16TH AIR TRANSPORT RESEARCH SOCIETY WORLD CONFERENCE

Risk management in the European air freight system: an institutional approach

Aaron B. Scholz[1], Li Zhang[2], Florian Gizzi[3], Klaus Jaekel[4]

Abstract

In this paper the air freight sector is analysed based on a framework for complex goods. Actors, roles, institutions and assets are the central building blocks of the framework which is filled out with modelled data, information obtained from literature and interviews with aviation professionals in order to understand the interactions and the responsibilities of and within the air freight system. The objective of this paper is to analyse the ability of the air freight system to respond to unexpected events like the eruption of the Eyjafjallajökull. A focus of the analysis is on the enhancement of flexibility by the provision of sufficient reactivity options to unexpected events which is interpreted as a risk management strategy. A dedicated focus is placed on the regulatory environment for air freight services in Europe and on Europe's air freight capacities as both directly influences the reactivity of the sector. Capacities are analyzed in three different ways: First, runway capacities of Europe's airports, second, air freight terminal capacities at the airports and third, staff and truck capacities where comprehensive security guidelines exist (European Directive 185/2010: "Standards on aviation security").

Keywords: air cargo, institutional economic approach, risk management, capacity limitations, infrastructure limitations

Classification: Air Cargo Forecasting, Management, Logistics and Operations, Air Transport Policy and Regulation, Aviation Infrastructure

[1]Institute for Economic Policy Research, Karlsruhe Institute of Technology, Waldhornstr. 27, 76137 Karlsruhe, Germany, Phone: +49 (0)721 608 – 44226, Fax: +49 (0)721 608 – 45890, aaron.scholz@kit.edu (corresponding author)
[2] Institute for Economic Policy Research, Karlsruhe Institute of Technology, Waldhornstr. 27, 76137 Karlsruhe, Germany, Phone: +49 (0)721 608 – 43391, Fax: +49 (0)721 608 – 45890, li.zhang@kit.edu
[3] Workgroup for Infrastructure Policy (WIP), Berlin Institute of Technology, Straße des 17. Juni 135, 10623 Berlin, Germany, Phone: +49 (0)30 314 – 25876, Fax: +49 (0)30 314 – 26934, fg@wip.tu-berlin.de
[4] Workgroup for Infrastructure Policy (WIP), Berlin Institute of Technology, Straße des 17. Juni 135, 10623 Berlin, Germany, Phone: +49 (0)30 314 – 25684, Fax: +49 (0)30 314 – 26934, kj@wip.tu-berlin.de

Introduction

The eruption of the Eyjafjallajökull volcano in Iceland impacted the aviation sector extensively, airports were closed, aircrafts were grounded and cargo terminals were overcrowded from exports whereas imports were cut. According to estimations of the International Air Travel Association (IATA) the widespread closure of European airspace in April came along with a loss in revenues of around €1.26 billion. In general, airlines, airports and freight forwarders are well prepared for flight delays as they occur very frequently (Figure 1). Short-term adaptations (including no action) are effective and do not require comprehensive re-planning activities.

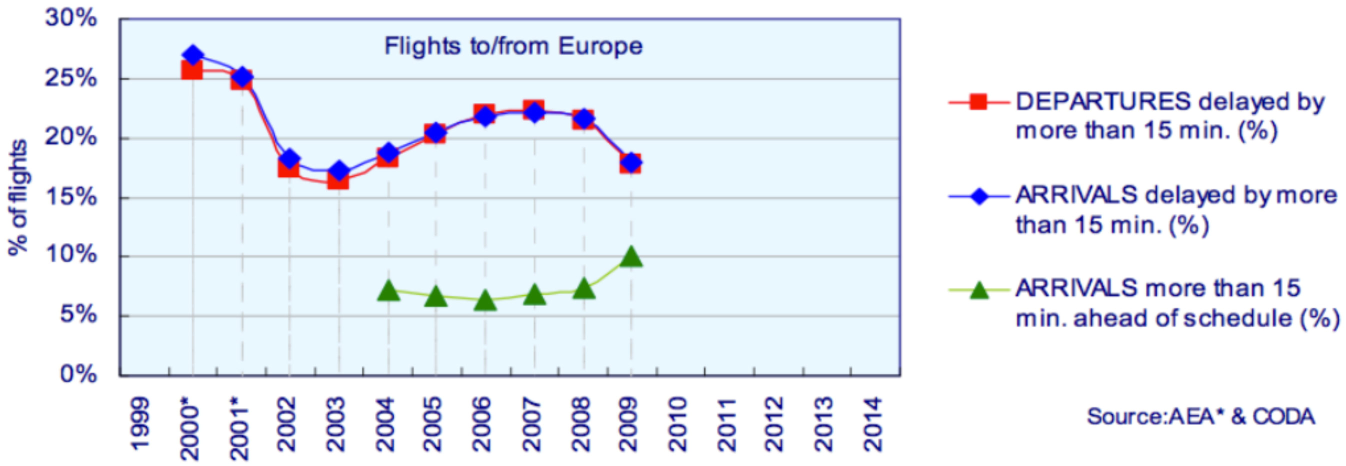


Figure 1: Performance of passenger and cargo flights to/from Europe (Eurocontrol, 2011)

The same can be observed for events, such as strikes, weather events or problems with aircrafts which do not occur frequently but regularly. Current season network control resolves such routing (network) problems and trouble-shooting is its major challenge (Goedeking, 2010). Unexpected events, such as the eruption of the Eyjafjallajökull volcano are likely to recur and impact network structures, crew scheduling as well as maintenance routing of aircrafts significantly. Another dimension of complexity is achieved because the more flights are cancelled the more network adaptations are required and the level of action increases significantly. Figure 2 shows the different levels of complexity by displaying the number of flight cancellations at a secondary airport in Germany (Stuttgart):

- Low complexity: short-term disruptions (e.g. runway closure for a few hours, approx 200 cancellations),
- Medium complexity: medium-term disruptions (e.g. winter storms, approx 500 cancellations) and
- High complexity: long-term disruptions (e.g. eruption of of Eyjafjallajökull, approx 1602 cancellations).

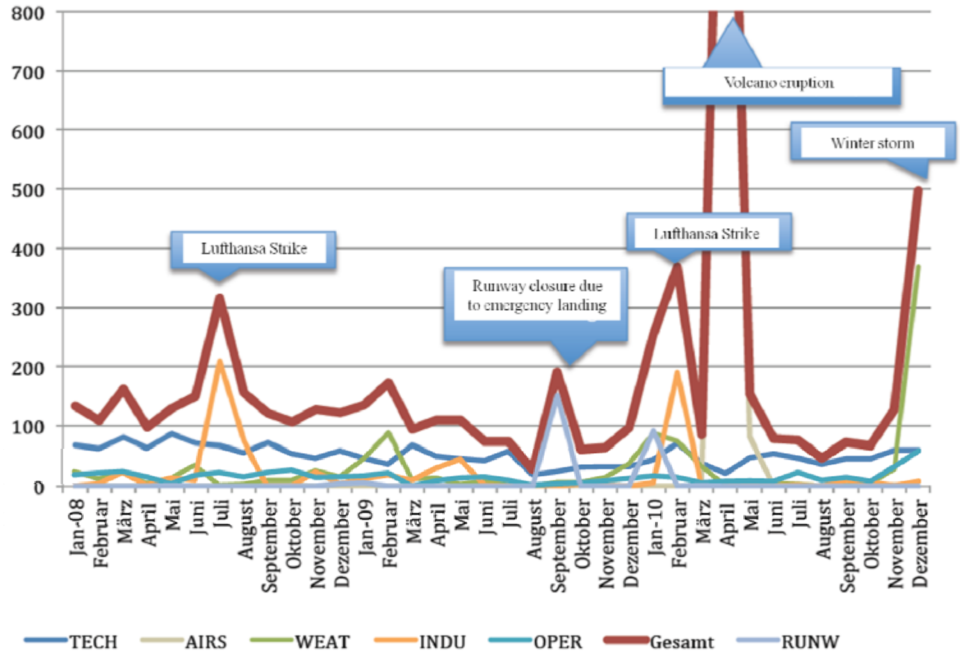


Figure 2: Causes of flight cancellations at Stuttgart airport (Eurocontrol, 2011)

Paradoxically, Europe's economy was only little affected by the ash cloud of Eyjafjallajökull's eruption. A high level of short-term network adaptations of airlines and freight forwarders reduced the adverse impacts for their customers significantly. The objective of the paper is to understand the responsibilities of the involved actors along the air freight supply chain and to analyze which factors limit the flexibility of their actions. An institutional economic framework is applied. The structure of the paper is as follows. Chapter 2 introduces the theoretical framework and defines its major elements. Afterwards, the application of the framework to the air freight system is presented. Chapter 4 analyzes if institutions (legal framework) and/or capacity (runway, terminal or feeder) limit the flexibility of the actors. Finally, chapter 5 presents the main conclusions drawn from this study.

Framework

The framework of (Beckers, Gizzi *et al.*, 2012) (inspired by (Ostrom, 2005), (Mayntz and Scharpf, 1995) and (Brandenburger and Nalebuff, 1998)) has been designed to describe and better understand complex systems. The system is decomposed into discrete elements which are homogeneous and which are interacting with each other. Furthermore, the interdependencies between these elements need to be understood to be able to identify the needs for coordination of complex systems (e.g. by regulation). The general structure of the framework is applied to the air freight system. The framework consists of nine discrete elements which is the technical system, the assets, the actors, the configurations of actors, the roles, the decisions, the relationships, the coordination areas and the institutions (Figure 3).

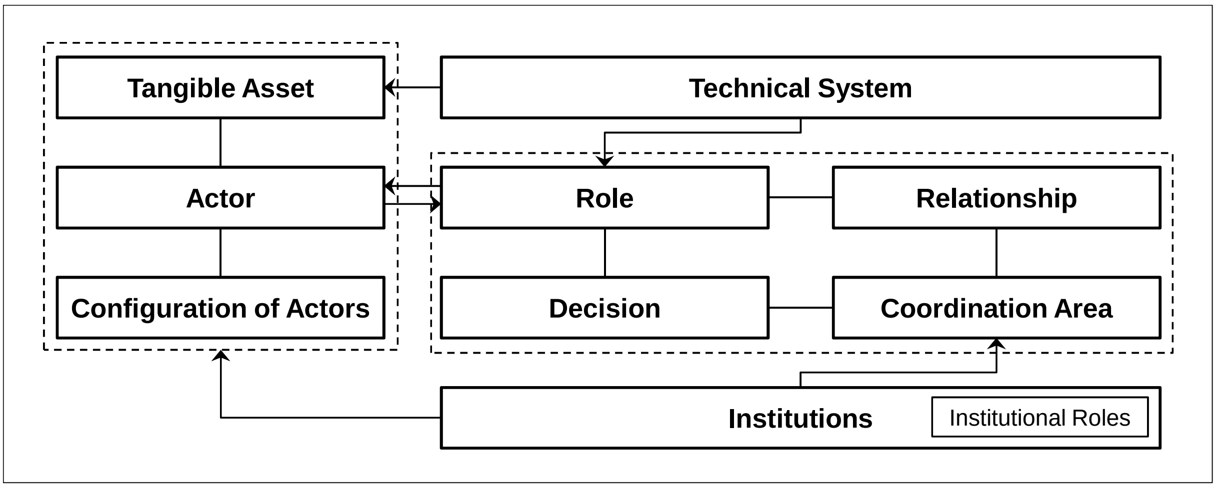


Figure 3: Essential elements of the framework and major connections

Crucial technical attributes of complex goods are described in the element "**technical system**". It contains the required processes including the objects affected by these processes, and the assets that are needed for the execution of the processes. Moreover, the technical interdependencies between processes and between assets are part of the technical system.

