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ECONOMIC EFFECTS AND COSTS OF A TEMPORARY SHUTDOWN OF AN AIRPORT – REVIEW AND CASE STUDY

DE LANGHE KATRIEN, DEPARTMENT OF TRANSPORT AND REGIONAL ECONOMICS, UNIVERSITY OF ANTWERP, ANTWERP, BELGIUM. PRINSSTRAAT 13, ANTWERP, BELGIUM. EMAIL: KATRIEN.DELANGHE@UA.AC.BE

STRUYF ELS, DEPARTMENT OF TRANSPORT AND REGIONAL ECONOMICS, UNIVERSITY OF ANTWERP, ANTWERP, BELGIUM. PRINSSTRAAT 13, ANTWERP, BELGIUM. EMAIL: ELS.STRUYF@UA.AC.BE

SYS CHRISTA, DEPARTMENT OF TRANSPORT AND REGIONAL ECONOMICS, UNIVERSITY OF ANTWERP, ANTWERP, BELGIUM. PRINSSTRAAT 13, ANTWERP, BELGIUM. EMAIL: CHRISTA.SYS@UA.AC.BE

VAN DE VOORDE EDDY, DEPARTMENT OF TRANSPORT AND REGIONAL ECONOMICS, UNIVERSITY OF ANTWERP, ANTWERP, BELGIUM. PRINSSTRAAT 13, ANTWERP, BELGIUM. EMAIL: EDDY.VANDEVOORDE@UA.AC.BE

VANELSLANDER THIERRY, DEPARTMENT OF TRANSPORT AND REGIONAL ECONOMICS, UNIVERSITY OF ANTWERP, ANTWERP, BELGIUM. PRINSSTRAAT 13, ANTWERP, BELGIUM. EMAIL: THIERRY.VANELSLANDER@UA.AC.BE

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De Langhe Katrien, Department of Transport and Regional Economics, University of Antwerp, Antwerp, Belgium. Prinsstraat 13, Antwerp, Belgium. Email: katrien.delanghe@ua.ac.be

Struyf Els, Department of Transport and Regional Economics, University of Antwerp, Antwerp, Belgium. Prinsstraat 13, Antwerp, Belgium. Email: els.struyf@ua.ac.be

Sys Christa, Department of Transport and Regional Economics, University of Antwerp, Antwerp, Belgium. Prinsstraat 13, Antwerp, Belgium. Email: christa.sys@ua.ac.be

Van de Voorde Eddy, Department of Transport and Regional Economics, University of Antwerp, Antwerp, Belgium. Prinsstraat 13, Antwerp, Belgium. Email: eddy.vandevoorde@ua.ac.be

Vanelslander Thierry, Department of Transport and Regional Economics, University of Antwerp, Antwerp, Belgium. Prinsstraat 13, Antwerp, Belgium. Email: thierry.vanelslander@ua.ac.be

ABSTRACT

Airports are crucial nodes, ensuring the economic activity in a region. This paper reports on the direct and indirect effects, and the corresponding costs of a temporary shutdown of an airport. Airports can be shut down for several reasons and this can have major effects on different stakeholders. Therefore, this paper offers an analysis of the shutdown issue. This analysis allows stakeholders to prepare themselves in case a shutdown occurs and/or to take measures on a short notice.

To identify the effects of a shutdown of an airport, first, an overview is made of all possible causes that can lead to a temporary shutdown. Second, a typology is set up, including possible implications for each type of disturbance as well as a set of relevant stakeholders. Third, an overview is made of all possible effects, including the valuation of these effects and an assessment of the possible economic loss for each possible effect. Different scenarios are employed. Fourth, the theory is applied on a case study at Brussels Airport.

The analysis indicates that the shutdown of an airport can cause important consequences for several stakeholders. Furthermore, the findings suggest that a temporary shutdown of an airport can disrupt the economic activity in a region. Knowledge of the possible consequences is most interesting for policymakers.

Keywords: airport, shutdown, cost, economic effects

INTRODUCTION

Airports are crucial nodes, ensuring the economic activity in a region. Since the ash cloud of 2010, growing interest has been directed towards the issue of shutdowns of airports. Recent shutdowns of airports indicate that those can occur in airports all over the world due to many different reasons. Appendix 1 gives a non-exhaustive overview of shutdowns that happened in the recent past and indicates the cause of the shutdown, the airport(s) involved and the consequences. Shutdowns can last for a few hours as well as for some weeks.

Previous studies (Shangyao Yan & Chung-Gee Lin, 1997; Government of Canada, 2002; Rupp, Holmes & DeSimone, 2003; Balvanyos & Lave, 2005; Gordon, Moore II, Park & Richardson, 2007) have produced estimates of the economic implications of terrorism on commercial aviation and the cost of a shutdown for a specific stakeholder. Pejovic, Noland, Williams & Toumi (2009) simulated and assessed the effects of a short-term shutdown at London-Heathrow for some stakeholders (airlines and passengers). Maertens (2012) used this research to assess more in depth the interruption losses of a shutdown for the airport and airlines. Therefore, the objectives of this research are to determine all economic effects and costs of a temporary shutdown of an airport for different stakeholders, and this both in the short and long run.

The paper consists of two main parts. In the first part, the following research questions are answered:

(1) What is a shutdown of an airport?
(2) What are the different causes of a shutdown?
(3) Who are the important stakeholders in the case of a shutdown?
(4) What are the different effects on the stakeholders?

In the second part, a recent case is studied. The consequences for the Flemish airports and Brussels Airport of hurricane Sandy are estimated. The methodology consists of both desk and field research. The desk research includes a literature study and quantification based on the method proposed in the study of Maertens (2012). In the field research, unstructured interviews with privileged stakeholders were held[1]. The stakeholders were chosen such that the research gives a representative overview of the air transport market.

[1] The authors thank the interviewees for their cooperation. The names of the interviewees are known by the authors, but for obvious reasons not published in this paper. Paragraphs without specific source are formulated based on information gathered in the interviews.

THE EFFECTS OF A TEMPORARY SHUTDOWN

General aspects regarding the effects of a temporary shutdown of an airport are listed. Answering the respective research questions delivers the structure of this part.

1 Definition of a shutdown

A first step in the analysis is the definition of the concept of a shutdown. Rupp, Holmes & DeSimone (2003) define a shutdown as "*the closure of the entire airport or the closure of a terminal that affects 100% of the fleet of a carrier*". Here, a shutdown is defined as "*the temporary entire closure of the airport with respect to air traffic. This implies that no air traffic occurs at the airport for a certain period of time, while at least one landing or take off was scheduled during that period, which was not cancelled due to other reasons than the air traffic stop at the airport*".

Only situations in which the airport cannot offer any capacity due to exogenous reasons are considered as a shutdown in this research. The airport will be (temporarily) closed if the air traffic controller decides to close the airport. This can happen when the airport management cannot guarantee that the operations can be performed in a safe way. This may occur due different reasons, which cause a partial or total decrease in capacity, among others depending on the size of the airport.

2 Causes of a shutdown

There are different sorts of reasons resulting in the shutdown of an airport. This becomes clear when observing the table shown in Appendix 1. From Appendix 1, it is clear that in the recent past, various important events resulted in the shutdown of different airports, spread over the world. Thus, it is interesting to examine different categories of causes of shutdowns in order to estimate the effects on different stakeholders.

When examining the different causes of a shutdown, a distinction can be made between nature and security. Nature-related shutdowns include those causes initiated by bad weather conditions (Shangyao Yan & Chung-Gee Lin, 1997; Thengvall, Yu & Bard, 2001) or by nature phenomena (Government of Canada, 2002; Goodenough, 2010; Adey, Anderson & Guerrero, 2011). Security issues can be caused by for instance a terrorist attack, unplugged or defective metal detectors, fake bombs found in luggage, passengers that bypass security points, etc. (Rupp et al., 2003).

The first difference between these two categories is that nature-related shutdowns can partly be forecasted and thus, airport stakeholders can take some preventive measures. In case of security reasons, stakeholders cannot predict the shutdown, and therefore cannot anticipate (Rupp et al., 2003). Another distinction between these two causes of an airport shutdown is

the capacity level after reopening[2]. After a nature-related shutdown, most airports operate for a certain period of time at a reduced capacity level, while after a security-related shutdown most airports can operate at full capacity level (Rupp et al., 2003). A third difference is the degree of concentration of the airports affected. Shutdowns caused by nature conditions are most of the time concentrated in a region, while those caused by security reasons occur more often at airports that are geographically scattered (Rupp et al., 2003).

Subsequently, there are some other occasions that might cause a shutdown but do not belong to one of the two categories mentioned. Examples are a fire (Su & Lu, 2012), accidents with aircraft, strikes or necessary construction works, etc.

These different types of causes can have different effects on different stakeholders at the airports. Therefore, an overview of airport stakeholders is given in the next section.

3 Airport stakeholders

A stakeholder is "*any group or individual who can affect or is affected by the achievement of the organization's objectives"* (Mitchell, Agle & Wood, 1997). Figure I gives an overview of the stakeholders, including their relationships in both financial (dotted line) and other (full line) terms.

