EVALUATING THE BENEFIT OF AIRCRAFT OPERATORS BY MARGINAL REDUCTION OF GROUND OR AIRBORNE DELAYS

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Abstract

Delayed or missed connecting flights are experiences shared by anyone who has ever travelled. The impacts of air traffic delay lead to a significant financial burden on both the economical and environmental aspects of airlines. Numerous sources estimate that delay costs reach up to several billion dollars each year. These additional costs vary according to the business model, the phase of flight where the delay occurs (e.g. airborne or ground delay) or the fleet, in particular. This paper intends to point out the potential benefit for airlines that arises if ground or airborne delays could be reduced.

Nomenclature

APU	Auxiliary Power Unit
ASMGCS	Advanced Surface Movement Guidance and Control System
ATM	Air Traffic Management
CDM	Collaborative Decision Making
DOC	Direct Operating Costs
DOT	Department of Transportation
FRA	Frankfurt International Airport
IOC	Indirect Operating Costs
LCC	Low Cost Carrier
MTOM	Maximum Take-Off Mass
SES	Single European Sky

1 Fundamentals

At first a brief overview about the recent delay situation in Europe and especially in Germany is given. Therefore the main subjects that contribute to delays for air travel are discussed. In chapter 2 the impacts of delay are identified. At this point the focus is laid on the airlines perception and the (mainly) financial consequences for airlines when operations in a time-dependent system are delayed.

In chapter 3 a brief overview about two different business models (Low Cost Carrier (LCC) and traditional network carriers) are given. Choosing significant operating costs comprehensive scenario analyses (further explanations see chapter 4) are designed to evaluate the amount of additional costs to airlines in case of ground or airborne delay.

Finally, in chapter 5 benefits for airlines arising by reducing delays are calculated and an interval of potentially achievable cost reductions will be given.

2 Delay Situation in Europe

In 2007 about 22 % of all commercial flights in Europe could be described as delayed which equals an annual 0.4 percentage change. The US Department of Transportation (DOT) defines a flight as «delayed» if it departs more than 15 minutes after its scheduled departure time. This 15-minute window is also used to define arriving flights as delayed. If a flight is cancelled it has no effect on an airline's delay rate [15].

The following Figure 1 gives an overview of the development of the punctuality rate in Europe from 2004 to 2007.

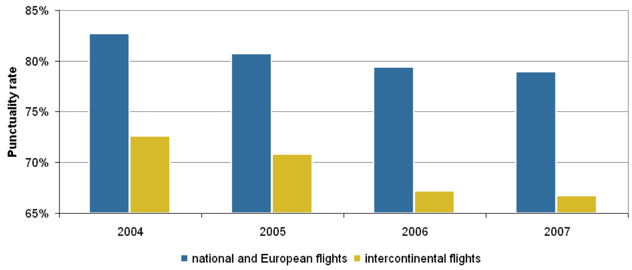

Fig. 1 Development of punctuality rate in Europe from 2004 to 2007
Source: [17]

Decreasing punctuality figures of both national / inner-European as well as intercontinental flights might be the consequence of steady growth in international air transport. As airspace and infrastructure on the ground (runways, aprons, taxiways, gates and terminals) are limited, there seems to be no chance to cope with that growth without significant initiatives such as the Single European Sky (SES) concept. It aims to reduce airspace fragmentation and thus to overcome current capacity issues as well as to improve air transportation's overall sustainability.

In the time period looked at in Figure 1, intercontinental flights reached lower punctuality than national and inner-European flights. This may be explained by the reliance on hub-and-spoke configurations at newtork carriers' hubs. Disturbances in one flight leg may generate significant effects on other flights in airlines' schedules. The interconnectivity between passengers, aircraft and crews explains the «phenomenon» that the arrival delay of one feeder aircraft at leading international hub airports such as Frankfurt/Main or London Heathrow may propagate through the whole network [1].

Related to selected leading German airports (measured in terms of numbers of passengers) the following data arises [6]:
Aircrafts bound for Frankfurt/Main are delayed on average approximately 3.4 minutes. In comparison, flights in Munich (1.5 minutes) and Dusseldorf (0.5 minutes) are less deeply affected by arrival delays. The essential reason for these differences corresponds with the high degree of ground and aerodrome capacity utilization at Frankfurt/Main. To meet growing demand, the airport is expanding its capacities. Apart from lacking infrastructure on both ground and air, delays in international air traffic arise for a large number of reasons. Finally an optimal interaction between ATM-Stakeholders (airlines, airports, air traffic control as well as ground services) is the necessary base to reach an acceptable punctuality level.

