E.02.14 – D4.1 – CASSIOPEIA – Study Report – Case Study 1

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Abstract

The results of the simulations performed in Case Study 1 are presented in this document. A number of different scenarios have been designed, simulating the implementation of different night ban intervals at different number of major European airports.

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Executive summary

The Case Study 1 contains the simulation of different scenarios in which the night curfew for commercial flights between 23:00 and 05:00, presently applied at Frankfurt Main airport, is extended to some or all the top 10 European airports by passenger traffic.

The purpose of this case is to illustrate the capabilities of the combination of Complex Systems Science and Agent Based Modelling for the study of the impact of regulatory changes on the European Air Traffic System and their environmental and economic consequences.

Taken a representative week flight schedule (June 13-19, 2011), the model simulates the consequences of the additional airport restrictions, with the affected airlines taken different decisions depending on the type of airline (network carrier, low cost, regional, charter, freighter or integrator), its relation with the regulated airport (hub, non hub, main base, secondary destination) and the alternative destination airport.

A number of different scenarios have been calculated in order to compare the application of this measure to individual airports being hub of Network Carrier, or main base of a Low Cost Carrier. The joint results of application to pair of airports or all top ten are also studied. Additional scenarios contemplate the effects of modifying the night ban interval for one or more airports, increasing the curfew time at the beginning or at the end of the interval.

The results of the schedule changes are quantified in terms of a series of indicators, reflecting the variations in airline turnover, airport turnover, airport region economic losses due to lower traffic, jobs reduction due to lower traffic, average movements per hour, cumulative noise load ratio per hour, NOx emissions ratio per year and CO emissions ratio per year.

The main conclusions of the study show important effects in airline economy, airport revenues and socioeconomic impact, while environmental effects are more limited, reducing noise in the restricted time bands but increasing it in the close time zones and in alternative airports. There is no sizeable effect in air quality around the airports.

The socioeconomic impact is comparable with results from other studies of much more limited scope. This seems to confirm the adequacy of the modelling system adopted.

1 Introduction

The CASSIOPEIA (Complex Adaptive Systems for Optimisation of Performance in ATM) Research Project describes and develops a new framework for ATM performance modeling, based on Complex Systems Science and the use of Agent Based Modelling. The Project establishes a High-Level Specification and a Logical Architecture of the proposed model, followed by a demonstrative software system to allow the evaluation of different practical cases.

In order to demonstrate the potential of this technique, three Case Studies have been prepared addressing, respectively, the impact of regulatory changes, the impact of changes in business and/or operational strategies and the impact of technological changes.

1.1 Purpose of the document

This document presents the description of the Case Study 1, covering the impact of regulatory changes, describes the procedures for the model application and discusses the obtained results.

1.2 Intended readership

This report assumes the reader having a good knowledge and understanding of the European air transport system and the way of working of airlines, airports and ATM within the European Union.

1.3 Inputs from other projects

N.A.

1.4 Structure of the document

The document is divided in three main sections, preceded by an introduction.

The first part defines the Case Study to be modeled, identifying the different agents (airlines, ATM, airports and their neighborhoods), and the traffic scenario in which the Case is to be studied.

A second part presents the results of the different simulations, analyzing separately the economic consequences for airlines, airports and local communities and the corresponding environmental impacts in terms of noise and emissions affecting local air quality.

The basic elements for this analysis are the Performance Indicators for the Case Study 1, defined in the chapter 2 of the E.02.14-D2.5-CASSIOPEIA-Performance Indicators Models.

1.5 Acronyms and Terminology

Term	Definition
AMS	Schiphol, Amsterdam airport (IATA code)
ATM	Air Traffic Management
BCN	El Prat, Barcelona airport (IATA code)

CDG	Charles De Gaulle, Paris airport (IATA code)
CO_2	Carbon dioxide
EDDF	Main, Frankfurt airport (ICAO code)
EDDM	Franz Joseph Strauss, Munich airport (ICAO code)
EDDS	Stuttgart airport (ICAO code)
EDFH	Hahn airport (ICAO code)
EGKK	Gatwick, London airport (ICAO code)
EGLL	Heathrow, London airport (ICAO code)
EGSS	Stansted, London airport (ICAO code)
EHAM	Schiphol, Amsterdam airport (ICAO code)
EHRD	Rotterdam airport (ICAO code)
EP	European Parliament
FCO	Fiumicino, Rome airport (IATA code)
ICAO	International Civil Aviation Organization
LEBL	El Prat, Barcelona airport (ICAO code)
LEGE	Girona airport (ICAO code)
LCC	Low cost carrier
LEMD	Barajas, Madrid airport (ICAO code)
LEVD	Valladolid airport (ICAO code)
LFOB	Beauvais, Paris airport (ICAO code)
LFPG	Charles De Gaulle, Paris airport (ICAO code)
LFPO	Orly, Paris airport (ICAO code)
LGW	Gatwick, London airport (IATA code)
LHR	Heathrow, London airport (IATA code)
LIRA	Ciampino, Rome airport (ICAO code)
LIRF	Fiumicino, Rome airport (ICAO code)
MAD	Barajas, Madrid airport (IATA code)
MUC	Franz Joseph Strauss, Munich airport (IATA code)
NO_x	Nitrous Oxides
ORY	Orly, Paris airport (IATA code)
PI	Performance Indicator

2 Case Study 1 Definition

2.1 Case Study definition

Future air transport growth is only possible if it can be made compatible with the restrictions needed to protect the environment from excessive anthropogenic interference. The environmental impact of air transport has a global effect related to the emissions of green-house gases along the whole flight and a local effect linked to the quality of the air around the airport and to the noise inflicted in that area. Measures are being taken by airports and local authorities to limit these local effects. Some of these measurements are economical, by imposing taxes or charges. Some others directly restrict or prohibit operations at certain hours of the day (night flights). They can even ban the operation of certain types of aircraft, considered as the most relevant polluters.

As a consequence, local environmental restrictions at airports have the potential to limit the capacity of both the airport and the airspace. Up to now, gaseous emissions restrictions are still relatively scarce and their use is not widely accepted. Only five European countries (Denmark, Germany, Sweden, Switzerland and the United Kingdom) have implemented NOx related charges in a group of selected airports and no operating restrictions have been adopted in relation with this contaminant. On the contrary, noise abatement related measures have become very common all around the world and particularly in Europe, where 241 airports have some type of noise curfew, 103 apply noise limits and 128 collect noise related charges (see Appendix A)

The most often applies noise restrictions, leaving apart the Market Base Measures like noise related charges, are:

- Noise abatement operational procedures (in 47 airports)
- Partial time restrictions (38)
- Marginal aircraft exclusion (10)
- Noise budget (10)
- Night ban (4)

Aircraft noise impact around the major European airports has become one the most important potential restriction to air transport in the European Union. ICAO recommendations, integrated in the European legislation by Directive 2002/30/EC, present a noise reduction strategy based on four simultaneous measures:

- reduction of noise at the source (airframe, engines and systems)
- noise abatement operational procedures
- land use planning around the airport
- operating restrictions at the airport.

Each airport would apply the combination of them that better fits its particular features, including noise related charges as a mean of financing the whole program.

While ICAO considers operative restrictions as the last resource, applicable when the other three have been shown insufficient to solve noise problems, putting limits to the operation of the noisiest aircraft types, in particular at night, is now very frequent in the major European airports. In some cases, a total prohibition of commercial night flights (night curfew) is imposed, with important consequences on the airline economy and behavior and for the economy and employment of the airport community.

The present Case Study is designed with the purpose of simulating the different stakeholders response to the potential implementation of curfews in the 10 largest (by number of passengers) European Union airports, following the stream of Frankfurt-Main, where the opening of an additional runway was traded off with a night curfew, entering into force last year. A list of the 2012 year traffic in European airports may be found in Appendix B. Although this level of noise restriction is a totally

hypothetical situation, similar proposals have been presented to the European Parliament and studied by the EP Transport Committee.

Stakeholders involved in the process may be classified in four different categories:

- Authorities imposing the restrictions, either national o local ones

- Airports applying the restrictions, considered as independent entities (no coordinated policies of facilities owned by the same company, like Charles de Gaulle and Orly, belonging to Aéroports de Paris, are considered)

- Airlines operating at the airports

- Local communities of residents living around the airports

A general scheme of the possible interactions among the stakeholders can be seen in the following scheme:

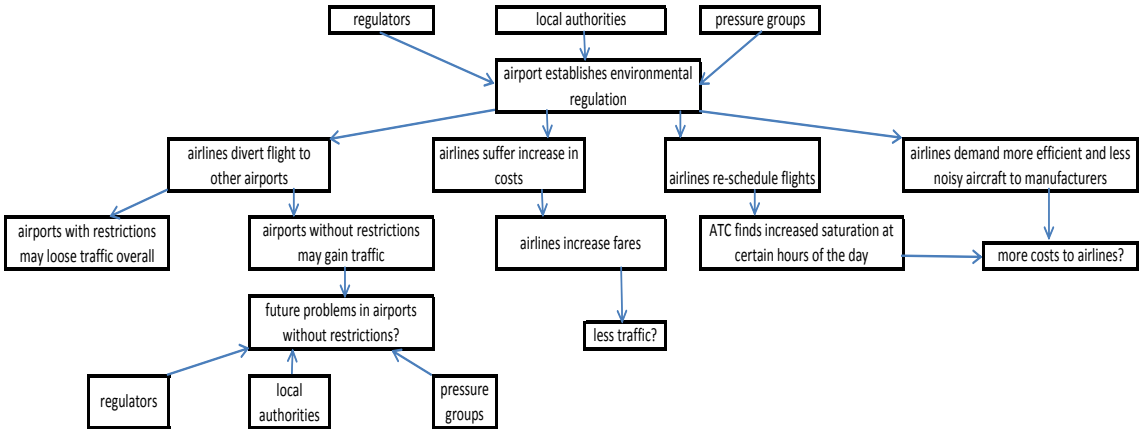

Figure 1 Stakeholders interaction scheme

In the modeling of this case action is taken by local authorities (probably responding to national regulators and pressure groups requests). These actions are implemented by the airports and have direct consequences on the operations of the airlines and on the airspace management in the short term. In the medium and long term, may affect also to the aircraft manufacturers and onboard equipment providers, who have to design products better fitted to the compliance with the new regulations. Only short term effects are studied in this Case study.

The airline response to the airport action is classified in seven types, depending on the class of services provided by each airline and on its relation with the regulated airport:

- Network airline with a hub in the regulated airport
- Network airline without a hub in the regulated airport
- Low cost carrier (LCC)
- Regional airline
- Cargo airline
- Charter company
- Integrator

The differentiation among the different categories is not always easy. Basic features of network airlines are often identified as those conforming the airline classic system since the end of the Second

World War: several levels of services, medium and long range routes, high rate of connecting passengers, etc. Low-cost carriers are supposed to fly point-to-point, with minimum service, short-medium range and no connections. Regionals are characterized by operating aircraft with less than 100 seats in short-range routes. Charters are basically non-scheduled. Cargo airlines are pure freighter operators and integrators offer door-to-door, multimodal services. Following these general concepts, airlines with flights included in the regulated periods have been allocated in one of the previous categories, after gathering data of their business behavior.

It is also needed to list the network airlines' hubs and determine which ones are *hubbing* in the regulated airports. The airlines using the top-ten European airports, ranked by passenger traffic, as hubs (or bases in the case of the Low cost Carriers) are listed in the following table:

Table 1. Airlines with hub or main base in the 10 top European airports

Airline	Hub
British Airways	LHR
Air France	CDG
Lufthansa	FRA
KLM	AMS
Iberia	MAD
Alitalia	FCO
Lufthansa	MUC
EasyJet (*)	LGW
Vueling (*)	BCN
Air France	ORY
(*) LCC base	

It is assumed that each airport is the hub of a unique airline, independently of the number of companies operating and the type of those airlines. This may be doubtful in the cases of London Gatwick, main EasyJet base, where British Airways has many flights; or in Paris Orly, hub of Air France, with many EasyJet services, but the majority of British Airways flights from Gatwick are typically bound for vacation destinations with low level of transfer traffic, and EasyJet has not yet reached enough concentration of departures in Orly, due to lack of slots. Therefore, the above classification looks like a sensible one.

Under these premises, the airlines having flights in the regulated periods may choose one of the following actions:

- keep the flight moving the scheduled time out of the restricted period
- maintain the schedule but using an alternative airport
- cancel the flight

The decision will be influenced by the type of company, its relation with the airport, the distance to the alternative airport, and the time interval between the original and the new schedule. The following table indicates the type of action adopted in each of the individual cases:

Table 2. Airline possible actions

Network company at its hub		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	cancel flight	cancel flight
	100-200 km	maintain destination	cancel flight	cancel flight
	> 200 km	maintain destination	cancel flight	cancel flight

Network company outside its hub		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain destination	maintain schedule
	100-200 km	maintain destination	maintain destination	maintain schedule
	> 200 km	maintain destination	maintain destination	cancel flight

Low Cost Carrier at its base		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	cancel flight	cancel flight
	100-200 km	maintain destination	cancel flight	cancel flight
	> 200 km	maintain destination	cancel flight	cancel flight

Low Cost Carrier outside its base		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain schedule	maintain schedule
	100-200 km	maintain destination	maintain destination	maintain schedule
	> 200 km	maintain destination	maintain destination	cancel flight

Charter operator at its hub		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain destination	maintain schedule
	100-200 km	maintain destination	maintain destination	maintain schedule
	> 200 km	maintain destination	maintain destination	cancel flight

Charter operator outside its hub		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain schedule	maintain schedule
	100-200 km	maintain destination	maintain schedule	maintain schedule
	> 200 km	maintain destination	maintain destination	cancel flight

Regional company at its hub		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	cancel flight	cancel flight
	100-200 km	maintain destination	cancel flight	cancel flight
	> 200 km	maintain destination	cancel flight	cancel flight

Regional company outside its hub		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain destination	maintain schedule
	100-200 km	maintain destination	maintain destination	maintain schedule
	> 200 km	maintain destination	maintain destination	cancel flight

Cargo Carrier at its base		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain destination	cancel flight
	100-200 km	maintain destination	maintain destination	cancel flight
	> 200 km	maintain destination	maintain destination	cancel flight

Cargo Carrier outside its base		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain destination	cancel flight
	100-200 km	maintain destination	maintain destination	cancel flight
	> 200 km	maintain destination	maintain destination	cancel flight

Integrator at its base		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain destination	cancel flight
	100-200 km	maintain destination	maintain destination	cancel flight
	> 200 km	maintain destination	maintain destination	cancel flight

Integrator outside its base		Interval between both schedules		
		< 1 h	1-2 h	> 2 h
Distance between original and alternate airport	< 100 km	maintain destination	maintain destination	cancel flight
	100-200 km	maintain destination	maintain destination	cancel flight
	> 200 km	maintain destination	maintain destination	cancel flight

These different types of behaviour are well characterised by the actual experience and has not changed since the inception of the hub & spoke network configuration, after US Deregulation Act approval in 1978. “Classic” carriers are dependent on their connecting flight waves at their hubs and will keep their flights if time change is small or will cancel if the change of schedule does not allow to connect. Flights to other airports are already connected and allow more flexibility in timing. Regionals move under the same trend, but flying shorter routes and are less tolerant for wider schedule changes. A good summary of this policy can be seen in [12], with special emphasis in Western Europe in [13].

In the case of LCCs, at their main base will behaviour in a similar way but for different reasons. If their destination airport closes at the scheduled time, can go to an alternate destination if it is close, but simply cancel the flight and allocate the aircraft to other route if the alternate airport is too far away. Outside of their main base, they are more prone to keep schedule even in a relatively distant airport. References [14] for the European case and [15] with a more general approach give a wide explanation of this example.

Charters are mainly vacation flights and less affected by change of schedule. At the same time, charters may go easily to an alternate airport, provided it is not very far away and there are surface

transportation means to move passengers to their original destination. Like LCCs, comnnections are not an issue for them.

Finally, cargo airlines and integrators are basically multimodal transporters, with the freight going to its final destination by road or train, and being very tolerant with schedule changes. Therefore, they will try to keep destinations as much as possible, Reference [16] shows a comprehensive survey among main cargo airlines on their choice of airport procedures and [17] provides theoretical evidence for the air cargo industry operation.