"**Roles**" are deduced from the technical system. They contain a structured set of tasks needed for the supply of a good. In case of interdependencies between the goods provided by two roles, a "**relationship**" between these two roles occurs. The tasks of a role come along with specific "**decisions**". If there are interdependent decisions between two roles, we call this a "**coordination area**".

Roles are accomplished by "**actors"** who perform the associated tasks and who make decisions. Actors have attributes like an individual goal and resources in form of "**assets**" (which have to meet the demands of the role the actor wants to maintain) and other resources, e.g. know-how. The "**configuration of actors**" primarily describes the number of actors who maintain the same role.

"**Institutions**", especially rules, change the outcomes of actions available to the actors in specific situations. They significantly influence different models for the supply of complex goods. Institutions may address the coordination of decisions between roles – thus the design of coordination areas – (e.g. in form of contracts or laws) or the fulfillment of a role by an actor (e.g. in form of licenses).

A. Technical System

The "technical system" is needed to describe crucial technical elements, which are technically necessary for the supply of a complex good:

- A „process" goes along with a modification of material, information or energy in matters of shape, space or time. Modifications in these three dimensions enables us to distinguish between transfer-processes (space and time), transformation-processes (shape and time) and storage-processes (time).
- "Assets" are needed for the execution of processes. If it is required or helpful for an analysis, assets (e.g. an airport's runway) furthermore can be classified in matters of shape, space and time (e.g. runway of an airport in Northern Europe).

Furthermore, the technical system is used to describe interdependencies between these elements:

- Interdependencies between assets require the definition of the associated interfaces (e.g. interface between train and railtrack in form of the wheelbase)
- Interdependencies between processes exist for example in form of sequentially connected transport-processes.

The technical system optionally allows the inclusion of quantities, like the required number or the concentration of assets or processes.

B. Roles and Relationships

Roles contain a structured set of tasks needed for the supply of a good. Based on the type of the good that is provided by a role, we distinguish between four role types:

- The role type "supply of a material good" contains tasks for the supply of material goods (e.g. "supply of planes").
- The role type "provision of assets" makes these material goods (assets) available for the use by others (e.g. "provision of an airport terminal")
- The role type "supply of an elementary process" involves the use of assets to execute processes (e.g. "supply of air transport process" or "supply of ground handling process").
- The coordination of different processes constitutes the role type "supply of a service" (e.g. "supply of multimodal forwarding").

A more precise description of a role can furthermore be done based on a classification of shape, space or time. For example, we could additionally describe the role "provision of a highway network" by their territorial coverage and differentiate between "provision of a highway network in Germany" and "provision of a highway network in France".

In the case of interdependencies between the goods provided by two roles, a "relationship" between these two roles occurs. Due to typical constellations between types of roles, we distinguish the following types of relationships:

- A "principal-agent relationship" exists between a principal and an agent. The principal draws requirements with regard to the good provided by the agent.
- A "time complementary relationship" is defined between roles which are connected through subsequent processes (transport, transformation or storage).
- A "de facto complementary relationships" exist between roles if their goods – from the user´s point of view – have to be used simultaneously.
- A „space complementary relationship" is defined between two roles that supply the same good in different regions.

Figure 4 exemplarily shows roles and relationships in the context of a multimodal transport.

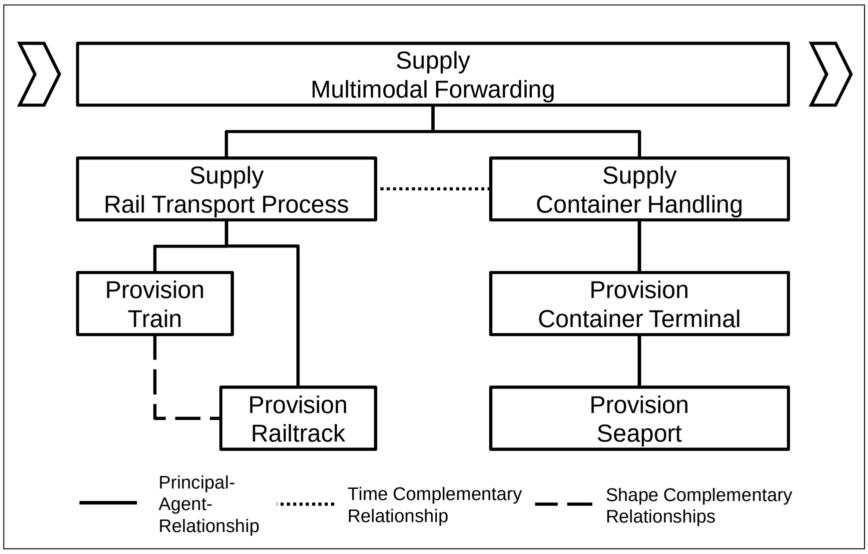


Figure 4: Example for roles and relationships in the context of a multimodal transport

C. Decisions and Coordination Areas

The tasks of a role come along with specific decisions. Complex decision situations are characterized by many decision alternatives and often by uncertainty. Furthermore, in complex systems often interdependencies between decisions exist. This means that the outcome of one decision also depend on another decision. The assignment of interdependent decisions to two different roles constitutes a "coordination area" (Figure 5). The coordination areas between two roles can be mapped on the relationship between these roles.

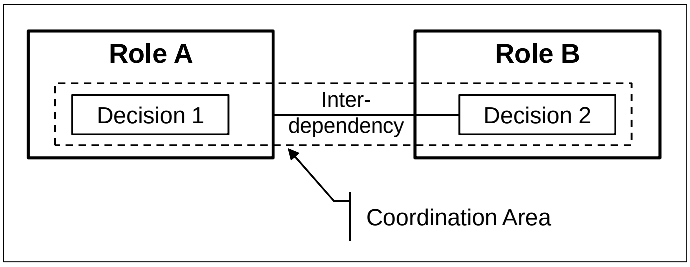


Figure 5: Decisions and Coordination Area

D. Actors, Configuration of Actors and Tangible Assets

An "actor" (an individual or an organization) accomplishes at least one role and performs the tasks associated with the role and makes the corresponding decisions. Actors are characterized by individual goals and other behavioral parameters (e.g. risk attitude), which have an enormous influence on their decision making and their willingness to cooperate in different coordination areas. Moreover, an actor possesses resources in form of assets and other resources (e.g. know-how). These have to meet the demands of the role the actor wants to maintain.

"Tangible assets" are used to physically realize a complex good. They have to meet the demands specified by the elements described in the technical system. The necessary amount of tangible assets could be determined by the quantities described in the technical system.

The "configuration of actors" describes how many actors maintain the same role (at the same time and in the same area). For example, the role "provision of cellular phone network in Germany" currently is maintained by four actors (T-Mobile, O2, Vodafone, E-Plus). The number of actors simultaneously maintaining a role arises from market processes or is determined by external regulation (see next section). In the case of more than one actor per role, so-called "competitive relationships" between these actors emerge.

E. Institutions

(Ostrom, 2005) describes institutions as "prescriptions that humans use to organize all forms of repetitive and structured interactions".[5] (North, 1990) defines institutions as "the rules of the game in a society" and as "humanly devised constraints that shape human interaction."[6] In the following we predominantly use institutions in form of rules.[7] Rules define the actors' scope of action in certain situations and lower the behavioral uncertainty in decision situations.[8] In detail, rules define necessary, prohibited and permitted actions.

[5] Cf. Ostrom (2005, S. 3).
[6] Cf. North (1990, S. 3).
[7] Rules (in contrast to norms or shared strategies) contain an "or else", hence a holder for the institutionally assigned consequence for not following the rule, cf. Ostrom (2005, S. 86 ff.).
[8] Cf. Ostrom (2005, S. 18).

Complex decision situations are characterized by a huge amount of decision alternatives and uncertainty, what makes a decision often quite difficult. Rules can reduce this problem by influencing the individual assessment of outcomes of decision alternatives in a structured manner:

- With regard to the supply of complex goods, firstly so-called "role rules" are of importance. They on the one hand define the requirement an actor must comply to simultaneously maintain a role (e.g. certification). On the other hand rules can regulate the allowed number of actors per role (e.g. licensing).
- Secondly, so-called "coordination rules" can help to reduce coordination problems in case of interdependent decisions (coordination areas). They address coordination and harmonization of these decisions. It is possible to distinguish between central coordination rules (e.g. laws) and decentral coordination rules (e.g. bilateral contracts).

To allow the analysis of the supply of rules – which is as important as the supply of material or immaterial goods – we use the concept of "institutional roles". Different types of institutional roles are concerned with the creation, monitoring and enforcement of rules. Just like the aforementioned roles, the institutional roles are maintained by actors and they also contain requirements regarding the power (needed to enforce) and the resources of actors.

The air freight supply chain from an institutional perspective

The general philosophy of (Beckers, Gizzi *et al.*, 2012) is applied to the air freight system. The air freight system contains all necessary processes from shipper to recipient of the air freight. A focus is placed on framework's discrete elements tangible assets, actors, configurations of actors, roles and institutions.

