COSTS OF AIR TRANSPORT DELAY IN EUROPE

Final report

November 2000

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INTRODUCTION

Air transport delays in Europe are a major concern for the industry and a relentless source of complaints from the passengers, as often verified in the media.

Not only is it a painful inconvenience for the actors, but delays also induce large costs, for the airlines, their customers and the community as a whole.

Air transport delay is a very complex phenomenon and needs investigations for a better appraisal of the various costs involved, as well as the information needed to analyse and evaluate them.

The aim of this study, which is sponsored by the EUROCONTROL Performance Review Unit (PRU), is to improve the understanding of the various aspects of air transport delay costs and to assess unit costs of the various types of delays that occur airborne or on ground.

Main results

The study shows that annual overall costs for airlines and passengers could be estimated between EUR6.6 and EUR11.5 billion for[1] 1999 with a corresponding average unit cost per minute of delay ranging from EUR39.4 - EUR48.6 for the airlines, and EUR 46.6 - EUR60 incurred by passengers, respectively[2]. In this evaluation, the costs burden for airlines (from EUR3.0 to EUR5.1 billion) as a whole, seem to be somewhat lower than the cost burden for the passengers (from EUR3.6 to EUR6.4 billion).

Primary and reactionary delays do not have the same impact on costs, as illustrated in the following table.

Scheduled Flights	Distribution	Airline unit costs	Passengers unit costs	Total
ATFM primary delays	60%	40-66	47-60	87-126
Reactionary delay	40%	28	47-60	75-88

NB. Those figures correspond to the actually observed delays encountered by airlines in the course of their operations

The results of the study suggest that the costs impact of a primary delay is higher than the cost impact of an induced (**reactionary**) delay, all else equal. Assuming that each minute of primary delay generates 2/3 minutes of reactionary delay, the total airline unit cost per minute of ATFM delay ranges from around EUR 59 to EUR85 for each minute of primary delay.

[1] Arguably an atypical year due to the Kosovo crisis.
[2] Those figures refer to scheduled traffic only (around 65% of total European traffic).

As far as the costs for airlines are concerned, passenger related costs constitute by far the most important costs (between 50 and 70% of total airline costs), as airline costs are highly linked to their commercial concern for passengers.

This study presents two aspects: the identification of the different types of delays from a conceptual viewpoint (part I), followed by an evaluation of their economic consequences on various cost items (part II).

PART I: METHOD

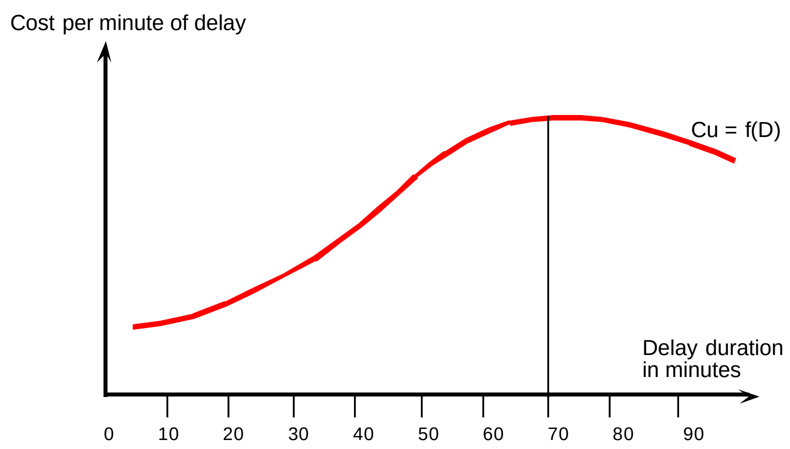
I.1. Theoretical background

Delay cost calculations usually involve the application of a cost factor based on reported values for the average direct aircraft operating costs per time unit to quantities of delay. The approach to delay cost estimation is based on strong assumptions that are rarely scrutinised or even acknowledged:

- The cost of delay is an additive function of the cost of individual delay events;
- The cost of each delay event is a linear function of the duration of the delay.

Such an assumption ignores the possibility that delay cost is non-linearly related to duration, as illustrated by the figure 1. A sixty minutes delay is likely to be more costly than 60 times one minute of delay. The sixty minutes delay is more likely to disrupt ground operations, gate assignments, crew schedules, and passenger itineraries. It is also possible that the unit cost of delay decreases beyond a certain duration (as depicted in the figure 1) because airlines take different measures in order to minimise the overall impact of delay (e.g. cancel the flight). Additionally, such assumptions ignore the possibility that the cost of 30 minutes of primary delay due to a lack of ATC capacity might be very different than the cost of 30 minutes of reactionary (secondary) delay due to late arrival of the aircraft. .

Figure 1: Cost of delay per minute distribution



Delay costs are also subject to combinatorial effects[3]. The severity of the impacts is likely to depend not only on the duration of delay to a specific flight but also on the interaction of delays for many flights. This is particularly relevant in the era of extensive hubbing. Finally, the cost of delay also depends on the nature of the airline (short-haul vs long-haul, schedule vs charter, etc) and on its adaptation behaviour. Carriers may take a variety of measures to make their operations less sensitive to delay. For example, they include a buffer into their schedule, they plan for extra aircraft, flight crew and ground personnel. While these measures decrease the cost of delays when they occur, they also increase costs of day-to-day operations.

[3] This section heavily draws on Hansen, Gillen and Djafarian-Tehrani paper in Transportation Research Part E (2000).

Figure 1b: Cost of delay for airlines

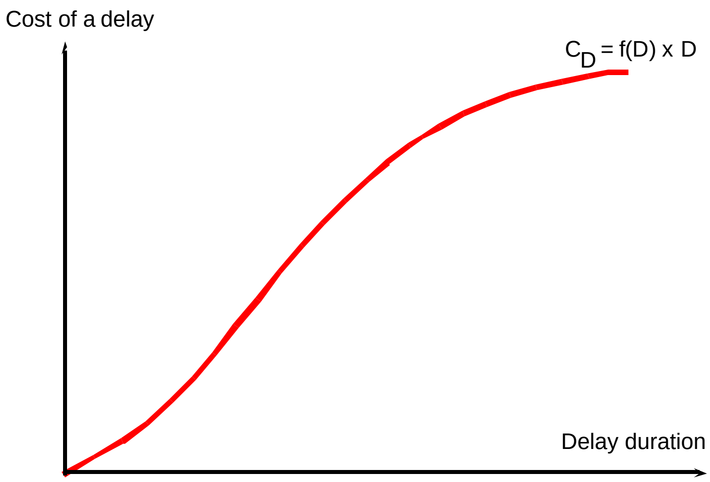
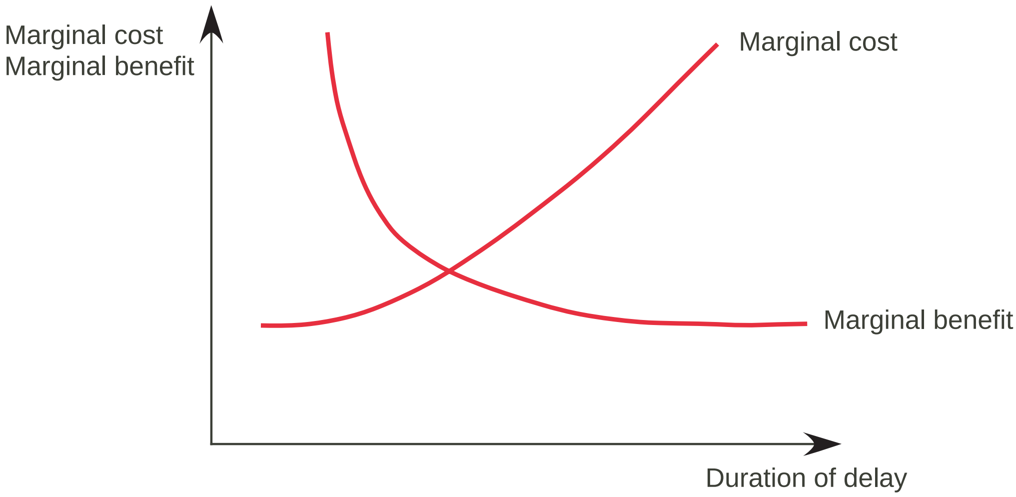


Figure 2: Marginal cost and marginal benefit



From a theoretical point of view, society should put resources (and direct investments) up to a point where the marginal cost to reduce delay equals the marginal benefit from a reduction of delay. The economic optimum does not necessarily require that delays should be reduced to zero (as it is shown in the figure above).

I.2. ITA's approach

Our approach is based on a cross-analysis according to:

- the concerned economic activities and individuals, and
- the nature of delay.

I.2.1 Involved economic activities and individuals

Occurring delays have financial and economic consequences on airlines, on their clients and on the community.
The airlines bear additional costs on fleet, as well as flying and ground personnel, since delays prevent them from operating in optimum conditions. They also must compensate passengers for their experienced discomfort and prejudices. Also, according to their type of operations, airlines might experience specific costs (i.e. linked to hub operations). Additional long-term costs might also be observed such as a loss of competitiveness and the consequences of a degraded social climate, which follows degraded working conditions.

The delay-related costs for users are mostly airline passenger's opportunity cost, measured by their value of time. Other users like military and general aviation costs, which are very difficult to address, have not been taken into consideration in the scope of this study.

The delay-related costs for the community involve environmental costs as well as costs incurred by other actors involved in the air transport business such as hotels, travel agents, tour-operators, airports, etc.
Detailed cost items are listed in table 1 ("summary of cost impact").

Table 1: Summary of cost impact

			(A) - Schedule vs Optimum				(B) - Operated flights vs Schedule					
			INCREASE OF DURATION				*TYPE OF DELAYS*					
							Primary delays				Reactionary delays	
			Airborne	Parking	Taxiing	Block to block	Airborne	Ground	Departure	Arrival	Departure	Arrival
		COSTS FOR AIRLINES	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(e)	(f)
I		**Aircraft operating costs**										
	1	Fuel	X		X		X	X				
	2	Aircraft parking		X				X				
	3	Air bridges		X				X				
	4	Maintenance	X				X					
II		**Operating staff costs**										
		Flying personnel										
	5	- Spare crews					X	X	X	X		
	6	- Scheduled crews				X	X	X	X	X		
	7	Ground personnel	X	X	X	X	X	X	X	X	X	X
III		**Structural costs**										
		Fleet size										
	8	- Spare aircraft							X	X		
	9	- Scheduled aircraft				X						
	10	Ground equipments						X	X	X	X	X
IV		**Passenger driven costs**										
	11	Food and drinks expenditures							X		X	
	12	Miscellaneous expenditures							X		X	
	13	Passenger rerouting								X		X
	14	Loss of revenue (cancellations by passengers)							X	X	X	X
	15	Commercial compensations								X		X
V		**Hub & connections additional costs**										
	16	Reduction of hub efficiency				X			X	X	X	X
	17	Flight cancellations							X	X	X	X
VI		**Induced (long term) airline costs**										
	18	Loss of market share to other airlines				X			X	X	X	X
	19	Loss of market share to other modes				X			X	X	X	X
	20	Loss of corporate image				X			X	X	X	X
	21	Subcontractors							X	X	X	X
	22	Average passenger revenue							X	X	X	X
	23	Social consequences	,						X	X	X	X
		COSTS FOR USERS										
VII		**Passengers**										
	24	Value of time				X				X		X
	25	Cost of automobile parking				X				X		X
	26	Prejudice compensation								X		X
VIII		**Other users**										
	27	Military										
	28	General aviation										
		COSTS FOR THE COMMUNITY										
IX		**Community**										
	29	Environment	X		X		X	X				
	30	Others ; (Travel agents, Tour operators, Hotels...)										