2.2 Scenarios design

The central scenario for Case Study 1 is the generalization of the ban on night flights in Frankfurt airport, where commercial operations are forbidden from 23:00 to 05:00 to protect local communities against noise. This central scenario is named S7 in Table 3, where a similar night ban is applied simultaneously at the rest of the top 10 European airports, ranked by passenger traffic in 2011.

Frankfurt is the main hub of Lufthansa, one of the three dominant network airline groups in Europe, although this carrier has other powerful hub at Munich-Franz Joseph Strauss airport. The potential effects of the same type of measures on the other two groups of main hubs, without a clearly defined dual hub strategy, are evaluated in Scenarios 1 and 2.

Scenario 1 (S1) is intended to investigate the application of a night ban in the largest airport in Europe, London Heathrow (see Table 5 with the ranking of European airports in 2011), hub of British Airways, as representative of the behavior of network carriers suffering a night ban at its main hub. Similarly, and in order to have a second sample of this type of behavior, in Scenario 2 (S2) the same night ban is applied to Paris Charles de Gaulle, the second largest airport in Europe, and main hub of Air France.

Scenario 5 (S5) tries to determine, applying simultaneously the night ban to London Heathrow and Paris Charles de Gaulle and comparing to S1 and S2 if there is any type of coupling by applying the night ban at this two large hub airports at the same time. Similarly, in Scenario 6 (S6) the night ban is applied at the same time at the four largest airports in Europe, and finally, in Scenario 7 (S7) the night ban is applied simultaneously at the top 10 airports in Europe, to complete the analysis of the dependence on the number of airports of the application of the night curfew.

Table 3. Scenarios to assess the influence of the number of airports where the night ban is applied.

Regulated airport	S1	S2	S3	S4	S5	S6	S7
LHR	X				X	X	X
CDG		X			X	X	X
AMS						X	X
MAD						X	X
MUC							X
FCO							X
BCN			X				X
LGW				X			X
ORY							X

Scenarios 3 (S3) and 4 (S4) have a different orientation. They are designed to explore the impact of the night ban at airports where the low cost carriers, characterized for low connection levels and no long range services, are dominant and have their most numerous aircraft base or at least a large flight center. This is the case of Barcelona (S3), base of the LCC Vueling, having 30 % of the total number of flights in the airport, with Ryanair and EasyJet having together another 20 % of the total number of flights (see table 3). It is also the case for London Gatwick (S4), base of EasyJet with 40 % of the total number of flights at that airport.

Once the impact on the key performance indicators of the application of the night ban at a different number of airports or at different airport types has been investigated, another set of scenarios is defined in order to assess the influence of the time interval where the night ban is applied. This new set of scenarios is defined in table 4. The rationale behind this scenario design consists of reducing the time interval from the central one (23:00 to 5:00), and applying a new time interval night ban first only to Frankfurt airports, and then in a different scenario to the top 10 European airports. Four new time intervals are defined, by moving the central one in steps of 30 minutes at each border, providing therefore eight more scenarios, from S8 to S15, as shown in table 4.

Table 4. Scenarios to assess the influence of the time interval where the night ban is applied.

Ban interval	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**
22:00 – 5:00	FRA	10 airports						
22:30 – 5:00			FRA	10 airports				
23:00 – 6:00					FRA	10 airports		
23:00 – 6:30							FRA	10 airports

Table 5. European airports ranking in 2011 by passengers, giving also the number of flights (frequencies per week), and indicating the share of the leading three carriers.

Airport	Passengers (thousands)	Frequencies per week	Proportion of flights by lead three carriers (%)					
			Carrier 1		Carrier 2		Carrier 3	
LHR	69.354	9.588	British Airways	44,7	BMI(1)	8,1	Lufthansa	3,8
CDG	60.971	8.952	Air France	41,9	Regional(2)	8,1	EasyJet	7,4
FRA	56.436	9.196	Lufthansa	53,0	Lufthansa(3) CityLine	11,0	Condor (3)	2,1
AMS	49.755	8.080	KLM	29,2	KLM Cityhopper(4)	25,5	EasyJet	6,9
MAD	49.644	7.542	Iberia	30,9	Air Nostrum(5)	15,7	Ryanair	10,0
MUC	37.764	7.290	Lufthansa	30,0	Lufthansa CityLine(3)	19,1	Air Berlin	8,3
FCO	37.651	6.290	Alitalia	41,0	EasyJet	7,2	Air Sofia	4,0
BCN	34.388	5.806	Vueling(6)	29,4	Ryanair	13,9	EasyJet	8,5
LGW	33.668	4.900	EasyJet	40,4	British Airways	17,8	Flybe	8,9
ORY	27.139	4.354	Air France	30,4	Brit Air(2)	9,3	EasyJet	9,1

(1) BMI was bought by IAG (British Airways and Iberia) in 2012

(2) Regional and Brit Air are owned by Air France and are integrated in the new low cost airline Hop

(3) Lufthansa City Line and Condor are owned by Lufthansa

(4) KLM Cityhopper is owned by KLM

(5) Air Nostrum operates for Iberia, under a franchise agreement

(6) Iberia has 49% of Vueling property. IAG has presently launched an IPO for the totality of Vueling capital, with the purpose of integrating Vueling operation in the IAG strategy

The list of flights and their arrival/departure local time out of each airport is taken from EUROCONTROL PRISME database. For this specific simulation the week of June 13-19, 2011 has been selected as representative average week traffic for the year.

3 Results of the simulations

The results of the different simulations are synthetized in a number of Performance Indicators (PIs) that have been previously defined in the Document E.02.14-D2.5-CASSIOPEIA-Performance Indicators Models [5].

Performance Indicators are grouped in four categories, to assess the impact of the new regulations respectively on airlines, airports, local communities and the environment:

Economic Impact on Airlines

- Performance Indicator 1 - Airline Turnover and Operating Margin for Network Airlines with a Hub at the Airport
- Performance Indicator 2 - Airline Turnover for the Rest of the Airlines

In both indicators the economic impact on airlines is estimated through the reduction of flights for that airline caused by the regulation set in place, assuming that airline turnover is directly related to the total number of flights in a period of time.

Economic Impact on Airports

- Performance Indicator 3 - Airport Turnover

This indicator is an approximation to the airport turnover variation; taking into account the fact that airport turnover is directly related to the number of movements in a period of time and to the MTOW of the aircraft.

Economic Impact on Communities

- Performance Indicator 4 - Economic Losses Due to Lower Traffic
- Performance Indicator 5 – Jobs Affected Due to Lower Traffic
- Performance Indicator 6 – Average Movements per Hour

The economic traffic unit impact in terms of money is calculated dividing the year GDP estimated for aviation-related activities by the number of passengers travelling in that country. The employment rate per passenger is calculated dividing the number of jobs of aviation-related industries by the number of passengers travelling in that country. For a more detailed explanation on the evaluation of traffic units in terms of economic losses and employment see Appendix C.

Environmental Impacts

- Performance Indicator 7 - Cumulative Noise Load Ratio per Hour
- Performance Indicator 8 - Cumulative NOx Emissions Ratio per Year
- Performance Indicator 9 - Cumulative CO Emissions Ratio per Year

Noise load is measured during a period of time as the addition of the certified noise level of all aircraft movements, represented by the average of landing noise and take-off noise (arithmetic average of flyover and lateral certification noise) in that period of time. Certified noise levels for each aircraft type are obtained from EASA TCDSN (Type Certificate Data Sheet Noise) [6]. This database provides certified noise levels of civil transport aircraft types certificated under ICAO Annex 16, Chapter 3 and Chapter 4 Standards.

NOx and CO data are extracted from the ICAO Aircraft Engine Emissions Databank [7], using the kilograms emitted by each aircraft type in the standard certification LTO (landing-take-off) cycle, including all aircraft maneuvers below 3.000 ft. over ground.

Scenario 1

Scenario 1 (S1) is intended to investigate the application of a night ban in the largest airport in Europe, London Heathrow, hub of British Airways, as representative of the behavior of network carriers suffering a night ban at its main hub. Once the night ban is in place at Heathrow, British Airways will try to shift the schedule of its affected flights in order not to change airport. The case modeling assumes Stansted as the airport where other legacy airlines may shift those flights that may be affected by the night ban at Heathrow (slots at Gatwick are difficult to be obtained). Low cost carriers most probably will cancel their flights at Heathrow if any.

Table 6. PIs of Scenario 1 (London Heathrow EGLL).

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport		99,97%
PI2: Airline Turnover for the rest of the Airlines		100,00%
PI3: Airport Turnover	EGLL	99,86%
PI3: Airport Turnover	EGSS	100,10%
PI4: Economic Losses due to lower traffic per year	London	65.732.584
PI5: Jobs affected due to lower traffic per year	London	1.100
PI6: Average Movements per hour	21h - EGLL - after	71
PI6: Average Movements per hour	21h - EGLL - before	58
PI6: Average Movements per hour	21h - EGSS - after	44
PI6: Average Movements per hour	21h - EGSS - before	44
PI6: Average Movements per hour	22h - EGLL - after	0
PI6: Average Movements per hour	22h - EGLL - before	15
PI6: Average Movements per hour	22h - EGSS - after	30
PI6: Average Movements per hour	22h - EGSS - before	30
PI6: Average Movements per hour	23h - EGLL - after	0
PI6: Average Movements per hour	23h - EGLL - before	0
PI6: Average Movements per hour	23h - EGSS - after	7
PI6: Average Movements per hour	23h - EGSS - before	7
PI6: Average Movements per hour	3h - EGLL - after	0
PI6: Average Movements per hour	3h - EGLL - before	2
PI6: Average Movements per hour	3h - EGSS - after	1
PI6: Average Movements per hour	3h - EGSS - before	1
PI6: Average Movements per hour	4h - EGLL - after	6
PI6: Average Movements per hour	4h - EGLL - before	4
PI6: Average Movements per hour	4h - EGSS - after	0
PI6: Average Movements per hour	4h - EGSS - before	0
PI7: Cumulative Noise Load Ratio per hour	0h - EGLL	0
PI7: Cumulative Noise Load Ratio per hour	1h - EGLL	0
PI7: Cumulative Noise Load Ratio per hour	20h - EGLL	99,91%
PI7: Cumulative Noise Load Ratio per hour	21h - EGLL	101,75%

PI7: Cumulative Noise Load Ratio per hour	22h - EGLL	0,00%
PI7: Cumulative Noise Load Ratio per hour	22h - EGSS	101,72%
PI7: Cumulative Noise Load Ratio per hour	23h - EGLL	0,00%
PI7: Cumulative Noise Load Ratio per hour	2h - EGLL	0,00%
PI7: Cumulative Noise Load Ratio per hour	3h - EGLL	0,00%
PI7: Cumulative Noise Load Ratio per hour	4h - EGLL	100,12%
PI8: Cumulative NOx Emissions Ratio per year	null	99,98%
PI9: Cumulative CO Emissions Ratio per year	null	99,98%

Looking at PI6 in Table 6 it can be seen that there is not a significant change in the number of movements at Heathrow as a consequence of the night ban implementation because some noisy aircraft restrictions are already applied in the night period. As a consequence the number of affected flights is only 117 (17 daily).

Most of the night flights are operated by British Airways, and the reaction of this airline is modifying the schedule of the affected flights and shift them to the hours previous to the night ban (it had 15 flights at the first hour of the ban, 23:00, which are affected by the night ban, but it increases the number of flights from 58 to 71 the hour previous to the ban, at 22:00).

The impact of the night ban in the economic results of airlines is therefore not too sizeable: this indicator shows a value of 99.97% for airlines with a hub at the regulated airport (PI1), mainly British Airways, and 100.00% for the rest of the airlines (PI2). However, it must be considered that profit margins of airlines are small comparative percentages (typically 1 – 2 % of revenues) and any small decrease in revenues may translate in important changes in net profits.

In the same sense, the economic impact on airports is modest, 99.86% for Heathrow and 100.10% for Stansted (PI3), but this size of changes is easily adapted by infrastructure operators.

Looking at the socio-economic impact on the airport local community, in this case the city of London, resting most of the flights in Heathrow, and shifting a few of them to Stansted, still in London, this impact is limited. The yearly economic losses due to lower traffic result in 65 million € (PI4) and the number of jobs affected due to lower traffic, also in a year, result in 1,100 (PI5).

On the environmental side, the impact of the night ban can be considered positive, because it obviously eliminates the noise at the restricted hours, and it does not result in a significant increase in noise at the adjacent hours (101.72% one hour before the ban at night, 100.12% one hour after the ban, in the morning, PI7).

One interesting element not contemplated in this simulation is the repercussion of arriving and departure time changes in intercontinental flights at Heathrow on other airports. Due to the different time zones, these changes may create arrivals/departures at other airports incompatible with their environmental limitations or simply produce additional nuisances to people living around the airports. Very recently, India has presented a formal complain to ICAO Council on this issue.

Local gas emissions are not affected by the noise abatement measure. For both NOx (PI8) and CO (PI9) the indicator shows a value of 99.98%.

Scenario 2

In Scenario 2 (S2) the night ban is applied to Paris Charles de Gaulle, the second largest airport in Europe, and main hub to Air France in order to have a second sample of this type of behavior (network carriers suffering a night ban at its main hub).

As a network carrier with its hub at Paris Charles de Gaulle, Air France will try to shift the schedule of its affected flights in order not to change airport.

The case modeling assumes Beauvais as the airport where other airlines may shift those of their flights that are affected by the night ban at Paris Charles de Gaulle, because Orly has a limit for the number of flights.

Table 7. PIs of Scenario 2 (Paris Charles de Gaulle LFPG).

description	influence	value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	99,53%
PI2: Airline Turnover for the rest of the Airlines	null	99,23%
PI3: Airport Turnover	LFOB	119,73%
PI3: Airport Turnover	LFPG	95,71%
PI4: Economic Losses due to lower traffic per year	Beauvais	- 587.298.049
PI4: Economic Losses due to lower traffic per year	Paris	5.560.169.653
PI5: Jobs affected due to lower traffic per year	Beauvais	- 7.399
PI5: Jobs affected due to lower traffic per year	Paris	70.048
PI6: Average Movements per hour	20h - LFPG - after	69
PI6: Average Movements per hour	20h - LFPG - before	42
PI6: Average Movements per hour	21h - LFOB - after	10
PI6: Average Movements per hour	21h - LFOB - before	5
PI6: Average Movements per hour	21h - LFPG - after	0
PI6: Average Movements per hour	21h - LFPG - before	42
PI6: Average Movements per hour	22h - LFOB - after	3
PI6: Average Movements per hour	22h - LFOB - before	0
PI6: Average Movements per hour	22h - LFPG - after	0
PI6: Average Movements per hour	22h - LFPG - before	26
PI6: Average Movements per hour	23h - LFPG - after	0
PI6: Average Movements per hour	23h - LFPG - before	11
PI6: Average Movements per hour	2h - LFPG - after	0
PI6: Average Movements per hour	2h - LFPG - before	9
PI6: Average Movements per hour	3h - LFPG - after	24
PI6: Average Movements per hour	3h - LFPG - before	13
PI7: Cumulative Noise Load Ratio per hour	18h - LFPG	99,91%
PI7: Cumulative Noise Load Ratio per hour	19h - LFPG	98,14%
PI7: Cumulative Noise Load Ratio per hour	20h - LFPG	98,52%
PI7: Cumulative Noise Load Ratio per hour	3h - LFPG	138,78%
PI8: Cumulative NOx Emissions Ratio per year	null	98,89%
PI9: Cumulative CO Emissions Ratio per year	null	98,97%

The results of this Scenario 2 are very similar to the results of Scenario 1, regarding the behavior of the network carrier with its main hub at the regulated airport. There is not a significant change in the number of movements at Paris Charles de Gaulle as a consequence of the night ban implementation,

as it can be observed looking at PI6 in Table 7. The flights that are affected by the night ban are shifted to the adjacent hours. A part of the flights are moved to Beauvais, as it is shown also by PI6 in Table 7. There are, however, a number of night flights at Paris Charles de Gaulle from airlines other than Air France.

Total number of affected flights, 609 or 87 daily, is higher than in the S1 scenario because CDG has a total noise energy limit during the night period and quieter modern technology aircraft allows a high number of movements.

As a consequence, the impact of the night ban in the economic results of airlines is therefore not too relevant: this indicator shows a value of 99.53% for airlines with a hub at the regulated airport (PI1) and 99.23% for the rest of the airlines (PI2).

