

# Network quality and catchment area analysis in the air cargo industry



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## Abstract

In this paper an airport connectivity model for air freight is derived. The model – named NetCargo – is based on the widely cited Netscan connectivity model (Veldhuis, 1997) and is adapted such that it reflects characteristics of the air cargo industry. In the model cargo connectivity is defined by all possible direct and indirect connections operated on widebody aircraft, weighted for the quality of the connection.

As an illustration of the model cargo networks of six European airports are analysed. Europe's largest hub airports carry most cargo thanks to their large intercontinental networks. Even at London Heathrow – with hardly any freighter operations – more than 1.5 million tons of cargo were handled in 2013 (Airports Council International, 2014). On the other hand, for smaller airports the relation between connectivity measured by the model and amount of cargo handled is less clear. Only those airports focused on air freight handle large amounts of cargo, mostly in full freighters as this is more a niche market.

The second part of this paper elaborates on the catchment area of cargo airports. The catchment area is much larger than for passenger airports and stretches as far as 1200 kilometres over Europe. Footloose air freight is trucked throughout entire mainland Europe. As many airports share the same catchment area airport competition is much stronger for air freight. Therefore airports with high-end facilities for air freight can attract more high-yield shipments. This makes the airport more attractive for air freight carriers.

The paper concludes with an analysis of the air freight connectivity for a miscellaneous set of European regions. Regions located well between the four largest European airports (London Heathrow, Paris Charles de Gaulle, Frankfurt and Amsterdam) have the highest level of air freight connectivity. There is strong competition between the largest cargo airports: Frankfurt and Amsterdam compete on around 80 percent of their full freighter routes, even though they share the same catchment area.

NetCargo uses OAG data as input which has some minor drawbacks regarding air freight operations. Non-scheduled freighter operations and operations of integrators such as FedEx or DHL are not included in the database, therefore the model only reports the connectivity for traditional air cargo carriers. With the NetCargo model a useful tool is developed to analyse and compare cargo networks of different airports. The connectivity model gives the opportunity to analyse the competitive playing field for cargo airports sharing the same catchment area. As well as other connectivity models, there are numerous applications for the NetCargo model.



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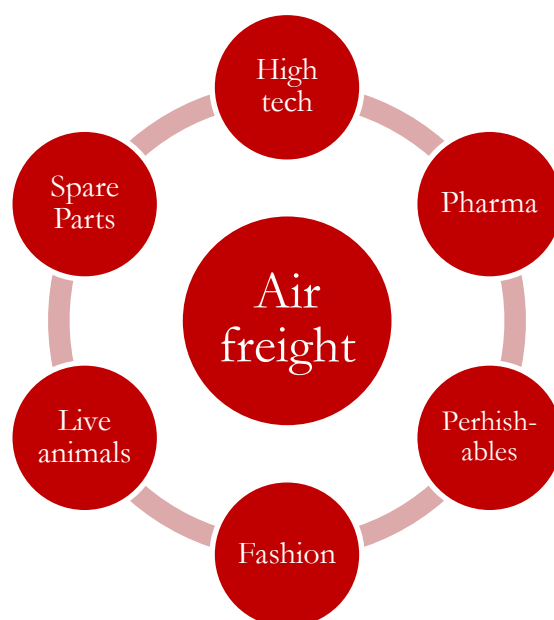


# 1 Introduction

The air cargo industry is of major importance in a global economy, as it is the main transport modality for luxury goods and other high value products. Although the air freight industry only covers 1 or 2 percent of the world trade in terms of tonnage, this is as much as 35 percent of the world total in terms of value. As the world economy is recovering from the financial crisis and strong growth rates of international trade and world GDP are expected, the air cargo industry is expected to experience strong growth in the next decades. According to Airbus average world cargo traffic continues to grow by 4.5 percent per year until 2033 (Airbus, 2014). Boeing forecasts an annual growth of 4.7 percent for the next 20 years.

Transport through air is the main modality for high valued goods as well as for perishable cargo. For less time-sensitive products sea freight is the preferred alternative as these shipping rates are much lower. Whereas it may take weeks for a shipment to reach its consignee by sea travel, air freight makes it possible to ship goods to any place in the world within 48 hours. This makes it very suitable for fresh food or flowers, or spare parts to prevent line stops in factories. High valued products also use air transport as it is much safer than sea freight, and the shipping costs are relatively low compared to the value of the product. The pharmaceutical industry is another major air cargo client – these air very high-valued products and need to be shipped under specific environmental conditions.

**Figure 1.1** Air freight is the main transport modality for high-end consumer goods and perishable products



Source: SEO Economic Research

Air freight is carried in full freighters as well as in the belly of widebody passenger aircraft. Belly cargo is mainly used by passenger airlines to generate additional revenue. All-cargo carriers operate

full freighter aircraft, which is a niche market. These full freighters have ‘main-deck’ capacity, allowing for large shipments. The size of a shipment in the belly hold of passenger aircraft is limited to 160 cm. Another limitation on belly cargo is the shipment of dangerous goods. Some products which are often transported through air are not allowed to be carried on passenger aircraft.

As the world diverges in a global economy which is strongly dependent on international trade, demand for air cargo will increase. Export rates have grown in both existing producing countries like Germany and in new ‘tigers’ like Vietnam and Cambodia. Growing middle class in developing economies like Brazil and Russia drives the demand for luxury goods which are mainly transported through air.

On the other hand there has been a huge increase in the availability of widebody aircraft, with a large amount of cargo capacity. The increased demand for passenger air traffic, partly caused by decreasing airfares, has resulted in strong overcapacity in the cargo industry. As a result air cargo space is sold at rock bottom prices and full freighter operations are struggling to remain viable. This has caused some operators – for instance Finnair and Martinair – to reduce or completely cease full freighter operations.

Figure 1.2 SWOT-analysis for the air cargo industry



Source: SEO Economic Research

## 2 Measuring network quality in the air cargo industry

*Air connectivity is of major importance for a country's economy. There are numerous models available to measure air passenger connectivity, while analyses of air cargo networks are underrepresented in literature. This paper describes the modification of the Netscan connectivity model to make it applicable for the air freight industry.*

Measuring network quality is of major importance in the air transport industry to determine the competitive position of an airport. Measuring network quality in the air cargo industry faces some difficulties compared to measuring network quality on the passenger side. Among these are:

- 
- Cargo is carried on freighter operations as well as on passenger aircraft. On scheduled passenger aircraft the available cargo capacity and effectively used capacity is unknown until departure;
- Not all air freight is carried on scheduled flights: charters account for a significant amount of cargo operations (90 percent is carried on scheduled operations (Heinitz, Hirschberger, & Werstat, 2013);
- The network of integrators, mainly focused on mail and express shipments, also tend to use excess capacity for the general air cargo operations by their affiliated forwarding companies, while other forwarders might not have access to this capacity;
- Not all air operations are used for air cargo: Some airlines – mainly low cost carriers – do not use their belly capacity at all, others only use their widebody aircraft for cargo;
- Road Feeder Services (RFS) of airlines might cater for a large part of the airline's short-haul network.

Hence the network is not concentrated on scheduled, fixed capacity operations as it is in the passenger industry. Air cargo is sometimes seen as a by-product from the air passenger industry. Therefore overcapacity might occur on routes with high passenger demand while cargo demand is low.

In the Netscan model connectivity is defined as the sum of all direct and indirect travel options (Veldhuis, 1997). Assuming that supply matches demand makes every flight a reasonable alternative for the individual passenger. Therefore the connectivity is solely determined by the frequency of flights and seat capacity is not taken into account.

For air cargo this is more difficult: not every flight is a travel option for air cargo. This depends on aircraft type or even on airline. Lufthansa for example offers a flight connection for air cargo from Frankfurt to Barcelona, while only road feeder services are available on Air France-KLM from Amsterdam to Barcelona<sup>1</sup>. EasyJet for example does not carry freight on any flight. Therefore we need to make assumptions on which flights cargo is accepted and on which flight this is not the case. Besides this we need to decide whether RFS should be incorporated in measuring the airport's cargo network.

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<sup>1</sup> Source: <http://www.af-klm.com/cargo/portalb2b/schedule>;  
[http://lufthansa-cargo.com/en\\_de/network/schedule-routings/](http://lufthansa-cargo.com/en_de/network/schedule-routings/)

In this paper we describe the development of an air cargo connectivity model based on the Netscan methodology, which is a widely used connectivity tool in the passenger industry (Veldhuis, 1997). First we elaborate on the literature on air cargo network models and air transport connectivity. Then we describe the difficulties of measuring air cargo connectivity and the way these complexities are managed. In section 2.3 a technical description of the Netscan Cargo model is given. Section 3 gives a possible application of the derived model by means of a cargo connectivity analysis for the airports Amsterdam Schiphol, Brussels Zaventem, Frankfurt, Paris Charles the Gaulle, Luxembourg and Madrid.

## 2.1 Literature review

### Measuring connectivity using Netscan

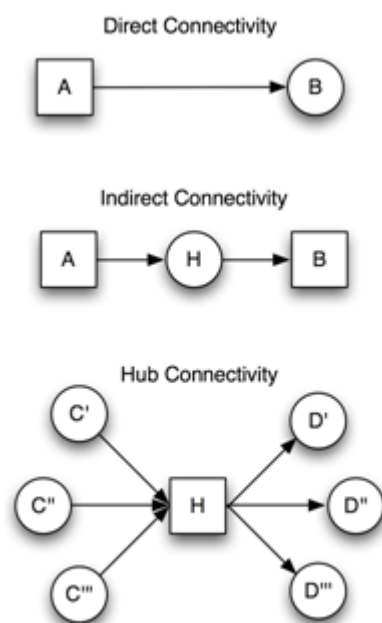
Traditionally connectivity has been represented in ‘top-10’ lists of number of destinations and number of flights per airport, broken down by geographical region. Although valuable in itself, this concept lacks the insights into the indirect connectivity potential of an airport (connectivity provided indirectly via other airports), as well as the connectivity via a certain hub airport (hub connectivity).

The Netscan connectivity model allows for measuring the connectivity of airports in a more comprehensive way. Using OAG schedules data as input, Netscan measures the quality and number of non-stop connections as well as indirect connections via other airports from various perspectives: airlines and their alliances, airports, and users. The value of the analysis lies in the comparison: either between competing networks (benchmarks of competing airline alliances or competing airports) or between distinct years (monitoring developments over time).

In the Netscan model, all the relevant network characteristics of every single connection (frequency, travel time, connecting time) are brought together into one single indicator: the connectivity index. This indicator expresses the overall network performance: how well two points are connected by air. In other words, it represents the number of frequencies (direct and indirect) weighted by their quality. Quality is defined here as how fast the connection is and this quality is represented by a specific index. This quality index ranges from 1 (one) for direct connections with the shortest possible travel time, to 0 (zero) when travel time (of indirect connections) exceeds particular predefined limits. Multiplying the quality index by the flight frequency yields the connectivity index.

Netscan distinguishes between various types of connectivity:

- Direct connectivity: The total direct connectivity offered from airport X;
- Indirect connectivity: The total connectivity offered from airport X via another *onward hub* airport;
- Hub connectivity: The total connectivity offered through airport X.

**Figure 2.1 Three types of connectivity**

Source: SEO Economic Research

Airport connectivity measures the network available to the local passenger, whereas hub connectivity measures the connectivity available to connecting passengers via a particular hub airport.

The Netscan connectivity approach is a widely acknowledged method for measuring air transport connectivity. For further descriptions and applications of the Netscan model we refer to (Veldhuis, 1997; Burghouwt & Veldhuis, 2006; Lieshout & Burghouwt, 2012).

### **Connectivity in air cargo networks**

Although a wide variety of connectivity models for passenger networks is available (an overview of frequently used models is given in Burghouwt & Redondi (2013)), very limited literature is available on air cargo networks.

A large-scale cargo model is developed for the European Commission known as WorldNet, which includes air cargo as one of the transport modalities (WORLDNET Final Report, 2009). The air cargo module in this network tries to find the optimal routing options between two regions, including trucking services and allowing for multiple transshipment points.

Another network model, specifically designed for air cargo, is developed by Heinitz and Meincke (Heinitz & Meincke, 2011). The world is divided into 90 world regions, and the model tries to find the optimal routing from one region to another. This model includes road feeder services – as well as the WorldNet model.

### The role of road transport in air cargo networks

An extensive analysis on the role of road transport in air freight networks is given in Heinitz, Hirschberger, & Werstat (2013). Airline's Road Feeder Services (RFS) are obtaining more importance as a feeder network for the airline's main hub. Whereas the long haul passenger network is fed through an extensive short-haul network, road feeder services are used to acquire freight from other airports to fill up long-haul flights. These RFS in fact represent the hinterland-hub structure for air cargo. However, this service is also provided by freight forwarders, which cater for the access and egress transportation of freight from the shipper to the airport and vice versa.

In the connectivity model described in the paper, we have decided not to include RFS for multiple reasons. These are given in the next paragraph.

## 2.2 How to measure connectivity for air cargo operations?

The network quality of an airport describes to what extent an airport connects the local market to the rest of the world, directly or indirectly, as well as the extent to which different world regions are connected via this airport. For the passenger industry the Netscan model is widely used for measuring direct-, indirect- and hub connectivity (Veldhuis 1997, Veldhuis and Burghouwt, 2005). One of the main goals of this research is to adopt this methodology to measure the network quality of an air cargo network.

The definition of network quality as used for the Netscan model: *The quality of an airport's network is determined by all possible direct and indirect route alternatives, weighted for the quality of the connection.*

Note that the passenger network quality depends on all route alternatives for an individual passenger. The offered seat capacity on a particular route alternative does not affect the network quality. The motivation behind this is that all routing options are available for the individual passenger at a certain point of time, and the complete set of alternatives should be evaluated. For indirect connections the number of seats used for serving a certain market might be a very small fraction of the total amount of seats available.

Adopting this methodology, cargo network quality needs to assess all realistic routing options available for cargo shipments. As cargo is usually only shipped on either widebody or full freighter aircraft, the aircraft type is of importance in specifying realistic routing options.

### How to quantify the network quality of a cargo airport?

In order to answer this question we need to evaluate the following aspects:

1. How much of the belly capacity is used for air cargo? Does this depend on aircraft type? Are domestic/intra-European narrow-body operations a (significant) part of the air cargo network?
2. Does the air cargo network quality differ for specific commodity types?
3. Is it possible to construct a commodity split and measure network quality separately for these commodities?

4. What is the time-sensitivity of air cargo with respect to the passenger's time sensitivity, in order to determine the quality of indirect connections?
5. Regarding the time-sensitivity, do connections with more than one stop cover an important part of an airport's cargo network?
6. Is the network quality limited to air transport or should airline's road feeder services (RFS) also be taken into account?
7. To what extent are airline alliances, codeshares and other partnerships important for airport connectivity? How can these be incorporated in the model?

