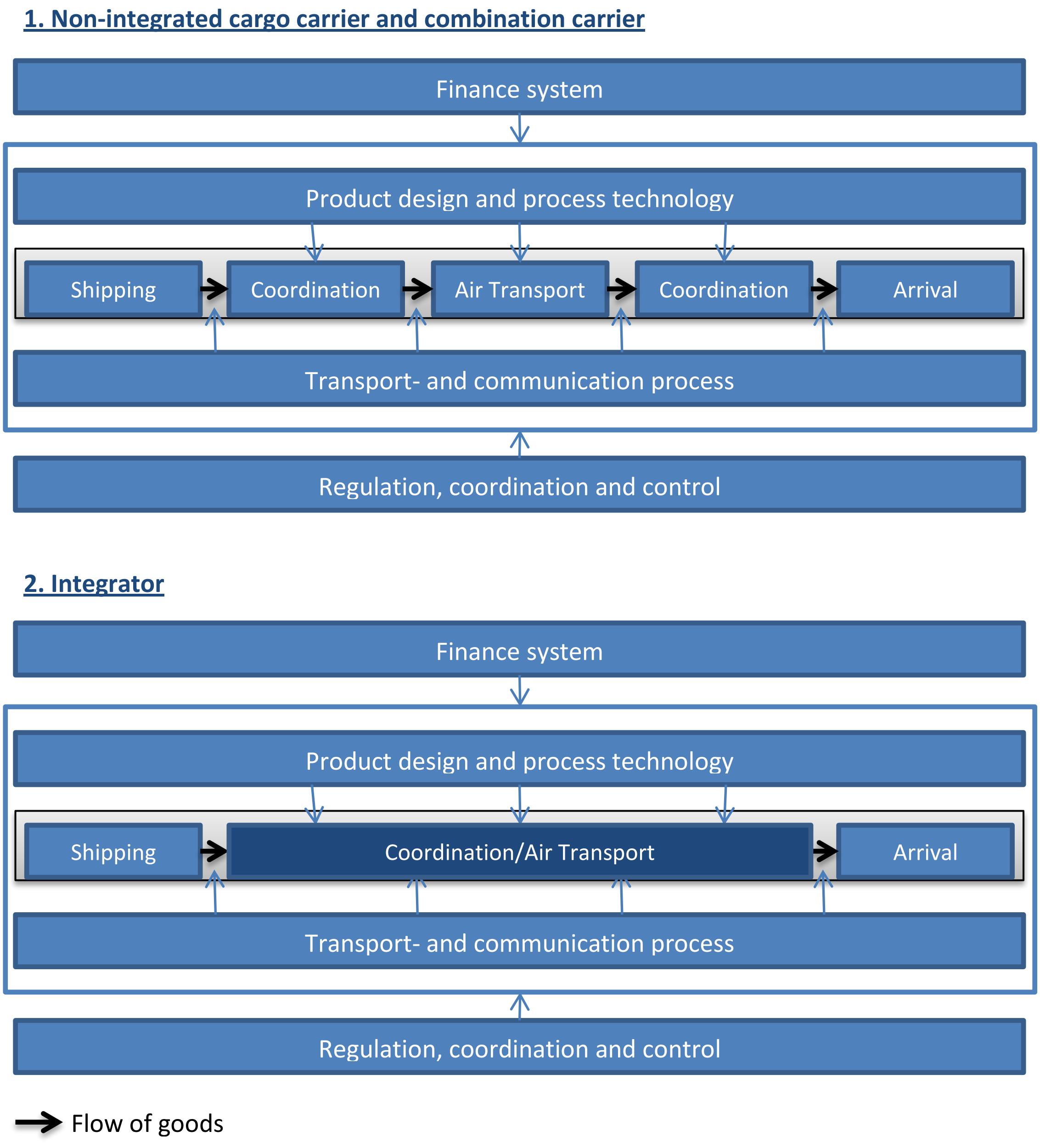
2.5.1. Integrators, Non-integrated Freight Carriers and Combination Carriers

In the air cargo environment, three kinds of carriers are serving the market: integrated carriers, combination carriers and non-integrated freight carriers. Integrated carriers "provide an integrated door-to-door service, merging four principal elements: (1) ground fleet of pick up/delivery trucks, (2) terminals for sorting and processing freight, (3) long-haul truck fleet for moving freight between terminals, and (4) an air fleet for moving freight between airports." (Hall, 2002, pp. 4, 5) Although integrators often focus on the transport of small time-intensive cargo such as packages, during the last years a trend towards an increase of general cargo transported by integrators can be seen. Before the take-over of TNT by UPS in 2012, the "Big 4" of the integrators were UPS, TNT, FedEx and DHL.

In contrast to the integrators, non-integrated freight carriers use freighter aircraft mainly for general cargo. However, they might also offer door-to-door services for a number of countries, as for example Emirates Sky Cargo does. (Emirates Sky Cargo, 2010) Non-integrated freight carriers offer mainly scheduled services but also outsource their services to other airlines (so-called ACMI carriers (MergeGlobal, 2009, p. 19)). In contrast to integrated airlines, non-integrated freight carriers serve a narrower geographic market. The largest non-integrated carriers are Cargolux and Nippon Cargo.

The third group of airlines carrying freight is the one of the combination carriers**.** Combination carriers mainly focus on passenger transport but also carry cargo, mainly in the belly space of the airplane or in combi aircraft, but sometimes also operate freighter aircraft. The difference between integrators, non-integrated freight carriers and combination carriers becomes clear in Figure 2.12. In the traditional air cargo service chain, the coordination of the transport is often executed by forwarders and agents. Integrators on the other hand, combine the coordination with transport. Therefore the control of the whole transport process is in the hand of the integrators, who can offer door-to-door services to their clients as a result. With the integration of the coordination, the integrators are able to offer faster and more reliable services to their customers. Moreover, the transaction costs of the coordination between the different actors can be greatly decreased. (Neiberger, 2003)

Figure 2.12 - The air freight service chain: integrator vs. non-integrated cargo carrier and combination carrier



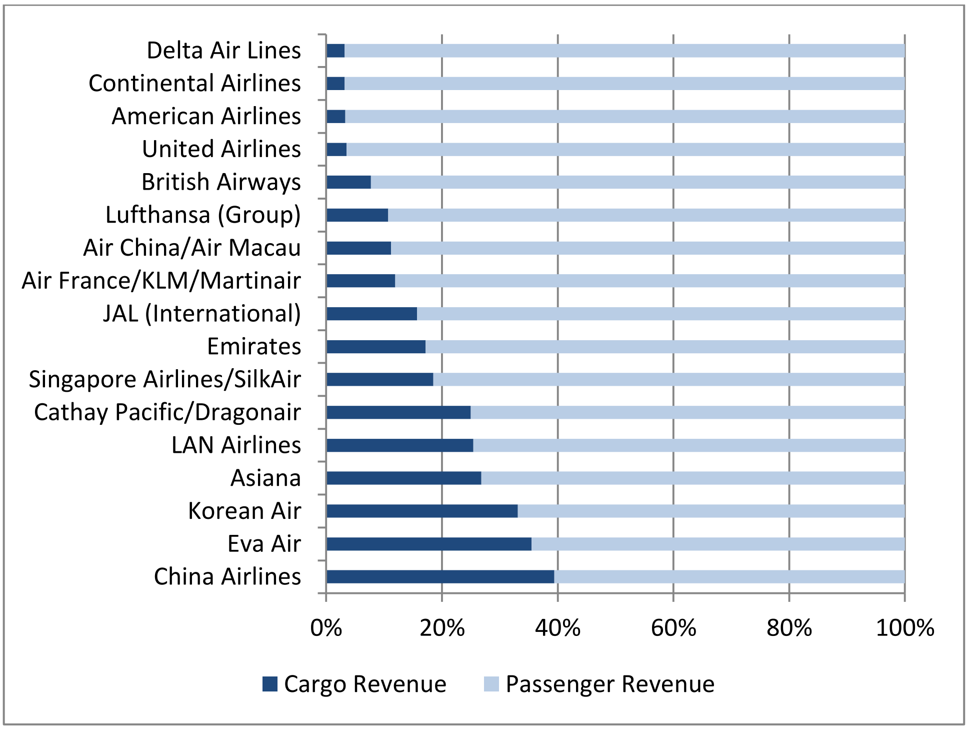
Source: own composition based on Neiberger (2003, p. 200)

In the US, cargo revenue accounts for only 5 to 10 percent of the total revenues of the combination carriers (Wensveen, 2007, p. 326), but it is far more important for European carriers (around 13% in 2008) and even more for Asian carriers (Air Cargo Management Group, 2006, p. 36). For Asian carriers, air cargo accounts for about 30-35% of total traffic revenue as air cargo in Asia is mainly transported in the belly space of wide-body aircraft (Air Cargo Management Group, 2006, p. 36).

Furthermore, the transport of belly cargo is often important for the profitability of intercontinental passenger operations.

The importance of air cargo for combination carriers in Asia can also be seen in Figure 2.13. Of the represented airlines, six of the seven airlines with the highest share of cargo revenue are Asian carriers. Furthermore, it can be seen that carriers from North America as well as from Europe have a very low share of cargo revenue in their total traffic revenue. The low share of air cargo revenue for the North American carriers comes mainly from the fact that in Northern America, the integrators play an important role concerning air cargo and therefore have a very high share of the air cargo market. However, air cargo becomes more and more important also for combination carriers in order to be able to remain profitable.

Figure 2.13 - Cargo revenue as % of total traffic revenue (2009)



Source: Air Cargo Management Group (2011b, p. 12)

Table 2.1 shows that the major part of the top 25 of the biggest cargo airlines are combination carriers. However, the two biggest cargo airlines are two integrated carriers, FedEx and UPS, which shows the importance of integrated carriers. In the table, only one all-cargo carrier is represented. With 712,000 tonnes of freight in 2010, Cargolux is the 17^{th} biggest cargo carrier in the world.

Table 2.1 - The world's biggest cargo airlines by type (2010)

Rank	Airline	Country	Type of carrier	Thousands of freight tonnes
1	Federal Express	US	Integrated	6949
2	UPS Airlines	US	Integrated	4509
3	Korean Air	South Korea	Combination	1805
4	Emirates	United Arab Emirates	Combination	1777
5	Cathay Pacific Airways	China	Combination	1579
6	United Airlines	US	Combination	1555
7	China Airlines	Taiwan	Combination	1347
8	Singapore Airlines	Singapore	Combination	1149
9	China Eastern Airlines	China	Combination	1104
10	Air China	China	Combination	1069
11	China Southern Airlines	China	Combination	1055
12	Lufthansa	Germany	Combination	1052
13	Japan Airlines	Japan	Combination	911
14	All Nippon Airways	Japan	Combination	895
15	EVA Air	Taiwan	Combination	850
16	Asiana Airlines	South Korea	Combination	784
17	Cargolux	Luxembourg	All-Cargo	712
18	Thai Airways	Thailand	Combination	709
19	LAN Airlines	Chile	Combination	694
20	British Airways	United Kingdom	Combination	682
21	Air France	France	Combination	667
22	Qatar Airlines	Qatar	Combination	645
23	Delta Air Lines	US	Combination	525
24	Malaysia Airlines	Malaysia	Combination	507
25	KLM	The Netherlands	Combination	480

Source: Ranking and tonnage based on Top 50 Cargo Airports (Air Cargo World, 2011c)

2.5.2. Strategic Alliances in the Air Cargo Business

When looking for alliances in the air transport business, it can be seen that airlines mostly engage in cooperation concerning passenger operations. In order to cut costs or increase revenues, passenger airlines cooperate by collective coordination of ground services, the use of ground capacities, coordination of discount systems, code-sharing, block-space-agreements, coordination of flight plans and collective system- and software development. (Becker, 1999)

In the passenger business, we can find three alliances: Star-alliance (with members such as Lufthansa, Air China, All Nippon Airlines, Singapore Airlines, United/Continental, and in the future Eva Air), Oneworld (with members such as British Airways, Cathay Pacific, Japan Airlines, LAN Airlines, Qantas and American Airlines), and SkyTeam (with members such as KLM/Air France, China Airlines, China Southern, Korean Airlines and Delta Air Lines). While passenger alliances were able to become a brand name, in the past, the two existing cargo alliances, WOW and SkyTeam Cargo, struggled with the commitment of their airlines and common strategies. This lead to the breaking up of WOW in 2008, after Lufthansa inactivated its membership. WOW was established in 2000 by SAS Cargo Group, Lufthansa Cargo and Singapore Airlines Cargo. In contrast to SkyTeam Cargo, however, the airlines of the WOW group were still offering their own branded products and lacked activity (Air Cargo Management Group, 2006, p. 209).

The only still active cargo alliance is SkyTeam Cargo, which was founded in 2000 by the four airlines Aeroméxico Cargo, Air France Cargo, Delta Air Logistics and Korean Air Cargo. In 2012 the alliance had eight members (SkyTeam Cargo, 2012):

- Aeroméxico Cargo
- Air France/KLM Cargo
- Alitalia Cargo
- China Southern Cargo
- Delta Cargo
- Korean Air Cargo
- Czech Airlines Cargo
- Aeroflot

In contrast to WOW, SkyTeam Cargo members offer standardized products and branding as well as shared terminals to their customers. The products include four different solutions: one for express shipments (called Equations), one for customized shipments (called Cohesion), one for special shipments (called Variation) and one for time-definite general freight (called Dimension) (SkyTeam Cargo, 2012). The decision of working with standardized products enables the airlines to align their processes and offer universal handling as well as to bundle their marketing and branding activities. This again leads to cost savings and wider visibility of their services. Moreover, the SkyTeam Cargo alliance and also cargo alliances in general enable the airlines to offer a wider network to its clients.

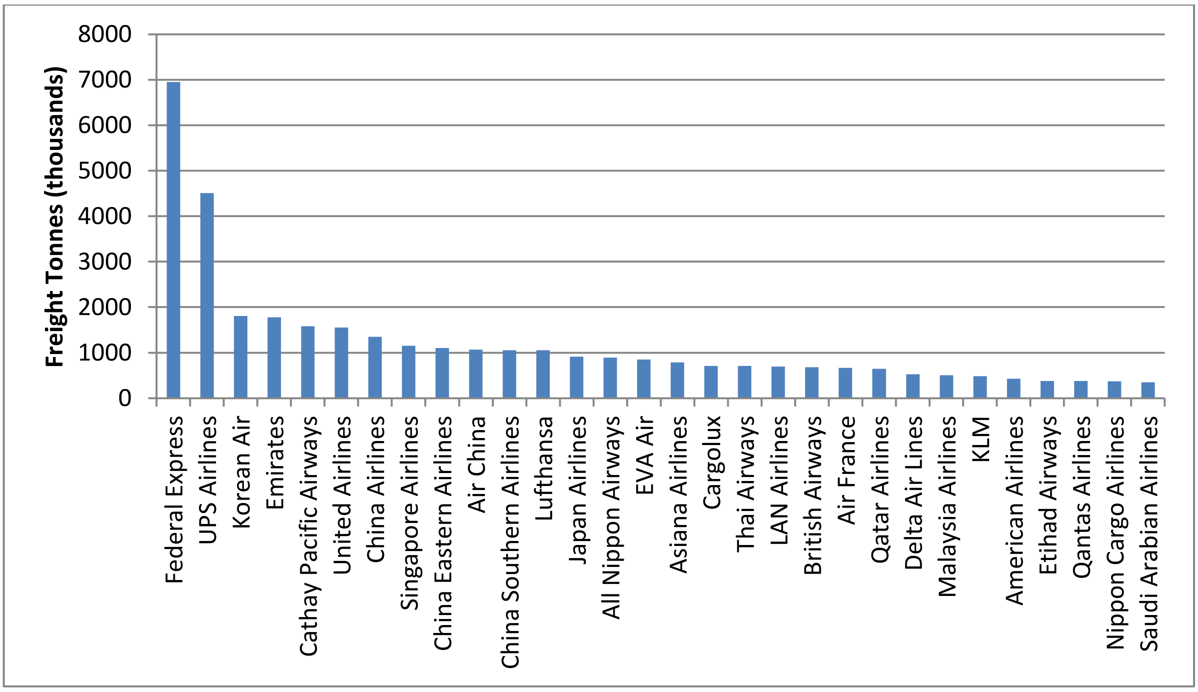
On passenger level, almost all airlines belong to one or the other alliances and airlines that do not belong to an alliance, become more and more scarce. In contrast, only a few airlines belong to a alliance concerning cargo. This and the failure of WOW show that cooperation between airlines with respect to cargo is still scarcer than on passenger level and more often ad-hoc than on a long-term strategic level. While for passenger operations the airport choice might be influenced by partner airlines, for cargo operations it remains the question whether this is also the case.

2.5.3. Top 30 Cargo Airlines

Figure 2.16 shows the most important cargo airlines of 2010 from another perspective, ranked by their freight volume in tonnes[9]. As seen in Section 2.5.1, on the first two places two integrators, FedEx and UPS Airlines, can be found. Although not shown in the top 30 of the figure, also one other integrator was represented in the top 50 cargo carriers of 2010: TNT Airways on place 34. (Air Cargo World, 2011c)

Furthermore it can be seen that in the air cargo business there is an ongoing concentration: FedEx and UPS alone amount to almost 24% (in 2008 this was 16%) of the worldwide air cargo traffic, while half of the worldwide traffic is generated by the 11 biggest cargo airlines. Moreover, about 75% of international cargo is transported by the 25 largest cargo carriers (Dewulf et al., 2011).

Figure 2.14 - World's biggest cargo airlines (Top 30 – 2010)



Source: Air Cargo World (2011c)

[9] A ranking for the year 2011 was unfortunately not possible as the data needed was not yet available when this thesis was published.

2.6. Cargo Airports – an Overview

Airports, as the infrastructure providers to airlines, form a very important part of the air cargo environment. As deregulation in the world increases and more open-sky agreements are negotiated, new possibilities for competition, not only for airlines but also for airports, are created. Still airports seem to have a lot of market power. This, as Starkie (2008) discusses, does however not come from their 'natural monopoly' as a result of high fixed costs, but rather from the difficulties associated with the access to competing sites. Although more and more open sky agreements are discussed, the air transport sector is still dominated by bilateral air service agreements. Those often do not only prevent airlines to compete but also lead to a lack in incentives for competition between airports. Services can only be operated from an airport in a country that has a bilateral agreement with the destination country. (Starkie, 2008) That is why especially for intercontinental routes, bilateral agreements still play an important role in the airport choice of cargo airlines.

In this section, first of all the different categories of airports are presented. The most important cargo airports worldwide and in Europe are introduced next. Finally, a look is taken at the quality of the cargo airports to get an idea which airports are most attractive in Europe.

2.6.1. Airport Categories

The classification of airports is often made based on throughput, especially passenger numbers. The Council of the European Parliament on Community guidelines for the development of trans-European transport network and the Committee of the Regions for example both distinguish only on passenger numbers in their airport classifications (European Commission, 2005). Academic studies such as by Graham (1998) and Malighetti et al. (2009) also incorporate the function of the airport, especially concerning regional functions, as well as incorporate the low-cost airline sector. However, most studies neglect cargo in their airport categorization.

Table 2.2 - General airport categories

	Sustainable business design				
Key drivers for future growth	Primary hub airport	Secondary hub airport	Major O&D airport	Low cost base	Leisure destination airport
Network interconnections	5	2	2	1	1
Network feeder	3	5	3	1	1
Low cost	1	2	3	5	4
Leisure travel	2	2	3	3	4
Representative airports[10]	FRA CDG AMS LHR	CPH VIE LGW OSL	FCO BCN MAN DUS	STN CGN DUB HHN	PMI (Palma) AYT (Antalya) AGP (Malaya) VCE (Venice)
1 – No importance 5 – Very high importance					

Source: based on Mercer Management Consulting (2005)

An example of such general airport categories can be found in Table 2.2. The former Merger Management Consulting distinguishes between primary hub airport, secondary hub airport, major O&D airport, low cost base and leisure destination airport, without considering for example airports that focus on cargo. Only one classification of cargo airports could be found in literature. Allaz (2004) distinguishes between all-cargo airports, hub airports of express freight operators and major international traffic platforms. An overview with examples can be found in Table 2.3.

Table 2.3 - Categories of cargo airports

	All-cargo airports	Hub airports of express freight operators	Major inter-continental traffic platforms
Examples in Europe	HHN XCR CHR	CGN (UPS) LGG (TNT) CDG (FedEx) LEJ (DHL)	CDG AMS LHR

Source: Own composition and examples based on Allaz (2004)

All-cargo airports, sometimes called "industrial airports" as some of them are located close to industrial sites, are airports whose main focus is on cargo transport. Some all-cargo airports also have passenger activity, which is, however, limited in scope. Those airports have specialized infrastructure to handle cargo and are often old military bases. For all-cargo carriers they can be an alternative for

[10] For an explanation of the airport codes see Abbreviations p.VIII.

major airports with environmental restrictions and capacity problems. For combination carriers, those airports on the other hand can be sub-optimal, as they would lose the advantage of interconnecting with passenger airplanes. (Allaz, 2004)

The hub airports of express freight operators rely for most of the cargo traffic on integrators. Allaz (2004, p. 372) puts forward three conditions for an airport to be chosen as an integrator hub:

1. 24 hour operations
2. Sufficient infrastructure to handle the incoming and outgoing aircraft simultaneously
3. Situated near the economic center or region that is being served

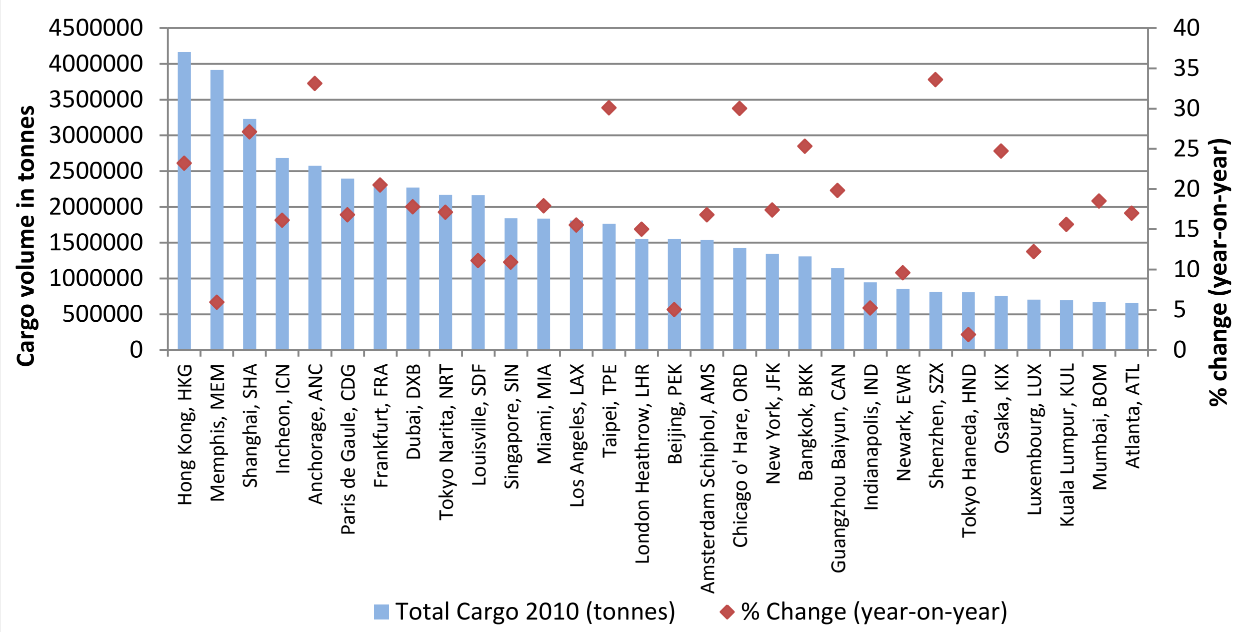
Furthermore, a central geographical location can be of importance. In some cases, however, the reality differs from those conditions. Out of the four integrator hubs in Europe (CDG, LGG, CGN, LEJ), Paris Charles de Gaulle for example does not offer 24 hour operations. (Boeing, 2010b) Furthermore, while all other integrator hubs are located close to the economic center of Europe, Leipzig-Halle Airport, the new European hub of DHL, is situated east of this center.

The last group, the major inter-continental traffic platforms, incorporates cargo airports whose influence stretches far beyond their region and also carry wider functions in logistics and distribution (Allaz, 2004). Often those airports are also major passenger gates.

2.6.2. Cargo Airports Worldwide

To have a better idea about the cargo going through airports worldwide, the world’s biggest airports are shown in Figure 2.15. The biggest airports by far are Hong Kong and Memphis with about 4.2 and 3.9 million tonnes of cargo in 2010 respectively. Memphis’ important position is due to the fact that the world’s biggest cargo airline FedEx build up their hub there. Hong Kong on the other hand is evolving into an important logistical hub in Asia. With some exceptions, such as Anchorage and Louisville, we can see that many of the important airports are major inter-continental traffic platforms and also important for passenger traffic.

Figure 2.15 - World's biggest cargo airports (2010)



Source: Air Cargo World (2011b)

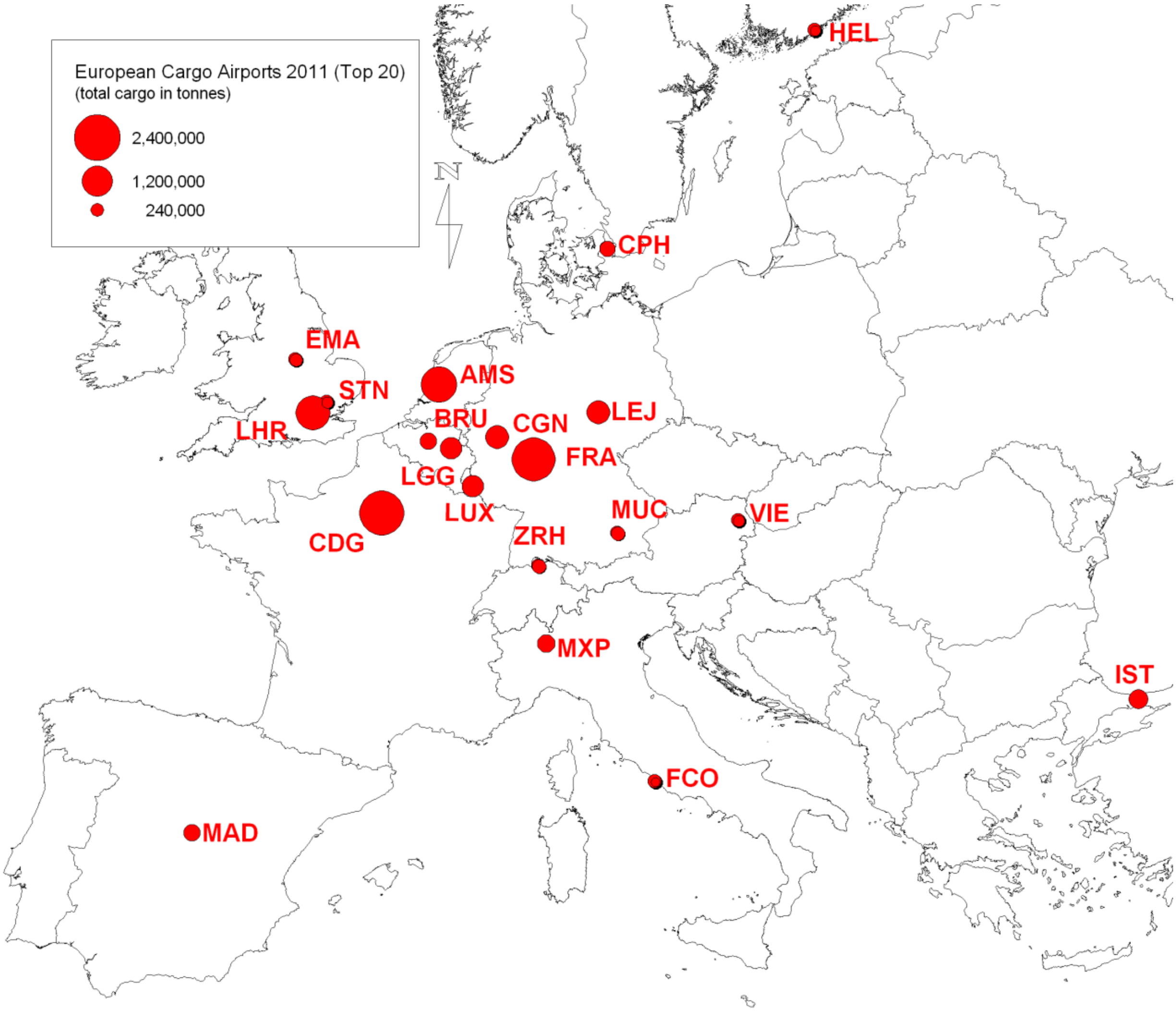
Figure 2.15 also shows the change in cargo between 2009 and 2010. Here it becomes apparent that due to the revival after the economic crisis of 2008/2009, all of the airports show a positive growth, while in 2008 only 5 and in 2009 only 14 airports showed a positive growth (Air Cargo World, 2009a, 2010a, 2011b). In recent years, Asian airports have known a high growth, especially Guangzhou Airport, which grew from 750,552 tonnes of cargo in 2005 to 1,144,458 tonnes in 2010. Also airports which were especially hit hard by the economic crisis such as Anchorage, Chicago and Luxembourg are catching up again.

2.6.3. European Cargo Airports

After taking a look at the biggest airports in the world, the analysis is further focused on the European airports as this study focusses on Europe. The top 20 airports for cargo in 2011 in Europe are depicted in Figure 2.16. The most important cargo airports in Europe are clearly Paris Charles de Gaulle, Amsterdam Schiphol, London Heathrow and Frankfurt. The area between those airports is also known as the Golden Triangle, as almost 66% of European freight transits within this zone. (Allett, 2008, p. 6) After the four big airports, a group of airports follows with freight volume between 150,000 and 740,000 tonnes. This group also includes airports that often play a smaller role in the passenger business but specialized themselves in air freight. Examples of those airports are Liège, Cologne/Bonn and East Midlands.

In 2011 the airports that gained most of the traffic were Leipzig/Halle airport (+12.2%), as an upcoming cargo airport, and Köln/Bonn airport (+12.8%) who gained FedEx Express as a customer in 2011. (see Appendix 1)

Figure 2.16 - Top 20 European cargo airports (2011)



Source: own composition based on ACI data and airport websites

The airports that have known the largest decrease in traffic were Vienna (-8.9%), Rome (-7%) and Zurich (-7.3%). Looking three years back, in 2008, the airport that gained the most traffic was Leipzig/Halle Airport which was able to become the European hub of DHL. Cargo traffic on Leipzig/Halle grew with more than 400%. However, due to the beginning of the economic recession, most European airports knew a decrease in traffic. Cologne/Bonn, Manchester, Brussels and Luxembourg were amongst the airports that experienced the most dramatic fall in traffic with a negative growth of respectively -18.6%, -14%, -11.8% en -8% (calculations based on ACI data).

Table 2.4 - The top 20 European cargo airports by volume in time

Rank	2004	2006	2008	2010
1	Frankfurt	Frankfurt	Paris CDG	Paris CDG
2	Paris CDG	Paris CDG	Frankfurt	Frankfurt
3	Amsterdam	Amsterdam	Amsterdam	London LHR
4	London LHR	London LHR	London LHR	Amsterdam
5	Luxembourg	Luxembourg	Luxembourg	Luxembourg
6	Brussels	Brussels	Brussels	Cologne
7	Cologne	Cologne	Cologne	Liege
8	Liege	Milan MXP	Liege	Leipzig
9	Madrid MAD	Liege	Leipzig	Istanbul
10	Milan	Copenhagen	Milan MXP	Brussels
11	Zurich	Madrid MAD	Istanbul	Milan
12	East Midlands	East Midlands	Madrid MAD	Madrid
13	Istanbul	Istanbul	Copenhagen	Zurich
14	London STN	Zurich	Zurich	East Midlands
15	London LGW	Frankfurt Hahn	East Midlands	Munich
16	Munich	London STN	Munich	Vienna
17	Hahn	Munich	London STN	London
18	Moscow	London LGW	Vienna	Frankfurt Hahn
19	Rome	Vienna	Manchester	Rome
20	Vienna	Rome	Rome	Moscow

Source: Air Cargo World

When analyzing the top 20 of the European cargo airports in time, we can see, that the top 7 of the airports has not changed from 2004 to 2008. However, since 2008 we clearly see Brussels Airport losing traffic in Europe. Brussels Airport, still on rank 6 in 2008, moved down to rank 10 in 2010, due to decreasing demand for air cargo during the economic recession as well as the relocation of DHL's European hub to Leipzig. Leipzig on the other hand entered the top 20 only in 2008 and could be found already on rank 8 in 2010.

2.6.4. Quality of European Cargo Airports

When analyzing the airports in Europe, not only their size has to be considered, but also their quality. Since 2006 Air Cargo World yearly publishes the results of their excellence survey. In the survey airline employees are asked to rate the different airports they do business with according to 4 criteria on a scale of 1 to 7, 1 being the lowest and 7 being the highest score. Those criteria are performance (fulfillment of agreements, customer service and allied services such as ground handling), value (competitive rates, rates commensurate with service level requirement, value added programs), facilities (apron, warehousing, perishables center, access to highway and other modes) and regulatory operations (customs, security). The airports are then grouped according to region and size and the average value of each criteria set to 100 in each group. A score below 100 therefore means a below-average performance and a score above 100 an above-average performance. (Air Cargo World, 2012) The results of the survey from the last two years are shown in Table 2.5.

From the largest airports, Paris CDG was judged the worst airport during the last two years. Even though before 2011, Air Cargo World used a different method to determine the scores, Paris CDG still scored below average (Air Cargo World, 2010b, 2011a, 2012). In 2012 its score was especially low due to below-average performance. Concerning the second group of airlines, especially Cologne/Bonn and Leipzig seem to have satisfied customers, while Madrid and Milan could improve their services. For the smallest airports, Munich, Frankfurt Hahn, London Stansted and Zurich seem to perform above average. According to the survey, in 2012 Zurich scored especially well in value and performance and in 2011 for facilities and operations (Air Cargo World, 2011a, 2012). However, Zurich was one of the airports that had to fight with decreasing traffic in 2011, which might not be due to dissatisfied customers but decreasing demand.