This table is organised along the following lines, for each identified cost items (horizontal), the vertical axis identifies the nature of delays (see below) -"schedule versus optimum" and "operated flight versus schedule", primary, reactionary, airborne and ground delays. Where, there is an identified impact, this is indicated with an X in the corresponding box. For example, commercial compensations costs occur only for arrival delays under the "operated flight versus schedule" concept.

I.2.2. Nature of delays

In this section we would like to introduce some important concepts or definitions[4] that will be used throughout this study.

- Delay concepts

In general, the estimation of the cost impact of air transport delay is based on the comparison between overall costs due to delayed operations (referred to here as "operated flights") and on-time operations as a reference (referred to here as "schedule") and will be referred to "**operated flights versus schedule**" costs.

But one might also consider costs derived from sub-optimal operations. In fact, the everlasting air congestion in Europe is a phenomenon, which has to be taken into account by airlines in the planning process

Indeed, air transport delays encountered in Europe are to some degree taken into account by airlines when they establish schedules for the next (e.g. IATA season) operating period. Published schedules generally incorporate a buffer, which is added to the planned flight time in order to accommodate statistically foreseeable delays. This leads airlines to increase the number of aircraft and crews they need and, consequently, the costs of operations. Therefore, corresponding costs should be identified, by comparing the actual schedules against "ideal" ones.

Within the scope of the study, this concept will be referred to as "**schedule versus optimum**" costs.

- Delay types

Within those two concepts, different types of delays have to be identified and measured, due to the specific impact they might have on the above-mentioned cost items (see table 1: summary of cost impact).

Delays can occur during the different phases of a flight: when the aircraft is airborne, taxing or parked on the apron. Block to block delays might also be taken into consideration. Specifically for operated flights versus schedule, one also has to consider another delay type breakdown, whether delays are primary delays (airborne/ground, departure/arrival) or reactionary delays (departure/arrival).
Primary delays correspond to initial delay caused to a given flight. They are classified according to delay causes: passenger and baggage, cargo and mail, aircraft and ramp

[4] See also definitions and acronyms in annex 1

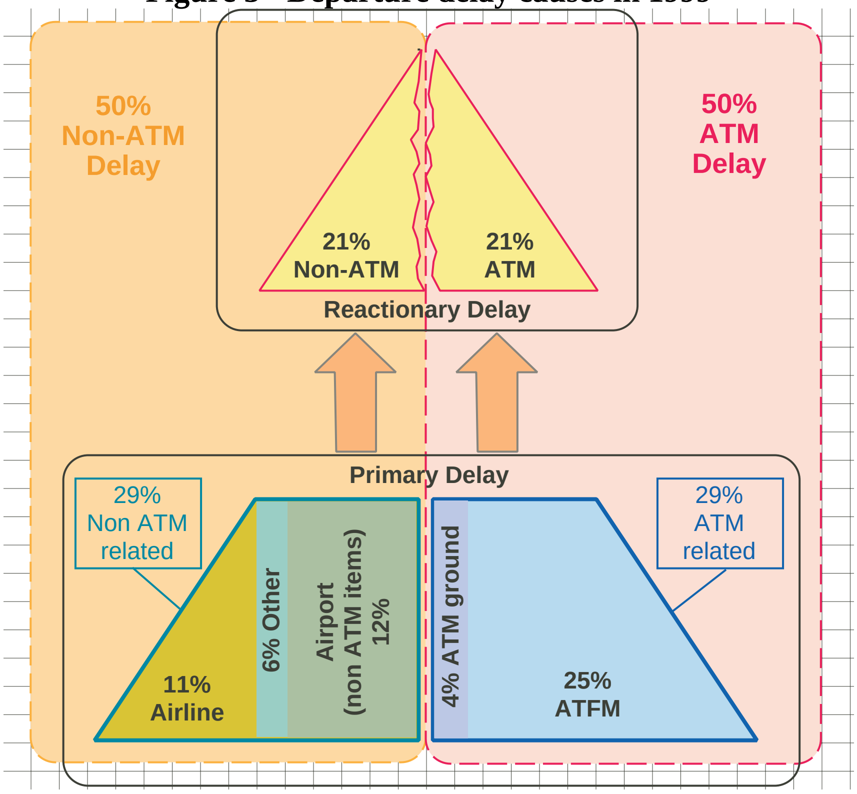
handling, technical and aircraft equipment, damage to aircraft, flight operations and crewing, weather, airport and governmental authorities (including ATC). Late arrivals of connecting flight, connecting passengers, baggage, load or crewmembers are not to be included in primary delay causes. Later on, only ATFM delays will be considered for the purpose of the study.

Reactionary delays correspond to delays due to the late arrival of aircraft delayed during its previous leg operation, late arrival of a connecting flight, passengers or load, and late arrival of crew members, expected from another flight.

One could note here that reactionary delays occur following primary delays and if the latter would be reduced, the former would also diminish consequently. Initial (**primary**) delay could indeed cause disturbances along the day, due to rather tight normal operating schedules, established to achieve economic efficiency, resulting in **reactionary** delays.

The relative shares of primary delays and reactionary delays are illustrated in figure 3 using 1999 data.

Figure 3 - Departure delay causes in 1999



Source: CODA & PRR 3

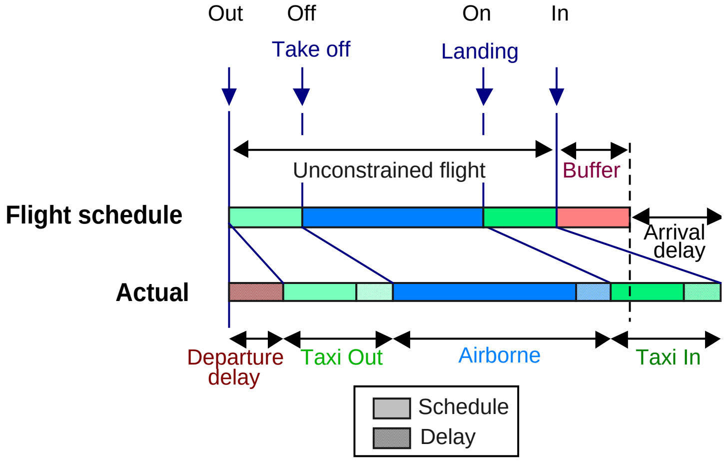
Because the costs impacts are different, there is a strong rationale for having this dichotomy between primary and induced (**reactionary**) delays. It is interesting to note that airlines are in some cases willing to take extreme operational measures in order to avoid, or minimise the impact of reactionary delays (like cancelling one or more waves in case of severe hub operation disturbance).

For a thorough cost assessment on a flight-by-flight basis, measuring delays is a difficult matter, since they have to be broken down according to the above-mentioned classification and would require very detailed delay statistics identifying for each flight:

- origin and destination,
- original schedule,
- actual time for each phase of flight (parking, taxiing towards take-off, airborne, and taxiing after touch down),
- name of operating airline, and
- type of aircraft.

The different elements, which constitute the various types of delays, are shown in figure 4.

Figure 4: Air transport delay and punctuality



"The figure compares the flight schedule and actual flight, and shows how a delay in the different phases (departure, taxi-out, en-route, taxi-in) affect arrival punctuality. Published airline schedules generally incorporate a buffer, which is added to the planned flight time, in order to accommodate statistically foreseeable delays. When accumulated delays exceed the buffer, arrival delays occur. Delays and buffer are linked by the following formula[5]:
Arrival delay = Departure delay + taxi-out delay + airborne delay + taxi-in delay – buffer."

Information on schedule and actual flight times are needed to measure all types of delay. Most will be available through ACARS (Aircraft Communication Addressing and Reporting System) source. Nevertheless, some will still be missing. They are identified in the following table.

[5] Source: EUROCONTROL PRC – PRR3- May 2000 p.9.

Table 2: Needed information to estimate airborne and ground delays breakdown

	DEPARTURE			ARRIVAL				FLIGHT TIME	BLOCK TIME
	Time BLOCK	Duration TAXI OFF	Time TAKE OFF	Time EST. ARR. TIME	Time TOUCH DOWN	Duration TAXI IN	Time BLOCK	Duration VALUE	Duration VALUE
SCHEDULED	STD	**SOFF - STD**	**SOFF**		**SON**	**STA - SON**	STA	**SON - SOFF**	STA - STD
ACTUAL	OUT	TOFF = OFF-OUT	OFF	ETA	ON	TIN = IN-ON	IN	FTIM = ON-OFF	BTIM = IN-OUT
DELAYS	OUT - STD	**TOFF - (SOFF - STD)**	**OFF - SOFF**		**ON - SON**	**TIN - (STA -SON)**	**IN - STA**	**FTIM - (SON - SOFF)** **ou ON - ETA**	**BTIM - (STA-STD)**

STD	scheduled time of departure
STA	scheduled time of arrival
SOFF	scheduled time of take-off
SON	scheduled time of touch-down
OUT	actual time of departure
OFF	actual time of take-off
ETA	estimated time of arrival
ON	actual time of touch-down
IN	actual time of arrival
TOFF	taxi-off duration
TIN	taxi in duration
FTIM	actual flight time
BTIM	actual block time

Missing elements

As noted earlier, delays can have different causes (ATFM, airport operations, aircraft technical problems, weather, etc.). For the purpose of this study, though, we will focus our attention on the economic evaluation of the ATFM related delays.

Overall comprehensive delay cost evaluation would require knowledge of each marked box content (duration of ATFM delays and unit costs).

Analysis of delay costs will, in particular, require gathering information from airlines in order to know how:

- they take into account delays in setting up flight schedules,
- they react to delays in modifying operation patterns, or in putting spare aircraft and crews into service,
- they determine the size of their fleet (including spare aircraft) and flying personnel (also including spare crews),
- they evaluate the cost related to passengers treatment (including additional spending and commercial compensations), and
- they value the impact of delays on various commercial issues like market share, modal split, average revenue, and increased costs for subcontractors, etc.

PART II: EVALUATION OF ECONOMIC CONSEQUENCES

II.1. Operated flights versus schedule costs

II.1.1. Costs for airlines

- Previous studies

Although there is some literature on assessing delay costs (especially in the US FAA), the assessment of delay costs has not been conducted in a fully comprehensive and systematic way.

To the best of our knowledge, there are no comprehensive studies available on this subject. The only partial information we could gather was found in an IATA document based on the results of the Airline Economic Task Force data collection, carried out along the lines defined in March 1999 (Data Collection 1999 – Definitions and instructions).

Nine IATA members participate in this exercise which is aimed at providing a continuous and consistent source of statistical and market data about financial matters, with specific attention to costs and revenues. Attention should be drawn on the fact that its general objective do not provide for specific delay cost evaluation.