By means of literature review and interviews with industry experts we answered the questions above to extract the ingredients for a useful air cargo connectivity model.

1. *How much of the belly capacity is used for air cargo? Does this depend on aircraft type? Are domestic/intra-European narrow-body operations a (significant) part of the air cargo network?*

In today's air cargo market, belly cargo is of crucial importance. Widebody passenger aircraft cater for 54 percent of the available ton kilometres (ATKs) (Boeing, 2012). At large – and congested – hub airports such as London Heathrow and Paris Charles de Gaulle as much as 95 percent of the freight volume is carried on widebody passenger aircraft (Freight Transport Association, 2014). In terms of volume, narrow body operations are negligible for air freight. Besides this, short-haul shipments are very rare in the air cargo industry and intra-European airport access links are generally covered by road transport. As most of the low cost carriers – operating narrow bodies – do not carry any air freight, narrow body operations are not considered as a part of the air cargo network in this study.

2. *Does the air cargo network quality differ for specific shipments or commodity types?*

Different commodities vary in time sensitiveness which is implicitly taken into account by measuring the quality of a connection. Some goods may only be shipped on full-freighter aircraft or require main-deck positions due to their size. The network of these types of shipments is significantly smaller. In other network studies variation in shipment type is taken into account as well (Heinitz & Meincke, 2011; WORLDNET Final Report, 2009)

3. *Is it possible to construct a small but accurate commodity split to measure the network quality for these types separately?*

After discussion with industry experts a split between widebody and freighter capacity should be made, as well as an option for extra time-sensitivity – either of these may be combined.

4. *What is the time-sensitivity of air cargo with respect to the passenger's time sensitivity, in order to determine the quality of indirect connections?*

Netscan uses a different time valuation for transfer time and in flight time (Veldhuis, 1997). Furthermore, the maximum travel time is not more than three times the – theoretical – non-stop travel time and is not more than 16 hours longer than this non-stop travel time (Boonekamp & Burghouwt, 2013). For air freight transfer time and flying time should have the same valuation, only the time span between departure and arrival has an impact on the quality of a connection. A fixed penalty cost for a transfer should be incorporated in the model

as additional disutility is experienced by the higher probability of damage or delay during a transshipment.

5. *Do connections with more than one transfer cover an important part of the cargo network?*

As we have assumed that only long-haul operations are incorporated in the freight network, connections with more than one transfer are not of large significance for this model. Given the time needed for transshipment the quality of a connection with two or more transfers would be close to zero.

6. *Is the network quality limited to air transport or should airline's road feeder services (RFS) also be taken into account?*

Heinitz and Meincke (2011), as well as the WorldNet model, take Road Feeder Services into account as an important part of the air freight network. There are multiple reasons why we do not use these services:

- Airport network quality describes direct and indirect *airport to airport* connections served by an airline. RFS include both door to door deliveries and intra-continental airport-to-airport connections.
- The data availability of RFS on OAG is limited and not always accurate. It is not clear whether the connections are available upon request or if these are scheduled services.
- Airlines or contracted transporters are not the only actors supplying an airport road access service. While not transported under an airway-bill (AWB)<sup>2</sup> and flight number, freight forwarders provide door-to-airport services which (indirectly) compete with the airline's RFS.
- In relation with the passenger Netscan model, ground access links are not incorporated in this model. While air-rail connectivity is gaining importance in the passenger industry, it is rather challenging to incorporate this in the connectivity model. Not all rail access links are equipped with a flight number while others are, therefore not the complete set of ground access links can be covered in the connectivity model.

7. *To what extent are airline alliances, codeshares and other partnerships important for airport connectivity? How can these be incorporated in the model?*

For passenger services – and even for some cargo services – codeshares of different airlines are displayed in the OAG schedule database. The three global alliances – SkyTeam, STAR and Oneworld – generally do not share cargo capacity and are therefore not a good proxy for a shared cargo network. Existing partnerships between cargo carriers do increase the level of airport connectivity and ideally should be incorporated. As the data about current cargo partnerships is limited and industry experts confirm that capacity is very rarely shared among airlines, we only include online carrier connections in our model.

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<sup>2</sup> The main shipping document for air freight



## 2.3 The cargo model

The NetCargo model differs from the original Netscan model designed for air passenger transport connectivity, where the quality of a connection is determined by perceived travel time based on assumed passenger preferences. These preferences are different for cargo shipments. In this paragraph we describe the assumptions made in the original model and how they are adjusted for air cargo.

### The Netscan model

The Netscan model determines the quality of a connection by the following formulae (Boonekamp & Burghouwt, 2013):

$$T_{max} = T_{nonstop} + c \cdot \ln(T_{nonstop} + d)$$

$$T_{perceived} = T_{fly} + (3 - 0.075 * T_{nonstop}) * T_{transfer}$$

$$q = 1 - \frac{T_{perceived} - T_{nonstop}}{T_{max} - T_{nonstop}}$$

$$CNU = q * f$$

Where:

- $q$ := Quality of the connection;
- $f$ := Weekly frequency;
- $T_{max}$ := Maximum travel time in hours;
- $T_{nonstop}$ := Theoretical non-stop flying time in hours;
- $T_{perceived}$ := Perceived travel time in hours;
- $T_{fly}$ := In-flight time in hours;
- $T_{transfer}$ := Transfer time in hours.

$T_{max}$  denotes the maximum time the passenger is willing to travel on the route considered. In the cargo case this will be the maximum acceptable time for a shipment to arrive at the desired destination airport. The maximum time will be different depending on the commodity of a shipment: perishables are subject to a much shorter maximum travel time.

$T_{nonstop}$  denotes the theoretical non-stop flying time and remains the same as in the passenger case, as this is the minimum time needed to fly from.

$T_{perceived}$  is the perceived travel time of the passenger. It is assumed that passengers experience additional disutility while waiting at the transfer airport. The transfer time is penalized stronger than the in-flight time. This is not the case for air cargo as the only important constraint is that the shipment arrives at the desired destination within a certain time frame. However, when a transfer occurs the perceived travel time is increased to penalize the loss in reliability due to missed connections or damaged shipments during the transfer.

### Adjustments for the NetCargo model

The adjusted formulae used to determine the quality of a cargo connection are given by:

$$\begin{aligned}
 T_{max} &= T_{nonstop} + \alpha \cdot \ln(T_{nonstop} + \tau) - \mathbf{1}_{\{if\ perishable\}} \cdot \xi \cdot T_{nonstop} \\
 T_{perceived} &= T_{fly} + T_{transfer} + \kappa \cdot \mathbf{1}_{\{if\ transfer\}} \\
 q &= 1 - \frac{T_{perceived} - T_{nonstop}}{T_{max} - T_{nonstop}} \\
 CNU &= q * f
 \end{aligned}$$

$\alpha$ : *Time-sensitivity parameter*. This parameter scales the function of maximum acceptable travel time. A higher value of  $\alpha$  indicates a lower time-sensitivity.

$\tau$ : *Correction parameter for short flights*. For very short non-stop flying times (less than 1 hour) the maximum travel time is very close to the non-stop flying time. Some direct connections take more time than the theoretical flight time, for instance due to airport congestion. Parameter  $\tau$  is included to allow for a little more time flexibility for short flights.

$\xi$ : *Perishables-parameter*. As perishable cargo is more time-sensitive, parameter  $\xi$  reduces the maximum travel time. This is a function of the non-stop travel time: the maximum *additional* travel time allowed reduces for longer flights.

$\kappa$ : *Additional penalty for transfer freight*. Next to the inconvenience of additional travel time needed for transfer freight, there might be additional inconvenience because of possible delays or damage during the trans-shipment of freight.

In the remainder of this report we use the following parameter values:

$\alpha := 10$

$\tau := 0.5$

$\xi := 1.2$

$\kappa := 3$

### Calibration of parameter values

#### Maximum travel time

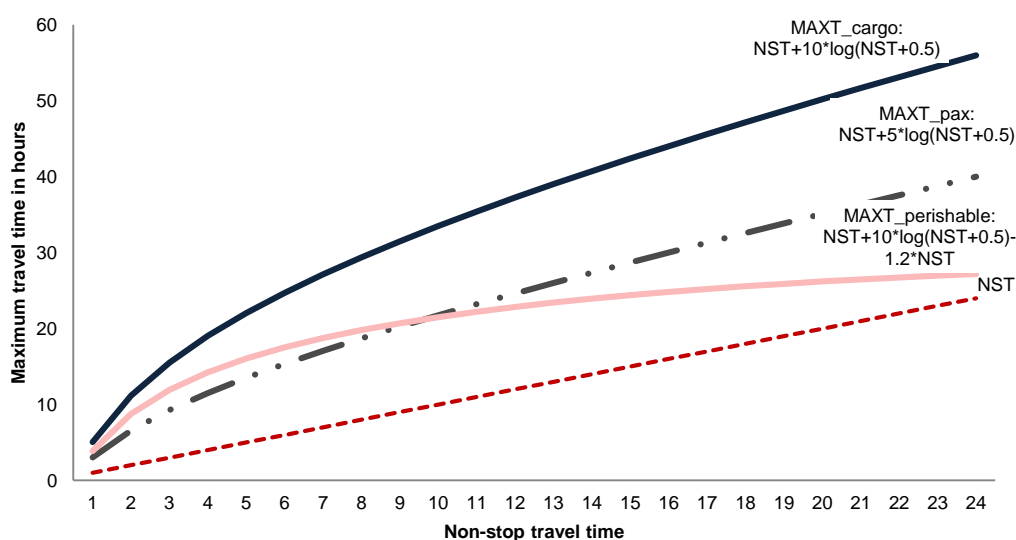
Other connectivity models do not use a limit to the maximum travel time, but choose a small set of best alternatives (Heinitz & Meincke, 2011). For measuring airport connectivity we argue that all alternatives of significant quality contribute to the network quality of an airport. For some routes there might be very few feasible routing options, while there can be numerous on other routes. As a result, the model can as well be used to determine the level of competition on certain routes (Burghouwt & Veldhuis, 2006).

The maximum travel time gives the upper limit of allowed travel time. Connections with a longer travel time are assigned a quality of zero. The parameter values chosen for passengers are chosen such that passengers are allowing a maximum of 12 hours extra travel time on a theoretical non-stop flight of 10 hours (for example Amsterdam – Buenos Aires). The maximum extra travel time is decreasing for longer flights (see Figure 2.2). For air freight longer travel times are acceptable. Industry experts claim that the maximum airport to airport transit time should not exceed two

days. IATA endeavours to reduce the average air freight transit times to 48 hours<sup>3</sup>, which supports this assumption. Following these assumptions the time-sensitivity parameter  $\alpha$  is set to 10, twice as high as in the Netscan model for passengers.

The model includes a parameter to determine the connectivity for perishable cargo. For perishables the maximum travel time is shorter. For longer flights in particular the flexibility of extra detour time is lower, as these shipments need to arrive before they lose their value. Figure 2.2 shows the maximum acceptable travel time for perishable cargo (MAXT\_perishable), with a parameter value of  $\xi = 1.2$ . This parameter value is used such that the maximum travel time only exceeds 24 hours for ultra long-haul flights over 15 hours. The maximum extra travel time decreases for longer flights.

**Figure 2.2** The maximum travel time for general cargo is higher than for passengers. For perishable cargo the maximum travel time does not exceed 30 hours



Source: SEO NetCargo

### Perceived travel time

The perceived travel time is the actual airport to airport travel time, including a penalty for inconvenience if a transfer is required. For air freight customers (shippers or forwarders) the routing is of minor importance, as long as the shipment arrives at the desired airport at the desired time. Nevertheless most forwarders prefer direct connections as these tend to be more reliable. In case of a transfer there is a risk of a missed connecting flight, as well as the probability of damage during transshipment. Therefore an additional penalty  $\kappa$  is included, set equal to the inconvenience of three hours extra travel time. This value is based on consulting various industry experts, but further (stated preference) research is required to calibrate this parameter. This parameter value is related to the minimum connecting time (MCT). When a longer minimum connecting time is used the additional transfer penalty  $\kappa$  can be set to a lower value as the disutility from a transfer is covered in the long transfer time and the probability of missed connections is lower.

<sup>3</sup> <http://www.iata.org/pressroom/pr/Pages/2014-03-12-02.aspx>

### Minimum connecting time

There are no industry standards for the MCT for air cargo transfers. This strongly differs for airports and airlines. Some airlines claim the MCT is equal to 6 hours, which is also used as a typical value by OAG's Cargo Flights.<sup>4</sup> Others report possible connections as fast as 1 hour<sup>5</sup>. Most airline representatives state that connection times shorter than 2 hours are not feasible. In this stage of model development we have set the MCT to 2 hours for all airports, in combination with a perceived travel time penalty of 3 hours. Therefore the quality of indirect connections is lower, while the model will not miss connections due to a too long MCT.

### Aircraft types

For some airports full freighter operations are the backbone of the cargo network. However, belly capacity is also widely used for air cargo, as these operations serve a wider variety of destinations on a more frequent basis. Belly capacity is not suitable for all types of air cargo. Some commodities – like dangerous goods – are not allowed to be shipped on passenger aircraft due to safety regulations. Others – for example large jet-engines – require main-deck capacity as the belly hold can only carry items lower than 160 cm. Main-deck capacity is only available on full freighter and mixed configuration (combi) aircraft. Only widebody aircraft operations are included in the model as the amount of freight carried on narrow-body aircraft is negligible. The NetCargo model provides separate results for 'freighter connectivity' and overall 'widebody connectivity'. Airports such as London Heathrow and Paris Charles the Gaulle are large cargo airports as they serve a wide variety of long-haul destinations, both by the hub carrier as other full service carriers. For these operations, air cargo is a lucrative by-product for the existing passenger services (Freight Transport Association, 2014). At small cargo airports such as Luxembourg or Liège all cargo is carried on full freighters, serving a niche market in the air freight industry.

## 2.4 Data input for NetCargo

The NetCargo model uses OAG schedule data as input. This database provides information for all scheduled air traffic. While the database seems very complete for passenger traffic the reliability of OAG data for cargo operations is sometimes questioned. Non-scheduled freighter operations are missing in the data and scheduled freighter operations are subject to frequent cancellations. Freighters might be deployed ad hoc on a route with high demand, while passenger operations are scheduled well in advance.

In this paragraph we compare the available freight volume according to OAG to the realised cargo volumes published by ACI. Table 2.1 shows the available capacity in full freighters for a selection of European airports, and the amount of handled cargo according to the ACI data (Airports Council International, 2014). The number of destinations and amount of weekly cargo flights are extracted from the OAG database for the third week of June 2014 in order to provide information for a typical week.