Table 2.5 - Air Carco World Excellence Survey (2011, 2012)

2012	Overall score	2011	Overall score
1,000,000 or more tonnes		**1,000,000 or more tonnes**	
Frankfurt, FRA	109	Amsterdam, AMS	103
Amsterdam, AMS	105	Frankfurt, FRA	101
London Heathrow, LHR	*97*	London Heathrow, LHR	101
Paris Charles De Gaulle, CDG	*88*	*Paris Charles De Gaulle, CDG*	*96*
400000 to 999999 tonnes		**300000 to 999999 tonnes**	
Cologne/Bonn, CGN	111	Cologne/Bonn, CGN	119
Leipzig, LEJ	111	Leipzig, LEJ	119
Istanbul, IST	105	Luxembourg, LUX	116
Luxembourg, LUX	104	Copenhagen, CPH	100
Brussels, BRU	100	Liege, LGG	100
Liege, LGG	*99*	*Madrid, MAD*	*95*
Madrid, MAD	*90*	*Brussels, BRU*	*93*
Milan, MXP	*89*	*Milan, MXP*	*83*
		Istanbul, IST	*75*
Up to 399999 tonnes		**100000 to 299999 tonnes**	
East Midlands, EMA	122	Frankfurt Hahn, HHN	118
Zurich, ZRH	121	London Stansted, STN	116
Munich, MUC	118	Zurich, ZRH	114
London Stansted, STN	112	Athens, ATH	111
Manchester, MAN	110	Munich, MUC	109
Frankfurt-Hahn, HHN	104	Manchester, MAN	105
Copenhagen, CPH	102	Vienna, VIE	103
Vienna, VIE	101	Lyon St. Exupery, LYS	101
Athens, ATH	*91*	*Rome, FCO*	*91*
Rome, FCO	*84*	*Moscow Sheremetyevo, SVO*	*71*
Moscow Domodedove, DME	*80*		
Chateauroux-Deols, CHR	*79*		
Lyon St. Exupery, LYS	*76*		

Source: Air Cargo World (2011a, 2012)

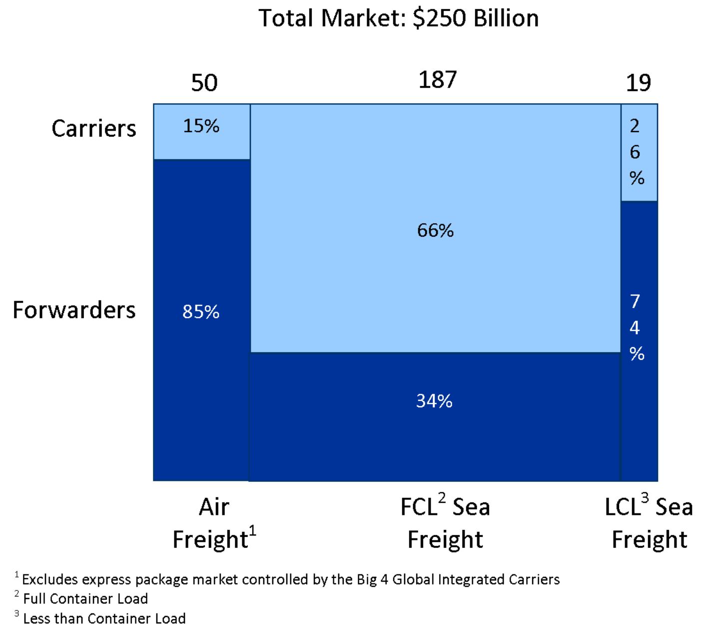
2.7. Airfreight Forwarders

A forwarder can be defined as: "One whose business it is to combine the various sections of transport into one whole, to see that the links of the chain […] are economically combined and interwoven so that the merchant or shipper has the fullest advantage of the lowest rates." (Paelinck, 2008, p. 46)

Originally air freight forwarders were only agents of the airlines that were authorized by IATA to close contracts on the basis of commissions. In the US for example, the air freight forwarders were legitimized in April 1948 as middlemen between shippers and airlines. (Wensveen, 2007, p. 323) The forwarders evolved, however, from companies that specialized in one mode into third-party or even fourth party logistic providers and into multifunctional air freight contractors, who do not only sale air transport service but also coordinate and manage the cargo shipment during its whole transport. (Neiberger, 2007a, p. 23; Park, Choi, & Zhang, 2009, p. 326) This can also be seen in their central position in the air cargo network (see Figure 2.11). The forwarder frequently organizes the whole transport chain from pick up over warehousing, ground handling, booking airline space and customs to contacting the consignee. This often gives him the possibility of steering the transport of goods including the choice of the route. (Neiberger, 2003) In their analysis about the choice of air cargo transshipment airport in Northeast Asia Ohashi et al. (2005) view amongst others the freight forwarders as decision makers of the routing of cargo. The airline on the other hand is only responsible for the services at the airport and the actual air transport.

In Figure 2.17 it becomes clear that the freight forwarder plays a very important role in the air freight business. About 85% of the revenue generated in intercontinental air freight trade is in the hands of the air freight forwarders (Air Cargo Management Group, 2011a, p. 36; MergeGlobal, 2009, p. 18). Especially in full container load sea freight this share lies considerably lower but it is also true for less than container load sea freight.

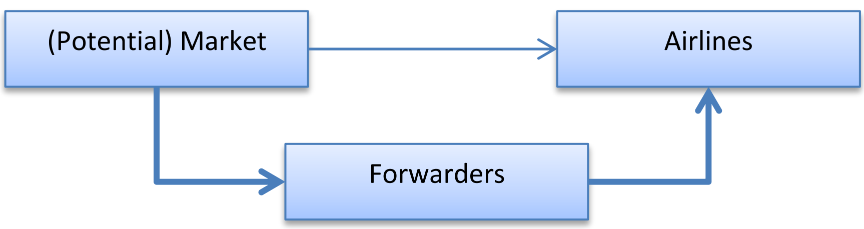
Figure 2.17 - Freight forwarder share of intercontinental trade by mode (gross revenue in billions of US$, 2007)



Source: MergeGlobal (2009, p. 18)

Figure 2.18 shows the relationship between the market, airlines and forwarders. Both, the forwarder and the airline discover and develop the (potential) market for airfreight. Most of the times, as already made clear by Figure 2.17, the airfreight comes via the forwarder to the airline. The task of the forwarder is e.g. to prepare the goods for transport such as consolidating them and preparing their customs documents. As forwarders often bring high volumes to the airlines, they also receive volume discounts with the airline.

Figure 2.18 - The relationship between market, airline and forwarder



Source: own composition

More than airlines, freight forwarders organize themselves in cooperations. This enables them first of all to achieve discounts when buying freight space from the airlines and reserving it when necessary in times of scarcity. Further advantages can be gained with the organization of cargo and with internationalization as the alliances can be of help with it. Research about the internationalization of airfreight forwarders showed that about 32% of all forwarders around Frankfurt am Main and Amsterdam interviewed for the study, used the alliances to expand into an international market (Neiberger, 2007b). Examples of such international forwarder alliances are WACO (World Air Cargo Organization) System, WWPC (Worldwide Partnership Cargolink Network) and FFSI (Feta Freight System International).

For cost cutting reasons, next to building alliances, large forwarders take over certain cargo services at the airport, which are normally carried out by the airline or by handling agents. Air freight forwarders directly take over the goods from the airline and un- and repack as well as declare them with the customs themselves. (Neiberger, 2006b) This is also a result of increasing dissatisfaction of freight contractors with slow handling at the airport. (Neiberger, 2008, p. 252) Some airports already recognize this trend by building extra facilities for the larger air freight forwarders. An example can be found at the new Al Maktoum International Airport which was officially opened in June 2010. There, even before the official opening, dedicated warehouses were ready for the large forwarders such as Panalpina.

In the 21th century the forwarder market is characterized by an ongoing consolidation trend. Concerning market size, three different kinds of forwarders can be identified. First of all, there are the biggest market players, the so called Global Player which often initiate mergers and acquisitions. The Global Players act as international forwarders with worldwide branches and are often of German, Swiss, Japanese or American origin. The services they offer are more than just (air) freight services and also include 3PL logistic services. The forwarders of the second group, the medium sized forwarders, are on the other hand often specialized in air freight forwarding with high turnover rates. The high turnover rates regularly make them the targets of mergers and acquisitions of bigger companies. Also the small and medium sized air freight contractors with a low turnover mostly offer services for general cargo and are often very specialized in the transport of non-standardized freight. (Neiberger, 2003) Although, there are many small companies, those companies only represent a small share concerning turnover. In Germany and the Netherlands for example small air freight contractors with a turnover of less than 1 million euro only had a share of 5% of total turnover in 2007. (Neiberger, 2008)

The top 10 of the forwarders by air and sea freight revenues on the other hand represented a share of 44% in 2010. As the largest forwarders are crowding out smaller players, this percentage has been gradually increasing from 40% in 2006. (Arabian Supply Chain, 2011; Transport Intelligence, 2011) Also, the Herfindahl-Hirschman Index, an index between 0 and 10000 that measures the market concentration in a specific sector, increased from 227 in 2008 to 258 in 2010. Although the index still points to a more or less fragmented market, the increase also shows that there is a trend towards the concentration of the forwarder business around the largest forwarders. Large forwarders are often more able to respond to short term changes in the market and better positioned to serve global customers. (Nkwocha, 2011; Transport Intelligence, 2011)

This consolidation and concentration trend can, however, also be a threat to the airlines by way of the large forwarders gaining more and more market power and therefore increasingly depending on them. If the airlines loose one customer in a fragmented market, there are still many others to do business with. In a consolidated market on the other hand, the airlines depend on the forwarders and cannot afford to lose their present customers as there are only a limited number of others.

Table 2.6 shows the 25 largest freight forwarders ranked by their airfreight transported. Amongst the top 10 are also two forwarders that are connected to the integrators DHL and UPS. We can see that also concerning the transport of airfreight by forwarders there is a concentration: the top two forwarders, DHL Supply Chain & Global Forwarding and DB Schenker Logistics, amount for more than 27% of the airfreight transported by the top 25 forwarders, the top 5 for 47% and the top 10 for 74%.

Table 2.6 - Top 25 Worldwide freight forwarders (2010)

Rank	Forwarder	Airfreight (tonnes)	Net Revenue ($ Millions)	Gross Revenue ($ Millions)
1	DHL Supply Chain & Global Forwarding	2458000	19816	30486
2	DB Schenker Logistics	1225000	9120	18999
3	Kuehne + Nagel	948000	5727	19476
4	Panalpina World Transport	892000	1423	6887
5	Kintetsu World Express	869225	468	3057
6	UPS Supply Chain Solutions	862000	6022	8670
7	Nippon Express	855400	1476	18450
8	Expeditors International of Washington	807211	1693	5968
9	CEVA Logistics	536000	5670	9091
10	Hellmann Worldwide Logistics	513278	937	4687
11	Bolloré/SDV Logistics	500000	1233	6163
12	Agility	490000	1701	5266
13	UTi Worldwide	421000	1556	4550
14	Sinotrans	384100	1044	6286
15	Yusen Logistics	337130	24000	3814
16	Pantos Logistics	330485	2972	2972
17	DSV	250000	1661	7587
18	Logwin	170000	1333	1801
19	Kerry Logistics	158900	840	1400
20	Geodis	152000	1673	5578
21	Toll Holdings	130000	4200	5303
22	Damco	75000	1200	2700
23	C.H. Robinson Worldwide	45000	1467	9274
24	Hyundai GLOVIS	34819	6303	6303
25	Sankyu	18060	490	2341

Source: based on the 25 largest forwarders by 2010 gross revenue and freight forwarding volumes and ranked by total airfreight tonnage (Armstrong & Associates, 2012)

2.8. Conclusions

Chapter 2 shows that air cargo gained importance during the last decades. While air cargo has been growing even more than passenger transport, it also shows more volatility. Especially in times of crisis, air cargo reacts more dramatically but on the other hand also rebounds faster. This characteristic of air cargo has to be kept in mind when conducting research in the air cargo sector.

Furthermore, due to the different demand on routes worldwide, imbalances in the air cargo traffic could be found. Those imbalances also influence the routes of the airlines and might also influence the airport choice as airlines need enough inbound as well as outbound demand from a specific airport in order to make a route viable.

In the third section the nature of air cargo was discussed. First of all, the difference was made between air cargo transported in combi-aircraft and full freighters, as well as between general cargo, express cargo and air mail. It was discovered that during the last 40 years an increase in the share of all-cargo traffic could be found. The analysis also showed that all-cargo traffic and combi traffic behave in a different way. This leads to the belief that due to this difference in all-cargo and combi traffic, also all-cargo carriers and combination carriers will react differently to their environment. Therefore when researching the decisions made by those carriers, a difference between all-cargo carriers and combination carriers can be made. Section 2.3 revealed further that due to the speed of transport especially high value products or products with a short life-cycle are transported by air.

Shippers, agents, forwarders, airlines, airports and hinterland transport companies were identified as major actors in the air cargo business. Moreover, it was seen that the air cargo transport chain is developing more and more into a network. In the analysis of the cargo carriers it could be seen that the most important cargo carriers are integrators, while in general most of the major cargo carriers are combination carrier. This enforces the idea that next to all-cargo carriers, combination carriers form a very important part of the air cargo business. Especially Asian combination carriers have a high share of cargo revenue in contrast to American cargo carriers.

The section about airports revealed that first of all, cargo airports are often neglected in the categorization of airports as most airport categories are defined based on passengers. However, three categories of cargo airports could be identified: all-cargo airports, hub airports of express freight operators and major intercontinental traffic platforms. Most of the large cargo airports worldwide belong to the third category but also integrator hubs such as Memphis, Anchorage and Louisville can be found at the top of the ranking. The important cargo airports of Europe can mostly be found in the center of the continent. Here a competitive environment for air cargo is formed due to the footloose nature of air cargo and the relative short distance between the airports. This competitive environment is also shown in the quality survey of Air Cargo World, where airports have to put a lot of energy into keeping up its quality as perceived by their customers.

In the last section the airfreight forwarders were introduced. They were identified as the most important customers of airlines, the largest forwarders gaining more and more influence due to the consolidation and concentration trend in the sector. Therefore, forwarders might also have an influence on the airport choice of airlines. To obtain an overview of the airport choice process and of the factors that influence airport choice, a literature review is carried out in the next chapter.

3. The Airport Choice Process and the Airport Choice Factors

When deciding which airport to operate to, every airline goes through a certain choice process. To understand the airport choice, an understanding of this process is crucial. Therefore, this chapter focusses on the airport choice process and the specific choice factors that play a role therein. The process itself can differ between airlines and often depends on company regulation, conventions and experience. However, some general directions of the airport choice process can be given.

First, information that could be found in literature is presented. Furthermore, the knowledge gained through literature review will be compared to the findings that could be made during discussions with different airline representatives.

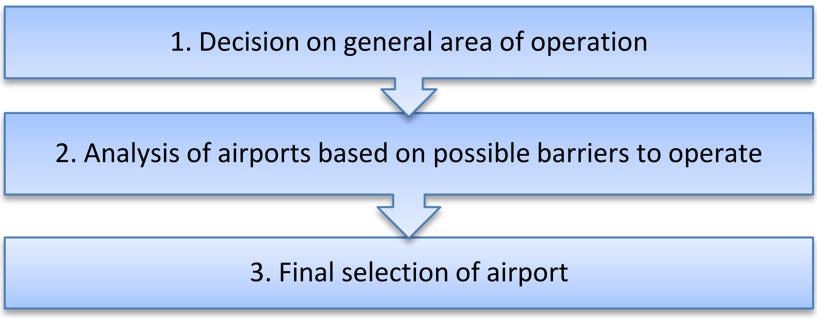
Section 3.3 then focusses more specific on the different phases identified in the airport choice process. Within this part also an overview of the airport choice factors is given. The overview was set up by looking at the literature to find information on the factors that can be of importance to the airport choice of freighter airlines. As, so far, only few studies have been carried out concerning the airport choice for freighter operations, the literature reviewed for this chapter not only comprises studies about the airport choice of freighter operators. Where of significance for this research, information of studies about the hub choice for cargo airlines, the airport choice of integrators or passenger airlines was included. For a better understanding, the airport choice factors are clustered into different groups, according to the phases of the airport choice process.

In Section 0 an example of the airport choice of an airline is given, while Section 3.5 attempts to answer the question about which of the airport choice factors an airport can change, which can be influenced and which cannot be influenced by the airport. The answer to this question can be important for the recommendations that can be given to the airports as a result of this research.

3.1. The Airport Choice Process in Literature

In literature, one study could be found in which the airport choice process was analyzed. Gardiner, Humphreys & Ison (2005a) identify the airport choice process as a three-stage process, which is pictured in Figure 3.2. First, the airline decides about the general area which it wants to start operations to.

Figure 3.1 - The airport choice process in literature



Source: own composition based on Gardiner et al. (2005a)

This choice is strongly driven by market factors such as the O-D demand and the presence of forwarders (see Table 3.1). After having decided on the general area, the airline will exclude airports whereas due to restrictions and other barriers, it cannot operate. Such restrictions can include night-time restrictions, provision of infrastructure or bilateral restrictions. At last the airline will compare all airports that are still in consideration on their individual merits to come to a final choice of airport for its operations. (Gardiner et al., 2005a, p. 99)

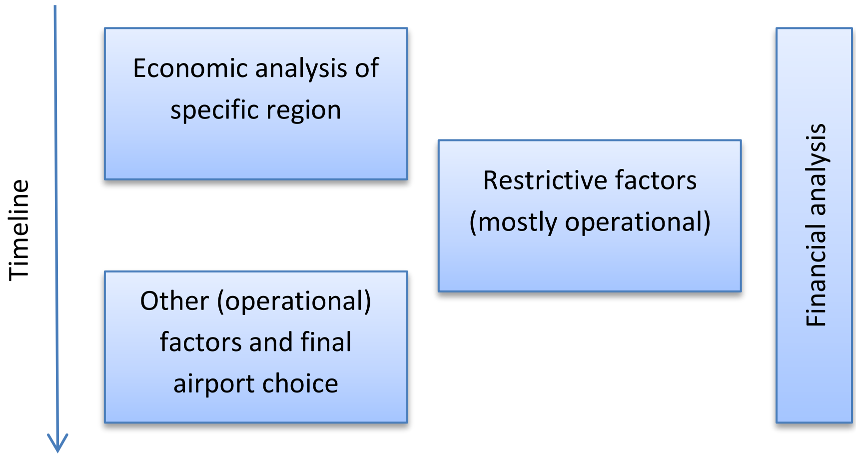
3.2. Findings From Discussions with Airline Representatives

In contrast to what was found in literature, during discussions that were carried out with airline representatives[11], it became clear that the process is less subsequent than previously understood. The three steps as presented by Gardiner et al. (2005a) make up an important part of the airport choice process but are not always followed subsequently by the airline. The process of the demand analysis (part of economic analysis), the analysis of possible barriers to operate (restrictive factors)

[11] When contacting the airlines, it was taken into account that they were representative for the group of airlines that have scheduled freighter operations into Europe.

and the final selection based on other operational factors often overlap or are carried out by the airline at the same moment. Therefore, those three parts should be seen more as the three main phases of the process, rather than as steps. The course of the airport choice process as understood after the discussions is depicted in Figure 3.2.

Figure 3.2 - The airport choice process: findings from discussions with airline representatives



Source: own composition

In parallel, during the whole airport choice process financial analyses are carried out as well. Different financial analyses are executed at various times during the airport choice process to check whether serving an airport is also financially viable.

In the survey, the airlines were also asked whether the airport choice process is different for the first-time choice of an airport and the relocation of services. Almost all airlines replied that there is no difference between the two. Two airlines mention, however, that relocation is often based more on economic aspects and that the first phase, the economic analysis of the region, is skipped, as it was already undertaken in the first-time choice. Only three airlines state that there is a difference between the first-time airport choice and the relocation of services, but do not further explain what this difference is.

Some airlines even expressed that the process of choosing an airport is not really an organized process at all and that the airports are not really chosen after a thorough analysis. One airline representative even went so far as to say that they sometimes just decide to try a new route and airport to see whether the route is viable in the longer term. However, as most airlines describe the airport choice as more or less of an organized process, we will follow this approach. Therefore, the different parts of the choice process are analyzed in more detail in the following section.

3.3. The Phases of the Airport Choice Process and the Associated Choice Factors

During an extended literature review, a list of factors could be identified that influence airlines in their airport decisions. Table 3.1 shows those airport choice factors according to the different airport choice phases. In the following sections, the phases and airport choice factors will be analyzed more in detail.

Table 3.1 - The airport choice factors in the airport choice process

Economic analysis of specific region	Restrictive factors	Other (operational) factors
- O-D demand	- Traffic right restrictions	- Market access
- Forwarders/large customer	- Infrastructure	- Congestion/delays
- Geographical location	- Noise restrictions	- Customs clearance times
	- Night-time restrictions	- Handling times
	- (Extra) capacity	- Line-haul costs
	- Government regulations	- Airport charges
		- Handling charges and fuel costs
		- Labor costs
		- Presence of other airlines
		- Incentives
		- Service quality
		- Experience with cargo
		- Marketing
		- Reputation
		- Climate
		- Labor availability
		- Behavioral variable

Source: own composition based on interviews and Gardiner, Humphreys & Ison (2005b)

3.3.1. Economic Analysis of Specific Region

Sometimes the proposition of an airline’s customer or an idea of the management can be the first reason to look into new destinations and airports, but generally the economic analysis is the first phase of the airport choice process. Within some airlines, especially larger ones, the economic analysis is even a constantly ongoing process. The aim of the economic analysis is to define the market and the possible demand in a certain region. To get insight into the potential demand, airlines analyze data from different sources such as the IATA Cargo Accounts Settlement Systems (CASS)[12], Seabury, or PIERS who supply data of Non-vessel operating Common Carriers (NVOCC). Airlines also use decision making tools such as the IATA CargoIS.[13] The phase of economic analysis can include studies on the general economy of the region as well as of its traffic in goods and its trade, with analyzing the imports and exports to and from the region. The economic analysis can also include revenue and profitability projections, where the yield plays an important role, as well as projections of the inbound and outbound expected demand. At this stage of the airport choice process, also the network of other competing carriers can play a role. If a competing carrier is very strong with services to a certain area, an airline might consider not to start services to this area due to the strong competition.

For some airlines, often smaller airlines with few airports that are served in Europe, the economic analysis is equal to finding an airport and maybe alternatives that are located at the center of the demand to be able to serve the whole demand area from a very limited number of points.

Origin-destination demand, the geographical location and the forwarders are the main factors that are considered by the airlines in this phase.

3.3.1.1. *Origin-destination Demand and Geographical Location*

The market factor origin-destination demand is often one of the first factors an airline considers when choosing on an area to operate. Here a difference between the choice of a hub-airport and origin-destination airport becomes clear. Concerning the hub choice, with all factors equal, the ideal place for an airline would be a central location which minimizes the total flight kilometers and cost within its network (Zhang, 2003). That is why many studies about the airport hub choice focus on the minimization of overall flight distance. Often, this problem is approached as a Weber least cost problem which finds the most preferable location by minimizing the weighted sum of Euclidean distances taking into consideration a set of demand points (Watanabe, Majima, Takadama, & Katuhara, 2009). In the 80's O'Kelly (1986) used this methodology to find the best location for a single hub in the US which turned out to be Cincinnati, considering the length of the flight as well as

[12] For more information on CASS see http://www.iata.org/ps/financial_services/pages/cass.aspx.
[13] For more information on the IATA CargoIS see http://www.iata.org/ps/intelligence_statistics/cargois/pages/index.aspx.

its costs. In the 90's Dennis (1994) applied the Weber least cost problem to Europe where he studied the 30 largest airports in Europe as possible airport hubs. He measured the relative change in weighted travel km, in respect to the optimal location and found the optimal hub location to be the location where the least number of travel kilometers is needed to interlink 30 airports. In his studies the optimal hub proved to be Paris or Brussels. A study by Huston & Butler (1991) on the other hand shows, that a passenger airline hub is best built close to a substantial number of potential customers and not based on geographical location. In a regression analysis the variable MARKET, which is reflected by the number of people closer than any other hub, was positive and significant at the level of 1 percent. This variable was even more significant than any other geographical variable such as the number of passenger miles when assuming that all markets are connected via the hub city. (Huston & Butler, 1991, p. 978)

For origin-destination airports in the air cargo context, demand was also revealed to be more important than the general central location. Especially the location near an economic cluster seems to be preferred as economic clusters can be an indicator of demand. (Gardiner & Ison, 2008) However, origin-destination demand is more important to carriers that operate short-haul services as carriers with long-haul services have a wider market (Gardiner et al., 2005b, p. 395).

3.3.1.2. Forwarders

While the location of an economic cluster can be seen as an indicator for market demand, so can be the presence of forwarders around the airport. The importance of the forwarders also becomes clear with the fact that in the forwarding business there is a trend towards concentration. Big forwarders like Kühne & Nagel, who acquired ACR Logistics in 2006, and Panalpina integrate more and more small companies which increase their market power. Gaining one of the bigger forwarders as a customer means more business for the airline. On the other hand, when losing one of the forwarders, it often also means losing a large share of business. That is why airlines often follow their main customers to airports or at least strongly value the presence of forwarders around airports. Lufthansa Cargo is one example of an airline that chooses its destinations by looking at its customers. The airline expanded its services at Leipzig-Halle in October 2009 as one of their customers' (Otto Group) distribution centers is situated about 130 km northwest of the airport. Lufthansa started to handle the inbound shipments for Hermes Transport Logistics, a subsidiary of the Otto Group, in August 2009 and now also handles the distribution to the logistics center. (Air Cargo World, 2009b)

3.3.2. Restrictive Factors

The restrictive factors that are looked at during the airport choice process are often restrictive factors from the operational point of view. One of the most restrictive and most mentioned factors are the bilateral agreements and traffic rights. Within a region an airline might not be able to operate to all airports/countries due to traffic right restrictions. Those limitations can very much restrict the list of possible airports to serve. Furthermore, an airline might also have no overflight privileges for certain countries, which can make the flight route much longer and therefore slower but also more expensive. Overflight restrictions are not often a problem, but if they have to be considered those flyover restrictions might determine which airports can be better integrated in a route. Carriers that very often have to consider overflight restrictions are for example Israeli carriers. In February 2012 Turkey for example announced to restrict the use of its airspace for Israeli cargo flights (Blumenkrantz, 2012). However, also European carriers have to sometimes consider overflight restrictions as was shown in 2007 when Russia temporarily withdraw the flyover rights for Lufthansa Cargo (Kazim, 2007; Lindsey, 2007). Other restrictive factors are infrastructure, noise and night-time restrictions, capacity restrictions and government regulations.

3.3.2.1. Traffic Right Restrictions

Since the Chicago Convention, the commercial aspects of international air transportation have been mostly covered by bilateral agreements between countries. Those bilateral agreements, however, often do not distinguish between passengers and cargo rights. Passenger and cargo traffic, however, have different traffic structures, which is why the bilateral agreements are often seen as too restrictive by cargo airlines (Gardiner et al., 2005b). According to a survey by Gardiner et al. (2005b) 71% of all airline respondents could not operate to their airport of choice, due to the lack of traffic rights.

Studies by Zhang (2003) and Zhang et al. (2004) also show that traffic rights are especially important for the attractiveness of cargo hubs. In their studies, the case of Hong Kong was put forward as in 2003 it still applied a 'one route, one carrier' policy. This means that on a specific international route, only one Chinese and one foreign airline are allowed to operate an agreed capacity. (Zhang, 2003; Zhang et al., 2004) In Europe, since the deregulation of air transport in the 1990's, all restrictions for European airlines on fares, routes and number of flights have been removed to create a single European aviation market. European cargo airlines that fly inside Europe are thus not hindered by any traffic right restrictions. However, for airlines also serving markets outside of Europe, bilateral agreements or open sky agreements are still of the utmost importance and influence their choice of airports.

Another restriction can be the lack of traffic rights or slots at a certain airport. The airports of London Heathrow and London Gatwick can be taken as an example. Due to the Traffic Distribution Rule, all-cargo aircraft are forbidden at the two airports during peak hours. This problem magnifies as peak hours were extended during the last years. (UK Competition Commission, 2009)

3.3.2.2. Infrastructure

When we look at the more local level, the airport level, the provision of infrastructure becomes important for an airline to be able to operate to a specific airport. Airlines need a certain minimum of infrastructure to be able to operate at an airport. Infrastructure such as warehouse facilities can be of utmost importance for some airlines and forwarders. (Zhang 2003, p.135) Other examples of necessary infrastructure are sufficient ramps, parking spaces, runways and terminal capacity (Kingsley-Jones, 2000; Page, 2003). Moreover, airlines expect the infrastructure to fit the need of air cargo and to be maintained and improved or expanded if necessary (Berechman & de Wit, 1996; Hall, 2002).

3.3.2.3. Noise and Night-time Restrictions

Another factor that restrict airlines in using certain airports are noise and night-time restrictions. General noise restrictions effect in particular operators, which use all-freighters as cargo aircraft as they are often older and louder than passenger aircraft. With many airports in Europe introducing noise related charges, those aircraft bring higher costs to the airlines and the higher the costs at an airport, the more unattractive it becomes for airlines. Night-time restrictions as a special case of noise restrictions are most important specifically for integrators. The integrators have a need for night-time flights as their network operations are built on the nightly transport of packages from airport to airport, mostly via hubs. Express operators like DHL, TNT, UPS and FedEx rely on night-time slots for departure to arrive at the major markets in the early morning, which enables them to transport express cargo from shipper to recipient in only one day. However, also non-integrated freight operators value night-time slots. Especially North American and European carriers were concerned about night-time restrictions (Gardiner et al., 2005b). A study by Gardiner and Ison (2008) showed that in particular on the Asian market night-time operations at an airport are a must, as the cargo leaves the Asian continent during the night to arrive in Europe the next morning. Gardiner and Ison also noted that airlines prefer an airport allowing night-time flights above one without night-time slots, whether the airlines uses the slots or not. (Gardiner & Ison, 2008) This actually puts the smaller regional airports at an advantage before the established traditional gateways, from which especially cargo airlines are driven away due to stringent noise regulations. In the future however, regional airports in Europe might also tighten their noise regulations, so that the problem of operating at a noise regulated airport is only temporarily circumvented by the airline.

The hub choices of two integrators can be traced back to night-time restrictions. One of the reasons why DHL for example relocated its European hub to Halle/Leipzig were the problems and insecurity about the night-time flights at Brussels. Also TNT's decision to develop their European Hub in Liège was made out of noise restriction considerations. In 1992 they analyzed the possibilities of Liège Airport and Cologne/Bonn Airport as a hub and decided against Cologne as they feared the strong environmental lobby with their demand to ban night-time flights in the area. (Conway, 2002; Kingsley-Jones, 2000, p. 46) The success of Liège Airport is in general often attributed to the possibility of night-time flights.

3.3.2.4. (Extra) Capacity

In the long term, airlines also think about their possible future growth. To airlines to operate flexible and to alter their services with changing demand, sufficient future capacity is of great importance. A cargo airline that operates out of Heathrow for example would not be able to add more frequencies to or from Heathrow even when demand for those services increases. As all major airports in Europe are slot coordinated, it also limits the airlines in their short term flexibility to change their operations between or to major airports in Europe. Furthermore, as a study by Dempsey and O'Connor (1997) reveals, the lack of capacity is also a disadvantage of many Asian-Pacific airports.

3.3.2.5. Government Regulations

As a result of their regulations and restrictions, also governments can have an influence on the attractiveness of airports for air cargo airlines. Especially Asian/Pacific carriers are influenced by the government support in their location decisions. In general governments should facilitate air transport operations and customs and give a stable regulatory environment concerning e.g. noise and night-time restrictions. However, often government regulations put additional costs and delays on shipments. Therefore, to relax those measures is one way governments can contribute to cost and time-savings for airlines. Moreover, all-cargo airlines can experience severe discrimination at some airports due to government regulations. Heathrow and Gatwick airport can be taken as examples. A Traffic Distribution Rule, which was put into action by the Secretary of State for Transport in 1991, forbids all-cargo flights at the two airports during peak hours. All-cargo carriers can ask for special permission for such flights, which is however, rarely granted. This problem increases as peak hours at those airports are extended. From these circumstances one can assume that Heathrow and Gatwick are not very attractive to all-cargo airlines. Contrary to expectations, cargo airlines still prefer Heathrow and Gatwick to for example Stansted, which means that other choice factors seem to be more important. British Airways World Cargo for example would like to relocate their operations to Gatwick out of cost savings reasons such as lower user charges or trucking costs. (UK Competition Commission, 2009)

To force an airline to change airports, however, only the strictest government measures seem successful. Due to this reason, when building new airports that are supposed to decrease congestion at an older airport, the replaced airport is often restricted to specific traffic, or even closed. (Neufville & Odoni, 2003, p. 145) Hong Kong Kai Tak airport closed after the opening of Hong Kong International Airport in 1998. Also Osaka/Itami and Gimpo International Airport were restricted in traffic when respectively Osaka/Kansai and Incheon International Airport opened. That it is very difficult to force an airline to change airports was also verified in an interview with DNata in Dubai. After the opening of the new Al Maktoum International Airport first the low cost airlines and cargo airlines are asked to move their operations. Although different incentives for the airlines to move to the new airport are developed by the airport, to actually convince airlines is a difficult task. (S. Hayman, personal communication, July, 05, 2009)

3.3.3. Other Decisive Factors

The last phase of the airport choice process is the analysis of other factors and the choice of an airport itself. In this step the airline compares different airports that are located in the chosen region and which meet their expectations with regard to the (lack of) restrictions, and finally choose the airport they wish to operate to according to its merits. The last phase can also include an on-site investigation to inspect the airport facilities. The services of an airport are also compared, but one airline which was interviewed mentioned, that services at an airport are not a major problem in Europe. On other continents and countries, the lack of airport services can be a much more serious problem (the airline for example mentioned Brazil). In this phase airlines will also compare the airport and handling rates as well as the experience of various airports to make a well-founded decision. Here, financial analysis plays a role, as two airports might be situated in the same area with the same restrictions, but differ in the airport or handling charges, which will influence the profit margin of the airline.