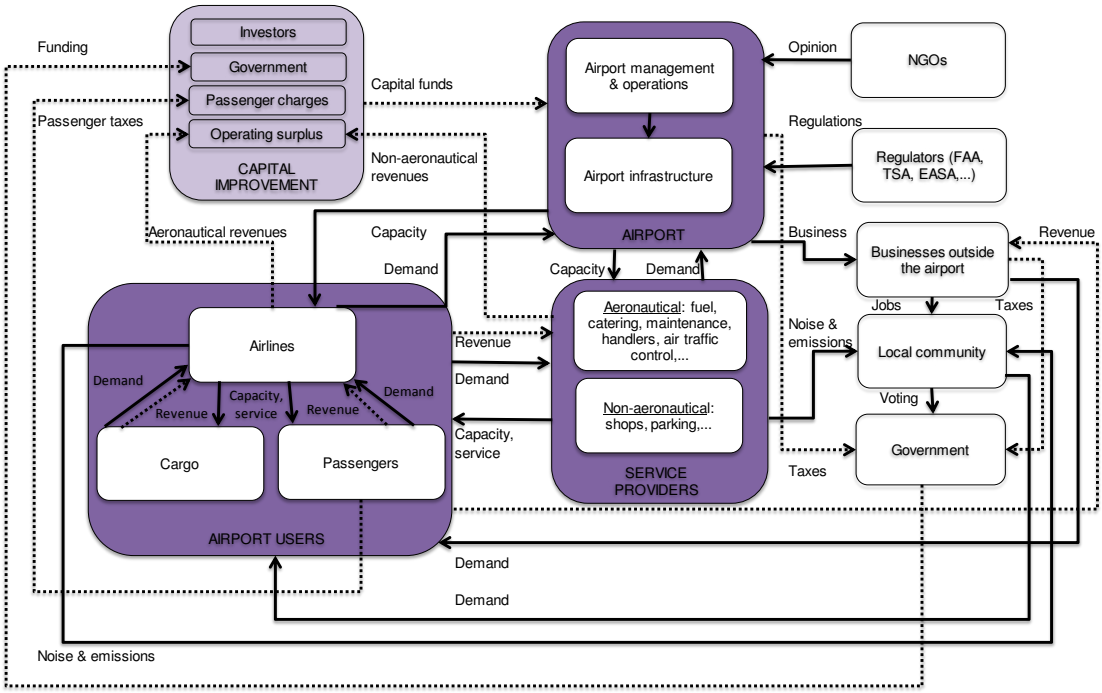

Figure I – Relationships between airport stakeholders
Source: Own composition based on Schaar & Sherry (2010), Macário & Van de Voorde (2012)

[2] Airport capacity is defined as "*the ability of a component in the airport system to handle aircraft*" (Meersman et al., 2006); it is often expressed in terms of operations per hour. Maertens (2012) makes a classification of the type of interruption by linking the type of damage, i.e. physical damage of the airport infrastructure, no physical damage or technical errors/low physical damage, to the responsible entities.

Besides the airport authority, there are two main categories of stakeholders: airport users and service providers. The most important groups of airport users are the airlines and the passengers/shippers of cargo (Meersman & Van de Voorde, 2008). These stakeholders provide some revenue for the airport (passenger charges and operating surplus). This revenue can be supplemented by capital from investors and the government. Furthermore, NGOs, regulators, businesses outside the airport, local communities and the government are connected to the airport. Hereafter, the airport and its stakeholder groups are described.

3.1 The airport

At the airport, the airport authority plays a central role. De Neufville & Odoni (2003) state that the structure of the airport organization varies from an individual airport to a group of airports, managed by the same organization. The airport can be financed by a private investor that might have shares in other airports too (Schaar & Sherry, 2010). The airport organization consists of the management and the airport infrastructure (see Figure I). The airport authority only has control over own operational procedures and the airport infrastructure (Schaar & Sherry, 2010).

It has to be mentioned that every airport has its own characteristics and is therefore unique. Airports with different characteristics also have a different cost structure. As a consequence, the same kinds of effects of a shutdown cause different monetary effects.

3.2 Airport users

The airlines[3] provide air services to passengers and shippers (Rupp et al., 2003). The main objective of airlines after a shutdown is to restore their flight schedule as soon as possible (Shangyao Yan & Chung-Gee Lin, 1997).

The passengers use the airport to transfer from ground to air transport modes or to make a transfer between two air flights. They can be arriving at or originating from the airport, make a transfer, take a domestic or international flight, travel via a charter, low cost airline or take a regular flight. Passengers are participants in the economic system of the airport by purchasing services. On the other hand, they are also individual travelers with expectations about the service offered (Schaar & Sherry, 2010).

The shippers/consignees want to have their cargo at the right time at the right place. Important actors for traditional cargo are cargo carriers, combination carriers and passenger airlines, in which cargo is transported in the belly; important actors for express cargo are integrators (Kupfer et al., 2011; Dewulf, Van de Voorde & Vanelslander, 2009).

[3] For a classification of air carriers, see Schaar & Sherry (2010).

3.3 Service providers

In the present analysis, service providers are divided into two groups: non-aeronautical and aeronautical service providers. Non-aeronautical service providers offer services that are only indirectly related to air transport. Examples are retail, trucking companies, fuel supply and parking.

Aeronautical service providers are "*private operators that offer services to air carriers and general aviation users*[4]" (Schaar & Sherry, 2010). In many cases, they work at the airport as concessionaires. However, some of the services can also be provided by the airport operator or the airlines[5].

3.4 Other stakeholders

First, several businesses can be affected by a shutdown. There are four types of circumstances why they might be affected: they are either located at the airport, in an area immediately surrounding the airport, away from the airport, but depend on the airport, or they are dependent on the airport for mail delivery or other services (Government of Canada, 2002). Examples are flight academies[6] and ground transportation providers (Schaar & Sherry, 2010; Meersman, Pauwels, Struyf, Van de Voorde & Vanelslander, 2011).

Second, the government can be both the national and the local level. The airport pays taxes to the government, but sometimes the government is involved in operating the airport. Another role of the government is to be a regulator (Schaar & Sherry, 2010).

Third, local communities are affected by airport operations. An important example for this is residents who live close to the airport. The effects of the airport on local communities are coming from the air traffic and from ground vehicles both on the airport and from/towards the airport. The effects can be noise, reduction of air/water quality, hazardous waste emissions and other externalities such as congestion on the road network (Meersman et al., 2012; Schaar & Sherry, 2010).

Furthermore, regulators have an influence on the airport by setting regulations that have to be applied by the airport. NGOs can launch some ideas about air transport, but have no direct influence on the functioning of the airport. Besides, some other sectors, such as (Government of Canada, 2002) tourism[7], agriculture/fisheries/aquaculture and health services are influenced.

[4] General aviation users can be for instance air taxi operators, flight instruction, aircraft rental, etc.
[5] Schaar & Sherry (2010) give a more detailed overview of different service providers.
[6] Flight academies are located at the airport, but considered 'outside' the airport, since they are not directly related to the airport's core activity which is facilitating the contact between the air transport providers and their customers.
[7] Tourism comprises both business as leisure travel (Government of Canada, 2002).

Schaar & Sherry (2010) add to this that airports have a large impact on employment, by providing a lot of jobs at the airport, but also outside the airport. Besides, airports stimulate the local economy since individuals and organizations in the neighborhood have air transport services at their disposal. In our research, direct employees of the airport are included in the airport authority; employees of companies operating at the airport are included in the respective companies.

4 Effects of a shutdown[8]

Potential consequences are described for different stakeholders. It has to be mentioned that not all consequences will appear for every shutdown and at every airport. When a shutdown occurs, these effects have to be tailored to the specific case before the impact can be estimated.

In general, most stakeholders of the airport are financially affected when a shutdown occurs. Total costs of a shutdown include the indirect cost and the direct cost. The indirect cost is the decrease in production of goods and services. Examples of indirect costs are business interruption in the period following the shutdown and production losses during reconstruction in case the airport was destroyed (Hallegatte, 2006). Examples of cost figures of shutdowns are shown in Appendix 2. Balvanyos & Lave (2005) found that the cost of having no air transport for one day (figures of 2005) amounts to $320 mn per day in the US air transport sector. Besides, it results in a loss of $36 mn in petroleum refining and a reduction of total spending in the economy by $637 mn.

As for the direct costs, the amount of the indirect costs depends on the length of the shutdown and its immediate cause. These costs result from operating losses of airlines and consumer welfare losses (Balvanyos & Lave, 2005). However, Gordon, Moore II, Park & Richardson (2007) find that the losses during the shutdown are quite small in comparison to the losses of the two years following the shutdown period, such as sector-specific impacts. As a result, the number of days that the airport is closed is not a critical variable in estimating the total losses for society incurred by the shutdown.

On the one hand, the fixed revenue and costs remain, but the variable revenue and costs change. Some stakeholders gain some extra revenue or have to make some extra costs while others see a reduction in revenue or costs. The focus of the monetary analysis in this research is thus on the relative change in costs and revenue.

[8] There are some general aspects that have an influence on the effects, such as the length of the shutdown (Abdelghany & Abdelghany, 2009a), the time of the year (Government of Canada, 2002), etc.

4.1 The airport

In case the operations cannot be performed in a safe way, the airport management will inform the authorities and the latter can decide to close the airport[9]. At this moment, the airport infrastructure (see figure I) is not available[10]. Then, the air traffic controller (i.e. Eurocontrol in Europe and Belgocontrol in Belgium) sends out a NOTAM (Notification to Airmen) to the airlines and the airport management informs the (local) station managers[11] of the airlines and the handling agents. Moreover, the passengers are informed as good as possible.

In case of a shutdown, the airport management faces some extra costs since it is responsible for the airport infrastructure. Therefore, they perform all actions necessary to re-open the airport (e.g. they clear the runway from any snow[12]). To do so, they can rely on some internal personnel and some externally hired workers. These external workers get a waiting fee in the period in which they are not called up and an extra fee in the period they are deployed. However, the purchase, maintenance and repair of the equipment needed are the biggest cost. Nonetheless, the airport management invests to a certain extent in this equipment since this cost is still lower than the cost of shutting down the airport. Furthermore, there are quite some fixed costs (e.g. maintenance and depreciation of the buildings, security,…).