The impacts of delays shall be mentioned briefly for the areas of airlines, passengers and third parties in the following. Airlines are primarily affected by additional costs which are the focus of consideration in the following chapter 4.
Notwithstanding the purpose of a journey (business or holiday trip) delays are an inconvenience to the majority of passengers. Increasing inconvenience among customers can be decisive for declining image values of airlines and may have negative effects on their market share. Furthermore, opportunity costs arise even for passengers in case of delays. Since the loss of use, e.g. by a missed business meeting, differ from the loss of use by late start into holidays, opportunity costs need to be monetarily judged differently depending on the purpose of journey.

Independently of this, efficiency decreases with every delay minute since ressources are not used optimally.

On the other hand, ground delays may have a positive effect on the non-aviation business of airports since passengers are encouraged to consume additional goods [9].

3 Brief overview about different business models

The scenarios defined are shown in Figure 2. They represent the already mentioned different business models between LCC (e.g. Southwest Airlines or Ryanair) and traditional airlines e.g. Lufthansa or others (see Standard-Cost). For each scenario representative aircraft types (Boeing B737-500 as a typical short-/medium haul aircraft and Boeing B747-400 for long haul flights) are chosen to establish a reliable basis. This differentiation allows the description and comparison of potential differences in additional costs considering the different business models.

According to Figure 2, calculations in the low cost scenario are only made for short and medium haul flights because long-haul routes are not offered by LCC [18]. Within the mentioned concept the specific financial impact of delays in different flight phases (ground/airborne) on the cost items are taken into account in order to provide reliable and realistic values.

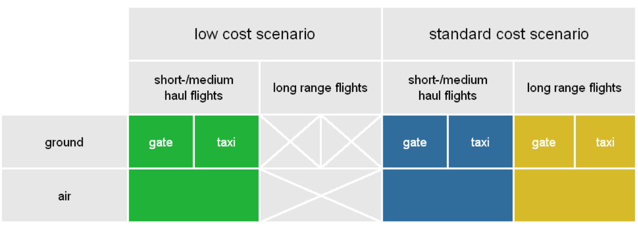

Fig. 2 Methodology

Data provided by numerous research institutes (e.g. US DOT) are used to calculate the additional airline expenses. Further information about, e.g. the true costs for cabin or flight crew or fuel burn, can be gathered from the Performance Review Report (PRR) or the Transport Studies Group, University of Westminster [3, 7]. Additional costs on airlines' customers in form of lost productivity, costs to passengers, environment or economy are no matter to be addressed in this paper.

4 Calculation

There are different methods for assigning airline costs caused by delays. For this paper a method was developed that implies the following important variable direct operating cost (DOC) elements:

- Fuel Costs
- Maintenance Costs
- Flight and Cabin Crew Allowances
- Route Charges
- Airport Charges

Indirect operating costs (IOC) such as marketing expenses or expenses for in-flight catering are not discussed in this paper as their amount is not influenced by changes in (un-)punctuality figures.

4.1 Fuel Costs

Airlines' fuel costs mainly depend on fuel consumption and fuel prices on the market. Since aviation fuel (Jet A-1) is closely linked to oil prices, the impact of climbing oil prices in past years needs to be considered when calculating fuel costs. Between 2001 and 2008 oil price rose more than 330 % and reached a peak of more than $ 120 per barrel in 2008. In order to keep the values up to date the following calculation is based on an average oil price of $ 60 per barrel in the year 2009 as can be seen in the following Figure 3.

Fuel burn data provided by [3] offers a reliable basis to determine different fuel consumption according to the different flight phases

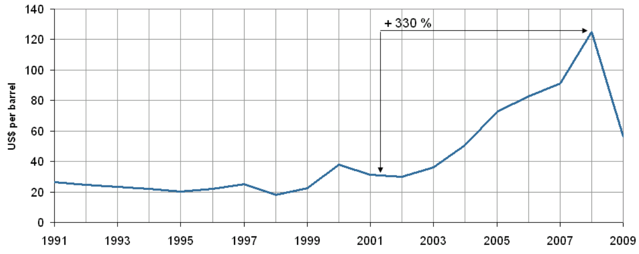

Fig. 3 Long term perspective of fuel price development
Source: [11]

(APU, stationary ground, taxi, en-route and approach) and different aircraft equipment used (B737 and B747). Fuel costs per minute for both aircrafts looked at are given by the following Figure 4.