3.3.3.1. Market Access

As important as it is for airlines that there is a market for air freight close to the airport, literature shows that also the market access is of importance. It is not enough to transport cargo to and from an airport without being able to transport it to the final customer. It could even be seen that the access to crucial markets is more important than the proximity of the market itself (Gardiner et al., 2005b). For the market access, often good connections with other modes of transport are necessary. A study about the air cargo service quality in Korea for example revealed that international airlines even rank the interconnectivity of the transportation from the airports highest (Hong & Jun, 2006). In particular good access to road networks is seen as important by airlines. It can also be the cause for forwarders to ship through a certain airport as good market access expands the catchment area and thus enables to consolidate cargo from a wider area. As example of how far the catchment area of an airport for cargo can reach, the trucking schedule of the AirBridgeCargo can be quoted. From Amsterdam AirBridgeCargo offers trucking to many places in whole Europe, such as Barcelona, Florence, Ljuljiana, Warsaw and Gothenburg. Smaller airports sometimes even generate almost half of their air cargo through road feeder service. In Frankfurt Hahn in 2011 for example about 49% of the air cargo was actually transported by road (Flughafen Frankfurt Hahn, 2012). Road connection is thus especially important to smaller regional airports that specialize in cargo traffic. The main competitive advantage of those airports is congestion free operations on the air- and on the landside, which the main airports in Europe often cannot offer anymore. However, the interconnectivity includes more than just the connection between road and air. Also the access with other modes of transport has to be considered. If an airport neglects trucking and rail, it can miss out on about 80% of the opportunities to attract cargo (Page, 2003).

The reason why good access to airports is important to airlines can also be illustrated by two examples from Asia: In Hong Kong it can be seen how insufficient access to the airport can lengthen the air cargo transport chain. When moving cargo from mainland China to Hong Kong, the time needed is often longer than for the onward air journey itself. (Zhang 2003) Furthermore a Korean study conducting surveys and applying the SERVQUAL[14] model shows that the most important factor for international airlines is the interconnectivity of transportation, which in this case is the convenience of the land transportation system (Hong & Jun, 2006).

3.3.3.2. Congestion/Airport Delays

The importance of congestion and delays can also vary with the kind of carrier. For all-cargo carriers, congestion is a primary factor in deciding against flying to a certain airport (Gardiner & Ison, 2008). When transporting goods by truck from a more remote airport to the destination takes less time than to transport them from another airport closer to the destination, the carrier will almost always choose the first possibility. Combination carriers on the other hand often find a certain level of congestion and delay acceptable to be able to benefit from the advantages of a major airport, like agglomeration advantages and collaboration with passenger flights. (Gardiner & Ison, 2008) Another disadvantage of congested airports where slots get scarce is that those airports are tempted to focus more on passenger flights as they generate extra income through indirect activities such as shops and restaurants. The most prominent example is Heathrow airport, where freighter aircraft were more and more pushed out of the airport. Even carriers that have their home base at Heathrow like British Airways World Cargo can only get full-freighter slots on an ad hoc basis (Conway, 2004). Furthermore, when avoiding the London area, airlines can save up to 45 minutes flying time and 20 minutes taxi time on a return flight by for example landing at Kent Airport (Buyck, 2002, p. 70).

Congestion and airport delays have a negative effect on airport attraction in two ways. Cargo airlines first of all might avoid the airport due to congestions and delays. However, there is some evidence in literature (see for example Ohashi et al. 2005) that also freight forwarders avoid large and congested airports. Therefore, cargo airlines might also avoid more congested airports, as their customers evade them.

[14] The SERVQUAL model was developed by Parasuraman et al. (1985) and measures the difference between expectations and perceptions.

3.3.3.3. Customs Clearance Times

The lead-time of cargo at an airport also depends on document requirements and customs administration. Murphy et al. (1989) for example found that 35% of airports and air cargo companies interviewed for a study perceived the documentation as the major problem at airports. Furthermore, the inefficiency of customs can form a source of delay at the airport. Zhang (2003) reveals that in developing countries like China and other Asian countries the main function of customs is still the collection of revenues. As no pre-clearance of shipments is given and the clearance process remains a lot of paper work, the clearance of shipments is often delayed. However, as air freight shipments are often time-sensitive, the delays can be a reason for airlines not to operate at a specific airport/country and for forwarders to rather ship their goods from other airports or even other countries. In contrast, airports that provide reliable, timely customs clearance or even pre-clearance can build up a competitive advantage. (Zhang & Zhang, 2002, p. 284) Nevertheless, as a study by Yuan et al. (2010) shows, when airports are already very efficient in customs service as for example Hong Kong Chek Lap Kok or Singapore Changi Airport, further simplifications will only have a very limited effect on the air cargo volume. In other words, customs at an airport are expected by the cargo airlines to be efficient, but when the efficiency is further increased, it does not lead to more airlines servicing the airport or more cargo throughput at the airport.

3.3.3.4. Handling Times

Furthermore the duration of cargo handling influences the time goods spend at an airport. A survey of airports and air cargo companies revealed that about one third of the respondents judged the pickup and delivery times at airports as too long (Murphy et al., 1989). A study about the airports in Northeast Asia on the other hand revealed that there seems to be very little variation in the duration of loading/unloading and customs.

3.3.3.5. Line-haul Costs

One of the direct cost factors of airlines are the line-haul costs. Line-haul costs can be defined as costs attached to flight time such as fuel and extra personnel costs. Gardiner & Ison (2008) for example view line-haul cost as an airport choice variable, especially when flying into a multiple airport region. Airlines themselves even refer to line-haul costs as important when choosing an airport (see for example El Al Cargo (2008)). However, other studies such as Ohashi et al. (2005) conclude that line-haul costs are not significant for the choice of an airport, in particular of an air cargo transhipment airport.

3.3.3.6. Airport Charges

As the maximization of profit is the main goal of a cargo airline, cost minimization plays a major role in their strategies. At the airport for example landing charges as well as parking charges can contribute to this goal of the airlines. And even though, airport charges only account for a small part of the airlines costs[15], they are one of the largest variable costs as many of the other costs, such as aircraft leasing, are fixed. Moreover, when looking at the user charges and station expenses as defined by ICAO, which include station expenses such as handling charges as well as en-route facility charges next to landing charges, it could be seen that they amounted to about 16.1% of total operating expenses in 2005. (Vasigh et al., 2008) Furthermore, using a network simulation, Berechman & de Wit (1996, p. 259) found in a study about hub choice that a change in airport charges can have a significant change of popularity of an airport. Gardiner & Ison (2008) on the other hand state that airport user charges were empirically much less important than earlier research expected.

3.3.3.7. Handling Charges and Fuel Cost

Additionally, airlines pay attention to the level of handling charges asked at the airports, as well as to the fuel costs at the different airports to manage their costs. Many airports have a disadvantage related to their fuel costs in comparison to neighboring airports. Dubai as upcoming cargo hub can be given as example for this problem as Dubai has little oil of its own and inefficient refineries which makes its fuel more expensive. This puts the airport at a disadvantage in comparison to the neighboring airports of Sharjah and Abu Dhabi. (S. Hayman, personal communication, July, 05, 2009) Concerning handling costs, however, a survey by Murphy et al. (1989) showed that almost 40% of the air cargo companies and airports questioned perceive handling charges as "neither important nor

[15] For European airlines airport charges amounted to 3.6% of the total operating expenses in the first three quarters of 2009. (AEA, 2009)

unimportant". Furthermore, there is a difference in the valuation of handling charges between airports and air cargo companies. While airports rank the charges only 9th, air cargo companies rank them 4th, together with the possibility of handling large shipments.

3.3.3.8. Labor Costs

Another cost factor for airlines is the labor cost, whose importance can be seen in different studies. In a study about the air cargo supply chain Yuan et al. (2010) point to a negative impact of labor cost on the volume of air cargo in the case of Hong Kong Chek Lap Kok airport and the same relationship for the outsourcing costs and air cargo volume at Hong Kong Chek Lap Kok and Singapore Changi. (Yuan et al., 2010) Furthermore, Hall (2002), Adler and Berechman (2001) and O'Connor (2001, p.169) confirmed that labor costs are a very important factor which affects the airport choice. However, O'Connor also found that labor costs are not the biggest concern to airlines.

3.3.3.9. Presence of Other Airlines

In their airport choice, airlines have to decide whether they want to operate close to passenger airlines, competitors or partner airlines. Concerning the presence of passenger airlines at the airport a study about the alternative access and location of air cargo in the US revealed that it is sometimes very difficult for airlines to operate at an airport that does not have any international passenger traffic (Hall, 2002). The reason behind it is, that forwarders often expect a wide range of destinations offered by an airline which only can be offered to them when cooperating with passenger airlines. However, this is especially true for combination carriers as they often use freighters for routes with large demand and the space in their passenger airplanes for routes with less demand. For all-cargo carriers, on the other hand, the presence of other cargo operators can be essential. In cooperating with other airlines, all-cargo carriers can offer more destination to their clients. It is not clear which influence the passenger operations of combination carriers have on the location of all-cargo services. (Gardiner et al., 2005b)

Moreover, the presence of other airlines decreases the risk that is associated with serving a new airport. This risk is also reduced by flying to the same airport as the competitor as he cannot build up a competitive advantage in operating from another airport. However, it was shown empirically that competitors have a low importance when it comes to the airport choices of airlines. (Gardiner & Ison, 2008)

In general airlines like to follow successful airlines, whether they are partners or competitors as they expect to be part of the success. One example is Dubai Airport, which profits from the success of Emirates and therefore is able to attract other carriers. However, this can also have its disadvantages as competition will be fiercer when serving the same airport as the competition.

3.3.3.10. Incentives

Government regulations were first of all classified as restrictive factor. However, governments do not only hinder air transport. In particular government incentives can make an airport become very attractive. In a survey carried out in 2004, 87% of the airlines reported to have received financial support to begin new services at an airport (Gardiner et al., 2005b). In the air transport business this is especially true for regional airports that want to attract low cost carriers but it is also true for increasing the attractiveness of cargo airports. Substantial subsidization can go even as far as making an airport attractive to airlines as a hub even when they otherwise would be very unlikely to develop a hub at a specific airport (Huston & Butler, 1991).

However, incentives, which can be financial as well as non-financial, can also come from the airports themselves. Airports can for example offer reductions in airport charges under specific conditions. As an extra incentive or in addition airports also often commit to marketing the airline together with the airport. With this method forwarders and shippers will be informed about the possibility to ship with a specific airline through a specific airport.

3.3.3.11. Service Quality

Cargo airlines expect the services provided by the airport to be efficient, fast and adapted to the needs of air cargo. While the time and cost effects of those services were already discussed, a study by Murphy et al. (1989) showed that not only those aspects are important for airlines but also the quality of the handling. The study, a survey amongst air cargo companies, emphasizes amongst others the importance of a minimum of loss and damage of the cargo when being handled on the airport. This is especially important as goods transported by air are often of high value.

Nevertheless, not only the quality of general handling services as loading and unloading of the cargo is important for cargo airlines. As some cargo airlines operate in niche markets, they have the need for the provision of special services and equipment (Murphy et al., 1989). Airlines that specialize in refrigerated goods need cooling facilities as well as other special handling. Furthermore, airlines that deal with live animals need a veterinary station with round-the-clock service for the animals. Other examples are airlines that deal with the transport of weapons. To be able to attract a cargo airline with this kind of cargo, stricter security measures must be ensured by the airport.

3.3.3.12. Experience of Airport with Cargo

Next to the experienced airport quality, also the perception of airport quality can play an important part in airport choice processes. The perception of airport quality can depend on the experience of the airport with cargo, whether cargo is a priority at the airport, the marketing of the airport and the airport reputation. Airports perceive an airport to have a better service quality if it has experience with cargo or if cargo is a priority at the airport.

3.3.3.13. Marketing

Marketing can be an efficient tool to attract new customers. Theoretically, this can also be true for airports. Especially airlines that are not familiar with a particular airport or that operate for the first time to a specific geographical area can be influenced by marketing. In their campaigns the airport should then focus on those of the airport choice factors where they have a competitive advantage. However, Gardiner & Ison (2008) and Gardiner et al. (2005a) raise the question of how effective airport marketing is empirically. Marketing will probably be most effective with airlines that want to operate to/from a new region, where they did not operate from before. For airlines that want to relocate in the same region, marketing might not have an important effect, as the advantages and disadvantages of alternative airports are already known to them.

3.3.3.14. Airport Reputation

Airport reputation, proved to be much more effective than marketing. When comparing the effect of financial incentives, airport reputation and airport advertisement, airport reputation was shown to be one of the most important choice factors. Airport marketing and incentives are often seen as only short-term advantages. Airlines however, also think in the long run, where a good airport reputation can be important as it decreases uncertainty. When an airport has experience and a good reputation concerning cargo, it can have a big advantage over its competitors. (Gardiner & Ison, 2008) However, due to the congested main airports in Europe, European cargo airlines often feel disadvantaged and even discriminated compared to passenger airlines with lower priority handling and inferior facilities as well as drawbacks in slot allocation (Gardiner et al., 2005b).

3.3.3.15. Climate Conditions

Climate conditions can play a role in the decision process of cargo airlines. Especially the absence of thick fog, heavy snow or strong winds is necessary to ensure continuous operations at the airport (Dennis, 1994; Hall, 2002; Huston & Butler, 1991). One of the variables that originally lead DHL to develop their hub in Brussels, were the good weather conditions with few fog and snow days. On the other hand, it was also shown that the weather record of an airport plays a less important role in the airport choice (Gardiner et al., 2005b).

3.3.3.16. Labor Availability

Labor availability can be a decisive factor in the airport choice. Sufficiently trained labor is necessary to ensure good airline and airport operations. DHL for example encountered problems after the move of their European hub to Leipzig in 2008. Technicians and ground handling staff were not sufficiently trained to handle the traffic brought by the company. (Birger, 2008)

Furthermore, labor relations can prove a problem for airport attractiveness and restrict the labor availability. In a survey of air cargo companies Murphy et al. (1989) show that 35% of the survey respondents perceive labor relations as more than only a minor problem of airport operations. Although his study was conducted in the 80's labor relations can still be an issue today, as airlines can make large losses during strikes of air traffic controllers, ground handlers etc.

3.3.3.17. Behavioral Variable

At last, there is still a behavioral variable that airports have to consider. Sometimes personal preference and other human factors can influence the decision process of cargo airlines. This is why when analyzing the airport choice further, also this behavioral aspect has to be taken into account.

3.3.4. Financial Analysis

During the three main phases of the airport choice process the airline also can and will make financial analyses at different times to test whether a certain region or airport is financially viable to fly to. Table 3.2 shows the process of the financial analysis as presented by one airline. To obtain the cash margin, the airline subtracts the direct operational cost from the total revenue on a specific route. After the cash margin is calculated, the costs of the aircraft have to be allocated, and which, subtracted from the cash margin, gives the profit margin. At the end, the airline thrives to obtain a profit margin that is as high as possible. In the beginning phase of the airport choice process, the focus of the financial analysis will especially be on the total revenue of the route, with the airline trying to maximize the revenue derived from the origin-destination demand. At the end of the choice process, the focus will be more on the direct operating cost as the airline will look at specific airports and compare them to each other. At this point, the airline will try to minimize for example landing fees, parking, crew costs etc.

Table 3.2 - Financial analysis

total revenue	**-**	**direct operating costs**	**=**	**cash margin**
O-D revenue (-trucking)		landing fee fuel crew costs parking etc..	→	allocation of cost of aircraft
			=	**profit margin**

3.4. An Airport Choice Example

During the interviews, one of the airlines gave a detailed example of the airport choice in South America. Although this study mainly focusses on the airport choice in Europe, it is interesting to understand the airport choice process based on an example. Some of the factors considered during the airport choice might not be relevant for the airport choice in Europe, the process, however, is similar.

Previous to the interviews, the airline wanted to add some routes to South America. They felt that due to the expansion of industries in countries such as Brazil, and the increase of value added industries in the region, it might be profitable to add new destinations in South America to their network. First, the airline looked at the possible demand in the area. For this, they asked its statistical department for support to obtain information about trade and possible demand. Second, the airline looked at restrictions and other operational factors at the different airports that came into consideration. The factors that were looked at included bilateral restrictions and the weather at the different airports, as it has implications for the runway usability. Furthermore, the runway was looked at to see whether it can carry the weight of an aircraft, more specifically the weight per wheel. In Europe for example, not all airports are able to handle an MD11, as its weight per wheel is quite high. The airline also looked at the equipment on the airport and whether it is operational all-year round. The availability of the equipment can be a problem in Asia and the provision of fuel for example is sometimes a problem in London.

Technical aspects concerning for example maintenance were also considered. This includes a check whether people at an airport can handle the aircraft and whether maintenance facilities for a specific aircraft are available. If this was not the case, a last resort of the airline would be to build an own facility, which is however more expensive than rely on the facilities of the airport. Not only the maintenance facilities were looked at during the airport choice process in South America. The airlines also inspected the warehouse infrastructure and warehouse handling. Usually this is not a very large problem in Europe but more on other continents. However, in Europe some airports exist, that do not have the ability to handle the needed capacity during peak times, which can be a problem.

At last, also smaller factors were considered in the airport choice for South America, which were whether the airport had a fire brigade, ILS and which kind of loading system they used. The last factor can be for example a problem in Ruanda, as loading does not happen on wheels and it therefore can be hard to safely secure the cargo in an aircraft.

As seen with this example, the airport choice process is similar with every airport choice. However, it could also be seen that different circumstances and different regions require different approaches. Therefore one airport choice factor can be very important in one region but less important in another region.

3.5. The Influence of Airports on Airport Choice Factors

The airport choice factors can also be divided into groups according to whether or not they can be changed or influenced by airports (see Table 3.3). Most of the factors that were found are actually directly or indirectly in the hands of the airports. For airports these factors are most important, as airports can adapt their strategies with regard to them, to better fulfill the needs of the airlines. Factors that airports can change themselves are e.g. the service level and marketing as well as airport charges and infrastructure. Furthermore, congestion can be positively influenced by the airport with for example optimizing processes and infrastructure use.

Table 3.3 - Airports influence on airport choice factors

Can directly be changed by airports	Can be influenced by airports	Cannot be influenced by airports
- Infrastructure - Capacity - Congestion - Airport services - Airport charges - Airport marketing	- Bilateral agreements - Noise regulations - Night-time restrictions - Accessibility - Government regulations - Airport reputation - Presence of other airlines (cargo/passenger) - Presence of forwarders	- Weather conditions - Location - Line-haul costs - Others (e.g. labor costs)

Source: own composition

The second group of factors can only be influenced by the airports but not changed directly. The presence of forwarders and other airlines are two examples. Airports can try to attract more forwarders and airlines with applying different strategies but can never be sure that they will actually come to the airport. On this group of factors the government often has the most influence. Bilateral agreements, noise regulations and night-time restrictions often are the result of government regulations. Other regulations concerning for example customs and import restrictions can also tempt airlines to choose a specific country or airport to operate to. Airports can have an influence on this group of factors by for example consulting and discussing them with the government or by lobbying. Third, there are also factors that cannot be influenced by airports as the location, the weather condition and line-costs of the airline, which heavily depend on the location of the airport.

3.6. Conclusions

Although in literature the airport choice is described as a “three-stage process” (see Gardiner et al. (2005a)), in discussions with airline representatives it became clear that this process is less sequential than originally suspected. The three stages as defined by Gardiner et al. (2005a) (decision on general area of operation, analysis of possible barriers to operate and final selection), should be rather seen as phases that can overlap instead of subsequent stages. Furthermore, also financial analysis plays an important role in the airport choice decisions of the airlines. Financial analyses are carried out throughout the process in order to test whether the decisions that are made are also financial viable.

Next to the airport choice process, in this chapter also the different airport choice factors were identified. Because only few studies have been carried out concerning the airport choice of freighter operation, also studies were reviewed concerning the hub choice of cargo airlines, the airport choice of integrators and the airport choice of passenger airlines. When identifying the different airport choice factors, two important observations can be made. As already suspected in Chapter 2, forwarders, especially the presence of forwarders at an airport, seem to be an important airport choice factor. Furthermore, also the presence of passenger services seemed to be one of the more important airport choice factors. (Hall, 2002) However, combination carriers appear to value the presence of passenger services on airports more than all-cargo carriers. (Gardiner et al., 2005b)

The literature review also revealed the methods used in the different studies. One of the methods analyzing the airport choice for cargo operations, that was used by for example Watanabe et al. (2009), was the Weber least cost model. However, this method only takes into account the distance and the cost as factors and does not give any information about e.g. the importance of the attributes of an airport. In other studies for example (see e.g. Gardiner et al. (2005b)) surveys were sent out to ask the airlines about the importance of different airport choice factors. On the one hand, those studies already give an idea about the relative importance of the airport choice factors. However, when making a decision, airlines have to make a trade-off between the different factors which is not considered in those studies. The trade-off that airlines make is still a topic that needs further research and therefore will be discussed in Chapter 5.

4. The Methodology for Identifying the Relative Importance of the Airport Choice Factors and Trade-Offs that are Made by Airlines in the Airport Choice

In Chapter 3, based on literature review, the different factors that influence the airport choice were identified. However, the aim of this research is not only to identify those factors, but also to understand the relative importance of the factors and which trade-offs the airlines make in their airport choice decisions. The relative importance of some airport choice factors was in the past researched by Gardiner et al. (2005b). Gardiner et al. asked airlines to rate a list of factors according to their importance in the airport choice and afterwards ranked them according to the mean score. However, with this method the airport choice is modeled far from realistic. In reality airlines do not rank the factors itself but weight the different advantages and disadvantages of airports before deciding on an airport. Another problem with the methodology used by Gardiner (2005b) is that it does not give an idea of the trade-offs that airlines make in their airport choice.

Therefore, another method that can be applied to the objective of this research had to be selected. This method needed on the one hand to give an idea about the relative value that airlines attach to the different airport choice factors and on the other hand give an understanding of the trade-offs that airlines make in their airport choice.

In economics, different valuation methods can be identified that might give an idea of the value that airlines attach to the different factors. Examples of such valuation methods are hedonic pricing, contingent valuation, conjoint analysis and discrete choice. In the hedonic pricing method, the implicit price (value) of an attribute of a good can be estimated by analyzing the prices of a good with different levels of each attribute. The hedonic pricing method is often used in the housing market, where the implicit price of the house is calculated by analyzing the prices of houses with different characteristics. However, for the problem of airport choice, the hedonic pricing method is less suitable. The airport charges could be used as price variable, as airlines have to pay it in order to be able to serve a specific airport. However, this price is not determined by a market where the price is a direct result of supply and demand and therefore cannot be used for hedonic pricing (for the theoretical foundation of hedonic pricing see Rosen (1974)).

Next to the hedonic pricing method, the contingent valuation method can be applied to measure the value of a good. The contingent valuation method presents the respondent with a detailed description of the good as well as the circumstances in which it is available to the respondents and then ask them questions that enables the researcher to elicit the respondent's willingness to pay for a good. (Mitchell & Carson, 1993) However, with contingent valuation, the good is valued in its entirety and with this method nothing is revealed about the value of the different attributes that comprises the good.(Kjær, 2005) Moreover, it does not say anything about the trade-offs that respondents make.

The discrete choice and the conjoint approach seem a more promising approach to answer the defined research questions as they enable the researcher to receive information on the value that the respondents attach to the different attributes of a good. They also account for the trade-offs an airline makes in the airport choice.

This chapter first gives an overview of the different conjoint and discrete choice methods and discusses the main differences between the two methods. Section 4.2 of this chapter then debates the use of stated and revealed preference data for the use in discrete choice models. The third section introduces the process of a stated preference discrete choice analysis. Methodology and model specifications of a stated discrete choice analysis are the content of Section 4.4, followed by some notes about special considerations concerning the experimental design. This section also includes information on the generation of the experimental design. Sections 4.6 and 4.7 explain the questionnaire design and the data collection of the airport choice experiment respectively. Next, some statistical concepts are explained that can help the reader to better understand and interpret the model results that are discussed in Chapter 5. Finally some conclusions will be drawn and the airport choice model which is the basis for the model estimation is presented.

4.1. Conjoint Analysis and Discrete Choice Analysis: Approaches and Differences

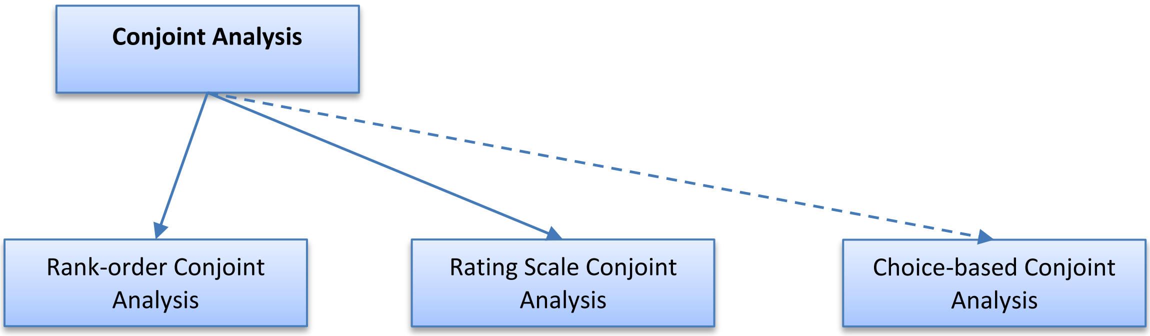
In this section, the methodologies of conjoint and discrete choice analysis are presented. In Section 4.1.1 different approaches for conjoint and discrete choice analysis are illustrated. Discrete choice analysis is often seen as a special case of conjoint analysis and therefore often named "choice-based conjoint analysis". However, as will be shown in Section 4.1.2 both methods have significantly different theoretical foundations.

4.1.1. Conjoint Analysis and Discrete Choice Analysis Approaches

In general, different types of conjoint analysis approaches, formats, or paradigms (as Louvière (1988) calls them) can be identified: rank-order conjoint analysis, rating scale conjoint analysis and to an extend choice-based conjoint analysis. Choice-based conjoint analysis is often inter-changeable used with discrete choice analysis. Looking back at the foundations of traditional conjoint analysis (ranking, rating), however, discrete choice analysis and conjoint analysis were derived from different methodologies which will be discussed in the following section.

In a **rank-order conjoint** analysis the respondent is presented with all the alternatives and asked to rank them according to his/her preference. The advantage of this kind of approach is that the respondent will have to consider all options at once. However, to be able to translate the ranking into actual choices, the assumption has to be fulfilled that the respondent is perfectly consistent and transitive in his ranking, that he/she has perfect information about all alternatives, lacks constraints (such as a budget) and always prefers one of the alternatives (Louvière, 1988). For the respondent to be able to carry out the ranking, the number of options also has to be limited. Another disadvantage is that, with this approach, the respondent judges the different options but does not really choose between them as in real life.

Figure 4.1 - Overview of conjoint analysis approaches



Source: own composition

This latter disadvantage applies also to the **rating scale conjoint** analysis. Here the respondent has to rate different options according to his/her preference; in most cases a pair-wise rating has to be made. The preference can then be indicated with some kind of score or expressions such as "very likely chose option A". However, as with rank-order conjoint analysis, the respondents have to be able to consistently rate the different choices to be able to obtain reliable data. (Pearmain, Swanson, Kroes, & Bradley, 1990)

As third approach to conjoint analysis, often **choice-based conjoint** analysis is named. In this approach the respondents choose between two or more alternatives. In Figure 4.1 the link between conjoint analysis and choice-based conjoint analysis is shown as dotted line, as choice-based conjoint analysis is actually discrete choice and has other theoretical foundations than conjoint analysis.

4.1.2. Differences Between Discrete Choice and Conjoint Analysis

Nowadays, the term „conjoint analysis" is often used for all methods of eliciting preferences which involve some variation of attributes and levels. Moreover, many researchers refer to discrete choice analysis as choice-based conjoint analysis, and therefore a special case of conjoint analysis. However, both methods have very different underlying axioms. Conjoint analysis on the one hand derives from the theory of conjoint measurements which is purely mathematical and not concerned with the behavior of humans or choice. In conjoint measurement theory it can be shown that people use a certain mathematical process "as if" to combine preferences for each level of an attribute into a preference for the alternative which consist of those attribute levels in order to rank or rate those alternatives. Also, in conjoint analysis error components lack a clear interpretation (Louvière, Flynn, & Carson, 2010). As Louvière et al. (2010, p. 61) put it: "[…] conjoint measurement theory originally was not a theory about the behavior of preferences or choices, but instead a theory about the behavior of sets of numbers in response to factorial manipulations of factor levels". Moreover, conjoint analysis is not consistent with utility theory as data are collected in a way (ranking, rating) that cannot readily translate into choice (Louvière et al., 2010).

Discrete choice theory on the other hand, is a theory based on choice behavior which can take connected behavior into account. Here, the behavioral process with making choices stands central. Furthermore, discrete choice theory is based on random utility theory which was first proposed by Marschak (1960). Random utility theory states that not all attributes which add to the overall utility of a good can be observed by the analyst. Therefore, the overall utility of a commodity or service has to be written as a composition of observed attributes and unobserved sources of utility. (Louvière et al., 2010)

$$U_{jsn} = V_{jsn} + \varepsilon_{jsn}$$

where

U_{jsn} is the unobservable utility that a respondent n attaches to alternative j in choice situation s
V_{jsn} is the explainable component of utility that a respondent n associates with alternative j in choice situation s
ε_{jsn} is the random error component associated with respondent n and alternative j in choice situation s

In discrete choice, the properties of the random error component plays a key role in the parameter estimates of the models.

To summarize, conjoint analysis is more of a mathematical method, while discrete choice analysis is based on behavioral theory. While discrete choice analysis tries to model the whole decision process and can take the different steps of the process into account, conjoint analysis only focusses on one level of the process. Moreover, while in discrete choice theory the properties of error components play a significant role, in conjoint analysis the error components lack clear interpretation. (Louvière et al., 2010)

In this study we want to understand the behavior of the airlines in their airport choice and not only calculate mathematical models. Therefore, the discrete choice approach seems to be a better starting point than conjoint analysis. Furthermore, as with discrete choice analysis the calculation of willingness to pay or related measurements is possible, this method is preferred. Willingness to pay measurements are often also calculated in conjoint analysis, but actually do not directly follow from the statistical fit to the data. (Louvière et al., 2010) Last but not least, the discrete choice approach seem a more realistic approach than the conjoint analysis as respondents not only rank or rate alternatives but actually make choices between them as they would in real life.

4.2. Stated and Revealed Preference Data

There are two types of data that can be used with discrete choice analysis: stated preference data and revealed preference data. Whereas with revealed preference data information on actual choices that are made by individuals is collected, stated preference analysis data is obtained through an experiment in which respondents are directly asked about their choices. The properties of revealed and stated preference data are shown in Table 4.1. As each method has its advantages and disadvantages, the discussion in the following sections is focused on those advantages and disadvantages to find the approach that best can be applied to the problem of the airport choice.[16]

Table 4.1 - Stated and revealed preference data

	Revealed preference data	Stated preference data
Preference	Choice behavior in actual markets Complies with actual behavior Personal and environmental constraints are accounted for	Preference statement for hypothetical scenarios May comply with actual behavior Market and personal constraints may not be considered
Alternatives	Actual alternatives Responses to possible new alternatives are unobservable	Generated alternatives Can include preference for new (non-existing) alternatives
Attributes	May include measurement errors Correlated attributes Ranges are limited	No measurement errors Multicollinearity can be avoided by experimental design Ranges can be extended
Choice Set	Ambiguous in many cases	Pre specified
Number of responses	Difficult to obtain multiple responses from an individual	Repetitive questioning is easily implemented
Response form	Only choice is available	Various response formats are available

Source: adapted from Ben-Akiva (2008a)

[16] Due to the different advantages and disadvantages of each method, some studies include both types of data in the analysis.

4.2.1. Revealed Preference Data

Revealed preference data, that is, observed choices, can be collected, for example, by observing the market, noting down the alternatives available to individuals and the choices that are made. Revealed preference data can also be collected electronically, for example through a cash register or flight reservation system.

The main advantage of revealed preference data is that it originates from real choices and therefore represents the actual behavior of individuals. However, this advantage also leads to disadvantages as it entails restrictions. The choices that can be observed are for example restricted to the alternatives that are offered to the decision maker and only choices between existing alternatives can be observed. Hypothetical choice situations cannot be tested or analyzed with the revealed preference approach. Therefore, new ideas and concepts as well as innovations cannot be tested with revealed preference data before their introduction. Also predictions or the calculation of possible market changes of those new alternatives cannot be accomplished with revealed preference data prior to their introduction. It would therefore not be possible to analyze the attractiveness of future, innovative airport concepts with revealed preference analysis as those concepts do not yet exist and therefore choices between them can only be observed in the future.

Furthermore, in revealed preference analysis the individual is restricted by his/her environment and personal constraints and has to make his/her choice accordingly. An airline would for example only choose an airport in a country to which it has traffic rights to fly to, even though another airport in a country where it does not have these rights would be more interesting for the airline in general. Another drawback of revealed preference analysis is that while the choices that are made are observed, often the alternatives to the choice that is made cannot be observed.