When examining the revenue, the Federal Aviation Administration (2001) (FAA) defines three different categories of airport revenue: aeronautical operating revenue, non-aeronautical operating revenue and non-operating revenue. The airport has quite some amount of variable revenue that is lost in all three categories if no flights are performed. For example, landing and take-off fees cannot be cashed (Schaar & Sherry, 2010). Besides, passengers pay facility charges in their airline tickets. In case of a shutdown, most airports only receive few passenger facility charges. However, if the airport is only shut down for a short period of time and the airlines decide to delay their flights instead of cancelling them, the effects on the variable revenue of the airport are limited. Furthermore, there is also fixed revenue (e.g. concession revenue). Concessionaires pay the airport a fixed annual fee or a percentage of gross revenue. In case a fixed annual fee is paid, the airport receives the same amount of money with or without shutdown. In case a percentage of gross revenue is paid, revenue is different when the airport is shut down for some time (Schaar & Sherry, 2010).

4.2 Airport users

This section examines the effects of a shutdown on airlines, passengers and cargo. An important group of airport users are the airlines. Suppose a destination airport D is shut down

[9] In some cases, institutions such as the Federal Aviation Administration in the USA and the European Aviation Safety Agency in Europe or governments, can decide about the grounding of flights in their airspace (Government of Canada, 2002).
[10] This is valid for the definition of a shutdown used in this research (see “definition of a shutdown”).
[11] During the length of the shutdown, there is constant consultation between the airport management and the station managers to predict when operations can be resumed.
[12] In some specific cases, the airport authority has an agreement with the airline that the airline itself clears the apron around its own aircraft from snow.

(see figure II). Then, airlines at origin airport O have two choices: or they divert their flight to an alternative airport A, or they keep their flight grounded.

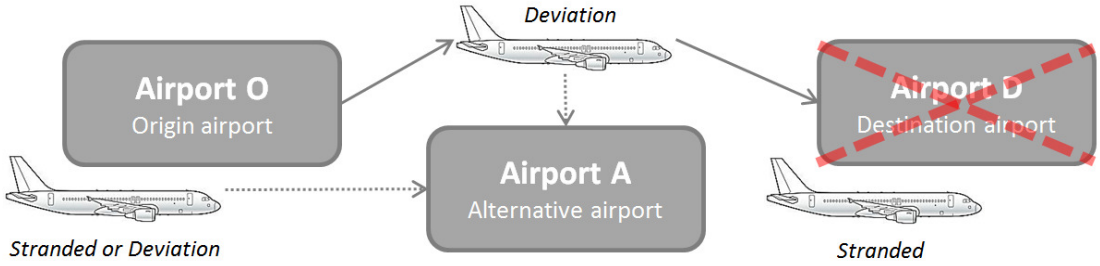

Figure II – Shutdown of destination airport
Source: Own composition

DESTINATION AIRPORT IS SHUT DOWN

Airlines which are heading for the closed airport, can divert their flights to another airport nearby[13] if possible since they want guarantees on the possibility of landing and minimum handling. People at the emergency crisis center of the airline will – in consultation with the air traffic control – adopt the emergency plan and decide to which airport the flights will be diverted. Decision variables are the location and costs of the alternative airport, the fact whether the airline is also offering its services from the alternative airport and the presence of the same handling agent[14]. It is important to bear in mind that not all airports can serve as diversion airport. In some cases, the airport infrastructure is not suitable to receive certain aircraft, either due to operational or regulatory restrictions. Furthermore, airports have a limited capacity with regard to the amount of aircraft they can receive within a given timeframe. Depending on the duration of the shutdown at the destination airport and the airline policy, the aircraft[15] will be handled at the alternative airport.

The most important resources of airlines are aircraft and staff so they want to maximize the utilization of these resources. To maximize the use of aircraft, the time that aircraft are grounded has to be minimal (Abdelghany & Abdelghany, 2009b; Rupp et al., 2003). As a result, there are only very few standby aircraft at the airport. After an airport shutdown, first of all airlines look for aircraft, in a second stage for pilots and then for cabin crew (Abdelghany & Abdelghany, 2009a).

Thus, airlines have to reschedule aircraft and staff, taking into consideration many constraints on both resources[16], because not all aircraft are at the airport at which they were expected to be. In case flights are directed towards another airport during the shutdown,

[13] This involves an extra landing and take-off fee.
[14] The handling agent can, in case of diversion, suggest an airport (at which they are also active) to which their client's flight can be diverted.
[15] A distinction can be made between full cargo planes and passenger planes having cargo on board. Passenger planes are handled along air passenger traffic; what happens with the belly cargo is dependent on what happens with the passengers and the passenger plane. In case of full freighters, cargo can be handled based on the cargo needs. In this analysis, passenger planes with belly cargo are considered.
[16] Possible constraints are the crew working hours, the type of aircraft, qualifications of the crew, etc.

(empty) aircraft and staff have to be repositioned and also the catering of the flights has to be reconsidered. All these actions bring along extra costs for the airline (Government of Canada, 2002; Abdelghany & Abdelghany, 2009b).

In case of a short-term shutdown[17], passengers and cargo stay in the airplane and the flight is resumed later. In case of a longer delay or if the airline policy is built around maximizing passenger satisfaction, the airline will opt to have the aircraft handled at the alternative airport. Then, the airline has to pay a handling fee to the handling agent offering the service.

Passengers can be disembarked, if the regulations of the country allow this[18], and in some cases transported by road to the destination airport. For instance, passengers who do not have a visa for the country in which the alternative airport is located cannot leave the restricted area at the airport. In case of transit passengers, the airline also has to rebook the flight. European airlines are restricted by the European Directive 261/2004[19] which stipulates the Denied Boarding Compensations, in case there is no force majeure[20]. If the delay is limited to some hours, the passengers have the right to get (a compensation for) food and beverages, refreshment, etc. If the delay lasts longer, the passengers also have to be accommodated in a hotel, are entitled to some monetary compensation - depending on the length of the delay and of the trip - or to rebooking their ticket free of charge. The costs of accommodation differ from airline to airline. For instance, an airline integrated with a tour operator can accommodate the passengers in hotels with whom they have contracts and therefore reduce the costs. It is important to note here that, if the shutdown of the airport lasts too long, the stranded passengers will be transported to their destination (airport) via road or rail. Subsequently, passengers in Europe have the right of information from the airline and the right of choosing between reimbursement of the plane ticket and another flight within a reasonable period of time (European Commission, 2010; Reals, 2010). For US airlines, this rule does not exist. These carriers only have to pay the accommodation and meals for passengers in case the flight cancellation is caused by the airline itself (Reed, 2010).

The cost of a shutdown to passengers is the extra time needed for travel and the cost of missing planned appointments. Balvanyos & Lave (2005) consider the value of time for passengers to be $20 an hour, which is half the average wage rate. They state that as a result, the minimum cost of a flight cancellation is at least $60 per passenger. In total, they estimate the cost of diverting a flight of 100 passengers to be $10,000, excluding the unsatisfactory feeling of passengers.

[17] The length of this depends on the specific situation and the airline policy.
[18] The airline has to take into account the regulations regarding travelling across borders For this reason, a diversion airport in the same country might be the first choice of the airline.
[19] This regulation can be consulted at:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004R0261:EN:HTML
[20] If there is a force majeure, airlines do not owe compensation to their clients (passengers/cargo). However, since the airline is also a commercial organization, in some cases it will provide some “care” to its passengers (e.g. food, beverages,...). Moreover, if the cargo gets damaged due to the delay or cancellation of the flight, e.g. perishables which lost its value, the shipper will file a complaint and will claim the damage on the airline, even though the airline is not at fault.

In general, there are three types of potential substitution effects concerning passengers and shippers/consignees when a shutdown occurs: between airports, transport modes and periods of time. Airport users have the choice between making use of another airport in the neighborhood that is not closed, taking another transport mode to get at their destination, or delaying their trip (Park, Gordon, Ii & Richardson, 2008; Maertens, 2012).

Furthermore, the airline has to decide whether the **cargo**[21] is unloaded. They can opt to not unload the cargo and resume the flight to the destination airport later. Or they can choose to unload the cargo in consultation with the shipper and either store it to resume the flight later or transport it to its destination via road. Cargo that had to be loaded at the closed airport can also be trucked[22] to the diversion airport and be loaded onto the diverted aircraft there. The airline has to bear the possible extra costs of transporting passengers and/or cargo via road or storing cargo. Consequently, the airline makes a cost-benefit analysis also taking into account the urgency of the cargo[23] in order to make the decision whether the aircraft is handled. It is clear that when talking about the effects on cargo, there are other effects on different types of cargo.

Besides, due to the shutdown, normal business production levels might be disrupted, since the freight cannot be transported and is grounded at the airport (Santos, 2006). Thus, another issue with cargo is that during a shutdown, a capacity problem might originate. The storage space may be full after some days and the longer the airport is closed, the longer the freight has to be kept at the airport. Even after reopening the airport, there might be less capacity due to a decrease of the amount of passenger flights due to consolidation. In case the airport is disrupted, there might be additional issues concerning the damage of storage facilities and electric power for refrigeration. Next to general cargo, mail is transported by air transport. After an airport shutdown, there might be some restrictions regarding mail (Government of Canada, 2002).