From the gathered data, they produced a very rough evaluation of the direct operating costs of carriers operating in Europe in 1997, both for on ground and airborne delays, which, by definition, does not allow for an overall evaluation of delay costs.

Table 3: IATA Airline Economics task force
Direct operating costs of carriers operating in Europe – 1997

1997 (US dollars)	Cost per hour	Ground cost per hour of ATFM delay	Cost per additional hour of flight time
Flight desk crew	517	517	517
Fuel & oil	543		543
Flight equipment insurance	20	20	20
Maintenance & overhaul	683		683
Flight equipment depreciation	464	464	
Rentals	439	439	439
Landing charges	490		
En-route charges	419		
Total	3574	1440	2202
EUR/min		**21.2**	**32.4**

Cost items in the IATA database are not detailed enough for an in-depth analysis. Moreover, some cost items that we have identified in this ITA's study, (i.e. cabin attendants, commercial compensations) are not included in the evaluation. IATA also considered that average unit (not marginal) costs could be used. On the contrary, the cost evaluations gathered by ITA from airlines are differentiated according to each specific item between average and marginal costs. A more detailed description of those differences is described in annex 3.

The only other evaluation we have identified is from a US Airline Transport Association (ATA) source, and is reported below.

Table 4: ATA calculated delay costs – 1999

1997 (US dollars)	Aircraft Operating cost per minute($)	Delay minutes (millions)	Delays costs ($ millions)
Gate	24.30	5.16	125.3
Taxi out	30.47	34.65	1055.7
Airborne	47.64	16.12	767.7
Taxi in	29.81	9.64	287.4
Total aircraft operating	34.11	65.56	2236.1
Added ground costs (guess)			850.0
Value of passenger time			2100.0
Total costs			5186.1

Source: Airline Financial News March 13,2000

According to this evaluation, the aircraft operating delay costs amounts to USD34.1 per minute. Unfortunately, we were not able to get further details on how this evaluation was made.

The results of table 3 and table 4 suggest that large differences might exist in the evaluation of the costs of delay. Although the breakdown provided in tables 3 and 4 is not detailed enough, those figures provide useful benchmark for this study.

- ITA's study

Given the limitations in the IATA approach, we feel the need to get information directly from individual airlines in order to better cover the list of items we had identified, as well as to get a better view of their practices and knowledge of the delays experienced along with their corresponding costs.
Each airline has specific in-house rules and procedures regarding its operations, such as

- Fleet management,
- Air crew management,
- Ground personnel management,
- Passenger treatment,
- Passenger compensation, and eventually,
- Specifics of hub operation,
- Accounting methods (delay costs attribution),

which impact differently each cost item, and their understanding was needed for this analysis.

This information was then gathered, altogether with delay data, and used for establishing global and unit costs for each item.

Those specific airline data were then combined with global EUROCONTROL data concerning delay statistics, as well as AEA or IATA information regarding airline activity in the European zone. In this process, various elements were taken into account such as:

- Delay length distribution, since this impacts passenger treatment when those passengers are faced with missed connections or cancelled flights and passenger compensation,
- Type of operation (short versus long haul), since it affects the number of passengers experiencing delays[6],
- Connecting traffic, with an emphasis on hub operations, since connecting passengers receive specific treatment from airlines in case of delays.

Computations were made using the following data and hypothesis concerning only <u>scheduled</u> flights:

[6] The estimate of number of passengers involved will be explained later on

Table 5: Data and assumptions for primary and reactionary delays

Delay data	Source	Year	Unit	Value
ATFM primary delays	CFMU	1999	million min.	43.263
ATFM primary and reactionary delays	calculated*	1999	million min.	72.105
Share of scheduled flights in total IFR flights	IATA & CFMU	1998	%	64
ATFM primary delays (scheduled flights)	calculated	1999	million min.	27.488
ATFM primary and reactionary delays (scheduled flights)	calculated*	1999	million min.	45.874

*split between delays : primary 60%, reactionary 40%

The number of passengers affected by ATFM delays was calculated using an estimated number of delayed flights, an average aircraft capacity and load factor. Passenger driven costs were affected only by the number of passengers delayed by more than one hour while hub and connections additional costs were affected by passengers delayed by more than 15 minutes.

Different computations were also made in assessing primary delay and reactionary delay costs separately, as each type of delays may have a different impact on some of the identified cost items. For example, regarding aircraft operating costs, no additional cost is to be borne by airlines due to reactionary delays, as they result only in changing flight schedules during the course of the day, but not affecting flight times. Some other items like ground personnel (EUR4.52/mins for the primary delays versus EUR1.92/mins for the reactionary delays) and ground equipment (EUR5.49/mins versus EUR4.73/mins) cover expenses more sensitive to primary delay than to reactionary delay, since extra working hours for the personnel and equipment is required to make up for primary delay consequences, the rest of activity being shifted along the day (see detailed cost table in annex 2).

The data gathered from airlines consider marginal crew costs, since airline crew remuneration generally includes a significant fixed portion and a compensation for additional working hours due to delays is paid on the top of regular allowances (illustrating the non linearity of this cost item). But, as considered in the IATA evaluation, this cost item has been based on total unit crew costs. This corresponds to the way some other airlines may set up their crew remuneration rules. At Virgin Atlantic, for example, crew remuneration is entirely proportional to actual flown hours.
This had led us to consider two alternatives with regard to crew costs: marginal versus total unit crew costs.

Our cost evaluation shows that the most significant cost items are, for the marginal unit crew costs evaluation: the hub and connections additional costs (41.3 % of total airline costs), followed by operating staff costs (14.1% of total airline costs) for an overall yearly airline delay cost of EUR 1625 million. On the other hand, when one takes into account total unit crew costs, the most significant item is operating staff costs (40.1% of total airline costs), followed by hub and connections additional costs (28.7% of total airline costs) for an overall yearly airline delay cost of EUR 2333 million.

Figure 3: Weight of airline costs

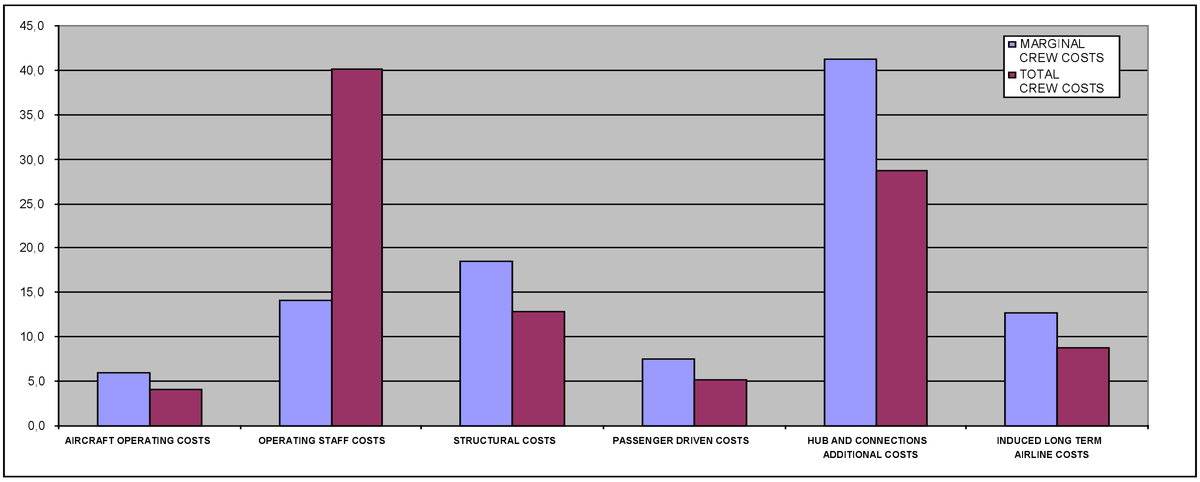


Table 6: Results of airline costs evaluation

.	MARGINAL CREW COSTS			TOTAL CREW COSTS		
	Unit costs (EUR/mn)	Overall costs (MEUR)	Weight (%)	Unit costs (EUR/mn)	Overall costs (MEUR)	Weight (%)
AIRCRAFT OPERATING COSTS	2.1	95.07	5.9	2.1	95.07	4.1
OPERATING STAFF COSTS	5.0	229.58	14.1	20.5	937.35	40.1
STRUCTURAL COSTS	6.6	300.20	18.5	6.6	300.20	12.9
PASSENGER DRIVEN COSTS	2.7	124.00	7.6	2.7	124.00	5.2
HUB AND CONNECTIONS ADDITIONAL COSTS	14.6	670.21	41.3	14.6	670.21	28.7
INDUCED LONG TERM AIRLINE COSTS	4.5	206.31	12.7	4.5	206.31	8.8
TOTAL	35.5	1 625.38	100.1	50.9	2 333.15	99.8

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Overall and unit costs breakdown for primary and reactionary delays is as follows:

Table 7: Results of airline costs evaluation for primary and reactionary delays

	MARGINAL CREW COSTS			TOTAL CREW COSTS		
	Unit costs (EUR/mn)	Overall costs (MEUR)	Weight of overall costs (%)	Unit costs (EUR/mn)	Overall costs (MEUR)	Weight of overall costs (%)
Primary delays	40.1	1 103.3	67.9%	65.9	1 811.1	77.6%
Reactionary delays	28.5	522.1	32.1%	28.5	522.1	22.4%
Overall costs	35.5	1 625.4	100.0%	50.9	2 333.2	100.0%

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Primary delays unit costs are higher than reactionary delays unit costs, since the latter do not affect aircraft either operating costs or spare and scheduled crews and aircraft cost items. Furthermore, overall costs are higher for primary than for reactionary delays, due, also, to the corresponding recorded delays.

It is important to note that overall costs are likely to be underestimated, since they do not include, due to the lack of detailed information, neither charter operations nor some cost items such as:

- Item 18 - Loss of market share to other airlines (but the loss for one airline constitutes a gain for another one, therefore resulting in a transfer of activity with no impact on the industry as a whole),
- Item 19 - Loss of market share to other modes,
- Item 20 - Loss of corporate image,
- Item 22 - Average passenger revenue,
- Item 23 - Social consequences.

Comparison with the IATA evaluation would prove extremely difficult, if not impossible, since IATA evaluation does not include the cabin crew, ground personnel, ground equipment, passenger driven and hub and connection additional cost items.

Comparison with the ATA evaluation is illustrated below.

Table 8: ATA and ITA 1999 costs evaluation

	ATA			**ITA**		
	Unit cost per minute (EUR)	**Delay minutes (million)**	**Delays costs (EUR million)**	**Unit cost per minute (EUR)**	**Delay minutes (million)**	**Delays costs (EUR million)**
Total aircraft operating costs	32.0	65.6	2 098.1	20.4	45.8	935.7
Ground costs			797.5	30.5	45.8	1 397.5
Total costs	32.0	65.6	2 895.6	50.9	45.8	2 333.2

Overall estimations are rather close (EUR 2333.2 million versus EUR 2895.6 million). But, unit costs diverge as well as the minutes of delays considered. Moreover, drawing conclusions would probably be a delicate matter because ATA figures come from 2000 airline routes in the US, which could differ significantly from what could be observed in the European environment.