The economic impact on airports is significant, 95.71% for Paris Charles de Gaulle and 119.73% for Beauvais (PI3).

The socio-economic impact on the Paris community is very important. The yearly economic losses due to lower traffic result in 5,560 million € (PI4) and the number of jobs affected due to lower traffic, also in a year, result in 70,048 (PI5). These big impacts are somehow attenuated by the impacts at Beauvais, whose community receives an economic gain of 587 million € and more than 7,000 employments. This big impact on the economy of the local airport community is due to a double effect: in first place, a significant number of flights is shifted to an airport outside of that community; in second place, the result is also a consequence of the big impact that the air transport industry overall as on the French economy, and how sensible is this economy to changes in the air transport indicators.

The impact of the night ban at Paris Charles de Gaulle is somehow difficult to assess because it shifts the noise problem to the hours adjacent to the ban (138.78% one hour before the ban finishes at night, PI7).

Local air quality gas emissions show a reduction of 98.89% for NOx (PI8) and 98.97% for CO (PI9).

Scenario 3

Scenario 3 (S3) is designed to explore the impact of the night ban at airports where the low cost carriers, characterized for low connection levels and no long range services, are dominant and have their most numerous aircraft base or at least a large flight center. This is the case of Barcelona, base of the LCC Vueling, having 30 % of the total number of flights in the airport, with Ryanair and EasyJet having together another 20 % of the total number of flights.

Table 8. PIs of Scenario 3 (Barcelona LEBL).

description	influence	value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport		99,83%
PI2: Airline Turnover for the rest of the Airlines		99,51%
PI3: Airport Turnover	LEBL	94,06%
PI3: Airport Turnover	LEGE	115,22%
PI4: Economic Losses due to lower traffic per year	Barcelona	1.282.840.522
PI4: Economic Losses due to lower traffic per year	Girona	- 579.284.565

PI5: Jobs affected due to lower traffic per year	Barcelona	21.679
PI5: Jobs affected due to lower traffic per year	Girona	- 9.789
PI6: Average Movements per hour	20h - LEBL - after	81
PI6: Average Movements per hour	20h - LEBL - before	51
PI6: Average Movements per hour	21h - LEBL - after	0
PI6: Average Movements per hour	21h - LEBL - before	52
PI6: Average Movements per hour	21h - LEGE - after	14
PI6: Average Movements per hour	21h - LEGE - before	10
PI6: Average Movements per hour	22h - LEBL - after	0
PI6: Average Movements per hour	22h - LEBL - before	26
PI6: Average Movements per hour	22h - LEGE - after	9
PI6: Average Movements per hour	22h - LEGE - before	2
PI6: Average Movements per hour	23h - LEBL - after	0
PI6: Average Movements per hour	23h - LEBL - before	4
PI6: Average Movements per hour	23h - LEGE - after	10
PI6: Average Movements per hour	23h - LEGE - before	0
PI6: Average Movements per hour	2h - LEBL - after	0
PI6: Average Movements per hour	2h - LEBL - before	3
PI6: Average Movements per hour	3h - LEBL - after	5
PI6: Average Movements per hour	3h - LEBL - before	1
PI7: Cumulative Noise Load Ratio per hour	19h - LEBL	99,03%
PI7: Cumulative Noise Load Ratio per hour	20h - LEBL	93,21%
PI7: Cumulative Noise Load Ratio per hour	21h - LEGE	104,49%
PI7: Cumulative Noise Load Ratio per hour	22h - LEGE	94,51%
PI7: Cumulative Noise Load Ratio per hour	3h - LEBL	121,43%
PI8: Cumulative NOx Emissions Ratio per year	null	99,65%
PI9: Cumulative CO Emissions Ratio per year	null	99,64%

Looking at PI6 in Table 8 it can be seen that there is a significant change in the number of movements at Barcelona as a consequence of the night ban implementation. Number of affected flights is similar to CDG case, 597 or 85 daily. Only a fraction of the flights which are not possible because of the night ban are shifted to the hours adjacent to the ban. A significant portion of the flights during the ban period are moved to the alternate airport, Girona in this case, roughly 100 kilometer away.

As a consequence, the impact of the night ban in the economic results of airlines is limited: this indicator shows a value of 99.83% for airlines with a hub at the regulated airport (PI1) and 99.51% for the rest of the airlines (PI2).

The economic impact is most apparent in the case of the airports. Barcelona airport turnover is affected in a 94.06%, while Girona airport obtains a 115.22% (PI3).

In the same sense, the socio-economic impact on the airport local community shows a big impact in the city of Barcelona, with yearly economic losses due to lower traffic of almost 1,300 million € (PI4) and a loss of 22,000 jobs (PI5), while Girona gets a positive impact in its local economy of 580 million € and almost 10,000 jobs in a year.

The impact of the night ban on the environmental side is only partially effective, because the noise problem (PI7) at Barcelona is shifted, together with most of the flights, to the hour previous to the night ban (a noise ratio of 121%), and to the Girona airport (noise ratio of 104%).

Local gas emissions are not affected by the noise abatement measure. For both NOx (PI8) and CO (PI9) the indicator shows a value of 99.65%.

Scenario 4

In Scenario 4 the night ban is implemented in London Gatwick (S4), base of the low cost carrier EasyJet, with 40 % of the total number of flights at that airport. Indicators in Table 9 show how most of the flights affected by the night ban at Gatwick are shifted to the alternate Stansted airport. Therefore, the economic parameters of the airlines (PI1 and PI2) are not affected. The airport turnover indicators (PI3) show this transfer of flights, with a 93.81% for Gatwick and a 116.84% for Stansted.

On the socio-economical side, since both airports are in the same city, London, and the effect is basically the shifting of flights from one airport to the other, the result on the city is neutral, and therefore PI4 and PI5 show respective values of 0.

Table 9. PIs of Scenario 4 (London Gatwick EGKK).

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport		100.00%
PI2: Airline Turnover for the rest of the Airlines		100.00%
PI3: Airport Turnover	EGKK	93.81%
PI3: Airport Turnover	EGSS	116.84%
PI4: Economic Losses due to lower traffic per year	London	0
PI5: Jobs affected due to lower traffic per year	London	0
PI6: Average Movements per hour	0h - EGKK - after	0
PI6: Average Movements per hour	0h - EGKK - before	7
PI6: Average Movements per hour	0h - EGSS - after	12
PI6: Average Movements per hour	0h - EGSS - before	4
PI6: Average Movements per hour	1h - EGKK - after	0
PI6: Average Movements per hour	1h - EGKK - before	5
PI6: Average Movements per hour	1h - EGSS - after	6
PI6: Average Movements per hour	1h - EGSS - before	1
PI6: Average Movements per hour	21h - EGKK - after	49
PI6: Average Movements per hour	21h - EGKK - before	39
PI6: Average Movements per hour	21h - EGSS - after	44
PI6: Average Movements per hour	21h - EGSS - before	44
PI6: Average Movements per hour	22h - EGKK - after	0
PI6: Average Movements per hour	22h - EGKK - before	24
PI6: Average Movements per hour	22h - EGSS - after	38
PI6: Average Movements per hour	22h - EGSS - before	30
PI6: Average Movements per hour	23h - EGKK - after	0

PI6: Average Movements per hour	23h - EGKK - before	16
PI6: Average Movements per hour	23h - EGSS - after	27
PI6: Average Movements per hour	23h - EGSS - before	7
PI6: Average Movements per hour	2h - EGKK - after	0
PI6: Average Movements per hour	2h - EGKK - before	3
PI6: Average Movements per hour	2h - EGSS - after	4
PI6: Average Movements per hour	2h - EGSS - before	1
PI6: Average Movements per hour	3h - EGKK - after	0
PI6: Average Movements per hour	3h - EGKK - before	2
PI7: Cumulative Noise Load Ratio per hour	1h - EGSS	101.15%
PI7: Cumulative Noise Load Ratio per hour	20h - EGKK	99.31%
PI7: Cumulative Noise Load Ratio per hour	21h - EGKK	97.60%
PI7: Cumulative Noise Load Ratio per hour	4h - EGKK	92.74%
PI8: Cumulative NOx Emissions Ratio per year	null	100.00%
PI9: Cumulative CO Emissions Ratio per year	null	100.00%

The impact on noise is beneficial, with a reduction of noise at Gatwick also in the hours adjacent to the night ban, and a modest increment of noise at Stansted in exchange (101%, PI7). The number of affected flights is higher than in Heathrow, 400 or 57 daily, because there are many charter flights leaving or arriving at night.

The value of local gas emissions (PI8 and PI9) is not altered because of the previously mentioned effect of just shifting flights between airports in the same community.

Scenario 5

Scenario 5 (S5) tries to determine, applying simultaneously the night ban to London Heathrow and Paris Charles de Gaulle and comparing to S1 and S2 if there is any type of coupling by applying the night ban at this two large hub airports at the same time.

Results in Table 10 show that there is not really a significant coupling in any of the indicators by applying simultaneously the night ban at these two leading airports, by comparing them to the results in Table 1 and Table 2 for the indicators of the ban individually implemented respectively at London Heathrow and Paris Charles de Gaulle.

Table 10. PIs of Scenario 5 (London Heathrow EGLL and Paris Charles de Gaulle LFPG).

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	99.63%
PI2: Airline Turnover for the rest of the Airlines	null	99.43%
PI3: Airport Turnover	EGLL	99.91%
PI3: Airport Turnover	EGSS	100.00%
PI3: Airport Turnover	LFOB	119.93%
PI3: Airport Turnover	LFPG	95.83%
PI4: Economic Losses due to lower traffic per year	Beauvais	- 599,476,889

PI4: Economic Losses due to lower traffic per year	London	86,940,645
PI4: Economic Losses due to lower traffic per year	Paris	5,389,255,529
PI5: Jobs affected due to lower traffic per year	Beauvais	- 7,552
PI5: Jobs affected due to lower traffic per year	London	1,455
PI5: Jobs affected due to lower traffic per year	Paris	67,895
PI6: Average Movements per hour	20h - LFPG - after	70
PI6: Average Movements per hour	20h - LFPG - before	42
PI6: Average Movements per hour	21h - EGLL - after	72
PI6: Average Movements per hour	21h - EGLL - before	58
PI6: Average Movements per hour	21h - LFOB - after	10
PI6: Average Movements per hour	21h - LFOB - before	5
PI6: Average Movements per hour	21h - LFPG - after	0
PI6: Average Movements per hour	21h - LFPG - before	42
PI6: Average Movements per hour	22h - EGLL - after	0
PI6: Average Movements per hour	22h - EGLL - before	15
PI6: Average Movements per hour	22h - LFPG - after	0
PI6: Average Movements per hour	22h - LFPG - before	26
PI6: Average Movements per hour	23h - LFPG - after	0
PI6: Average Movements per hour	23h - LFPG - before	11
PI6: Average Movements per hour	2h - LFPG - after	0
PI6: Average Movements per hour	2h - LFPG - before	9
PI6: Average Movements per hour	3h - EGLL - after	0
PI6: Average Movements per hour	3h - EGLL - before	2
PI6: Average Movements per hour	3h - LFPG - after	24
PI6: Average Movements per hour	3h - LFPG - before	13
PI7: Cumulative Noise Load Ratio per hour	20h - LFOB	99.38%
PI7: Cumulative Noise Load Ratio per hour	20h - LFPG	99.81%
PI7: Cumulative Noise Load Ratio per hour	21h - EGLL	101.56%
PI7: Cumulative Noise Load Ratio per hour	22h - EGSS	101.72%
PI7: Cumulative Noise Load Ratio per hour	23h - EGSS	100.37%
PI7: Cumulative Noise Load Ratio per hour	2h - EGSS	111.90%
PI7: Cumulative Noise Load Ratio per hour	3h - LFPG	138.78%
PI7: Cumulative Noise Load Ratio per hour	4h - EGLL	100.12%
PI8: Cumulative NOx Emissions Ratio per year	null	99.16%
PI9: Cumulative CO Emissions Ratio per year	null	99.20%

There are 712 flights affected (102 per day), roughly the same figure than adding up individual cases in S1 and S2.

Scenario 6

In Scenario 6 (S6) the night ban is applied at the same time at the four largest airports in Europe (in addition to Frankfurt): London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol and Madrid Barajas.

Table 11. PIs of Scenario 6 (EGLL, LFPG, EHAM and LEMD).

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	98.69%
PI2: Airline Turnover for the rest of the Airlines	null	99.41%
PI3: Airport Turnover	EGLL	99.82%
PI3: Airport Turnover	EGSS	100.10%
PI3: Airport Turnover	EHAM	99.17%
PI3: Airport Turnover	EHRD	138.73%
PI3: Airport Turnover	LEMD	93.65%
PI3: Airport Turnover	LEVD	582.51%
PI3: Airport Turnover	LFOB	110.10%
PI3: Airport Turnover	LFPG	95.79%
PI4: Economic Losses due to lower traffic per year	Amsterdam	405,692,607
PI4: Economic Losses due to lower traffic per year	Beauvais	- 563,205,128
PI4: Economic Losses due to lower traffic per year	London	99,136,313
PI4: Economic Losses due to lower traffic per year	Madrid	1,991,779,844
PI4: Economic Losses due to lower traffic per year	Paris	5,434,145,142
PI4: Economic Losses due to lower traffic per year	Rotterdam	- 308,544,571
PI4: Economic Losses due to lower traffic per year	Valladolid	- 871,175,321
PI5: Jobs affected due to lower traffic per year	Amsterdam	6,392
PI5: Jobs affected due to lower traffic per year	Beauvais	- 7,095
PI5: Jobs affected due to lower traffic per year	London	1,659
PI5: Jobs affected due to lower traffic per year	Madrid	33,659
PI5: Jobs affected due to lower traffic per year	Paris	68,461
PI5: Jobs affected due to lower traffic per year	Rotterdam	- 4,862
PI5: Jobs affected due to lower traffic per year	Valladolid	- 14,722
PI6: Average Movements per hour	20h - EHAM - after	52
PI6: Average Movements per hour	20h - EHAM - before	28
PI6: Average Movements per hour	20h - LEMD - after	92
PI6: Average Movements per hour	20h - LEMD - before	74
PI6: Average Movements per hour	20h - LFPG - after	70
PI6: Average Movements per hour	20h - LFPG - before	42
PI6: Average Movements per hour	21h - EGLL - after	72
PI6: Average Movements per hour	21h - EGLL - before	58
PI6: Average Movements per hour	21h - EHAM - after	0
PI6: Average Movements per hour	21h - EHAM - before	18

PI6: Average Movements per hour	21h - LEMD - after	0
PI6: Average Movements per hour	21h - LEMD - before	67
PI6: Average Movements per hour	21h - LEVD - after	9
PI6: Average Movements per hour	21h - LEVD - before	0
PI6: Average Movements per hour	21h - LFOB - after	10
PI6: Average Movements per hour	21h - LFOB - before	5
PI6: Average Movements per hour	21h - LFPG - after	0
PI6: Average Movements per hour	21h - LFPG - before	42
PI6: Average Movements per hour	22h - EGLL - after	0
PI6: Average Movements per hour	22h - EGLL - before	15
PI6: Average Movements per hour	22h - EHAM - after	0
PI6: Average Movements per hour	22h - EHAM - before	8
PI6: Average Movements per hour	22h - LEMD - after	0
PI6: Average Movements per hour	22h - LEMD - before	23
PI6: Average Movements per hour	22h - LEVD - after	12
PI6: Average Movements per hour	22h - LEVD - before	0
PI6: Average Movements per hour	22h - LFPG - after	0
PI6: Average Movements per hour	22h - LFPG - before	26
PI6: Average Movements per hour	23h - EHAM - after	0
PI6: Average Movements per hour	23h - EHAM - before	4
PI6: Average Movements per hour	23h - EHRD - after	5
PI6: Average Movements per hour	23h - EHRD - before	0
PI6: Average Movements per hour	23h - LEMD - after	0
PI6: Average Movements per hour	23h - LEMD - before	11
PI6: Average Movements per hour	23h - LEVD - after	12
PI6: Average Movements per hour	23h - LEVD - before	0
PI6: Average Movements per hour	23h - LFPG - after	0
PI6: Average Movements per hour	23h - LFPG - before	11
PI6: Average Movements per hour	2h - EHAM - after	0
PI6: Average Movements per hour	2h - EHAM - before	3
PI6: Average Movements per hour	2h - LEMD - after	0
PI6: Average Movements per hour	2h - LEMD - before	2
PI6: Average Movements per hour	2h - LFPG - after	0
PI6: Average Movements per hour	2h - LFPG - before	9
PI6: Average Movements per hour	3h - EGLL - after	0
PI6: Average Movements per hour	3h - EGLL - before	2
PI6: Average Movements per hour	3h - EHAM - after	19
PI6: Average Movements per hour	3h - EHAM - before	16
PI6: Average Movements per hour	3h - LEMD - after	8
PI6: Average Movements per hour	3h - LEMD - before	4
PI6: Average Movements per hour	3h - LFPG - after	24
PI6: Average Movements per hour	3h - LFPG - before	13
PI6: Average Movements per hour	4h - EGLL - after	6
PI6: Average Movements per hour	4h - EGLL - before	4