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<sup>4</sup> <http://cargoflights.oagcargo.com/Help/Cargo%20Flights%20Help.pdf>

<sup>5</sup> <http://www.siacargo.com/hub.asp>

**Table 2.1** Freighters and mixed configuration operations for a number of European airports. A large number of freighter operations does not necessarily indicate the magnitude of the freight operation at the airport

Airport	Number of destinations	Number of weekly flights	Average freight-tons per flight	Dominant carrier	Total freight-tons on scheduled freighter operations (OAG, 2013)	Cargo handled (yearly, in tons) (ACI)
Amsterdam (AMS)	74	140	96	Martinair/KLM (MP/KL) AirBridge Cargo (RU)	896 094	1 565 961
Brussels (BRU)	19	26	102	Saudia (SV) Singapore Airlines (SQ)	180 412	405 078
Paris Charles de Gaulle (CDG) <sup>6</sup>	12	17	94	Cathay Pacific (CX) AirBridge Cargo (RU)	182 656	2 069 200
Cologne-Bonn (CGN) <sup>7</sup>	16	17	31	MNG Airlines Cargo (MB)	62 541	717 146
Frankfurt (FRA)	63	129	95	Lufthansa (LH) AirBridge Cargo (RU)	962 241	2 094 453
Istanbul Atatürk (IST)	54	82	45	Turkish Airlines (TK) MNG Airlines Cargo (MB)	232 486	650 199
Leipzig-Halle (LEJ) <sup>8</sup>	6	5	51	AirBridge Cargo (RU) MNG Airlines Cargo (MB)	16 853	878 024
Liège (LGG)	11	34	92	CAL cargo airlines (75C) TNT Express (3V)	334 673	561 160
London Heathrow (LHR)	14	15	76	British Airways (BA) Cathay Pacific (CX)	65 506	1 515 056
Luxembourg (LUX)	64	87	112	CV (Cargolux)	488 716	673 823
Madrid (MAD)	10	13	50	Iberia (IB) British Airways (BA)	54 171	370 794
Maastricht-Aachen (MST)	3	13	74	Cargolux (CV) Turkish Airlines (TK)	67 837	92,500 <sup>9</sup>
Zürich (ZRH)	2	4	32	Turkish Airlines (TK)	9 427	329 996

**Source:** Official Airline Guide (OAG), ACI, SEO Economic Research

Frankfurt is the largest European cargo airport according to the ACI ranking, followed by Paris Charles de Gaulle, London Heathrow and Amsterdam Schiphol Airport. Remarkably, the amount of available freight tons strongly differs from the total amount of cargo handled according to ACI.

<sup>6</sup> Two Air France freighters are missing in OAG; CDG is a hub for integrator FedEx, integrator operations are missing in OAG.

<sup>7</sup> CGN is a hub for UPS, these flights are missing in OAG

<sup>8</sup> LEJ is a hub for DHL, these flights are missing in OAG

<sup>9</sup> Source: <http://www.maa.nl/nl-nl/about/figures> (2011)

Frankfurt and Amsterdam have the largest amount of available freight tons on freighter aircraft, followed by Luxembourg, Liège and Istanbul Ataturk airport. This indicates that cargo carried to and from London Heathrow and Paris Charles de Gaulle is mainly carried on passenger aircraft. Leipzig/Halle and Cologne-Bonn airport rank very low in the amount of freighter capacity as their respective integrator hub carriers DHL and UPS are not listed in the OAG database. Interestingly flights of integrator TNT express, which has a hub at Liège airport, are listed in OAG.

It should be noted that mixed configuration aircraft are incorporated in the OAG database as cargo flights. These aircraft carry passengers in the front and cargo in the rear main deck. Combi aircraft have more capacity than available in the belly of passenger aircraft and can carry larger items at the main deck. However these aircraft have the same restrictions regarding dangerous goods which may not be carried on passenger aircraft. KLM operates flights with 15 combi aircraft to several destinations from Amsterdam. Asiana also operates one mixed configuration aircraft from Frankfurt to Seoul Incheon.

The above analysis indicates that the full freighter network of an airport does not depict the entire air cargo network of an airport. Especially at congested airports like London Heathrow and Paris Charles the Gaulle, almost all cargo is carried on passenger aircraft. These airports are attractive for freight forwarders as they are well connected to all world regions by their extensive passenger networks. Therefore these airports handle large amounts of air cargo despite their limited full freighter network.

### **Measuring two levels of connectivity**

The NetCargo model measures two levels of connectivity: ‘freighter connectivity’ and ‘widebody connectivity’. This distinction is made because some shipments can only be transported through full freighters. Whenever an airport has a large freighter network, its catchment area tends to be larger as main-deck capacity is scarcer than belly capacity. In the second part of this paper we elaborate on the catchment area of a cargo airport.

#### *Freighter connectivity*

The first connectivity measure is the freighter connectivity of an airport. This indicates the network of an airport which is covered by full freighters with at most one stop at an intermediate hub airport.

#### *Widebody connectivity*

As a large part of all cargo is shipped in the belly of passenger aircraft, freighter connectivity does not cover the entire airport’s cargo network. Therefore we determine the cargo connectivity of the entire widebody network, which includes freighter operations. This adds up to the complete network for all air freight which is not restricted to freighter aircraft.

### 3 Case study: Benchmarking the cargo networks of six European airports

In this case study we show an application of the NetCargo model by providing a benchmark analysis of six European cargo airports. We show the direct and indirect connectivity for these airports for both the freighter network and the complete widebody network. These connectivity figures are also broken down by world region to show on which trade lanes different airports have a dominant position.

Added to this, we illustrate on which markets the benchmark airports function as an important transfer hub for air freight. The hub connectivity is a measure to show all the possible connections which can be made at the considered airport.

#### 3.1 Direct connectivity

Direct connectivity indicates the extent to which an airport is connected with the rest of the world without the need of an intermediate change of planes. Hence the direct connectivity consists of all direct connections, as well as destinations which can be reached with one or more intermediate stops on the same aircraft. For air cargo, the latter frequently occurs as freighter aircraft tend to make round trips across a specific continent or around the world.

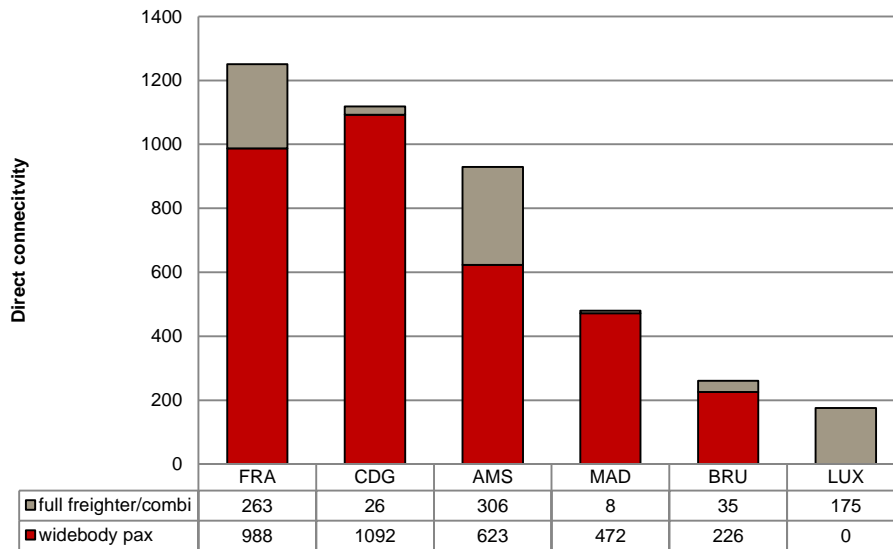
##### **Widebody connectivity**

Figure 3.1 shows the amount of direct connectivity of the widebody network of the benchmark airports, including both freighter and passenger operations. One can observe that Frankfurt has the largest direct widebody network, followed by Paris Charles de Gaulle and Amsterdam Schiphol. Frankfurt has a direct connectivity of 1250 CNU, which corresponds to 1250 direct weekly flights operated by widebody aircraft. On these 1250 aircraft movements 141 unique destinations are served. For Paris Charles the Gaulle and Amsterdam this is 122 and 121 respectively, indicating that the average frequency on Charles the Gaulle's destination is higher than at Schiphol.

##### **Freighter connectivity**

The upper parts of the bars show the freighter and mixed configuration aircraft networks of the benchmark airports. The share of aircraft with main-deck capacity strongly differs over the benchmark airports. For Luxembourg airport the entire widebody network consists of full freighters. On the contrary, only 26 of the 1119 CNU of Paris Charles the Gaulle are covered by freighter aircraft. Shipments which require main-deck capacity have less airport alternatives; only Amsterdam, Frankfurt and Luxembourg have a relatively large freighter (or combi) network.

**Figure 3.1** Frankfurt ranks highest on direct cargo connectivity, Amsterdam Schiphol has the highest amount of connectivity on aircraft with main-deck capacity



Source: Official Airline Guide (OAG), SEO Economic Research

### Breakdown by carrier

All benchmark airports are hub airports with one or more carriers operating a wave-system at the airport. This is KLM for Schiphol, Brussels Airlines for Brussels, Air France for Paris Charles the Gaulle, Lufthansa for Frankfurt, Cargolux for Luxembourg and Iberia and Air Europa for Madrid Barajas airport. There is a strong difference in these carriers regarding their cargo operations; some operate an extensive cargo fleet while others do not have any freighter network at all. This does not necessarily mean the airline has an inferior air freight operation, but the airline cannot handle any shipments which require a main-deck position. Table 3.1 shows the connectivity for the ten largest carriers per airport. For the widebody connectivity this is the hub carrier in all cases. For the freighter connectivity the hub carrier is less dominant at the six airports. Air France and Brussels Airlines do not have any scheduled freighter operations according to the OAG database<sup>10</sup>.

<sup>10</sup> AF operates two Boeing 777 freighters which are missing in OAG.



Table 3.1<sup>11</sup> Some hub carriers do not have a strong focus on air freight and do not provide any freighter operations

## WIDEBODY CONNECTIVITY

	AMS			BRU			CDG			FRA			LUX			MAD		
	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share
1	KL	417	45%	SN	69	26%	AF	537	48%	LH	597	48%	CV	139	80%	IB	162	34%
2	DL	123	13%	9W	34	13%	DL	67	6%	DE	61	5%	Y8	22	13%	UX	109	23%
3	MP	79	8%	DL	24	9%	AA	42	4%	UA	55	4%	7C8	6	3%	DL	24	5%
4	CZ	26	3%	UA	21	8%	CX	24	2%	CA	46	4%	QR	5	3%	AA	23	5%
5	OR	24	3%	TB	16	6%	US	23	2%	US	41	3%	75C	2	1%	LA	23	5%
6	EK	23	2%	SV	14	6%	TS	23	2%	EK	35	3%	-	-	-	AV	22	5%
7	CK	23	2%	ET	11	4%	QR	21	2%	AC	34	3%	-	-	-	BA	16	3%
8	UA	20	2%	US	11	4%	UA	20	2%	DL	31	2%	-	-	-	EK	14	3%
9	SQ	20	2%	SQ	9	4%	EK	20	2%	CX	29	2%	-	-	-	US	10	2%
10	CX	14	1%	EY	8	3%	SV	17	1%	SQ	21	2%	-	-	-	TK	10	2%

## FREIGHTER CONNECTIVITY

	AMS			BRU			CDG			FRA			LUX			MAD		
	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share	carrier	CNU	Share
1	KL	82	27%	SV	14	42%	CX	10	37%	LH	143	54%	CV	139	80%	IB	3	39%
2	MP	79	26%	SQ	9	27%	MB	6	21%	CX	22	8%	Y8	22	13%	TK	3	35%
3	CK	23	8%	OZ	5	13%	CA	2	8%	CA	15	6%	7C8	6	3%	BA	2	26%
4	RU	13	4%	CX	4	10%	KE	2	8%	EK	14	6%	QR	5	3%	-	-	-
5	SQ	13	4%	BA	1	3%	N2	2	8%	BA	12	4%	75C	2	1%	-	-	-
6	CA	13	4%	KE	1	3%	RU	2	8%	RU	11	4%	-	-	-	-	-	-
7	CZ	12	4%	BR	1	2%	CK	2	7%	KE	7	3%	-	-	-	-	-	-
8	EK	9	3%	-	-	-	BA	1	4%	CZ	6	2%	-	-	-	-	-	-
9	CX	7	2%	-	-	-	-	-	-	TK	6	2%	-	-	-	-	-	-
10	KZ	7	2%	-	-	-	-	-	-	MH	6	2%	-	-	-	-	-	-

Source: Official Airline Guide (OAG), SEO Economic Research

### Breakdown by region

Figure 3.2 (see box 1) shows the direct widebody connectivity of the five benchmark airports with six world regions. Altogether the airports are best connected to Asia-Pacific and North-America. To these world regions, Frankfurt and Paris Charles the Gaulle together account for more than 60 percent of the direct connectivity. Madrid is best connected to Latin America, while the other world regions are underserved from this airport.

The freighter (and combi) networks of the benchmark airports are shown in Figure 3.3. Only Amsterdam Schiphol, Frankfurt and Luxembourg have a large freighter network. Interestingly most freighter operations connect the airports with the Asia-Pacific region. In contrast with the widebody passenger network North-America has a low connectivity share. There is also a fairly large share of intra-Europe connectivity on freighter aircraft. These are mainly flights to cargo airports in Eastern Europe, including Moscow Sheremetyevo (Russia), Krasnoyarsk (Russia), Istanbul (Turkey) and Baku Airport (Azerbaijan).