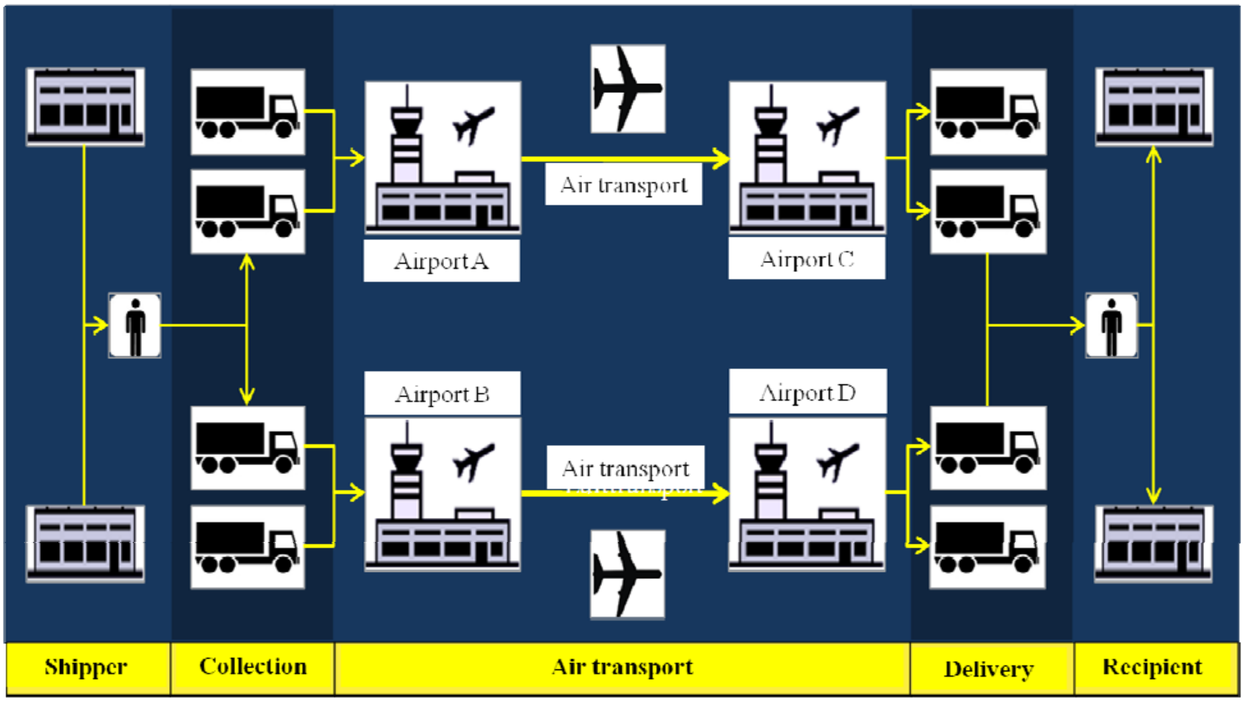


Figure 6: Air freight logistics chain (based on (Gass, 2010))

Different processes compose the air transport service from shipper to recipient. The typical three main processes of the air freight logistics chain commences after transport capacities have been sold to the (end) customer either via the airline or in general via the freight forwarder. In step 1, goods are collected by a forwarder from the (end) customer or a dedicated assembly point and are transported (usually by truck) to a trans–shipment centre. In the trans–shipment centre goods are sorted, consolidated and pooled to larger units (e.g. pallets, containers). Such units are finally packaged according to their requirements, their destination and the aircraft operating on that specific route either at the trans–shipment centre or directly at the airport. Most air freight forwarders operate trans–shipment centre directly at the airport to minimise transport cost and to be more flexible concerning available aircraft capacities. However, also the direct delivery from a non–airport trans–shipment centre to the airline is possible. In case that the end customer books capacities directly via the airline a delivery to the airport is common, and the airline carries out sorting, consolidating and pooling of the goods. This first step of the air freight logistics chain usually takes approx one fourth of total transport time (Helmig, 2005).

In step 2 ground handling agents load the aircraft and assure that all specific requirements of the transported goods are fulfilled. Afterwards, the core of the air freight logistics chain proceeds, the flight from origin to destination airport. In average air freight is in the air for only one fifth of total transport time (Helmig, 2005). This core step of the air freight logistics chain is the object of investigation for the present dissertation.

At the destination airport freight is unloaded by ground handling agents and cleared by customs (step 3). The transported units (e.g. pallets, containers) are unpooled, unconsolidated and shipped to their final destination usually by freight forwarders. The last step takes more than half of total transport time (Helmig, 2005).

The elaborations document that the following major agents exist in the air freight logistics chain:

- Airlines (air transport)
- Airports (trans-shipment point from surface to air transport and vice versa)
- Handling Agents (loading and unloading of aircrafts)
- Forwarders, including carriers (collection, delivery and consolidation of freight)
- Others (customs, etc.)

A. <u>Airlines</u>

Airlines provide air transport services for passengers and freight. In freight transportation airlines are in charge of the airport-to-airport transport but are able to offer additional services with the help of forwarding agents. Their business can be managed and organized in different ways that a deeper look into the airlines' business models and their configuration is needed. (Kleiser, 2010) developed an approach to classify airlines according to their business model which bases on three steps (Figure 7).

Step 1 – Coverage of the logistics chain

Cargo airlines are firstly examined by their coverage of the logistics chain. Vertically integrated carriers, the so–called Integrators (e.g. FedEx), offer door–to–door services (Grandjot, Roessler *et al.*, 2007) whereas airport–to–airport carriers (e.g. Lufthansa) focus on the core part of the air freight logistics chain (Jansen, 2002). The largest Integrators are FedEx, DHL, UPS and TNT. Integrators are focused on freight transport only. Therefore, only pure cargo fleets (so–called freighter aircrafts) are used which are operated on scheduled services (Kleiser, 2010). Integrators operate an air cargo network of global coverage, and their worldwide network is organized as a multiregional hub–and–spoke system with dedicated departure and arrival waves. Integrators operate large fleets of trucks to be able to carry out the delivery transports independently. Integrators' main customers are end customers whereas airport–to–airport providers primarily serve freight forwarders.

Apart from distinguishing between door–to–door and airport–to–airport providers, a third business philosophy can be differentiated the so–called Aircraft, Crew, Maintenance, Insurance Providers (ACMI Provider). ACMI providers (e.g. Atlas Air) lease their entire aircrafts (including crew) to air cargo airlines and do not offer transport services to (end) customers.

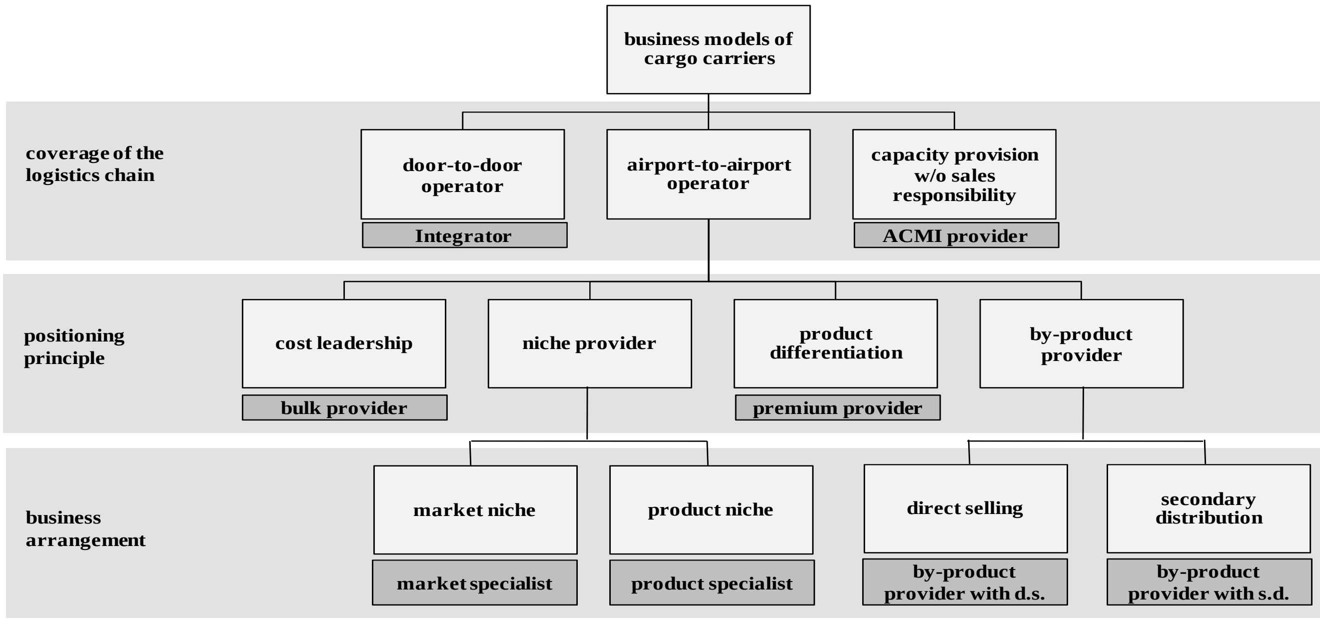


Figure 7: Classification scheme to characterize cargo airlines according to their business model

(based on (Kleiser, 2010))

Step 2 – Positioning principle

Cost leadership in a competitive market implies a very lean service and it requires easily–manufactured products (standardized products), an efficient and inexpensive distribution system and a high output level ((Porter, 1999), (Grund-Ludwig, 2008)). In the air cargo sector such properties are possessed by the so–called mass providers (or standard or bulk freight airlines). A typical mass provider is the cargo airline Cargolux. Mass providers are airport–to–airport operators with a corporate strategy of offering under–average priced services to achieve the cost leadership in the market (Kleiser, 2010). Cost leadership is achieved through economies of scale with scheduled services, high capacities, high frequencies, efficient distribution systems and standardized products and aircrafts (Grund-Ludwig, 2008). In order to achieve a competitive position as a mass provider, it is essential to have a simple business model with lean handling processes (no auxiliary services such as chilled/frozen transport products). Mass providers offer services on the major global markets, but they do not aim at a full global coverage as Integrators do. A reason for that are the high capacities and frequencies offered for achieving economies of scale. Mass providers operate a homogeneous pure freighter fleet (usually B 747F), which concentrates on selected routes with a sufficiently large demand for mass cargo. Mass providers' main customers are freight forwarders (Jansen, 2002). The freight forwarder usually operates the feeder services to/from the airport whereas the airline focuses on the airport–to–airport transport. Mass providers mainly transport standardized goods and determine their permitted sizes as well as the type of required packaging. Standardized freight does not need comprehensive customized handling activities, and lean services can be achieved by the carrier. They offer services on the major global markets but they do not aim for a full global coverage. A less concentrated and less centralized network configuration exist mass providers (Scholz, 2011).

Furthermore, the importance of single airports (e.g. the hub airport) is much smaller than for combined carriers (e.g. Lufthansa, Air France, etc.) that such carriers are relatively uncommitted to the airport and have the flexibility to change the airports to which they operate rapidly. Pure cargo airlines can be regarded as the low-cost carriers in freight transportation (cost leadership, high flexibility). (Francis, Fidato *et al.*, 2003) analyzed the impact of low-cost carriers at European airports and their airport–airline interaction and found out that the sustainability of the relationship is very questionable as market access and exit were very dynamic. The same holds true for pure cargo carriers (e.g. Jade Cargo International, Aloha Air, etc.). The primary influencing factor for pure cargo carriers is the demand structure within a radius of the airport acceptable to the airline and the operating costs at the airport.