Another disadvantage of revealed preference data is that attribute-level ranges of the alternatives are often quite limited or sometimes attribute-levels do not vary between the alternatives at all in real choice situations. This provides difficulties in the choice modeling as due to the small variation in attribute levels it becomes more difficult to explain the different choices. (Hensher, Rose, & Greene, 2005, p. 94) Therefore only attributes that can be expressed as *objective* attributes and that are easily identified can be included in revealed preference data. Other attributes that depend on how the respondent *perceives* them, such as comfort, cannot be included as they cannot be observed. (Kroes & Sheldon, 1988) Furthermore, when attributes cannot be clearly defined, measurement errors might occur. Attributes of revealed preference data are also sometimes correlated as for example in passenger airport choice the price of an airplane ticket and the travel comfort would be, as more comfortable seats are often seats of a better cabin class which are almost always more expensive. This correlation can be avoided by using stated preference data and experimental designs.

Last but not least there is the difficulty of data collection that can arise with revealed preference data. In some research domains, revealed preference data might be costly but available. In a recent study Behrens and Pels (2011) used revealed preference data to study the intermodal competition between rail and aviation in the London-Paris passenger market. Other examples of the use of revealed preference data in the air transport business are the different studies published about the airport choice in the San Francisco Bay area. Those studies were published based on data from the passenger survey conducted by the Metropolitan Transportation Commission in the San Francisco Bay Area in 1995. Examples of such studies include Hess and Polak (2005, 2006a, 2010), Başar and Bhat (2004) and Pels et al. (1998, 2000, 2003). However, to obtain revealed preference data is not always possible. It is often difficult to obtain multiple observations/responses for an individual. The complexity of the airport choice for example requires the collection of a larger data set to be able to build statistically significant models. Through observation only a limited number of airport choices for freighter operations could have been identified, as the airlines that serve Europe with freighters are limited in numbers and as airlines often only choose a restricted number of airports in Europe to serve. Therefore, a revealed preference dataset for the airport choice for scheduled freighter operations would not have been sufficient for building statistical significant and realistic models.

4.2.2. Stated Preference Data

In contrast to revealed preference data, stated preference data are not obtained from real life situations but through experimental designs with hypothetical situations, which are often administered by questionnaire. Therefore analysis of stated preferences data overcomes some of the problems associated with the analysis of revealed preference data such as measurement errors of attributes, multicollinearity, narrow attribute level ranges and the restriction of the alternatives to existing alternatives. On the other hand, with stated preference experiments, the alternatives and attributes have to be defined in advance. Therefore, the right definition of them is crucial to the quality of the model results.

The main advantage of the stated preference approach is that hypothetical and non-existent alternatives can be included in the experiment. Therefore, new methods and innovations can be included in the alternatives and the model results can be used for predictions and the calculation of future market shares. Furthermore, the personal and environmental limitations that might exist in real-life situations from which revealed preference data are collected, can be broadened. With regard to the airport choice, we could ask an airline for example to choose between two airports in two different countries, assuming that the airline had traffic rights in both countries. Recent examples of studies applying stated preference analysis in the passenger airport or airline choice are Marcucci and Gatta (2011), De Luca (2009), Loo (2008) and Martín et al (2008).

However, the main reason why at the end it was decided to work with stated preference data was that respondents can be asked to express their preference in a number of choice situations. Revealed preferences on the other hand relies on observations and the airport choices that can be observed in Europe are not sufficient to calculated statistically significant models.

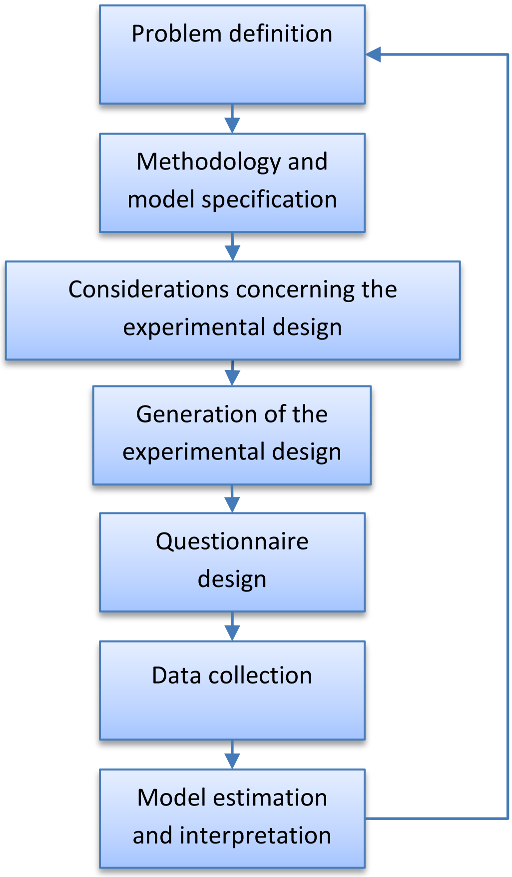
4.3. The Process of Stated Preference Experiments

The main difference between working with stated and revealed preference data is, that when dealing with stated preference data, one deals with an experiment instead of real observations. As the quality of the results of an analysis of stated preference data depends for a large part on the quality of the experiment, a lot of considerations and time need to go into the preparation and execution of the experiment.

The process of setting up a stated preference experiment is shown in Figure 4.2. First of all, the problem has to be clearly defined. This includes considerations about which question the researcher is trying to answer, which method is most appropriate for that question and which methods have been used in previous, maybe similar research.

Concerning the airport choice study, the research question for the stated preference part is clearly defined: How do airlines with scheduled freighter operations value different airport choice factors in their decision for an airport to operate to and which trade-offs are made between the factors? As already specified in the aim of this study, this research question refers to the general airport choice and not the choice between two specific European airports such as Amsterdam Schiphol or Frankfurt Airport. Chapter 3 showed, that most studies about the airport choice concern the airport choice for passenger operations or the airport choice from a passenger perspective. The few studies that analyze the airport choice for cargo operations either apply the Weber least cost model (see for example Watanabe et al. (2009)) or rely on the rating of the airport choice factors on a Likert-scale (see for example Gardiner et al. (2005b)). However, both approaches have disadvantages: the Weber least cost model only considers costs as factors and the rating of the factors does not give any idea about the trade-off between the factors. This method further has the disadvantage that the correspondents might rate the factors strategically and rate for example airport charges as very important to manipulate the airport in keeping the charges low to attract airlines, which is less the case in the stated preference exercise.

Figure 4.2 - The process of stated preference experiments



Source: own composition based on Hensher et al. (2005)

After defining the research problem, a methodology and model that specifically fits the research needs has to be selected. Among the discrete choice stated preference experiments, different types of models can be distinguished, such as the multinomial logit model, the nested multinomial logit model and the mixed multinomial logit model. The model also has to be specified including the alternatives, attributes and attribute levels as well as the model type. Before generating the experimental design, specific issues have to be considered such as the question of a labeled or unlabeled experiment as well as the size of the experimental design. One of the main parts in setting up a stated preference study is the generation of the design. A good design can maximize the information of the experiment. Once the design has been generated, a questionnaire is set up. If required, it can also include other questions to gain information which is necessary as input for the stated preference analysis such as socio-economic variables or information needed to answer the research questions. In the stated preference experiment concerning the airport choice of freighter operators, for example, additional questions about the airport choice process were asked. Finally, the data for the stated preference analysis have to be collected to subsequently estimate and interpret the stated preference model. While the content of the previous steps are subjects of this chapter, the results and interpretation of the model will be the topic of Chapter 5. After this last step one also has to go back to the problem definition to see whether the research question could satisfactorily be answered. This will be done in Chapter 6 of this research.

4.4. Methodology and Model Specification

In this section, first, the methodology behind discrete choice analysis is reviewed and different discrete choice models are presented. Second, to enable the reader to better understand the model calculations carried out in the following chapter, some additional issues are discussed. In Section 4.4.3, some model specifications concerning the alternatives, attributes and attribute levels will be dealt with.

4.4.1. The Methodology Behind Choice Analysis

As it incorporates different economic theories, the theoretical foundation of discrete choice analysis is rather complex. Discrete choice analysis first of all is based on probabilistic theory as one cannot perfectly predict choices due to unobservable parameters. Therefore, instead of identifying one option as the chosen option, each alternative is assigned a probability to be chosen. Discrete choice analysis is furthermore in line with Lancaster's (1966) economic theory that states, that the utility of a good or service derives from its different "hedonistic" characteristics and not the good itself, as consumer demand theories before Lancaster stated. Another theory that can be considered as a foundation of discrete choice analysis is Thurnstone's (1927) "Law of comparative judgement" in which he tried to explain imperfect discrimination.

In 1960 Marschak generalized Thurnstone's idea in treating preferences as stochastic or random (Marschak, 1960). He called this the Random Utility Model (RUM), which was already introduced in Section 4.1.2. In 1959 the scientist Duncan Luce introduced the Independence from Irrelevant Alternatives (IIA) axiom, to facilitate the experimental measurement of choice probabilities (Luce, 1959). This axiom is further explained in the following section. McFadden (1974) combined the ideas of Lancaster (1927), Marschak (1960) and Luce in a model, called the MNL model. (McFadden, 2008)

4.4.1.1. *The Multinomial Logit Model*

One of the most simple and widespread discrete choice models is the multinomial logit (MNL) model that was first introduced by McFadden (1974). In this model the relative utility of an alternative in a choice situation can be written as follows:

$$U_{jsn} = x'_{jsn}\beta + \varepsilon_{jsn},$$

where

U_{jsn} is the utility that a respondent n attaches to alternative j in choice situation s

x'_{jsn} is k x 1 vector containing the attribute levels of alternative j in choice set s for respondent n

β is k x 1 vector of parameter values (part-worths)

ε_{jsn} is the IID Gumbel error term, which incorporates the unobserved sources of utility.

Given the random utility model, the MNL probability that respondent n chooses profile j in choice set s is (McFadden, 1974):

$$\text{Prob}_{jsn} = \frac{\exp(x'_{jsn}\beta)}{\sum_{t=1}^{J}\exp(x'_{tsn}\beta)}.$$

If ε_{jsn} in the first equation would be normally distributed instead of Gumbel (Extreme Value 1) distributed, the random utility model would lead to another well-known model, the multinomial probit model.

The three most important shortcomings of the MNL model are that first, it does not account for taste heterogeneity between respondents. Second, it does also not account for the fact that the respondents usually answer multiple choice tasks and therefore correlations might be introduced. Third, it is assumed that the unobserved components of the utility are independent and identically distributed (the IID assumption). (Bliemer & Rose, 2010) To understand the IID assumption, one has to understand that as the unobserved components of the utility function have to be independent and identically distributed. Furthermore, the ratio between the probabilities of two alternatives has to be independent of the presence of additional alternatives (Independent from Irrelevant Alternatives – IIA). Therefore, when adding a third alternative to a set of two alternatives, this should not affect the ratio of the probability of the two other alternatives.

Why this can be a problem, can be best explained by means of an example, the red bus/blue bus problem. Assume that we have two different choices of transport to get from point A to B: either we take the car or a red bus. Assume also that the probability for choosing a car is 0.75 and for choosing the red bus 0.25, with a ratio of the probabilities of 3. Let us now introduce another possibility of transport, the blue bus. If the IIA assumption holds, the probabilities that are calculated with the MNL model would be for example 0.6 for choosing the car, 0.2 for choosing the red bus (the ratio between the probabilities for choosing a car and a red bus remains 3) and 0.2 for choosing the blue bus. However, this is quite unrealistic, as one would expect that the probability for choosing the blue bus would for the most part draw from the choice probability of the red bus and not from the car as the red and blue bus are public transports and very similar. Because of the shortcomings of the multinomial logit model, different and more advanced models were developed.

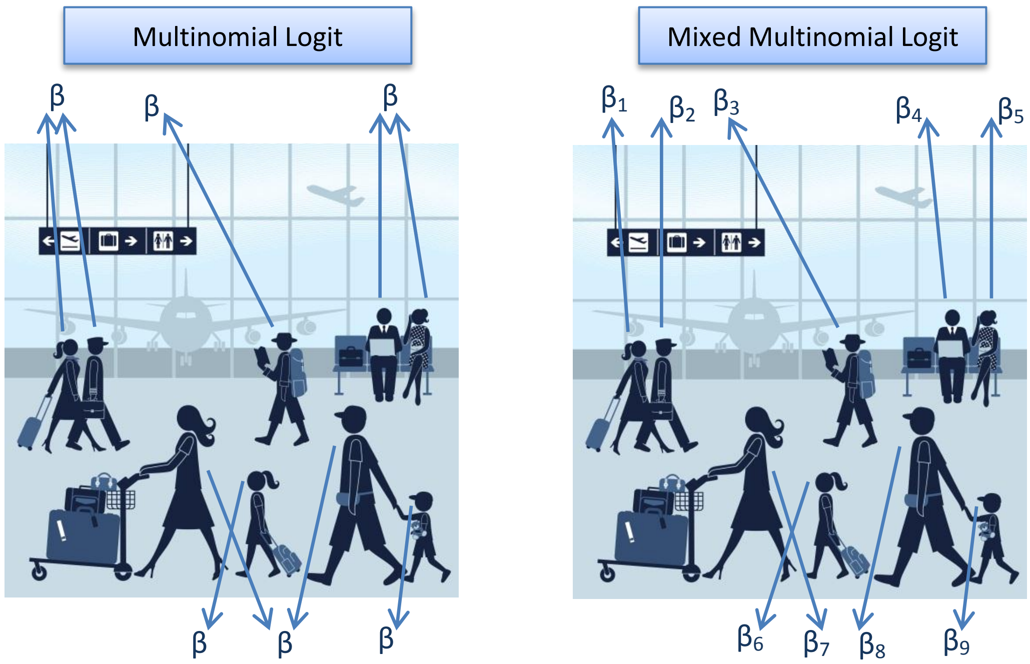
4.4.1.2. The Nested Logit Model

The most well-known of those models in applied research are nested logit models and mixed logit models such as the cross-sectional mixed logit model and the panel mixed logit model. In nested logit models the IID assumption is relaxed as the alternatives are placed in different groups or nests in which the unobserved attributes have to be independent between nests but which allows the unobserved alternatives to be correlated within a nest. In the previous example the car would form one nest and the red and blue bus another. The unobserved attributes between the two nests would then be independent but the unobserved attributes within the nest of the blue and the red bus dependent. The nested logit model has been applied by many researchers in transportation, e.g. by authors such as Román & Martín (2011), Hsiao & Hansen (2011), Pels et al. (2009), Hensher & Rose (2007) and Hess & Polak (2006b). Often the nested logit model is applied when a choice context can be considered as hierarchical, which means that the choice is made in different consecutive steps. As explained however in Section 3.2, the airport choice process was found not to be subsequent process, which is why the nested logit model seemed less suitable for modeling the airport choice of air cargo operators.

4.4.1.3. The Mixed Logit Models

In the mixed logit models the unobserved attributes can assume any distribution as the unobserved attributes are decomposed in two parts: one part that is IID Gumbel distributed and a part that can have any distribution. The mixed logit models were first applied in the 1980’s but became increasingly popular with the development of powerful computers as the models are calculated by simulation. The most interesting part of the mixed logit models is that they can be derived based on random coefficients. This means that not only one single value for a coefficient is calculated as kind of average for all respondents, but that a distribution of values for the coefficients across the population is computed. This allows the researcher to account for taste heterogeneity between respondents. Figure 4.3 represents this difference in a graphical way.

Figure 4.3 - Graphical comparison between multinomial logit and mixed multinomial logit models



Source: own composition based on Yu et al. (2009)

Most of the time the random parameters are assumed to be distributed according to the normal distribution, the uniform distribution, the lognormal distribution, the triangular distribution or the discrete distribution. (Bliemer, Rose, & Hensher, 2010) The problem with mixed logit models is that the choice probability is defined by an integral (see Table 4.2) which does not have a closed form solution and therefore has to be calculated by simulations. For the simulation, a number of draws have to be taken from the assumed distribution of the parameters. Pseudo-random draws, quasi-random draws (for instance, Halton sequences) and Gaussian draws are types of draws that are often used. (Bliemer et al., 2010)

Table 4.2 shows a simple comparison between the utility and probability formulation in the MNL and in the mixed multinomial logit model.

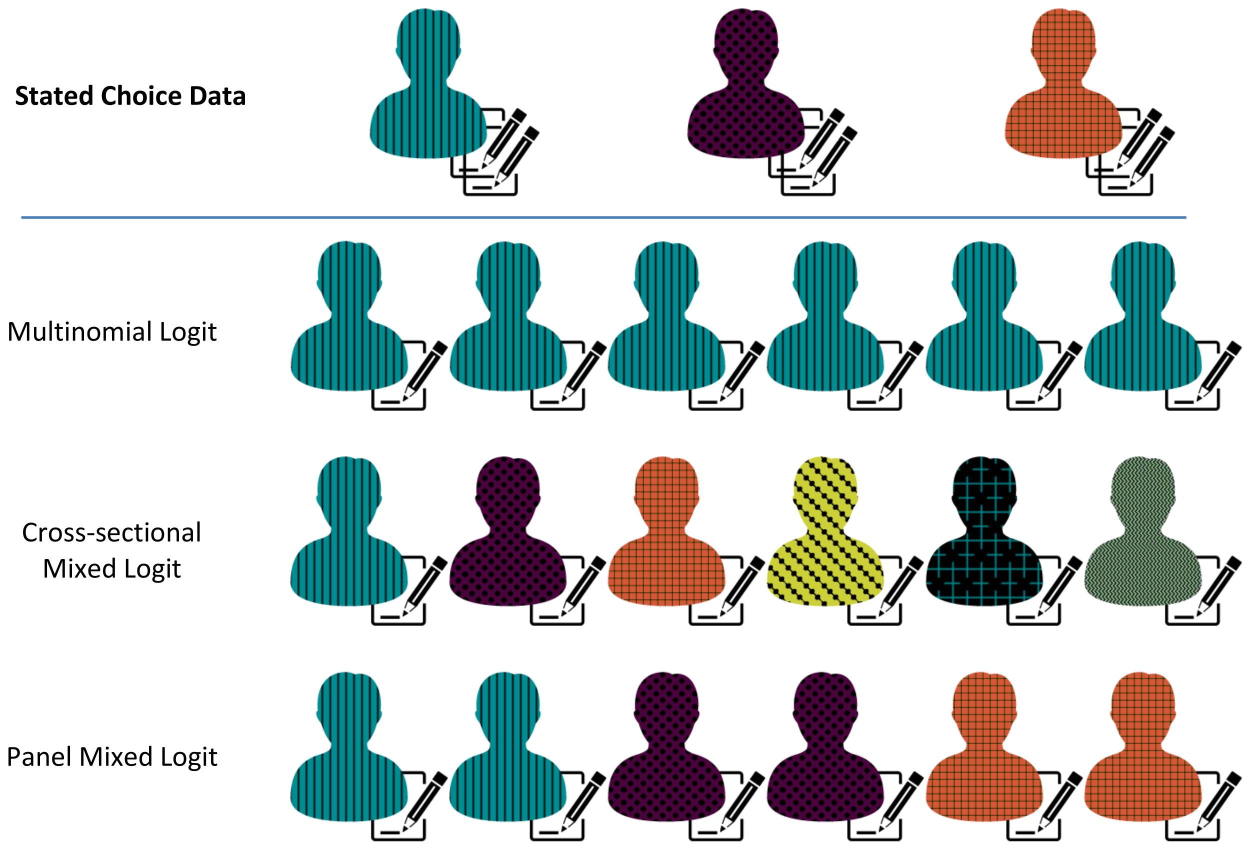
Table 4.2 - Utility and probability formulation of the MNL and mixed multinomial logit model

	Utility	Probability
Multinomial Logit[17]	$U_{jsn} = x'_{jsn}\beta + \varepsilon_{jsn}$	$Prob_{jsn} = \frac{\exp(x'_{jsn}\beta)}{\sum_{t=1}^{J}\exp(x'_{tsn}\beta)}$
Mixed Multinomial Logit[18]	$U_{jsn} = x'_{jsn}\beta_n + \varepsilon_{jsn}$ With for example $\beta_n \sim N(\beta; \Sigma_\beta)$	$Prob_{jsn} = \int \frac{\exp(x'_{jsn}\beta_n)}{\sum_{t=1}^{J}\exp(x'_{tsn}\beta_n)} f(\beta_n)d\beta_n$

The difference between the cross-sectional mixed logit model and the panel mixed logit model lies in the fact that the panel mixed logit model takes into account the repeated choices by each respondent. (Train, 2009) In essence, in the panel mixed logit model, the model over the whole population is calculated based on the assumption that every respondent behaves according to the MNL model. (Yu, Goos, & Vandebroek, 2011)[19] Therefore it is more realistic and solves the second shortcoming of the MNL model. Figure 4.4 is a simple graphical illustration of the differences between the MNL, the cross-sectional and the panel mixed logit model.

17 See McFadden (1974).
18 See Train (2009, pp. 137–138) and Goos (2007).
19 For a more statistical and more detailed discussion of the mixed multinomial logit models the reader can consult, for example Bliemer & Rose, (2010) or Train (2009).

Figure 4.4 - Graphical comparison of multinomial logit, cross-sectional and panel mixed logit model



Source: own composition based on Bliemer et al. (2010)

4.4.2. Notes Concerning the Estimation of The Discrete Choice Models

In order to enable the reader to understand the model calculations in the following chapter and to better follow the interpretation of the results, some additional issues should be discussed. First, the maximum likelihood approach that is used to estimate the discrete choice models will be presented. Subsequently, some hypothesis tests such as the maximum likelihood ratio test and goodness of fit measurements like the rho square and the Wald test for individual parameters will be introduced, and their use in the analysis of the stated choice data of the study is explained.

4.4.2.1. The Maximum Likelihood Estimation

Models such as the MNL model are based on maximum likelihood estimation. The aim of the approach is to find the part-worth values that most likely result in the observed choices. This means that we look for the value of the parameters in the utility function that most likely result in the choices made by the respondents.

For a binary multinomial logit model, that is, a model resulting from the respondent making a choice between two alternatives at a time, the likelihood of a sample composed of N observations can be defined as:

$$L(\beta_1, \dots, \beta_K) = \prod_{n=1}^{N} \prod_{s=1}^{S} P_{ns}(1)^{y_{1ns}} P_{ns}(2)^{y_{2ns}} \text{ , where}$$

L is the likelihood depending on the parameters $\beta_1, \dots, \beta_K$,
Pn(1) and Pn(2) are the probabilities with which respectively alternative 1 or 2 are chosen
y_{1n} is 1 if the individual n has chosen alternative 1, and 0 otherwise, and
y_{2n} is 1 if the individual n has chosen alternative 2, and 0 otherwise.

The product of all probabilities is maximized with respect to $\beta_1, \dots, \beta_K$ to achieve the highest likelihood. The likelihood function will be between 0 and 1 as it is a product of probabilities (which are between 0 and 1). However, mathematically it is easier to maximize the logarithm of the likelihood function (l), which equals

$$l(\beta_1, \dots, \beta_K) = log(L\,(\beta_1, \dots, \beta_K)),$$

$$\text{or } l(\beta_1, \dots, \beta_K) = \sum_{n=1}^{N} \sum_{s=1}^{S} (y_{1ns} log P_{ns}(1) + y_{2ns}\, log P_{ns}(2))$$

The problem is then to find the values for the part worths that maximize the log-likelihood. (Bierlaire, 2008)

As the likelihood will be between 0 and 1, the log-likelihood function will be negative. The maximum of the log-likelihood function is therefore the value that is closest to zero and the closer the log-likelihood is to zero, the better the model explains the data. (Washington et al., 2001)

To be able to find the maximum likelihood estimates, different optimization algorithms are available. In BIOGEME the following algorithms can be used: BIO, BIOMC, DONLP2, CFSQP and SOLVOPT.[20] On the one hand, a specific algorithm can solve a particular problem (that is calculate a particular model)

[20] For more information about the different optimization algorithms, please consult Bierlaire (2009) or http://biogeme.epfl.ch/algorithms.php

that another algorithm cannot. On the other hand, the different algorithms may also produce different parameter estimates. However, the differences are usually very small. (Bierlaire, 2009)

Furthermore, one important quality of the likelihood function that is very useful for the goodness of fit assessment, the so-called deviance, is that $-2logL$ or $-2l$ is approximately chi-squared distributed. (Goos, 2007)

4.4.2.2. The Likelihood Ratio Test and Its Use in This Study

The likelihood ratio test is performed to compare the fit of two different models that are a variation of each other with estimating the models and comparing their fit to each other. This is done by comparing the log-likelihoods of two models and to check whether those differ significantly from each other.

Let $\hat{\theta}$ be a vector of parameter estimates, L_U the likelihood of the unrestricted model, the one with more parameters, and L_R the likelihood of the restricted model, the one with less parameters.

The likelihood ratio can then be defined as $\frac{L_R}{L_U}$. Moreover, the likelihood ratio test (D) is actually a comparison between the deviances of the restricted and unrestricted model and is defined as follows:

$$D = -2\ log\left[\frac{L_R(\hat{\theta})}{L_U(\hat{\theta})}\right] = -2\left[l_R(\hat{\theta}) - l_U(\hat{\theta})\right],$$

under the null hypothesis, that the restricted model is equal to the unrestricted model, and which is chi-squared distributed with the degrees of freedom equal to the number of restrictions imposed. The disadvantage of the likelihood ratio test is that it can only be applied when one model is a more restricted version of the other. (Greene, 2002)

The likelihood ratio test will, in this study, mainly be used for testing two different things: first to test whether the model has some statistically significant explanatory value overall and second to test whether individual or groups of parameters are statistically significant.

The likelihood ratio test for the explanatory value of the estimated model is similar to the F test in regression models. To see whether the full model is statistically significant, the estimated model is compared to a trivial model that has no explanatory value and in which all beta's were assumed to be zero.

The specific log likelihood ratio test would then be defined as

$$D = -2[l(\hat{\theta}) - l_0(\hat{\theta})],$$

with $l(\hat{\theta})$ being the log-likelihood of the estimated model and $l_0(\hat{\theta})$ the log-likelihood of the trivial model.

In Chapter 5, the result of this likelihood ratio test is reported in the tables as *likelihood ratio*. When the p-value of D is small, the conclusion is that the difference in the log-likelihood of the models is significant and the estimated model fits the data much better than the trivial model. This means that the estimated model has some statistically significant explanatory value. (Bierlaire, 2008; Goos, 2007)

The second use of the likelihood ratio test in this research concerns the test of whether certain parameters or groups of parameters have some explanatory value. It can be tested, for example, whether the parameters for the presence of forwarders have an significant explanatory value. To this end, the fit of, for example, a simple MNL model including all parameters (the base model or the less restricted model) is compared to the fit of a restricted model (in our example a model that excludes all parameters for the presence of forwarders) by means of a likelihood ratio test. If the difference in fit is statistically significant, this means that the less restricted model (that is the simple MNL model including all parameters) fits the data significantly better than the restricted model (the model without the parameters for the presence of forwarder), the likelihood ratio test will be significant. In that case the parameters for the presence of forwarders are significant and cannot be dropped from the model without losing significant explanatory value. If the likelihood ratio is not significant, the parameters can be excluded without the loss of significant explanatory value.

To make the difference in significance between (groups of) parameters more apparent, the –log10 of the p-values of the likelihood ratio tests can be calculated. Those values can then be scaled to the highest value, so that a ranking of the (groups of) parameters are received according to their overall statistical significance.

4.4.2.3. Rho Square and Adjusted Rho Square

The **rho square** is a goodness of fit measure in which the goodness of fit of an estimated model is compared to a trivial model with all parameters set to zero (and which therefore has no explanatory value).

Rho square (ρ^2) is defined as follows:

$$\rho^2 = 1 - \frac{l(\hat{\beta})}{l(0)},$$

where

$l(\hat{\beta})$ is the value of the log-likelihood function of the estimated model and

$l(0)$ is the value of the trivial model with all parameters set to zero.

If the estimated model does not fit the data better than the trivial model, their log-likelihood will be the same and therefore $l(\hat{\beta})$ = $l(0)$, which leads to ρ^2 being 0. Zero is therefore the minimum value that rho square can assume. The maximum value of 1 is obtained when the likelihood of the model is 1 and therefore the log-likelihood is 1 as well. This would mean that all choices of the respondents are predicted perfectly well and therefore the probability of observing the choices that are made by the respondents was 1.

The rho square seems similar to the coefficient of determination R^2 in linear regression analysis as it also ranges between 0 and 1. However, its interpretation is not at all similar. R^2 shows the percentage of the variation of the dependent variable that can be explained by the model. Rho square on the other hand only indicates that the model with the higher score fits the data better than a model with a lower score. The values between 0 and 1, however, have no intuitive interpretation. (Train, 2009, p. 68) Furthermore, rho square is no absolute value, which is why it should only be used to compare models which are calculated based on the same sample data, have the same dependent variable and the same number of parameters. (Ben-Akiva, 2008b)

To compare models with a different number of parameters, the **adjusted rho square** ($\bar{\rho}^2$) is a better goodness of fit measurement, as it takes into account the difference in numbers of parameters.

The adjusted rho square is defined as:

$$\bar{\rho}^2 = 1 - \frac{L(\beta^*) - K}{L(0)},$$

with K defined as the number of parameters. A decreasing adjusted rho square means that the model over-fits, which means that it is optimized for the sample but may perform less well in general. (Bierlaire, 2008)

4.4.2.4. Wald Test for Individual Coefficients

The Wald test for individual coefficients is similar to the classical t-value in linear regression and is often indicated as such. However, testing whether a certain variable possesses explanatory value in logistic regression actually a Wald test is applied and therefore a z-value calculated.

The Wald test is defined as

$$z = \frac{estimated\ coefficient\ \beta_i}{estimated\ standard\ deviation\ of\ \beta_i}$$

The z test statistic is squared to conduct a hypothesis test using the chi-squared distribution with one degree of freedom. (Goos, 2007)

4.4.3. Model Specifications

Before generating an experimental design for a stated preference survey, the model for which the design is generated has to be identified. To this end, the alternatives as well as the attributes and their levels have to be well defined.

4.4.3.1. Definition of Alternatives

First of all, a choice has to be made concerning the alternatives of the experiment. In general, every possible alternative has to be defined to make the experiment as realistic as possible. For our experiment this would mean that all airports in Europe where freighter operations are possible would have to be identified. However, as the alternatives are often numerous, not all alternatives can be included in the experiment, but a choice has to be made on how to reduce their number. One option is to work with unlabeled alternatives in which the alternatives are not defined by their true name but only by their attributes and attribute levels. In the airport choice study, it was decided to follow this approach. In this case, however, this tactic was used not to limit the alternatives but rather to generalize the alternatives. That is because the focus of the study is the airport choice in Europe in general and not the choice between the existing airports in Europe. Furthermore, when working with labeled alternatives, the attribute levels would not vary as much as in an unlabeled experiment if the choices are kept as realistic as possible. There are for example only a limited number of airports such as Liège Airport and Leipzig/Halle Airport with 24h operations.

4.4.3.2. Definition of Attributes and Levels

A second step in the model specification is the identification of the airport choice factors/attributes and their levels to be used in the discrete choice experiment. The literature review in Chapter 3 provided an idea of the airport attributes, but only a study by Gardiner et al. (2005b) quantified the importance of those attributes. Therefore, five exploratory interviews with airlines and airport managers were carried out in 2010 to identify the attributes and their levels that can be best used in the discrete choice experiment. The airlines and airports were asked to first rate the different attributes according to a Likert scale from 1, not at all important, to 5, very important. A list of the attributes that were shown to the airline and airport managers can be found in Appendix 2. When asked whether there are other factors the airlines consider when choosing the airport which were not mentioned, the respondents replied that the list of attributes was considered as complete.

Based on the rating of the attributes by the airline representatives and airport managers as well as discussions during the exploratory interviews, the following attributes were retained for the discrete choice experiment: origin-destination demand, airport charges (including handling), night-time restrictions, the presence of forwarders, the airports' experience with cargo and the presence of passenger airlines. Those attributes were chosen either because they were said to be very important in the airport choice and/or judged to be from special interest in the study. The noise restrictions, night-time restrictions, origin-destination demand, the presence of forwarders at an airport and the airports' experience with cargo were considered by the airlines as very important attributes. Moreover, the presence of passenger airlines was included as this attribute showed a high variation between airlines and was expected to show, for example, differences between all-cargo airlines and combination carriers. Also noise and night-time restrictions were rated very differently by the respondents, which can point to substantial differences between airlines. In the end, the noise and night-time restrictions were included as one factor because noise and night-time restrictions often go hand in hand. An airport with strict noise regulations in general also has night-time restrictions. One reason to include the airport and handling charges was, that that attribute could be expressed in monetary units so it was possible to calculate willingness-to-pay or compensation ratios (see Section 5.6).

The access to the airport was one other attribute we considered including in the analysis but decided against. First of all, the exploratory interviews revealed that the transport to the market is most of the time the responsibility of the forwarder, which is why this factor should be more important for the forwarder than the airlines. Furthermore, it is very difficult to find levels that can measure the access to the airport. Categorical measurements such as good access/bad access can be interpreted very differently by the airlines. Levels on a ratio scale on the other hand are very hard to define. Transport time or distance to the market for example can vary considerably and do not always depict the real access quality to the airport. Pallets arriving by air to Amsterdam Schiphol, for example, could be transported to either Rotterdam in the Netherlands or Barcelona in Spain. Therefore, transport times of 1 hour (from Amsterdam Schiphol to Rotterdam) or 20 hours (from Amsterdam Schiphol to Barcelona) could mean the same access quality, in this case the access quality to Amsterdam Schiphol Airport. Table 4.3 shows all attributes and levels that were retained for the stated preference experiment. The presence of a forwarder at an airport can be defined as having at least an agent of the forwarder or the forwarder itself at the airport perimeters or very close by. Furthermore, due to the difficulty in getting reference data for airport demand and charges that could be used for all airlines, the airlines were asked to compare the airports for those two attributes using a benchmark airport of their choice, with an actual difference of up to 40% between the hypothetical airports. We also discussed asking the respondents about the specific benchmark airport and their respective demand and charges. However, this might have led to confidentiality issues with some airlines and therefore to less data. Hence, these types of questions were omitted from the questionnaire.