PI7: Cumulative Noise Load Ratio per hour	20h - EGLL	99.19%
PI7: Cumulative Noise Load Ratio per hour	20h - EGSS	102.10%
PI7: Cumulative Noise Load Ratio per hour	20h - EHAM	86.70%
PI7: Cumulative Noise Load Ratio per hour	20h - EHRD	99.80%
PI7: Cumulative Noise Load Ratio per hour	20h - LEMD	97.52%
PI7: Cumulative Noise Load Ratio per hour	20h - LFPG	98.12%
PI7: Cumulative Noise Load Ratio per hour	21h - EGLL	101.65%
PI7: Cumulative Noise Load Ratio per hour	22h - EGLL	134.23%
PI7: Cumulative Noise Load Ratio per hour	22h - EGSS	101.72%
PI7: Cumulative Noise Load Ratio per hour	23h - EGSS	100.37%
PI7: Cumulative Noise Load Ratio per hour	2h - EGSS	111.90%
PI7: Cumulative Noise Load Ratio per hour	3h - EHAM	95.51%
PI7: Cumulative Noise Load Ratio per hour	3h - LEMD	128.95%
PI7: Cumulative Noise Load Ratio per hour	3h - LFPG	138.78%
PI7: Cumulative Noise Load Ratio per hour	4h - EGLL	100.12%
PI8: Cumulative NOx Emissions Ratio per year	null	98.62%
PI9: Cumulative CO Emissions Ratio per year	null	98.79%

Results in Table 11 show that there is only a slight coupling in the indicators by applying simultaneously the night ban at the four leading airports, by comparing them to the results in Table 1 and Table 2 for the indicators of the ban individually implemented respectively at London Heathrow and Paris Charles de Gaulle.

The number of affected flights is quite high: 1797 or 257 daily, what requires a major shakeup of the schedules.

Regarding the other two big airports, Amsterdam Schiphol and Madrid Barajas, hubs of respectively KLM and Iberia, the results are qualitative the same: loss of activity at these airports with a beneficial effect on their alternates, Rotterdam for Amsterdam and Valladolid for Madrid. In the same sense, negative impact on the economy of Amsterdam and Madrid economies and employment, and remarkable benefit for the economy and employment in Rotterdam and Valladolid.

Although qualitative the effects are similar in Amsterdam and Madrid, there are quantitative differences, showing the larger impact of the air transport industry on the Spanish economy, compared to the Dutch economy.

Scenario 7

In Scenario 7 (S7) the night ban is applied simultaneously at the top 10 airports in Europe, to complete the analysis of the dependence on the number of airports of the application of the night curfew.

Results are shown in Table 12.

Table 12. PIs of Scenario 7 (top 10 airports).

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	98.27%
PI2: Airline Turnover for the rest of the Airlines	null	98.55%
PI3: Airport Turnover	EDDM	98.92%
PI3: Airport Turnover	EDDS	101.21%
PI3: Airport Turnover	EGKK	99.72%
PI3: Airport Turnover	EGLL	99.67%
PI3: Airport Turnover	EGSS	99.70%
PI3: Airport Turnover	EHAM	99.03%
PI3: Airport Turnover	EHRD	138.73%
PI3: Airport Turnover	LEBL	93.73%
PI3: Airport Turnover	LEGE	114.70%
PI3: Airport Turnover	LEMD	93.63%
PI3: Airport Turnover	LEVD	556.62%
PI3: Airport Turnover	LFOB	127.22%
PI3: Airport Turnover	LFPG	94.50%
PI3: Airport Turnover	LFPO	99.65%
PI3: Airport Turnover	LIRA	152.59%
PI3: Airport Turnover	LIRF	98.57%
PI4: Economic Losses due to lower traffic per year	Amsterdam	454,015,639
PI4: Economic Losses due to lower traffic per year	Barcelona	1,369,817,525
PI4: Economic Losses due to lower traffic per year	Beauvais	- 554,997,649
PI4: Economic Losses due to lower traffic per year	Girona	- 570,377,152
PI4: Economic Losses due to lower traffic per year	London	425,236,077
PI4: Economic Losses due to lower traffic per year	Madrid	1,997,530,747
PI4: Economic Losses due to lower traffic per year	Munich	477,364,201
PI4: Economic Losses due to lower traffic per year	Paris	9,051,141,272
PI4: Economic Losses due to lower traffic per year	Rome	121,789,377
PI4: Economic Losses due to lower traffic per year	Rotterdam	- 308,544,571
PI4: Economic Losses due to lower traffic per year	Stuttgart	- 189,604,273
PI4: Economic Losses due to lower traffic per year	Valladolid	- 820,109,032
PI5: Jobs affected due to lower traffic per year	Amsterdam	7,154
PI5: Jobs affected due to lower traffic per year	Barcelona	23,149
PI5: Jobs affected due to lower traffic per year	Beauvais	- 6,992
PI5: Jobs affected due to lower traffic per year	Girona	- 9,639
PI5: Jobs affected due to lower traffic per year	London	7,117
PI5: Jobs affected due to lower traffic per year	Madrid	33,756
PI5: Jobs affected due to lower traffic per year	Munich	8,118
PI5: Jobs affected due to lower traffic per year	Paris	114,028
PI5: Jobs affected due to lower traffic per year	Rome	1,913

PI5: Jobs affected due to lower traffic per year	Rotterdam	- 4,862
PI5: Jobs affected due to lower traffic per year	Stuttgart	-3,224
PI5: Jobs affected due to lower traffic per year	Valladolid	- 13,859
PI6: Average Movements per hour	21h - EDDM - after	0
PI6: Average Movements per hour	21h - EDDM - before	26
PI6: Average Movements per hour	21h - EGKK - after	79
PI6: Average Movements per hour	21h - EGKK - before	39
PI6: Average Movements per hour	21h - EGLL - after	71
PI6: Average Movements per hour	21h - EGLL - before	58
PI6: Average Movements per hour	21h - EHAM - after	0
PI6: Average Movements per hour	21h - EHAM - before	18
PI6: Average Movements per hour	21h - LEBL - after	1
PI6: Average Movements per hour	21h - LEBL - before	52
PI6: Average Movements per hour	21h - LEGE - after	14
PI6: Average Movements per hour	21h - LEGE - before	10
PI6: Average Movements per hour	21h - LEMD - after	1
PI6: Average Movements per hour	21h - LEMD - before	67
PI6: Average Movements per hour	21h - LEVD - after	8
PI6: Average Movements per hour	21h - LEVD - before	0
PI6: Average Movements per hour	21h - LFOB - after	8
PI6: Average Movements per hour	21h - LFOB - before	5
PI6: Average Movements per hour	21h - LFPG - after	0
PI6: Average Movements per hour	21h - LFPG - before	42
PI6: Average Movements per hour	21h - LFPO - after	0
PI6: Average Movements per hour	21h - LFPO - before	3
PI6: Average Movements per hour	21h - LIRA - after	11
PI6: Average Movements per hour	21h - LIRA - before	7
PI6: Average Movements per hour	21h - LIRF - after	0
PI6: Average Movements per hour	21h - LIRF - before	12
PI6: Average Movements per hour	22h - EDDM - after	0
PI6: Average Movements per hour	22h - EDDM - before	2
PI6: Average Movements per hour	22h - EDDS - after	5
PI6: Average Movements per hour	22h - EDDS - before	4
PI6: Average Movements per hour	22h - EGKK - after	0
PI6: Average Movements per hour	22h - EGKK - before	24
PI6: Average Movements per hour	22h - EGLL - after	0
PI6: Average Movements per hour	22h - EGLL - before	15
PI6: Average Movements per hour	22h - EGSS - after	31
PI6: Average Movements per hour	22h - EGSS - before	30
PI6: Average Movements per hour	22h - EHAM - after	0
PI6: Average Movements per hour	22h - EHAM - before	8
PI6: Average Movements per hour	22h - LEBL - after	0
PI6: Average Movements per hour	22h - LEBL - before	26
PI6: Average Movements per hour	22h - LEGE - after	10

PI6: Average Movements per hour	22h - LEGE - before	2
PI6: Average Movements per hour	22h - LEMD - after	0
PI6: Average Movements per hour	22h - LEMD - before	23
PI6: Average Movements per hour	22h - LEVD - after	12
PI6: Average Movements per hour	22h - LEVD - before	0
PI6: Average Movements per hour	22h - LFOB - after	3
PI6: Average Movements per hour	22h - LFOB - before	0
PI6: Average Movements per hour	22h - LFPG - after	0
PI6: Average Movements per hour	22h - LFPG - before	26
PI6: Average Movements per hour	22h - LIRF - after	0
PI6: Average Movements per hour	22h - LIRF - before	2
PI6: Average Movements per hour	23h - EGKK - after	0
PI6: Average Movements per hour	23h - EGKK - before	16
PI6: Average Movements per hour	23h - EHAM - after	0
PI6: Average Movements per hour	23h - EHAM - before	4
PI6: Average Movements per hour	23h - EHRD - after	5
PI6: Average Movements per hour	23h - EHRD - before	0
PI6: Average Movements per hour	23h - LEBL - after	0
PI6: Average Movements per hour	23h - LEBL - before	4
PI6: Average Movements per hour	23h - LEGE - after	9
PI6: Average Movements per hour	23h - LEGE - before	0
PI6: Average Movements per hour	23h - LEMD - after	0
PI6: Average Movements per hour	23h - LEMD - before	11
PI6: Average Movements per hour	23h - LEVD - after	12
PI6: Average Movements per hour	23h - LEVD - before	0
PI6: Average Movements per hour	23h - LFPG - after	0
PI6: Average Movements per hour	23h - LFPG - before	11
PI6: Average Movements per hour	23h - LIRF - after	0
PI6: Average Movements per hour	23h - LIRF - before	1
PI6: Average Movements per hour	2h - EGKK - after	0
PI6: Average Movements per hour	2h - EGKK - before	3
PI6: Average Movements per hour	2h - EHAM - after	0
PI6: Average Movements per hour	2h - EHAM - before	3
PI6: Average Movements per hour	2h - LEBL - after	0
PI6: Average Movements per hour	2h - LEBL - before	3
PI6: Average Movements per hour	2h - LEMD - after	0
PI6: Average Movements per hour	2h - LEMD - before	2
PI6: Average Movements per hour	2h - LFPG - after	0
PI6: Average Movements per hour	2h - LFPG - before	9
PI6: Average Movements per hour	3h - EHAM - after	19
PI6: Average Movements per hour	3h - EHAM - before	16
PI6: Average Movements per hour	3h - LEBL - after	5
PI6: Average Movements per hour	3h - LEBL - before	1
PI6: Average Movements per hour	3h - LEMD - after	8

PI6: Average Movements per hour	3h - LEMD - before	4
PI6: Average Movements per hour	4h - EGKK - after	16
PI6: Average Movements per hour	4h - EGKK - before	5
PI7: Cumulative Noise Load Ratio per hour	20h - EDDM	93.84%
PI7: Cumulative Noise Load Ratio per hour	20h - EGKK	94.68%
PI7: Cumulative Noise Load Ratio per hour	20h - EGLL	98.72%
PI7: Cumulative Noise Load Ratio per hour	20h - EGSS	99.95%
PI7: Cumulative Noise Load Ratio per hour	20h - EHAM	86.50%
PI7: Cumulative Noise Load Ratio per hour	20h - EHRD	99.80%
PI7: Cumulative Noise Load Ratio per hour	20h - LEBL	89.18%
PI7: Cumulative Noise Load Ratio per hour	20h - LEGE	99.35%
PI7: Cumulative Noise Load Ratio per hour	20h - LEMD	96.03%
PI7: Cumulative Noise Load Ratio per hour	20h - LFPG	94.14%
PI7: Cumulative Noise Load Ratio per hour	20h - LFPO	96.53%
PI7: Cumulative Noise Load Ratio per hour	20h - LIRA	102.60%
PI7: Cumulative Noise Load Ratio per hour	20h - LIRF	94.83%
PI7: Cumulative Noise Load Ratio per hour	21h - EDDM	155.51%
PI7: Cumulative Noise Load Ratio per hour	21h - EDDS	104.54%
PI7: Cumulative Noise Load Ratio per hour	21h - EGKK	95.33%
PI7: Cumulative Noise Load Ratio per hour	21h - EGLL	102.08%
PI7: Cumulative Noise Load Ratio per hour	21h - EGSS	96.90%
PI7: Cumulative Noise Load Ratio per hour	21h - LEBL	176.19%
PI7: Cumulative Noise Load Ratio per hour	21h - LEGE	106.83%
PI7: Cumulative Noise Load Ratio per hour	21h - LEMD	159.32%
PI7: Cumulative Noise Load Ratio per hour	21h - LFOB	82.37%
PI7: Cumulative Noise Load Ratio per hour	21h - LFPO	148.77%
PI7: Cumulative Noise Load Ratio per hour	21h - LIRA	118.80%
PI7: Cumulative Noise Load Ratio per hour	21h - LIRF	137.97%
PI7: Cumulative Noise Load Ratio per hour	22h - EDDM	129.22%
PI7: Cumulative Noise Load Ratio per hour	22h - EDDS	105.98%
PI7: Cumulative Noise Load Ratio per hour	22h - EGLL	134.23%
PI7: Cumulative Noise Load Ratio per hour	22h - EGSS	101.68%
PI7: Cumulative Noise Load Ratio per hour	22h - LEBL	194.01%
PI7: Cumulative Noise Load Ratio per hour	22h - LEGE	91.42%
PI7: Cumulative Noise Load Ratio per hour	22h - LIRA	113.71%
PI7: Cumulative Noise Load Ratio per hour	22h - LIRF	67.73%
PI7: Cumulative Noise Load Ratio per hour	23h - EDDS	100.99%
PI7: Cumulative Noise Load Ratio per hour	23h - EGSS	100.11%
PI7: Cumulative Noise Load Ratio per hour	23h - EHAM	100.31%
PI7: Cumulative Noise Load Ratio per hour	23h - LEMD	67.92%
PI7: Cumulative Noise Load Ratio per hour	23h - LIRA	115.53%
PI7: Cumulative Noise Load Ratio per hour	2h - EGSS	111.90%
PI7: Cumulative Noise Load Ratio per hour	3h - EGSS	117.02%
PI7: Cumulative Noise Load Ratio per hour	3h - EHAM	95.51%

PI7: Cumulative Noise Load Ratio per hour	3h - LEBL	123.93%
PI7: Cumulative Noise Load Ratio per hour	3h - LEMD	128.95%
PI7: Cumulative Noise Load Ratio per hour	3h - LIRF	82.07%
PI7: Cumulative Noise Load Ratio per hour	4h - EGKK	73.52%
PI7: Cumulative Noise Load Ratio per hour	4h - EGLL	100.12%
PI7: Cumulative Noise Load Ratio per hour	4h - LEBL	100.47%
PI8: Cumulative NOx Emissions Ratio per year	null	97.94%
PI9: Cumulative CO Emissions Ratio per year	null	98.10%

There is now, when applying simultaneously the night ban at the ten leading airports, a relevant coupling in the indicators, as shown in the results in Table 12, and summarized in Table 13. Number of affected flights rises up to 3535 or 505 a day.

Table 13. Results of the coupled impact of implementing the night ban in several airports simultaneously.