II.1.2. Costs for users[7]

After studying costs for operators, most economic studies also take into account cost for users in order to assess global social costs and will therefore include the opportunity cost for the passengers. Indeed depending on who should pay for improved ATC, one would or would not include those costs. In fact, some of the inconveniences encountered by passengers have been

[7] At this stage, only passenger costs have been taken into account.

directly compensated by airlines (cf. item 15) but those compensations certainly do not cover, by far, the full cost incurred by passengers.

Time lost by passengers has an opportunity cost. During the time lost, they could work and receive compensation or they could have had some leisure time and derived utility. The appraising of passengers delay costs is based on estimates and empirical analysis of the value of time for delayed passengers.

This value of time consists in a monetary evaluation, equivalent to the additional money passengers would agree to pay in order to save (or not loose) time. From an economic point of view, passengers make arbitration between the ticket price and the travel time, and by their choice (of transportation mode, of route, or of itinerary) reveal their value of time.
This time value depends on travel motive, time of departure, fare class, length of travel and sojourn, as well as, on passenger characteristics (revenue, socio-economic group, etc.).

- Previous studies

The ATA evaluation with regard to the value of time in the US environment amounts to a global cost of EUR 1970 million, with no more details.
EUROCONTROL PRC evaluation is based on 60 EUR/minute/flight and amounts to EUR 4200 million for 1999.

- ITA’s study

European passenger traffic distribution according to travel motives was estimated (table 9), based on several surveys carried by ITA, among the population of the major European countries.

Multi-modal surveys, carried out in European countries, have been used to estimate value of time for air travellers, according to their travel motive (business, personal convenience and tourism), based on various modal split econometric models. The results of these estimations are outlined in annex 4.

The number of passengers encountering ATFM delays was calculated using an estimated number of delayed flights, an average aircraft capacity and load factor. The estimated distribution of passengers according to travel motives was applied to the delayed passengers.

The delay duration distribution per delayed flight was considered identical regardless of the motive.

Cost per passenger was calculated by multiplying the number of passengers delayed in each category, by the average length of delay for delayed flight and the value of time per motive of travel.

Given the range of available value of time estimates, a conservative range from EUR 34 to EUR 44 per hour, used in-house by ITA, was retained.

Table 9: Assumptions for passengers time value

Time value per hour	Motive split	Value (EUR)
Scenario: Low		
business	49%	47
personal convenience	16%	28
tourism	35%	20
average		34
Scenario: High		
business	49%	63
personal convenience	16%	33
tourism	35%	23
average		44

When applying those unit values to the number of delayed passengers, global estimation of value of time costs for passengers ranges from EUR2130.1 to EUR2747.3 million for 1999 (scheduled flights only).

Due to the lack of useful detailed information, the other listed users cost items have not been included:

- costs of automobile parking and prejudice compensation for passengers
- costs for military and general aviation users.

II.2.3. Costs for the community

Environment could be affected by delays in two ways: aircraft emissions and noise.
Air transport burns fuel into the atmosphere, which produces emissions of pollutant substances. Through lengthening flight and taxiing times, delays have an effect on the volume of emissions into the atmosphere.

- Results of previous studies have been considered with regard to assessment of pollution costs and noise costs. Some research has been conducted on individual aircraft emissions along with cost evaluation on damage caused by pollution in the neighbouring of airports. (annex 5) Those results could be used, provided that statistics on delayed traffic (aircraft and engine type, phase of flight, location of occurrence) are available. Since they are not, evaluation is impossible at this stage.

- Noise is another source of annoyance, mainly to the population living under the approach and departure paths of airports. Nevertheless, new generation aircraft have become quieter. Improved take-off performance of today engines means that aircraft climb much more quickly after take-off. Therefore significantly fewer people under the departure flight path are being disturbed, all else equal. On approach, the disturbance created by aircraft is mainly due to airframe noise, rather than to engines.

  Studies have been carried out to estimate noise social costs at airports. Some elements can be found in annex 5.

With regard to monetary consequences of delays, it seems that the only significant noise impact of delays would occur during stacks before landing. But, since aircraft are still flying at a high altitude, and since EPNdB during this flight stage have not been measured, the evaluation of this item would not be worthy of a detailed study. Moreover, information on stacks is not readily available.

- Costs for other economic agents in the community (i.e. travel agents, tour-operators, airports, hotels…) have not been surveyed. This could possibly be done at a later stage, but would prove difficult and costly.

II.2. Schedule versus optimum costs

Given past experience of encountered delays, airborne as well as on the ground, airlines are led to take them into account, when establishing their flight programs (schedules), therefore lengthening flight times, or turnaround times at given airports and according to the time of day.

II.2.1. Costs for airlines

- Previous studies

We have not been able to identify any study on this subject.

- ITA's study

Schedule versus optimum costs correspond to costs incurred by an increase in programmed flight duration. Therefore, corresponding additional costs are to be assessed for the following cost items:

- Aircraft operating costs,
- Operating staff costs with the exception of spare crews,
- Structural costs; excluding spare aircraft and ground equipment,
- Reduction of hub efficiency.

Passenger driven costs are not concerned, since for passengers, there is no change compared to what they are expecting in term of travel time and duration, although the real increase of the schedule has a cost as indicated in Section II.2.2.

Impact on induced (long-term) airline costs has not been assessed by the airlines we have surveyed.

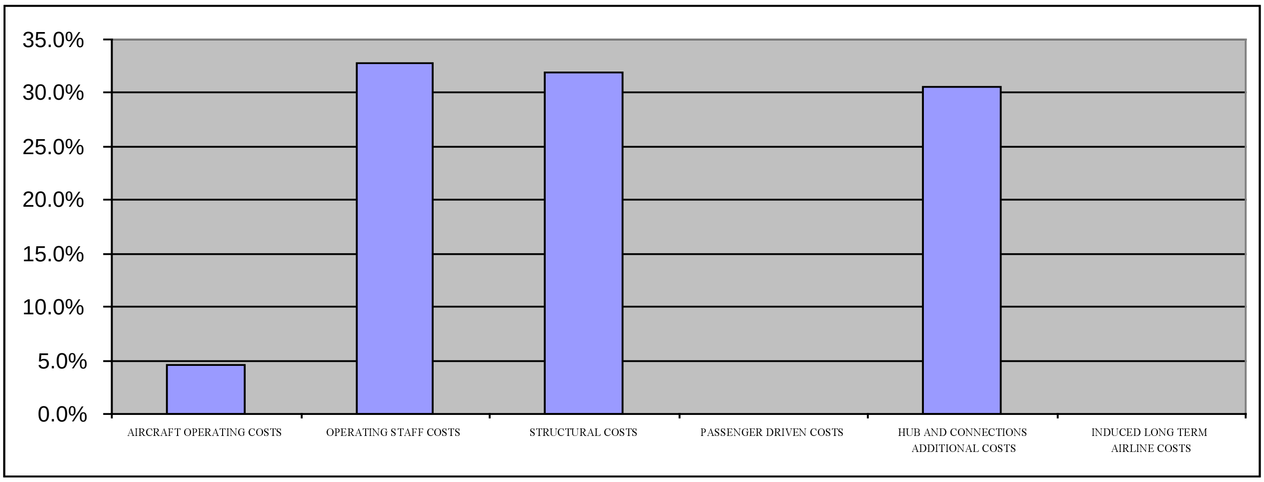
The same unit costs, as assessed for the "operated flight versus schedule" concept, have been used to value all relevant items, except for scheduled crews and aircraft. For those items being part of the flight programme, it has been considered that total costs (average unit) should be applied, for which costs from the IATA study have been used.

The approach consisted in examining the results that would be obtained if one assumes an increased flight time of either 5 or 10% (see detailed cost table in annex 2). These figures were retained, considering the block to block flight time increase observed on the London-Paris route, where scheduled times have increased by ten to fifteen minutes over the last decade. Although this flight duration increase might occur only at specifically congested airports or routes and mostly at peak hours, this is significant, given that an average internal European flight lasts 83 minutes for a distance of 760 kilometres. The flight time increase was 25% on London-Paris route, but we have limited ourselves to a maximum increase of 10%, nevertheless considering an intermediate value of 5% in order to get a first idea of the sensitivity of this cost concept.

For airlines, the delay unit cost due to the difference between scheduled and optimum time is estimated at EUR 45 per minute of delay.

The cost evaluation we have carried out, shows that the most significant cost items are both aircraft operating costs (32%) and structural costs (32%), followed by the hub and connections additional costs (30.6 % of total airline costs), other items being non significant.

Figure 4: Weight of airline costs (hyp: 5% lengthening of flight time)



If the difference between schedule and optimum flight time is 5%, the 1999 global evaluated costs of non-optimum scheduling for airlines are estimated at EUR 1.4 billion, and estimated at EUR 2.8 billion for 10%.

Table 10: Results of airline costs evaluation for lengthening of flight time

	Hyp : 5% of total flight time			Hyp : 10% of total flight time		
	Unit costs (EUR/mn)	Overall costs (MEUR)	Weight (%)	Unit costs (EUR/mn)	Overall costs (MEUR)	Weight (%)
AIRCRAFT OPERATING COSTS	2.1	63.5	4.6%	2.1	127.0	4.6%
OPERATING STAFF COSTS	14.8	454.0	32.9%	14.8	908.1	32.9%
STRUCTURAL COSTS	14.4	441.5	32.0%	14.4	883.0	31.9%
PASSENGER DRIVEN COSTS	0.0	0.0	0.0%	0.0	0.0	0.0%
HUB AND CONNECTIONS ADDITIONAL COSTS	13.8	422.4	30.6%	13.8	845.7	30.6%
INDUCED LONG TERM AIRLINE COSTS	0.0	0.0	0.0%	0.0	0.0	0.0%
TOTAL	45.2	1381.4	100.0%	45.2	2763.8	100.0%

II.2.2. Costs for users

- Previous studies

As we have already mentioned for airline costs, we have not been able to identify any study on this subject.

- ITA's study

The same method we used for the operated versus schedule concept applies here also (cf. definition of value of time for passengers). EUR 34 or EUR 44 per hour are the value used. The OAG source provided the total flight time, which, divided by the number of flights allowed to compute an average flight time. A 5% or 10% increase on that value was applied, which multiplied by the number of passengers (IATA source) and their value of time, produced an estimate of EUR1.42 and EUR2.85 billion, respectively. This has to be considered as a very rough estimate given the uncertainty attached to the intermediate evaluations used and will required further refinements.

II.2.3. Costs for the community

The same difficulties as outlined in the "operated flights versus schedule" concept analysis have been encountered, and therefore, at this stage, no meaningful evaluation could be carried out.

CONCLUSION

General results

These results should be considered as a first evaluation stage. More economical and statistical information in the future should allow us to complete and refine those results and reduce uncertainties. At this stage, only scheduled airline costs and the costs corresponding to the value of time for passengers have been taken into account.

One should note that, regarding airline costs, loss of revenue to other airlines which could not be isolated should be ignored, since we could consider that it would, at least partly, benefit another one and therefore be neutral for the industry considered as a whole. Other specific individual cost items could not be appraised among the induced airline costs.

Table 11 summarises and consolidates the results for both concepts “operated flights versus schedule” and “optimum versus schedule”, according to the previous assumptions of a block-to-block time increase of 5 or 10%.