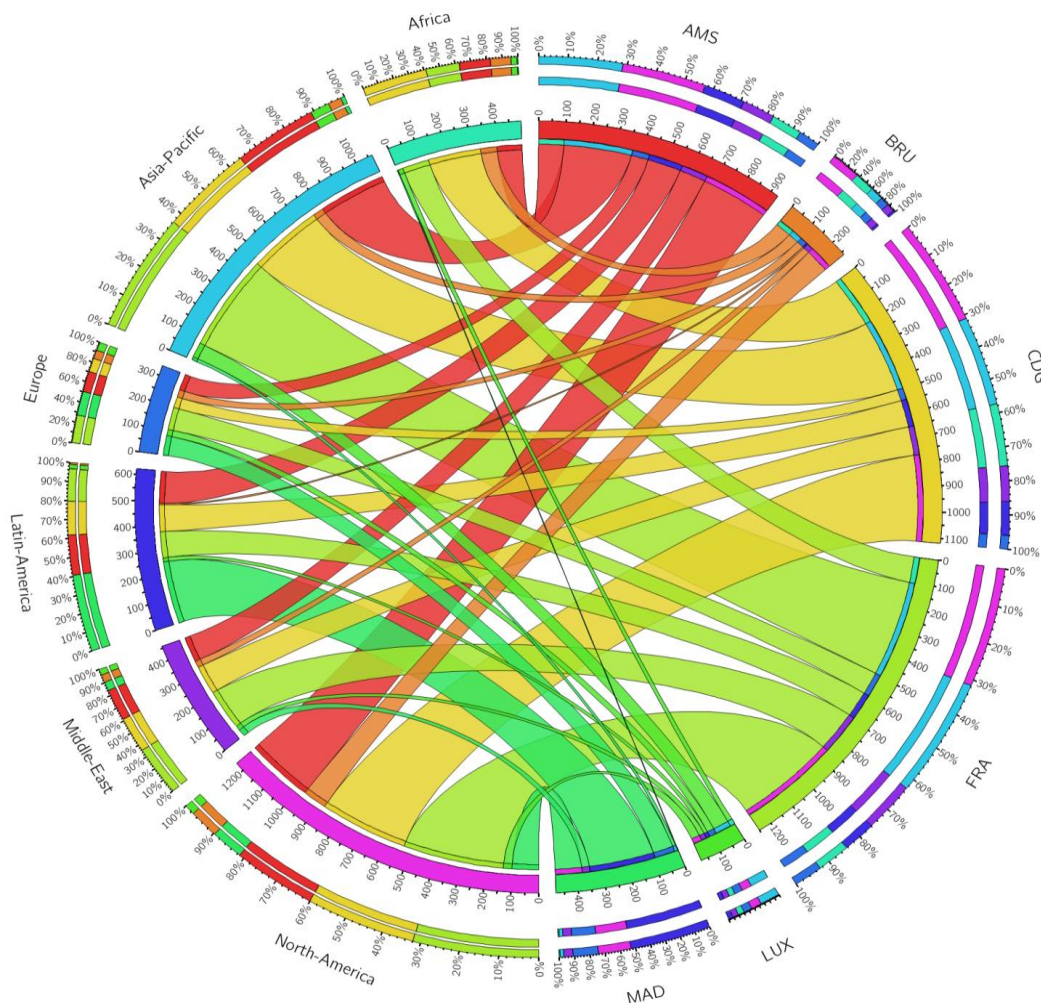
<sup>11</sup> All carrier codes are listed in Appendix A

**Box 1: Circos visualisation (Krzywinsky, 2009)**

Circos is a data visualisation tool developed at the University of British Columbia. Originally it was used in genomics to visualise relationships between genomes. Various newspapers and journals have adopted the tool to visualise the dynamics of miscellaneous topics. Examples are worldwide migration flows or the dynamics of the US presidential debate<sup>1</sup>.

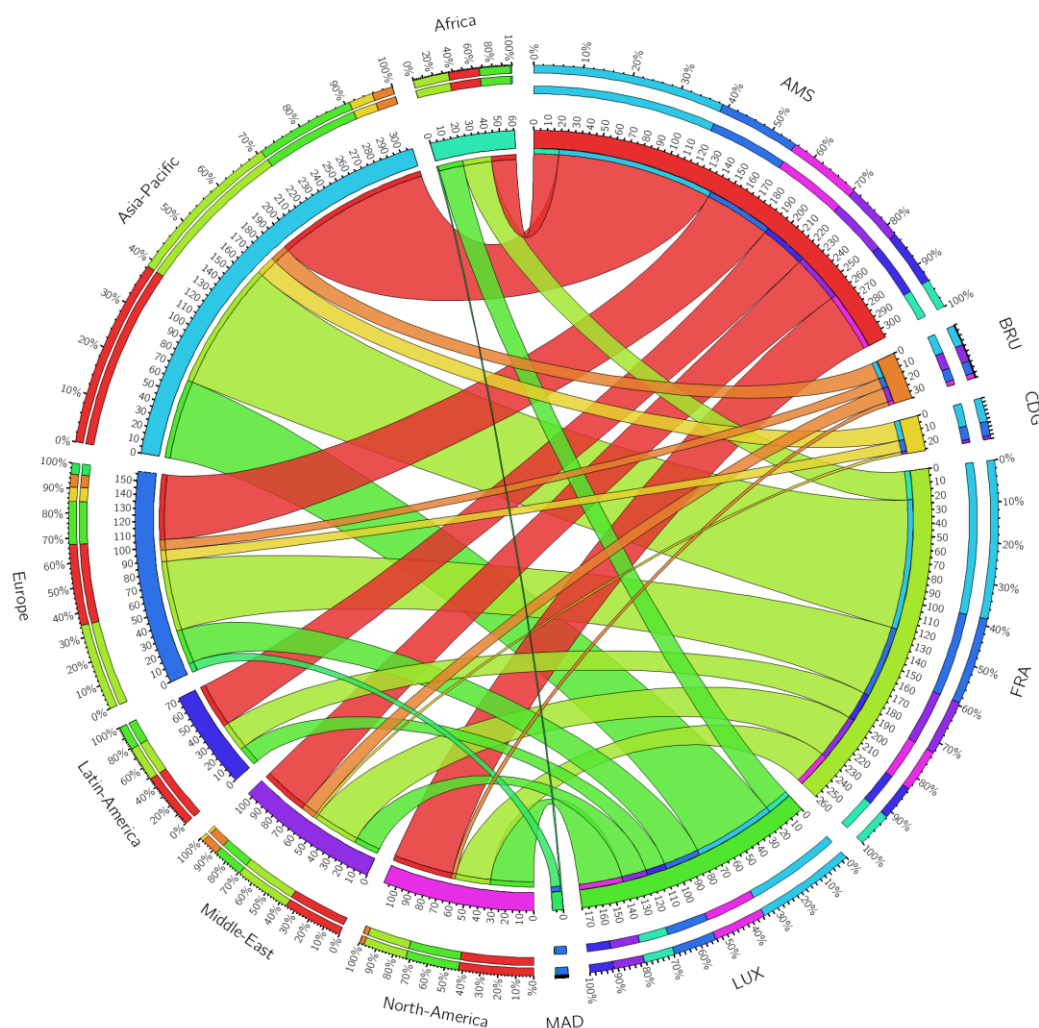
In this paper Circos is used to visualise airport connectivity. The right half of the figure shows the originating airports, the left hand side of shows the destination world regions. The thickness of the line between the airport and the destination region depicts the amount of connectivity. The inner circle around the figure shows the total amount of connectivity for the respective airport or world region. The outer circle breaks down the connectivity by destination world region (for the airports) or by originating airport (for the world regions).

**Figure 3.2** Widebody connectivity broken down by world region. The thickness of the line indicates the amount of connectivity



Source: Official Airline Guide (OAG), Krzywinsky et al. (2009), SEO Economic Research

Figure 3.3 Direct connectivity with main-deck capacity by world region



Source: Official Airline Guide (OAG), Krzywinsky et al. (2009), SEO Economic Research

## 3.2 Indirect connectivity

The connectivity of an airport does not solely rely on the direct connections offered. As a large amount of air freight reaches its destination airport via a transfer at an intermediate hub, indirect connections play a significant role in the network quality of an airport.

### Lower deck connectivity

The number of destinations which can be reached indirectly is – for most airports – much larger than the number of unique destinations directly served (see Table 3.2). For most airports the number of destinations indirectly served is about twice the amount of unique direct destinations. In this case, the only exception is Luxembourg. As this airport is not frequently used by other carriers besides hub carrier Cargolux, its indirect connectivity is limited. Qatar Airways and Turkish Airlines are the only other carriers operating scheduled freighter operations to Luxembourg.

**Table 3.2** The number of unique destinations served is much higher when indirect connections are allowed

	No. unique destinations directly served	No. unique destinations directly or indirectly served
<b>AMS</b>	121	247
<b>BRU</b>	64	179
<b>CDG</b>	122	283
<b>FRA</b>	141	296
<b>LUX</b>	60	95
<b>MAD</b>	59	217

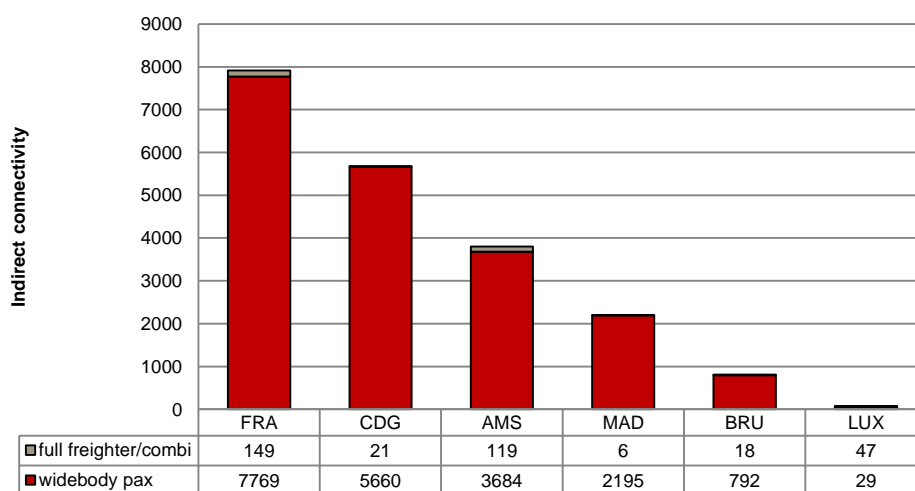
Source Official Airline Guide, SEO Economic Research

Figure 3.4 shows that Frankfurt's indirect connectivity adds up to almost 8000 connectivity units, which is more than six times the amount of direct connectivity. Paris Charles the Gaulle's and Amsterdam Schiphol's indirect connectivity are multiples of their respective direct connectivity as well, albeit less than Frankfurt. This indicates that the widebody network of Frankfurt is well connected to other main hub airports all over the world, providing a vast amount of onward connections. A probable cause of a high level of indirect connectivity lies in the destination region. For example Brussels is well connected to Africa, where less onward connections are provided than at large Asian hub airports.

### Main-deck connectivity

The ranking of airports according to indirect connectivity, as shown in Figure 3.4, is the same as for direct connectivity. Interestingly the share of indirect connectivity where both flight legs consist of full freighter operations is very limited. This is because there are far less full freighter operations than widebody passenger operations. As a result, connections from freighter to freighter generally are subject to long connecting times, resulting in a lower quality for these connections.

**Figure 3.4** Indirect connectivity is concentrated on passenger aircraft, as these generally operate at a higher frequency



Source: Official Airline Guide (OAG), SEO Economic Research

### Breakdown by onward hub

In contrast with direct connectivity, indirect connectivity is mainly generated by other carriers than the home carrier of the respective airport. Indirect connections are generated by carriers flying into their main hubs.

Table 3.3 shows that hubs in the Middle-East provide most connectivity on widebody aircraft. This follows from the fact that the lion's share of the Gulf carriers' operations are catered by twin-aisle aircraft. Other important onward hubs for the cargo network include Hong Kong and Singapore, two of the world's largest cargo airports.

For freighter aircraft, other hubs generate a large share of indirect connectivity. Seoul Incheon for instance is an important freighter hub as Korean Air operates a large full freighter fleet (28 full freighter aircraft). Shanghai Pudong is an important hub for freighters as well; this is the main hub for China Cargo Airlines.

**Table 3.3** Middle-Eastern hubs provide most *onward connectivity* on widebody aircraft, while Seoul Incheon and Shanghai Pudong are the most important freighter hubs

#### WIDEBODY

AMS			BRU			CDG			FRA			LUX			MAD		
hub	CNU	Share	hub	CNU	Share	hub	CNU	Share	hub	CNU	Share	hub	CNU	Share	hub	CNU	Share
DXB	951	25%	DOH	120	15%	DXB	960	17%	DXB	1332	17%	DOH	32	42%	DXB	699	32%
HKG	406	11%	IST	114	14%	HKG	688	12%	HND	1115	14%	MXP	8	11%	LHR	412	19%
SIN	293	8%	AUH	88	11%	HND	488	9%	PEK	769	10%	VCP	7	9%	PEK	173	8%
PEK	281	7%	BKK	86	11%	ICN	402	7%	HKG	568	7%	PVG	5	6%	MIA	148	7%
LHR	259	7%	SIN	73	9%	PVG	327	6%	SIN	527	7%	ORD	4	6%	IST	131	6%
KUL	210	6%	ICN	46	6%	DOH	315	6%	BKK	444	6%	GYD	4	5%	DOH	120	5%
AUH	201	5%	ADD	39	5%	PEK	307	5%	ICN	418	5%	JFK	3	4%	BKK	92	4%
PVG	197	5%	YYZ	31	4%	IST	214	4%	PVG	326	4%	SIN	3	4%	ICN	81	4%
ICN	173	5%	ATL	29	4%	SIN	200	4%	DOH	290	4%	LAX	2	2%	JFK	66	3%
CAN	149	4%	HKG	28	3%	BKK	190	3%	IST	281	4%	HAN	1	1%	LIM	46	2%

#### FREIGHTER

AMS			BRU			CDG			FRA			LUX			MAD		
hub	CNU	Share	hub	CNU	Share	hub	CNU	Share	hub	CNU	Share	hub	CNU	Share	hub	CNU	Share
PVG	41	34%	SIN	5	29%	ICN	10	48%	ICN	21	14%	MXP	8	17%	IST	6	100%
LUX	11	10%	MXP	3	18%	PVG	4	20%	DXB	20	14%	VCP	7	15%			
DXB	10	9%	ICN	3	14%	SVO	3	15%	PVG	17	12%	PVG	5	10%			
HHN	9	7%	HKG	2	12%	HKG	2	9%	IST	14	9%	ORD	4	9%			
SVO	7	6%	RUH	2	8%	BOM	1	4%	HKG	11	7%	GYD	4	8%			
DOH	6	5%	JED	1	6%	DEL	1	3%	SVO	10	7%	JFK	3	7%			
SIN	6	5%	SHJ	1	6%	BEY	0	2%	KJA	8	5%	DOH	3	6%			
NRT	4	4%	IST	1	4%				PEK	6	4%	SIN	3	6%			
KUL	3	2%	TPE	0	3%				VCP	5	3%	LAX	2	3%			
TSN	2	2%							ORD	4	3%	HAN	1	2%			