		Airport alone (S1 / S2)	**Two airports (S5)**	**Four airports (S6)**	**Ten airports (S7)**
Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport		99,97% / 99,53%	99.63%	98.69%	98.27%
Airline Turnover for the rest of the Airlines		100,00% / 99.23%	99.43%	99.41%	98.55%
London	Airport turnover	99,86%	99.91%	99.82%	99.67%
	Economic losses	65.732.584	86,940,645	99,136,313	425,236,077
	Employment	1.100	1,455	1,659	7,117
Paris	Airport turnover	95,71%	95.83%	95.79%	94.50%
	Economic losses	5.560.169.653	5,389,255,529	5,434,145,142	9,051,141,272
	Employment	70.048	67,895	68,461	114,028
Amsterdam	Airport turnover			99.17%	99.03%
	Economic losses			405,692,607	454,015,639
	Employment			6,392	7,154
Madrid	Airport turnover			93.65%	93.63%
	Economic losses			1,991,779,844	1,997,530,747
	Employment			33,659	33,756
Cumulative NOx Emissions Ratio per year		99,98%	99.16%	98.62%	97.94%
Cumulative CO Emissions Ratio per year		99,98%	99.20%	98.79%	98.10%

There is a significant amplification of the socio-economic impact on both London and Paris when increasing the perimeter of the night ban implementation from just four airports (London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol and Madrid Barajas) to the top ten airports (adding Munich, Roma, Barcelona, London Gatwick and Paris Orly to the above mentioned four). This is so because in the top ten airports there are two airports at each one of these communities, London and Paris, and the socio-economic effect is therefore basically doubled at Paris, and largely amplified at London, as it can be seen in Table 8 when passing to Scenario 6 to Scenario 7.

Scenarios 8, 10, 12, 14

This new set of scenarios, from scenario 8 to scenario 15 is defined in order to assess the influence of the time interval where the night ban is applied. The rationale behind this scenario design is expanding or the time interval from the existing one (23:00 to 5:00), and applying a new time interval night ban first only to Frankfurt airport, and then in a different scenario to the top 10 European airports. Four new time intervals are defined, by moving the central one in steps of 30 minutes at each border, providing therefore eight more scenarios, from S8 to S15, as shown in table 4 in the chapter 2.2 of this report.

Scenarios 8, 10, 12 and 14 are intended to analyze the sensibility of modifying the nominal night ban at Frankfurt airport (from 23:00 to 5:00) in intervals of 30 minutes. Scenarios 8 and 10 enlarge the interval at the beginning (late night) by 30 or 60 minutes, and scenarios 12 and 14 do the same but at the end of the interval (early morning).

In this way more flights are affected by noise restrictions in an area with high density of flights due to the existence of the original restriction. The number of affected flights is higher at night (653 and 1006 or 93 and 144 per day) than in the morning (633 and 685 or 90 and 98 daily).

Table 14 shows the indicators for scenario 8, the more restricting one, when the night ban at Frankfurt airport is enlarged one hour at the beginning of the night, and one hour in the morning, up to the interval from 22:00 to 6:00. As it can be observed, the impact on the economy of the Frankfurt community is quite relevant (more than 5,000 million € and 92,000 jobs), losses that become gains for Hahn. Obviously the number of flights affected in the interval from 22:00 to 23:00 is very important.

On the environmental side, the noise problem is transferred to Hahn airport, used as Frankfort alternate.

Same type of behavior it is observed for scenarios 10 (Table 15), 12 (Table 16) and 14 (Table 17) from a qualitative point of view, with different quantitative impact depending on how big is in each scenario the increase in the night ban interval.

Table 14. Results of Scenario 8, modification of the night ban at Frankfurt airport.

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	100.00%
PI2: Airline Turnover for the rest of the Airlines	null	99.90%
PI3: Airport Turnover	EDDF	90.68%
PI3: Airport Turnover	EDFH	242.27%

PI4: Economic Losses due to lower traffic per year	Frankfurt	5,410,392,677
PI4: Economic Losses due to lower traffic per year	Hahn	- 5,145,043,083
PI5: Jobs affected due to lower traffic per year	Frankfurt	92,008
PI5: Jobs affected due to lower traffic per year	Hahn	- 87,496
PI6: Average Movements per hour	18h - EDDF - after	79
PI6: Average Movements per hour	18h - EDDF - before	57
PI6: Average Movements per hour	19h - EDDF - after	90
PI6: Average Movements per hour	19h - EDDF - before	71
PI6: Average Movements per hour	20h - EDDF - after	0
PI6: Average Movements per hour	20h - EDDF - before	73
PI6: Average Movements per hour	20h - EDFH - after	15
PI6: Average Movements per hour	20h - EDFH - before	3
PI6: Average Movements per hour	21h - EDDF - after	0
PI6: Average Movements per hour	21h - EDDF - before	43
PI6: Average Movements per hour	21h - EDFH - after	34
PI6: Average Movements per hour	21h - EDFH - before	7
PI6: Average Movements per hour	22h - EDDF - after	0
PI6: Average Movements per hour	22h - EDDF - before	19
PI6: Average Movements per hour	22h - EDFH - after	33
PI6: Average Movements per hour	22h - EDFH - before	2
PI6: Average Movements per hour	23h - EDDF - after	0
PI6: Average Movements per hour	23h - EDDF - before	2
PI6: Average Movements per hour	23h - EDFH - after	21
PI6: Average Movements per hour	23h - EDFH - before	0
PI6: Average Movements per hour	2h - EDDF - after	0
PI6: Average Movements per hour	2h - EDDF - before	4
PI6: Average Movements per hour	3h - EDDF - after	24
PI6: Average Movements per hour	3h - EDDF - before	20
PI7: Cumulative Noise Load Ratio per hour	18h - EDDF	110.90%
PI7: Cumulative Noise Load Ratio per hour	19h - EDDF	98.80%
PI7: Cumulative Noise Load Ratio per hour	19h - EDFH	109.51%
PI7: Cumulative Noise Load Ratio per hour	1h - EDFH	193.32%
PI7: Cumulative Noise Load Ratio per hour	20h - EDFH	138.75%
PI7: Cumulative Noise Load Ratio per hour	21h - EDFH	169.56%
PI7: Cumulative Noise Load Ratio per hour	22h - EDFH	151.74%
PI7: Cumulative Noise Load Ratio per hour	23h - EDFH	74.12%
PI7: Cumulative Noise Load Ratio per hour	2h - EDFH	95.41%
PI7: Cumulative Noise Load Ratio per hour	3h - EDDF	107.77%
PI8: Cumulative NOx Emissions Ratio per year	null	99.90%
PI9: Cumulative CO Emissions Ratio per year	null	99.94%

Table 15. Results of Scenario 10, modification of the night ban at Frankfurt airport.

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	100.00%
PI2: Airline Turnover for the rest of the Airlines	null	99.93%
PI3: Airport Turnover	EDDF	94.25%
PI3: Airport Turnover	EDFH	206.51%
PI4: Economic Losses due to lower traffic per year	Frankfurt	3,417,511,600
PI4: Economic Losses due to lower traffic per year	Hahn	- 3,230,317,040
PI5: Jobs affected due to lower traffic per year	Frankfurt	58,118
PI5: Jobs affected due to lower traffic per year	Hahn	- 54,934
PI6: Average Movements per hour	18h - EDDF - after	62
PI6: Average Movements per hour	18h - EDDF - before	57
PI6: Average Movements per hour	19h - EDDF - after	83
PI6: Average Movements per hour	19h - EDDF - before	71
PI6: Average Movements per hour	20h - EDDF - after	62
PI6: Average Movements per hour	20h - EDDF - before	73
PI6: Average Movements per hour	21h - EDDF - after	0
PI6: Average Movements per hour	21h - EDDF - before	43
PI6: Average Movements per hour	21h - EDFH - after	26
PI6: Average Movements per hour	21h - EDFH - before	7
PI6: Average Movements per hour	22h - EDDF - after	0
PI6: Average Movements per hour	22h - EDDF - before	19
PI6: Average Movements per hour	22h - EDFH - after	25
PI6: Average Movements per hour	22h - EDFH - before	2
PI6: Average Movements per hour	23h - EDDF - after	0
PI6: Average Movements per hour	23h - EDDF - before	2
PI6: Average Movements per hour	23h - EDFH - after	14
PI6: Average Movements per hour	23h - EDFH - before	0
PI6: Average Movements per hour	2h - EDDF - after	0
PI6: Average Movements per hour	2h - EDDF - before	4
PI6: Average Movements per hour	3h - EDDF - after	24
PI6: Average Movements per hour	3h - EDDF - before	20
PI7: Cumulative Noise Load Ratio per hour	0h - EDFH	117.42%
PI7: Cumulative Noise Load Ratio per hour	18h - EDDF	104.31%
PI7: Cumulative Noise Load Ratio per hour	19h - EDDF	101.39%
PI7: Cumulative Noise Load Ratio per hour	1h - EDFH	193.32%
PI7: Cumulative Noise Load Ratio per hour	20h - EDDF	91.73%
PI7: Cumulative Noise Load Ratio per hour	20h - EDFH	126.24%
PI7: Cumulative Noise Load Ratio per hour	21h - EDFH	172.12%
PI7: Cumulative Noise Load Ratio per hour	22h - EDFH	149.39%
PI7: Cumulative Noise Load Ratio per hour	23h - EDFH	72.34%
PI7: Cumulative Noise Load Ratio per hour	2h - EDFH	95.41%
PI7: Cumulative Noise Load Ratio per hour	3h - EDDF	107.77%

PI8: Cumulative NOx Emissions Ratio per year	null	99.93%
PI9: Cumulative CO Emissions Ratio per year	null	99.96%

Table 16. Results of Scenario 12, modification of the night ban at Frankfurt airport.

description	influence	value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	100.00%
PI2: Airline Turnover for the rest of the Airlines	null	99.95%
PI3: Airport Turnover	EDDF	95.60%
PI3: Airport Turnover	EDFH	180.34%
PI4: Economic Losses due to lower traffic per year	Frankfurt	2,672,259,574
PI4: Economic Losses due to lower traffic per year	Hahn	- 2,539,082,754
PI5: Jobs affected due to lower traffic per year	Frankfurt	45,444
PI5: Jobs affected due to lower traffic per year	Hahn	- 43,179
PI6: Average Movements per hour	20h - EDDF - after	90
PI6: Average Movements per hour	20h - EDDF - before	73
PI6: Average Movements per hour	21h - EDDF - after	0
PI6: Average Movements per hour	21h - EDDF - before	43
PI6: Average Movements per hour	21h - EDFH - after	20
PI6: Average Movements per hour	21h - EDFH - before	7
PI6: Average Movements per hour	22h - EDDF - after	0
PI6: Average Movements per hour	22h - EDDF - before	19
PI6: Average Movements per hour	22h - EDFH - after	20
PI6: Average Movements per hour	22h - EDFH - before	2
PI6: Average Movements per hour	23h - EDDF - after	0
PI6: Average Movements per hour	23h - EDDF - before	2
PI6: Average Movements per hour	23h - EDFH - after	9
PI6: Average Movements per hour	23h - EDFH - before	0
PI6: Average Movements per hour	2h - EDDF - after	0
PI6: Average Movements per hour	2h - EDDF - before	4
PI6: Average Movements per hour	2h - EDFH - after	3
PI6: Average Movements per hour	2h - EDFH - before	0
PI6: Average Movements per hour	3h - EDDF - after	0
PI6: Average Movements per hour	3h - EDDF - before	20
PI6: Average Movements per hour	3h - EDFH - after	1
PI6: Average Movements per hour	3h - EDFH - before	0
PI6: Average Movements per hour	4h - EDDF - after	49
PI6: Average Movements per hour	4h - EDDF - before	29
PI7: Cumulative Noise Load Ratio per hour	0h - EDFH	113.55%
PI7: Cumulative Noise Load Ratio per hour	18h - EDDF	100.43%

PI7: Cumulative Noise Load Ratio per hour	19h - EDDF	101.31%
PI7: Cumulative Noise Load Ratio per hour	1h - EDFH	206.29%
PI7: Cumulative Noise Load Ratio per hour	20h - EDDF	93.74%
PI7: Cumulative Noise Load Ratio per hour	21h - EDFH	165.47%
PI7: Cumulative Noise Load Ratio per hour	22h - EDFH	152.47%
PI7: Cumulative Noise Load Ratio per hour	23h - EDFH	66.07%
PI7: Cumulative Noise Load Ratio per hour	2h - EDFH	89.33%
PI7: Cumulative Noise Load Ratio per hour	4h - EDDF	100.13%
PI8: Cumulative NOx Emissions Ratio per year	null	99.95%
PI9: Cumulative CO Emissions Ratio per year	null	99.97%

Table 17. Results of Scenario 14, modification of the night ban at Frankfurt airport.

description	**influence**	**value**
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	100.00%
PI2: Airline Turnover for the rest of the Airlines	null	99.94%
PI3: Airport Turnover	EDDF	95.44%
PI3: Airport Turnover	EDFH	182.92%
PI4: Economic Losses due to lower traffic per year	Frankfurt	2,763,547,546
PI4: Economic Losses due to lower traffic per year	Hahn	- 2,621,695,757
PI5: Jobs affected due to lower traffic per year	Frankfurt	46,996
PI5: Jobs affected due to lower traffic per year	Hahn	- 44,584
PI6: Average Movements per hour	20h - EDDF - after	90
PI6: Average Movements per hour	20h - EDDF - before	73
PI6: Average Movements per hour	21h - EDDF - after	0
PI6: Average Movements per hour	21h - EDDF - before	43
PI6: Average Movements per hour	21h - EDFH - after	20
PI6: Average Movements per hour	21h - EDFH - before	7
PI6: Average Movements per hour	22h - EDDF - after	0
PI6: Average Movements per hour	22h - EDDF - before	19
PI6: Average Movements per hour	22h - EDFH - after	20
PI6: Average Movements per hour	22h - EDFH - before	2
PI6: Average Movements per hour	23h - EDDF - after	0
PI6: Average Movements per hour	23h - EDDF - before	2
PI6: Average Movements per hour	23h - EDFH - after	9
PI6: Average Movements per hour	23h - EDFH - before	0
PI6: Average Movements per hour	2h - EDDF - after	0
PI6: Average Movements per hour	2h - EDDF - before	4
PI6: Average Movements per hour	2h - EDFH - after	3
PI6: Average Movements per hour	2h - EDFH - before	0

PI6: Average Movements per hour	3h - EDDF - after	0
PI6: Average Movements per hour	3h - EDDF - before	20
PI6: Average Movements per hour	3h - EDFH - after	2
PI6: Average Movements per hour	3h - EDFH - before	0
PI6: Average Movements per hour	4h - EDDF - after	41
PI6: Average Movements per hour	4h - EDDF - before	29
PI6: Average Movements per hour	5h - EDDF - after	57
PI6: Average Movements per hour	5h - EDDF - before	51
PI7: Cumulative Noise Load Ratio per hour	0h - EDFH	113.55%
PI7: Cumulative Noise Load Ratio per hour	18h - EDDF	100.43%
PI7: Cumulative Noise Load Ratio per hour	19h - EDDF	101.30%
PI7: Cumulative Noise Load Ratio per hour	1h - EDFH	206.29%
PI7: Cumulative Noise Load Ratio per hour	20h - EDDF	93.74%
PI7: Cumulative Noise Load Ratio per hour	21h - EDFH	165.98%
PI7: Cumulative Noise Load Ratio per hour	22h - EDFH	152.03%
PI7: Cumulative Noise Load Ratio per hour	23h - EDFH	66.07%
PI7: Cumulative Noise Load Ratio per hour	2h - EDFH	84.83%
PI7: Cumulative Noise Load Ratio per hour	4h - EDDF	102.45%
PI7: Cumulative Noise Load Ratio per hour	5h - EDDF	96.34%
PI7: Cumulative Noise Load Ratio per hour	6h - EDDF	99.91%
PI8: Cumulative NOx Emissions Ratio per year	null	99.95%
PI9: Cumulative CO Emissions Ratio per year	null	99.97%

Table 18. Summary of results from scenarios 8, 10, 12 and 14, modifying the night ban interval at Frankfurt airport.