Total scheduled airlines costs for “operated flights versus schedule” delays could be estimated between EUR1.6 and EUR2.3 billion in 1999. Costs for passengers[8] for scheduled flights appear to be at least of the same order of magnitude that, or higher than, the airline costs we have identified so far.

If we add the costs of non-optimal scheduling, airline costs would rise significantly, with estimation ranging between EUR 3 and EUR5.1 billion.

In other words, taking into account inefficient scheduling could lead to a global cost, which could be as high as 160% up to 250% of the “operated flights versus schedule” delay costs, depending on the different assumptions made.

Overall 1999 delay costs, including passenger costs, could then be comprised between EUR 6.6 and EUR 11.5 billion.

[8] Not including prejudice compensation or cost of automobile parking.

Table 11: ATFM delay costs corresponding to "schedule versus optimum" and to "operated flights versus schedule" in 1999

ATFM DELAY COSTS CORRESDONDING TO "SCHEDULE VERSUS OPTIMUM" AND TO "OPERATED FLIGHTS VERSUS SCHEDULE" IN 1999 (billion EUR)

SENSITIVITY ANALYSIS : Schedule vs Optimum (A) : 5% of total flight time and 10% of total flight time

	Schedule vs Optimum (A) : 5% of total flight time			Schedule vs Optimum (A) : 10% of total flight time		
	Delays million minutes	Basic marginal crew costs	Total crew costs	Delays million minutes	Basic marginal crew costs	Total crew costs
Airlines	**30.6**	1,38 (45,2)		**61.2**	2,76 (45,2)	
Passengers		(a) 1,42 (46,5) / 1,83 (60,0) (b)			2,85 (46,5) / 3,67 (60,0)	
Total		2,80 (91,7) / 3,22 (105,1)			5,61 (91,7) / 6,43 (105,1)	
Airlines	**45.8**	1,63 (35,5)	2,33 (50,9)	**45.8**	1,63 (35,5)	2,33 (50,9)
Passengers		2,13 (46,5) / 2,75 (60,0)			2,13 (46,5) / 2,75 (60,0)	
Total		3,76 (82,0) / 4,37 (95,4)	4,46 (97,4) / 5,08 (110,9)		3,76 (82,0) / 4,37 (95,4)	4,46 (97,4) / 5,08 (110,9)
Airlines	**76.4**	3,01 (39,4)	3,72 (48,6)	**107.0**	4,39 (41,0)	5,10 (47,6)
Passengers		3,56 (46,5) / 4,58 (60,0)			4,98 (46,5) / 6,42 (60,0)	
Total		6,56 (85,9) / 7,59 (99,3)	7,27 (95,1) / 8,30 (108,6)		9,36 (87,5) / 10,81 (101,0)	10,07 (94,1) / 11,51 (107,6)

EMBED

- (a) low value of time, (b) high value of time
- In brackets, the unit cost in EUR/minute.
- The unit costs for passengers are valid only for a given average number of passengers per flight

Airline costs are highly linked to the commercial concern of airlines for their passengers. While **aircraft operating costs** amount to 4 to 6% of the total costs, and **crew costs** represent around 4% for our basic evaluations (but if total crew costs are considered, the share of crew costs would raise to 33%), **passenger related costs**[9] amount between 50 and 70% of total airline costs (see Table 6 and Annex 2).

Therefore, our analysis suggests that, rather than on basic internal operating costs, delays have the most important impact on all passenger-related activities, which reflects the strongly commercial and competitive character of air transport.

Sensitivity analysis

A sensitivity analysis of the various airline cost items was also carried out using a 10% unit cost increase applied to each assessed item on both "operated flights versus schedule" and global ("operated flight versus schedule" plus "schedule versus optimum") delay costs.

The main observations that can be drawn from the sensitivity analysis are as follows.

When we consider basic marginal crew costs (see figure 5), the most significant items are the reduction of hub efficiency with an elasticity of 0.39 (i.e. a 3.9% increase of total airline costs is induced by a 10% increase of the "reduction of hub efficiency" cost item) for "operated flights versus schedule" costs and 0.35 when we add "schedule versus optimum" costs (as referred to as total costs).
This is followed by the "ground equipment" cost item with elasticities of 0.15 and 0.08, "subcontractors" (0.13 and 0.07) and "ground personnel" costs (0.1 and 0.09), respectively. Note that the elasticity of the remaining items is always inferior to 0.1 for "operated flights versus schedule" concept.

When considering total crew costs (see figure 6), the most significant item remains the "reduction of hub efficiency" with an elasticity close to 0.3 in both cases, followed by "scheduled crews" (0.2 and 0.25), "ground equipment" (0.1 and 0.05), and "spare crews" (0.1 and 0.05), respectively.

In both cases, the scheduled aircraft items, which appear only in total costs, have elasticities of at least 0.15.

[9] Passenger related costs include item 7, item 10, items 11 to 16, 18 and 19.

Figure 5: Sensitivity analysis for "marginal crew costs"

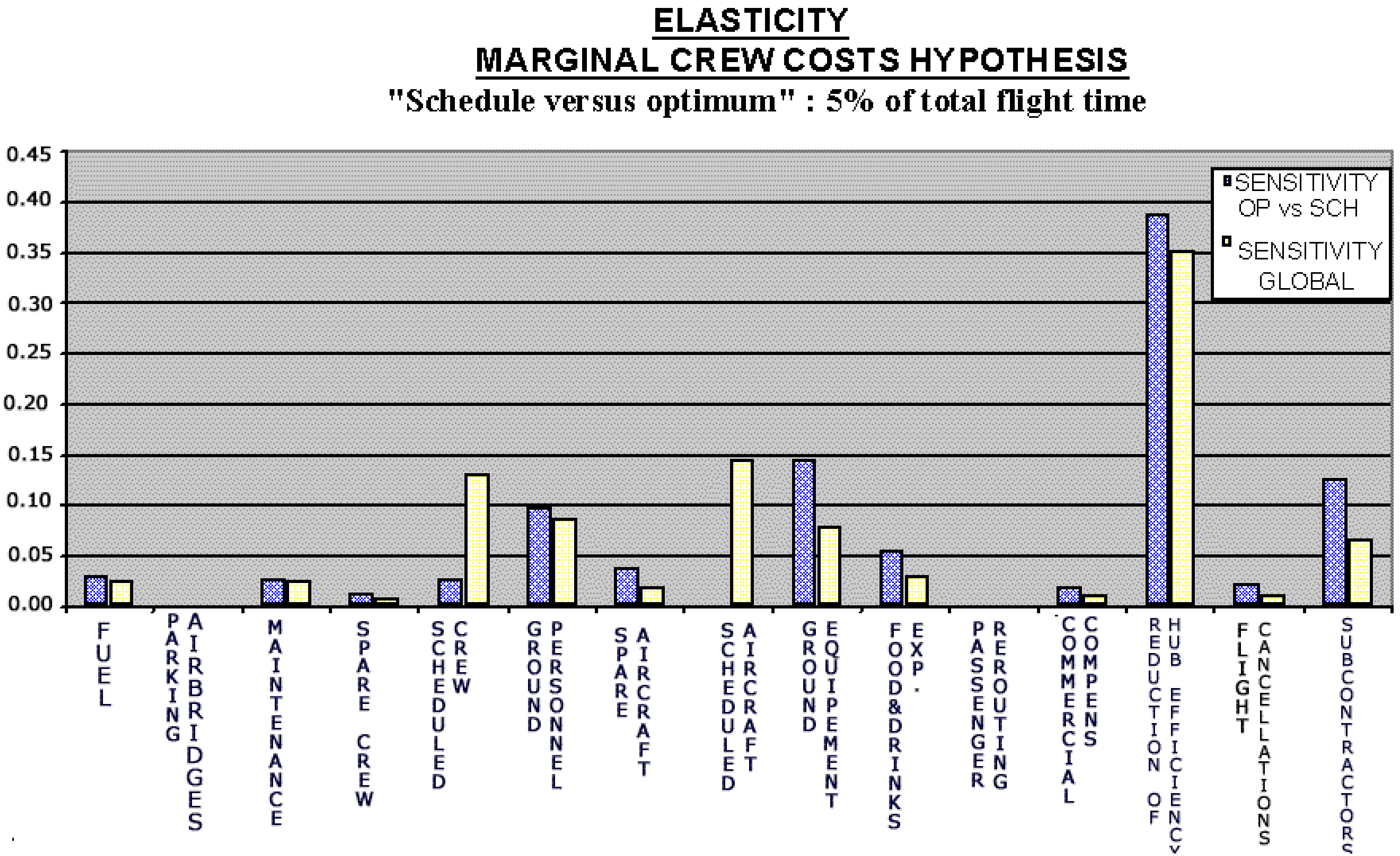
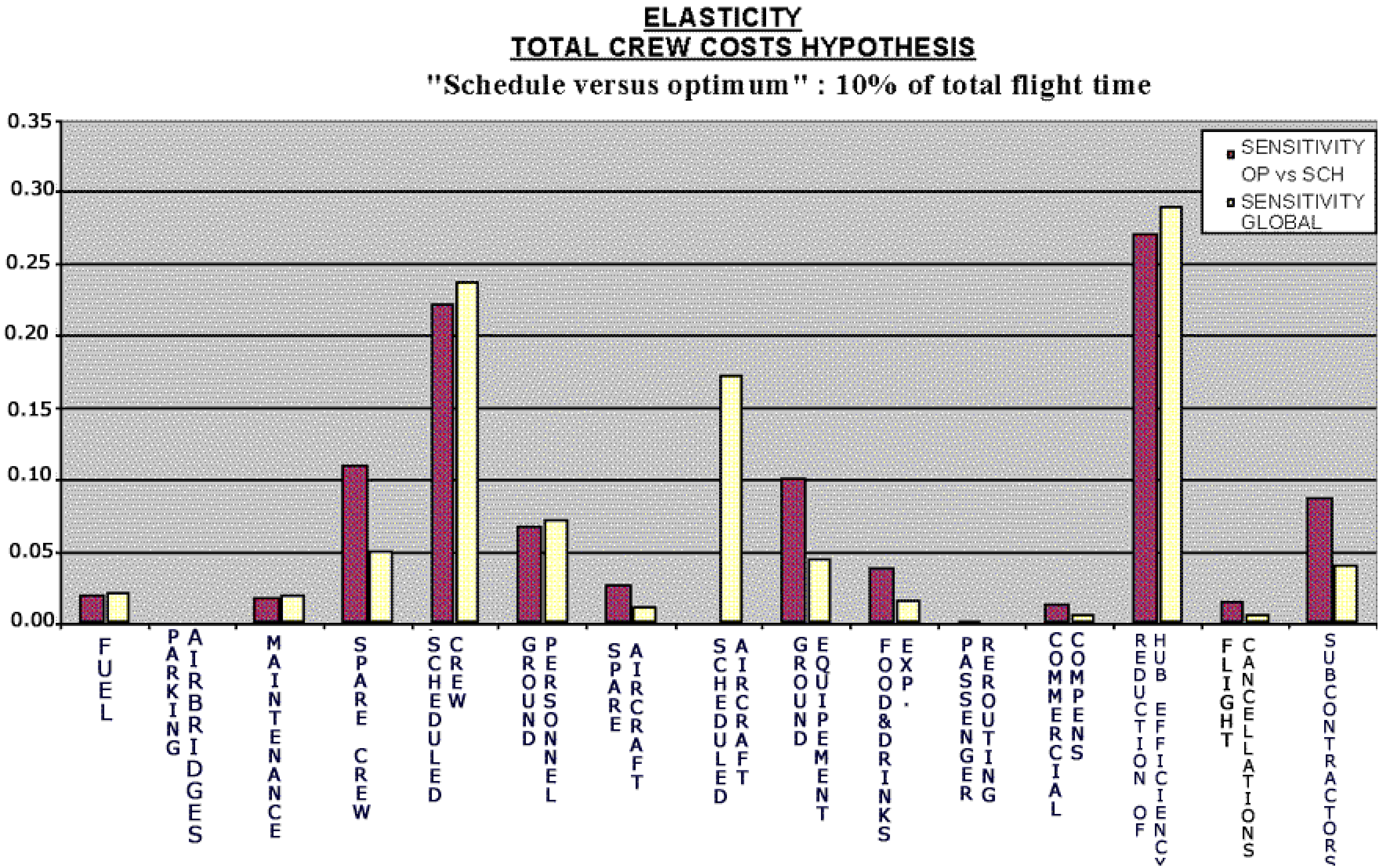


Figure 6: Sensitivity analysis for "total crew costs"



Items with the highest elasticities are the most sensitive, since they would contribute the most to cost reduction if delays would be reduced with an unchanged unit cost.