The strategy of differentiation aims to achieve a clear distinction from competitors by concentrating on characteristics that assure an island position in the market (Porter, 1999). The intention is to tie customers by the added value of the offered products. Premium providers emphasize on a differentiation strategy. Premium providers differ from their competitors by emphasizing on quality and service in the segment of express, special and standardized cargo. Airlines following a premium strategy are e.g. Lufthansa Cargo, Air France Cargo, and Singapore Airlines Cargo. Premium providers offer a broad, fast and attractive network to their customers which are mainly freight forwarders and the production sector (Kleiser, 2010). Premium providers are globally acting passenger airlines that build their freight services on a comprehensive passenger network. Therefore, destinations can be offered with a low freight but sufficient passenger demand. H&S schemes are the predominant network configurations (with mainly one dominant hub airport) which are determined by the spatial concentration of cargo capacity at dedicated hub airports and the temporal concentration around a number of synchronized waves of flights (Scholz and Cossel, 2011). The hub airport for cargo business is the passenger hub of the airline with very high concentrations at this hub airport. The operation of a comprehensive wave-system structure that is based on a spatially concentrated airline network requires a highly sophisticated network realization including appropriate slots, sufficient airport capacities and an adequate demand that such airlines are bound for a long-term time horizon at their hub airport (Scholz and Cossel, 2011).

Step 3 – Market position arrangement

Niche providers concentrate on services for an explicit group of customers, for a special part of the logistics chain or/and for a geographically limited market. Niche providers “can achieve their strategically limited goal more effectively and efficiently than competitors who are situated in the broad competition” (Porter, 1999). Product specialists and market specialists can be differentiated (Kleiser, 2010). Goods that are transported very irregular or that need special treatment are the core business of product specialists. Product specialists need to be extremely flexible, operate pure freighter fleets only and offer services globally on–demand (charter flights). Product specialists generally do not operate a fully developed hub–and–spoke system but turn over the freight as required by their customers. Product specialists distribute their capacities via direct distribution or via chart broker (Schmeling, 2006). An exemplary airline is Volga–Dnepr which concentrates on oversized goods. Market specialists transport goods from their core market which is in most cases their home market to non–home destinations. Freight is primarily turned over at the home basis of the carrier in case that the market specialist is a pure cargo carrier or at the passenger hub of the airline when the carrier is a combined airline. Market specialists mainly transport standardized freight. Market specialists are traditional airport–to–airport providers whose main customers are freight forwarders. Airlines such as Royal Jordanian Airlines (combined carrier) and Air India (combined carrier) are market specialists.

Airlines that do not follow a predominant positioning strategy consider freight transport only as a by–product. Their overall focus is on passenger transport. Freight is only shipped on existing routes when cargo does not constrain passenger services and conveniences (e.g. maximum payload of the aircraft) and when the necessary cargo load devices fit into the operating aircraft. Such airlines can be differentiated by means of their distribution system into providers with and without a corporate distribution unit (by–product provider with direct distribution versus by–product–provider with secondary distribution).

The largest part of air freight is transported by such airport-to-airport airlines which combine passenger and freight transport. Such airlines are either premium providers (e.g. Lufthansa, Air France, etc.), market specialists (e.g. Air India, etc.) or by-product providers.

Table 1: International air freight by type of carrier (Morrell, 2011)

Business model	Freight (tone-kms in 2008)	%
Freighter flights of combined carriers	74,071	44.8
Passenger flights of combined carriers	65,364	39.5
Integrators	13,133	7.9
Pure-freighter airlines (e.g. mass providers, product specialists)	12,745	7.7
Total international	165,313	100.0

A large share of international freight is still transported in aircrafts on passenger flights. It also underlines the importance of combined airlines for the air cargo business. Out of the ten largest air cargo transporting airlines seven follow the business model of combined airlines (Table 2).

Table 2: Top 10 airlines by total FTks carried (Morrell, 2011)

Airline	Country of origin	Freight (tone-kms in 2008)	Business model
FedEx	US	15,463	Integrator
Air France	France	10,217	Premium provider
UPS	US	10,024	Integrator
Korean Air	South Korea	9,005	Premium provider

Cathay Pacific	People's Republic of China	8,842	Premium provider
Lufthansa	Germany	8,238	Premium provider
Singapore Airlines	Singapore	7,299	Premium provider
Emirates	United Arab Emirates	6,156	Premium provider
China Airlines	Taiwan	5,384	Premium provider
Cargolux	Luxembourg	5,324	Mass provider

Airlines which operate concentrated networks where a focus is placed on a limited number of airports are heavily dependent on the operational availability of these airports. Such airlines are especially combined airline which operate a large share of traffic through their passenger hub. Unscheduled limitations at the hub airport (e.g. weather events) heavily impact the entire network operations (e.g. disturbed routing, delays at secondary airports, congestion, etc.).

B. Airports

Airports are the interfaces between the surface and the air networks. Surface transport is dominated by truck delivery and distribution whereas rail only plays a marginal role within the air freight network. Airports provide runways, taxiways and aircraft parking areas which is often called the airside system (Mensen, 2007). The landside contains passenger and/or cargo terminals, surface vehicle parking areas, access roads to the trunk road network, etc. ICAO (International Civil Aviation Organization) standards serve for designing and operating these facilities (Morrell, 2011). Special emphasis for the air freight system is given to cargo terminal facilities (cargo centers) as they directly determine the effectiveness of the operating airline. Previous surveys have identified that mostly airports are the source of delays in the air freight logistics chain (Morrell, 2011). Therefore, Integrators, such as DHL, TNT, FedEx or UPS prefer to operate from secondary airports with few passenger movements where high level of flexibility exist (e.g. slots) and delays are uncommon. Integrators’ shipment sizes are less than 30 kg that automated sorting machines are used. Automation is the only opportunity for Integrators to fulfill their transportation promise and to achieve the desired turnaround times at their hub airports (e.g. Leipzig, Germany for DHL, Louisville International Airport, USA for UPS, Memphis International Airport, USA for FedEx).

Combined airlines establish their cargo hubs usually at the passenger hubs. Separate cargo terminals are used for freight handling, consolidation, storage, packaging and value added services. Cargo terminals are often owned by the major carrier or are split between carrier and airport authority. Forwarders also have their own cargo terminals at or around the airport to be flexible and to be able to consolidate freight according to destination and the operated aircraft.

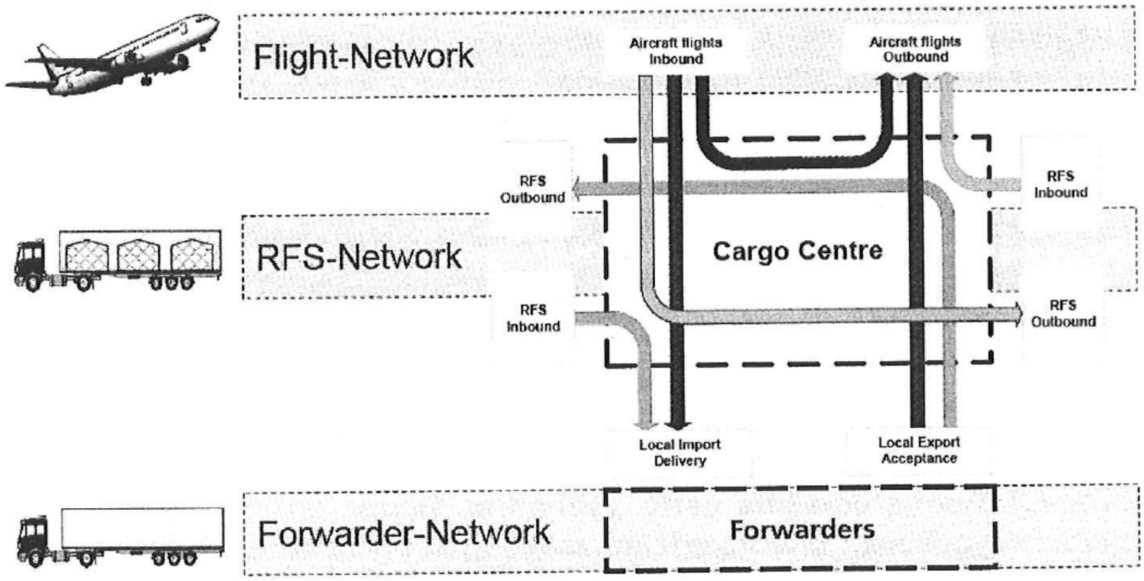


Figure 8: Airport (Grandjot, Roessler *et al.*, 2007)

A small number of airports serve as hubs in Europe. Airlines operate highly sophisticated waves of flights from their hub airports with the aim to optimize the quantity and quality of connections offered (Reynolds-Feigham, 2001). These hub airports are the gateways to the international routes which connect the world's core air freight markets. More than eighty percent of worldwide air freight is shipped between the core markets of Asia, North America and Europe (Crabtree et al., 2006). The concentration of air freight demand limits the number of airport alternatives for the airlines but airport competition can be observed in many world regions. At most primary airports (e.g. FRA, HKG, LAX) slots are hardly available for new entrants (also because of the grandfather right policies) but close-by secondary airports offer comprehensive capacities to the airlines and are not working at capacity (e.g. HHN: 115 km away of FRA, SZX: 80 km away of HKG, SNA: 65 km away of LAX). The hub airports of combined airlines have the highest importance for the European air freight system. Based on data of the WORLDNET research project Frankfurt (Lufthansa) ranks first, followed by Amsterdam (KLM), Paris Charles de Gaulle (Air France) and London Heathrow (British Airlines) (Figure 9).

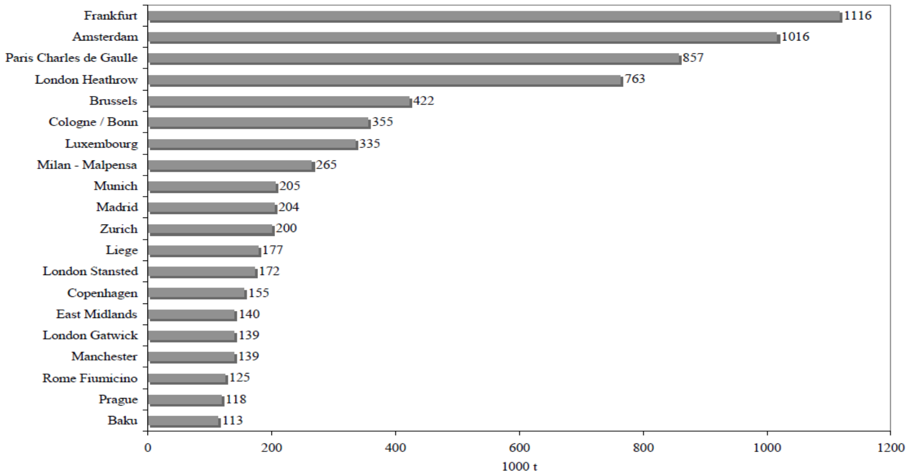


Figure 9: Concentration of air freight at European airports (WORLDNET, 2009)

The same picture can be observed for the world's airports. Few airports exist which serve as international gateways for air freight. Table 3 shows these airports and it becomes obvious that airports with an international operating combined airline are the dominating cargo airports. The higher the importance of a single airport for the airline, the higher is the potential impact of disruptions at the airport for the airline's entire network.