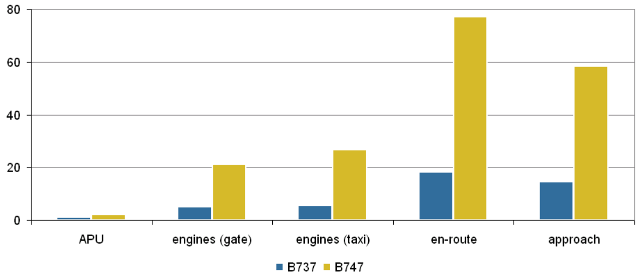

Fig. 4 Fuel costs per minute

Since LCC as well as traditional airlines are equally affected by rising oil prices there is no further distinction needed between the different business models. LCC may profit by lower fuel costs at secondary airports [22], on the contrary traditional airlines may benefit from cost-savings achieved by synergies established in alliances and fuel hedging practices [10, 14].

4.2 Flight and Cabin Crew Allowances

Marginal crew cost contribution to airlines allowances is another factor that needs to be examined. Payment mechanisms depend on a wide range on parameters beginning with the base country, economical development, social security contributions or type of operation [12, 22].

Most important cost drivers are the different payment mechanisms [20], size of aircrafts flown and legal restrictions concerning number and composition of cabin crew and labor time [5, 8].

Calculating the marginal crew costs for LCC it is assumed in this paper that a high percentage of total wages are paid by sectors flown or «sector pay» in order to increase productivity [20]. In consequence delays do not have any financial effects on crew wages and will not be considered subsequently.

The following considerations are taken as a basis for the standard cost scenario:
As introduced, crew wages depend on the amount of seats available in an aircraft which is correlated with the size of the equipment used. For B747 a total number of 347 seats in a three-class configuration represents the basis for calculation[1]. In order to provide a higher service level in business and first class, more crew members than legally required are used. The number of seats as well as the number of crew members (including one senior flight attendant for medium haul flights and two senior flight attendants for long haul flights) corresponds with most both European and US network carrier seatings and therefore offer a valid basis for the following examinations.

Apart from the size of crew per aircraft, wages for both cabin crew and flight crew members are another point of interest. According

[1]This number complies with the average number of seats of airlines looked at (e.g. Lufthansa, United Airlines et al)

to own examinations salaries increase by the size of the equipment used. Therefore higher marginal flight crew costs are taken into account for a B747 than for a B737. For both aircraft types a flight crew of one pilot in command and one first officer is assumed. In order to provide reliable results, values used in this part were both derived by detailed examination done by [20] and own examinations of payment mechanisms of German airlines.

Finally total marginal crew costs (flight crew and cabin crew) of approx. $ 10 per minute for B737 and approx. $ 20 per minute for B747 for ground and airborne delays. Reasons for this deviation can be seen in the already mentioned different crew size as well as seniority-based payments.

4.3 Aircraft Maintenance

Maintenance costs basically depend on the following cost components:

- Labor
- Materials
- Third Party
- Burden

[21] analyzed that total direct costs reach up to 60-70 % of maintenance costs. Consequently 30-40 % can be allocated to the burden costs. Representing the fixed costs, these cost elements do not vary respective to the delay level. In order to determine airlines' marginal delay costs, fixed costs can be excluded from the following calculation method. It offers an approach that basically depends on these parameters:

- Block Hours per year
- Total Maintenance Costs per year

At first glance it is organized into block hours per year. In-depth analyses were arranged to obtain reliable information about the fleet and the aircraft mix. It is assumed that every aircraft is available 365 days a year. Aircraft groundings due to economic crises or aircraft losses as a result of accidents are not taken into account.