Table 4.3 - Retained design attributes and levels

Origin-destination demand	Airport charges (including handling)	Night-time restrictions	Presence of forwarders	Airport experience with cargo	Presence of passenger airlines
20% less origin-destination demand	20% lower airport charges	No night-time restrictions	No forwarders present	Airport has no experience with cargo	No passenger airline operations at airport
10% less origin-destination demand	10% lower airport charges	Limited or very expensive night-time slots	Only major forwarders present	Airport has limited experience with cargo	Only passenger operations of own airline/group or of main passenger airline partner
Equal origin-destination demand	Equal airport charges	Night-time flight prohibitions	Broad range of forwarders present	Airport has extended experience with cargo	Different passenger airline operations from own airline/group as well as other airlines
10% more origin-destination demand	10% higher airport charges				
20% more origin-destination demand	20% higher airport charges				

To verify that the attributes that were retained are relevant and that their levels are realistic, two airline representatives were contacted. Both confirmed the relevance/realistic value of the attributes and levels.

4.5. Considerations Concerning the Experimental Design

An additional step before generating an experimental design is to decide whether the experiment will be labeled or unlabeled, and which kind of design will be generated (full factorial or fractional factorial design; orthogonal or Bayesian optimal design; full or partial profile design). Furthermore, it has to be decided how the parameters are coded, whether to include interaction effects or only main effects, and whether the design will be blocked. Those decisions are discussed in the following sections and the decisions that are made for the airport choice study are explained.

4.5.1. Labeled and Unlabeled Experiments

First, the researcher has to decide whether labeled or unlabeled alternatives should be included in the experiment, as discussed previously. This decision also has repercussions on the number of parameters that have to be estimated in the experiment. Unlabeled experiments only require the estimation of general parameters, which are the same for every alternative. This means that, when looking for example at the choice of airlines by passengers, only one general parameter would be estimated for the price. Labeled experiments on the other hand might also require the estimation of alternative specific parameters. Those parameters can be different for each alternative. We would, for example, estimate a parameter for the ticket price of British Airways but also one for Lufthansa. Often, in labeled experiments, a constant is included as alternative specific parameter to model the overall preference for one of the alternatives. For example, the estimation of a positive constant for Lufthansa would mean that, all other things being equal, the customer has a positive attitude towards Lufthansa. In unlabeled experiments however, respondents will not have such an a priori preference for one of the options; they will not a priori prefer airline A over airline B as “A” and “B” do not have a meaning to the respondent. Therefore, constants should not be included in unlabeled experiments. (Bates, 2011)

4.5.2. Full Factorial and Fractional Factorial Designs

Another question that has to be discussed is which design type should be used. In general there are two groups of stated choice designs: the full factorial design, featuring all possible choice situations given a particular number of attributes and levels and the fractional factorial designs, in which only a part of all possible choice situations is included. The disadvantage of full factorial designs is, that they often leave the respondents with too many choices that have to be made. With six attributes, two of them with 5 levels and four with 3 levels (see Table 4.3), the number of different hypothetical airports that can be generated is 2025 (=5x5x3x3x3x3 levels) which makes, when working with two choices in each choice set, over 2 million different choices in the full factorial design. This is much more than a respondent can handle. Therefore full factorial designs are only useful for problems that involve very few attributes and/or levels. For problems with more attributes and/or levels, a fractional factorial design is more convenient. In a fractional factorial design, only a number of possible choices are retained. A decision has to be made on which choices to include in a fractional factorial design. For this, different choice designs can be created.

4.5.3. Orthogonal and Bayesian Optimal Designs

Two well-known fractional factorial designs are orthogonal designs and (Bayesian) optimal design (also called efficient designs). The orthogonal designs are created with the aim to minimize the correlation between the attribute levels in the choice situations (for different orthogonal designs see Louvière, Hensher and Swait (2000)). Full factorial designs are for example orthogonal designs as the correlation between the different attribute levels is zero.

Efficient designs on the other hand have the purpose of maximizing the information from each choice situation. They exclude, for example, choice sets in which one alternative which includes the most unattractive attribute levels is compared with an alternative with only the most attractive levels. Such a choice would reveal no information to the researcher as the decision of every respondent would be known beforehand. For determining the most efficient design, the D-error is one of the most widely-used criterion, which leads to so-called D-optimal designs[21]. However, to be able to determine the D-error, the part-worths (estimates) of the attributes have to be known a priori. As we do not have those, three different paths can be followed. First, educated guesses can be made for the values of the part-worth, which leads to so-called locally D-optimal design. Second, the part-worths can be assumed to be 0, which leads to utility neutral design. This assumption, however, is highly unrealistic as it assumes that respondents do not have preferences. The third and most robust path is to assume the part-worths to follow a specific distribution, which leads to so-called Bayesian D-optimal designs[22]. (Kessels, Jones, & Goos, 2011)

For this study, Bayesian D-optimal designs were generated as they considered the state-of-the-art for discrete choice experiments. They were generated with input data from the exploratory interviews, e.g. information on how a certain attribute level was expected to influence the utility, and for the MNL model. A Bayesian D-optimal design for the panel mixed logit model format was also

[21] For more information about D-optimal designs see for example Gotwalt, Jones & Steinberg (2009).
[22] For more information about Bayesian D-optimal designs see Kessels et al. (2011), Rose and Bliemer (2009) and Bliemer, Rose and Hess (2008).

considered, where the choice design would be also individually adapted to the previous answers of a respondent (Yu et al., 2011). At the end, this design was discarded as not enough information and input data for the design generation was available. Eventually, two different Bayesian D-optimal designs each consisting of 40 choice situations were generated: one design including origin-destination demand as an attribute and another design excluding origin-destination demand (see Appendix 3). Two different designs were generated as origin-destination demand was expected to be dominant. In the case that origin-destination demand is dominant, and the variable is included in all choice sets, the respondent will always choose the option with the best level for origin-destination demand. Therefore, only information on the importance of origin-destination demand would be gained, but not on the other attributes. However, to answer the research questions of this study, also information on the importance of other attributes is needed.

4.5.4. Full Profile and Partial Profile Designs

Another aspect that has to be considered when designing stated choice designs is the number of attributes that will be shown to a respondent. When using too many attributes, a respondent can very easily be overwhelmed by the information and therefore find it difficult to make a choice between the alternatives. In that case, respondents often proceed to make their choice only based on one or a limited number of attributes. Their behavior at this point is non-compensatory and hence violates the assumption of the compensatory decision making of the random utility model. Therefore, to prevent this so-called lexicographic behavior the attributes shown to the respondents should be limited. Authors such as Green (1974) and Schwabe, Grasshof & Grossman (2003) found that respondents are often already overwhelmed with alternatives with more than four attributes. Therefore, the number of attributes shown with each choice situation was limited to four in our study using so-called partial profiles.

Those designs were created following a 2-stage design algorithm. In the first stage, the attributes to be shown in each choice situation were selected, whereas in the second stage, the levels of these attributes were determined. For more information about this state-of-the-art partial-profile D-optimal Bayesian design algorithm see (Kessels, Jones, & Goos, 2011, 2012).

In the first stage of the design algorithm two approaches can be followed. First, the design is calculated balancing the number of times an attribute is kept constant and the number of times an attribute is kept constant with another attribute (so-called attribute balance).[23] The second approach is to generate the design by keeping attributes with fewer levels more constant than attributes with more levels as to gain the same amount of information on each attribute level (so-called variance balance).[24] As the second approach is especially useful for choice design where the attributes have a different number of levels, this approach has been followed.

4.5.5. Dummy and Effects Coding

For the design of the experiment as well as for the calculation and interpretation of the stated choice models, the form of coding of the attributes is also important. If one only estimates one parameter per attribute, the model will produce a linear estimate. If we want to estimate non-linear effects or use qualitative attributes such as *no forwarders present* or *only major forwarders present*, we have to create a number of new *coded* attributes. Different coding schemes for this process are available that each have implication for the interpretation of the estimated models. The two most useful and well-known coding schemes are dummy and effects coding. Dummy coding means that an attribute is coded in a series of 0s and 1s. Effects-coding on the other hand codes the variables in a series of 0s, 1s and -1s. With dummy and effects coding the number of new variables will always be the same as the number of original levels of an attribute minus 1. Table 4.4 shows dummy and effects coding demonstrated on the attribute *presence of forwarders.*

Table 4.4 - Dummy and effects coding

Coding scheme	**Dummy coding**		**Effects coding**	
Variable / **Attribute level**	Forwarders_no	Forwarders_major	Forwarders_no	Forwarders_major
No forwarders present	1	0	1	0
Only major forwarders present	0	1	0	1
Broad range of forwarders present	0	0	-1	-1

[23] For more information about attribute balance see Kessels et al. (2011, 2012).
[24] For more information about variance balance see Kessels et al. (2012).

In the example for dummy coding, the utility V_i for the *no forwarders present* for alternative i can be written as follows[25]:

$V_i = (\beta_{i0} +)\ \beta_{i\ forwarders\_no} \times 1 + \beta_{i\ forwarders\_major} \times 0 = (\beta_{i0} +)\ \ \beta_{i\ forwarders\_no}$

For the utility of only major forwarder present we get:

$V_i = (\beta_{i0} +)\ \beta_{i\ forwarders\_no} \times 0 + \beta_{i\ forwarders\_major} \times 1 = (\beta_{i0} +)\ \ \beta_{i\ forwarders\_major}$

And for the utility of broad range of forwarders present:

$V_i = (\beta_{i0} +)\ \beta_{i\ forwarders\_no} \times 0 + \beta_{i\ forwarders\_major} \times 0 = (\beta_{i0} +)\ \ 0$

When applying effects coding, only the utility for a broad range of forwarders is different:

$V_i = (\beta_{i0} +)\ \ \beta_{i\ forwarders\_no} \times (-1) + \beta_{i\ forwarders\_major} \times (-1) = (\beta_{i0} +) - \beta_{i\ forwarders\_no}\ - \beta_{i\ forwarders\_major}$

From those example utilities we can see that the coding scheme of the variables also has a repercussion on the interpretation of the parameters of the model. With dummy-coding the base level for interpreting the estimates for the dummy parameters of an attribute is defined as 0 or in case of including a constant parameter β_{i0}. However, it is not clear whether the base level represents the utility of the base level, the overall or the grand mean. This is the reason why estimates from effects coded attributes are more logical to interpret. Here, the base level corresponds simply to the grand mean of the utility function. (Hensher et al., 2005, p. 120)

For the experimental design as well as for the model calculation, the airport choice attributes were effects coded if assumed non-linear. The translation of the attribute levels to possible model parameters can be seen in Appendix 3. However, as explained, not all possible model parameters of the effects or dummy coded attributes are estimated in a model, but only so many as attribute levels exist minus one. The marginal utility of the not estimated attribute level can then be calculated using the coding scheme. Which parameters are estimated does not influence the results of the estimation.

[25] In the formulas, β_{i0} is a constant parameter which is included in most labelled preference models. However, as the airport choice experiment is a non-labelled experiment where constants make less sense (Bates, 2011), the constant parameter here is shown in parentheses and only as an example of the problem when including constant parameters.

4.5.6. Main Effects and Interaction Effects Models

An attribute can have different effects on the utility function. The effect that an attribute has on the overall utility independent of the other attributes is called main effect. A second effect is the so-called interaction effect. Interaction effects occur when the effect of one attribute on the overall utility depends on the level of another attribute. (Ben-Akiva, 2008a) In other words, this is the effect that two or more attributes combined have on the overall utility. We focus on main effects as these are often the most important, and because estimating interactions requires a different design generally. However, in some models, also interaction variables were included to see the difference in valuation for the attributes between the airlines (see Section 5.5).

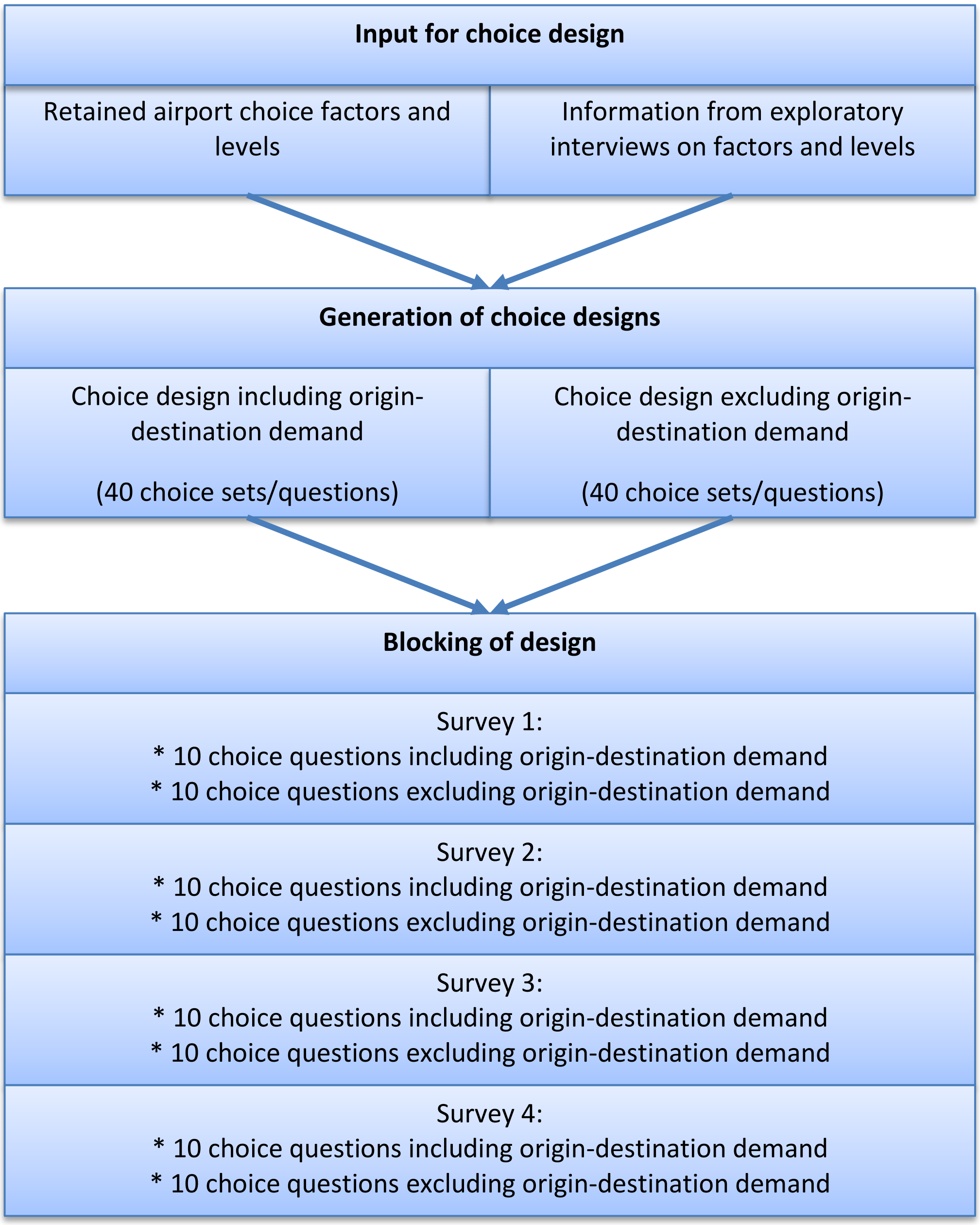
4.5.7. Blocking of the Design

The final two partial profile designs (that is one including and one excluding origin-destination demand) involve 40 choice situations with each a choice of two airports to collect as much information as possible. However, as respondents will get overly tired with 80 (40 including and 40 excluding origin-destination demand) choice situations and maybe will not answer consistently after a certain number of choice situations, it was decided to divide the designs each into four blocks of 10 questions each. A block of 10 choice situations from each partial profile design was administered to every respondent, so that every respondent had to make a choice from a total of 20 choice situations. The four blocks of 10 choice situations from each design were equally spread over all respondents.

4.5.8. Overview of Choice Design Generation

Figure 4.5 shows an overview of the choice design generation. The input for the choice design were on the one hand the retained airport choice factors and levels and on the other hand information from the exploratory interviews on factors and levels. With this information two different partial profile Bayesian D-optimal designs were generated; one including origin-destination demand and one excluding it. Last, those two designs were blocked to end up with 4 surveys, each with 10 choice questions of the choice design where origin-destination demand was included and 10 choice questions from the design where origin design was excluded.

Figure 4.5 - Overview of choice design generation



4.6. Questionnaire Design

In the final step of the experimental setup, the questionnaire was developed. In order to receive the information that was needed and to make the questionnaire as understandable for respondents as possible, research was done into the principles of questionnaire design (see for example Dillman et al. (2008)). Special attention was given to the structure of the questionnaire and the design of the questions.

At the beginning of the questionnaire, a short introduction was given about the background and the aim of the study. The questionnaire was further divided into three parts: in the first part, information was asked about the respondent and the airline. In the second part, the airlines had to make 21 choices between hypothetical airports within the framework of the discrete choice exercise. Those choices included a test choice to make the respondents familiar with the type of question. An example of the questions asked in part 2 can be found in Appendix 5. The data obtained in this part of the survey were used for the model estimation described in Chapter 5. Finally, questions about the airport choice strategy of the airlines were asked as background information for the analysis.

Before distributing the questionnaire, it was sent to various representatives from the air cargo sector for testing. The representatives were asked to fill in the survey and communicate all questions and suggestions concerning the understanding and the relevance of the questions. The suggestions were then incorporated before distributing the final questionnaire.

4.7. Data Collection

Between 17th February 2011 and 10th May 2011, a total of 32 surveys were collected of which 30 completed. This was done in two ways: through personal interviews and through the internet. Personal interviews give a more in-depth view, especially on the third part of the questionnaire, the airport choice strategies of the airlines. For the internet surveys, the respondents were e-mailed personally, reminded by e-mail of the questionnaire after two weeks and called when no reply was received.

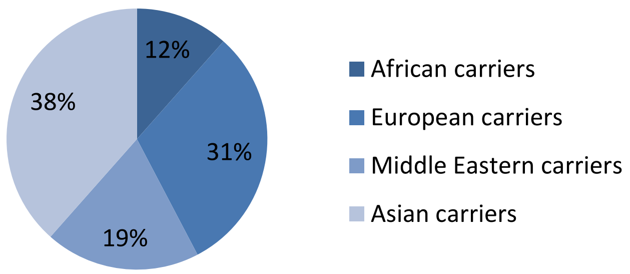
Table 4.5 - Airlines which submitted surveys with complete data for the discrete choice analysis

Region	Airline	Airline type
Europe	ACG Air Cargo Germany GmbH	All-cargo airline
	British Airways	Division or subsidiary of combination carrier
	Cargoitalia	All-cargo airline
	Cargolux	All-cargo airline
	Czech Airlines	Division or subsidiary of combination carrier
	Icelandair Cargo	Division or subsidiary of combination carrier
	Lufthansa Cargo	Division or subsidiary of combination carrier
	Martinair	Division or subsidiary of combination carrier
Asia	Cathay Pacific	Division or subsidiary of combination carrier
	China Airlines	Division or subsidiary of combination carrier
	China Southern Airlines	Division or subsidiary of combination carrier
	Eva Airways	Division or subsidiary of combination carrier
	Jade Cargo International	All-cargo airline
	Korean Air	Division or subsidiary of combination carrier
	Maskargo	Division or subsidiary of combination carrier
	Shanghai Airlines Cargo	All-cargo airline
	Nippon Cargo Airlines (NCA)	All-cargo airline
	Singapore Airlines Cargo	Division or subsidiary of combination carrier
Africa	Ethiopian Cargo	Division or subsidiary of combination carrier
	Royal Air Maroc Cargo	Division or subsidiary of combination carrier
	Avient	All-cargo airline
Middle East	CAL (Cargo Airlines)	All-cargo airline
	Emirates	Division or subsidiary of combination carrier
	Royal Jordanian Airlines- Cargo	Division or subsidiary of combination carrier
	Saudi Arabian Airlines	Division or subsidiary of combination carrier
	TMA	All-cargo airline

With 4 airlines, completed surveys from two respondents were received. As the inclusion of the data from both respondents would lead to a distortion in the models that are calculated, only the data of one respondent of each airline was included. The decision on which data to include was made based on the function of the respondent in the airline and their assumed knowledge of the airport choice. Therefore, from the 30 completed surveys that were received, the data of only 26 could be used for the discrete choice analysis. This reflects more than 50% of the population (freighter operators with scheduled services to Europe) and, as each respondent had to make 20 choices, 520 choices. The airlines that submitted surveys with complete data for the discrete choice part are shown in Table 4.5.

The 26 surveys originated from 11 independent cargo carriers and 15 cargo subsidiaries or cargo divisions of combination carriers; 8 were European carriers, 10 were Asian carriers, 5 were Middle-Eastern carriers and 3 were African carriers (see Figure 4.6). Also American carriers were approached for the survey. However, even after repeated contact, no response from an American carrier was received.

Figure 4.6 - Regional breakdown of surveyed carriers



The positions of the respondents within the carriers suggest that the results are reliable: the majority of the respondents hold a position that makes them a key decision maker in the airport choice decision process.

Figure 4.7 - Breakdown of respondents function in the airline

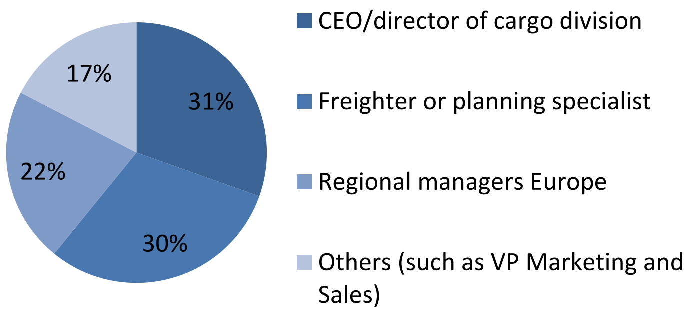


Figure 4.7 shows that seven respondents were, for example, CEOs or directors of the carrier/subsidiary/division, seven respondents were freighter or planning specialists and five respondents were regional managers for Europe.

4.8. Conclusions Concerning Choice Model

Chapter 4 introduced the concept of preference analysis, the difference between stated and revealed preference data, as well as the process of conducting stated preference experiments. The methodology as well as model specifications and special considerations were discussed. Also, the different steps that were taken for the airport choice study were outlined and different theoretical concepts were introduced, which makes it easier for the reader to better understand and interpret the results of models and the analysis (see Chapter 5).

In this chapter, the choice of experimental design for the airport choice of scheduled freighter operations in Europe was argued as well. First off all, the decision was made to work with an unlabeled fractional factorial design, as especially unlabeled experiments fits the problem definition of this research. Furthermore, the design that was generated is a partial profile Bayesian D-optimal design. A partial profile design was used to avoid lexicographic behavior, while Bayesian D-optimal designs attempt to maximize the information that can be gathered with the experiment.

At the end, 30 completed surveys from different airlines could be collected which are used as input for the model estimations of Chapter 5.

5. The Airport Choice for Full-Freighter Services - A Discrete Choice Approach

Previous research on the airport choice of freighter operations has centered itself mostly around the identification and ranking of important factors in the decision making process, as has part of the literature review in Chapter 3. However, a more in depth and more quantitative analysis has not yet been made. Hence, this chapter aims at gaining a better insight in the airport choice by discussing the results of a discrete choice experiment. It raises the question which attributes are most important for airlines in the airport choice process. Moreover, the discrete choice models will give a better idea of the relative importance of the airport choice factors (also called attributes in this chapter) and the trade-offs between them. The question whether there are differences between the airlines regarding the importance of the various attributes is also dealt with.

First, the main utility function is defined. Second, a simple multinomial logit (MNL) model was calculated with three different statistical software programs in order to see whether there are any differences in the results due to the various underlying estimation procedures. Next, the multinomial logit model was further developed to come to a model that better represents the choice data. Insignificant parameters were identified and excluded and the possible linearity of some part worths was investigated.

One disadvantage of the MNL models calculated in the first sections is that they do not account for preference heterogeneity and only one non-random estimate per parameter is calculated for the choice data across observations (see Section 4.4.1). Furthermore, every respondent is confronted with a number of choice situations in the survey, therefore making more than only one choice when answering the questionnaire (see Chapter 4). The panel mixed logit (PML) models in Section 5.4 account for the preference heterogeneity by estimating a distribution for the parameters and also take into account the panel characteristic of the data.

The question whether taste differences between market segments exist was also dealt with. The taste variations were studies in Section 5.5, where socio-economic variables are included in the model to see whether they have some explanatory value in the airport choice.

In Section 5.6, compensation indices of the parameters are calculated to obtain a better idea of the trade-offs made by airlines when choosing an airport for freighter operations. Those trade-offs can be especially interesting for airports and policy makers as it allows them to effectively respond to them. Finally, the results of the calculations including all available data are discussed in Section 5.7.

5.1. The Utility Function

As a starting point, a utility function for the airport choice for scheduled freighter operations has to be defined. After taking a number of considerations into account (see Chapter 4), one can define the utility of an alternative for the airport choice for scheduled freighter operations as follows:

$$U_i = UNight_i + UExperience_i + UForwarders_i + UPassenger_i + UDemand_i + UCharges_i + \varepsilon,$$

where

U is the utility of an alternative i in a choice situation

$UNight_i$ is the utility of night-time restrictions corresponding to alternative i

$UExperience_i$ is the utility of airport experience with cargo corresponding to alternative i

$UForwarders_i$ is the utility of presence of forwarders corresponding to alternative i

$UPassenger_i$ is the utility of presence of passenger airlines corresponding to alternative i

$UDemand_i$ is the utility of origin-destination demand corresponding to alternative i

$UCharges_i$ is the utility of airport charges (including handling) corresponding to alternative i

ε is the error term.

When including all six attributes as effects coded variables, we obtain the following multinomial logit model.

$$\begin{aligned} U = {} & \beta_1 Night_{limited} + \beta_2 Night_{prohibition} + \beta_3 Experience_{limited} + \beta_4 Experience_{no} \\ & + \beta_5 Forwarders_{major} + \beta_6 Forwarders_{no} + \beta_7 Passenger_{no} + \beta_8 Passenger_{sibling} \\ & + \beta_9 Demand_{+10\%} + \beta_{10} Demand_{equal} + \beta_{11} Demand_{-10\%} + \beta_{12} Demand_{-20\%} \\ & + \beta_{13} Charges_{-10\%} + \beta_{14} Charges_{equal} + \beta_{15} Charges_{+10\%} + \beta_{16} Charges_{+20\%} \\ & + \varepsilon \end{aligned}$$

This utility function is the basis of the first MNL model that is estimated in the following section and will be adapted according to the results of the analysis.

5.2. MNL Model Calculations With Different Software Packages

A first step in the discrete choice analysis was to calculate a simple multinomial logit (MNL) model. The simplest model, including all attributes using effects coded non-linear variables (see Section 4.8) was calculated with three different programs of which the results can be found in Table 5.1. This was done in order to see whether differences in the results of the three underlying estimation procedures can be detected. The programs that were used for the calculations were JMP from SAS (SAS, 2010), a general statistical program, and two programs built specifically to solve discrete choice questions: Nlogit (Econometric Software Inc., 2009) and Biogeme (Bierlaire, 2003). Biogeme was used employing the algorithm *BIO* as well as *DONLP2* and working with pseudo-random draws for the mixed-logit models.

It can be seen that the estimates for the different parameters from Nlogit and Biogeme are the same. The MNL estimates from JMP on the other hand differ, although not much, from the ones computed in Nlogit and Biogeme. This is due to the fact that the estimates from JMP have been calculated using the Firth bias correction for the maximum likelihood estimates (Firth, 1993, 1995). Because the airport choice study involves only a small number of respondents, and a reasonably small number of choices per respondent, the *Firth bias* correction is especially useful in the study for reducing the bias of the maximum likelihood estimates.

A more in-depth analysis of the parameters, their significance and the MNL model in general is carried out in 5.3. For further analysis mainly the program Biogeme was used, as it can be used to calculate multinomial logit[26], cross-sectional and panel mixed logit models and is very flexible in adapting the model structure. However, also JMP and Nlogit were used for specific questions whenever those programs proved to be more suitable.

[26] Although JMP is better with only a small number of respondents as it incorporates the Firth bias correction in the maximum likelihood estimation, it cannot calculate mixed logit models and it is also less flexible in model building.

Table 5.1 - Parameter estimates for the simple MNL model with JMP, Nlogit and Biogeme[27]

		JMP	Nlogit	Biogeme	z-value
Night-time	no restrictions	0.266	*0.276*	*0.276*	
	limited	0.009	0.009	0.009	0.1
	prohibitions	*-0.275*	-0.285	-0.285	-2.17**
Experience	extended	0.580	*0.600*	*0.600*	
	limited	-0.167	-0.174	-0.174	-1.82
	no	*-0.413*	-0.426	-0.426	-3.22*
Forwarders	broad range	0.732	*0.757*	*0.757*	
	major	0.412	0.426	0.426	4.28*
	no	*-1.144*	-1.183	-1.183	-8.59*
Passenger	different	0.190	*0.198*	*0.198*	
	no	-0.106	-0.110	-0.110	-1.1
	sibling	*-0.084*	-0.088	-0.088	-0.9
Demand	20%	0.671	*0.695*	*0.695*	
	10%	0.273	0.283	0.283	1.38
	equal	0.007	0.007	0.007	0.03
	-10%	-0.374	-0.387	-0.387	-2.05**
	-20%	*-0.577*	-0.598	-0.598	-2.78*
Charges	-20%	0.52	*0.537*	*0.537*	
	-10%	0.370	0.384	0.384	2.85*
	equal	0.011	0.012	0.012	0.09
	10%	-0.366	-0.379	-0.379	-2.72*
	20%	*-0.535*	-0.554	-0.554	-3.83
log-likelihood function			-302.584	-302.584	
likelihood ratio test				115.705	
rho square				0.161	
adjusted rho square				0.116	
* significant at 1% ** significant at 5%					

[27] Italic numbers in this chapter signify numbers that are indirectly calculated from estimates but are not estimates themselves (see Section 4.5.5.).

5.3. Multinomial Logit Results

After comparing the results from the different programs, the MNL model was further analyzed and developed to find a model that best corresponds with the choice data. In total, five different MNL models were estimated.

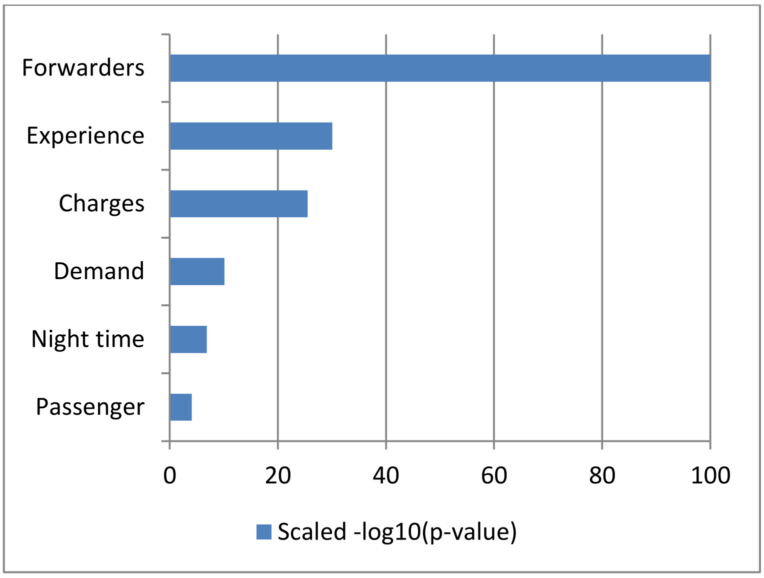
Table 5.2 shows the parameter estimates for the various models, as well as their z-value. Furthermore, for each model the log-likelihood function, as well as some measures for the goodness of fit (the likelihood ratio test, the rho square and the adjusted rho square) are shown. As can be seen, all parameter estimates have the expected sign. For example, positive demand changes (i.e. increasing potential demand) result in an increase in relative utility and therefore relative attractiveness of an airport, whereas negative changes in demand result in a decrease of relative utility or attractiveness.

When discussing the multinomial logit results further, a step-wise approach is followed. First the development of the various models and their main contributions are discussed. Second, the final multinomial logit model, the MNL noPax Clin DLin model, and its parameter estimates are discussed more in detail.

First, a simple MNL model was calculated, with the utility function as represented in Section 5.1. This model shows that concerning the overall importance of the different attributes (derived from effect likelihood-ratio tests for the factors) the presence of forwarders is the most significant attribute for the airlines when choosing an airport for freighter operations in Europe. The second most significant attribute concerns the airport charges, followed by the experience of an airport with cargo, origin-destination demand, night-time restrictions and the presence of passengers at an airport (see Figure 5.1).

The hypothesis that demand is one of the most important airport choice factors can therefore be dismissed. The reason that the demand is less important than expected might be due to the fact that there is a certain interdependence between the demand and the presence of forwarders. Forwarders are the main customers of the airlines, as already shown in Section 2.7. Furthermore, forwarders often consolidate the freight before bringing them to the airlines after discovering (potential) markets. Therefore airlines, who are interested in the potential market see forwarders as proxy variable for potential demand.

Figure 5.1 - Importance ranking of parameters for the MNL model



When answering the discrete choice questions in the survey, the airlines may have in first instance decided their choices according to the presence of forwarders - assuming that when there are sufficient forwarders at an airport, there will be also sufficient demand for air cargo - and only afterwards considered the demand. Although one could argue that both attributes are very similar to airlines, they do, however, not represent the same thing. The attribute of the presence of forwarders was mainly included to see how the actual presence of forwarders influences the airlines decision. It is expected that there are differences between the airlines concerning the importance of the presence of forwarders as there are many forwarders present in the vicinity of main airports, but often none in the vicinity of regional airports that are also served by scheduled freighter operations.