Table 3: Top 12 world airports in terms of international cargo tonnes, 2009 (IATA, 2010)

Airport	Tonnes (000)	Hub airlines
Hong Kong	3,350	Cathay Pacific
Seoul	2,268	Korean Air
Dubai	1,846	Emirates
Tokyo	1,810	Japan Airlines
Paris	1,785	Air France, FedEx, La Poste
Shanghai	1,775	China Eastern, UPS, Great Wall Airline
Frankfurt	1,758	Lufthansa, Deutsche Post
Singapore	1,634	Singapore Airlines
Taipei	1,345	China Airlines, Eva Airways
Miami	1,332	South American gateway
Anchorage	1,307	Transpacific transit point
Amsterdam	1,284	KLM

A different picture arises for non-hub airports of cargo carriers as these airports are mainly served because of the surrounding geographical market (local air freight demand). (Very) low concentration and centrality scores underline the low strategic importance of these airports for the entire network configuration of combined airline (Scholz and Cossel, 2011). Of the freighter operators surveyed by Gardiner et al. (2005a) around half of them (43%) had relocated a cargo service from one airport in a region to another in the same region in the past two years. The predominant reason for the relocation was an air freight demand change from a primary customer. Lufthansa, for example, operates services to Shenzhen (SZX) and Sharjah (SHJ) instead of Hong Kong (HKG) and Dubai (DXB) because of much lower airport charges and adequate feeder service opportunities to/from these airports to the surrounding core markets. Long-term collaborations (e.g. service contracts) are therefore hardly achievable and are strongly dependent on the incentives (e.g. airport charges, environmental restrictions) these airports offer to the airlines. Disruptions at secondary airports are usually of smaller significance to airlines as airport alternatives exist which can be used for emergency routing. Higher costs will incur but cascading effects can be avoided.

Liberalization of the European aviation market has lead to privatization tendencies of airports but public authorities are still highly involved in German and European airports (Table 4 and Table 5). In particular in times of unexpected (natural) events the involvement of public shareholders seems sustainable because decision making on a political level (e.g. expanded opening times of airports) goes hand in hand with airport operation requirements (e.g. additional manpower).

Table 4: Ownership structure of Germany Airports (based on company information)

Airport	Operating company	Main shareholder
FRA (Frankfurt)	Fraport AG	Federal State of Hesse (31.49%), Public utility company of Frankfurt GmbH (20.11%), Artio Global Investors Inc. (9.96%), Deutsche Lufthansa AG (9.92%)
MUC (Munich)	Flughafen München GmbH	Federal State of Bavaria (51%), Federal Republic of Germany (26%), City of Munich (23%
DUS (Düsseldorf)	Flughafen Düsseldorf GmbH	City of Düsseldorf (50%), Airport Partners Gmbh (50%, incl. HOCHTIEF Concessions, HOCHTIEF AirPort Capital and Aer Rianta)
TXL (Berlin-Tegel)	Flughafen Berlin-Schönefeld GmbH	Federal State of Brandenburg (37%), Federal State of Berlin (37%), Federal Republic of Germany (26%)
HAM (Hamburg)	Flughafen Hamburg GmbH	Federal State of Hamburg (51%), HOCHTIEF Concessions (49%)
CGN (Cologne-Bonn)	Flughafen Köln/Bonn GmbH	City of Cologne (31.12%), Federal Republic of Germany (30.94%), Federal State of Nordrhein-Westfalen (30.94%)
STR (Stuttgart)	Flughafen Stuttgart GmbH	Federal State of Baden-Württemberg (65%), City of Stuttgart (35%)
SXF (Berlin-Schönefeld)	Flughafen Berlin-Schönefeld GmbH	Federal State of Brandenburg (37%), Federal Republic of Germany (26%), Federal State of Berlin (37%)
LEJ (Leipzig/Halle)	Flughafen Leipzig/Halle GmbH	Mitteldeutsche Flughafen AG (94%), (thereof Federal State of Sachsen 76.64%, Federal State of Sachsen-Anhalt 18.54%)
NUE (Nuremberg)	Flughafen Nürnberg GmbH	Federal State of Bayern (50%), City of Nuremberg (50%)

Table 5: Ownership structure of selected European Airports (based on company information)

Airport	Share of public authorities	Share of private investors	Main private shareholder
Vienna Int. (Austria)	40.0%	60.0%	Silchester International Investors (10%), Airport Vienna AG (10%)
Brüssel Zaventem (Belgium)	30.0%	70.0%	Macquarie Airports Group (70%)
Copenhagen (Denmark)	39.2%	60.8%	Macquarie Airports Group (12,1%), LD Pensions
Athens Int. (Greece)	55.0%	45.0%	Hochtief Concessions (HTA/HTCA) (40%)
Rome Fiumicino (Italy)	0.0%	100.0%	Leonardo srl (51%), Macquarie Airports Group (44.7%)
Luqa Int. (Malta)	40.0%	60.0%	Malta Mediterranean Link Consortium Limited (40%), MML (57% Airport Vienna AG)
Ljubljana (Slovenia)	49.0%	51.0%	Pension Fund (7.4%), Slovenian Restitution Fund (6.8%), Other private investors (35.1%)
Zurich (Switzerland)	46.8%	53.2%	City of Zurich (5.4%), Small shareholders (>5%)

C. Forwarder (incl. Carrier)

Forwarders arrange the shipment on behalf of the consignor and bring together supply and demand. Freight forwarders determine the best means of transport by using services of shipping lines, airlines, road and/or rail operators. A (worldwide) network is needed, either by establishing branches in the world regions or by cooperating with reliable partners (Grandjot, Roessler *et al.*, 2007). Freight forwarders usually book capacities with several airlines well in advance. Overbooking is a well know phenomenon on the airline side. Flexibility is the key to success for freight forwarders because around 70% of international air freight shipments are emergency shipments. The level of overbooking depends on the world's economic situation and the demand for air freight services. Rates are negotiated between the airline and the forwarder on an individual basis. They are market driven and depend on the total amount the forwarder ships with the airline and on the average utilization of the route (e.g. much higher transport rates from Asia to Europe than vice versa). The high market concentration of freight forwarders which developed rapidly during the last twenty years has strength their position against the airlines (Table 10).

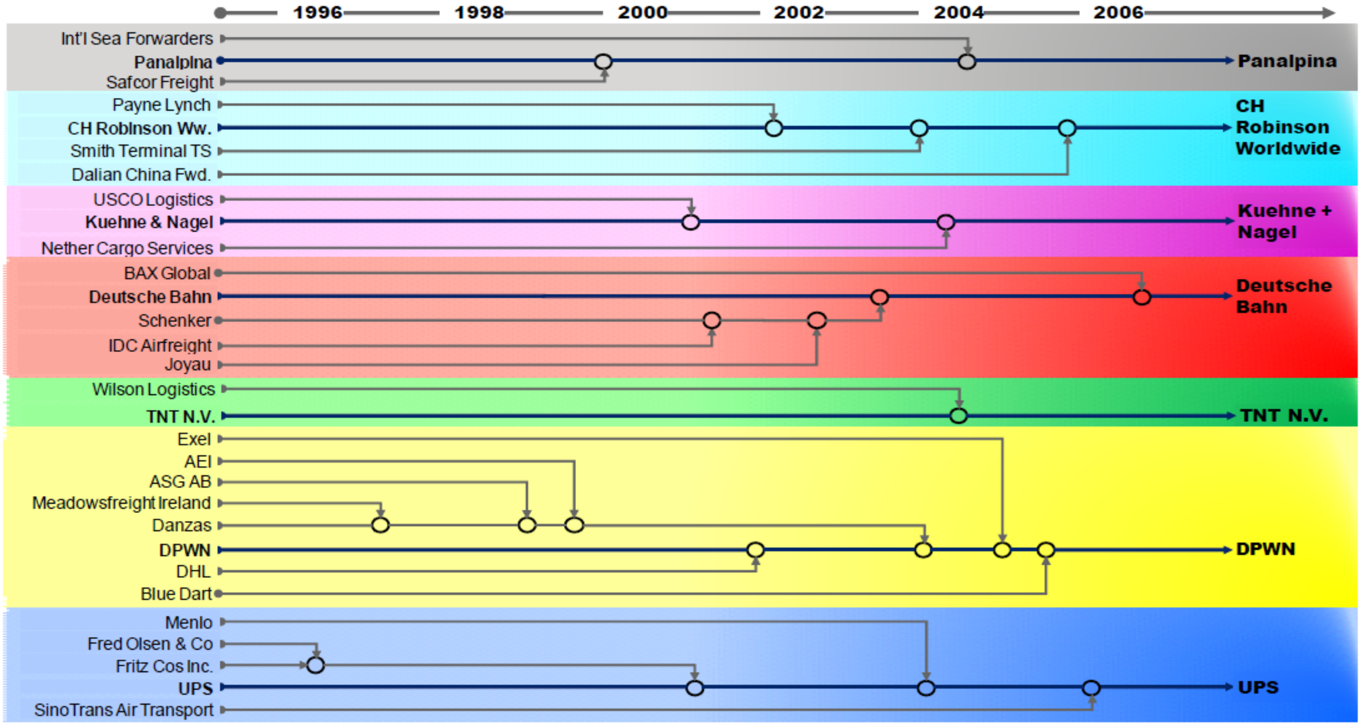


Figure 10: Development of market concentration of forwarders (Spohr, 2007)

Nowadays, the top 10 forwarding companies account for approx. 40% of total forwarding revenues. DHL is estimated to be the largest enterprise (based on revenues) with Kuehne + Nagel and DB Schenker ranked second and third (Table 6). Even though, high market concentration can be observed, still a large number of smaller forwarders exist which are either product or market specialists. Product specialists specialize in certain kinds of freight (e.g. oversized goods) whereas market specialists concentrate their business on a dedicated geographical market.