Source: Official Airline Guide (OAG), SEO Economic Research

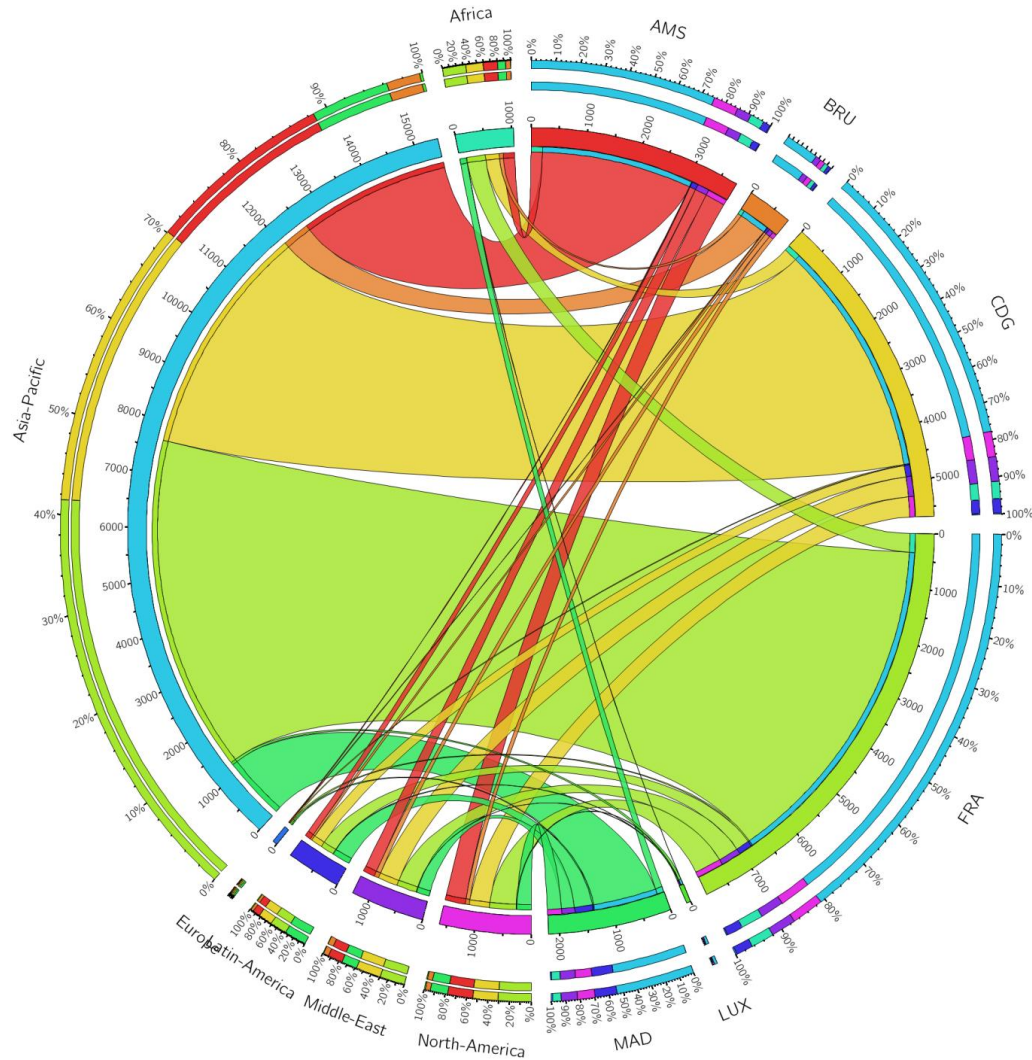
### Breakdown by world region

Figure 3.5 shows the world regions which can be reached indirectly for each of the benchmark airports. The Asia-Pacific region accounts for over 80 percent of all the indirect connectivity. While North-America has a large share in direct widebody connectivity, indirect connections with North-



America are limited. This is caused by the fact that many operations within the US and Canada are operated on single-aisle aircraft. For air freight North-America has – as well as Europe – an extensive network of Road Feeder Services.

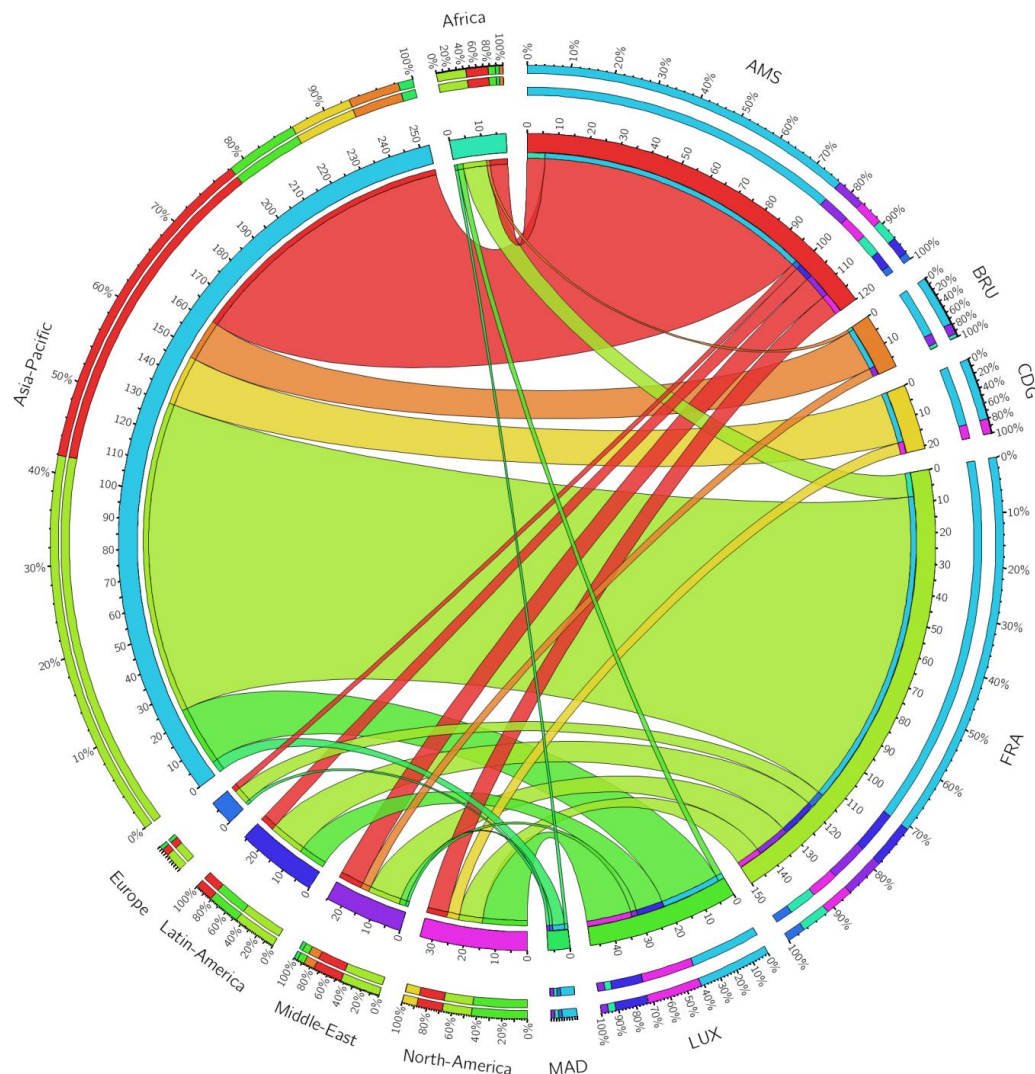
**Figure 3.5** The majority of destinations served indirectly is located in the Asia/Pacific region



Source: Official Airline Guide (OAG), Krzywinsky et al. (2009), SEO Economic Research

Indirect connectivity on freighter aircraft, as depicted in Figure 3.6, is also mainly concentrated in the Asia-Pacific region. However, the share of other world regions which can be indirectly reached by freighter aircraft is somewhat larger than for overall indirect connectivity. Latin-America and North-America have some indirect freighter connections.

**Figure 3.6 Frankfurt and Amsterdam have the largest share in indirect freighter connectivity**

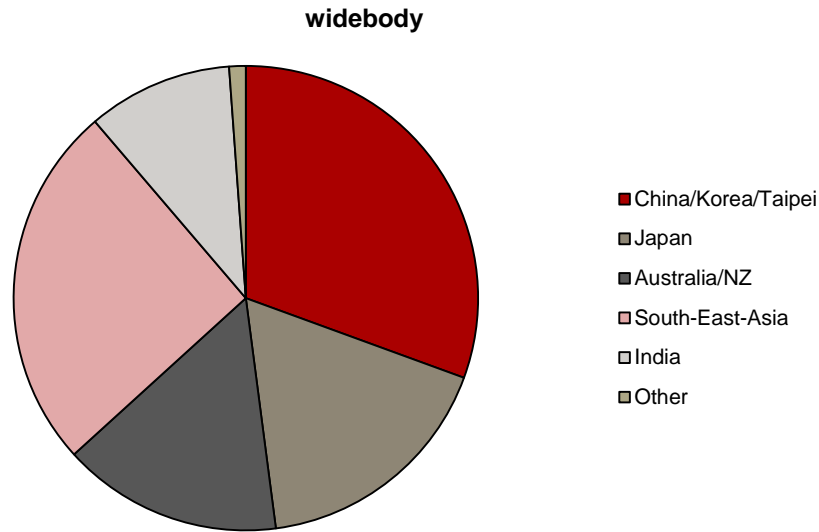


Source: Official Airline Guide (OAG), Krzywinsky et al. (2009), SEO Economic Research

#### **Further breakdown of indirect connectivity with Asia-Pacific**

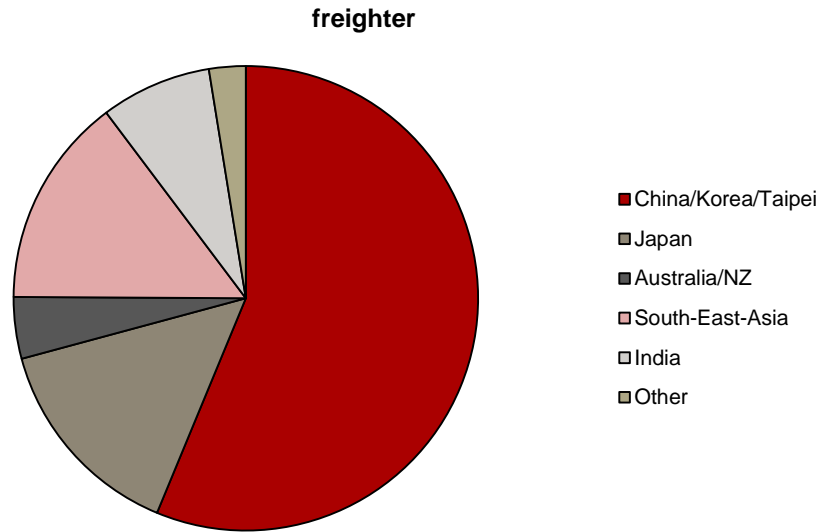
Most of the indirect connectivity is concentrated in the Asia-Pacific region. The pie charts in Figure 3.7 and Figure 3.8 show that China and South-East Asia are the best indirectly served destination regions. Especially full freighter operations are concentrated in China and Korea. Australia and New-Zealand are not very well connected by full freighter aircraft.

Figure 3.7    The European benchmark airports are indirectly best connected with China and South-East-Asia



Source:   Official Airline Guide (OAG), SEO Economic Research

Figure 3.8    Indirect freighter connections are mainly to destinations in China or Korea



Source:   Official Airline Guide (OAG), SEO Economic Research



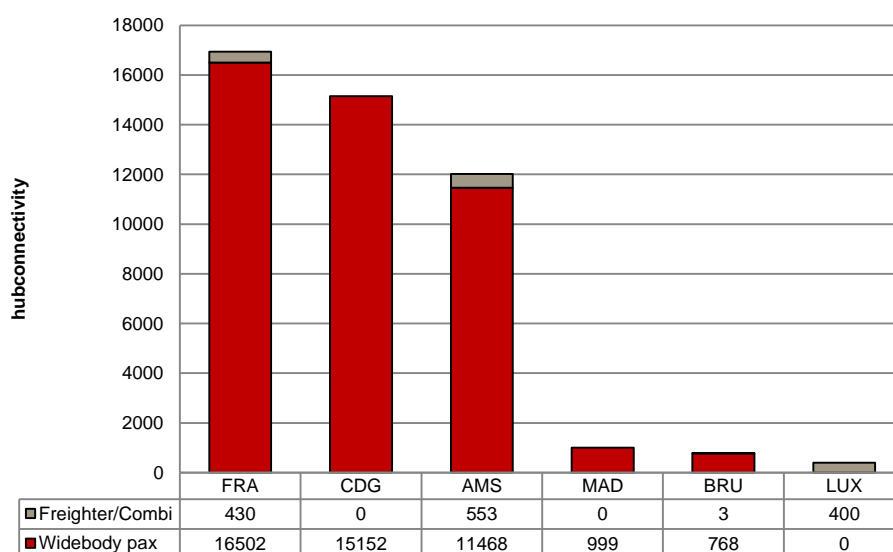
### 3.3 Hub connectivity

Hub connectivity for air cargo indicates the potential of an airport to provide connections from one world region to another, serving as a transfer hub. For passenger airlines transfer traffic is of major importance. For large hub carriers it is not an exception that more than two-thirds of the passengers are transfer passengers. At European hub airports most of this transfer traffic travels from Europe to an intercontinental destination or vice versa. As much cargo is being trucked throughout Europe the share of aircraft to aircraft transfer is much lower for European cargo carriers.

However, to keep cargo operations profitable transfer freight can be very helpful to obtain a sufficient load factor. Particularly hub airports where transfers are regularly made between two long-haul flights have a higher share of transfer traffic. Examples are the hub airports in the Middle-East, where local demand for freight is low and much freight is transported from Europe to Asia via one of the hub airports. Other examples of cargo hub airports are Hong Kong and Singapore.

Figure 3.9 shows the hub connectivity of the six airports. Frankfurt and Paris Charles the Gaulle both have a large long haul network of their hub carriers Lufthansa and Air France, respectively, which give these airports a strong position in providing transfer options for air freight. Whenever main deck capacity is required Amsterdam Schiphol has the highest amount of hub connectivity.

**Figure 3.9 Frankfurt and Paris Charles the Gaulle provide most widebody hub connections**



Source: Official Airline Guide (OAG), SEO Economic Research

Although freighter-freighter connections only account for a very small part of the hub connectivity (except for cargo-hub Luxembourg), there are many widebody passenger operations which connect well to freighter aircraft. Freight from these passenger services can be transhipped onto freighter aircraft for their final destination. For Amsterdam Schiphol – as can be seen in Table 3.4 – 36 percent of the hub connectivity includes at least one full-freighter or combi operation. Hence the full freighters can be used to attract transfer cargo to fill the long-haul passenger operations.