As previously mentioned, also the choice design can have an impact on the results and therefore the importance ranking of the factors. In the choice design process, the decision was made to generate two different designs, one including origin-destination demand and one excluding it (see Section 4.4). To assess whether this design strategy had an influence on the significance ranking of the attributes in the MNL model two separate MNL models were estimated. For one MNL model, only the observations related to the choice design including demand as an attribute were used, whereas for the other MNL model, only the observations from the choice design excluding demand as an attribute were used. In both sub-models, the forwarders turned out to be the most important choice attribute. Therefore, the decision to generate two different choice designs and to pool the associated data for the estimation of the MNL model did not have an influence on the significance ranking of the attributes.

Table 5.2 - Results of MNL airport choice modelling

	MNL[28]		MNL noPax[29]		MNL noPax Clin DLin[30]	
	parameter estimate	z-value	parameter estimate	z-value	parameter estimate	z-value
Night-time						
no restrictions	*0.276*		*0.277*		*0.278*	
limited	0.009	0.1	0.018	0.18	0.016	0.17
prohibitions	-0.285	-2.17**	-0.295	-2.24**	-0.294	-2.25**
Experience						
extended	*0.6*		*0.587*		*0.592*	
limited	-0.174	-1.82	-0.164	-1.74	-0.169	-1.8
no	-0.426	-3.22*	-0.423	-3.21*	-0.423	-3.21*
Forwarders						
broad range	*0.754*		*0.758*		*0.759*	
major	0.426	4.28*	0.422	4.25*	0.421	4.24*
no	-1.18	-8.59*	-1.18	-8.63*	-1.18	-8.61*
Passenger						
different	*0.198*					
no	-0.11	-1.1				
sibling	-0.088	-0.9				
Demand					0.0325	3.63
20%	*0.695*		*0.689*			
10%	0.283	1.38	0.294	1.45		
equal	0.007	0.03	0.002	0.01		
-10%	-0.387	-2.05**	-0.383	-2.04**		
-20%	-0.598	-2.78*	-0.602	-2.8*		
Charges					-0.029	-5.11*
-20%	*0.537*		*0.537*			
-10%	0.384	2.85*	0.384	0.384*		
equal	0.012	0.09	0.005	0.04		
10%	-0.379	-2.72*	-0.362	-2.63*		
20%	-0.554	-3.83*	-0.564	-3.89*		
log-likelihood function	-302.584		-304.477		-304.942	
likelihood ratio test	115.705		111.919		110.989	
rho square	0.161		0.155		0.154	

[28] MNL – MNL model including all six attributes as effects coded variables
[29] MNLnoPax - Same as MNL model but excluding parameters for passenger operations at airport
[30] MNLnoPaxClinDlin – Same as MNLnoPax model but specifying airport charges and demand as linear attributes

	MNL[28]		MNL noPax[29]		MNL noPax Clin DLin[30]	
adjusted Rho square	0.116		0.116		0.132	
Parameters	16		14		8	
* significant at 1% ** significant at 5%						

Furthermore, it can be seen that both estimated attributes for the passenger operations (no/sibling) were found to be insignificant in the MNL model, which is why they were excluded from the model specifications (see MNLnoPax). This means that for scheduled freighter operations, airlines do not consider the fact whether there are passenger operations at an airport or not when choosing which airport to serve. This partly contradicts Gardiner and Ison (2008) who observed that for combination carriers, an airport is more attractive when it also has passenger operations. The notion that passenger operations do not influence the attractiveness of an airport could also support the idea of cargo-only airports.

After excluding the parameters for passenger operations at an airport, the parameters of demand and charges were assessed. These parameters were effects coded and therefore included as non-linear in the MNL and MNLnoPax model to capture a possibly non-linear relationship with the relative utility. However, the question arises whether these two parameters might have a linear instead of non-linear relationship with the utility. To test this, the MNL noPax ClinDlin model was calculated specifying airport charges and demand as linear attributes. The utility function that the model is based on can be defined as follows:

$$U = \beta_1 Night_{limited} + \beta_2 Night_{prohibition} + \beta_3 Experience_{limited} + \beta_4 Experience_{no} + \beta_5 Forwarders_{major} + \beta_6 Forwarders_{no} + \beta_7 Demand + \beta_8 Charges + \varepsilon$$

At first sight the two sets of parameters seem to indeed have a linear relationship when plotting the marginal utilities[31] in a graph (see Figure 5.2 and Figure 5.3).

[31] The marginal utility represents the "increase in utility due to an incremental increase of an attribute". (Hensher, Rose, & Greene, 2005, p. 701)

Figure 5.2 - Marginal utilities of demand, obtained with effects coding and linear coding

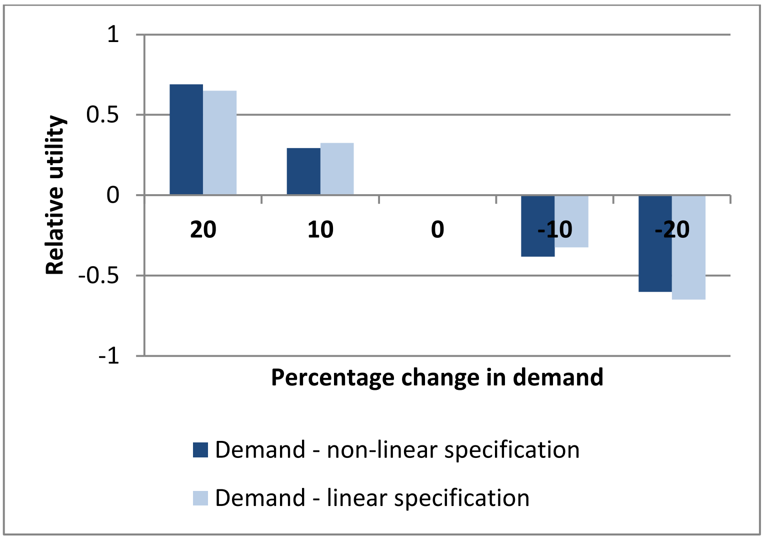
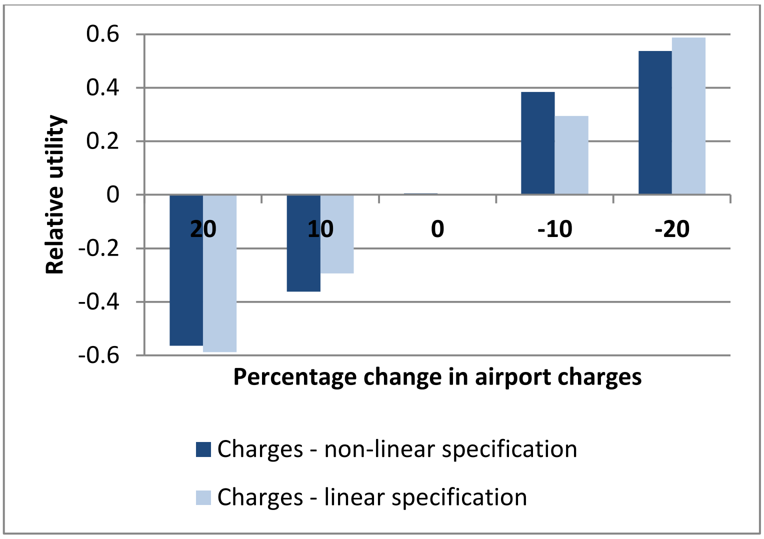


Figure 5.3 - Marginal utilities of airport charges, obtained with effects coding and linear coding



Finally, a log-likelihood test comparing the MNLnoPax model and the MNLnoPaxClinDlin indicated that the non-linear specification of the attributes did not add to the quality of the model. Moreover, the fit of the model improved slightly when specifying the two attributes as linear variables, as shown by the higher adjusted Rho square. In summary, model MNLnoPaxClinDlin provided the best fit to the choice data. 71% of the choices made by the respondents (369 out of 520) could be predicted correctly with this model. Also the order of significance of the other variables did not change between the MNL and the MNLnoPaxClinDlin model. As can be seen in Table 5.3 and Figure 5.4, the presence of forwarders remains the most important choice attribute, followed by the airport charges and the experience of the airport with cargo. Night-time restrictions are the least important attribute, with significance at only 5%. However, as earlier studies showed night-time restrictions as one of the most important attributes it was kept in the model. For further analysis, unless stated otherwise, the parameters for airport charges and demand are specified as linear.

Table 5.3 - Overview effect likelihood ratio test

		MNL		MNL noPax ClinDlin	
	DF	ChiSquare	Prob>ChiSq	ChiSquare	Prob>ChiSq
Night-time	2	6.291	0.043**	6.62	0.037**
Experience	2	27.625	< 0.0001*	27.454	< 0.0001*
Forwarders	2	91.854	< 0.0001*	92.45	< 0.0001*
Passenger	2	3.761	0.1525		
Demand	4 (1)	13.396	0.0095*	13.316	0.0098*
Charges	4 (1)	28.913	< 0.0001*	28.106	< 0.0001*
* significant at 1% ** significant at 5%					

Figure 5.4 - Importance ranking of parameters for the MNL noPaxClinDlin model

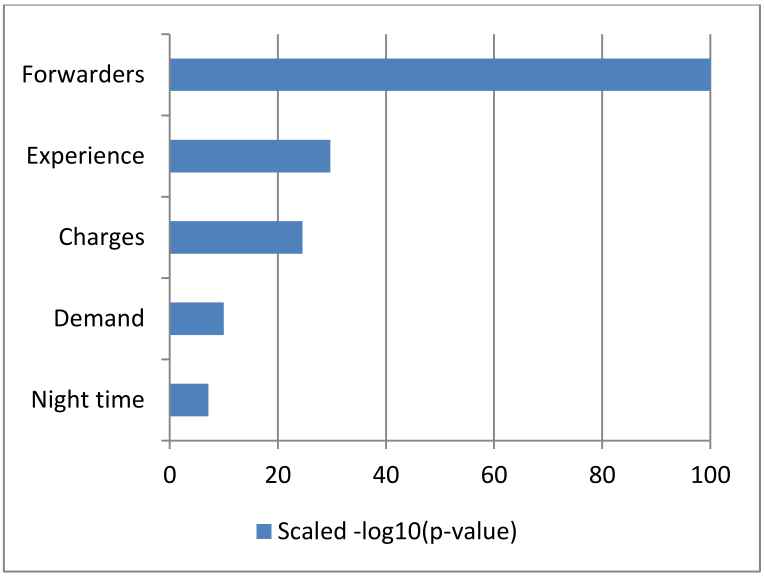
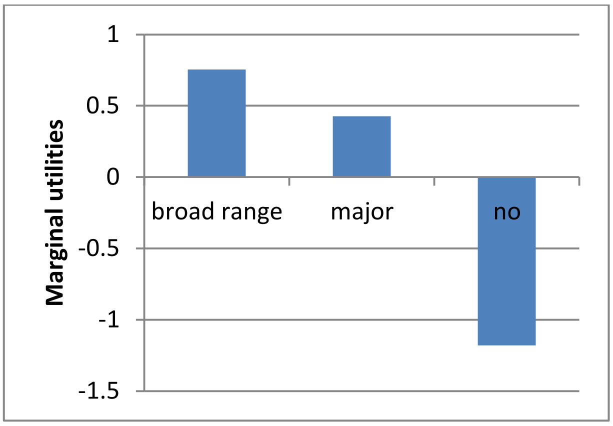


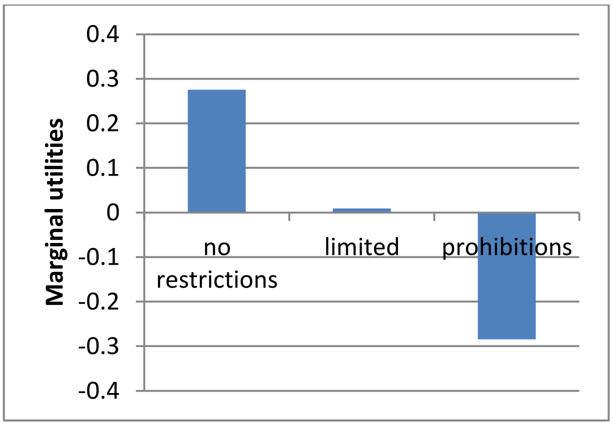
Figure 5.4, Figure 5.6, and Figure 5.6 show the marginal utilities of the estimated parameters for the attributes for respectively experience with cargo, presence of forwarders and night time restrictions of the MNL noPaxClinDlin model.

Figure 5.5 - Marginal utilities of forwarders (MNL noPaxClinDlin)



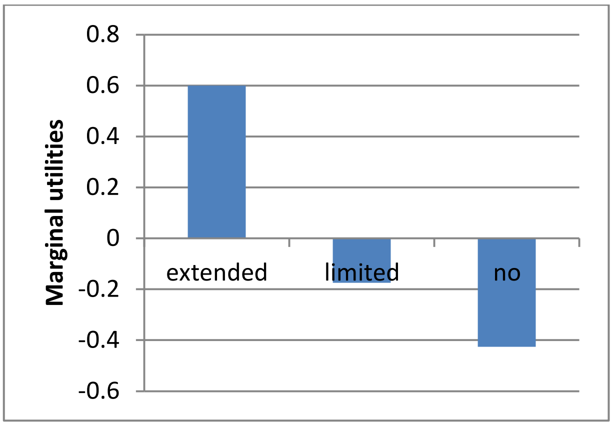
The marginal utilities correspond to the parameter values associated with all levels of each attribute and do not differ very much from the original MNL model. The marginal utilities are as expected. For example, they are negative for the night-time flight prohibitions and for no forwarders at the airport and positive for no night-time restrictions and extended experience with cargo. Moreover, it can be seen very clearly that the largest difference in relative utility is between having no forwarders at the airport and having only the major forwarders. This means that an airport with no forwarders nearby is much less attractive than an airport with the major forwarders only.

Figure 5.6 - Marginal utilities of night-time restrictions (MNL noPaxClinDlin)



The difference between the relative utility of limited experience with cargo and extended experience with cargo is also very large, but not as large as the difference between having no forwarders and only the major forwarders. Moreover, a small difference in relative utility between limited experience with cargo and no experience shows that airlines do not make a big difference between airports with limited experience with cargo and those with no such experience.

Figure 5.7 - Marginal utilities of airport's experience with cargo (MNL noPaxClinDlin)



5.4. Panel Mixed Logit Models

Panel mixed logit models account for the heterogeneity between respondents but also recognize the possible correlation between the different choices made by the same respondents. Therefore, the PML model takes into account that each respondent is most of the time confronted with numerous choice situations in a survey and therefore several choices for a respondent are registered.

To estimate a panel mixed model, a random parameter that represents the variation of the error term between respondents is often included as constant parameter. However, as constant parameters make less sense in an unlabeled experiment, it is difficult to interpret such a parameter. (Bates, 2011) Therefore, the panel property of the data is included in the different variables.

Table 5.4 - Results of the panel mixed logit models

	PML allRandom[32]		**PML noPaxAllRandom**[33]		**PML noPaxRandom DExFwNight**[34]	
	parameter estimate (std deviation)	z-value	parameter estimate (std deviation)	z-value	parameter estimate (std deviation)	z-value
Night-time						
limited	-0.131 (-0.752)	-0.72 (-1.69)	-0.0643 (0.345)	-0.43 (0.72)	-0.0661 (0.508)	-0.44 (1.39)
prohibitions	-0.950 (2.22)	-2.41** (3.76)*	-0.911 (-2.11)	-2.50* (-4.08)*	-0.734 (-1.83)	-2.26** (-4.15)*
Experience						
limited	-0.159 (-0.850)	-0.91 (-2.02)	-0.166 (-0.652)	-1.08 (-1.80)	-0.170 (0.420)	-1.23 (1.03)
no	-0.821 (1.31)	-2.99* (3.10)*	-0.759 (1.15)	-3.09* (3.15)*	-0.688 (1.20)	-2.86* (3.52)*
Forwarders						
major	0.935 (-1.17)	3.35* (-2.51)*	0.757 (0.795)	3.60* (1.73)	0.734 (0.924)	3.44* (2.04)**
no	-2.66 (2.87)	-4.80* (4.28)*	-2.43 (2.44)	-5.30* (4.44)*	-2.21 (-2.40)	-5.60* (-4.48)*

[32] PML allRandom - Panel mixed logit model including all parameters and accounting for the panel structure of the data, specifying airport charges and demand as linear attributes and assuming that the parameters are either randomly normal distributed (charges and demand) or uniform distributed (all other parameters).

[33] PML noPaxAllRandom - Panel mixed logit model excluding parameters for passenger operations at an airport, taking into consideration the panel structure of the data, specifying airport charges and demand as linear attributes and assuming that the parameters are either randomly normal distributed (charges and demand) or uniform distributed (all other parameters).

[34] PML noPaxRandomDExFwNight - same as PML noPaxAllRandom but considering airport charges as non-random parameter.

	PML allRandom[32]		PML noPaxAllRandom[33]		PML noPaxRandom DExFwNight[34]	
Passenger						
no	-0.250 (-0.646)	-1.39 (-1.78)				
sibling	-0.0598 (0.375)	-0.35 (0.73)				
Demand	0.0858 (-0.102)	3.06* (-3.23)**	0.0682 (0.0826)	2.96* (3.45)*	0.0646 (-0.0838)	2.96* (-3.41)*
Charges	-0.0525 (-0.0335)	-4.13* (-2.13)**	-0.0468 (0.0300)	-4.12* (2.13)**	-0.0471	-4.94*
algorithm	DONLP2		DONLP2		DONLP2	
number of draws	2000		2000		2000	
log-likelihood function	-253.551		-256.027		-256.909	
likelihood ratio test	213.772		208.819		207.054	
rho square	0.297		0.290		0.287	
adjusted Rho square	0.241		0.245		0.246	
parameters	20		16		15	
* significant at 1% ** significant at 5%						

First, a model was estimated including passenger operations at an airport based on the utility function defined in Section 5.4. All variables were specified as randomly distributed and the panel property was included in all variables. It was assumed that the effects coded variables are uniformly distributed, which some authors state as best assumed for dummy or effects coded variables. (Hensher et al., 2005, p. 612) However, to control the estimation results, some calculations were also made assuming the effects coded variables as normally distributed. Those calculations showed that assuming the effects coded variables as normal distributed did not reveal significantly different results. The airport charges and demand were assumed to have a normal distribution as most natural phenomena assume this type of distribution, and the estimation results often produce a good model fit. However, when applying the optimization algorithm *BIO*, no convergence could be reached. Therefore the calculations were done with the *DONLOP2* algorithm. As in previous models, in the *PML all random* model the passenger operations and their standard deviations turned out to be insignificant.

When excluding the passenger operations (PML noPaxAllRandom), the standard deviation of the airport charges was only significant at a 5% level. Therefore, a model treating the effect of airport charges as not random was calculated (PML noPaxRandomDExFwNight). Moreover, this decision was supported as interviews with the airlines showed that the variance of the importance-rating of the airport charges was relatively small. A likelihood ratio test showed that the PML RandomDExFwNight model actually fits the data better than the PML noPaxAllRandom model. Moreover, the adjusted rho square of the PML noPaxAllRandom model is slightly higher than that of the PML RandomDExFwNight model. To further reduce the number of insignificant variables, the parameters for the experience of the airport with cargo were also assumed to be fixed and not randomly distributed across observations. This decision was made because the interviews showed, that this variable had the smallest variation between airlines when asked to rate this attribute according to its importance during the survey/interview that was conducted. However, when excluding randomness of the experience parameters, the corresponding model proved to contain less information than the PML RandomDExFwNight model.

To reduce the number of insignificant variables even further, one could assume the parameters for night-time restrictions as fixed across observations as well. However, only the standard deviation of one dummy variable was insignificant and the interviews showed that there was a high variation between the answers of different airlines concerning the importance of night-time restrictions. This supports the choice of leaving the parameters as randomly distributed variables and taking into account the panel structure of the data.

Further it can be seen that the standard deviation of some parameters was negative. Two different reasons for this can be cited. First, the negative standard deviation could be due to the estimation algorithm so that the negative sign can be ignored for the interpretation of the standard deviation. (Bierlaire, 2006) Second, it could also be due to the lack of sufficient information in the data as log-likelihood estimations in general require a large number of data. (Gilmour & Goos, 2009; Hill, 1965)

The highest standard deviation can be found in the estimation of the parameter for no forwarders at the airport. This supports the idea that the different airlines value the presence of forwarders at the airport differently. The standard deviation of this parameter was on the one hand only slightly higher than the parameter estimate itself, whereas the standard deviation of night-time flight prohibitions on the other hand was about 2.5 times larger than the parameter estimate. Hence, the difference in valuation of night-time restrictions is even higher between the airlines. The last parameter that showed a large standard deviation was the parameter corresponding with the airport having no experience with cargo. This variation may be ascribed to the difference between smaller and larger airlines. Larger airlines often have the capability and financial possibility to send their employees to a new airport to work together with the airport and to train and advice the staff as well as to share their experience. Furthermore they can provide some airport services as, e.g. handling, themselves and are therefore not dependent on the experience of the airport with cargo. Smaller airlines often do not have that possibility and hence are dependent on the experience of the airport. The question whether various groups of airlines with different preferences can be identified will be treated in the following section.

Summarizing, it can be said that the panel structure in the model especially showed the significance of the standard deviation of night-time prohibitions, no experience of the airport with cargo and the absence of forwarders on the airport. This means that the airlines have different preferences according to those airport choice attributes. The panel mixed logit models are also preferred to the simple MNL models as those do not account at all for the possibility that the parameters are randomly distributed around the mean of the parameter.

5.5. Models Taking Into Account Socio-economic Variables of Airlines

The results in part 5.4 showed that the group of respondents were heterogeneous in their preferences. High standard deviations for the presence of forwarders (no forwarders), night-time flight prohibitions as well as for the experience with cargo (no experience) could be found in the PML noPaxRandomDExFwNight model. Therefore, the question arises whether these standard deviations arise only due to the differences between the respondents as such or whether actually various groups of airlines with different preferences can be identified.

To deal with that question, first of all, sub-groups were defined. It was decided to define two types of sub-groups: the first sub-groups reflect the differences between airlines that mainly serve regional airports and those that serve main airports. Second, two sub-groups were defined for, on the one hand, all-cargo airlines and, on the other hand, subsidiaries or divisions of combination carriers. It was also considered to build sub-groups according to the size of the airline but unfortunately not all airlines publish numbers concerning transported tonne-kilometer or financial information separately for their all-cargo operations. Therefore it was not possible to build sub-groups for the different sizes of airlines.

A log-likelihood test (see Table 5.5) shows that there are large differences between the MNL noPaxClinDlin model and the models of the two subgroups for the different kinds of airlines concerning the airports they serve. There are also differences in the models with the sub-groups concerning the type of airline. However, the null-hypothesis that the tastes of those two sub-groups are the same could not be rejected at a 99% confidence interval.

Table 5.5 - Log-likelihood ratio test of MNLnoPaxDemLinCharLin model and sub-group models

Market segments	L-R ChiSquare	Prob>ChiSq
Served airports	91.25	< 0.0001
Type of airline	19.868	0.0108

To analyze the differences in preferences between the groups of airlines, two approaches are taken. First, an MNL model is calculated integrating interaction variables that reflect the differences between airlines. Second, different MNL models, one for each sub-group of airline, are calculated and compared.

5.5.1. MNL Model Integrating Socio-economic Variables

To make the differences between the airlines more apparent, a socio-economic variable can be included into the original MNL model. However, as the experiment is an unlabeled experiment and therefore constants are not meaningful, the socio-economic variables cannot be included additively. Instead, they have to be included as interaction terms. (Hensher et al., 2005, p. 373)

Two socio-economic attributes, which reflect the different kinds of airlines mentioned previously, were used to form interaction variables. The attribute *main airport*, which takes the levels yes (-1) and no (1), expressed whether the airline serves major airports or regional airports. The aim of this variable was to see whether airlines that serve major airports value the various attributes in a different way than airlines that serve regional airports. The second variable, *full cargo*, which could also take the levels yes (1) and no (-1), expressed whether the airline is a full cargo airline or not and was included to see whether full cargo airlines value the attributes differently than divisions or subsidiaries of combination carriers.

It would also have been interesting to form and include interaction variables with the size of the airline, but unfortunately due to the aforementioned reasons this variable could not be calculated.

The difference between airlines that mainly serve regional airports and those serving main airports includes for a part the difference between smaller and larger airlines. For different reasons such as less competition and more flexibility, smaller airlines prefer regional airports. Bigger airlines often prefer main airports, however, smaller airlines can sometimes be found serving main airports and larger airlines serving regional airports.

First, a model was built with the six main effects attributes and all possible interaction variables with the socio economic variables *main airport* and *full cargo*.[35] The attributes and interactions that were not significant in this model were discarded and a subsequent model calculated with JMP. Table 5.6 shows the results of the model that was found after repeating this procedure.

In the MNLsocio model the utility of an alternative in a choice set can be written as follows:

$$
\begin{aligned}
U = {} & \beta_1 Night_{limited} + \beta_2 Night_{prohibition} + \beta_3 Experience_{limited} + \beta_4 Experience_{extended} \\
& + \beta_5 Forwarders_{major} + \beta_6 Forwarders_{broadrange} + \beta_7 Demand + \beta_8 Charges \\
& + \beta_9 Night_{limited} * MainAirport + \beta_{10} Night_{prohibition} * MainAirport \\
& + \beta_{11} Forwarders_{major} * MainAirport + \beta_{12} Forwarders_{broadrange} \\
& * MainAirport + \varepsilon
\end{aligned}
$$

In the MNLsocio model all attributes are significant. It includes only two interaction variables, both of which are formed with the socio economic attribute *main airport*. All interaction variables with the attribute *full cargo* turned out to be insignificant. This was not very surprising, takeing into account that previous calculations showed that the taste differences between full-cargo airlines and airline cargo subsidiaries/divisions were only significant at a 95% confidence level but not at a 99% confidence level.

[35] Interaction variables were for example created between the parameter $Night_{prohibition}$ and MainAirport ($Night_{prohibition}$ * MainAirport), $Night_{prohibition}$ and FullCargo ($Night_{prohibition}$ * FullCargo), $Night_{limited}$ and MainAirport ($Night_{limited}$ * MainAirport), $Night_{limited}$ and FullCargo ($Night_{limited}$ * FullCargo) etc.

Table 5.6 - MNL models with socio-economic variables

	MNLsocio[36]		
	parameter estimate	z-value	marginal utilities
Night-time			
no restrictions	0.988		0.988
limited	-0.010	-0.075	-0.010
prohibitions	-0.977	4.932*	-0.977
Experience			
extended	0.663	5.272*	0.663
limited	-0.160	-1.575	-0.160
no	*-0.502*		*-0.502*
Forwarders			
broad range	0.704	4.617*	0.704
major	0.173	1.305	0.173
no	*-0.877*		*-0.877*
Demand	0.040	41.178*	0.040
Charges	-0.034	-5.325*	-0.034
Forwarders*main_airport			
broad range, no	-0.292	-2.048**	0.451
broad range, yes	*0.292*		1.034
major, no	-0.472	-3.638*	-0.261
major, yes	*0.472*		0.683
no, no	*0.764*		-0.075
no, yes	*-0.764*		-1.603
Night-time*main_airport			
limited, no	-0.022	-0.163	0.005
limited, yes	*0.022*		0.050
no restrictions, no	0.921	4.885*	1.947
no restrictions, yes	*-0.921*		0.105
prohibitions, no	*-0.899*		-1.838
prohibitions, yes	*0.899*		-0.040
* significant at 1% ** significant at 5%			

As in the MNLnoPaxClinDlin model, the forwarders are the most important attribute that an airline considers when choosing an airport (see Figure 5.8 and Table 5.7). It is noteworthy that when taking into account the differences between airlines, the second most important parameter is night-time restrictions. Night-time restrictions were also found to be significant in the MNL noPaxClinDlin

[36] MNLsocio – MNL model excluding parameters for passenger operations at an airport, specifying airport charges and demand as linear attributes and including interaction variables 1) of the presence of forwarders with main airport and 2) night-time restrictions with main airport.

model, but turned out to be much less important than other attributes. The model MNLsocio model is not only more realistic than the MNL noPaxClinDlin model as the differences between airlines is acknowledged, moreover, the high importance of night-time flights is actually much more in line with the results of previous studies (see Gardiner et al. (2005b)). In the MNLsocio model, the demand turned out to be significantly less important than other attributes, which is against previous assumptions. However, as previously debated there might be some dependence between the presence of forwarders and the origin-destination demand.

Figure 5.8 - Importance ranking of parameters for the MNLsocio model

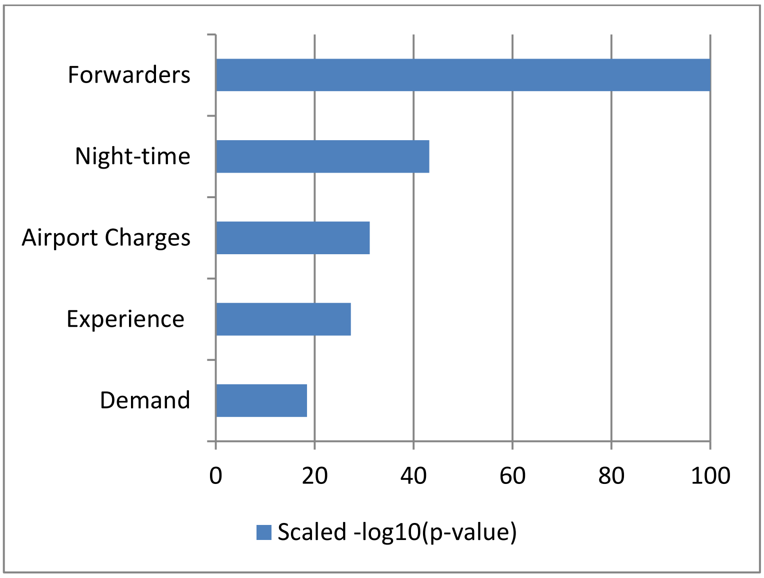


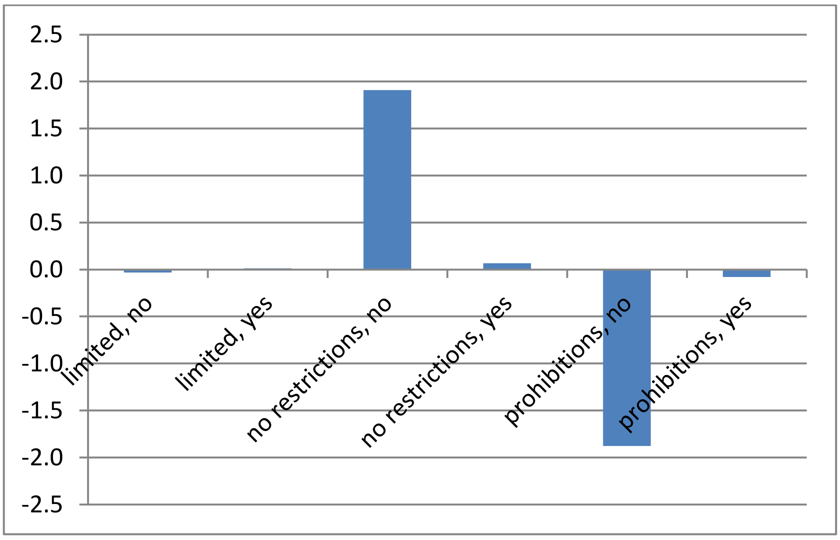
Table 5.7 - Effect likelihood ratio test MNLsocio model

	ChiSquare	Degrees of Freedom	Prob>ChiSquare
Forwarders	125.102	4	< 0.0001
Airport Charges	32.386	1	< 0.0001
Demand	18.083	1	< 0.0001
Experience	31.904	2	< 0.0001
Night-time	57.217	4	< 0.0001

Figure 5.9 shows the differences in marginal utilities between the two types of carriers concerning the night-time restrictions. A large difference in the marginal utility especially for no night-time restrictions at the airport as well as night-time flight prohibition can be seen. It is clear that for carriers who fly to regional airports, night-time restrictions or better the lack of night-time restrictions are very important, therefore the marginal utility of having no restrictions is much higher for carriers that fly to regional airports than those who fly to major airports. That means that having

no night-time restrictions at an airport influences the probability of that airport being chosen much more for carriers that fly to regional airports than carriers flying to major airports (see Figure 5.10). For the attribute night-time flight prohibitions we can observe the same. An airport that has night-time flight prohibitions is less interesting for an airline that mainly flies to regional airports than for an airline that mainly serves main airports.

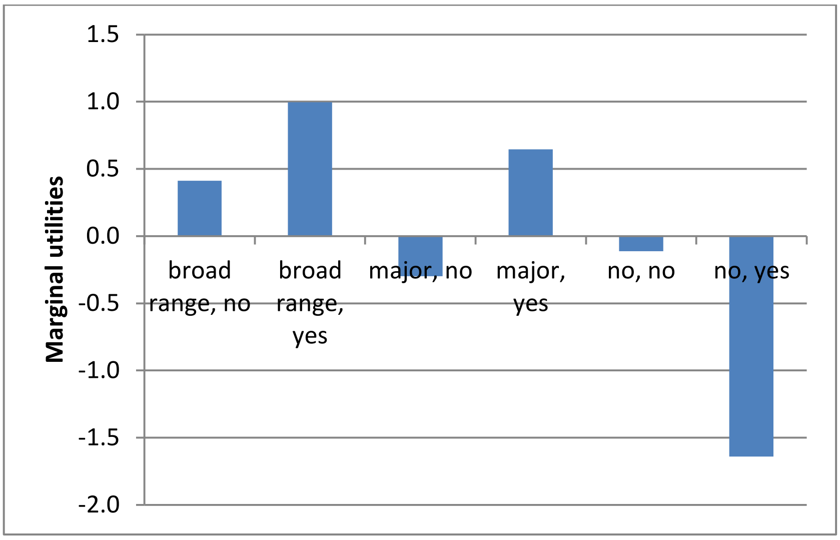
Figure 5.9 - Marginal utilities of interaction variable night-time*main airport



There are also differences in the marginal utilities of the interaction variable forwarders*main airport. The differences between the airlines that fly to regional airports and the ones who mainly serve main airports become most apparent when looking at on the one hand the presence of only the major forwarders and on the other hand at the absence of forwarders. The biggest difference between the airlines is present in the marginal utilities of no forwarders present at the airport. Although, the levels for both groups of airlines are negative, the marginal utility of having no forwarders present around the airport for carriers that fly to main airport is more negative. Those airlines therefore find the absence of forwarders much less acceptable than airlines that fly mainly to regional airports.