The overall correlation between unit costs and delays is non-linear, with the exception of flights that have been delayed between 15 to 50 minutes, compared to their schedule time. This highlights the necessity of available relevant delay statistical distribution.

Further investigation

Further investigations on the type of delays and their statistical distribution, on the kind of traffic to be taken into consideration, and on specific airlines policies and costs, appear essential for a more thorough and comprehensive assessment of costs of air transport delay.

Built-in costs, due to delay-sensitive airline schedules planning, will also require further investigation.

At a later stage, a larger panel of European and other airlines operating in Europe should therefore be constituted and possibly organised as a task force devoted to the detailed collection and analysis of missing or incomplete information. This would also help us assess the possible diversity of airline procedures and their impact on unit and global costs. Charter airlines should probably be also included in the panel.

ANNEX 1

Definitions and acronyms

AIR TRANSPORT DELAYS

Delays occurred when the published or planned departure and arrival times for commercial operators are not observed. There are primary delays, reactionary delays, departure or arrival delays, on ground or airborne delays.

AIRCRAFT OPERATING COSTS

Relate to flight and ground costs that are linked to the operation of an aircraft, such as fuel, aircraft parking, air bridges and maintenance costs.

ATFM (EUROCONTROL)

Air Traffic Flow Management measures consist of re-routing aircraft over non congested areas and controlling access to congested areas by the organisation of traffic flows and by the staggering of arrival times into these areas. The access control is performed by imposing appropriate ground delays (take-off slots).

ATFM DELAY (EUROCONTROL)

Duration between the last take-off time requested by the aircraft operator and the take-off slot given by the central flow management unit (CFMU)

ATFM delays do not take into account possible differences between the slot take-off time and the actual departure time caused by airport operations or aircraft operator operations.

ATFM delays do not correspond to the total daily attributable to ATC operations, which include the reactionary delays caused indirectly by ATFM measures.

BLOCK TO BLOCK TIME

Elapsed period from time aircraft starts to move (leaves parking) at beginning of mission to time it comes to rest at conclusion (stops at gate).

CFMU

The Central Flow Management Unit is located at EUROCONTROL Headquarters and is responsible for balancing demand and available airspace capacity, thus helping reduce congestion in European airspace.

COSTS FOR USERS

Include the costs of delays to passengers, to other users (military aviation, general aviation) and to the community as a whole (environment costs occurred by noise and pollutant emissions, additional costs or loss of revenue imposed to airports, travel agents, hotels…).

FPP (FREQUENT FLYER PROGRAM)

Program offering a variety of bonuses to their customers according to their fidelity.

GDS

GDS means Global Distribution System. These are computerised systems available to travel agents containing information about schedules, availability, fares and related services and through which reservations can be made and tickets issued. These systems provide information and booking facilities for all types of travel services (hotels, train, car rental,) on a worldwide basis.

HUB AND CONNECTION ADDITIONAL COSTS

Relate to costs occurred through the loss of hub efficiency, e.g. lengthening of connecting times, missed connections, flight cancellations

INDUCED (LONGER TERM) AIRLINE COSTS

All delay costs not immediately born by airlines but which incur though the disturbances and could lead to a less competitive situation. They include loss of market share to other modes of transport (e.g. high speed train), loss of corporate image, drop of average passenger revenue due to bad on-time performances, development of inefficiency among airline staff or subcontractors…

MCO (MISCELLANEOUS CHARGE ORDER)

A sort of check for future payment of the issuing airline services

OPERATED FLIGHTS VERSUS SCHEDULE

The estimation of the cost impact of air transport delay is based on the comparison between costs due to delayed operations (referred to here as “operated flights”) and costs due to on time operations (referred to here as “schedule”).

OPERATING STAFF COSTS

Correspond to flying personnel costs and to the part of ground personnel costs linked to the passenger and aircraft handling.

PRIMARY DELAYS

Correspond to initial delay caused to a given flight. Several causes have to be considered with the exception of the late arrival of connecting flight, connecting passengers, baggage, load or crewmembers. Primary delays are classified under following causes: passenger and baggage, cargo and mail, aircraft and ramp handling, technical and aircraft equipment, damage to aircraft, flight operations and crewing, weather, airport and governmental authorities.

Reactionary delays
Correspond to delays due to the late arrival of a connecting flight, late arrival of connecting passengers or load, and late arrival of crewmembers, awaited from another flight.

SCHEDULE VERSUS OPTIMUM

Air transport delays encountered in Europe are taken into account by airlines when they establish schedules for the next (e.g. IATA season) operating period. Therefore published schedules generally incorporate a buffer, which is added to the planned flight time in order to accommodate statistically foreseeable delays. This could lead airlines to increase the number of aircraft and crews they need and, consequently, the costs of operations.

These additional costs have been estimated separately from the direct impact of observed air transport delays, as they are not linked with the day-to-day computed delays, but with delays encountered in the past.

The optimum used here is referring neither to the optimum for airlines, nor to the optimum for the community as a whole, but to the ideal operational conditions that airline would have without experiencing delays.

STRUCTURAL COSTS

Include all equipment costs that have to be tailored to the size of operations (fleet, ground equipment)

List of acronyms

ACARS	Aircraft Communication Addressing and Reporting System
AEA	Association of European Airlines
ANCAT	Abatement of Nuisance Caused by Air Transport, a technical committee of the ECAC
APU	Auxiliary Power Unit
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
CAA	Civil Aviation Authority
CFMU	EUROCONTROL Central Flow Management Unit
ECAC	European Civil Aviation Conference
EEA	European Environment Agency
FFP	Frequent Flyer Program
GDS	Global Distribution System
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IPCC	International Panel on Climate Change
ITA	Institute of Air Transport
LTO	Landing and Take-off cycle
MCO	Miscellaneous Charge Order
MTOW	Maximum Take-Off Weight
VFR	Visual Flight Rules
VOC	Volatile Organic Compounds

ANNEX 2

Detailed costs
"Optimum versus schedule"
"Operated flights versus schedule"

SYNTHESIS OF RESULTS (OPERATED FLIGHTS VERSUS SCHEDULE)

BASIC MARGINAL CREW COSTS EVALUATION

ITEMS		UNIT COSTS		TOTAL ATFM COSTS			
		PRIMARY DELAYS	REACTIONARY DELAYS	PRIMARY DELAYS	REACTIONARY DELAYS	TOTAL	*WEIGHT*
Items	COSTS FOR AIRLINES	EUR/minute	EUR/minute	EUR	EUR	EUR	
I	**Aircraft operating costs**	**3.46**		**95 072 847**		**95 072 847**	***5.8%***
1	Fuel	1.75		48 137 921		48 137 921	*3.0%*
2	Aircraft parking	0.06		1 730 745		1 730 745	*0.1%*
3	Air bridges						
4	Maintenance	1.64		45 204 181		45 204 181	*2.8%*
II	**Operating staff costs**	**7.07**	**1.92**	**194 385 572**	**35 190 522**	**229 576 095**	***14.1%***
	Flying personnel						
5	- Spare crews	0.85		23 228 540		23 228 540	*1.4%*
6	- Scheduled crews	1.71		46 942 953		46 942 953	*2.9%*
7	Ground personnel	4.52	1.92	124 214 080	35 190 522	159 404 603	*9.8%*
III	**Structural costs**	**7.77**	**4.73**	**213 545 174**	**86 658 309**	**300 203 483**	***18.5%***
	Fleet size						
8	- Spare aircraft	2.28		62 636 771		62 636 771	*3.9%*
9	- Scheduled aircraft						
10	Ground equipments	5.49	4.73	150 908 403	86 658 309	237 566 712	*14.6%*
IV	**Passenger driven costs**	**2.71**	**2.71**	**74 399 966**	**49 596 300**	**123 996 266**	***7.6%***
11	Food and drinks expenditures	1.95	1.95	53 602 171	35 731 235	89 333 405	*5.5%*
12	Miscellaneous expenditures						
13	Passenger rerouting	0.07	0.07	1 980 681	1 320 323	3 301 003	*0.2%*
14	Loss of revenue (cancellations by passengers)						
15	Commercial compensations	0.68	0.68	18 817 114	12 544 743	31 361 857	*1.9%*
V	**Hub & connection additional costs**	**14.63**	**14.63**	**402 128 731**	**268 085 821**	**670 214 551**	***41.2%***
16	Reduction of hub efficiency	13.82	13.82	379 879 712	253 253 142	633 132 854	*39.0%*
17	Flight cancellations	0.81	0.81	22 249 019	14 832 679	37 081 698	*2.3%*
VI	**Induced long term airline costs**	**4.50**	**4.50**	**123 792 542**	**82 520 172**	**206 312 714**	***12.7%***
18	Loss of market share to other modes	0.00	0.00	0	0	0	*0.0%*
19	Loss of corporate image	4.50	4.50	123 792 542	82 520 172	206 312 714	*12.7%*
20	Subcontractors						
21	Average passenger revenue						
22	Social consequences						
	TOTAL	**40.14**	**28.49**	**1 103 324 831**	**522 051 125**	**1 625 375 956**	***100.0%***
	COSTS FOR USERS	EUR/h	EUR/h	EUR	EUR	EUR	
VII	**Passengers**						
23	Value of time : - low	**34**	**34**	1 278 085 293	852 056 862	2 130 142 155	
	- high	**44**	**44**	1 648 358 308	1 098 905 539	2 747 263 846	

SYNTHESIS OF RESULTS (OPERATED FLIGHTS VERSUS SCHEDULE)