Rationalizing the full freighter network may cause a decrease in the demand for transfer cargo, being an additional burden for the belly capacity load factor.

**Table 3.4** A large part of the hub connectivity includes at least one leg on a full freighter aircraft

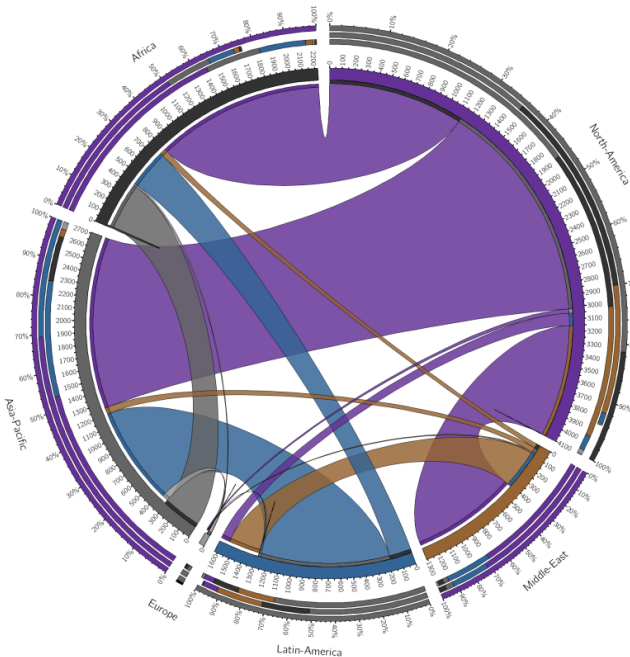
	AMS		FRA	
	CNU	Share	CNU	Share
pax-pax	7735	64%	12408	73%
pax-FF/Combi	3733	31%	4094	24%
FF-FF	553	5%	430	3%

Source: Official Airline Guide (OAG), SEO Economic Research

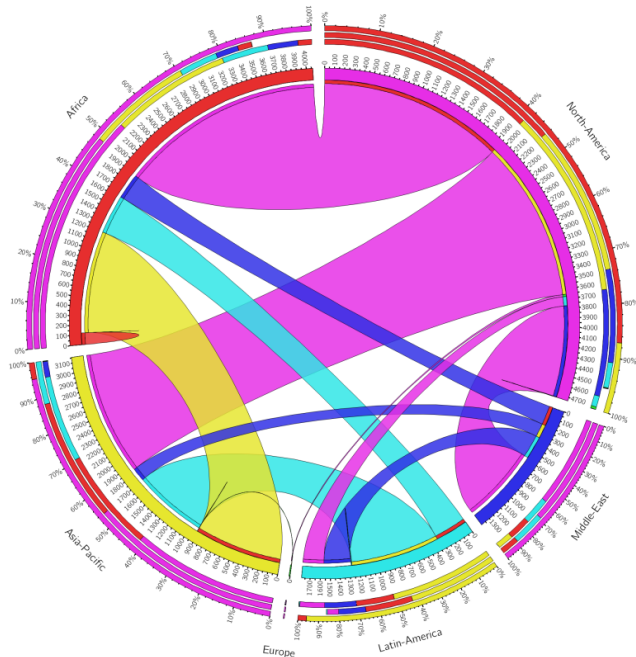
### Breakdown by world region

The Circos diagrams below show the world regions of the airports which are connected via the respective hubs. Amsterdam Schiphol and Paris Charles the Gaulle have a very small widebody network inside Europe, therefore the largest part of the connections via these hubs contain two intercontinental flights. The best connected markets for Amsterdam and Frankfurt are North-America and Asia-Pacific. For Paris Charles the Gaulle and Brussels this is North-America and Africa. Madrid and Luxemburg mainly connect European airports to other world regions. Interestingly the connectivity between two world regions is strongly unbalanced. For example Luxembourg airport has a much higher share of connections from Europe to Asia, while the connectivity from Asia to Europe is much smaller. The incoming flights from Europe connect better to the outbound flights to Asia than vice versa.

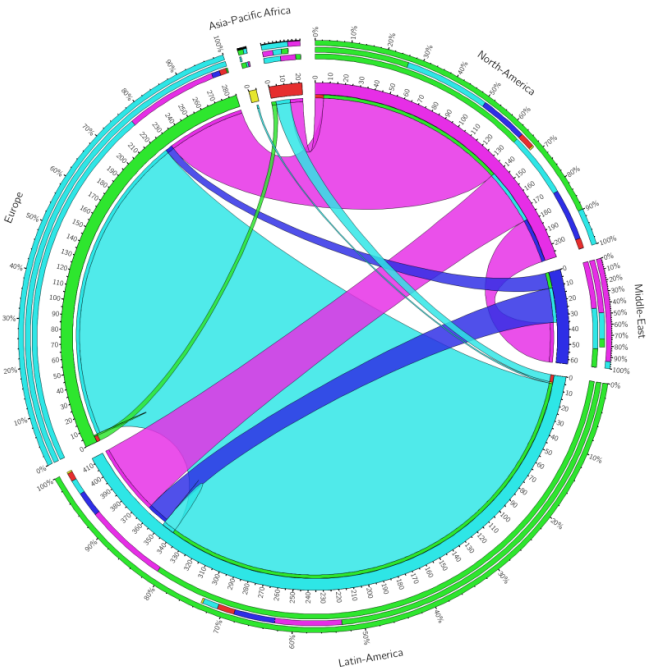
Amsterdam Schiphol Airport



Paris Charles de Gaulle Airport



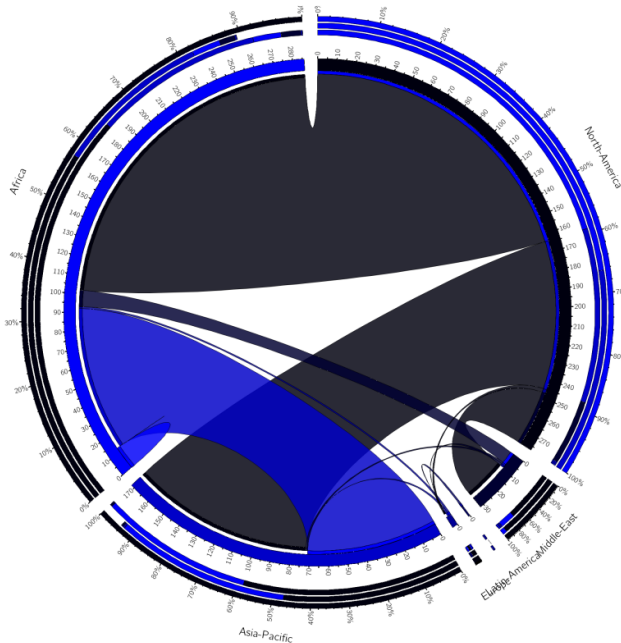
Madrid Barajas Airport



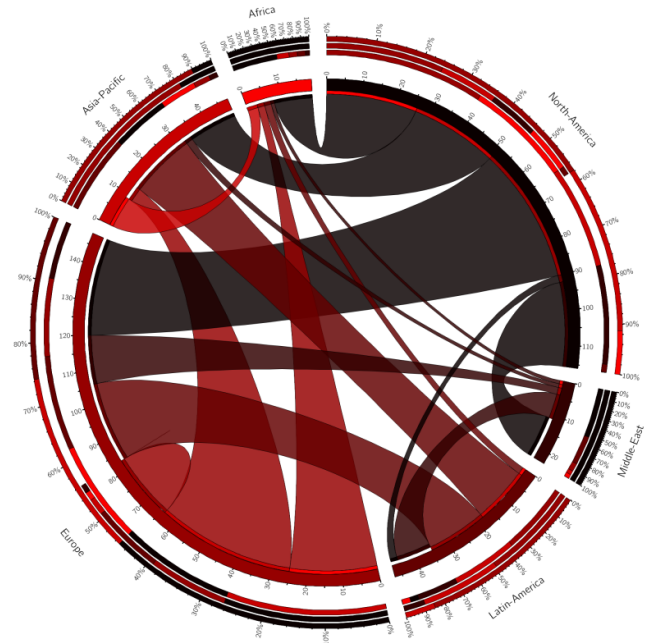
Frankfurt Airport



Brussels Zaventem Airport



Luxembourg Airport



### 3.4 Conclusions

In this paper we derived a connectivity model for air cargo operations, NetCargo. The connectivity model can show the magnitude of both the widebody and the full freighter network of a certain airport. These figures can be used to analyse the size and scope of a single airport network, as well as to provide a benchmark study on the networks of different airports. Connectivity figures may as well be used to indicate the level of competition on certain markets between airlines or between different hub airports.

We have shown an application of the model by providing a benchmark study of the cargo networks of six European airports for 2014. This may be extended by showing the connectivity trends over a number of years, for instance to indicate the development of the full freighter network or to find out whether a strong shift from freighter to belly capacity has taken place.

These analyses can also be extended by determining the airport connectivity for perishable cargo, which are more time-sensitive. For these products there are less indirect alternatives as the quality of a connection decreases strongly whenever extra travel time is needed.

NetCargo can be applied to extend various airport connectivity studies with a separate analysis of the air cargo network. It might as well be a useful tool for airports or airlines to determine the level of competition in various markets, which can be used as input for strategic decision making or revenue management applications.

## 4 Catchment area analysis for air cargo airports

*The catchment area of cargo airports tends to be much larger than for passengers. Much cargo is trucked through mainland Europe before it is loaded onto the plane, which implies there are many airports serving the same market. Whereas for example the London area is a multi-airport region serving the local O&D market of London for the passenger industry, the cargo O&D market of north-west Europe is served by several airports including Frankfurt, Schiphol, Paris Charles de Gaulle, Luxembourg and Liège.*

The main question for this chapter is to find out how large the catchment area for air cargo airports is. We describe the choice process of air cargo customers and give illustrations of typical door-to-door routings. By means of a literature study and information of industry experts we estimate the size of the catchment area of a cargo airport.

### 4.1 Literature review

Competition between cargo airports in the origin-destination market is not widely described in literature. Zhang classifies three types of air freight in his analysis on the cargo hub in Hong Kong: Local cargo, gateway cargo and hub cargo (Zhang A. , 2003). Local cargo contains shipments to or from the local market of Hong Kong, whereas gateway cargo are shipments transported to Hong Kong from mainland China through other modes of transport. Hub cargo is cargo between two different countries, transhipped at Hong Kong airport.

In order to define the size of the catchment area, gateway cargo is the most interesting air cargo type. Most airports have a small local market with relatively little competition; however for most goods no airport is irreplaceable.

The European Commission has commissioned research on the cargo catchment area by means of a questionnaire under cargo customers (Commission decision, 2008). Respondents indicated that within a range of around 800 kilometres airports are substitutable, or within a 12-hour truck range, which more or less coincides.

For the US and Europe, air freight transport links from continent to continent are defined by the European Commission as services for the same market. For other continents with inferior surface transport links a further division on country level might be required (Commission decision, 2008; SEO Economisch Onderzoek, 2012).

Deregulation in the European markets have turned traditional freight forwarders into multimodal logistics suppliers offering specialized services, warehousing and other value added services. Large forwarding companies are global players which are not restricted to a single airport (Neiberger, 2008). Traditional hub airports at Amsterdam, Frankfurt, London Heathrow and Paris Charles the Gaulle compete for cargo by trucking consolidated pallets (by the freight forwarder) to their respective hubs. Simultaneously, regional airports have emerged as hub locations for integrators,

for example Leipzig/Halle for DHL and Cologne/Bonn airport for UPS. This has led to more competition between the European airports and as a result airports need a strong focus on offering a competitive product for air freight services. For example a new perishable centre at Frankfurt Airport has been built to compete for the large flower market at Amsterdam Schiphol<sup>12</sup>, and London Heathrow is planning to double its cargo handling capacity (London Heathrow Airport, 2014)<sup>13</sup>.

The size of the catchment area might differ for different types of cargo airports. While the large European hubs serve a large number of unique destinations, smaller cargo airports like Hamburg have a significantly smaller catchment area. The airport's website claims that the catchment area stretches within a region of 200 km<sup>14</sup>. This is significantly less than figures claimed for Frankfurt and Schiphol, and follows from the fact that Hamburg has no scheduled freighter operations and a small long-haul network.

## 4.2 Access distance based on AWB data

Freight from other parts of Europe is trucked to its departure airport either by a freight forwarder or is facilitated by the carrier's Road Feeder Services (RFS), or eventually through the carrier's short-haul network (which is usually more expensive). In the previous chapter we argued why Road Feeder Services (RFS) are not included in the connectivity model, neither are narrow-body airline operations.

The main difference between access links provided by the airline's RFS or a freight forwarder, is that the airline's trucking leg is executed as if it were a genuine flight. Therefore, the 'flight' leg is on the airway bill (AWB<sup>15</sup>) and this leg is always a connection between two airports, whereas the freight forwarder carries the shipment from any address to the airport.

Figure 4.1 shows the percentage of outbound air freight for Amsterdam Schiphol airport which is transported from another airport within the distance given on the x-axis. 47 percent of the air cargo has an access distance of 0 kilometres, indicating that the access transport is carried out by a freight forwarder (as we assume no goods are produced at the airport). We have no information on the access distance of these shipments.