Table 6: Global freight forward value share by top 10 forwarders (Morrell, 2011)

Forwarder	% in 2008
DHL	8.8
Kuehne + Nagel	7.6
DB Schenker	5.8
Panalpina	4.2
Expeditors	3.3
Sinotrans	2.8
Agility	2.5
UPS SCS	2.4
CEVA	2.4
DVS	2.1
Others	58.1
Total	100.0

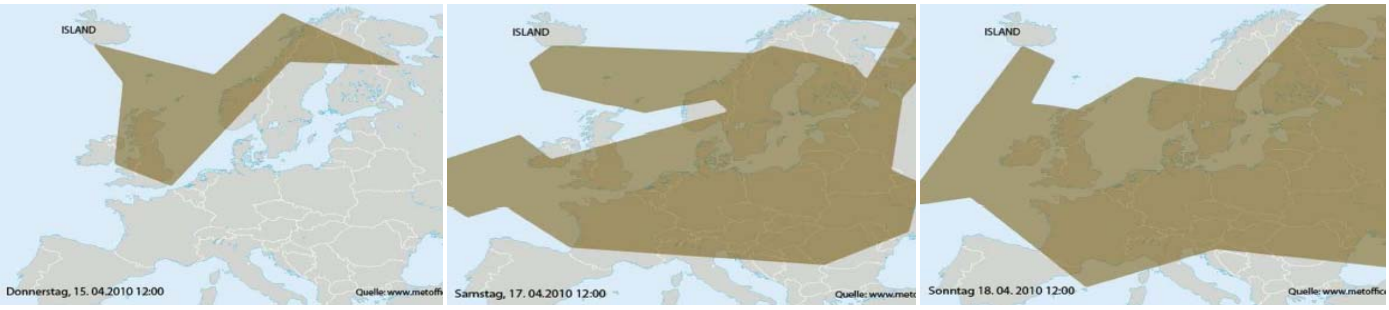
D. <u>Others</u>

Besides the three major actors of the air freight system (airline, airports and forwarders) further actors exist in the market which are especially servicing at the interfaces between the major actors. Ground handling agents are service providers who are appointed by the airline to fulfill airline-related services, such as handling of freight, (un-) loading of aircrafts, departure coordination, etc. Historically, ground handling activities were organized and operated by the national carrier or the airport authority (Grandjot, Roessler *et al.*, 2007). The trend to outsource non-core services has lead to multifaceted business models for ground handling services. Furthermore, the European Union has opened up ground handling services to competition (Directive 96/67/EC). The Directive stipulates that at larger airports access to the ground handling market is free. Only for certain categories of services (baggage handling, ramp handling, fuel and oil handling, freight and mail handling) the European Member State may limit the number of suppliers for each category but at least one has to be independent of the airport or the dominant airline. A new proposal for further liberalization packages of ground handling services is currently discussed.

Furthermore, customs authorities are assigned by each government to execute national law. In some countries customs clearance can last several days which reduces transport time advantages of air freight compared to other transport modes significantly. A smooth collaboration between the different supply chain actors is therefore crucial for efficient transport. Automated and internet-based systems are first achievements which offer time savings.

Risk management through flexibility: the case of the Eyjafjallajökull eruption

In the aftermath of Iceland's Eyjafjalljökull volcano's eruption the Airspace in Germany and much of Europe was closed for days in mid April 2010 (Table 11). The major disruptions of the flight schedule, caused by the giant ash cloud emitted by the volcano, left thousands of passengers stranded at airports all over the world and turned out to be particularly damaging for European airlines. According to estimations of the International Air Transport Association (IATA) the widespread closure of European airspace in April came along with a loss in revenues of around €1.26 billion.



Thursday, 15.04.2010 Saturday, 17.04.2010 Sunday, 18.04.2010

Figure 11: Propagation of the ash cloud of Eyjafjalljökull volcano's eruption

Clearly, economic damages could easily exceed airlines' losses. Since Europe's fragile economies were still recovering from 2008's and 2009's financial crises, any major disturbance of the production process could have hampered the economic turnaround. This is particularly true for industries that rely on air freight, such as the automobile sector. Examples exist (e.g. BMW, Opel) where companies were affected by the airspace closure and where production was brought to a halt due to missing components. Nevertheless, disruptions have been rather small. The experiences with the Eyjafjalljökull volcano's eruption show the high level of flexibility that exists in the air freight system. Therefore, the actors' course of actions but also their limitations will be analyzed in the following. With regard to the frequent occurrence of temporary disturbances, such as natural events or terrorism, and having in mind the strong interdependence of economic production, trade and (air) freight transport, these elaborations might serve as best practice for other transport modes as well as show improvement opportunities for the air freight system.

A. Institutions

Institutions set the framework for being able to operate air freight services. The authors define institutions in the understanding of (Ostrom, 2005) as rules which define the actors' scope of action. "Role rules" define the requirement (e.g. certification) an actor must comply to accomplish a dedicated role (e.g. unloading of aircrafts). "Role-rules" can be used to regulate market entrance and to limit the number of actors per role (e.g. licensing). Furthermore, "coordination rules" reduce coordination problems in case of interdependent decisions of actors (coordination areas). The following Institutions determine flexibility and opportunities in unexpected events of the air freight system:

- Air Service Agreements
- Security guidelines (including Dangerous Goods Regulation)

In contrast to other transport modes, and especially to shipping, no unique international law exists for air transport. Historically, each country had its own flag-carrier. National and political interests dominated and in a liberalized environment still dominate the business (Grandjot, Roessler *et al.*, 2007). After World War II international flights had grown significantly that an international framework was thought essential. The Chicago Convention (1944) set standards for civil aviation both technical and commercial aspects but failed to include economic regulation for international air transport services (Morrell, 2011). Therefore, a web of bilateral or multilateral Air Service Agreements emerged. Air Service Agreements are rules ("role rules") between at least two countries which define the conditions under which airlines of these countries are able to operate services between them. Air Service Agreements contain traffic rights for the carriage of passenger and freight, capacity restrictions and tariff and price information. Traffic rights can be provided in a variety of ways, ranging from very liberal (including cabotage rights) to restrictive (only overfly rights). The Freedoms of the Air define the level of liberalization between the signatory countries. Even for emergency landings the second degree of freedom is necessary which allows technical stops in another country. Open sky agreements between countries are increasing which minimizes governmental interventions and allows market based routing of airlines. Since 1998, flights between member states of the European Union are treated as domestic flights which allows airlines of another country to carry out services on routes with origin/destination airports in its home country. Five important principles are defined for air freight (Morrell, 2011):

- National ownership of airlines is replaced by EU ownership
- Unrestricted third, fourth and fifth freedom rights on all intra-EU routes
- No restrictions on frequency, capacity and aircraft type
- Complete rate setting freedom, subject to regulatory intervention on predatory grounds
- No distinction between scheduled and charter services

Especially the unrestricted rights on all intra EU routes are essential for a high flexibility of air services especially in case of unexpected events, such as the Eyjafjalljökull volcano's eruption. Airlines are able to re-route their inbound services to other countries where airports are still operable and are also allowed to operate outbound services from these airports. Furthermore, charter services could be offered from every European Union's airport.

Besides the right to land, debark, embark or departure at an airport the question how and from whom freight is handled during the air freight supply-chain and if security guidelines are guaranteed also for alternative transport choices (e.g. emergency airport). Especially since 9/11 and the more recent discovery of bombs in cargo planes strict guidelines have been developed for securing shipments, aircrafts and third parties against terrorist attacks. Prior 9/11 security measures have dealt with restricted access to the airside areas of airports and security checks of passengers. Both measures have been tightened up and (in some countries) extended to domestic flights because of transfer opportunities at hub airports (Morrell, 2011). Cargo security needs to be achieved in a different way because screening of all air freight is not practicable (trade-off between effectiveness and cost) and would lead to significant disadvantages compared to competitive transport modes (e.g. shipping, rail). The European Union established a number of Directives to cover air freight security[9]. The basis of European air freight security is the known shipper/agent approach ("role-rule"). All cargo no matter how it is transported (passenger vs cargo flights) is subjected to security controls before loading on an aircraft. The airlines only accepts cargo (and mail) if it either has been controlled by itself or their application has been confirmed and accounted for by a regulated agent, a known consignor or an account consignor (EC 300/2008). A known consignor is an accredited company which guarantees that dedicated security guidelines are fulfilled within their company's territories. In Germany, in the past a consignor needed to sign a "security declaration" to their respective forwarders to receive the known consignor status. As of April 29, 2010 government aviation security authorities certify known consignors and a standardized evaluation process is needed. Once approved the known consignor is published in an EU-wide database which can be accessed by regulated agents. Regulated agents are logistics companies (including shipper and trucker) which carry out the transport service and which are responsible to supervise the rules in the airfreight transport chain. Regulated agents also need to be certified by local authorities. Freight transport is only defined as secured if the all steps of the transport chain (e.g. pick-up, consolidation, delivery) are carried out by certified companies (e.g. sub-contractors and haulage companies).

Freight which was sent by known consignors and which is shipped by a regulated agent is defined as secure and can be transported by the airlines without further security measures. The same holds true in case that an unknown consignor's freight is secured by a regulated agent (e.g. by x-rays). Finally, freight of an unknown consignor or/and an unregulated agent needs to be screened and secured by the airline. A period of transition has been defined to allow companies to be certified and to receive the new and updated accreditation. The transition period terminates in Germany on March, 25 2013.

In the past, approx. 10% of German air freight has been unsecure because of an unknown consignor or/and an unregulated agent. The airline or a regulated agent needed to scan and secure such freight. It is expected that the scan rate will increase to 30 – 50% after the transition period (Bierwirth, 2011). Capacities at the airports and at the air freight terminals of the freight forwarder are not designed for such dimensions and space hinders further expansions which could cope with such volumes. A lot of pressure is put on transport companies (incl. haulage companies) to get certified and on logistics companies to provide x-ray capacities for unsecured air freight (security gateways at consolidation terminals of forwarders). Contrarily, consignors are very reserved to certify as known consignor because of

[9] EC 300/2008, EC 272/2009, EC 18/2010, EC 185/2010, EC 357/2010, EC 358/2010 and EC 72/2010

comprehensive guidelines for the valuation process as well as of liability and responsibility claims in case of an event.

The most comprehensive security guidelines exist for freight transported on passenger aircraft to/from the US. A system is required which guarantees to screen 100% of cargo no matter who sends or transports the freight or where it is embarked. Such guidelines need to be considered and followed also in emergency events.

On an international level the treatment of dangerous goods is regulated by the International Air Transport Association (IATA) the international industry group of airlines. The dangerous goods regulation (DGR) is published in Annex 18 to the Convention on International Civil Aviation (Grandjot, Roessler *et al.*, 2007). All IATA airlines are obliged to carry only those dangerous goods which are defined by IATA. Furthermore, uniform standards on labeling, naming, packaging, trainings, etc. are provided by IATA.