TOTAL CREW COSTS EVALUATION

ITEMS		UNIT COSTS		TOTAL ATFM COSTS			
		PRIMARY DELAYS	REACTIONARY DELAYS	PRIMARY DELAYS	REACTIONARY DELAYS	TOTAL	*WEIGHT*
Items	**COSTS FOR AIRLINES**	EUR/minute	EUR/minute	EUR	EUR	EUR	
I	**Aircraft operating costs**	**3.46**		**95 072 847**		**95 072 847**	***4.1%***
1	Fuel	1.75		48 137 921		48 137 921	*2.1%*
2	Aircraft parking	0.06		1 730 745		1 730 745	*0.1%*
3	Air bridges						
4	Maintenance	1.64		45 204 181		45 204 181	*1.9%*
II	**Operating staff costs**	**32.82**	**1.92**	**902 159 903**	**35 190 522**	**937 350 425**	***40.2%***
	Flying personnel						
5	- Spare crews	9.37		257 519 754		257 519 754	*11.0%*
6	- Scheduled crews	18.93		520 426 069		520 426 069	*22.3%*
7	Ground personnel	4.52	1.92	124 214 080	35 190 522	159 404 603	*6.8%*
III	**Structural costs**	**7.77**	**4.73**	**213 545 174**	**86 658 309**	**300 203 483**	***12.9%***
	Fleet size						
8	- Spare aircraft	2.28		62 636 771		62 636 771	*2.7%*
9	- Scheduled aircraft						
10	Ground equipments	5.49	4.73	150 908 403	86 658 309	237 566 712	*10.2%*
IV	**Passenger driven costs**	**2.71**	**2.71**	**74 399 966**	**49 596 300**	**123 996 266**	***5.3%***
11	Food and drinks expenditures	1.95	1.95	53 602 171	35 731 235	89 333 405	*3.8%*
12	Miscellaneous expenditures						
13	Passenger rerouting	0.07	0.07	1 980 681	1 320 323	3 301 003	*0.1%*
14	Loss of revenue (cancellations by passengers)						
15	Commercial compensations	0.68	0.68	18 817 114	12 544 743	31 361 857	*1.3%*
V	**Hub & connection additional costs**	**14.63**	**14.63**	**402 128 731**	**268 085 821**	**670 214 551**	***28.7%***
16	Reduction of hub efficiency	13.82	13.82	379 879 712	253 253 142	633 132 854	*27.1%*
17	Flight cancellations	0.81	0.81	22 249 019	14 832 679	37 081 698	*1.6%*
VI	**Induced long term airline costs**	**4.50**	**4.50**	**123 792 542**	**82 520 172**	**206 312 714**	***8.8%***
18	Loss of market share to other modes	0.00	0.00	0	0	0	*0.0%*
19	Loss of corporate image						
20	Subcontractors	4.50	4.50	123 792 542	82 520 172	206 312 714	*8.8%*
21	Average passenger revenue						
22	Social consequences						
	TOTAL	**65.89**	**28.49**	**1 811 099 162**	**522 051 125**	**2 333 150 286**	***100.0%***
	COSTS FOR USERS	EUR/h	EUR/h	EUR	EUR	EUR	
VII	**Passengers**						
23	Value of time : - low	**34**	**34**	1 278 085 293	852 056 862	2 130 142 155	
	- high	**44**	**44**	1 648 358 308	1 098 905 539	2 747 263 846	

UNIT COSTS CORRESPONDING TO THE DIFFERENCE BETWEEN SCHEDULED AND OPTIMUM TIME IN 1999 (EUR)

		Hyp : 5% of total flight time		Hyp : 10% of total flight time	
ITEMS		**UNIT COSTS** (EUR/mn)	**TOTAL COSTS** (EUR)	**UNIT COSTS** (EUR/mn)	**TOTAL COSTS** (EUR)
Items	**COSTS FOR AIRLINES**				
I	**Aircraft operating costs**	**2.1**	**63 496 322**	**2.1**	**126 992 643**
1	Fuel	1.1	32 149 883	1.1	64 299 766
2	Aircraft parking	0.04	1 155 913		
3	Air bridges				
4	Maintenance	1.0	30 190 526	1.0	60 381 051
II	**Operating staff costs**	**14.8**	**454 038 649**	**14.8**	**908 077 298**
	Flying personnel				
5	- Spare crews				
6	- Scheduled crews	11.4	347 577 065	11.4	695 154 129
7	Ground personnel	3.5	106 461 584	3.5	212 923 169
III	**Structural costs**	**14.4**	**441 514 273**	**14.4**	**883 028 546**
	Fleet size				
8	- Spare aircraft				
9	- Scheduled aircraft	14.4	441 514 273	14.4	883 028 546
10	Ground equipments				
IV	**Passenger driven costs**	**0.0**	**0**	**0.0**	**0**
11	Food and drinks expenditures				
12	Miscellaneous expenditures				
13	Passenger rerouting				
14	Loss of revenue (cancellations by passengers)				
15	Commercial compensations				
V	**Hub & connection additional costs**	**13.8**	**422 850 568**	**13.8**	**845 701 136**
16	Reduction of hub efficiency	13.8	422 850 568	13.8	845 701 136
17	Flight cancellations				
VI	**Induced long term airline costs**	**0.0**	**0**	**0.0**	**0**
18	Loss of market share to other Modes				
19	Loss of corporate image				
20	Subcontractors				
21	Average passenger revenue				
22	Social consequences				
	TOTAL	**45.2**	**1 381 899 812**	**45.2**	**2 763 799 624**

	COSTS FOR USERS	EUR/h	EUR	EUR/h	EUR
VII	**Passengers**				
23	Value of time : - low	**0.57**	**1 422 668 038**	**0.57**	**2 845 336 076**
	- high	**0.74**	**1 834 827 998**	**0.74**	**3 669 655 996**

ANNEX 3

Definitions of
IATA & ICAO cost items

AVAILABLE ECONOMIC INFORMATION

In this stage, we have focused on airlines and passenger delays. These delays generate costs that have been identified and classified in different categories. The costs for airlines include aircraft operating costs, operating staff costs, structural costs, passenger driven costs and induced airline costs.

IATA

Airlines suffering from ATM-related delays are European as well as non-European airlines. The unit operating costs computed within IATA is relevant to the study, as they include data from non-European airlines and from European airlines on European routes. However, one must note that IATA data are not public, so it makes their use less practical. The way this information will have to be computed must be agreed beforehand with IATA representatives.

The reporting requirements of IATA database aim at collecting information, based on common definitions of revenues and charges.
In fact, direct operating costs include the following main cost items:

- flight deck crew (but not cabin crew),
- fuel and oil,
- flight equipment insurance,
- maintenance and overhaul,
- flight equipment depreciation and rental expenses,
- aircraft related charges.

Other items like air navigation charges are not relevant to the present study, as they are not directly linked to the length of flight time or turnaround time. In Europe, they are nevertheless distance-related, but more information will be needed regarding route lengthening.

The typology used is not as detailed as needed. It does not correspond to all individual costs incurring through ATM-related delays, as they have been identified in the analysis of the delay impact.

Flight deck crew information could be used, but does not provide information on the additional costs incurred through the lengthening of the working period of flight crews for delay reasons. Those marginal costs should be higher than the average, as allowances given for overtime hours are usually costly for airlines. The cost for spare crews cannot be identified within IATA data bases, having been added to the costs for crews in the course of their normal activity.

The same problem arises when considering flight equipment depreciation expenses.

The aircraft related charges include the charges paid for the parking of aircraft, but also include the fees paid for the use of runways, taxiways and ramp areas, lighting, etc. Parking of aircraft charges are therefore not known.

Fuel and oil average expenses per flying hour do not inform about corresponding expenses specific to cruise and taxi phases.

Most problems arise for the evaluation of indirect operating expenses, like passenger service charges. Contrary to ICAO (see §2.1.2 below), IATA typology allows for the independent identification of station and ground expenses, cabin attendants expenses and passenger service charges.

As far as cabin attendants are concerned, the problem of evaluating the cost for spare crews and additional hours is identical to the one identified with regards to flight deck crew expenses.

Station and ground expenses include different items like remuneration of all station staff, and the maintenance of airport facilities. From this item, one will not be able to identify the cost of additional equipment needed to transfer delayed passengers and luggage.
Passenger service expenses include cost of personnel and supplies, extra costs for passengers incurred because of cancelled and delayed flights, the costs of other services provided for passengers, the cost of flight kitchens, and overheads directly related to passenger service.

From this item, it would be therefore difficult to evaluate the cost of increasing the number of ground personnel staff needed to cope with problems caused by the late arrival of the aircraft to the connecting passengers and connecting luggage. The costs for re-routing passengers and for commercial compensations given to the delayed passengers are also included in this item. But all these specific costs cannot be known individually.

ICAO

Data collected through ICAO could also be useful, as they include information for scheduled and non-scheduled airlines. Out of the available information, a group of airlines could be selected to estimate the average operating unit costs of airlines operating in Europe, but this might be difficult, as time series concerning one or several main airlines could be incomplete.

The definitions used by ICAO differ from the ones used by IATA and some discrepancies between the two sources exist.

The definitions adopted for the direct operating expenses seem to be quite similar to the ones used by IATA. On the other hand, passenger service costs are more widely defined in the ICAO version than in the IATA one. Passenger service costs include cabin attendants and passenger service personnel remuneration. They also include:

- premiums for passenger liability insurance,
- passenger accident insurance,
- meals and accommodation,
- expenses of handling passengers incurred because of interrupted flights…

This item is therefore not relevant to the estimation of neither the cabin attendants costs, nor the passenger driven costs.

This analysis leads to the conclusion that IATA and ICAO cost data bases would not be totally appropriate for estimating the delay costs for airlines, when considering aircraft operating costs (fuel, aircraft parking, maintenance), operating staff costs (flying and ground personnel), structural costs (fleet and ground equipment costs) and passenger driven costs (meals and accommodation, re-routing, commercial compensations, loss of revenue). Furthermore, they would not be sufficient for assessing the induced airline costs that include the loss of market share and loss of corporate image due to delays.

Individual airline expertise and data will therefore be necessary. It is known that the main European airlines are very conscious of the needed quality of services. They frequently conduct internal audit to appraise the impact of delays on the operating costs as well as on the passenger level of satisfaction. Information would therefore be available directly from them.

Such data being often considered as confidential or sensitive, one would aggregate the data in order to cope with confidentiality constraints. Furthermore, a sample of participating airlines should be built in order to take into account the various strategies adopted by either European or non-European carriers. Scheduled carriers are more punctuality focused than non-scheduled carriers, hubbing airlines more than other airlines. Policy towards passenger re-routing, and passenger compensations for example, vary from one airline to another. As a consequence, the amount of expenses incurred to solve problems due to delay will vary accordingly. Those data will be used to estimate unit costs per minute of delay or per delayed passenger, depending on the delay duration.