ORIGIN AIRPORT IS SHUT DOWN

If the origin airport is closed, **airlines** cannot perform their flight and passengers/cargo are stranded. In case of a short-term airport shutdown, the flights will be delayed. This affects the crew performing that flight, since the airline has to take into account the duty time of the

[21] The effects differ for cargo carriers of normal air cargo and integrators. Integrators have for instance the advantage that they own a fleet of trucks. Therefore, they can use their ground transportation system to get the goods at the destination (Government of Canada, 2002). As a consequence, clients keep on sending their goods and thus, revenue of integrators is less affected by a shutdown than revenue of normal cargo carriers.
[22] Transportation via rail is not a viable alternative for air cargo since it involves an extra actor. Cargo would have to be trucked to the rail station, be transshipped upon the train, and again at the destination railway station upon a truck which would transport the cargo to its final destination. Thus, this would involve an increase in costs and time which is not ideal for air cargo, which by definition is time sensitive. Concerning road transport, it has to be added that the offer of appropriate trucks to transport containers is limited.
[23] Air cargo is, by definition, time sensitive cargo, but some air cargo is more urgent than other. For example, live animals and human organs are more urgent than perishables which are more urgent than other cargo. This time-sensitive nature can be explained by perishability, urgency or seasonality (Government of Canada, 2002; Balvanyos & Lave, 2005; Adey, Anderson & Guerrer, 2011).

crew, and the passengers and cargo on the flight. The European Directive 261/2004 also applies in case the origin airport of a certain flight is closed.

The airline also has to take into account that a departure delay may have some repercussions on the subsequent flights (Rupp et al., 2003). In case of a long delay, the airline may decide to cancel the flight. Here, the airline has to take into account the repercussions for the **passengers**. For instance, transit passengers have to rebook their ticket, passengers with visa for a certain country experience some problems, etc. Furthermore, losses in revenue and goodwill of consumers result in costs for the airlines (Rupp et al., 2003). Suzuki (2000) states that passengers do switch airlines after the experience of a flight delay. As a consequence, the losses for airlines are larger than the direct impact of the shutdown alone.

The average revenue of a flight equals the average flight fare multiplied by the monthly average number of occupied seats for the airline on that route. In their study, Rupp & Holmes (2006) assume that, on average, a plane holds 162 seats and has a potential revenue[24] of $31,000 per flight. Taking into account an average load factor of 2/3, it results in an average revenue per flight of $21,000 in 2006. However, when using the worldwide average load factor of 2012, published by IATA (2012), of 78.3%, the average revenue per flight would be $24,000. In estimating the lost revenue of a cancelled flight, the potential revenue is the upper bound, making the assumption of a load of 100%. The average revenue is a better measure since it takes into account the average number of passengers for that specific route and airline.

With respect to **cargo**, the forwarder sending the cargo first decides on what to do, in consultation with the shipper, depending on the costs and urgency of the shipment. He can suggest having the cargo shipped by another airline at another airport, in which case the original airline loses some income, and therefore truck the cargo to the right place. These costs have to be borne by the shipper/consignee. If the forwarder does not choose to switch between airlines, the original airline has to find a solution. It can have the cargo stored and ship it later in time or the airline can warn the shipper that the cargo should not be transported to the airport yet[25], eventually to be shipped later. Urgent cargo might be trucked to its destination if this is possible. In this case, the airline has to bear the costs.

In case the airline cannot perform all flights scheduled, it loses some variable revenue related to the passengers (e.g. passengers and security charges can only be levied in case the passenger flies) and to the performance of the flight (e.g. revenue from flexible tickets is only cashed if the flight is performed). On the other hand, there are some changes in the variable costs. The airline does not have to pay some direct operating costs such as the take-off or landing charges, the handling charges and the fuel burnt. However, there are

[24] The potential revenue of a flight equals the quarterly average one-way passenger fare multiplied by the seating capacity of the plane (Rupp & Holmes, 2006).
[25] For instance, in case of living animals.

some other costs which increase, such as the cost of parking the aircraft[26], the compensations to be paid to the passengers, repatriation of passengers, additional crew expenses, and the storage of the cargo if the flight is performed later. The fixed costs, e.g. salaries, depreciation of the aircraft, etc. still have to be paid and count for 50% of all costs.

A NEARBY AIRPORT IS SHUT DOWN

If an airport in the region is shut down, the airport management (of the airport which still operates) informs the air traffic control about its free capacity. Then, the air traffic controller decides on which flights are diverted to the operating airport. This ensures that all players are treated in a fair way. Airlines which have some slots allocated to them are of course certain that they can depart from or land at the airport, but may still experience some delay due to the congestion at the airport. After all, the ground handlers present at the operating airport also have to handle the aircraft stranded there, disregarding the fact whether they are clients or not.[27]

4.3 Service providers

Another group of stakeholders are the service providers, which deliver air transport related services (e.g. ground handling agents) and extra services (e.g. retail). The latter will indirectly be affected by the airport shutdown, while the former is directly affected. In case of a short-term shutdown, the retailers will gather quite some extra revenue due to the passengers waiting, but if the airport is shut down for a longer period of time, retail will suffer losses since there will not be any passengers present at the airport (Balvanyos & Lave, 2005).

The aeronautical service providers' revenue depends upon the number of flights at the airport. For instance, if no flights are performed, the handling agents do not get handling fees. This reduces their variable revenue. On the other hand, service providers also have fixed costs such as rent, personnel, etc. Depending on the length of the shutdown and whether it could be predicted, the service provider tries to reduce its fixed costs by, for instance, filing for technical unemployment due to force majeure for some of its personnel. The service provider can also try to guarantee its revenue by reallocating some of its personnel to its handling station at an airport to which flights are diverted. This way, the handling agent can still handle the flights; and therefore cash the handling fees it otherwise would have lost. The personnel that cannot be reallocated or sent on technical unemployment is used for maintenance and repair, training etc. One has to bear in mind that a service provider also has fixed costs. However, these are only slightly influenced by a shutdown. Other examples of service providers that are influenced are catering (Government of Canada, 2002) and taxi companies (Balvanyos & Lave, 2005).

[26] However, during a shutdown some airports might not raise charges for the parking of aircraft at the airport. An example of this is the airport authority of Frankfurt, which did not charge airlines for parking during the closure of the European airspace in 2010 due to the ash cloud (Airline Industry Information, 2010). Virgin Atlantic refused to pay landing and parking charges after a shutdown of London Heathrow due to snow (Prynn, 2011).

[27] It is important to bear in mind that for some reasons, such as the presence of cold storage facilities or the type of runway and the type of aircraft, aircraft cannot be diverted to airports within nation's borders.

4.4 Other stakeholders

Finally, there are some potential effects of a shutdown on other stakeholders. First, financial institutions may experience some delays in bill payments (Government of Canada, 2002; Balvanyos & Lave, 2005). Besides, the health sector may experience delays in transport of organs, blood, etc. Third, insurance companies might start offering new services. As a result of previous shutdowns, an insurance company started to offer airports and airlines insurance contracts to cover shutdowns that are due to pandemics (Airfinance Journal, 2009). Next, due to a shutdown, the activities at some businesses in the airport are reduced. This can result in local businesses outside the airport experiencing lower sales volumes too, since for instance fresh food served in the airplanes comes mainly from local distributors (Government of Canada, 2002).

Consequently, local governments and regulators can take measures. In the USA, the FAA sent repair crews to airports to restore service. In some cases, the government can set up a crisis management center to track breakdowns in the air transport sector (The Washington Times, 2003). Furthermore, the FAA set a Ground Delay Program, which includes that the take-off of flights is delayed at their origin airport until weather conditions allow a safe landing at the destination airport (Abdelghany & Abdelghany, 2009c).

In some countries there might be rural communities that are located very remotely. Sometimes they are depending on air transport to get mail and general cargo delivered. In case the closest airport is shut down, goods cannot be transported towards these communities without significant time delays (Government of Canada, 2002). A positive effect of the shutdown is the lower impact of airlines on the local communities. There are no aircraft landing or taking off at the airport, so the amount of noise and emissions is reduced for nearby residents.

Another sector that is influenced by a shutdown of an airport is the tourism sector. First, the reputation of the airport as a destination for tourists might be affected. In case passengers consider the cause of the shutdown as airport-specific, they are more inclined to switch to other destinations. The tourism sector is especially vulnerable to terrorist attacks. Second, small tourism businesses such as tour operators, might experience difficulties due to the decrease of the number of tourists. In case of large uncertainty about the number of future tourists, there might be effects on salary levels and hiring processes (Government of Canada, 2002).

Next to these negative effects, there are some positive effects for the tourism sector too. In the short run, there might be an increased demand for accommodation nearby the airport. Some passengers that are stranded at the airport, will have to find accommodation waiting for the airport to reopen. These extra benefits are only applicable in the short run; in case of a shutdown due to terrorism related reasons there will be even rather losses in the long run (Government of Canada, 2002).

Appendix 3 gives an overview of potential effects of a shutdown on all stakeholders discussed in this research and the variables determining the monetary value of these effects.

As stated earlier, past research studied the topic of disruptions in the air transport sector. Table I gives an overview of relevant studies that are useful to develop a methodology to tackle the issue of the effects of a shutdown on different stakeholders. Different methodologies for calculating indirect effects of a shutdown are used by different authors. The most used is Input-Output analysis and also our analysis confirms that this model is the most suitable. A caveat is that many data are needed to run this model. Unfortunately, these data were not available in the time span of this research. Therefore, indirect effects are not calculated in this research.