Besides these generally accepted guidelines, such as dangerous goods guidelines, Air Service Agreements and security guidelines which can be characterized as "role rules" and which define the requirement an actor must comply with to accomplish air freight services, also institutions between actors exist which are negotiated between them (e.g. service contracts). Such institutions are the so called "coordination rules" which reduce coordination requirements in case of interdependent decisions of actors. The standard shipping documents for air freight services is the Air Waybill. Information on shipper and consignee, departure and destination airports, goods description, weight, charges and signature are needed. Where an air cargo forwarder consolidates individual shipments into larger units a Master Air Waybill is sufficient. Air Waybills refer to a receipt issued by an international airline that the goods are handed over to the airline. General terms and conditions are defined by IATA to standardize contracts and especially to harmonize liability limits for air cargo services.

Finally, contracts also exist between consignor and freight forwarder, between freight forwarder and hauling companies, between airlines and airports, between airlines and ground handling agents, etc. The competitive environment leads to negotiations between the actors on the general terms and conditions. As for the Air Waybill guidelines also exist for these contracts but do not have to be followed by the parties. Liability limits, responsibilities, etc. for the normal case as well as in case of unexpected events are then defined by the individual contract.

B. Capacity

An unexpected event was the eruption of the Eyjafjallajökull volcano in Iceland and in particular the impact of its ash cloud on Europe's aviation system. Airports were closed, aircrafts were grounded and cargo terminals were overcrowded from exports whereas imports were cut. Paradoxically, Europe's economy was only little affected because a high level of flexibility was observed within the air freight system as well as for the affected industries. The example of the Eyjafjallajökull volcano served as scenario which was applied in expert interviews with representatives of an air freight forwarder as well as a leading European airline. The previous elaborations have shown that three different capacities might limit the flexibility of the air freight system in case of an unexpected event:

- Runway capacities at alternative (emergency) airports (do reserve capacities exist which can absorb additional flights)
- Air cargo terminal capacities (does capacities exist which can be used for additional freight handling or do terminals work at capacity already)
- Truck capacities (can additional feeder or truck-flight services be operated)

a) Truck capacities

The maintenance of a secure air freight supply chain depends on sufficient capacities also on the road. Rerouted inbound or outbound flights to or from alternative airports as well as additional charter services from airports which are still in operation require comprehensive additional trucking capacities. The air freight logistics chain is optimized according to the status-quo (normal case) that unexpected events lead to inefficient but effective transport operations. Therefore, above-average road capacities are needed for operating the additional feeder services. Also feeder services in case of unexpected events need to be operated under the European Directive on common rules in the field of civil aviation security (EC 300/2008). Security guidelines need to be fulfilled. The European Directive 185 (2010) defines that persons implementing security controls for cargo and mail other than screening (e.g. truckers) need to be trained according to air freight security. Staff of a regulated agent (logistics company) needs to be instructed by a representative of a public authority (Luftfahrtbundesamt) which takes approx four hours but can hardly be carried out at short notice. In contrast, staff of road haulier needs to be instructed only that the road transport can be carried out without major barriers but handling (consolidation, packaging, etc.) can become a problem which is carried out by staff of the regulated agent. The question remains whether sufficient truck capacities are available for additional air freight feeders.

2.385.100 trucks (2010) have been licensed in the largest air freight market, namely Germany. With these trucks over 3 billion tonnes of freight were transported. In contrast, the entire air freight services (inbound and outbound tonnages to/from German airports) sum up to only 4 million tonnes in 2010. In case that the entire air freight demand needs to be transported by truck to alternative airports, a maximum increase in road freight services of 0.13% would be necessary (ceteris paribus), a negligible small value. Furthermore, the high value of goods which is transported by air would lead to a high willingness to pay for the additional truck services that the supply of sufficient truck capacity (including staff) will not restrict the flexibility of the air freight system.

b) Runway capacities

Airports provide the infrastructure which serves as interfaces between air and surface transport system. Runways, taxiways, aircraft parking areas and terminals are the primary infrastructures. In case of unexpected events when flexible alternative supply chains are needed, sufficient infrastructure capacities are required. In particular, runway capacities as well as terminal capacities are seen as limiting factors by experts as well as in theory (e.g. (Urbatzka and Wilken, 2011)) which will be analyzed in the following[10].

The general term capacity refers to the capability of an infrastructure to handle people, freight, vehicles, etc. Capacity is used as the maximum number of traffic units which pass through the facility within a given time span (Urbatzka and Wilken, 2011). In strategic airport planning annual capacities are used as indicator and airport infrastructures are designed to accommodate annual volumes. Detailed airport and infrastructure planning applies an airport's hourly capacity as planning criterion. Empirical approaches to estimate hourly capacities are based on observations, surveys, and statistics (Wilken, Berster *et al.*, 2011). The paper follows the approach of (Wilken, Berster *et al.*, 2011) who estimates the declared capacity of airports based on traffic ranking curves functions relating the 5% peak hour traffic volume (dependent variable) with the annual traffic. Six runway capacity classes have been calibrated based on OAG data with annual traffic volume, runway utilisation, and regulation conditions as independent variables. Single runway, two runways (independent parallel), two runways (dependent parallel), two runways (crossing system), three runways and four runways and more have been differentiated. The results of the regression model are displayed in Table 7.

Table 7: Estimation results (dependent variable: 5% peak hour volume of an airport) (Wilken, Berster *et al.*, 2011)

RWY system	Variable	Coefficient	Mean	Min/Max	R^2	No. of obs.
Single RWY	Constant	−213.085347***			89.41%	58
	LN(YACM)	22.9069415 ***	87473	72360/197511		
	GF	−0.00409076***	5831	4388/7481		
Two RWYs, independent parallel	Constant	49.9137726 ***			98.12%	23
	YACM	0.00020994 ***	180545	75668/430154		
	GF	−0.00703262***	6966	5927/8581		
Two RWYs, dependent parallel	Constant	34.9994481 ***			96.29%	29
	LN(YACM)	0.00020215 ***	155934	73367/347602		
	GF	−0.00478635 ***	6735	5124/8784		
Two RWYs, crossing	Constant	−353.486327***			98.51%	21
	LN(YACM)	37.4226666 ***	139783	74270/386757		
	GF	−0.00811951***	6613	5466/8783		
	EUR	−3.14929516***				
Three RWYs	Constant	−500.055692***			93.49%	40
	LN(YACM)	47.7821666 ***	210778	72261/479294		
	GF	−0.00452502***	6781	5990/8641		
	EUR	−4.22136284***				
Four RWYs and more	Constant	77.0506432***			99.15%	29
	YACM	0.0002053***	377438	113195/956380		
	GF	−0.01064904***	6928	5782/8334		
	EUR	−0.0010366***				

The regression models have been applied to European airports to analyze if runway capacities exist which can be used in case of unexpected events. The largest European airports are considered because expert interviews have shown that airlines and airfreight forwarders prefer operating from airports which are also serviced normally. Data are taken from Eurostat (YACM: flight movements) and from the study on "Assessing the Economic Costs of Night Flight Restrictions" (GF: opening hours). Only airports were considered with annual movements of at least 70,000 because data for calibrating the regression models

[10] Expert interviews have been carried out with freight forwarders and an international operating cargo airline.

only considered “large” airports. The calculated values are compared to the declared capacity to be able to estimate utilisation and reserve capacity of the airports. Flight Plan Coordinators determine the so-called declared capacity of airports. The resulting capacity reflects the airport’s capacity under current regulation (e.g. night flight ban, etc.) and serves as good indicator for the present research question as in case of comprehensive unexpected events (e.g. ash cloud) regulations might be released. Therefore, declared capacity presents a lower limit for airport’s capacity which can be realized in any way.

Table 8 displays European airports with reserve capacities. These airports are located around Europe. Thus, only short distances to these alternative airports are needed in case of unexpected events. A few of these airports even serve as hub airports for their respective flag carrier (e.g. Athens International with Olympic Airlines, Copenhagen-Kastrup and Oslo Gardermoen with SAS, Rome Fiumicino with Alitalia, Vienna International with Austrian) but mainly secondary airports have reserve capacities (e.g. Berlin, Cologne/Bonn, Dublin, Manchester, etc.). The primary European hub airports are summarized in Table 9 where airports which operate at capacity are displayed (e.g. Paris Charles-de-Gaulle, Frankfurt, London Heathrow).

Table 8: Airports with large flight movements and without capacity problems

Airport	**Annual volume in 2010 (in flight movements)**	**5% peak hour (flights per hour)**	**Declared Capacity (flights per hour)**	**Utilisation (%)**
Athens Airport	186,613	29	60	0.48
Berlin Brandenburg (approximated value)	215,000	53	90	0.59
Berlin Tegel	150,485	37	52	0.71
Brussels Airport	205,227	49	74	0.66
Cologne/Bonn	120,634	20	52	0.39
Copenhagen-Kastrup	240,553	56	83	0.67
Dublin Airport	156,415	28	54	0.51
Hamburg Airport	138,445	32	53	0.60
Hensinki Vantaa	169,934	30	80	0.38
London Stansted	142,987	34	50	0.68
Manchester Airport	148,877	39	61	0.64
Milan Malpensa	187,764	32	70	0.45
Oslo Gardermoen	212,074	48	65	0.73
Palma de Mallorca	165,156	24	60	0.40
Paris Orly	215,618	50	70	0.71
Rome Fiumicino	327,344	53	90	0.59
Stockholm Arlanda	185,429	34	84	0.40
Stuttgart	111,740	26	42	0.62
Vienna	242,323	40	68	0.60

International				

Table 9: Airports with large flight movements and with capacity problems

Airport	Annual volume in 2010 (in flight movements)	5% peak hour (flights per hour)	Declared Capacity (flights per hour)	Utilisation (%)
Amsterdam Schiphol	390,378	91	110	0.83
Barcelona	268,537	51	61	0.83
Düsseldorf	211,359	48	47	1.02
Frankfurt	455,993	98	84	1.17
Istanbul Atatürk International Aorport	286,953	54	40	1.34
London Gatwick	233,542	53	53	1.00
London Heathrow	449,233	102	88	1.16
Madrid-Barajas	426,941	95	120	0.79
Munich	368,219	85	90	0.95
Paris Charles-de-Gaulle	491,900	110	115	0.96
Zurich	227,377	55	66	0.83

The analysis has shown that sufficient runway capacities exist in Europe. Secondary airports are able to absorb additional demand at short notice. Because only airports with at least 70,000 flight movements per annum have been considered it can be expected that at smaller airports reserve runway capacities are available. Nevertheless, the smaller the airport the less likely it is that sufficient ground handling equipment is present which is needed for (un) loading the aircrafts. Therefore, the assumption of focussing on larger airports is a close-to-reality approach which analyzes the airports which might serve as alternative airport only. Finally, it also becomes obvious that in case of unexpected events, the existing hubs (e.g. Paris, Frankfurt) cannot serve as alternative airports and will not be able to absorb additional demand.

c) Air freight terminals

In air freight terminals cargo is handled, consolidated and packaged for air transport. Usually three types of air freight terminals are differentiated:

- Type 1: Air freight terminals for mainly inbound and outbound freight
- Type 2: Air freight terminals with inbound and outbound freight and additionally a significant share of trans-shipment cargo
- Type 3: Air freight terminals with only trans-shipment cargo

Depending on the primary air freight business of the airport and/or its main customer (airline) terminals need to be designed and dimensioned accordingly. Reserve capacities of existing air freight terminals are analyzed in detail in the following with the objective to assess if additional demand can be handled by these terminals or if terminals determine flexibility of the air freight system. Therefore, the largest European passenger and freight airports are considered (plus the largest 10 German air freight airports)[11]. Data on terminal capacities has either been determined from publications of the airports or by available maps.