ANNEX 4

Value of time for passengers

Value of time estimated in different studies

Source	Value of Time (1999) *	Source	Value of Time (1999) *
Orlyval (1)	57 EUR/h (business) 37 EUR/h (tourism)	**Manchester (5)**	78 EUR/h (long haul business passengers) 30 EUR/h (short haul optional passengers)
F.Heinitz (2)	22 EUR/h (business) 13 EUR/h (leisure)	**ITA (6)**	54 EUR/h
Montpellier (3)	model 1: 66 EUR/h model 2: between 49 EUR/h and 16 EUR/h	**US study (7)**	between 38 EUR/h and 260 EUR/h
Chicago/Dallas (4)	38 EUR/h (business) 10 EUR/h (leisure)	**Chile (8)**	40 EUR/h

* These values of time are extrapolated to 1999 taking into account the evolution of labour cost.
(1) Orlyval : INRETS study for Orlyval in 1986/1987.
(2) F. Heinitz : "Methodological Developments within the Quasi-Direct Format Demand Structure : the Multicountry Application for Passengers" F. Heinitz BETA n°9815 september1998.
(3) Montpellier : « Valeur du temps de transport : l'apport de la modélisation micro-économétrique du choix modal » (1997) Thierry Blayac et Anne Causse, Université de Montpellier/SES/DEE/METL - Actes du colloque déplacements à longue distance. Février 1998

(4) Chicago/Dallas : "The choice of air carrier, flight, and fare class" - K. Proussaloglou, F.S. Koppelman - Journal of Air Transport Management (October 1999).
(5) Manchester : Air traffic predictions for Manchester International Airport Authority - "Stated preference methods" by E.P. Kroes and R.J. Sheldon - Journal of Transport economics and policy (January 1988).
(6) ITA : Econometric model built by ITA to estimate the modal split between HST and air transport (1993).
(7) Chile : "Modelling route and multi-modal choices with revealed and stated preference data" - Juan de Dios Ortuzar - Transportation planning methods (september1996).
(8) U.S. Study: "Impact of Air Traffic Management on Airspace User Economic Performance" J.H Sinncott and W.K. Mac Reynolds, in 2nd USA/Europe Air Traffic Management R&D Seminar, Orlando, December 1998.

ANNEX 5

Environmental costs

Environment could be affected by delays in two ways: aircraft emissions and noise.

WHICH TYPE OF DELAY?

Air transport needs fuel, which, burning into the atmosphere, produces emissions of pollutant substances. Through lengthening flight and taxiing times, delays have an effect on the volume of emissions into the atmosphere.

METHODOLOGY

International requirements for emission inventories have been set up through several international agreements adopted during the last 20 years. Parties to the conventions are required to submit annual emissions of CO_2, NO_x, CO, SO_x, and VOC (Volatile Organic Compounds). Several institutions are involved in the development of the methodology of such a collection of information as far as air transport is concerned: the European Commission, the EEA (European Environment Agency), the ECAC (through the ANCAT working group). Research institutes are also associated to this work.

One of the existing methodologies proposed by the EEA[10], in order to assess the overall emissions by the air transport industry is based on individual emission standards for each engine or aircraft type involved in domestic or international air traffic. Three different approaches have been set up, as they may be significant differences in available data within different countries. In a very simple approach, estimations will be made without consideration of the various types of aircraft involved.

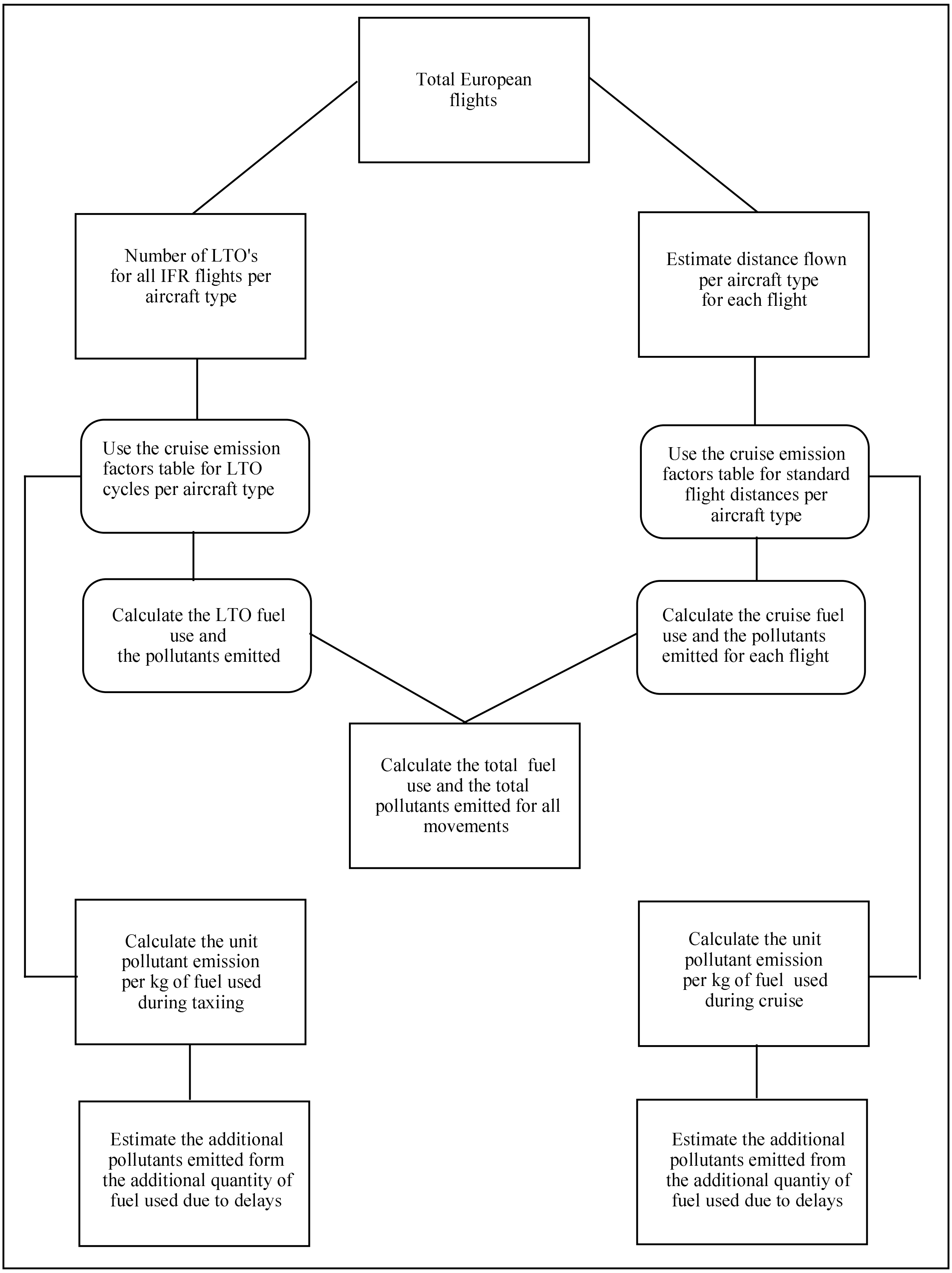
A more detailed approach would be possible, as information could be gathered on the aircraft types used for both domestic and international aviation, and on the number of LTOs[11] carried out with the various aircraft types. Information regarding commercial flights and non-commercial flights could be found in CFMU data base. The Official Airline Guide (OAG) data base would offer only a limited scope, because non-scheduled flights and non-commercial flights are not included in such data bases.

The process for assessing emission costs is outlined in the following figure.

[10] Source: Atmosphere emission inventory guidebook – September 1999

[11] LTO is a landing and take-off cycle which includes all activities near the airport that take place under the altitude of 1000 m and therefore includes taxi-in and out, climbing and descending. Cruise is defined as all activities that take place at altitudes above 1000m.

Estimations of aircraft emissions



source: Atmospheric emission inventory guidebook - September, 1999 – EEA

Individual aircraft emissions could be estimated from the tables derived from ICAO Exhaust emission databank and presented in the EEA methodology. Average cruise distances may be derived from airline schedules, but would not reflect the actual distances flown. Estimates of additional emissions due to delayed flights within the ECAC area would be possible, based on induced additional fuel consumption. This would require the availability of information concerning taxiing and airborne delay duration.

Many environmental cost estimates have been carried out. Their main results, with regard to the method of evaluation and the cost assessed in Euro per ton of pollutant are featured in "Pricing aircraft emissions at Lyon-Satolas airport", a 1997 study by A. Perl, J.Patterson and M. Perez.

Several methods are identified: the first one seeks to calculate the direct evaluation of damage, the second one aims at revealing public preference through opinion research (the "willingness to pay" method) and the last is based on a calculation of the prices that would be needed to avoid specific thresholds of air pollution. In addition, a proposal is made to identify urban and rural pollution costs separately.

The authors of Lyon-Satolas' study suggest mixing two approaches and assessing two range of prices for urban and rural zones: one based on minimal damage costs and the other on potential avoidance costs, thus offering a spectrum of estimates to the policymakers who will have to base their decisions upon.

The following table present the pollution prices in four different scenarios. These prices might be used to estimate the upper and lower bounds of the costs induced by air transport delays, i.e. in multiplying them by the additional amount of pollutant emissions, due to delays, as calculated from the EEA emission table.

Cost (Euro/tonne)	Rural/minimal	Urban/minimal	Rural/potential	Urban/potential
NO_x	1300	2782	2814	6018
HC	837	3251	1206	4682
SO_2	516	3672	1450	10326
CO	159	159	180	180
CO_2	32	32	38	38

Generally speaking, the present contribution of air transport to total global anthropogenic CO_2 emission is considered to be about 2% by the International Panel on Climate Change (IPCC – 1999). This relatively small contribution is due to the fact that most aircraft emissions are injected almost directly into the upper free troposphere and lower stratosphere. IPCC has estimated that the contribution to radiative forcing[12] is about 3.5%.

[12] radiative forcing is an index of the magnitude of a mechanism that can impact on climate. Positive values reflect a warming up of the climate, negative values reflect a cooling of the climate.

Noise is another source of emission that causes annoyance, mainly to the population living under the approach and departure paths of airports. New generation aircraft have become quieter. Improved take-off performance of today engines means that aircraft climb much more quickly after take-off. Therefore significantly fewer people under the departure flight path are being disturbed. On approach, the disturbance created by aircraft is mainly due to the airframe noise, rather than to engines.

However, studies have been carried out to estimate noise social costs at airports and to check whether the existing noise charges cover social costs totally or only partially. According to the C. Lu and P.Morrell study[13], at Amsterdam airport, the average noise social cost per landing is Euro 623, which is 3.6 times more than the current average noise charge at Amsterdam Airport Schiphol. This estimate is based on several variables, namely the Effective Perceived Noise level (EPNdB) for take-off, sideline and approach for different types of aircraft (as the dynamic noise related data for a specific flight is impossible to obtain) and the average social cost pricing method. This evaluation is based on the noise nuisance imposed on the residents, measured in monetary terms. The noise nuisance cost is itself derived from the annual average house rent in the vicinity of airports, the noise depreciation index (NDI- percentage reduction of house price per dB(A) and the number of residences within the zone considered.

With regard to monetary consequences of delays, it seems that the only significant noise impact of delays would occur during stacks before landing. But, since aircraft are still flying at a high altitude, since EPNdB measures during this flight stage have not been taken, the evaluation of this item would not be worthy of detailed study. Moreover, information on stacks is not readily available.

[13] The evaluation and implication of environmental charges on commercial flights" C. Lu and P. Morrell- Air Transport Group – Cranfield University