Table I – Literature overview

Author	Year	Objective	Methodology	Case study
Maertens	2012	Classify different types of airport closures, develop a scheme to estimate the loss potentials of airports and airlines	Interviews	Birmingham Airport
Pejovic, Noland, Williams & Toumi	2009	Simulate the effects of a short-term shutdown for some stakeholders	Reorganized ATC Mathematical Simulation Plus model	London-Heathrow
Park, Gordon, Li & Richardson	2008	Examining whether the effects of the shutdown of a port are mitigated by substitutions over time, by mode or by port	National Interstate Economic Model	Los Angeles-Long Beach ports, 2002
Gordon, Moore II, Park & Richardson	2007	Estimating the economic impacts of a terrorist attack on the US commercial air transport system	IMPLAN (= input-output model of US economy for 2001; multipliers)	US air sector
Hallegatte	2006	Modeling changes in production capacity due to capital losses and adaptive behavior after a disaster	Adaptive regional input-output model	Katrina, Louisiana
Santos	2006	Modeling terrorism effects on interdependent economic systems	Inoperability Input-output	US economy
Balvanyos & Lave	2005	Measuring the economic implications of a terrorist attack on commercial aviation in the USA	Input-output table (changes in consumer surplus)	USA
Santos & Haimes	2004	Modeling the demand reduction Input-Output inoperability due to terrorism of interconnected infrastructures	Inoperability input-output model	USA
Rupp, Holmes & DeSimone	2003	How flight schedules were recovered after security-related terminal closures in the year after 9/11	Discrete choice econometric model	US Airports
Government of Canada	2002	Exploring the potential impact of airport disruption due to earthquakes and terrorism threats on different stakeholders	Interviews	Canada, USA
Thengvall, Yu & Bard	2001	Optimal rescheduling of aircraft following hub closures	Integer multi-commodity network model	Continental Airlines
Shangyao Yan & Chung-Gee Lin	1997	Minimization of the schedule-perturbed period after an incident + getting the most profitable schedule given the schedule-perturbed period	Integer programming, Lagrange relaxation with sub gradient methods	China Airlines

Source: Own composition

CASE STUDY: EFFECTS OF HURRICANE SANDY ON THE REGIONAL FLEMISH AIRPORTS AND BRUSSELS AIRPORT

At the end of October 2012, hurricane Sandy hit the East Coast of the USA. This caused among others the shutdown of many airports in the USA and indirect effects in other parts of the world. Therefore, it is useful to examine the effect of hurricane Sandy on the regional Flemish airports and Brussels Airport. This specific case study was chosen because it can be used to indicate how the effects of a shutdown can be measured by stakeholders such as airlines and airports[28]. Moreover, the incident happened during the period of this research and therefore accurate data could be collected. On the other hand, the case study has the advantage of being rather comprehensive in scope, so that the analysis is more clarifying. In this example, the effects of a shutdown on another airport are measured. However, the proposed methodology can also be used to calculate the effects of a shutdown of the airport itself.

1 Method

All cancelled flights for both passenger and cargo traffic[29] between the USA and Brussels Airport in the period of hurricane Sandy were put in a database. Maertens (2012) provides a calculation method to estimate the total cost of a shutdown for an airline and for an airport concerning passenger operations. This method can be used as a starting point to estimate the effects for cargo operations too. Some significant differences between passenger and cargo operations have to be taken into account. Cargo flights on average need larger aircraft than passenger flights. As a result, the parking and fuel costs are higher, they pay a larger landing and take-off fee and these aircraft have to fly at the height at which they do not interfere with (smaller) passenger aircraft. Thus, they might have to make a detour (when repositioning or deviating their aircraft). The two methods for passenger operations are shown in figures III and IV.

2 Scope

The impact of the shutdown of some airports in the United States on the airports in Flanders and Brussels is measured. The effects are measured in number of cancelled flights and associated consequences. For the Flemish regional airports, it is noticed that no flights are cancelled because of Sandy. A reason for this is that there are no direct flights from the airports of Antwerp, Ostend-Bruges and Kortrijk-Wevelgem to the USA. Therefore, in the following analysis, only cancelled flights between Brussels Airport and the USA are

[28] Measuring the effects can only be done by each stakeholder itself and this for two important reasons. First, generalisation would not lead to an accurate calculation. Two airlines, flying the same route with the same aircraft, loaded with the same number of passengers and amount of cargo, etc. would not experience the same costs and revenue, due to amongst others unequal rebates given by the airport (authority). Second, only the stakeholder himself has access to the necessary data to make a correct calculation without the need of making too many assumptions.

[29] It is important to note that repositioning flights are not included in both the database and the conducted analysis.

considered. Other flights that are cancelled during the observed period, are considered as being cancelled due to other reasons than hurricane Sandy and are therefore not included in the analysis.

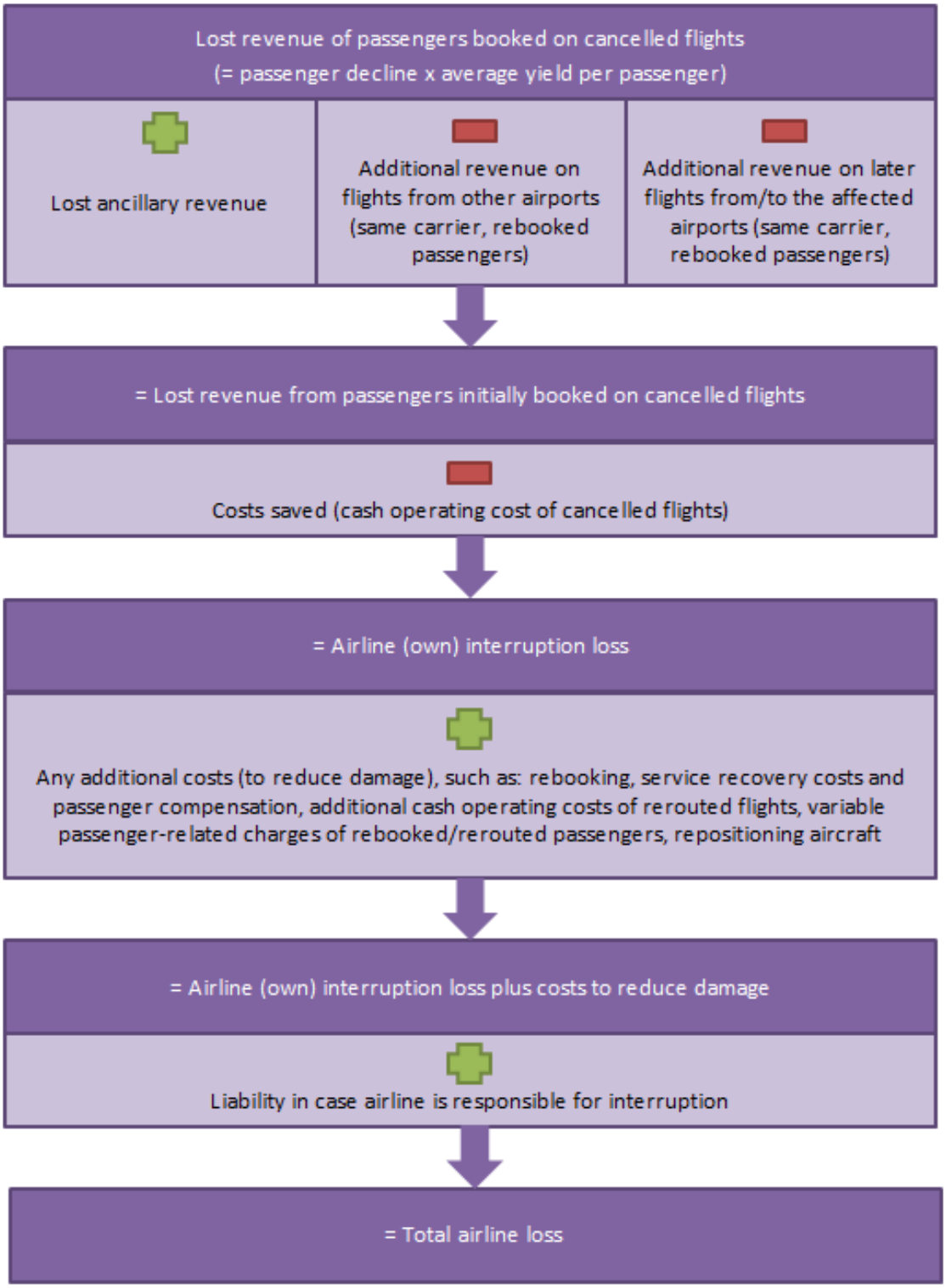

Figure III – Total airline losses
Source: Own composition based on Maertens (2012)