For airlines that mainly serve regional airports, the presence of only major forwarders at an airport is a disadvantage. For those airlines it adds negatively to the utility of an airport, while it adds significantly positive to the attractiveness of an airport for airlines serving major airports. This might be explained by the fact that airlines that serve regional airports are often smaller airlines, which depend more on short term and ad-hoc assignments. Major forwarders often have long-term contracts with specific and often bigger airlines, which is why they are less interesting for smaller airlines. Hence the lack of smaller forwarders even contributes negatively to the utility of an airport.

Figure 5.10 - Marginal utilities of interaction variable forwarders*main airport



5.5.2. Comparing Separate Models for Different Airline Groups

Another way to see the difference in how various airlines value the parameters is to calculate one model for each airline type and to compare the models. This method was only applied to the two groups of on the one hand airlines that mainly serve regional airports and those flying to mainly main airports as previously no difference in relative utility between all cargo carriers and subsidiaries/divisions of combination carriers could be detected. The models were calculated without the variable for the presence of passenger operations as those turned out to be insignificant. Origin-destination demand as well as airport charges were moreover assumed to be linear. It has to be noted however, that a comparison between two groups from the same sample is not without criticism. The differences in the residual variation (unobserved heterogeneity; recorded in the error term) across groups can influence the estimated coefficient, which is why differences in the coefficients between models cannot always be brought back to true differences in causal effects. (Allison, 1999, p. 187) To overcome the problem of differences in unobserved heterogeneity between groups, authors such as Allison (1999), Mood (2010) and Williams (2009) developed different elaborate methods. However, the aim of this section is mainly to see whether the results of taking into account socio-economic variables of the airlines in this manner differs from the results when integrating them as interaction variables.

The estimates for the models of both groups differ from each other quite substantially. As already indicated in the MNLsocio model, this is especially true for night-time restrictions, where the difference is significant at 1%, and the presence of forwarders, where the difference is also significant at 1% (see Table 5.8).

Table 5.8 - Model estimates for different airline groups

	MNL mainAirports[37]		**MNL regionalAirports**[38]		**ratio of coefficients**	**chi-square for difference**
	estimates	z-value	estimates	z-value		
Night-time						
no restrictions	0.070	0.528	1.926	4.676*	0.037	18.373*
limited	0.013	0.109	0.049	0.186	0.254	0.016
prohibitions	*-0.083*		*-1.975*		0.042	
Experience						
extended	0.584	4.361*	1.054	2.848*	0.554	1.428
limited	-0.105	-0.936	-0.366	-1.385	0.287	0.825
no	*-0.479*		*-0.688*		0.695	
Forwarders						
broad range	0.998	6.839*	0.502	1.666	1.989	2.198
major	0.640	5.034*	-0.276	-1.053	-2.323	9.896*
no	*-1.638*		*-0.226*		7.237	
Demand	0.046	4.233*	0.026	1.061	1.770	0.557
Charges	-0.034	-4.876*	-0.042	-2.312**	0.810	0.168
* significant at 1% ** significant at 5%						

The importance ranking and significance of the different parameters also vary widely between the two models. For airlines that mainly serve regional airports, the night-time restrictions are by far the most important attribute, followed by the experience of the airport with cargo and the airport charges (see Figure 5.11 and Table 5.9).

Furthermore, the demand and the presence of forwarders are not significant in the MNL regionalAirportsmodel. Both observations stand very much in contrast to the general MNL noPax Clin Dlin model, but show the possible relation between forwarders and demand. The reason behind the fact that forwarders and origin-destination demand is not important might be the fact that airlines that serve regional airports do not rely on the origin-destination demand from its vicinity but on trucking from/to regions with sufficient demand.

[37] MNL mainAirports - MNL model calculated with data of airlines that mainly serve main airports, excluding parameters for passenger operations at an airport, specifying airport charges and demand as linear attributes.
[38] MNL regionalAirports - MNL model calculated with data of airlines that mainly serve regional airports, excluding parameters for passenger operations at an airport, specifying airport charges and demand as linear attributes.

Figure 5.11 - Importance ranking of parameters for the MNL regionalAirports model

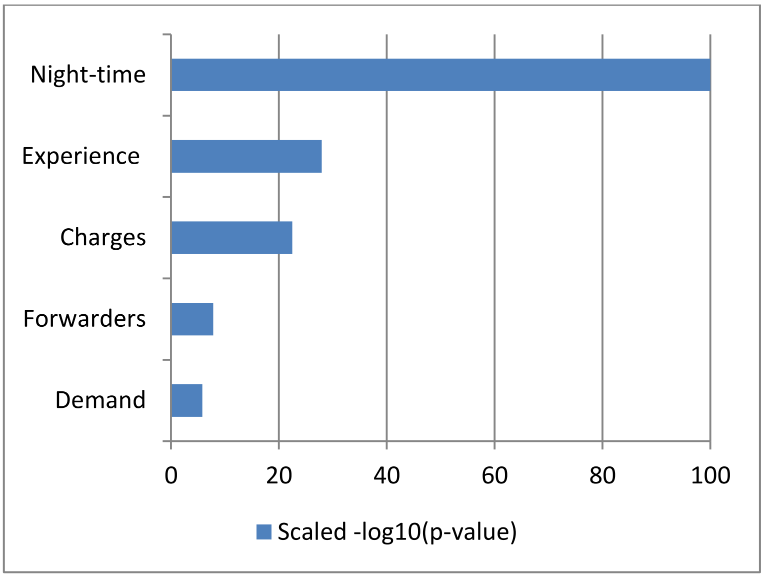
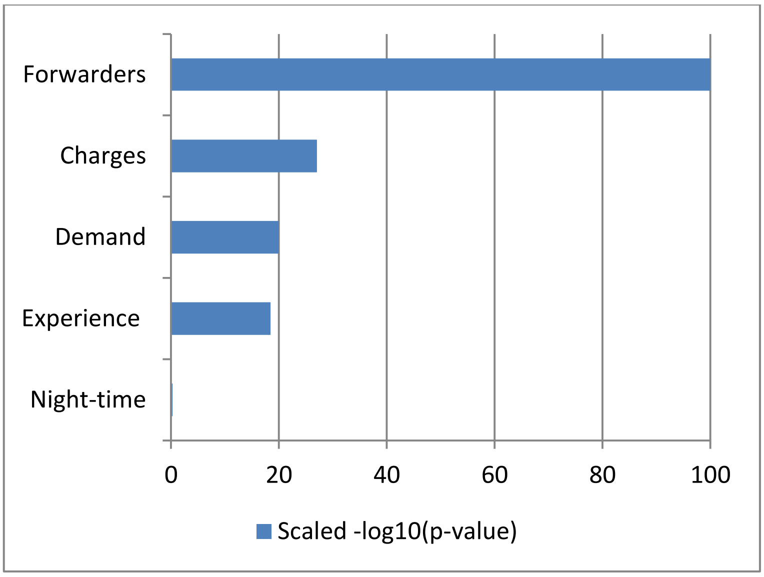


Figure 5.12 - Importance ranking of parameters for the MNL mainAirports model



Airports that mainly serve main airports on the other hand show the picture of the general MNL noPaxClinDlin model (see Figure 5.12 and Table 5.9): the forwarders are the most important attribute, followed by airport charges and the experience of the airport with cargo. Night-time restrictions for this group seem not important in the airport choice.

Table 5.9 - Effects likelihood ratio test MNL mainAirports and MNL regionalAirports

		MNL regionalAirports		MNL mainAirports	
	DF	ChiSquare	Prob>ChiSq	ChiSquare	Prob>ChiSq
Demand	1	1.105	0.293	19.422	< 0.0001
Forwarders	2	3.314	0.190	114.750	< 0.0001
Airport Charges	1	6.913	0.009	27.221	< 0.0001
Experience	2	11.840	0.003	21.130	< 0.0001
Night-time	2	42.363	< 0,0001	0.335	0.8456

Figure 5.13 - Marginal utility of night-time restrictions (MNL regionalAirports and MNL mainAirports)

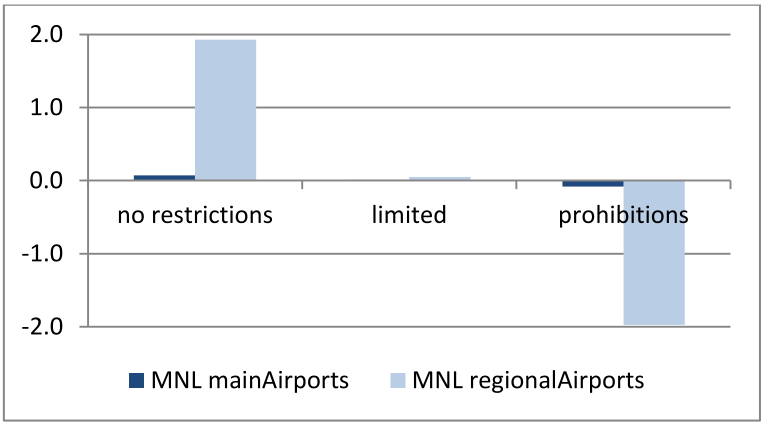
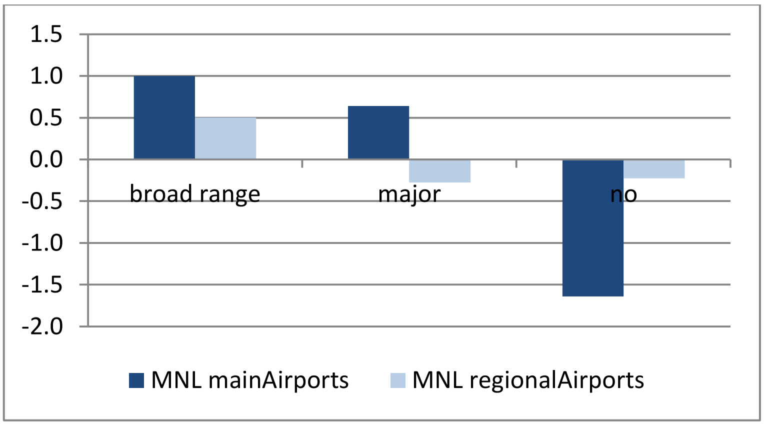


Figure 5.14 - Marginal utility of forwarders presence (MNL regionalAirport and MNL mainAirport)



Also the marginal utilities for night-time restrictions and forwarders presence show the differences in models and therefore in airlines. Moreover, the differences in marginal utilities of those attributes lead to the same conclusions as in the MNLsocio model: between both groups, the relative utility differs especially for night-time (prohibitions), night-time (no restrictions), forwarders presence (no) and forwarders presence (major) (see Figure 5.13 and Figure 5.14).

5.6. Compensation Indices

A very interesting feature of discrete choice analyses is the possibility to calculate willingness to pay estimates. Those measurements provide more information on the value of for example time or the value of other parameters that were used in the models. They are especially valuable for decision makers as they provide information on how effectively respond to the different parameters. Unfortunately the willingness to pay measurements require at least one parameter to be specified in monetary terms, which was not possible for this stated preference experiment. The variables demand and airport charges, which could be specified in monetary terms, could only be specified in percentage changes. This was due to some confidentiality issues of the airlines as well as the lack of previous research and therefore reference values as discussed earlier in Chapter 4 were used.

However, selected compensation indices (CI) could be calculated, which similarly give the decision makers and airports an idea about the specific value of a parameter and trade-offs between parameters. In the past, such compensation indices could be found for example in Danielis e.a. (2005). The compensation indices were calculated analogously to the willingness to pay ratios (see also Danielis et al. (2005)):

$$CI_{xc} = -\frac{\Delta U_x}{\Delta U_c},$$

Where

ΔU_x is the change in utility when passing from one attribute level to another, and ΔU_c the change in utility due to a 1% change in airport charges or demand.

This means that the compensation indices are calculated taking either the changes in airport charges or demand changes as basis. The base values for the calculations are shown in Table 5.10. The airport charges indices show how high the difference in airport charges has to be between two airports when passing from one level of one of the non-linear parameters to another, so that the airports still retain the same relative utility for the airlines (and therefore relative attractiveness). In other words, they show how much percentage change in airport charges an airline theoretically is willing to accept or need to be offered to be willing to make the change from one level of the non-linear parameter to another. The meaning of the demand compensation indices is similar.

Table 5.10 - Summary of variable effects on relative utility

	MNL noPax Clin Dlin	MNLsocio - main airports	MNLsocio - regional airports
Night-time			
no restrictions	0.278	-1.898	-0.056
limited	0.016	0.012	-0.032
prohibitions	-0.294	1.887	0.089
Experience			
extended	0.592	0.663	0.663
limited	-0.169	-0.160	-0.160
no	-0.423	-0.502	-0.502
Forwarders			
broad range	0.759	0.996	0.412
major	0.421	0.645	-0.299
no	-1.180	-1.641	-0.113
Demand	0.033	0.401	0.401
Charges	-0.029	-0.034	-0.034

The indices were calculated for the MNL noPaxClinDlin model and the MNLsocio model to see the difference between the various types of airlines. The MNLsocio model was chosen over the MNL mainAirports and MNL regionalAirports model as the calculations of the latter ones is not without criticism. Also, the demand in the MNL regionalAirports model turned out to be insignificant and therefore no demand-compensation indices could be calculated. (Hensher et al., 2005, p. 359)

First of all, we can see that the compensation indices with airport charges as basis and with demand as basis are quite similar. Looking at the MNL noPax Clin Dlin model for example we see that an airport that wants to retain its attractiveness and wants to switch from no night-time restrictions to limited night-time slots, would have to offer an airline 8.9% lower airport charges or attract 8% more demand (see Table 5.11).

Table 5.11 - Compensation indices

	Airport charges – compensation indices			Demand – compensation indices		
From/to level	MNL noPax Clin Dlin	MNLsocio - main airports	MNLsocio - regional airports	MNL noPax Clin Dlin	MNLsocio - main airports	MNLsocio - regional airports
Night-time						
no restrictions - limited	-8.9	-1.6	-57.1	8.0	1.4	48.4
limited - prohibitions	-10.6	-2.6	-54.2	9.5	2.2	46.1
no restrictions - prohibitions	-19.5	-4.3	-111.3	17.6	3.6	94.4
Experience						
extended - limited	*-25.9*	-24.2	-24.2	-23.4	20.5	20.5
limited - no	-8.6	-10.1	-10.1	-7.8	8.5	8.5
extended - no	-34.5	-34.3	-34.3	-31.2	29.1	29.1
Forwarders						
broad range- major	-11.5	-10.3	-20.9	-10.4	8.8	17.8
major - no	-54.5	-67.2	5.5	-49.3	57.0	-4.6
broad range - no	-66.0	-77.6	-15.5	-59.7	65.8	13.1

The highest compensation index, as expected from earlier results, can be found when comparing an airport with no forwarders with an airport with a broad range of forwarders. To have the same attractiveness, the airport charges at the airport with no forwarders would have to be more than 65% lower than at the airport with major forwarders. This shows clearly again the importance of the presence of forwarders at an airport. We can also see the difference in compensation index between airlines that serve regional airports and those serving main airports. A change from an airport with a broad range of forwarders to an airport with no forwarders would need to be accompanied with a 77% decrease in airport charges or a 66% increase in demand for airlines that serve main airports but only a 15% decrease in airport charges or a 13% increase in origin-destination demand for airlines that mainly serve regional airports. This again is due to the fact that the presence of forwarders is much less important in the airport choice for airlines that mainly serve regional airports than for airlines that operate to main airports.

It is also interesting that for airlines that serve regional airports a change from only major forwarders present to no forwarders present, the airline would be willing to accept an increase of airport charges. This results from the fact that, as previously explained, those airlines are usually small and more frequently deal with smaller forwarders as the major forwarders often have long-term contracts with bigger airlines. The presence of major forwarders therefore does not add to the attractiveness of the airport but might even be a sign for more competition with larger airlines.

Another high compensation index based on the MNL noPaxClinDlin model can be found between an airport with extended experience with cargo and one with no experience. In order to bridge this difference a change in more than 34% of airport charges or more than 31% in demand is needed.

As night-time restrictions at airports are a very much discussed issue in Europe, it is also interesting to look at the compensation indices concerning the night-time attribute. It can be seen that to preserve its attractiveness an airport that previously had no night-time restrictions and wants to restrict its night-time slots to a limited number or ask a very high price for those slots, based on the MNL noPaxClinDlin model, the airport would have to reduce its charges by almost 9% or attract 8% more business for the airline. This is similar for an airport that currently only has a limited number of night-time slots or where night-time slots are very expensive. If it wants to introduce night-time flight prohibitions it would have to decrease its charges with about 10.5% or achieve to attract 9.5% in extra demand for the airline. Especially the differences in compensation indices of airlines that mainly serve regional airports and those serving main airports should be noted. The compensation index concerning night-time restrictions are up to 35 times higher for airlines mainly operating to regional airports compared to those of airlines that serve main airports. Airlines that fly to regional airports for example, would, according to the compensation index, be willing to pay more than 110% more airport charges for an airport with no night-time restrictions compared to an airport with night-time flight prohibitions (all other factors being equal between the airports). Airlines that mainly serve main airports on the other hand, would only be willing to pay an increase in 4% in airport charges. Again, we see that for airlines that mainly serve regional airports, the possibility for night-time flights is very important.

5.7. Calculations with all Available Data

In the previous estimations, the decision was made to only use data from one representative per airline. This decision was made because including data of more than one representative with some airlines might bias the results. However, to check whether significant differences in results occur when including all observations, also estimations with all available data are carried out.

The results of the MNL model estimations with all data included actually lead to the same results as the MNL models previously discussed. As in the models with data from 26 airline representatives, the presence of passenger operations at an airport turned out to be insignificant in the airport choice, while the presence of forwarders at an airport was considered the most important airport choice factor. Also the decision of including origin-destination demand and airport charges as linear variable could be justified in the MNL models which include all available observations. That the estimates between the MNL model with data from 26 and 30 respondents do not differ much can be seen when comparing the compensation indices based on airport charges (see Table 5.12). The largest difference can be seen when changing from a broad range of forwarders to no forwarders at the airport. However, also then the difference is only about 7%.

Concerning the panel mixed logit models also no significant differences with the estimations discussed in Section 5.4 can be found. Passenger operations at an airport stay insignificant and also the standard deviation of the beta for the airport charges was insignificant. Unfortunately, the standard deviation of some betas still turned out to be negative. Therefore, to include the data of 4 extra representatives could not overcome this problem. Also in the panel mixed logit models the parameter values do not differ much from the previous calculations.

In general the results of the MNLsocio model with data from 30 respondents were also very similar to the results of the models with data from 26 respondents. To make this apparent also the compensation indices based on airport charges were calculated. The highest compensation index could still be found when changing from level no night-time restrictions to level night-time flight prohibitions for airlines that mainly serve regional airports, with respectively -111.3% for the model based on data from 26 respondents and -112.4% for the model with data from 30 respondents.

Table 5.12 - Compensation indices based on airport charges for models with data from 26 and 30 respondents

	Airport charges – compensation indices					
From/to level	MNL noPax Clin Dlin		MNLsocio - main airports		MNLsocio - regional airports	
	26 respondents	30 respondents	26 respondents	30 respondents	26 respondents	30 respondents
Night-time						
no restrictions - limited	-8.9	-11.7	-1.6	-2.5	-57.1	-65.5
limited - prohibitions	-10.6	-10.9	-2.6	-4.5	-54.2	-46.9
no restrictions - prohibitions	-19.5	-22.6	-4.3	-7.0	-111.3	-112.4
Experience						
extended - limited	*-25.9*	*-25.6*	-24.2	-23.8	-24.2	-23.8
limited - no	-8.6	-7.9	-10.1	-9.1	-10.1	-9.1
extended - no	-34.5	-33.5	-34.3	-32.9	-34.3	-32.9
Forwarders						
broad range-major	-11.5	-12.5	-10.3	-11.0	-20.9	-23.5
major - no	-54.5	-60.9	-67.2	-74.5	5.5	1.5
broad range - no	-66.0	-73.4	-77.6	-85.5	-15.5	-22.0

The highest difference in compensation indices could also be found concerning night-time restrictions. While the compensation indices for the change from no night-time restrictions to limited night-time flights amount to a change of -57.1% in airport charges in the model with data from 26 airlines, this change was seen to be -65.5% in the model with data of all 30 respondents.

5.8. Synthesis and Discussion of Discrete Choice Models

In Chapter 5, the question of the airport choice of freighter operators in Europe was dealt with in a quantitative way. A discrete choice analysis was executed to get a more detailed view on which attributes are most important in the airport choice process and to better understand the trade-offs between them. For this, different MNL models as well as panel mixed logit models were estimated. Nested logit models were not estimated due to different reasons. First, as discussed in Section 4.4.1.2, the airport choice process was found not to be a subsequent process and therefore the nested logit model seems less suitable for this problem. Furthermore, to estimate a nested logit model a large amount of good data is required, which was not given. (Munizaga, 1999) Possible problems with the data could already be seen with the estimation of the panel mixed multinomial logit models (c.f. negative standard deviation of parameter estimates). Last, the differences between the airlines concerning the airport choices have been analyzed. A summary of the most important models that were calculated can be seen in Table 5.13.

One of the most important results of the analysis of the MNL model was that the presence of passenger operations at an airport proved to be insignificant (see Table 5.13). This means that airlines do not consider passenger operations at an airport when making their airport choice decisions. Therefore, the relationship between cargo transported in a passenger aircraft and cargo transported in a freighter aircraft is less than often assumed. Furthermore this result supports the idea of all-cargo airports and could be an argument to further investigate the possibility of all-cargo airports in order to decrease the pressure on the capacity of major airports. Currently some regional airports in Europe such as Liège airport succeed in developing their business relying mostly on air cargo. Past studies have also analyzed the feasibility of regional air-cargo airports in the US, which, however, come to other conclusions.

However, cargo transported in freighters only amounts for about 50% of the worldwide air cargo traffic and even less when excluding the traffic generated by integrators. The air cargo transported in the belly space of an aircraft follows an entirely different kind of process in which passenger operations play a major role. Therefore, even though the results support the idea of all-cargo airports, the overall viability of such an airport depends on the total volume of freighter traffic which it could attract and whether this is enough to cover the costs of the airport. For the airports it might also be strategically interesting to not only focus on cargo and therefore be dependent on it. With attracting passenger traffic as well as cargo traffic, airports might be less tangible to the volatility of especially full-cargo traffic.

Table 5.13 - Summary discrete choice models

	MNL		**MNL noPax Clin DLin**		**PML noPaxRandom DExFwNight**		**MNLsocio**	
	parameter estimate	z-value	parameter estimate	z-value	parameter estimate (std deviation)	z-value	parameter estimate	z-value
Night-time								
no restrictions	*0.276*		*0.278*				0.988	
limited	0.009	0.1	0.016	0.17	-0.0661 (0.508)	-0.44 (1.39)	-0.010	-0.075
prohibitions	-0.285	-2.17**	-0.294	-2.25**	-0.734 (-1.83)	-2.26** (-4.15)*	-0.977	4.932*
Experience								
extended	*0.6*		*0.592*			-1.23 (1.03)	0.663	5.272*
limited	-0.174	-1.82	-0.169	-1.8	-0.170 (0.420)	-2.86* (3.52)*	-0.160	-1.575
no	-0.426	-3.22*	-0.423	-3.21*	-0.688 (1.20)		*-0.502*	
Forwarders								
broad range	*0.754*		*0.759*				0.704	4.617*
major	0.426	4.28*	0.421	4.24*	0.734 (0.924)	3.44* (2.04)**	0.173	1.305
no	-1.18	-8.59*	-1.18	-8.61*	-2.21 (-2.40)	-5.60* (-4.48)*	*-0.877*	
Passenger								
different	*0.198*							
no	-0.11	-1.1						
sibling	-0.088	-0.9						

Table 5-14 - Summary discrete choice models (continued)

	MNL		**MNL noPax Clin DLin**		**PML noPaxRandom DExFwNight**		**MNLsocio**	
	parameter estimate	z-value	parameter estimate	z-value	parameter estimate (std deviation)	z-value	parameter estimate	z-value
Demand			0.0325	3.63	0.0646 (-0.0838)	2.96* (-3.41)*	0.040	41.178*
20%	*0.695*							
10%	0.283	1.38						
equal	0.007	0.03						
-10%	-0.387	-2.05**						
-20%	-0.598	-2.78*						
Charges			-0.029	-5.11*	-0.0471	-4.94*	-0.034	-5.325*
-20%	*0.537*							
-10%	0.384	2.85*						
equal	0.012	0.09						
10%	-0.379	-2.72*						
20%	-0.554	-3.83*						
Forwarders* main_airport								
broad range, no							-0.292	-2.048**
broad range, yes							*0.292*	
major, no							-0.472	-3.638*
major, yes							*0.472*	
no, no							*0.764*	
no, yes							*-0.764*	

Table 5-14 - Summary discrete choice models (continued)

	MNL		MNL noPax Clin DLin		PML noPaxRandom DExFwNight		MNLsocio	
	parameter estimate	z-value	parameter estimate	z-value	parameter estimate (std deviation)	z-value	parameter estimate	z-value
Night-time* main_airport								
limited, no							-0.022	-0.163
limited, yes							*0.022*	
no restrictions, no							0.921	4.885*
no restrictions, yes							*-0.921*	
prohibitions, no							*-0.899*	
prohibitions, yes							*0.899*	
log-likelihood function	-302.584		-304.942		-456.909		-262.224	
Likelihood ratio test	115.705		110.989		207.054		196.426	
Rho square	0.161		0.154		0.287		0.272	
Adjusted Rho square	0.116		0.132		0.246		0.239	
Parameters	16		8		15		12	
* significant at 1% ** significant at 5%								

Another interesting result of the study concerns the importance of the presence of forwarders. The estimated multinomial logit models clearly show the significance of the forwarders' presence in the airport choice. Moreover, it could be seen that an absence of forwarders on the airport has a major negative impact on the relative utility, whereas the presence of a broad range of forwarders adds significantly to the relative utility. The reasoning behind the importance of the presence of forwarders is that the consolidation and growth in the forwarding business during the last decades increased the forwarders' market power and therefore their ability to influence a cargo carrier in their airport decision. Some authors actually attribute the increase of competition for freight amongst airports to the shift in market power towards large international forwarders (see for example Andriulaitis (2010)).

The importance of demand on the other hand turned out to be less than expected. This could be due to the interdependence between forwarders and demand as the forwarders are the main customers of airlines and therefore represent the demand for the airlines.

The following step in the discrete choice analysis of the airport choice of freighter operators in Europe was to develop the model further and introduce heterogeneity between respondents. This was done by calculating different panel mixed logit models. As explained previously those models represent another and even more realistic way to incorporate preference variations between respondents. As can be seen in Table 5.13, in the PML noPaxRandom DExFwNight model, the standard deviations of demand, the presence of forwarders, the experience of the airport with cargo as well as the night time restrictions proved to be significant. This confirms that there are taste variations between respondents for those attributes. High standard deviations and therefore large differences in valuation can especially be found with the attributes of night-time restrictions and the presence of forwarders.

These differences could be confirmed with the models that include socio-economic variables. The analysis was focused on the differences in attribute valuation between airlines that mainly serve regional airports and those that serve main airports. It was found that those groups differ mostly in their valuation of night-time restrictions and the presence of forwarders. For airlines that mainly serve regional airports for example it is very important not to have night-time restrictions. Often smaller airlines serve regional airports which frequently need to be very flexible in their operations to be competitive and night-time flights are one of the factors that facilitate flexibility. The presence of forwarders and the demand are of much less importance for airlines that mainly serve regional airports as those airlines often rely less on the origin-destination demand from the vicinity of the airport but on trucking from/to regions with sufficient demand.

Airlines that mainly serve main airports on the other hand find the presence of forwarders very important and do not consider night-time restrictions at an airport when choosing an airport for scheduled freighter operations. The differences between airlines that mainly fly to regional airports and those serving main airports also become apparent in the compensation indices that were calculated. For airlines that serve main airports an airport with no forwarders would only have the same attractiveness than an airport with a broad range of forwarders when it is accompanied by 77% less airport charges or 66% more demand. For airlines that mainly serve regional airports, the difference in airport charges or demand would only have to be 15% or 13% respectively. Also the differences in compensation indices concerning night-time restrictions are quite high. The indices are up to 35 times higher for airlines mainly operating to regional airports compared to those of airlines that serve main airports. Airlines that fly to regional airports might be willing to pay more than 110% more airport charges for an airport with no night-time restrictions compared to an airport with night-time flight prohibitions (all other factors being equal between the airports). Airlines that mainly serve main airports on the other hand, would only be willing to pay an increase of 4% in airport charges.

All of the models calculated in this chapter provide valuable insights into the airport choice of freighter operators. The PMLnoPaxRandomDExFwNight as well as the MNLsocio model provided an even more realistic base for analysis than the simple MNL model in taking into account the differences between airlines or different groups of airlines. This can also be seen at the values for the rho square and adjusted rho square, two criteria that measure the fit of the model with the data. Both measurements are significantly higher in the PMLnoPaxRandomDExFwNight and the MNLsocio model, than in the other MNL models, which shows that researchers need to account for the differences in airlines when analyzing airport choice for freighter operations.

6. Conclusions, Recommendations and Further Research

During the last decades, air cargo has developed from a by-product of air transport to an important part of business for airlines as well as for airports. Traffic growth has been strong and more and more airlines pay particular attention to air cargo and even formulate their own strategies regarding this part of the air transport sector. Moreover, the number of airports focusing on air cargo is increasing.

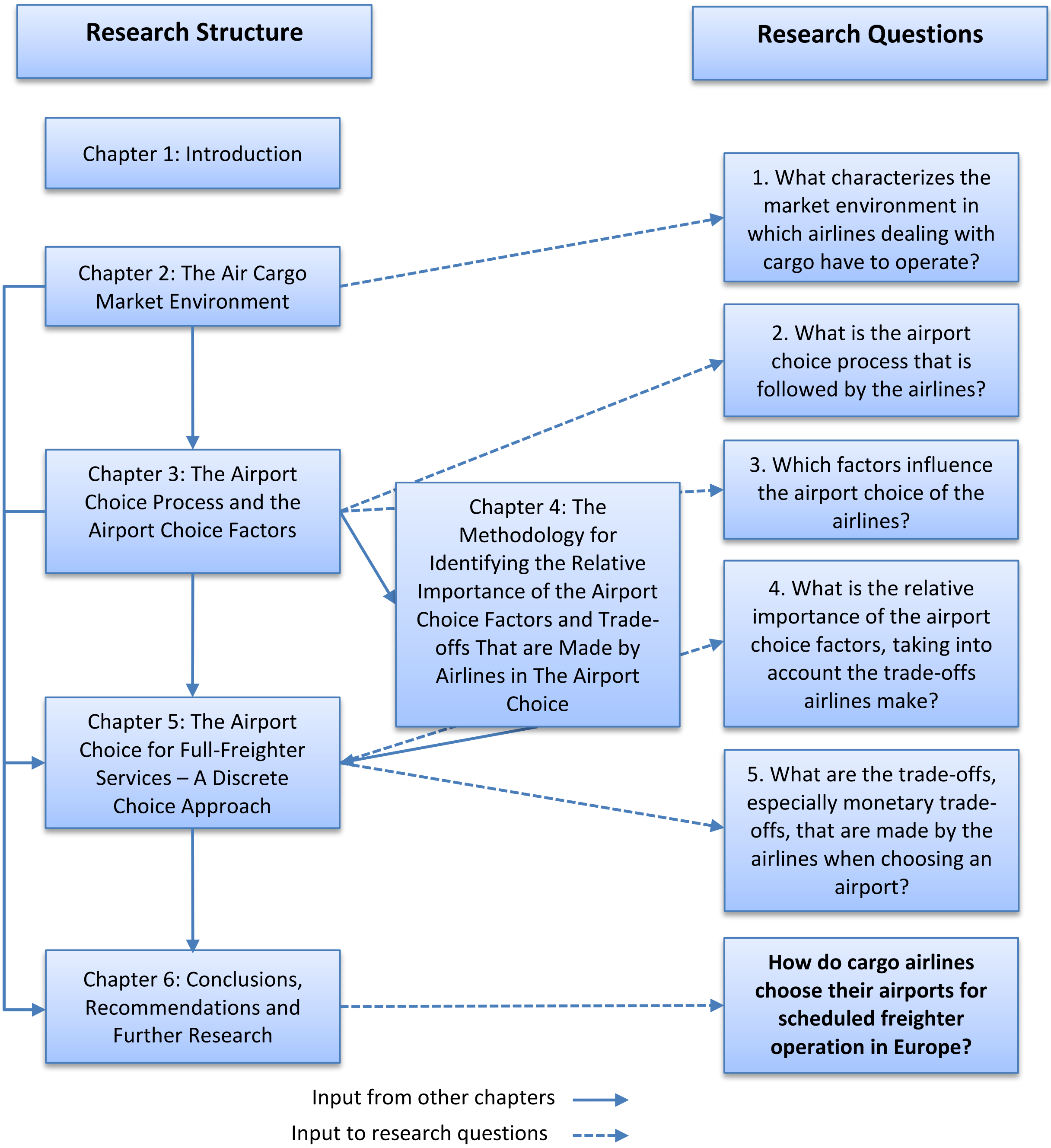
Given this development, also the airport competition for cargo increases, especially in Europe, where airports sometimes are only at a few hours time-distance from each other. Here, the catchment areas of the airports often overlap and in some situations at least five European airports compete for the same freight (Messelink, 2009, p. 4). However, studies looking at the airport competition for cargo or what influences guide the cargo operators in their choice of airport, are still quite limited. Therefore, this study was set up to gain a better understanding of the airport choice of freighter operators and more in particular to research how airlines choose their airports for scheduled freighter operations in Europe.