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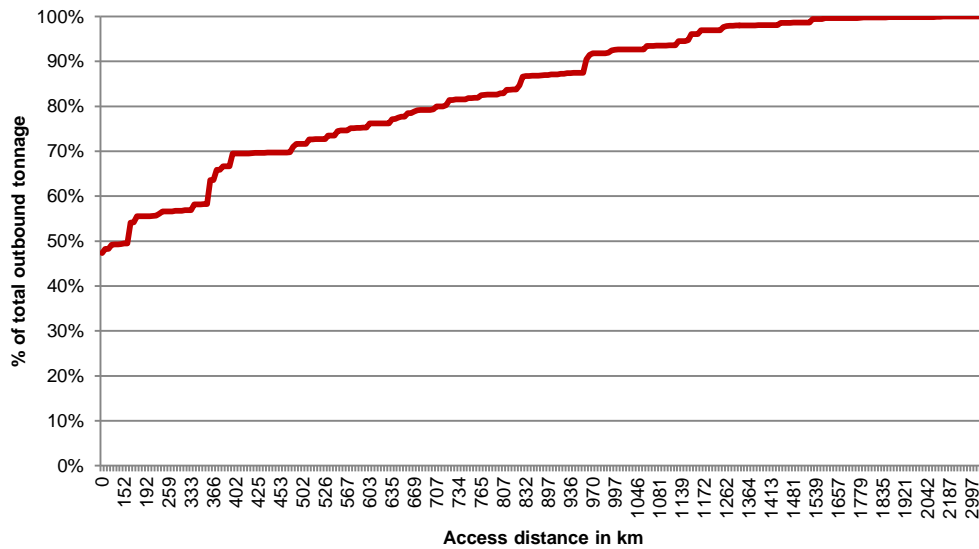
<sup>12</sup> <http://theloadstar.co.uk/fra-takes-flowers-ams/>

<sup>13</sup> [http://www.fta.co.uk/media\\_and\\_campaigns/press\\_releases/2014/20140513\\_heathrow\\_plans\\_good\\_news\\_for\\_freight\\_echoing\\_fta\\_report.html](http://www.fta.co.uk/media_and_campaigns/press_releases/2014/20140513_heathrow_plans_good_news_for_freight_echoing_fta_report.html)

<sup>14</sup> [http://www.airport.de/en/b\\_cargo\\_about\\_us\\_air\\_cargo.html](http://www.airport.de/en/b_cargo_about_us_air_cargo.html)

<sup>15</sup> Main shipping document for air freight

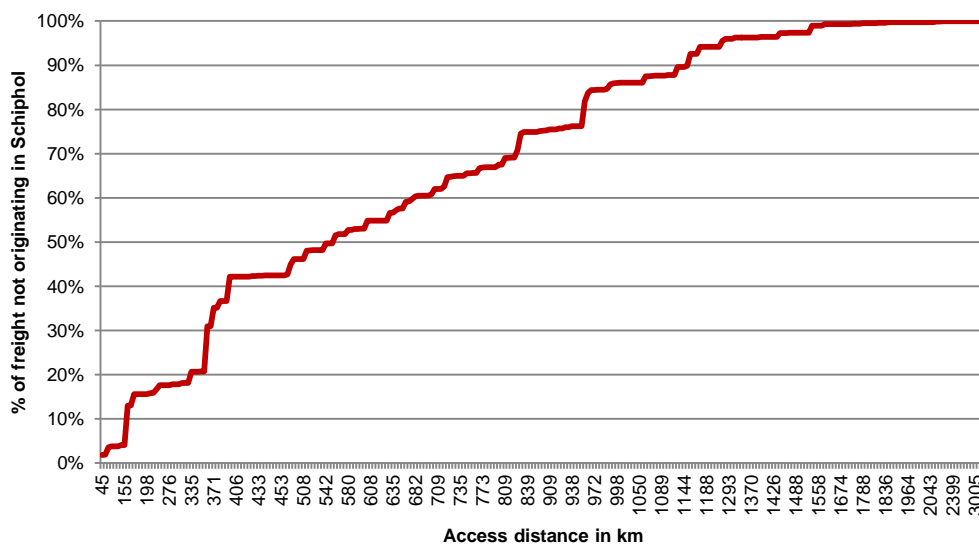
**Figure 4.1** More than 50 percent of the outbound air freight at Schiphol Airport originates in another European airport



Source: SEO Economisch Onderzoek, 2012

Figure 4.2 shows the cumulative percentage of freight relative to the access distance. 50 percent of the cargo not originating in Schiphol is within 550 kilometres of the airport. 95 percent of the freight for Schiphol originates within an access distance of 1250 kilometres, which is the distance between Amsterdam and Barcelona. This strokes with the assumptions of the European Commission (Commission decision, 2008) that airports within 800 kilometres of the airport are interchangeable.

**Figure 4.2** Air freight shipments can be trucked over 1250 kilometres through mainland Europe



Source: SEO Economisch Onderzoek, 2012

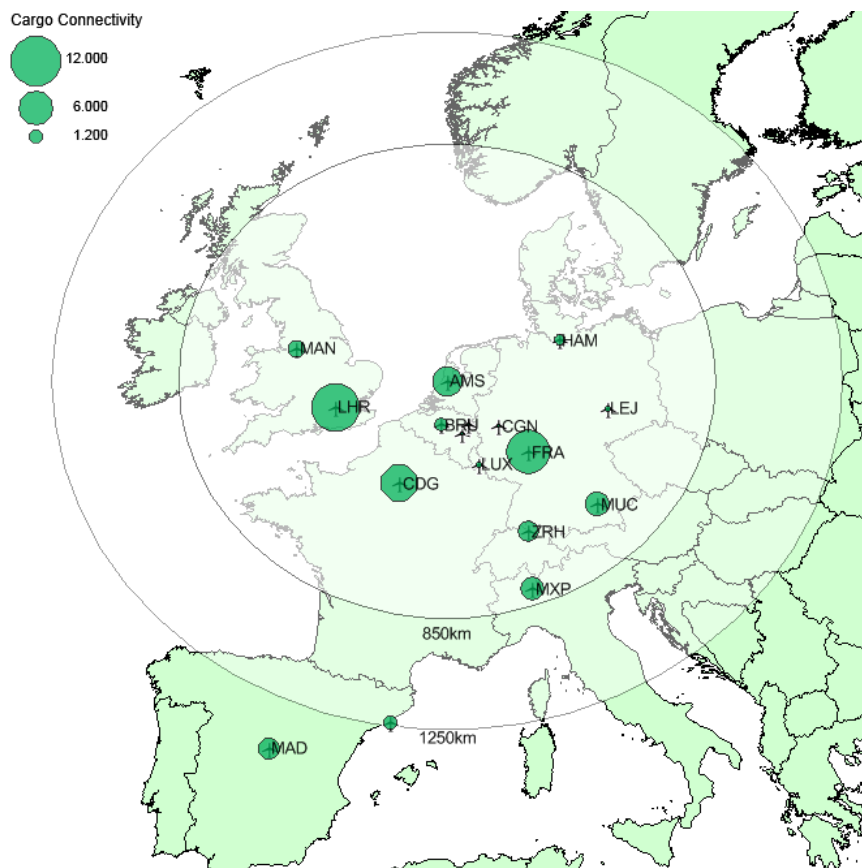


### 4.3 The catchment area of Schiphol Airport

In this paragraph we give an illustration of the catchment area of Amsterdam Schiphol airport, and show the most important competitors. As follows from the literature study, the catchment area of local air cargo is within a range of 850 to 1250 kilometres.

Figure 4.3 shows the 850 and 1250 kilometres catchment areas for Schiphol Airport. The size of the circles around the included airports shows the total cargo connectivity (direct and indirect). The four largest European airports are all within the radius of 850 kilometres. London Heathrow might have a slight competitive advantage for UK cargo (and a disadvantage for shipments from continental Europe). There is a large difference between the total connectivity of these four airports and the smaller airports. For belly cargo, these four airports have a strong competitive advantage by their large variety of long-haul destinations.

**Figure 4.3** The catchment area of Schiphol contains entire north-west Europe



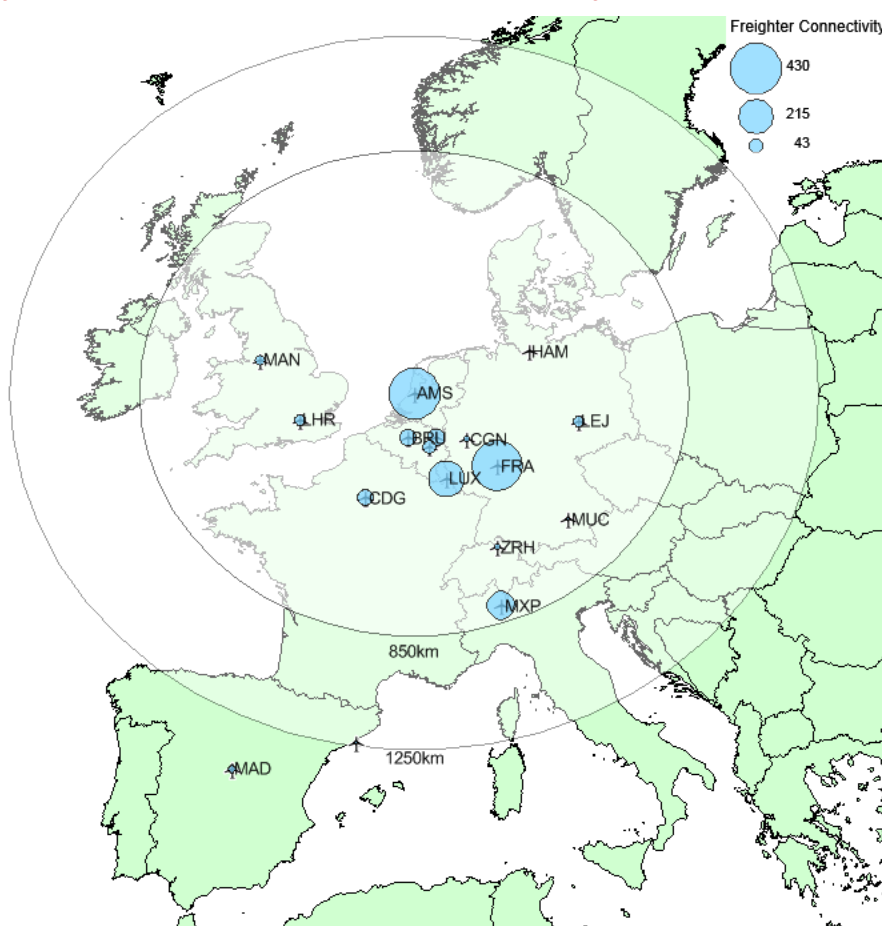
Source: SEO Economic Research

Figure 4.4 shows the freighter connectivity of some European airports. As also results from the connectivity analysis in chapter 3, freighter connectivity accounts for a fraction of the connectivity generated by belly operations. This is mainly because there are little onward freighter connections, whereas passenger operations are more frequent and better connections are available at other hub



airports. In this figure a difference can be observed between the main airports of London and Paris and those in Amsterdam and Frankfurt. The first two are rather capacity constraint and therefore have little full freighter operations. Frankfurt and Schiphol are the leading full freighter airports in Europe, and are followed by Luxembourg and Milan Malpensa. Also smaller airports like Liège and Maastricht Aachen airport have some scheduled freighter operations, making their freighter connectivity comparable to the size of Paris Charles de Gaulle.

**Figure 4.4** There are far less alternatives when full freighter operations are required



Source: SEO Economic Research



## 5 Cargo connectivity for European regions

*In chapter 4 we showed that airports within a radius of 850 km are strong competitors for air cargo. To analyse the competitive playing field we use the developed NetCargo model for determining the cargo connectivity for various European regions. We use an access penalty function to correct for the additional access time required and show which airports provide most connectivity for a certain region. This analysis provides insight in which markets airports compete and to what extent these airports offer a unique product.*

### 5.1 Methodology

By calculating the connectivity of a region we adopt the methodology from Zuidberg, Boonekamp, & Burghouwt (2014). We determine the connectivity of a region by multiplying the airport's connectivity by a penalty factor depending on the travel time from the region's centroid to the respective airport. These travel times are obtained using Google Maps.

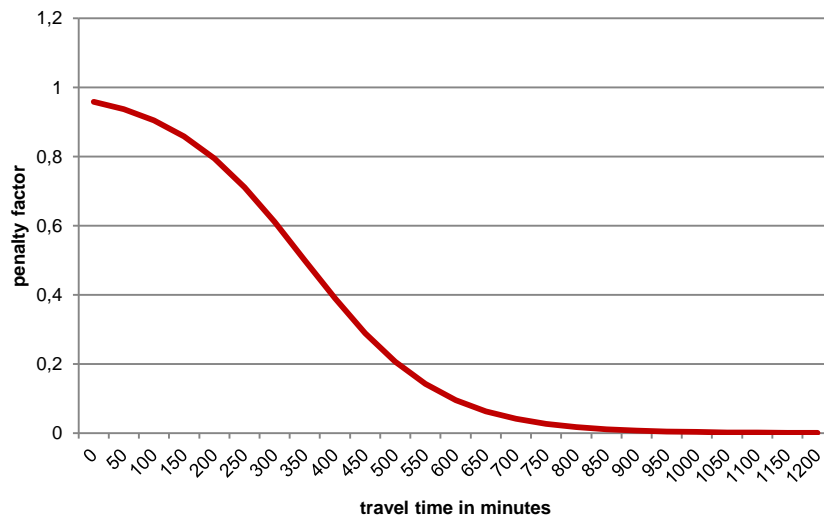
The distance decay function or penalty function we used is an S-shaped function which is frequently used in literature (Geurs, Ritsema, & Eck, 2001). This choice is motivated by the fact that the difference in valuation of short access times (within 2 hours) is small, while the utility decreases faster for longer travel times. We define the connectivity generated for region  $r$  via airport  $a$ ,  $C_{ra}$ :

$$C_{ra} = cnx_a \cdot \frac{1}{1 + e^{\beta \cdot (t_{ra} - \alpha)}}$$

with shape parameter  $\beta$ , location parameter  $\alpha$  and  $cnx_a$  is the airport connectivity of airport  $a$ .

In our numerical example we use parameter values  $\beta = 0.009$  and  $\alpha = 350$ . The function is shown in Figure 5.1. Given these values the access time penalty is 0.5 for an access time of 350 minutes, which means that the connectivity generated via an airport located 350 minutes away is worth half the connectivity it would have generated if no access time was required.

Figure 5.1 Access time penalty function for  $\beta = 0.009$  and  $\alpha = 350$



Source: SEO Economic Research

## 5.2 Regional connectivity

Air freight connectivity is a key feature for a strong economic region. High-tech industry demands fast air transport links to all world regions whereas the local population shows strong demand for luxury goods. Besides this, regions with high air freight connectivity attract logistic activities and are suitable for distribution centres of large companies.

In this paragraph we determine the air freight connectivity of 13 European regions located in various parts of the continent. We show the total air freight connectivity and zoom in on the airports which contribute most to the region's connectivity.

The air freight connectivity is generated for the regions around the following European cities:

- Rotterdam
- Eindhoven
- Antwerp
- Copenhagen
- Oslo
- Paris
- Lyon
- Munich
- Karlsruhe
- Milan
- Barcelona
- Birmingham
- Vienna

These cities are chosen to determine the connectivity for a miscellaneous set of regions spread around the continent. Some regions contain large airports (Paris, Munich), while other regions need more travel time to a relatively large airport.

Table 5.1 shows the total air freight connectivity for each region and the connectivity generated only by full freighter operations. The number in brackets denotes the ranking of the city region. Interestingly regions with a central location between the three large airports of Amsterdam, Frankfurt or Paris have the highest air freight connectivity. The more peripheral regions such as Oslo, Barcelona and Copenhagen rank substantially lower. When full freighter operations are required the ranking shows some differences. The region of Birmingham shows the largest drop in its ranking as there are less freighter operations from airports on the British Isles.