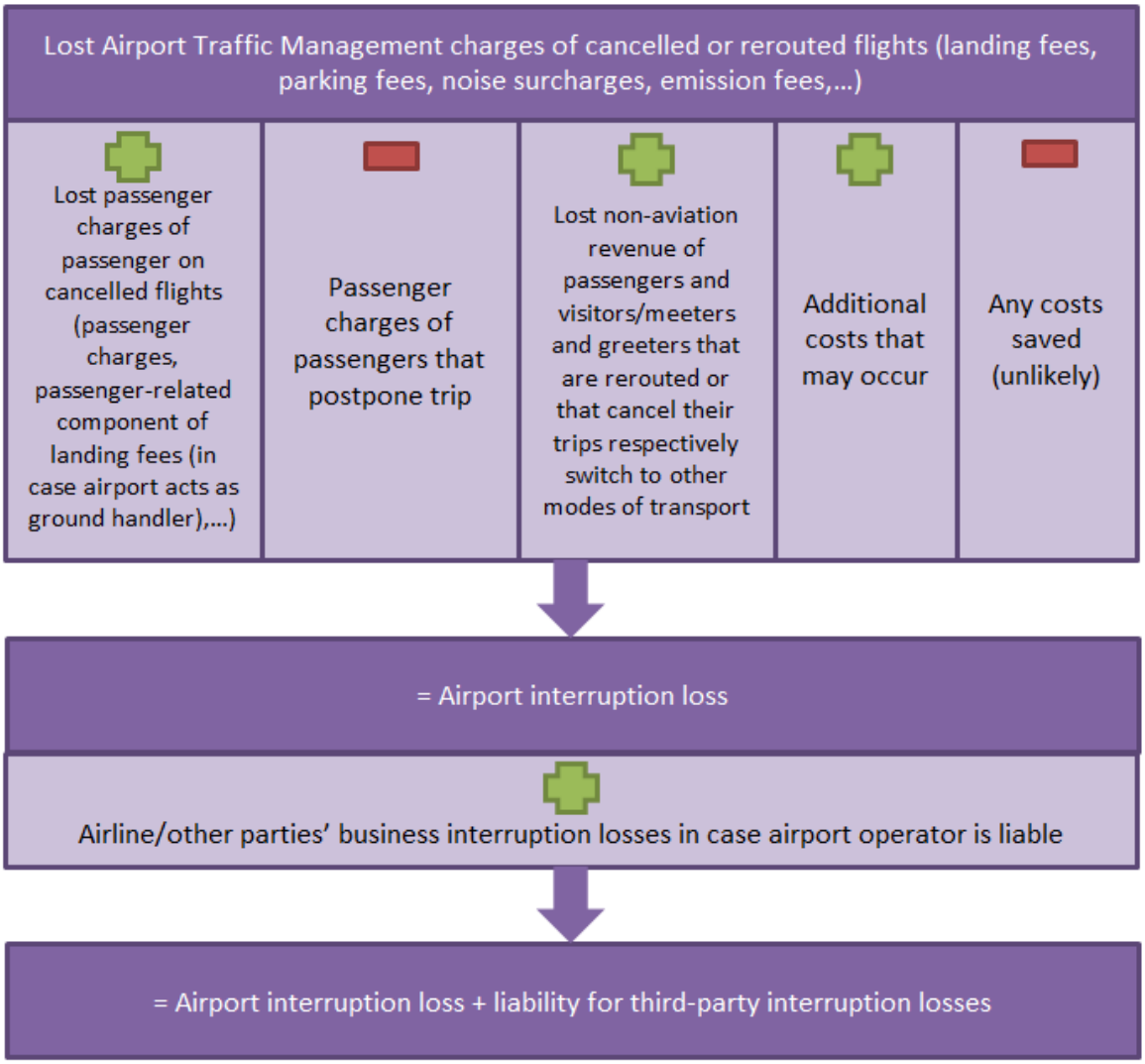

Figure IV – Total airport losses
Source: Own composition based on Maertens (2012)

3 Results

The results for Brussels Airport are analyzed respectively for passengers and cargo. The calculation tables are added in Appendices 4-7.

The period under study at Brussels Airport is for departing **passenger** flights between the 29th of October and the 1st of November, while for the arriving passenger flights the period from the 30th of October until the 1st of November is considered. A comparison between the arriving and departing passenger flights indicates that the first effect of the shutdown of airports in the US is that there are no flights from these airports in the US arriving anymore in Brussels. Only the day after do flights not depart from Brussels towards the closed airports in the US anymore.

Second, based on the plane type, the amount of passengers that are affected in case there is a utilization rate of 100% can be calculated. With operations at 100% utilization, at most 4,599 incoming passengers and at most 6,464 departing passengers are affected due to the shutdown of some airports in the US. Third, in total, there is a potential loss of freight that can be transported in the passenger planes. For the arriving flights this totals to at most 1,508 m^3, for the departing flights at most 2,156 m^3.

Fourth, it has to be mentioned that some planes might have to be rerouted to another airport. Therefore, cancelled planes do not cover the scheduled distance of in total 77,060 km for the arriving flights and 107,001 km for the departing flights. Thus, the actual net savings on fuel and energy are coming from the total distance saved minus the extra distance covered.

Furthermore, it can be figured out which ground handlers are involved based on the flight number. Some airlines rely on self-handling or third party handling by another airline. However, it is important to mention that for these activities the personnel of licensed ground handlers at Brussels Airport is deployed. Another observation is that many flights have code sharing. This means that one does not know how many passenger seats on the cancelled flights belong to which airline.

The first **cargo** flights at Brussels Airport are cancelled on the 30th of October. The period under study is for the arriving flights considered to be till the 5th of November and for the departing flights till the 6th of November.

A first important observation is that the cancellation period for the cargo flights is longer than the one for the passenger flights. Cargo flights consist of different legs and thus, flights that cannot fly the full stretch do not always leave the origin airport of one of the first legs due to the risk of getting stranded. For example, a flight from Jeddah to New York via Brussels may not leave Jeddah if it cannot fly its scheduled trajectory departing from Brussels.

All cancelled cargo flights involved are executed with a Boeing 747-400 Freighter. This aircraft has a capacity of 124 tons. This means that maximum 39 flights times 124 tons of cargo, without taking into consideration weight/volume, cannot be transported via Brussels during the observed period. However, this capacity does not indicate the value of the goods and thus, it is impossible to estimate the lost revenues for these cancelled flights. The total distance of the cargo flights that is not covered, is 128,128km for the arriving flights and 124,611 for the departing flights and this each time only for the first leg of the trip.

Based on the method presented by Maertens (2012), Brussels Airport or the affected airlines can calculate the effects of hurricane Sandy. The exact figures of lost revenues for each stakeholder are not known by other parties and therefore, a complete quantification is possible if all company-specific data can be added.

CONCLUSIONS AND POLICY RECOMMENDATIONS

The aim of this paper was to report the direct and indirect effects and the corresponding cost of a shutdown of an airport for all stakeholders. More specifically, four research questions were studied. In order to do this, a literature review was conducted and supplemented with field research and a quantification methods as proposed in the study of Maertens (2012).

The analysis leads to the following conclusions. Concerning the first research question, an appropriate definition is developed. The analysis of the second research question revealed that there are more causes of a shutdown than expected. With respect to the third research question, a scheme was developed which shows the important stakeholders and the relations between them. Based on this scheme, the fourth research question was addressed and this demonstrated that a shutdown can have many and far-reaching effects.

The first part of this study shows that the cause of the shutdown has no consequence for the effects on the stakeholders. It is rather the duration of the shutdown that determines the (monetary) effect on the stakeholders. However, one has to bear in mind that the size of the airport and the number of activities the stakeholder has on the affected airport determines the effects. In the second part, a case study was analyzed, which consisted of applying the method as proposed by Maertens (2012) on Brussels Airport in response to hurricane Sandy (October 2012). Both in the passenger and cargo market, arriving and departing flights are cancelled. However, quantifications can only partially be made based on information that is publicly available. For detailed calculations of the effects for different stakeholders, company-specific information is needed about for example lost revenues due to the shutdown.

Furthermore, policymakers should take the consequences of airport shutdowns into account. If policy makers want to keep traffic in their own country, an environment should be created in which the airports of the country work together so that each airport has one or more permanent back-up airports to which the scheduled flights can be diverted. Several parameters have to be considered when suggesting a back-up airport, such as the airport choice variables of airlines, the capacity at the back-up airports, the interaction with other types of policies such as land use and the incentives to make actors participate.

Moreover, some indirect policy recommendations can be formulated. It might be useful to provide and use new technologies with which ash concentrations may be tracked, identified and measured. By doing research about how much ash it takes to damage engines and airframes and coordinating all air navigation services, the issue of a shutdown of airports due to ash clouds can be addressed in a more proper way (Learmount, 2012). Besides, it is recommended to select the most critical sectors to recover after a shutdown of an airport. This can for instance be done by making an interdependency analysis (Santos & Haimes, 2004).

An interesting extension of this work would be to elaborate this paper further by developing a generic model to quantify the effects of a shutdown on a given stakeholder.

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APPENDIX 1: OVERVIEW OF RECENT SHUTDOWNS

Year	Cause	Airport	Consequences
2012	Hurricane Sandy	American East Coast	More than 18,000 flight cancellations, closed roads.
	Plane incident	St. George Airport	Passengers are re-accommodated on other flights and ground transportation, all commercial flights are cancelled.
	Maintenance runway	Ostend Airport	Airport is closed for 5 days.
2011	Strike air traffic controllers for 4 hours in morning and 4 hours in evening, 2 days long	Athens Eleftherios Venizelos Airport	Planes are grounded for 2 days.
	Snow and icing	London Heathrow Airport	Tens of thousands of passengers are stranded, Virgin is withholding less than £10 million from BAA (wants a compensation for all costs unnecessarily incurred after the airport should have reopened but did not), airlines had to pay for thousands of passengers to be accommodated and rebooked.
	Bomb threat	Ronald Reagan Washington Airport	The airport is closed for 20 minutes.
2010	Volcanic ash cloud from Iceland (9 days)	Copenhagen Airport	The airport is closed for 5.5 days, there are only limited operations before and after the shutdown.
		European Airports	More than 100,000 flights are cancelled in Europe; the total loss of revenue is estimated to be €1 bn. 5 million passengers are stranded midtrip; they need food and a place to stay, but: • European Union requires airlines to cover hotel and meal costs of passengers whose flights are cancelled • US carriers are only required to pay for disrupted passengers' hotels and meals when the flight cancellation is caused by the airline; when the weather forces a flight to be cancelled, passengers are on their own • Rights vary by carrier.
2009	Wind and dust storm	Airport in Riyadh	The airport is closed.
	Fire	Perth Airport	The airport is closed for 5 hours.
2008	Refusal of licence	Newquay Airport	The airport is closed for 3 weeks; 209 departures are cancelled, 7,000 passengers are affected.
2006	Winter storm	Denver International Airport	The airport is closed for 1 week.
2003	Hurricane Isabel	Ronald Reagan Washington Airport	The airport is closed for 14 hours; More than 2,000 flights are grounded, there are delays throughout the nation's airline system, flight schedules are expected to be regular after 2 days, flights are suspended in 19 airports in the region, railroad shut down all trains in region, there are reduced trains in other regions (many regular passengers stayed at home), there is a shutdown of a bus terminal, repair crews are sent to major airports to restore services.
		Baltimore-Washington International Airport	The airport is closed for 15 hours
2001	Nisqually earthquake	SeaTac International Airport	The airport is closed for 2 hours because of damaged control tower; operations are for 3 months at reduced capacity.
		King County International Airport	Short runway is closed for 2 days, long runway for 2 weeks.
	Terrorist attack of 9/11	All North American Airports	Threat of terrorism.
		Ronald Reagan Washington Airport	The airport is closed for 23 days; and is gradually reopened for 6 months.