Gathering and analyzing further airline specific information, «operating minutes per year» can be calculated based on the determinations given before. Operating minutes imply total flight, taxi and gate minutes of an aircraft during one year. According to the following Figure 5 it can be assessed that wide bodies are airborne about 13.4 hours/day. Relating to a whole year the percentage is about 56 % of total operating minutes. Remaining 44 % can be allocated to gate (29 %) and taxi (15 %)[2].

	temporary weighting factors	minutes in respective flight phase per year
gate	0,29	17.833.608
taxi	0,15	9.224.280
en-route	0,56	34.437.312
	1,00	61.495.200

Fig. 5 Overview of operating minutes per year in different flight phases

In the next step, specific «load minutes »are calculated. They offer an overview about how the most important aircraft components (airframe and engines) are exposed on the ground and in the air. Due to difficult mechanical loads in the particular flight phases, weighting factors are set to underline the difference in additional delay costs when a delay occurs on the ground or in the air. Weighting factors for each flight phase can be seen in the following Figure 6.

According to this figure aircraft engines are exposed only during taxi and in-flight. Numbers «1» and «0.5» represent the degree of exposure, e.g. full technical load is represented by «1» while standing at the gate is assumed to have no

[2] Exact data may vary depending on specific airline procedures, airport layouts or aircraft operations.

	minutes in respective flight phase per year	airframe		engines
		interior exposure	mechanical exposure	
gate	17.833.608	1,0	0,0	0,0
taxi	9.224.280	1,0	0,0	0,5
en-route	34.437.312	1,0	1,0	1,0
	61.495.200	61.495.200	34.437.312	39.049.452

Fig. 6 Overview of load minutes per year

effect («0»).

Apart from the block hours, delay dependent maintenance costs are the second important parameter that needs to be calculated. As already mentioned, variable delay costs are calculated by subtracting fixed cost components from total annual maintenance costs.
According to [20] delay dependent maintenance costs can be assigned as the following:
65 % can be allocated for maintaining the airframe and 35 % for the engines. Monetary weighting factors are set in order to calculate the different additional delay costs (analog to flight phase depending weighting factors in Figure 6).

On basis of this method, marginal maintenance costs of about $ 8 per minute can be calculated for a B747. Costs for both taxiing to/from runway (approx. $ 2.46) and standing at gate (approx. $ 1.04) are certainly lower.

In case of a B737 temporary weighting factors are changed due to different aircraft turnings compared to long range jets. Mid-range jets like the B737 usually have more starts / landings per day and spend more time on the ground than long range jets consequently[3].

In contrast to the calculation of fuel costs, analyzing marginal maintenance costs do require a differentiation between standard and low cost scenario. The following Figure 7 gives an overview about calculated marginal costs for relevant flight phases and scenarios.

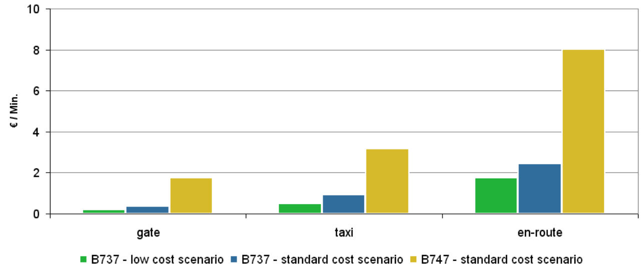

Fig. 7 Marginal maintenance costs per minute

As can be seen in Figure 7, costs for LCC are lower in every flight phase than for airlines in standard cost scenario. One important reason for this cost saving potential can be seen in attempts for fleet standardization in aircraft fleet. Typical LCC such as Ryanair in Europe or Southwest Airlines in the US hold only one aircaft type (B737) whereby synergies can be achieved[4]. Furthermore LCC operate a younger aircraft fleet (compared to regular network airlines) which leads to another chance to cut costs [16].

4.4 Route Charges

Air navigation charges are set to remunerate costs incurred for providing en-route services to airspace users. Charges are basically based on the number of service units multiplied by the unit rate. Number of service units is equal to weight factor (square root of the MTOM divided by 50) multiplied by the distance factor (great circle distance). In order for delays to affect route charges either the entry or exit points have to change or charging area boundaries have to be crossed (e.g. in case of re-routing). Analyses carried out by [3] show that delays only have little potential to change route charges. According to this source differences in route charges represent only 1 % to 3.5 % of total fuel costs.
Therefore additional route charges due to delays are considered to be negligible in this paper.