To achieve this aim, a number of research questions were formulated. Based on the results of this study, in the following section those research questions will be answered. Second, a number of recommendations will be given to airports and governments how to better respond to the needs of freighter operators. Third, some directions for further research will be presented and discussed.

6.1. Conclusions of Research Results

To better understand how airlines choose their airports for scheduled freighter operations, five research questions were set up. A recapitulation of those questions can be found in Figure 6.1., as well as their integration into the research structure. To summarize the research, in the following sections the answers to the different research questions will be covered.

Figure 6.1 - Recapitulation of research questions and research structure



6.1.1. What characterizes the market environment in which airlines dealing with cargo have to operate?

First, the market environment in which airlines who deal with cargo are operating, was sketched. Due to increasing trade, changes in production processes and the liberalization of the air transport industry, air cargo has known an enormous growth in the last 30 years from 9 million tonnes in 1975 to about 48 million tonnes in 2010 (own calculations based on ICAO data). However, also a high volatility in air cargo traffic could be seen, amongst others as in times of crisis the shippers opt for less expensive transport modes. This volatility is especially high for all-cargo traffic as in times of crisis, airlines more often use the available space in passenger aircraft instead of freighter aircraft. Air cargo traffic was furthermore distinguished from passenger traffic as passengers most of the time travel two ways, while air cargo is only transported one way, from production to consumption center. This leads to high imbalances in the traffic flows, which influences the airport choice for airlines as an airport will need to have sufficient inbound but also outbound traffic for a route to be viable for airlines.

Furthermore, shippers, agents, forwarders, airlines, airports and hinterland transport companies were identified as major actors in the air cargo business. It was shown that the airfreight transport chain more and more develops into a network and also the difference between traditional cargo operators and integrators became clear. When looking specifically at the airlines it was established that first of all, the share of cargo revenue in the overall revenue differs significantly between airlines. Especially Asian airlines generate a high percentage of their revenue with the transport of cargo. Furthermore it was seen that about 75% of international cargo is transported by the 25 largest cargo carriers (Dewulf et al., 2011).

For airports a distinction was made between all-cargo airports, hub airports of express freight operators, and major international traffic platforms. Most large cargo airports are major international traffic platforms and situated in Europe, North America, Asia or the Middle East. All-cargo airports are often smaller regional airports, which are also present in Europe. Here, the most important cargo airports can be found in the center of the continent, which increases the competition for air cargo. At the end of Chapter 2 also the forwarders as important actor in the air cargo chain were introduced. During the last years, an ongoing consolidation and concentration of forwarders could be noted. Furthermore, the forwarders were identified as the main customers of the airlines. As a result it was suspected that the forwarders would be an important factor influencing the airport choice.

6.1.2. What is the airport choice process that is followed by the airlines?

Concerning the airport choice process, different ideas could be identified in literature and during discussions with airline representatives. In literature, the airport choice process is described as a sequential approach in which the airlines first decide which general area/region they want to operate to. As a second step, the airlines look at the barriers to operate in this area. Last, the airline will decide based on the merits of the different airports, which airport it wants to operate to. (Gardiner et al., 2005a) However, during interviews with airline representatives the airport choice process was found to be much less of a sequential process than shown in past studies. It was recognized that the airport choice process is more or less a process in which the different steps described by Gardiner et al. (2005a) are actually various phases which overlap and which airlines might even go through simultaneously. With some larger airlines, the choice process is even a constantly ongoing process in which the phases are very often repeated over time. One the other hand, it could also be found that some airlines just try out a route to see whether it will be successful. Finally, during the airport choice process financial analyses are carried out from time to time to test what financial influence certain specific airport choices have on the viability of the airline.

6.1.3. Which factors influence the airport choice of the airlines?

In Chapter 3 the factors that influence airlines in their airport choice were identified. For the analysis not only studies about the airport choice of freighter operators were included, as those are still scarce. Where of significance for this research, information of studies about the hub choice for cargo airlines, the airport choice of integrators or passenger airlines was included. The different factors could be grouped into three different categories according to the phases of the airport choice process when they are considered. First, the factors that play a role in the economic analysis of a region are presented. In this phase factors such as the origin-destination demand as well as the forwarders play a role. In the second phase of the airport choice process, the airlines will look at the restrictive factors. They for example consider the restrictions in traffic rights as well as for the infrastructure. Another restriction that can be important for airlines are the noise and night-time restrictions. Especially integrators attach great value to night-time slots, although also other carriers prefer airports that are open during night-time hours. In the phase where restrictions are looked at, airlines also evaluate whether the capacity at an airport is sufficient for their operations or whether extra capacity will be needed for an expansion of their operations in the future. Furthermore, government regulations can put restrictions on the airport choice of an airline.

Finally, other decisive factors will be taken into consideration before deciding on which airport to operate to. Factors that were identified in this phase are for example the market access and the congestion or airport delays at an airport. As goods shipped by air are often time-sensitive, it is very important for the airports that there are as few delays as possible. Therefore airlines also often investigate the customs clearance times, the handling times and the congestion or delays that they have to deal with when flying to a specific airport. Furthermore, as airlines are profit-maximizing enterprises, also costs play a role in their airport choice. Especially airport charges and handling charges can influence the airlines in their decision which airport to serve. However, also line-haul costs, fuel charges and labor cost are an issue. In the third phase, airlines also have to decide for example whether they value the presence of other airlines at the same airport, competitors or partner airlines, passenger or cargo airlines. However, concerning financial incentives it was found that airlines often see those elements only as short term advantage. As their airport choice decisions however, are made for the long term, financial incentives do not influence the airline very much in their airport choice. Other factors, that are of more long-term significance are for example the service quality. Also the experience of an airport with cargo and the marketing might influence the airline's perception of the service quality of an airport. However, marketing was found to be not as important as the airport's reputation.

Last but not least, there are other factors that influence the airlines in their airport choice but were not mentioned before. Those are for example climate conditions, labor availability and manager's preferences.

6.1.4. What is the relative importance of the airport choice factors, taking into account the trade-offs airlines make?

The study showed that there are many different attributes influencing the airport choice. From those attributes, six were chosen to be included in a discrete choice experiment: origin-destination demand, presence of forwarders, presence of passenger airlines, night-time restrictions, airport charges (including handling) and the experience of the airport with cargo. Airline employees knowledgeable about the airport choice processes were asked to make a choice between hypothetical airports. Observations from managers from 26 different airlines were collected.

The estimation of the multinomial logit model showed clearly the significance of the forwarders' presence in the airport choice in general. Furthermore, it could be seen that an absence of forwarders contributes to the highest relative disutility, whereas the presence of a broad range of forwarders adds significantly to the relative utility. This result reinforces the idea that the consolidation and growth in the forwarding business during the last decennia lead to an increasing importance of the forwarders.

Also the experience of the airport with cargo as well as airport charges were found to be quite significant in the airport choice. Demand on the other hand turned out to be less important than expected. However, one has to be careful with the relationship between demand and the forwarders' presence, as forwarders are the main customers of the airlines and therefore interrelations between both might exist. Night-time restrictions were also found to be significant in the airport choice process, but turned out to be the least significant choice factor in the general MNL model. One factor that was shown not to be significant in the airport choice for scheduled freighter operation was the presence of passenger operation. This knowledge can have great implications for the sector, which will be discussed in Section 6.2.

Multinomial logit models, however, do not directly take into account the taste variations between airlines. That is why mixed logit models were calculated in which the parameters were treated as random variables. The panel mixed logit models showed that there were many taste variations between airlines and especially the standard deviations of night-time prohibitions, no experience of the airport with cargo and the absence of forwarders at the airport were significant. This means that the airlines have different preferences with regard to those airport choice attributes.

To further investigate the difference between airlines concerning their valuation of the attributes, multinomial logit models were calculated taking into account different characteristics of the airlines. The main conclusion that can be drawn from this exercise is that, when comparing airlines that mainly serve regional airports with those serving main airports, the presence of forwarders as well as night-time restrictions are valued very differently. For airlines that mainly serve regional airports night-time restrictions are very important in order to operate from an airport. The presence of forwarders on the other hand is far less important. The presence of only major forwarders can actually be a disadvantage for airlines that mainly serve regional airports as they are more often smaller airlines which depend more on short term and ad-hoc assignments commonly from smaller forwarders. Major forwarders frequently have long-term contracts with often bigger airlines, which is why these can be less interesting for smaller airlines.

For airlines that mainly serve major airports on the other hand the presence of forwarders turned out to be the most important of the variables. It could be seen that to have no forwarders at an airport brings a very high disutility to those airlines. The disutility of having night-time restrictions on the other hand for those airlines is very low in comparison to the disutility airlines experience that mainly serve regional airports. In general, night-time restrictions turned out not to be a very important airport choice factor for airlines that mainly serve main airports.

6.1.5. What are the trade-offs, especially monetary trade-offs, that are made by the airlines when choosing an airport?

To see the trade-offs that airlines make in their airport choice, especially trade-offs with demand and airport charges, compensation ratios were calculated. It was seen that the compensation indices with airport charges as basis and with demand as basis are quite similar. Looking at the final multinomial logit model for example we see that an airport with limited night-time slots can only be as attractive as an airport with no night-time restrictions when it offers an airline 8.9% lower airport charges or attracts 8% more demand. The compensation indices showed that the biggest trade-offs are made between the presence of forwarders and airport charges for airlines that mainly serve main airports and between night-time restrictions and airport charges for airlines that mainly serve regional airports. Airlines that fly to regional airports for example, would, according to the compensation index, be willing to pay more than 110% more airport charges for an airport with no night-time restrictions compared to an airport with night-time flight prohibitions (all other factors being equal between the airports). This again shows the importance of the possibility for night-time flights for airlines that mainly serve regional airports. The importance of forwarders for airlines that mainly serve main airports is also depicted in the compensation ratios. Comparing two airports, one with no forwarders and one with a broad range of forwarders, the first one would have to offer more than 77% less airport charges to obtain or retain the same attractiveness.

6.2. Sector Recommendations

The results of this study can support airports as well as policy makers. First, they can help airports to attract more air cargo by attracting full freighter services. Second, they can help policy makers to deal with increasing traffic growth at congested main airports. If it is necessary to relocate air cargo services to other less congested airports, the results can give policy makers indications which factors they have to influence in order to facilitate the relocation.

The idea about the relocation of freighter services to other, less congested airports was supported by the results of this study. The MNL models showed that passenger operations at an airport are not important in the airport choice of airlines concerning scheduled freighter operations. This idea could be an argument to further look into the possibility of all-cargo airports in order to decrease the capacity pressure that many major airports feel. Currently some regional airports in Europe like Liège Airport succeed in developing their business relying mostly on air cargo. However, the restriction has to be made that in 2009 still about 48% of scheduled international air freight was transported in the belly of passenger aircraft (Dewulf et al., 2011). Therefore, it is not enough to know that passenger operations are not necessary for the airlines, but it is also important to know how much all-cargo traffic can be attracted by an all-cargo airport in general in order to be able to cover the cost of operation of the airport. Furthermore, it might strategically be interesting for airports to also attract passenger traffic in order to spread their risks as full-cargo traffic can be especially volatile.

The policy implications can also be divided into implications for regional airports and those for main airports. For airlines that mainly serve major airports, especially the presence of forwarders is important in their airport choice. This derives from the fact that the majority of customers of the airlines are freight forwarders. This could be verified by information from discussions with airline representatives. Many airline representatives mentioned that they almost never deal directly with the shipper, due to different reasons. First, some airlines value the security of payment when dealing with forwarders. This security is given to them by the IATA Cargo Accounts Settlement Systems (CASS)[39] via which the billing and settlement of accounts between the forwarders and the airlines is carried out. Second, the system has historically grown, with the forwarders acting as middlemen between airlines and shippers. The forwarders therefore gained more and more power which makes it very hard for the airlines to skip the forwarder in the supply chain and to deal directly with the shippers.

[39] For more information on CASS see http://www.iata.org/ps/financial_services/pages/cass.aspx.

Therefore, to be able to attract all-cargo services, main airports first of all have to try to convince forwarders to ship through their airports. They can influence the forwarders decisions in the way that they can make sure that their airport is attractive to them. Airports often concentrate on their direct customers, the airlines, in their marketing efforts. However, the results of this study suggest that some of the effort also has to go to attract forwarders.

The study also revealed that major airports do not need night-time slots to be attractive to airlines that mainly serve major airports. Most of those airlines said to be able to work around them. Those airlines are mostly larger airlines although some larger airlines also said that night-time flights are crucial for their operations. Other airlines are not concerned about night-time restrictions as most main European airports have night-time restrictions anyway or have very high airport charges during the night, so that it is not viable for airlines to use those night-time slots.

Regional airports on the other hand should pay more attention to obtaining or maintaining the possibility of night-time flights. The results of this study show that night-time slots are very important for airlines that mainly serve regional airports. Also discussions with airlines revealed that smaller airlines that serve regional airports and airlines that mainly deal with perishables often find night-time flights essential to their operation. For smaller airlines night-time flights are essential for being able to optimize operations and for the configuration of their route network. For them the possibility to fly at night is often also an insurance that if a delay occurs, for example due to extra maintenance, the aircraft will still be able to depart. Hence, the aircraft utilization can be maximized. Furthermore, to transport goods overnight is the most time efficient way for the shipper, as during the night no value-added activities can be carried out. A shipper would therefore be interested to ship goods at the end of the day and receive goods as early as possible at the beginning of the day.

In contrast to major airports, regional airports do not need to be concerned about the presence of forwarders at the airports. It could even be seen in the results that to have only major forwarders at the airport can be a disadvantage for regional airports as major forwarders often have their fixed airlines and that, due to their high volume of cargo, they often have a very strong negotiation advantage with regard to, for example, price.

For their strategies airports therefore have to first look at which airlines they want to address. If they want to address airlines that mainly serve regional airports, they will have to focus their strategies on night-time operations to attract airlines. On the other hand, if they want to address airlines that mainly serve main airports, they should focus their energy not only directly on attracting airlines but also on attracting forwarders.

6.3. Suggestions For Further Research

Future research concerns on the one hand suggestions that are a consequence of the results of this study and on the other hand ideas that were formed in the progress of the study.

A main research track that results directly from the research output of this study is to look into the airport choice of the forwarders. As especially for airlines that mainly serve major airports, the presence of forwarders is an important airport choice factor, the decisions of the forwarders to ship via a specific airport should be analyzed more in detail. This will also be important for airports and policy makers to further understand how to attract forwarders to their airports in order to attract more cargo. Furthermore, the relationship between the forwarders and the airline can be researched more in detail. In Chapter 2 of this research it was shown that 85% of intercontinental trade in air freight is actually in the hands of forwarders (MergeGlobal, 2009). Therefore, the forwarders are the main customers of the airlines. During the research it was already argued that there is a potential interrelation between the forwarder and the origin-destination demand, which in the future should be analyzed and explained further.

Another research track concerns the interdependence between air cargo transported in passenger aircraft and those transported in freighter aircraft. The research showed that for the airport choice for scheduled freighter operations, passenger operations at an airport are not an important choice factor. Also, discussions with the airlines indicated that for goods that are transported in freighters, airlines try to minimize interlining as much as possible. Some airlines do not interline with passenger aircraft at all. This contradicts a study by Hall (2002) in which he states that it is difficult for cargo airlines to operate at an airport that has no international passenger services. His study, however, was carried out in the American context. Especially in Europe, interlining between full-freighter and belly space of a passenger aircraft is not often done. On other continents, however, interlining is done more frequently to distribute the cargo further in the region. Although it might be true in general that passenger operations do not play a role in the airport choice, discussions with airlines also revealed that there are still some, mostly smaller airlines that still have a high interdependence between air cargo transported in the belly of an aircraft on the one hand and air freight transported in a freighter aircraft on the other hand. It is therefore interesting to analyze which position freight transport with freighter aircraft has in an airline and what the interdependencies are with air freight transported in passenger aircraft. Here also differences between various kinds of airlines can be expected. A good starting point for this research track can be the study by Dewulf et al. (2011) in which the authors analyze the general strategies of cargo airlines but also give indications on the importance of freighters for the airlines.

Other research directions result from the chosen methodology. The main method used in this study, the discrete choice analysis, is a very suitable methodology for the elicitation for preferences for attributes of a good or service. However, as the data for stated preference discrete choice analysis has to be collected by surveys or interviews, not all attributes that play a role in the airport choice could be included in the discrete choice exercise. If too many attributes are included in such an exercise, respondents are often overwhelmed with the choice between alternatives and may result to lexicographic behavior, in which they make the choices only based on one or a limited number of attributes. To avoid such behavior, the decision was made to only include six attributes and even show only four at a time. For further research it would therefore be interesting to include also other attributes in a stated preference discrete choice experiment. For example the decision was made to exclude road access to the airport as airport choice variable in the discrete choice exercise as this variable did not prove to be very important in the preliminary interview. During later discussions with airlines, however, road access to airports was mentioned more often as influential variable. Therefore, it would be interesting to include this variable in future research.

Based on the choice data collected in the surveys and interviews, different models were built, not only multinomial logit models were calculated, but also more advanced models like panel mixed logit models. However, to obtain further insights into the taste heterogeneity of airlines in the airport choice, another type of model can be calculated, the latent class model. While unobserved taste heterogeneity in cross-sectional mixed logit and panel mixed logit models is represented by the random parameters, in latent class models, the taste heterogeneity is represented in a number of finite classes. This means for latent class models a number of classes is defined, for which each a set of parameters is estimated. Hereby homogeneity between classes is assumed. For this research the classes could be represented by different groups of airlines. To go even further, also an attempt to generate a model with the latent class structure but assuming preference heterogeneity within each class could be considered (for an example of such a model see Campbell et al. (2010)).

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Appendices

Appendix 1 - Europe's Cargo Airports 2011

Rank	City/Airport	Code	Total Cargo (tonnes)	%change
1	Paris	CDG	2300064	-4.1
2	Frankfurt	FRA	2133330	-3.0
3	Amsterdam	AMS	1523805	0.8
4	London	LHR	1484487	0.8
5	Leipzig	LEJ	743980	12.2
6	Cologne	CGN	726250	12.8
7	Liege	LGG	674360	5.4
8	Luxembourg	LUX	656653	-6.9
9	Istanbul	IST	498047	10.2
10	Milan	MXP	440258	4.2
11	Brussels	BRU	418898	-2.7
12	Madrid	MAD	393431	5.4
13	Copenhagen	CPH	332877	7.6
14	Munich	MUC	286201	4.2
15	Zurich	ZRH	285943	-7.3
16	East Midlands	EMA	266498	7.0
17	London	STN	203830	0.5
18	Vienna	VIE	199810	-8.9
19	Helsinki	HEL	155998	8.3
20	Rome	FCO	142716	-7.0

Source: based on data from ACI Europe and airport’s websites

Appendix 2 - Attributes Tested in Exploratory Interviews

Attributes Tested in Exploratory Interviews	
Restrictions:	
	Bilateral agreements
	Provision of infrastructure
	Noise restrictions (not considering night time)
	Night time restrictions
Market factors:	
	O-D demand
	Market access
	Proximity to the market
	Intermodal access
	Road access
	Presence of forwarders
Cost factors:	
	Fuel costs
	Airport charges
	Handling charges
	Line-haul costs
	Labour costs
Time factors:	
	Airport delays
	Customs clearance time
	Turnaround time
	Handling time
	Congestion
Strategic factors:	
	Presence of passenger airlines
	Presence of partner airlines
	Presence of competitive airlines
	Location of hub-airports
	Government regulations
	Extra capacity at airport
	(Financial) Incentives from airport
(Perception of) Airport quality:	
	Airport reputation
	Airport marketing
	Airports experience with cargo
	Airports priority with cargo
	Service quality
Other:	
	Climate/weather conditions
	Labour availability
	Human preferences
	Other (to be specified by respondent)

Appendix 3 - Discrete Choice Design

A) Choice Design Including Origin-destination Demand

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Demand	Charges
1	1	no restrictions	no	broad range	different	10% more	15% lower
1	1	no restrictions	extended	major	different	10% less	equal
1	2	no restrictions	limited	broad range	of own airline/group	equal	30% higher
1	2	limited	no	broad range	of own airline/group	10% more	equal
1	3	no restrictions	limited	broad range	no	10% less	30% higher
1	3	limited	no	broad range	no	equal	15% higher
1	4	prohibitions	no	no	no	10% less	15% lower
1	4	no restrictions	no	no	of own airline/group	30% less	30% higher
1	5	no restrictions	limited	major	different	30% more	15% higher
1	5	no restrictions	extended	major	of own airline/group	10% more	30% lower
1	6	prohibitions	extended	no	no	10% more	15% higher
1	6	no restrictions	no	no	no	10% less	15% lower
1	7	prohibitions	no	major	no	30% more	30% higher
1	7	prohibitions	no	broad range	of own airline/group	10% less	30% lower
1	8	limited	no	broad range	of own airline/group	30% more	30% lower
1	8	limited	limited	major	of own airline/group	10% more	equal
1	9	no restrictions	extended	no	different	equal	equal
1	9	no restrictions	limited	no	no	30% less	30% lower
1	10	no restrictions	no	major	different	equal	30% lower
1	10	limited	limited	major	different	30% less	equal
2	1	no restrictions	extended	major	of own airline/group	30% less	30% lower
2	1	limited	extended	no	of own airline/group	10% more	30% higher

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Demand	Charges
2	2	no restrictions	limited	major	no	10% more	30% lower
2	2	limited	extended	major	no	30% more	15% lower
2	3	limited	extended	no	of own airline/group	30% more	30% lower
2	3	no restrictions	extended	broad range	of own airline/group	equal	15% lower
2	4	prohibitions	limited	broad range	no	equal	equal
2	4	prohibitions	extended	major	no	10% more	15% lower
2	5	limited	no	broad range	different	10% less	30% higher
2	5	no restrictions	no	no	different	30% more	15% higher
2	6	limited	limited	no	of own airline/group	equal	15% lower
2	6	no restrictions	limited	no	different	30% less	equal
2	7	prohibitions	limited	major	no	10% less	30% lower
2	7	no restrictions	no	no	no	10% less	equal
2	8	prohibitions	no	major	different	10% more	30% higher
2	8	prohibitions	limited	no	no	10% more	15% higher
2	9	no restrictions	limited	no	of own airline/group	10% more	30% higher
2	9	no restrictions	extended	no	different	30% less	15% lower
2	10	limited	extended	broad range	no	equal	30% lower
2	10	no restrictions	extended	broad range	different	10% more	15% lower
3	1	no restrictions	no	no	no	equal	equal
3	1	no restrictions	no	major	of own airline/group	30% less	15% higher
3	2	prohibitions	no	broad range	different	10% more	15% higher
3	2	no restrictions	no	no	no	10% more	15% lower
3	3	no restrictions	extended	broad range	of own airline/group	10% less	15% higher
3	3	prohibitions	extended	major	of own airline/group	30% more	30% lower
3	4	prohibitions	extended	no	no	10% less	30% higher

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Demand	Charges
3	4	limited	limited	no	of own airline/group	10% less	equal
3	5	no restrictions	extended	broad range	no	10% more	equal
3	5	prohibitions	limited	broad range	different	10% more	15% lower
3	6	prohibitions	no	broad range	no	10% more	equal
3	6	limited	no	no	different	10% more	30% higher
3	7	limited	extended	major	no	30% less	30% lower
3	7	prohibitions	extended	no	of own airline/group	30% more	30% lower
3	8	limited	no	broad range	different	10% more	equal
3	8	prohibitions	no	major	of own airline/group	30% more	equal
3	9	no restrictions	limited	broad range	of own airline/group	30% less	15% lower
3	9	no restrictions	no	broad range	no	30% more	30% higher
3	10	limited	extended	broad range	no	30% less	30% higher
3	10	limited	extended	no	different	10% less	30% lower
4	1	prohibitions	extended	no	of own airline/group	30% less	30% lower
4	1	limited	limited	no	different	10% less	30% lower
4	2	prohibitions	no	broad range	of own airline/group	equal	equal
4	2	limited	no	broad range	no	10% less	15% higher
4	3	limited	extended	no	different	30% less	30% lower
4	3	prohibitions	no	major	different	10% less	30% lower
4	4	limited	extended	broad range	of own airline/group	10% less	30% higher
4	4	limited	no	major	of own airline/group	10% more	15% higher
4	5	no restrictions	limited	major	different	equal	equal
4	5	no restrictions	extended	no	of own airline/group	10% less	equal
4	6	prohibitions	limited	broad range	of own airline/group	30% more	equal
4	6	no restrictions	no	major	of own airline/group	equal	equal
4	7	prohibitions	limited	no	no	30% more	15% lower

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Demand	Charges
4	7	prohibitions	extended	broad range	different	30% more	15% higher
4	8	no restrictions	no	broad range	of own airline/group	30% more	equal
4	8	no restrictions	extended	no	of own airline/group	equal	15% higher
4	9	no restrictions	extended	major	of own airline/group	10% less	15% higher
4	9	no restrictions	extended	no	different	30% less	30% lower
4	10	prohibitions	extended	major	no	10% more	15% higher
4	10	limited	no	major	of own airline/group	30% more	15% higher

B) Choice Design Excluding Origin-destination Demand

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Charges
1	1	limited	extended	major	different	30% lower
1	1	no restrictions	limited	major	no	15% higher
1	2	limited	extended	major	no	30% lower
1	2	prohibitions	limited	major	different	15% lower
1	3	limited	extended	broad range	of own airline/group	15% higher
1	3	limited	no	major	different	30% lower
1	4	prohibitions	extended	broad range	of own airline/group	30% higher
1	4	prohibitions	limited	major	no	15% higher
1	5	prohibitions	no	broad range	different	15% higher
1	5	limited	no	no	of own airline/group	30% higher
1	6	no restrictions	extended	no	no	30% higher
1	6	limited	no	no	of own airline/group	15% lower
1	7	no restrictions	no	no	different	15% higher
1	7	prohibitions	no	broad range	of own airline/group	15% lower
1	8	no restrictions	extended	broad range	no	15% higher
1	8	no restrictions	limited	major	different	equal

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Charges
1	9	prohibitions	extended	broad range	different	30% lower
1	9	no restrictions	extended	major	of own airline/group	equal
1	10	limited	limited	major	no	15% higher
1	10	no restrictions	no	no	no	30% lower
2	1	no restrictions	no	broad range	no	30% lower
2	1	limited	extended	major	no	30% higher
2	2	no restrictions	no	major	of own airline/group	15% lower
2	2	prohibitions	limited	major	no	30% higher
2	3	no restrictions	extended	broad range	no	equal
2	3	no restrictions	limited	major	different	15% lower
2	4	no restrictions	limited	no	of own airline/group	15% lower
2	4	limited	extended	no	different	equal
2	5	prohibitions	no	broad range	different	equal
2	5	no restrictions	limited	no	different	30% higher
2	6	no restrictions	limited	no	of own airline/group	30% higher
2	6	limited	limited	major	no	equal
2	7	no restrictions	no	major	no	30% lower
2	7	limited	limited	broad range	no	15% lower
2	8	limited	no	major	no	equal
2	8	prohibitions	extended	major	different	15% lower
2	9	limited	extended	no	different	30% lower
2	9	prohibitions	extended	major	no	equal
2	10	prohibitions	limited	broad range	no	15% lower
2	10	prohibitions	extended	major	of own airline/group	30% higher
3	1	no restrictions	no	major	different	15% higher
3	1	no restrictions	limited	no	of own airline/group	30% lower
3	2	prohibitions	no	major	of own airline/group	30% higher
3	2	no restrictions	no	no	different	15% higher
3	3	no restrictions	no	no	of own airline/group	equal
3	3	prohibitions	limited	major	of own airline/group	30% higher
3	4	prohibitions	extended	no	no	30% lower

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Charges
3	4	no restrictions	no	broad range	no	30% higher
3	5	limited	limited	broad range	different	30% higher
3	5	no restrictions	limited	major	no	15% lower
3	6	prohibitions	extended	major	no	30% lower
3	6	limited	extended	no	different	equal
3	7	prohibitions	extended	broad range	different	equal
3	7	limited	extended	no	no	15% higher
3	8	prohibitions	extended	no	different	30% lower
3	8	limited	no	broad range	different	30% higher
3	9	limited	no	major	no	15% lower
3	9	no restrictions	limited	major	different	15% higher
3	10	prohibitions	limited	no	no	equal
3	10	prohibitions	extended	major	of own airline/group	15% higher
4	1	no restrictions	limited	no	different	equal
4	1	limited	no	broad range	different	15% higher
4	2	no restrictions	limited	broad range	no	30% higher
4	2	no restrictions	no	major	of own airline/group	15% higher
4	3	no restrictions	no	major	no	30% higher
4	3	limited	limited	major	of own airline/group	equal
4	4	no restrictions	extended	major	different	15% lower
4	4	limited	limited	major	of own airline/group	30% lower
4	5	prohibitions	extended	no	of own airline/group	15% higher
4	5	no restrictions	no	broad range	of own airline/group	30% higher
4	6	prohibitions	extended	no	no	equal
4	6	limited	no	major	no	30% lower
4	7	limited	limited	no	no	15% lower
4	7	no restrictions	limited	major	of own airline/group	equal
4	8	limited	limited	broad range	of own airline/group	15% higher
4	8	limited	extended	major	no	15% lower
4	9	prohibitions	limited	no	of own airline/group	30% lower
4	9	limited	extended	no	different	15% lower

Survey	Choice set	Night-time	Experience	Forwarders	Passenger	Charges
4	10	limited	limited	major	different	30% lower
4	10	limited	extended	no	of own airline/group	15% lower

Appendix 4 - Translation of Attribute Levels to Possible Model Parameters

Attribute level	Possible model parameter[40]
Origin-destination demand (non-linear)[41]	
20% less origin-destination demand	$\text{Demand}_{-20\%}$
10% less origin-destination demand	$\text{Demand}_{-10\%}$
Equal origin-destination demand	$\text{Demand}_{\text{equal}}$
10% more origin-destination demand	$\text{Demand}_{+10\%}$
20% more origin-destination demand	$\text{Demand}_{+20\%}$
Origin-destination demand (linear)[42]	Demand
Airport charges (including handling) (non-linear)[43]	
20% lower airport charges	$\text{Charges}_{-20\%}$
10% lower airport charges	$\text{Charges}_{-10\%}$
Equal airport charges	$\text{Charges}_{\text{equal}}$
10% higher airport charges	$\text{Charges}_{+10\%}$
20% higher airport charges	$\text{Charges}_{+20\%}$
Airport charges (including handling) (linear)[44]	Charges
Night time restrictions	
No night time restrictions	Night_{no}
Limited or very expensive night time slots	$\text{Night}_{\text{limited}}$
Night time flight prohibitions	$\text{Night}_{\text{prohibitions}}$
Presence of forwarders	
No forwarders present	$\text{Forwarders}_{\text{no}}$
Only major forwarders present	$\text{Forwarders}_{\text{major}}$
Broad range of forwarders present	$\text{Forwarders}_{\text{broadrange}}$
Airport experience with cargo	
Airport has no experience with cargo	$\text{Experience}_{\text{no}}$
Airport has limited experience with cargo	$\text{Experience}_{\text{limited}}$
Airport has extended experience with cargo	$\text{Experience}_{\text{extended}}$
Presence of passenger airlines	
No passenger airline operations at airport	$\text{Passenger}_{\text{no}}$
Only passenger operations of own airline/group or of main passenger airline partner	$\text{Passenger}_{\text{sibling}}$
Different passenger airline operations from own airline/group as well as other airlines	$\text{Passenger}_{\text{different}}$

[40] Not all possible model parameters of the effects or dummy coded attributes are estimated in a model, but only so many as attribute levels exist minus one.
[41] When the origin-destination is assumed to be non-linear.
[42] When the origin-destination is assumed to be linear.
[43] When airport charges are assumed to be non-linear.
[44] When airport charges are assumed to be linear.

Appendix 5 - Part 2 of The Airport Choice Questionnaire

Part 2: Discrete choice exercise

The second part of the survey consists of 21 choice sets with each two airports which will be presented to you.

Based on literature review and preliminary interviews I have decided to work with the following airport characteristics:

- the origin-destination demand (O-D demand)
- the night time restrictions
- the experience of the airport with cargo
- the presence of passenger airlines
- the presence of forwarders and
- the airport charges (inclusive handling)

The choice sets will consist of hypothetical airports with each 4 of these characteristics. We assume that the airports only differ in those characteristics that are shown and that all other characteristics are the same between airports.

When comparing the O-D demand and the airport charges of the two airports, please use the O-D demand and the airport charges of an airport known to you as a benchmark.

Although these airports are hypothetical, please keep in mind that the choices concern **full-freighter operations in Europe.**

Choice 1:

This first question is an exercise question to give you an idea about how the choices are presented. The instructions are the same for every question; however the choices that have to be made differ.

If you had to choose between the following two European airports for full-freighter operations, which one would you choose?

Please choose one of the airports by checking one of the boxes below:

Airport A	**Airport B**
Night time flight prohibitions	Limited or very expensive night time slots
Airport has extended experience with cargo	Airport has no experience with cargo
No passenger airline operations at airport	Only passenger operations of own airline/group or of main passenger airline partner
10% more origin-destination demand*	20% more origin-destination demand*
○	○

Airport A: ☐ Airport B: ☐

* When comparing the O-D demand and the airport charges of the two airports, please use the O-D demand and the airport charges of an airport known to you as a benchmark.

Choice 2:

If you had to choose between the following two European airports for full-freighter operations, which one would you choose?

Please choose one of the airports by checking one of the boxes below:

Airport A	**Airport B**
Airport has no experience with cargo	Airport has extended experience with cargo
Broad range of forwarders present	Only major forwarders present
10% more origin-destination demand*	10% less origin-destination demand*
10% lower airport charges (including handling)*	Equal airport charges (including handling)*
○	○

Airport A: ☐ Airport B: ☐

* When comparing the O-D demand and the airport charges of the two airports, please use the O-D demand and the airport charges of an airport known to you as a benchmark.

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