Source: Own composition based upon various sources

APPENDIX 2: OVERVIEW COST INFORMATION IN LITERATURE

Year	Victim	Cost	Estimated by	Event	Cost subject
2011	BAA	£10 mn	Virgin Atlantic	Snow	Landing and parking fees that Virgin Atlantic refuses to pay
2010	All UK airports	£5[31] mn – £6 mn	BAA	Ash cloud volcano Iceland	Expected maximum daily impact of shutdowns on adjusted EBITDA and cash flow
2010	Aer Lingus	€15 mn - €20 mn	Aer Lingus		Grounding of aircraft for six days
2010	Fraport	€0.5 mn	Fraport		Loss of parking revenue during shutdown of Frankfurt Airport
2010	Fraport	€15 mn	Fraport		Revenue loss due to shutdown of 5 days of Frankfurt Airport
2010	Air industry	€1.3 bn	IATA		Lost revenue of week-long closure of Europe's airspace
2010	Members of Association of European Airlines	€850 mn	Association of European Airlines		Cost of nine days around the ash cloud
2010	European airports	€250 mn	ACI Europe		Losses due to 6 days shutdown
2010	Finnair	€20 mn[32]	Finnair		Direct lost revenue
2010	Germanwings	€2 mn	Germanwings		Daily cost of shutdown
2010	World economy	€1.1 tn	European Commission		Total cost after ash cloud in Europe for a week
2010	Airlines	€1.7 bn	European Commission		Total cost after ash cloud in Europe for a week
2005	USA economy	$1 bn	RAND	A large aircraft has been shot down; all aircraft grounded for 2.5 days	Cost per grounded aircraft, including compensation for dead passengers
2005	Airlines	$1.6 bn	RAND		Cost in reduced airline and associated spending
2005	Passengers	$4.75 bn	RAND		Losses to business and leisure passengers
2001	D.C. Reagan National Airport	$0.4 mn	Metropolitan Washington Airports Authority	9/11 attacks	Daily cost of shutdown (24 days closed in total)
2001	Reagan National Airport and Northern Virginia businesses	$330 mn	Government of Canada		Daily economic impact of airport shutdown
2001	State and local tax revenue	$27 mn	Government of Canada		Daily economic impact of airport shutdown

Source: Own composition based on The Washington Times (2001), Balvanyos & Lave (2005), Airline Industry Information (2010), Evening Standard (2010), Reals (2010), Prynn (2011), Learmount (2012)

[31] At that time USD1 = GBP0.65.
[32] Lower passenger volumes in future and potential passenger compensation are not yet calculated in this amount.

APPENDIX 3: AIRPORT STAKEHOLDERS AND THE EFFECTS OF A SHUTDOWN

Main stakeholders	Potential consequences of the shutdown	Main effects on specific stakeholder	Variables determining monetary value
Airport Authority	• No capacity for airlines and some service providers during shutdown	• Image problem, loss of landing and take-off charges, loss of passenger charges	• Number of movements, number of passengers
	• Reopening at reduced capacity	• Image problem, loss of landing and take-off charges, loss of passenger charges	• Number of movements, number of passengers
Airlines (concerning cargo and passengers)	• Reimbursement of passengers	• Reimbursement costs	• Height of reimbursement fee (depending on regulation 261/2004), number of passengers
	• Lost passengers due to cancellations	• Loss of passenger yield	• Yield per passenger, number of passengers
	• Rescheduling aircraft and staff	• Extra costs due to reallocation	• Number of aircraft, number of rescheduled staff
	• Accommodation costs for passengers	• Accommodation costs	• Height of accommodation fee, number of passengers
	• Competition from other transport modes	• Loss of revenue due to loss of passengers and pressure on prices	• Number of passengers, potential difference in prices
	• Loss of cargo clients	• Loss of cargo yield	• Yield per cargo unit, volume and weight of cargo
	• Regaining passengers	• Gain of passenger yield	• Yield per passenger, number of passengers
	• Increased security measures and higher insurance costs	• Increased security and insurance costs	• Amount of personnel, number of insured items, potential difference insurance price
	• Firing of personnel if large long run losses	• Decrease of operational cost and potential increase of workload for remaining personnel	• Labor cost, amount of personnel
Passengers	• Extra time needed for travelling and cost of missed appointments	• Loss of valuable time	• Hours, value of time
	• Reimbursement	• Remuneration of (extra) costs	• Height of reimbursement fee (depending on regulation 261/2004)
	• Substitution of flight	• (Potential) increased transportation costs	• Ticket price of other mode and/or generalized cost of trip with private mode
Cargo businesses	• Losses due to time sensitive nature of cargo	• Depreciation of goods and potential cash flow problems	• Number of items, value of each item
	• Capacity problems at the airport storage	• Costs related to alternative storage space and additional transport	• Volume and weight of cargo, height of rent, price of transport
	• Additional future restrictions and regulatory policies	• Adaptation costs	• Adaptations needed, cost per adaptation

Main stakeholders	Potential consequences of the shutdown	Main effects on specific stakeholder	Variables determining monetary value
Mail services	• Reallocation of mail	• Extra transport costs	• Price of transport, distance, volume of mail
	• Delays	• Image problem, potential additional operational costs	• Hours, labor cost
	• Loss of mail delivery in areas only accessible by air	• Potential loss of revenue	• Number of mail items, revenue per item
	• Stronger security measures	• Adaptation costs	• Adaptations needed, cost per adaptation
Service providers	• Less work	• Excess of personnel	• Hours, labor cost
	• Loss of customs revenue from imported goods	• Loss of taxes	• Value of goods, taxation rate
	• Reduction in sales volumes to passengers and airlines, in the short and long run	• Loss of revenue	• Number of items, price per item
	• Firing personnel if large long run losses	• Decrease of operational costs and potential increase of workload for remaining personnel	• Labor cost, amount of personnel
Other stakeholders			
Financial institutions	• Delays in bill payments	• Delayed revenue and potential cash flow problems	• Hours, interest rate, amount of revenue
Health sector	• Delays in moving blood, organs, etc. – potentially resulting in closing of blood centers and transportation via other modes	• Image problem, extra transport costs, potential change in operational costs	• Price of transport, labor cost, amount of personnel
Insurance companies	• New types of insurance contracts might exist	• Potential adaptation costs and additional revenue	• Adaptations needed, cost per adaptation, number of insured items, insurance fee
Local businesses	• Decrease in sales volumes	• Loss of revenue	• Number of items, price per item
Local governments	• Communication problems in emergency situations	• Image problem	• Number of votes lost
Regulator	• Setting up crisis management center	• Additional costs, a.o. equipment, change in (workload for) personnel	• Operational costs, labor cost, amount of personnel
	• Sending repair crews to airports	• Extra transport costs and change in (workload for) personnel	• Price of transport, operational costs, labor cost, amount of personnel
Rural communities	• Time delays for arriving and departing goods	• Inconvenience	• Hours, value of time
Tourism sector	• Some businesses (entertainment, retail/accommodation, transport) may experience short run benefits – potentially resulting in snowball effect on other businesses	• Additional revenue	• Number of services, price per service
	• Losses because of the reputation of the airport	• Image problem, potentially resulting in loss of revenue	• Number of services, price per service

Source: Own composition; columns 1 & 2 based on Government of Canada (2002) and Macário & Van de Voorde (2012)

APPENDIX 4: ARRIVING PASSENGER FLIGHTS CANCELLED AT BRUSSELS AIRPORT[33]

Date	Origin	Flight number	Plane type	#pax seats	Freight	Flight Distance	Ground handler
Monday 29th of October 2012	/						
Tuesday 30th of October 2012	Newark	UA960*, AC5148, LH8855, SN8808	B777-200	301-440	151 m3	3,668 miles/ 5,903 km	(Brussels Airlines) Swissport
Tuesday 30th of October 2012	New York JFK	AA172*, BA1581, EY3052, IB4248,	B757-200	200-228	43.3 m3	3,655 miles/ 5,882 km	(American Airlines) Swissport
Tuesday 30th of October 2012	Philadelphia	US750*, A33403, SN9172	B767-200	181-255	90.1 m3	3,748 miles/ 6,032 km	Swissport
Tuesday 30th of October 2012	Washington	UA950*, AC5970, LH9383, LO4304,	B777-200	301-440	151 m3	3,879 miles/ 6,242 km	(Brussels Airlines) Swissport
Tuesday 30th of October 2012	Newark	9W227*	A330-200	253-380	136 m3	3,668 miles/ 5,903 km	Swissport
Tuesday 30th of October 2012	New York JFK	DL140*, KL6140	B767-300	218-350	118.4 m3	3,655 miles/ 5,882 km	Swissport
Wednesday 31st of October 2012	New York JFK	SN502*, LH5621, UA9928	A330-300	295-440	162.8 m3	3,655 miles/ 5,882 km	(Brussels Airlines) Swissport
Wednesday 31st of October 2012	Newark	UA960*, AC5148, LH8855, SN8808	B777-200	301-440	151 m3	3,668 miles/ 5,903 km	(Brussels Airlines) Swissport
Wednesday 31st of October 2012	New York JFK	AA172*, BA1581, EY3052, IB4248,	B757-200	200-228	43.3 m3	3,655 miles/ 5,882 km	(American Airlines) Swissport
Thursday 1st of November 2012	New York JFK	SN502*, LH5621, UA9928	A330-300	295-440	162.8 m3	3,655 miles/ 5,882 km	(Brussels Airlines) Swissport
Thursday 1st of November 2012	New York JFK	AA172*, BA1581, EY3052, IB4248,	B757-200	200-228	43.3 m3	3,655 miles/ 5,882 km	(American Airlines) Swissport
Thursday 1st of November 2012	Newark	9W227*	A330-200	253-380	136 m3	3,668 miles/ 5,903 km	Swissport
Thursday 1st of November 2012	New York JFK	DL140*, KL6140	B767-300	218-350	118.4 m3	3,655 miles/ 5,882 km	Swissport

Source: Own composition

[33] The flight numbers have following meaning: 9W = Jet Airways, A3 = Aegean Airlines, AA = American Airlines, AC = Air Canada, BA = British Airways, DL = Delta Airlines, EY = Etihad, IB = Iberia, KL = KLM, LH = Lufthansa, LO = Polish Airlines, SN = Brussels Airlines, UA = United Airlines, US = US Airways.