Table 10: Air freight terminal capacity (incl. freight volumes)

Airport	Air freight terminal at the airport [m²]	Air freight (inbound and outbound)[12] [t]	Proportion of terminal capacity to air freight [t/(m²*a)]
Amsterdam Schiphol	315,000	1,538,034	4.9
Athens Airport	11,250	82,343	7.4
Barcelona El Prat	48,100	105,899	2.2
Bergamo/Orio al Serio	15,800	105,787	6.7
Berlin Brandenburg	12,000	30,692	2.6
Brussels	95,000	384,029	4.1
Cologne/Bonn	67,100	638,184	9.5
Dublin Airport	21,650	105,339	4.9
Düsseldorf	23,600	87,061	3.7
Frankfurt	486,940	2,270,237	4.7
Frankfurt-Hahn	34,809	164,523	4.7
Hamburg	19,000	27,221	1.4
Helsinki Vantaa	34,000	157,508	4.6
Istanbul Atatürk	74,000	381,174	5.2
Kopenhagen Kastrup	39,900	138,088	3.5
Leipzig/Halle	68,000	637,815	9.4
Liège-Bierset	76,400	693,434[13]	8.4
London Gatwick	24,000	108,552	4.5
London Heathrow	162,200	1,551,308	9.6
London Stansted	35,000	229,812	6.6
Luxembourg	77,000	705,829	9.2
Madrid Barajas	57,600	400,477	7.0
Manchester	45,000	116,559	2.6
Milan Malpensa	40,000	432,667	10.8
Munich	53,000	291,061	5.5
Nottingham East Midlands	58,850	304,049	5.2
Nuremberg	30,000	7,964	0.3
Oslo Gardermoen	25,000	44,668	1.8
Palma de Mallorca	5,500	16,256	3.0
Paris Charles-de-Gaulle	391,000	2,399,067[14]	6.1
Paris Orly	56,500	102,618[15]	1.8

[11] In addition, the largest ten German freight airports are also incorporated. Because of double-counting 36 airports will be analyzed in the following.
[12] Data are taken from Eurostat (2010) if not other stated
[13] Data is taken from Airport Liège-Brest
[14] Data is taken from Aéroports de Paris

Rome Fiumicino	24,000	164,368	6.8
Stockholm Arlanda	42,000	99,390	2.4
Stuttgart	40,000	29,531	0.7
Vienna International	55,000	231,763	4.2
Zurich	50,000	304,166	6.1

Information on the effectiveness of air freight terminals is rare and several characteristics determine the performance of terminals, such as mail versus standard cargo versus perishables. A valuation is achieved by applying benchmarks which have been determined by (VDI, 1996) and which are displayed in Table 11.

Table 11: Air freight terminal capacity (incl. freight volumes) (VDI, 1996)

Terminal type	**Planned capacity**	**Performance**	
		range	**average**
1	< 75,000 t/a	6 – 15 t/m²	10 t/m²
2	75,000 – 250,000 t/a	6 – 15 t/m²	10 t/m²
3	> 250,000 t/a	10 – 20 t/m²	15 t/m²
4	different (e.g. Integrator terminals)	5 – 10 t/m²	9 t/m²

The performance values are based on 24 terminals which have been analyzed by (VDI, 1996). Comparing the average with the calculated values it becomes obvious that most terminals are currently not working at full capacity. Even when assuming that a level of uncertainty exist in the above mentioned values capacities are still present at most airport. No differences can be observed for hub or secondary airports that for both airport categories reserve capacities are available. Airport specific information and discussions can be found in (Schreck, 2011) including further analyses on freight forwarder terminal capacities at and around airports.

[15] Data is taken from Aéroports de Paris

Conclusions

Air freight has developed at high growth rates and even if the share of air freight to total freight (measure in tonnes) is low, the share of values transported is extremely high. In particular, high valued goods are transported by air and determine the need for a fast and reliable supply chain. Based on an institutional framework the air freight system is analyzed systematically. Three major actors could be extracted, namely the airlines, the airports and the freight forwarders. Further actors exist which play secondary roles for the entire system (e.g. ground handling agents, customs). A dedicated focus is placed on the regulatory environment (e.g. Air Service Agreements, Security guidelines) and on Europe's air freight capacities. Both directly determine the flexibility of actors within the air freight system. Capacities have been analyzed in three different ways:

- Runway capacities of the airports (are sufficient airport capacities available that airlines can react in case of unexpected events?)
- Air freight terminal capacities at the airports (do terminal capacities determine the reactivity of airlines)
- Staff and truck capacities (is it possible to retain security guidelines also in case of unexpected events, e.g. European Directive 185/2010: "Standards on aviation security").

The framework as well as the capacity and the institutional considerations have been filled out with modelled data, information obtained from literature and interviews with aviation professionals. Results show that sufficient runway capacities exist in the European air freight system. Especially secondary airports are able to absorb short-term demand peaks. The same was observed for air freight terminals. All but very few are already working at or close to capacity that reserve capacities do exist in the system. The question whether ground handling equipment (incl. staff) should be hold available at secondary airports should be discussed between airlines, airports and the public. In case of unexpected events a high level of flexibility can be maintained if equipment is available at alternative airports. The question who has to bear the cost for the equipment (incl. cost of capital, wages, etc.) which is only needed in case of events and is therefore not utilized to capacity is crucial. A fair allocation to the entire system reveals necessary as otherwise no individual stakeholder has incentives to hold infrequently used equipment available.

References

Beckers T, Gizzi J, and Jaeckel K (2012) Ein Untersuchungsansatz für Systemgüter: Einordnung, Darstellung, Vorgehen bei der Anwendung. WIP-Workingpaper No. 2012-1, www.wip.tu-berlin.de/typo3/index.php?id=2971.

Bierwirth B (2011) Sicherheitsdebatte Luftfracht. Internationales Verkehrswesen, 63, 34-36.

Brandenburger AM and Nalebuff BJ (1998) Co-opetition: 1. A Revolutionary Mindset that combines competition and cooperation, 2. The Game Theory Strategy that's changing the Game of Business., Currency Doubleday, New York.

Eurocontrol (2011) Performance Review Report on European Air Traffic Management Performance in 2010. Brussels.

Francis G, Fidato A, and Humphreys I (2003) Airport-airline interaction: the impact of low cost carriers on two European airports. Journal of Air Transport Management, 9, 267-273.

Gass J (2010) Räumliche Verteilung des Luftfrachtaufkommens. Bachelor Thesis at the Institute for Economic Policy Research, Karlsruhe Institute of Technology.

Goedeking Ph (2010) Networks in Aviation., Springer-Verlag, Berlin.

Grandjot H-H, Roessler I, and Roland A (2007) Air Cargo Guide. 1 edn, Huss-Verlag GmbH, Munich.

Grund-Ludwig P (2008) Wettbewerb der Frachtflieger verschärft sich. In Handelsblatt, 30.05.2008.

IATA (2010) World Air Transport Statistics. Canada.

Jansen J-P (2002) Die zukünftige Entwicklung der Luftfracht [Neuntes Kolloquium Luftverkehr]. In Arbeitskreis Luftverkehr der TU Darmstadt, Darmstadt.

Kleiser KJ (2010) Kategorisierung und Bewertung von Geschäftsmodellen in der Luftfracht. In Diploma Thesis at the Institute for Economic Policy Research, Karlsruhe Institute of Technology.

Mayntz R and Scharpf FW (1995) Der Ansatz des akteurzentrierten Institutionalismus. In Mayntz R and Scharpf FW (eds) Gesellschaftliche Selbstregelung und politische Steuerung. Campus Verlag, Frankfurt, pp. 39-72.

Mensen H (2007) Planung, Anlage und Betrieb von Flugplätzen., Springer-Verlag, Berlin.

Morrell PS (2011) Moving boxes by air: The economics of international air cargo., Ashgate Publishing Limited, Farnham.

North DC (1990) Institutions, Institutional Change and Economic Performance., Cambridge University Press, Cambridge.

Ostrom E (2005) Understanding Institutional Diversity. Princeton.

Porter ME (1999) Wettbewerbsstrategie. Methoden zur Analyse von Branchen und Konkurrenten. 10 edn, Campus-Verlag, Frankfurt.

Reynolds-Feigham A (2001) Traffic distribution in low-cost and full-service carrier networks in the US air transportation market. Journal of Air Transport Management, 7, 265-275.

Schmeling U (2006) 2005 - ein Superjahr für die Spezial-Luftfracht. Internationale Transport Zeitschrift, 13-14, 19.

Scholz AB (2011) Spatial network configurations of cargo airlines. Working paper series in Economics, 20, http://econpapers.wiwi.kit.edu/downloads/KITe_WP_20.pdf.

Scholz AB and Cossel vJCh (2011) Assessing the importance of hub airports for cargo carriers and its implications for a sustainable airport management. Research in Transportation Business and Management, 1, 1, pp. 62-70.

Schreck A-K (2011) Auswirkungen extremer Ereignisse auf Logistiknetzwerke im Zu- und Ablauf von Luftfracht. Bachelor Thesis at the Institute for Economic Policy Research, Karlsruhe Institute of Technology.

Spohr C (2007) Luftfrachtverkehr und die Lufthansa Cargo. Lecture at the Karlsruhe Institute of Technology.

Urbatzka E and Wilken D (2011) Estimating runway capacities of German airports. Journal of Transportation Planning and Technology, 20, 103-129.

VDI (1996) Airport Logistics: Gepäckbeförderung, Catering, Fracht. In VDI Berichte (ed) VDI-Verlag, Düsseldorf.

Wilken D, Berster P, and Gelhausen MC (2011) New empirical evidence on airport capacity utilisation: Relationships between hourly and annual air traffic volumes. Research in Transportation Business and Management.

WORLDNET (2009) Deliverable 8. Research Project funded by the European Commission under the 6th RTD Programme.