		22:00-5:00 (S8)	**22:30-5:00 (S10)**	**23:00-6:00 (S12)**	**23:00-6:30 (S14)**
Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport		100.00%	100.00%	100.00%	100.00%
Airline Turnover for the rest of the Airlines		99.90%	99.93%	99.95%	99.94%
Frankfurt	Airport turnover	90.68%	94.25%	95.60%	95.44%
	Economic losses	5,410,392,677	3,417,511,600	2,672,259,574	2,763,547,546
	Employment	92,008	58,118	45,444	46,996
	Noise load ratio (max)	110.90%	107.77%	101.31%	101.30%
Cumulative NOx Emissions Ratio per year		99.90%	99.93%	99.95%	99.95%
Cumulative CO Emissions Ratio per year		99.94%	99.96%	99.97%	99.97%

Scenario 9, 11, 13, 15

Finally, scenarios 9, 11, 13 and 15 extend to the top 10 European airports the modifications in the night ban interval already explored for the Frankfurt airport in scenarios resp. 8, 10, 12 and 14 (Table 4).

Results are shown in Table 19 (S9), Table 20 (S11), Table 21 (S13) and Table 22 (S15).

From a qualitative point of view, the conclusions are the same already explained for the case of Frankfurt in Scenarios 8, 10, 12 and 14.

In quantitative terms, the number of affected flights is much greater, with the same trend than the Frankfurt scenarios, with more flights in the night periods (5211 and 7154 or 744 and 1022 daily) and comparatively less flights (4134 and 4646 or 591 and 664daily) in the morning.

Table 19. Results of Scenario 9, modification of the night ban at the top ten airports.

Description	Influence	Value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	95.51%
PI2: Airline Turnover for the rest of the Airlines	null	98.20%
PI3: Airport Turnover	EDDF	90.69%
PI3: Airport Turnover	EDDM	94.42%
PI3: Airport Turnover	EDDS	109.82%
PI3: Airport Turnover	EDFH	242.56%
PI3: Airport Turnover	EGKK	89.11%
PI3: Airport Turnover	EGLL	95.60%
PI3: Airport Turnover	EGSS	137.38%
PI3: Airport Turnover	EHAM	95.96%
PI3: Airport Turnover	EHRD	324.41%
PI3: Airport Turnover	LEBL	87.56%
PI3: Airport Turnover	LEGE	180.07%
PI3: Airport Turnover	LEMD	87.79%
PI3: Airport Turnover	LEVD	892.40%
PI3: Airport Turnover	LFOB	159.26%
PI3: Airport Turnover	LFPG	93.11%
PI3: Airport Turnover	LFPO	98.67%
PI3: Airport Turnover	LIRA	296.99%
PI3: Airport Turnover	LIRF	94.68%
PI4: Economic Losses due to lower traffic per year	Amsterdam	1,620,929,868
PI4: Economic Losses due to lower traffic per year	Barcelona	2,643,837,114
PI4: Economic Losses due to lower traffic per year	Beauvais	- 2,117,794,251
PI4: Economic Losses due to lower traffic per year	Frankfurt	5,403,990,872
PI4: Economic Losses due to lower traffic per year	Girona	- 1,285,283,575
PI4: Economic Losses due to lower traffic per year	Hahn	- 5,016,870,434

PI4: Economic Losses due to lower traffic per year	London	2,281,210,065
PI4: Economic Losses due to lower traffic per year	Madrid	3,643,348,375
PI4: Economic Losses due to lower traffic per year	Munich	2,622,450,801
PI4: Economic Losses due to lower traffic per year	Paris	10,003,645,646
PI4: Economic Losses due to lower traffic per year	Rome	139,609,142
PI4: Economic Losses due to lower traffic per year	Rotterdam	- 1,157,042,141
PI4: Economic Losses due to lower traffic per year	Stuttgart	- 224,424,630
PI4: Economic Losses due to lower traffic per year	Valladolid	- 1,642,942,177
PI5: Jobs affected due to lower traffic per year	Amsterdam	25,541
PI5: Jobs affected due to lower traffic per year	Barcelona	44,678
PI5: Jobs affected due to lower traffic per year	Beauvais	- 26,680
PI5: Jobs affected due to lower traffic per year	Frankfurt	91,899
PI5: Jobs affected due to lower traffic per year	Girona	- 21,720
PI5: Jobs affected due to lower traffic per year	Hahn	- 85,316
PI5: Jobs affected due to lower traffic per year	London	38,179
PI5: Jobs affected due to lower traffic per year	Madrid	61,569
PI5: Jobs affected due to lower traffic per year	Munich	44,597
PI5: Jobs affected due to lower traffic per year	Paris	126,028
PI5: Jobs affected due to lower traffic per year	Rome	2,193
PI5: Jobs affected due to lower traffic per year	Rotterdam	- 18,231
PI5: Jobs affected due to lower traffic per year	Stuttgart	- 3,817
PI5: Jobs affected due to lower traffic per year	Valladolid	- 27,764
PI8: Cumulative NOx Emissions Ratio per year	null	96.66%
PI9: Cumulative CO Emissions Ratio per year	null	96.90%

Table 20. Results of Scenario 11, modification of the night ban at the top ten airports.

description	influence	value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	97.28%
PI2: Airline Turnover for the rest of the Airlines	null	98.86%
PI3: Airport Turnover	EDDF	94.02%
PI3: Airport Turnover	EDDM	97.67%
PI3: Airport Turnover	EDDS	111.29%
PI3: Airport Turnover	EDFH	205.79%
PI3: Airport Turnover	EGKK	92.22%
PI3: Airport Turnover	EGLL	98.92%
PI3: Airport Turnover	EGSS	110.84%
PI3: Airport Turnover	EHAM	98.75%
PI3: Airport Turnover	EHRD	156.24%
PI3: Airport Turnover	LEBL	91.65%
PI3: Airport Turnover	LEGE	122.31%

PI3: Airport Turnover	LEMD	96.77%
PI3: Airport Turnover	LEVD	368.14%
PI3: Airport Turnover	LFOB	111.90%
PI3: Airport Turnover	LFPG	96.15%
PI3: Airport Turnover	LFPO	100.90%
PI3: Airport Turnover	LIRA	202.36%
PI3: Airport Turnover	LIRF	97.49%
PI4: Economic Losses due to lower traffic per year	Amsterdam	573,317,309
PI4: Economic Losses due to lower traffic per year	Barcelona	1,809,631,883
PI4: Economic Losses due to lower traffic per year	Beauvais	- 661,099,168
PI4: Economic Losses due to lower traffic per year	Frankfurt	3,589,765,938
PI4: Economic Losses due to lower traffic per year	Girona	- 732,029,413
PI4: Economic Losses due to lower traffic per year	Hahn	- 3,249,675,070
PI4: Economic Losses due to lower traffic per year	London	848,239,726
PI4: Economic Losses due to lower traffic per year	Madrid	1,110,940,411
PI4: Economic Losses due to lower traffic per year	Munich	1,040,393,709
PI4: Economic Losses due to lower traffic per year	Paris	9,970,656,877
PI4: Economic Losses due to lower traffic per year	Rome	153,832,588
PI4: Economic Losses due to lower traffic per year	Rotterdam	- 391,503,572
PI4: Economic Losses due to lower traffic per year	Stuttgart	- 384,630,401
PI4: Economic Losses due to lower traffic per year	Valladolid	- 294,312,189
PI5: Jobs affected due to lower traffic per year	Amsterdam	9,034
PI5: Jobs affected due to lower traffic per year	Barcelona	30,581
PI5: Jobs affected due to lower traffic per year	Beauvais	- 8,329
PI5: Jobs affected due to lower traffic per year	Frankfurt	61,047
PI5: Jobs affected due to lower traffic per year	Girona	- 12,371
PI5: Jobs affected due to lower traffic per year	Hahn	- 55,264
PI5: Jobs affected due to lower traffic per year	London	14,197
PI5: Jobs affected due to lower traffic per year	Madrid	18,774
PI5: Jobs affected due to lower traffic per year	Munich	17,693
PI5: Jobs affected due to lower traffic per year	Paris	125,612
PI5: Jobs affected due to lower traffic per year	Rome	2,417
PI5: Jobs affected due to lower traffic per year	Rotterdam	- 6,169
PI5: Jobs affected due to lower traffic per year	Stuttgart	- 6,541
PI5: Jobs affected due to lower traffic per year	Valladolid	- 4,974
PI8: Cumulative NOx Emissions Ratio per year	null	97.77%
PI9: Cumulative CO Emissions Ratio per year	null	97.95%

Table 21. Results of Scenario 13, modification of the night ban at the top ten airports.

description	influence	value
PI1: Airline Turnover and Operating Margin for	null	97.78%

Network Airlines with a hub at the Airport		
PI2: Airline Turnover for the rest of the Airlines	null	98.36%
PI3: Airport Turnover	EDDF	95.24%
PI3: Airport Turnover	EDDM	98.74%
PI3: Airport Turnover	EDDS	101.26%
PI3: Airport Turnover	EDFH	182.21%
PI3: Airport Turnover	EGKK	93.63%
PI3: Airport Turnover	EGLL	99.45%
PI3: Airport Turnover	EGSS	116.52%
PI3: Airport Turnover	EHAM	98.80%
PI3: Airport Turnover	EHRD	139.47%
PI3: Airport Turnover	LEBL	93.60%
PI3: Airport Turnover	LEGE	114.18%
PI3: Airport Turnover	LEMD	93.44%
PI3: Airport Turnover	LEVD	580.89%
PI3: Airport Turnover	LFOB	107.58%
PI3: Airport Turnover	LFPG	94.05%
PI3: Airport Turnover	LFPO	99.62%
PI3: Airport Turnover	LIRA	155.84%
PI3: Airport Turnover	LIRF	98.57%
PI4: Economic Losses due to lower traffic per year	Amsterdam	668,357,068
PI4: Economic Losses due to lower traffic per year	Barcelona	1,398,139,641
PI4: Economic Losses due to lower traffic per year	Beauvais	- 422,420,393
PI4: Economic Losses due to lower traffic per year	Frankfurt	2,920,941,985
PI4: Economic Losses due to lower traffic per year	Girona	- 560,410,361
PI4: Economic Losses due to lower traffic per year	Hahn	-2,638,362,941
PI4: Economic Losses due to lower traffic per year	London	700,816,836
PI4: Economic Losses due to lower traffic per year	Madrid	2,076,227,314
PI4: Economic Losses due to lower traffic per year	Munich	592,187,039
PI4: Economic Losses due to lower traffic per year	Paris	11,933,369,495
PI4: Economic Losses due to lower traffic per year	Rome	123,299,831
PI4: Economic Losses due to lower traffic per year	Rotterdam	- 320,926,511
PI4: Economic Losses due to lower traffic per year	Stuttgart	- 192,415,605
PI4: Economic Losses due to lower traffic per year	Valladolid	- 869,078,187
PI5: Jobs affected due to lower traffic per year	Amsterdam	10,531
PI5: Jobs affected due to lower traffic per year	Barcelona	23,627
PI5: Jobs affected due to lower traffic per year	Beauvais	- 5,322
PI5: Jobs affected due to lower traffic per year	Frankfurt	49,673
PI5: Jobs affected due to lower traffic per year	Girona	- 9,470
PI5: Jobs affected due to lower traffic per year	Hahn	- 44,868
PI5: Jobs affected due to lower traffic per year	London	11,729
PI5: Jobs affected due to lower traffic per year	Madrid	35,086

PI5: Jobs affected due to lower traffic per year	Munich	10,071
PI5: Jobs affected due to lower traffic per year	Paris	150,339
PI5: Jobs affected due to lower traffic per year	Rome	1,937
PI5: Jobs affected due to lower traffic per year	Rotterdam	- 5,057
PI5: Jobs affected due to lower traffic per year	Stuttgart	- 3,272
PI5: Jobs affected due to lower traffic per year	Valladolid	- 14,687
PI8: Cumulative NOx Emissions Ratio per year	null	97.23%
PI9: Cumulative CO Emissions Ratio per year	null	97.41%

Table 22. Results of Scenario 15, modification of the night ban at the top ten airports.

description	influence	value
PI1: Airline Turnover and Operating Margin for Network Airlines with a hub at the Airport	null	97.68%
PI2: Airline Turnover for the rest of the Airlines	null	98.50%
PI3: Airport Turnover	EDDF	95.05%
PI3: Airport Turnover	EDDM	98.54%
PI3: Airport Turnover	EDDS	101.35%
PI3: Airport Turnover	EDFH	184.80%
PI3: Airport Turnover	EGKK	93.31%
PI3: Airport Turnover	EGLL	101.01%
PI3: Airport Turnover	EGSS	111.04%
PI3: Airport Turnover	EHAM	98.51%
PI3: Airport Turnover	EHRD	139.47%
PI3: Airport Turnover	LEBL	93.60%
PI3: Airport Turnover	LEGE	114.01%
PI3: Airport Turnover	LEMD	93.36%
PI3: Airport Turnover	LEVD	576.04%
PI3: Airport Turnover	LFOB	107.94%
PI3: Airport Turnover	LFPG	93.49%
PI3: Airport Turnover	LFPO	99.62%
PI3: Airport Turnover	LIRA	189.25%
PI3: Airport Turnover	LIRF	98.67%
PI4: Economic Losses due to lower traffic per year	Amsterdam	920,486,841
PI4: Economic Losses due to lower traffic per year	Barcelona	1,390,334,844
PI4: Economic Losses due to lower traffic per year	Beauvais	- 443,270,037
PI4: Economic Losses due to lower traffic per year	Frankfurt	2,989,618,813
PI4: Economic Losses due to lower traffic per year	Girona	- 557,124,131
PI4: Economic Losses due to lower traffic per year	Hahn	-2,686,396,559
PI4: Economic Losses due to lower traffic per year	London	- 511,515,262
PI4: Economic Losses due to lower traffic per year	Madrid	2,104,938,589
PI4: Economic Losses due to lower traffic per year	Munich	726,608,878

PI4: Economic Losses due to lower traffic per year	Paris	12,976,553,270
PI4: Economic Losses due to lower traffic per year	Rome	101,398,242
PI4: Economic Losses due to lower traffic per year	Rotterdam	- 320,926,511
PI4: Economic Losses due to lower traffic per year	Stuttgart	- 207,275,504
PI4: Economic Losses due to lower traffic per year	Valladolid	- 855,500,868
PI5: Jobs affected due to lower traffic per year	Amsterdam	14,504
PI5: Jobs affected due to lower traffic per year	Barcelona	23,495
PI5: Jobs affected due to lower traffic per year	Beauvais	- 5,584
PI5: Jobs affected due to lower traffic per year	Frankfurt	50,841
PI5: Jobs affected due to lower traffic per year	Girona	- 9,415
PI5: Jobs affected due to lower traffic per year	Hahn	- 45,684
PI5: Jobs affected due to lower traffic per year	London	- 8,561
PI5: Jobs affected due to lower traffic per year	Madrid	35,572
PI5: Jobs affected due to lower traffic per year	Munich	12,357
PI5: Jobs affected due to lower traffic per year	Paris	163,481
PI5: Jobs affected due to lower traffic per year	Rome	1,593
PI5: Jobs affected due to lower traffic per year	Rotterdam	- 5,057
PI5: Jobs affected due to lower traffic per year	Stuttgart	- 3,525
PI5: Jobs affected due to lower traffic per year	Valladolid	- 14,457
PI8: Cumulative NOx Emissions Ratio per year	null	97.29%
PI9: Cumulative CO Emissions Ratio per year	null	97.33%

4 Conclusions

The results of Case Study 1 are presented in this document. Case Study 1 uses Cassiopeia to simulate the response of the different stakeholders to the potential implementation of curfews in the largest (by number of passengers) European Union airports, following the stream of Frankfurt-Main, where the opening of an additional runway was traded off with a night curfew, entering into force in 2012.

The central scenario for Case Study 1 is the generalization of the ban on night flights in Frankfurt airport, where commercial operations are forbidden from 23:00 to 05:00 to protect local communities against noise. A number of alternative scenarios are designed to assess the impact of this same measured applied to the rest of the largest EU airports, individually, or in groups. Also, a sensitivity analysis is performed on the influence of the size of the time interval in which the night ban is applied.

The results of the simulations can be looked at from different perspectives, expressed by the different Performance Indicators that have been defined for this Case Study 1, with the purpose of highlighting the repercussions on the different stakeholders:

Economic impact on airlines

Results show that the restrictions imply a relatively important economic impact on airlines, both for network carriers with a hub at the regulated airport and for the rest of the companies, regardless the decisions these companies make take in response to the restriction. The same conclusion applies to low cost carriers. The indicators that measure this impact (PI1 and PI2) show a small reduction in percentage of the number of flights, but it has to be considered that this percentage affects a very large figure as it is the revenues of the airline and may produce a non-negligible impact on profits.