APPENDIX 5: DEPARTING PASSENGER FLIGHTS CANCELLED AT BRUSSELS AIRPORT

Date	Destination	Flight number	Plane type	#pax seats	Freight	Flight Distance	Ground handler
Monday 29th of October 2012	New York JFK	SN501*, LH5620, UA9929	A330-300	295-440	162.8 m3	3,655 miles/ 5,882 km	(Brussels Airlines) Swissport
Monday 29th of October 2012	New York JFK	AA171*, BA1580, EY3051, IB4247	B757-200	200-228	43.3 m3	3,655 miles/ 5,882 km	(American Airlines) Swissport
Monday 29th of October 2012	Newark	UA961*, AC5147, LH8854, SN8807	B777-200	301-440	151 m3	3,668 miles/ 5,903 km	(Brussels Airlines) Swissport
Monday 29th of October 2012	Newark	9W228*	A330-200	253-380	136 m3	3,668 miles/ 5,903 km	Swissport
Monday 29th of October 2012	Philadelphia	US751*, SN9171	B767-200	181-255	90.1 m3	3,748 miles/ 6,032 km	Swissport
Monday 29th of October 2012	Washington	UA951*, AC5947, LH9382, LO4303,	B777-200	301-440	151 m3	3,879 miles/ 6,242 km	(Brussels Airlines) Swissport
Monday 29th of October 2012	New York JFK	DL141*, KL6141	B767-300	218-350	118.4 m3	3,655 miles/ 5,882 km	Swissport
Tuesday 30th of October 2012	New York JFK	AA171*, BA1580, EY3051, IB4247	B757-200	200-228	43.3 m3	3,655 miles/ 5,882 km	(American Airlines) Swissport
Tuesday 30th of October 2012	Newark	UA961*, AC5147, LH8854, SN8807	B777-200	301-440	151 m3	3,668 miles/ 5,903 km	(Brussels Airlines) Swissport
Tuesday 30th of October 2012	Philadelphia	US751*, SN9171	B767-200	181-255	90.1 m3	3,748 miles/ 6,032 km	Swissport
Tuesday 30th of October 2012	Newark	9W228*	A330-200	253-380	136 m3	3,668 miles/ 5,903 km	Swissport
Tuesday 30th of October 2012	New York JFK	DL141*, KL6141	B767-300	218-350	118.4 m3	3,655 miles/ 5,882 km	Swissport
Tuesday 30th of October 2012	New York JFK	SN501*, LH5620, UA9929	A330-300	295-440	162.8 m3	3,655 miles/ 5,882 km	(Brussels Airlines) Swissport
Tuesday 30th of October 2012	Washington	UA951*, AC5947, LH9382, LO4303,	B777-200	301-440	151 m3	3,879 miles/ 6,242 km	(Brussels Airlines) Swissport
Wednesday 31st of October 2012	New York JFK	AA171*, BA1580, EY3051, IB4247	B757-200	200-228	43.3 m3	3,655 miles/ 5,882 km	(American Airlines) Swissport
Wednesday 31st of October 2012	Newark	9W228*	A330-200	253-380	136 m3	3,668 miles/ 5,903 km	Swissport
Wednesday 31st of October 2012	New York JFK	DL141*, KL6141	B767-300	218-350	118.4 m3	3,655 miles/ 5,882 km	Swissport
Wednesday 31st of October 2012	New York JFK	SN501*, LH5620, UA9929	A330-300	295-440	162.8 m3	3,655 miles/ 5,882 km	(Brussels Airlines) Swissport
Thursday 1st of November 2012	/						

Source: Own composition

APPENDIX 6: ARRIVING CARGO FLIGHTS CANCELLED AT BRUSSELS AIRPORT[34]

Date	Origin (last leg)	Flight number	Plane type	Capacity	Flight Distance	Other origin legs	Comment
Tuesday 30th of October 2012	New York	OZ9625, OZ962	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Anchorage, Seoul	
Wednesday 31st of October 2012	Dallas DFW	SQ7969	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km	Sao Paulo	
Wednesday 31st of October 2012	New York	OZ9625	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Anchorage, Seoul	
Thursday 1st of November 2012	New York	OZ9625	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Anchorage, Seoul	
Thursday 1st of November 2012	New York	OZ962	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Anchorage, Seoul	
Thursday 1st of November 2012	Atlanta	SQ7329	B747-400 Freighter	124 ton	4,412 miles/ 7,101 km	Los Angeles	
Friday 2nd of November 2012	Dallas DFW	SQ7335	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km	Chicago O'Hare	
Friday 2nd of November 2012	New York	KE251	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Anchorage, Chicago O'Hare,	
Saturday 3rd of November 2012	Jeddah	SV901	B747-400 Freighter	124 ton	2,745 miles/ 4,418 km		Flight to New York later today cancelled
Saturday 3rd of November 2012	New York	OZ587	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Anchorage, Seoul	
Saturday 3rd of November 2012	Dallas DFW	SQ7973	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km	Sao Paulo	
Saturday 3rd of November 2012	Atlanta	SQ7955	B747-400 Freighter	124 ton	4,412 miles/ 7,101 km	Chicago O'Hare	
Sunday 4th of November 2012	Jeddah	SV901	B747-400 Freighter	124 ton	2,745 miles/ 4,418 km		Flight to New York later today cancelled
Sunday 4th of November 2012	Dallas DFW	SQ7195	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km		
Sunday 4th of November 2012	Dallas DFW	SQ7979	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km		
Sunday 4th of November 2012	Dallas DFW	SQ7331	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km	Los Angeles	
Sunday 4th of November 2012	Houston	SV902	B747-400 Freighter	124 ton	5,031 miles/ 8,097 km		
Monday 5th of November 2012	New York	OZ9625, OZ962	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Anchorage, Seoul	
Monday 5th of November 2012	Jeddah	SV901	B747-400 Freighter	124 ton	2,745 miles/ 4,418 km		Flight to New York later today cancelled
Monday 5th of November 2012	Chicago O'Hare	SQ7953	B747-400 Freighter	124 ton	4,145 miles/ 6,671 km	Los Angeles	

Source: Own composition

[34] The flight numbers have following meaning: OZ = Asiana Airlines, SV = Saudi Airlines, SQ = Singapore Airlines.

APPENDIX 7: DEPARTING CARGO FLIGHTS CANCELLED AT BRUSSELS AIRPORT

Date	Destination (first leg)	Flight number	Plane type	Capacity	Flight Distance	Other destination legs	Plane did not arrive from:
Tuesday 30th of October 2012	Almaty	OZ9625, OZ962	B747-400 Freighter	124 ton	3,311 miles/ 5,328 km	Seoul, Yantat	New York
Wednesday 31st of October 2012	Sharjah	SQ7969	B747-400 Freighter	124 ton	3,193 miles/ 5,139km	Singapore	Dallas DFW
Wednesday 31st of October 2012	Almaty	OZ9625	B747-400 Freighter	124 ton	3,311 miles/ 5,328 km	Seoul	New York
Wednesday 31st of October 2012	Atlanta	SQ7330	B747-400 Freighter	124 ton	4,412 miles/ 7,101 km		
Thursday 1st of November 2012	Almaty	OZ9625	B747-400 Freighter	124 ton	3,311 miles/ 5,328 km	Seoul	New York
Thursday 1st of November 2012	Dallas DFW	SQ7336	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km		
Thursday 1st of November 2012	Seoul	OZ962	B747-400 Freighter	124 ton	5,389 miles/ 8,673 km	Yantat	New York
Saturday 3rd of November 2012	Dallas DFW	SQ7332	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km		
Saturday 3rd of November 2012	New York	SV901	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km	Houston	
Saturday 3rd of November 2012	Seoul	OZ588	B747-400 Freighter	124 ton	5,389 miles/ 8,673 km		New York
Saturday 3rd of November 2012	Mumbai	SQ7955	B747-400 Freighter	124 ton	4,263 miles/ 6,860 km	Singapore	Atlanta
Sunday 4th of November 2012	New York	SV901	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km		
Sunday 4th of November 2012	Dallas DFW	SQ7334	B747-400 Freighter	124 ton	4,943 miles/ 7,955 km		
Sunday 4th of November 2012	Sharjah	SQ7979	B747-400 Freighter	124 ton	3,193 miles/ 5,139km	Singapore	Dallas DFW
Sunday 4th of November 2012	Damman	SV902	B747-400 Freighter	124 ton	2,902 miles/ 4,670 km	Jeddah, Riyadh	Houston
Monday 5th of November 2012	Almaty	OZ9625, OZ962	B747-400 Freighter	124 ton	3,311 miles/ 5,328 km	Seoul, Yantat	New York
Monday 5th of November 2012	New York	SV901	B747-400 Freighter	124 ton	3,655 miles/ 5,882 km		
Monday 5th of November 2012	Mumbai	SQ7953	B747-400 Freighter	124 ton	4,263 miles/ 6,860 km	Singapore	Chicago O'Hare
Tuesday 6th of November 2012	Seoul	OZ962	B747-400 Freighter	124 ton	5,389 miles/ 8,673 km	Yantat	

Source: Own composition