**Table 5.1** Regions centrally located between large airports show highest connectivity figures

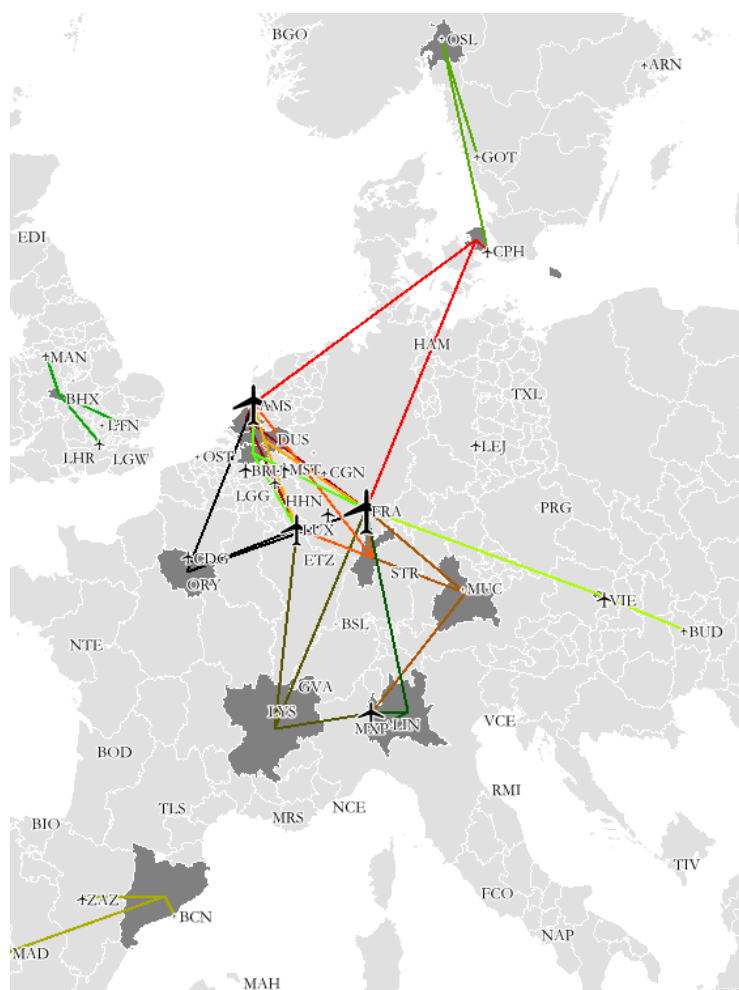
Region	Air freight connectivity	Air freight connectivity (Full freighter)
Antwerp	22685 (1)	966 (2)
Eindhoven	21055 (2)	988 (1)
Karlsruhe	19277 (3)	844 (4)
Rotterdam	18275 (4)	869 (3)
Paris	15833 (5)	509 (5)
Birmingham	13806 (6)	138 (9)
Munich	13365 (7)	441 (6)
Lyon	8094 (8)	250 (7)
Milan	7740 (9)	225 (8)
Vienna	5216 (10)	137 (10)
Copenhagen	2388 (11)	70 (11)
Barcelona	2235 (12)	36 (12)
Oslo	1145 (13)	25 (13)

Source: SEO Economic Research

Figure 5.2 shows the top three airports generating most connectivity for the corresponding regions. One can observe that Frankfurt and Paris Charles the Gaulle are in the top three of most regions. The figure also illustrates that the most important airports for a region can be as far as 500 kilometres away.



Figure 5.3 Luxembourg (LUX) is a key airport when full freighter operations are required



Source: SEO Economic Research

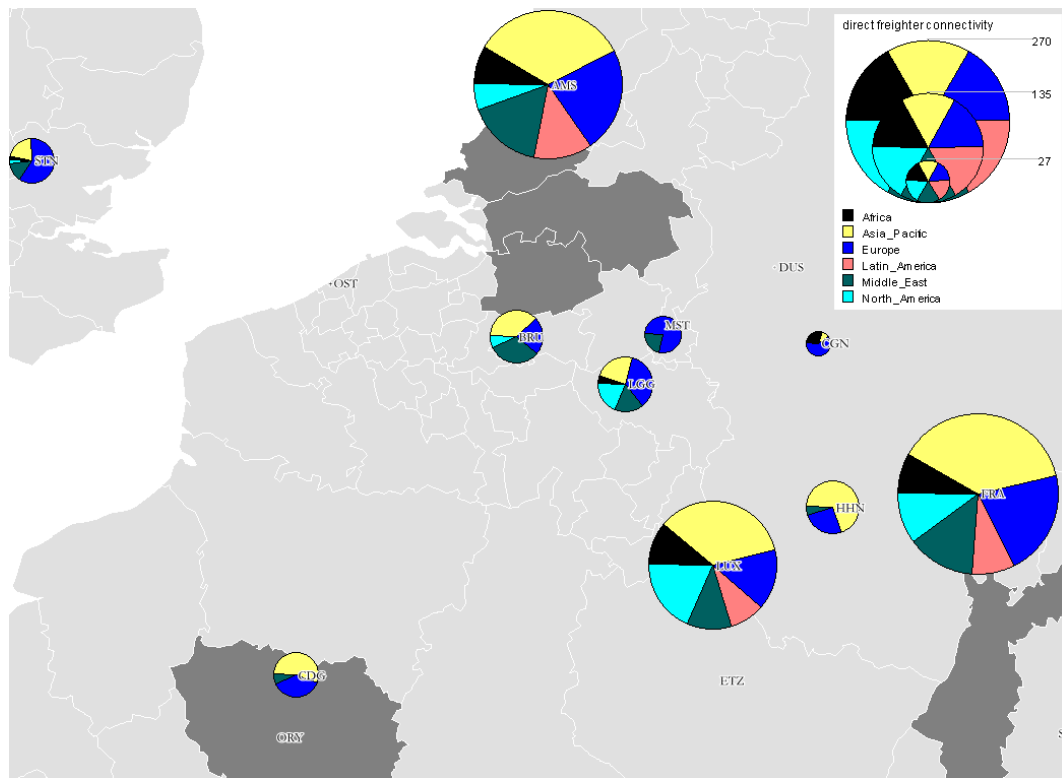
## 5.3 Regional breakdown of freighter destinations

### Breakdown by world region

Figure 5.4 shows to which regions direct freighter services are offered by the largest cargo airports in North-Western Europe. Most freighter operations serve the Asia-Pacific region, the Middle-East region is the second largest for most regions. Interestingly North-America – which provides most direct connectivity with widebody passenger aircraft – is less well connected by full freighters. This is caused by the fact that the large US carriers do not use any freighter aircraft due to the dominance of the integrators in the United States.

The spread over the various destination regions seems quite similar for most airports. Airports do not seem to obtain a stronger competitive position by concentrating on connectivity with a certain world region. The unique position of an airport might be revealed when we look at individual destinations. The smaller cargo airports such as Liège (LGG) and Maastricht (MST) have a larger share of destinations within Europe or the Middle East. Cargo carriers at those airports are mostly trunk lines to hub airports such as Istanbul (Turkish Airlines) or Doha (Qatar Airways)

Figure 5.4 Direct freighter connectivity of airports in North-Western Europe



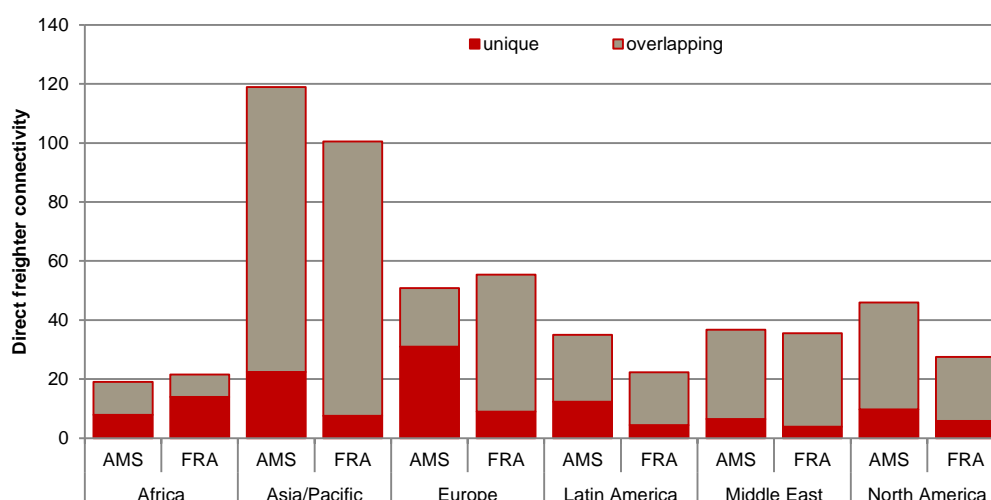
Source: SEO Economic Research

#### Competition between Frankfurt and Schiphol: breakdown by individual destination

In this paragraph we compare the individual freighter destinations of Schiphol Airport and Frankfurt. These airports seem to serve the same home markets and offer a similar amount of freighter flights to each world region. For each region we show whether Schiphol and Frankfurt serve the same destinations and are strong competitors for the same home market, or if these airports offer a differentiated product.

Figure 5.5 breaks down the connectivity for Schiphol and Frankfurt by world region and unique or overlapping destination. A destination which is offered by both Amsterdam and Frankfurt is counted as an overlapping destination, while destinations not offered by the other airport are considered unique. These 'unique' destinations could however be offered by other airports in the catchment area such as Luxembourg or Brussels.



**Figure 5.5 Schiphol and Frankfurt compete on a large part of their direct full freighter destinations**

Source: SEO Economic Research

Most of the freighter connectivity of Schiphol and Frankfurt is to destinations which are also served by the other airport. Schiphol offers a slightly more unique product. 29 percent of Schiphol's connectivity is to destinations not offered by Frankfurt, while only 17 percent of Frankfurt's connectivity is to destinations not served by Schiphol.

In particular the freighter destinations served in Europe from Schiphol are unique. However these destinations mainly consider multistop freighter destinations, such as Copenhagen, Frankfurt Hahn or Vienna. On these routes the amount of origin-destination cargo carriers is negligible. When European routes are not taken into account the fraction of connectivity to unique destinations is 23 percent for Schiphol and 17 percent for Frankfurt.

Lufthansa offers a daily freighter service to Dakar, which is also served by Emirates from Frankfurt. This destination is not served from Schiphol. Although less frequently, Martinair serves many unique destinations in Africa by its multistop routes. Examples are Khartoum, Kigali, Harare and Entebbe. Both airports have frequent freighter services to Nairobi.

The Asia/Pacific routes offered by Schiphol and Frankfurt are overlapping for a large part. The most frequent freighter operations (and combi operations by KLM) serve the large cargo airports of Hong Kong, Seoul and Shanghai. Both airports also serve unique markets in Asia. Schiphol has unique services to Chengdu, Tianjin and Singapore. Frankfurt has services to the Indian cities of Hyderabad and Calcutta and to the Chinese city of Chongqing.

The same pattern is shown for the other world regions. The most frequent freighter destinations are those to large airports with high cargo demand, such as Sao Paulo in Latin America and Dubai and Abu Dhabi in the Middle East. The airports differentiate their product by offering some (less frequent) freighter services to secondary airports. Frankfurt offers unique freighter services to among others Manaus, Montevideo, Amman and Dallas. Examples of the unique destinations served from Schiphol are Bogota, Beirut, Muscat and Seattle.

## 5.4 Conclusions

There is fierce competition between cargo airports in Europe. Especially in the North-Western part of Europe there are many large airports offering frequent belly cargo services to destinations all over the world. In the same region there are smaller airports offering additional full freighter services, while also some of the large airports offer full freighter capacity.

Using an access time penalty function we have determined the regional cargo connectivity for various European regions. The regions in mainland Europe located well between the airports of Frankfurt, Schiphol and Paris Charles de Gaulle have the highest regional cargo connectivity. British regions or regions close to large passenger airports such as Munich or Zürich rank lower, however still fairly high thanks to the large number of widebody passenger operations.

Regions in the northwest of Europe have a stronger advantage when freighter operations are required. Airports such as Vienna and Barcelona as well as those on the British Isles offer less freighter operations. These are concentrated in Frankfurt, Amsterdam, Luxembourg and the smaller airports in between. For some regions, such as Copenhagen, Frankfurt and Schiphol provide most freighter connectivity for the region, while these are located more than 800 kilometres away.

To what extent are airports competitors and to what extent do they provide a differentiated product? Passenger operations of large European airports are more or less comparable, while some airports focus more on specific world regions than others. For instance Brussels Airport has a large network in Africa. This is necessary for passenger operations as these airports do not serve the same catchment area. For air cargo these airports serve the same catchment area. However, freighter operations offered from various European airports tend to serve the same world regions. The lion's share of freighter operations is to large cargo airports in the different world regions. Airports try to improve their competitive position by offering freighter services to secondary airports which are not served by other European airports. Serving unique smaller markets on those routes where demand for main deck capacity is high could be crucial in becoming a successful market place for air cargo. The main objective for cargo airports is to provide an optimal mix of frequent belly cargo services and freighter services where the market needs them.

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## Appendix A: Carrier codes

IATA-code	Name
75C	C.A.I. Cargo Airlines
7C8	Cargolux Italia S.p.A.
9W	Jet Airways (India) Ltd
AA	American Airlines
AC	Air Canada
AF	Air France
AV	Avianca
BA	British Airways
BR	EVA Airways
CA	Air China
CK	China Cargo Airlines
CV	Cargolux Airlines International
CX	Cathay Pacific Airways
CZ	China Southern Airlines
DE	Condor Flugdienst
DL	Delta Air Lines
EK	Emirates
ET	Ethiopian Airlines
EY	Etihad Airways
IB	Iberia
JL	Japan Airlines
KE	Korean Air
KL	KLM-Royal Dutch Airlines
KZ	Nippon Cargo Airlines
LA	Lan Airlines
LH	Lufthansa German Airlines
MB	MNG Airlines Cargo
MH	Malaysia Airlines
MP	Martinair Holland
MU	China Eastern Airlines
N2	Trans Mediterranean Airways
NH	All Nippon Airways
OR	Arkefly
OZ	Asiana Airlines
QF	Qantas Airways
QR	Qatar Airways
RU	AirBridgeCargo
SN	Brussels Airlines

<b>IATA-code</b>	<b>Name</b>
<b>SQ</b>	Singapore Airlines
<b>SV</b>	Saudi Arabian Airlines
<b>TB</b>	Jetairfly
<b>TG</b>	Thai Airways International
<b>TK</b>	Turkish Airlines
<b>TS</b>	Air Transat A.T.Inc.
<b>UA</b>	United Airlines
<b>US</b>	US Airways
<b>UX</b>	Air Europa
<b>VA</b>	Virgin Australia International
<b>Y8</b>	Yangtze River Express Airlines





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