These indicators are sensitive to the variation of the size of the night ban interval with greater impact at night than in the morning.

Economic impact on airports

Airports economy is equally affected by the restrictions. Results show that this impact is different depending on the airport, and it can vary appreciably from one airport to another. This fact depends on the number of night flights that each airport has before the night ban implementation, and the possibilities of that airport to accommodate potential re-scheduling of the airlines as a consequence of the restriction.

Results also show how alternate airports, where airlines move the flights that cannot re-schedule in the restricted airport, increase their economic results, in a larger proportion in airports relatively small, compared to the restricted airport.

Socio-economic impact on local communities

Impact on local communities, both in terms of yearly economic losses and jobs affected by having lower traffic is very important. It has to be taken into account that these socio-economic figures measure the full range of effects: direct, indirect, induced and catalytic.

Cassiopeia results show that there is a significant amplification of the socio-economic impact on both London and Paris when increasing the perimeter of the night ban implementation from just four airports (London Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol and Madrid Barajas) to the

top ten airports (adding Munich, Roma, Barcelona, London Gatwick and Paris Orly to the above mentioned four). This is so because in the top ten airports there are two airports at each one of these communities, London and Paris, and the socio-economic effect is therefore basically doubled at Paris, and largely amplified at London.

Results for individual airports are consistent with other studies on this subject already published, although these studies show a significant scatter in the figures they present. For instance a report from Oxford Economics evaluates the impact of a night ban in Heathrow in 543 million £ and 6,800 jobs in 2011. A similar report from CE Delft for HACAN (Heathrow Association for the Control of Aircraft Noise) [1], [2], sets the economic impact on UK economy in a range between 28 and 898 million £. The different scenarios in Cassiopeia give an economic impact of the night ban at Heathrow from 66 to 2,280 million € and the jobs losses from 1,100 to 38,179.

It is not easy to find similar studies for other airports, but for instance in a presentation at the G.A.R.S. conference of Air Cargo – Policy and Processes [3] the authors evaluate for the Paris Charles de Gaulle airport the impact of cargo flights in employment generation: 12,300 jobs for the period between 0:00 and 5:00; and a generation of a turnover of 2,700 € by 1 ton of general cargo and 10,000 € by a ton of express cargo. Cassiopeia results for Paris Charles de Gaulle airport also gives impacts of the night ban on employments in tenths of thousands.

Environmental impact

Regarding noise, obviously the night ban eliminates the noise problem during the period at which the ban is applied, but it shifts the noise load to the hours adjacent to the ban, and also and more heavily to the alternate airport where an important portion of the flights are moved.

The impact of the restrictions on emissions affecting local air quality in the airport area is almost negligible.

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Appendix A European airports with environmental restrictions

AIRPORT	CODE	COUNTRY	City	APU	CURFEW	RUN-UPS	NAP	NOISEBUD	NOISE Limits	NOISE Chrgs	Emissions Chrgs	Quotas	Pref Rwys	Stg3-Ch3 Rest
651				137	241	414	517	14	103	128	25	55	366	75
Graz Airport	GRZ	Austria	Graz		cur	run	nap						pr	
Innsbruck Airport	INN	Austria	Innsbruck	apu	cur	run	nap			ns			pr	
Klagenfurt	KLU	Austria	Klagenfurt				nap						pr	
Linz Blue Danube Airport	LNZ	Austria	Linz	apu	cur	run	nap						pr	
Salzburg Airport WA Mozart	SZG	Austria	Salzburg	apu	cur	run	nap		nl					s3r
Vienna International	VIE	Austria	Vienna	apu	cur	run	nap			ns			pr	
Antwerp Airport	ANR	Belgium	Antwerpen			run	nap		nl				pr	
Brussels Airport	BRU	Belgium	Brussels	apu	cur	run	nap	nb	nl	ns		oq	pr	s3r
Charleroi	CRL	Belgium	Brussels		cur	run	nap	nb		ns		oq	pr	s3r
Liege Airport	LGG	Belgium	Grâce-Hollogne			run	nap		nl	ns		oq	pr	s3r
Ostend International	OST	Belgium	Ostend	apu	cur	run	nap					oq		s3r
Burgas Airport	BOJ	Bulgaria	Burgas	apu		run	nap						pr	
Sofia Airport	SOF	Bulgaria	Sofia		cur		nap		nl				pr	
Dubrovnik Airport	DBV	Croatia	Dubrovnik		cur	run	nap						pr	
Split Airport	SPU	Croatia	Split/Kastela				nap			ns				
Pafos International	PFO	Cyprus	Pafos				nap			ns				

Ostrava International	OSR	Czech Republic	Ostrava											
Pardubice Airport	PED	Czech Republic	Pardubice		cur	run							pr	
Prague Ruzyne	PRG	Czech Republic	Prague	apu	cur	run	nap		nl	ns		oq	pr	s3r
Aalborg Airport	AAL	Denmark	Aalborg	apu		run	nap					oq		
Aarhus Airport	AAR	Denmark	Aarhus	apu		run	nap					oq		
Billund Airport	BLL	Denmark	Billund	apu		run	nap		nl					
Copenhagen	CPH	Denmark	Kastrup/ Copenhagen	apu	cur	run	nap	nb	nl		es		pr	s3r
Copenhagen Airport Roskilde	RKE	Denmark	Roskilde/ Copenhagen			run	nap		nl			oq	pr	s3r
Esbjerg Airport	EBJ	Denmark	Esbjerg				nap							
Odense Airport	ODE	Denmark	Odense	apu	cur		nap		nl				pr	s3r
Helsinki-Vantaa	HEL	Finland	Helsinki	apu		run	nap		nl	ns			pr	
Kittilä Airport	KTT	Finland	Kittilä				nap							
Lappeenranta Airport	LPP	Finland	Lappeenranta				nap		nl				pr	s3r
Oulu Airport	OUL	Finland	Oulundsalo				nap							
Rovaniemi	RVN	Finland	Rovaniemi				nap							
Tampere-Pirkkala	TMP	Finland	Pirkkala		cur		nap						pr	
Vassa Airport	VAA	Finland	Vaasa				nap						pr	
Agen-La Garenne Airport	AGF	France	Le Passage		cur								pr	
Ajaccio Airport	AJA	France	Ajaccio				nap			ns				
Bastia Poretta	BIA	France	Bastia							ns				

Beauvais Airport	BVA	France	Beauvais	apu	cur		nap						pr	s3r
Biarritz Bayonne Anglet	BIQ	France	Biarrit	apu	cur		nap			ns			pr	
Bordeaux Airport	BOD	France	Merignac		cur	run	nap		nl	ns			pr	
Cannes	CEQ	France	Mandelieu	apu	cur		nap						pr	
Charles de Gaulle	CDG	France	Paris-Roissy		cur	run	nap		nl	ns				s3r
Clermont-Ferrand/Auvergne	CFE	France	Clermont-Ferrand			run	nap			ns			pr	
Cote D'Azur	NCE	France	Nice	apu	cur	run				ns			pr	s3r
Dijon Bourgogne Airport	DIJ	France	Dijon	apu	cur								pr	
Dinard-Pleurtuit	DNR	France	St. Malo				nap							
Le Bourget	LBG	France	Paris		cur	run	nap			ns			pr	
Lille Airport	LIL	France	Lille			run	nap			ns				
Lourdes-Pyrenees	LDE	France	Trabes							ns				
Lyon Saint Exupery	LYS	France	Satolas		cur	run	nap			ns		oq	pr	s3r
Marseille-Provence Intl	MRS	France	Marignane	apu	cur	run	nap			ns			pr	s3r
Metz-Nancy-Lorraine	ETZ	France	Goin										pr	
Montpellier Airport	MPL	France	Montpellier		cur		nap			ns			pr	
Nantes Atlantique Airport	NTE	France	Nantes	apu	cur	run	nap			ns		oq		s3r
Orly	ORY	France	Paris		cur	run	nap		nl	ns		oq	pr	
Pontoise	POX	France	Paris				nap			ns				
Rodez Marcillac Airport	RDZ	France	Rodez	apu		run							pr	
Strasbourg Airport	SXB	France	Strasbourg	apu	cur	run				ns				s3r

Toulouse-Blagnac	TLS	France	Blagnac		cur	run	nap			ns				
Allgau Airport	FMM	Germany	Memmingen		cur	run								
Augsburg Airport	AGB	Germany	Augsburg			run				ns				
Bremen-Neueland	BRE	Germany	Bremen		cur	run	nap			ns				s3r
Dortmund Airport	DTM	Germany	Dortmund		cur	run	nap			ns				
Dresden	DRS	Germany	Dresden		cur	run	nap			ns				
Dusseldorf	DUS	Germany	Dusseldorf		cur	run				ns	es	oq		s3r
Dusseldorf Monchengladbach	MGL	Germany	Monchengladbach	apu	cur	run	nap			ns			pr	
Dusseldorf Niederrhein Weeze	NRN	Germany	Weeze		cur	run	nap							
Egelsbach Airport	QEF	Germany	Egelsbach		cur		nap			ns			pr	
Erfurt	ERF	Germany	Erfurt		cur	run			nl	ns			pr	
Frankfurt	FRA	Germany	Frankfurt		cur	run	nap		nl	ns	es	oq	pr	s3r
Friedrichshafen Airport	FDH	Germany	Friedrichshafen	apu	cur	run	nap	nb		ns			pr	
Hahn Airport	HHN	Germany	Lautzenhausen		cur	run	nap			ns			pr	
Hamburg	HAM	Germany	Hamburg	apu	cur	run	nap			ns	es		pr	s3r
Hannover-Langenhagen	HAJ	Germany	Hannover		cur	run	nap			ns			pr	s3r
Karlsruhe-Baden	FKB	Germany	Baden-Baden		cur									
Kiel Holtenau Airport	KEL	Germany	Kiel		cur	run	nap			ns				
Koln-Bonn/ Cologne-Bonn	CGN	Germany	Koln		cur	run	nap		nl	ns				s3r
Leipzig Halle Airport	LEJ	Germany	Leipzig		cur	run	nap			ns				

Luebeck Airport	LBC	Germany	Luebeck			run				ns				
Munich	MUC	Germany	Munich		cur	run	nap			ns	es	oq	pr	s3r
Munster	FMO	Germany	Munster/ Osnabruck		cur	run				ns				
Neubrandenburg Airport	FNB	Germany	Neubrandenburg										pr	
Nurnberg	NUE	Germany	Nurnberg		cur	run	nap			ns			pr	s3r
Paderborn-Lippstadt	PAD	Germany	Paderborn		cur	run				ns				s3r
Saarbrueck en-Ensheim	SCN	Germany	Saarbrucken		cur	run				ns				
Schonefeld	SXF	Germany	Berlin		cur		nap			ns				
Stuttgart Airport	STR	Germany	Stuttgart		cur	run	nap			ns				
Tegel	TXL	Germany	Berlin		cur	run	nap			ns				s3r
Gibraltar Airport	GIB	Gibraltar			cur									
Athens International	ATH	Greece	Athens	apu		run	nap						pr	
Balaton	SOB	Hungary	Budapest				nap							
Budapest	BUD	Hungary	Budapest	apu	cur	run	nap			ns			pr	
Keflavik	KEF	Iceland	Keflavik	apu		run	nap						pr	
Reykjavik Airport	REK	Iceland	Reykjavik	apu	cur	run	nap						pr	
Cork	ORK	Ireland	Cork				nap							
Dublin	DUB	Ireland	Dublin			run	nap						pr	
Kerry Airport	KIR	Ireland	Killarney		cur									
Shannon	SNN	Ireland	County Clare				nap							
Isle of Mann Airport	IOM	Isle of Man	Ballasalla				nap							
Alghero Fertilia Airport	AHO	Italy	Alghero	apu	cur	run			nl				pr	
Ancona Airport	AOI	Italy	Ancona	apu		run	nap							

Bari - Palese	BRI	Italy	Bari	apu		run	nap							
Bergamo Orio al Serio	BGU	Italy	Orio al Serio	apu		run	nap						pr	
Bologna G Marconi Airport	BLQ	Italy	Bologna	apu	cur	run	nap		nl				pr	
Brindisi-Casale	BDS	Itlay	Brindisi			run	nap						pr	
Cagliari Airport	CAG	Italy	Cagliari				nap							
Ciampino Airport	CIA	Italy	Rome	apu	cur	run	nap						pr	
Cuneo Airport	CUF	Italy	Levaldigi - Cuneo		cur								pr	
Fiumicino	FCO	Italy	Rome	apu	cur		nap						pr	
Forli International	FRL	Italy	Forli				nap							
Genova Airport	GOA	Italy	Genova	apu		run	nap						pr	
Lampedusa Airport	LMP	Italy	Lampedusa		cur		nap							
Linate Airport	LIN	Italy	Milan	apu		run	nap		nl				pr	
Malpensa Airport	MXP	Italy	Milan	apu	cur	run	nap		nl				pr	
Naples International	NAP	Italy	Naples	apu	cur	run	nap							
Olbia-Costa Smeralda	OLB	Italy	Olbia Sassari	apu		run	nap							
Pescara - Abruzzo	PSR	Italy	Pescara	apu		run	nap							
Pisa Galileo Galilei Airport	PSA	Italy	Pisa	apu		run	nap						pr	
Rimini - Federico Fellini	RIM	Italy	Rimini				nap							
Verona - Valerio Catullo	VRN	Italy	Verona				nap							

Torino Caselle Airport	TRN	Italy	Caselle	apu	cur	run	nap							
Treviso Airport	TSF	Italy	Treviso	apu		run	nap							
Venice Marco Polo	VCE	Italy	Tessera - Venezia	apu		run	nap		nl				pr	
Riga International	RIX	Latvia	Riga			run	nap							
Kaunas Intl.	KUN	Lithuania	Kaunas						nl					
Palanga International	PLQ	Luthuania	Palanga											
Luxembourg International	LUX	Luxembourg	Luxembourg	apu	cur	run	nap			ns				s3r
Malta International	MLA	Malta	Luqa			run	nap						pr	
Bergen	BGO	Norway	Bergen			run	nap							
Bodo	BOO	Norway	Bodo				nap						pr	
Kristiandand	KRS	Norway	Kjevik				nap							
Molde Airport	MOL	Norway	Molde				nap							
Stavanger Airport	SVG	Norway	Stavanger	apu		run	nap							
Torp Airport	TRF	Norway	Sandefjord	apu	cur		nap							
Oslo Gardermoen Airport	OSL	Norway	Oslo	apu	cur	run	nap		nl				pr	s3r
Wroclaw - Strachowice	WRO	Poland	Wroclaw				nap						pr	
Okecie Warsaw Frederic Chopin	WAW	Poland	Warsaw		cur	run	nap			ns			pr	
Faro Airport	FAO	Portugal	Faro	apu	cur	run	nap							

Francisco Sá Carneiro-Porto	OPO	Portugal	Porto	apu	cur	run	nap		nl					s3r
Lisbon International	LIS	Portugal	Lisbon	apu	cur	run	nap		nl			oq	pr	s3r
Madeira Airport	FNC	Portugal	Santa Cruz - Mareira	apu	cur	run	nap		nl			oq	pr	s3r
Bacau	BCM	Romania	Bacau				nap							
Bucharest Baneasa	BBU	Romania	Bucharest	apu	cur	run	nap			ns			pr	
Bucharest Henri Coanda Intl	OTP	Romania	Bucharest	apu		run	nap		nl				pr	
Cluj-Napoca	CLJ	Romania	Cluj-Napoca				nap							
Timisoara International	TSR	Romania	Timisoara	apu			nap						pr	
Koltsovo Airport	SVX	Russian Fed.	Ekaterinburg			run	nap							
Sheremetyevo	SVO	Russian Fed.	Moscow			run	nap		nl				pr	
Aberdeen Airport	ABZ	Scotland	Aberdeen	apu	cur	run	nap			ns		oq	pr	s3r
Edinburgh	EDI	Scotland,	Edinburgh		cur	run	nap			ns				
Nikola Tesla Airport	BEG	Serbia	Belgrade				nap							
Bratislava M.R. Stefanik	BTS	Slovakia	Bratislava	apu		run	nap						pr	
Ljubljana JP	LJU	Slovenia	Brnik				nap						pr	
Maribor Airport	MBX	Solvenia	Maribor				nap							
Albacete Airport	ABC	Spain	Albacete			run	nap							
Alicante	ALC	Spain	Alicante			run				ns				
Barajas-Madrid Airport	MAD	Spain	Madrid	apu	cur	run	nap			ns			pr	s3r
Barcelona	BCN	Spain	Barcelona	apu			nap		nl	ns			pr	s3r
Bilbao	BIO	Spain	Bilbao	apu	cur	run	nap							

Fuertevent ura Airport	FU E	Spain	Puerto del Rosario		cur	run	nap						pr	
Girona-Costa Brava	GR O	Spain	Girona				nap							
Gran Canaria Airport	LP A	Spain	Telde			run	nap			ns				
Ibiza Airport	IBZ	Spain	Ibiza			run	nap						pr	
Jerez Airport	XR Y	Spain	Jerez de al Frontera			run								
Malaga Airport	AG P	Spain	Malaga			run	nap		nl	ns				s3r
Menorca Airport	MA H	Spain	Menorca			run	nap							
Moron Airport	OZ P	Spain	Moron				nap							
Palma de Mallorca	PMI	Spain	Palma de Mallorca	ap u		run	nap			ns			pr	
San Sebastian	EA S	Spain	San Sebastian				nap							
Santander Airport	SD R	Spain	Santander			run								
Sevilla - San Pablo	SV Q	Spain	Sevilla		cur							oq	pr	
Tenerife Sur-Reina Sofia	TFS	Spain	Tenerife			run	nap			ns				
Valencia Airport	VL C	Spain	Valencia				nap			ns				
Vitoria Airport	VIT	Spain	Vitoria			run								
Bromma	BM A	Sweden	Stockholm	ap u	cur	run	nap		nl	ns	es	oq		s3r
Goteborg City Airport	GS E	Sweden	Gothenbur g	ap u	cur		nap		nl				pr	
Luleå - Kallax	LL A	Sweden	Luleå				nap			ns	es			
Stockholm Skavsta	NY O	Sweden	Stockholm				nap							
Stockholm Vasteras	VS T	Sweden	Vasteras				nap							
Sundsvall-Härnösand	SD L	Sweden	Sundsvall-Härnösand				nap			ns	es			
Jonkoping	JK G	Sweden	Jonkoping	ap u			nap			ns	es		pr	

Kalmar Airport	KLR	Sweden	Kalmar				nap		nl	ns	es		pr	
Karlstad	KSD	Sweden	Karlstad	apu		run	nap			ns	es	oq		
Kiruna Airport	KRN	Sweden	Kiruna		cur					ns	es		pr	
Landvetter	GOT	Sweden	Goteborg	apu	cur	run	nap			ns	es		pr	
Malmo Airport	MMX	Sweden	Malmo	apu		run				ns	es			
Norrkoping	NRK	Sweden	Norrkoping		cur		nap		nl				pr	
Stockholm-Arlanda	ARN	Sweden	Stockholm	apu		run	nap	nb	nl	ns	es		pr	
Umea Airport	UME	Sweden	Umea	apu	cur		nap			ns	es		pr	
Växjö Smaland	VXO	Sweden	Växjö	apu			nap							
Visby Airport	VBY	Sweden	Visby				nap			ns	es			
Bern-Belp	BRN	Switzerland	Bern	apu	cur		nap		nl	ns	es		pr	
Geneva-Cointrin	GVA	Switzerland	Geneva	apu	cur	run	nap		nl	ns	es			
Lugano Airport	LUG	Switzerland	Lugano	apu	cur		nap		nl	ns	es			
Samedan Airport	SMV	Switzerland	Samedan	apu		run	nap			ns			pr	s3r
Sion Airport	SIO	Switzerland	Sion	apu	cur		nap			ns			pr	
Zurich Airport	ZRH	Switzerland	Zurich	apu	cur	run	nap			ns	es		pr	
Basel-Mulhouse Airport	BSL	Switzerland	Basel	apu	cur	run	nap			ns	es		pr	s3r
	MLH	France	Mulhouse											
Eindhoven Airport	EIN	The Netherlands	Eindhoven				nap			ns				
Maastricht Aachen	MST	The Netherlands	Maastricht		cur	run				ns				
Rotterdam	RTM	The Netherlands	Rotterdam		cur	run	nap			ns		oq		
Schiphol	AMS	The Netherlands	Amsterdam	apu	cur	run	nap	nb	nl	ns			pr	s3r

Belfast City Airport	BHD	UK	Belfast	apu	cur	run	nap		nl			oq	pr	s3r
Belfast International	BFS	UK	Belfast			run	nap							
Benbecula Airport	BEB	UK	Benbecula										pr	
Biggin Hill Airport	BQH	UK	London	apu	cur	run	nap		nl			oq		s3r
Birmingham International	BHX	UK	Birmingham	apu	cur	run	nap		nl	ns		oq	pr	s3r
Blackpool Airport	BLK	UK	Blackpool	apu		run	nap						pr	
Bournemouth Intl. Airport	BOH	UK	Christchurch, Dorset	apu	cur	run	nap						pr	
Bristol International	BRS	UK	Bristol	apu	cur		nap		nl	ns		oq	pr	s3r
Cambridge Airport (UK)	CBG	UK	Cambridge	apu	cur	run	nap						pr	
Cardiff International	CWL	UK	Cardiff			run	nap							
Coventry Airport	CVT	UK	Coventry		cur		nap		nl			oq		s3r
Durham Tees Valley	MME	UK	Darlington			run	nap							
East Midlands	EMA	UK	Castle Donington, Derby	apu	cur	run	nap		nl	ns			pr	
Exeter Airport	EXT	UK	Exeter	apu	cur	run	nap							
Farnborough Airport	FAB	UK	Hampshire	apu	cur	run	nap					oq		
Gatwick Airport Limited	LGW	UK	London	apu	cur	run	nap		nl	ns	es	oq		s3r
Glasgow	GLA	UK	Glasgow		cur	run	nap		nl	ns		oq		
Guernsey Airport	CGI	UK	Guernsey		cur	run	nap							

Heathrow	LHR	UK	London	apu	cur	run	nap		nl	ns	es	oq	pr	s3r
Humberside International	HUY	UK	Kirmington, North Lincolnshire			run								
Jersey Airport	JER	UK	St. Helier		cur	run	nap		nl					
Kent International Airport	MSE	UK	N. Caterbury		cur	run	nap			ns		oq	pr	s3r
Leeds-Bradford Intl.	LBA	UK	Leeds	apu	cur	run	nap		nl	ns		oq	pr	
Liverpool John Lennon	LPL	UK	Liverpool		cur	run	nap					oq	pr	
London City Airport	LCY	UK	London		cur	run	nap		nl			oq		s3r
London Southend Airport	SEN	UK	Southend-on-Sea,Essex			run	nap							
Londonderry	LDY	UK	Londonderry				nap							
Luton	LTN	UK	Luton		cur	run	nap		nl	ns	es			
Manchester	MAN	UK	Manchester	apu	cur	run	nap	nb	nl	ns		oq	pr	s3r
Newcastle Airport	NCL	UK	Newcastle Upon Tyne	apu		run	nap							
Norwich International	NWI	UK	Norwich		cur	run	nap			ns			pr	
Prestwick International	PIK	UK	Prestwick			run	nap							
Robin Hood	DSA	UK	Doncaster	apu	cur	run	nap					oq	pr	s3r
Southampton Intl.	SOU	UK	Southampton	apu	cur	run	nap			ns		oq		s3r
Stansted Airport Limited	STN	UK	London	apu	cur	run	nap		nl	ns		oq		s3r
Boryspil International	KBP	Ukraine	Kyiv				nap						pr	
Donetsk Airport	DOK	Ukraine	Don				nap							

Appendix B The 30 largest European airports ranked by passenger traffic in 2012

Rank 2012	Country	Airport	City	Passengers 2011	Passengers 2012	Change 2011-2012
1	United Kingdom	London Heathrow Airport	London	69,433,230[1]	69,984,868[1]	▲00.9%
2	France	Paris-Charles de Gaulle Airport	Paris	60,970,551[2]	TBA	TBA
3	Germany	Frankfurt Airport	Frankfurt	56,436,255[3]	57,500,000[1]	▲01.9%
4	Netherlands	Amsterdam Airport Schiphol	Amsterdam	49,755,252[4]	51,000,000[5]	▲02.5%
5	Spain	Barajas Airport	Madrid	49,671,270[6]	45,195,014[6]	▼09.0%
6	Turkey	Atatürk International Airport	Istanbul	37,394,694[7]	44,998,508[7]	▲20.3%
7	Germany	Munich Airport	Munich	37,763,701[3]	TBA	TBA
8	Italy	Leonardo da Vinci-Fiumicino Airport	Rome	37,651,700[8]	TBA	TBA
9	Spain	Barcelona El Prat Airport	Barcelona	34,398,226[6]	35,145,176[6]	▲02.2%
10	United Kingdom	Gatwick Airport	London	33,674,264[1]	TBA	TBA
11	Russia	Domodedovo International Airport	Moscow	25,701,610[9]	28,200,000[10]	▲09.6%
12	France	Paris-Orly Airport	Paris	27,139,076[2]	TBA	TBA
13	Turkey	Antalya Airport	Antalya	25,113,635[7]	24,993,667[7]	▼0.14%
14	Switzerland	Zürich Airport	Zürich	24,337,954[11]	TBA	TBA
15	Denmark	Copenhagen Airport	Copenhagen	22,725,517[12]	23,336,187[12]	▲02.7%
16	Spain	Palma de Mallorca Airport	Palma de Mallorca	22,726,707[6]	22,666,682[6]	▼00.3%

Rank 2012	Country	Airport	City	Passengers 2011	Passengers 2012	Change 2011-2012
17	Russia	Sheremetyevo International Airport	Moscow	22,555,000[13]	TBA	TBA
18	Norway	Oslo-Gardermoen Airport	Oslo	21,103,623[14]	22,080,433[14]	▲04.6%
19	Austria	Vienna International Airport	Vienna	21,106,292[15]	TBA	TBA
20	Germany	Düsseldorf International Airport	Düsseldorf	20,339,466[3]	TBA	TBA
21	Sweden	Stockholm-Arlanda Airport	Stockholm	19,069,065[16]	19,642,029[17]	▲03.0%
22	Italy	Malpensa Airport	Milan	19,303,131[8]	TBA	TBA
23	Ireland	Dublin Airport	Dublin	18,741,095[18]	19,100,000[19]	▲01.9%
24	United Kingdom	Manchester Airport	Manchester	18,892,756[1]	TBA	TBA
25	Belgium	Brussels Airport	Brussels	18,786,034[20]	18,971,332[20]	▲01.0%
26	United Kingdom	London Stansted Airport	London	18,052,843[1]	17,456,733[1]	▼03.3%
27	Germany	Berlin Tegel Airport	Berlin	16,919,820[3]	TBA	TBA
28	Portugal	Lisbon Portela Airport	Lisbon	14,805,624[21]	15,301,176[22]	▲03.5%
29	Finland	Helsinki Airport	Helsinki	14,865,871[23]	TBA	TBA
30	Turkey	Sabiha Gökçen Airport	Istanbul	12,749,230[7]	14,487,242[7]	▲10.38%

Appendix C Methodology for the definition of PIs related to Economic Impact on Communities

In this Appendix a number of statistics are provided aiming at quantifying the economic impact of airports in communities, measured in terms of economic impact and job creation impact [8, 9, 10, 11]. These impacts may be classified taking into account the type of link with the air transport process [11]:

- Direct: wealth and jobs related to the air transport stakeholders (airports, airlines, air navigation service providers).
- Indirect: wealth and jobs created by the provision of supplies needed by the air transport stakeholders (catering, fuel, handling systems, etc.).
- Induced: wealth and jobs created by the normal expenses and taxes paid by the air transport stakeholders (personal expenses, income tax, etc.).
- Catalytic: wealth and jobs created by activities other than air transport but needing air transport services for their accomplishment (the most relevant, tourism moved by plane).

A direct impact of airports is on a country GDP. Next graph provides for the European Union countries the GDP (in € billions) supported by aviation [10]:

	AUSTRIA	BELGIUM	BULGARIA	CYPRUS	CZECH REP.	DENMARK	ESTONIA	FINLAND	FRANCE	GERMANY	GREECE	HUNGARY	IRELAND	ITALY
Aviation sector	1.8	2.5	0.23	0.36	0.42	1.4	0.09	2.8	26.2	22.2	3.3	0.38	1.9	4.7
+ Indirect	3.0	4.8	0.36	0.48	0.71	2.1	0.15	4.5	48.1	37.8	4.4	0.66	3.1	9.8
+ Induced	3.6	5.8	0.47	0.62	0.91	2.7	0.19	5.8	61.8	47.9	5.7	0.84	4.1	12.7
+ Tourism catalytic (total)	4.6	7.7	1.75	2.66	1.18	2.9	0.27	7.1	75.2	63.1	14.1	1.13	9.4	23.6

	LATVIA	LITHUANIA	LUXEMBOURG	MALTA	NETHERLANDS	POLAND	PORTUGAL	ROMANIA	SLOVAKIA	SLOVENIA	SPAIN	SWEDEN	UK	EU27
Aviation sector	0.08	0.17	0.64	0.09	5.4	0.6	1.1	0.44	0.42	0.23	6.5	2.5	23.9	110.3
+ Indirect	0.12	0.28	0.79	0.12	8.9	1.2	1.8	0.62	0.66	0.36	11.1	3.9	42.2	245.4
+ Induced	0.15	0.36	0.99	0.15	11.8	1.6	2.3	0.78	0.85	0.47	14.2	5.0	55.7	306.3
+ Tourism catalytic (total)	0.37	0.60	1.35	1.11	17.5	2.0	5.7	1.03	0.96	1.05	54.3	11.3	78.9	474.8

The percentage of the country GDP supported by aviation is given in the following table [10]:

Country	GDP supported by aviation (% of economy)
Austria	2,0
Belgium	1,9
Bulgaria	0,5
Cyprus	0,6
Czech Republic	1,0
Denmark	2,2
Estonia	0,1
Finland	1,4
France	12,2

Germany	15,7
Greece	3,2
Hungary	0,7
Ireland	1,9
Italy	11,4
Latvia	0,4
Lithuania	0,2
Luxembourg	0,1
Malta	0,3
Netherlands	4,0
Poland	1,6
Portugal	2,3
Romania	0,8
Slovakia	0,2
Slovenia	0,1
Spain	15,5
Sweden	2,7
UK	17,1

Another important indicator is the number of jobs supported. Following graph shows the number of jobs (in thousands) supported by aviation for the European Union countries [10]:

	AUSTRIA	BELGIUM	BULGARIA	CYPRUS	CZECH REP.	DENMARK	ESTONIA	FINLAND	FRANCE	GERMANY	GREECE	HUNGARY	IRELAND	ITALY
Aviation sector	32	36	18.2	9.6	14	29	3.3	62	297	323	53	18	26	69
+ Indirect	50	71	29.7	12.2	25	39	5.5	86	596	623	75	29	42	152
+ Induced	60	84	38.8	15.5	31	45	7.1	104	780	816	100	37	54	195
+ Tourism catalytic (total)	75	112	141	63.9	43	50	10.3	121	989	1,146	300	48	117	382

	LATVIA	LITHUANIA	LUXEMBOURG	MALTA	NETHERLANDS	POLAND	PORTUGAL	ROMANIA	SLOVAKIA	SLOVENIA	SPAIN	SWEDEN	UK	EU27
Aviation sector	4.4	7.9	8.7	3.8	87	20	24	28	13.6	5.6	120	44	326	1,700
+ Indirect	6.5	12.8	9.8	4.5	138	45	44	41	22.1	9.1	203	67	672	3,700
+ Induced	8.2	16.8	11.0	5.5	175	65	59	54	28.9	11.8	260	83	921	4,600
+ Tourism catalytic (total)	18.6	28.3	14.5	31.6	287	84	183	78	32.3	25.6	872	185	1,440	7,800

Looking more specifically at the influence of airports, according to ACI estimations, the European airports support, on average, around 950 on-site jobs per million passengers (workload units) per annum [11].
Airports are then classified according to this workload unit in the following categories:

Workload unit range	**Airport classification**
300-600	Low density
600-900	Medium density
900-1200	High density

+ 1200	Very high density

The top-ten European airports being considered in Cassiopeia all lay within the High Density or Very High Density categories.

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