[3] According to own analyses of leading European and US airlines only 1,73 starts and landings per day are performed by long range aircrafts whereas typical mid-range aircrafts have 4,2 take offs and landings per day in average.

[4] For more information see [19]

4.5 Airport Charges

Airport charges represent an essential source of income for airports. Information about the general conditions as well as the amount of charges to be paid can be taken from the airport charge system. The parameters of this system are identical for most airports, they vary however, in the amount of the charges being fixed by the individual airport operators. The following calculations are based on the system of Frankfurt/Main international airport (FRA). The amount of charges primarily depends on following parameters:

- Landing and Take-Off Charges
- Passenger Charges
- Parking Charges

Landing and Take-Off Charges are based on the Maximum Take-Off Mass (MTOM) of the aircraft as entered in the registration documents. According to the airport charge system €0,79 per 1.000 kg of MTOM are charged per landing and take-off for passengers flights. In additional to the mass-related landing and take-off charges a variable, passenger-related charge of €1,02 has to be paid per departing passenger.
The last component are the noise-related charges depending on the allocation of the aircrafts to their respective ICAO classification (ICAO Annex 16, Chapter 2, 3 or 4 respectively). B737 is allocated to category 1 (equals €12 per movement) and B747 to category 3 (equals €72 per movement)[5].

Furthermore passenger charges are imposed based on the numbers of passengers aboard and the destination the aircraft is bound for[6].

Parking charges mainly depend on the stand size required, the length of parking time and the time of day. As opposed to other airport charge components, parking charges are calculated for every hour or part thereof. This means that if the period of an hour is not exceeded, there will be no effect on the amount of additional charges either. After one hour, charges jump to a higher level and remain there for a similar period of time (step cost function).

The determination of the additional costs in the case of delays is made more difficult by the following conditions:

The calculation of airport charges depends, as already mentioned, on the airport charges set by the individual airport operator. Thus charges can not be assumed as constant and calculations applying to all airports are hardly possible. Furthermore in-depth knowledge about the focused airport is necessary (e.g. for calculating passenger charges a differentation in non-transfer and transfer passengers has to be done which basically depends on the quality of hub and spokes system).

An exemplary calculation is carried out for an major European hub which represents an airport of the standard cost scenario though. The analysis of the low cost scenario is carried out following this calculation.

For B747 a MTOM of 397 tonnes and a max. number of 347 seats are taken as a basis. Corresponding values for B737 are 79 tons (MTOM) as well as a number of approx. 104 seats. A seat-load factor of approx. 80 % and 70 % can be assumed for short- and long-haul flights. The significant hub function shall be reflected by representative 50-percent share of transfer traffic.
Finally additional airport charges of €0,43 per minute for B737 and €0,73 per minute for B747 in case of delays could be assessed by linear approximation.

In the low cost scenario different requirements need to be considered:
First off all LCC typically operate «point-to-

[5] Additional night surchages are imposed for movements between 10pm and 05.59am local time

[6] Destinations are distinguished in «Domestic», «EU», «Non-EU» and «International»

point» networks in which they can minimize aircraft ground times and eliminate meals to increase aircrafts' productivity.
Furthermore it can be assumed that LCC are forced to pay no or at least lower airport charges as airport operators may even support LCC when launching scheduled services from their (secondary) airports [4].
In consequence no additional costs in the low cost scenario are assumed in this paper.

5 Evaluating the benefit for airlines

On basis of additional delay cost per minute (see chapter 4), airlines' reduction potential shall be examined in the following. The mentioned differences in delay costs per minute between LCC and network airlines suggest a differently minted cost reduction potential. On the one hand it is assumed that the amount of cost reduction depends on the degree by which the present average delay per movement can be reduced. On the other hand reductions increase with a growing number of movements.

It is necessary for the following consideration to define an «interval» in which «delay reduction per movement» due to current or future measures can be expected. This procedure offers considerably more meaningful values than the definition of one concrete number since this is aggravated by the variety of factors influencing punctuality in air traffic. [2] has shown that every rolling process can be lowered by optimized ground guidance control (A-SMGCS) by 24 seconds on average. Besides examinations dealing with the principle of Collaboratice Decision Making (CDM) (see [7]) prove that additional ground time of an aircraft can be reduced by a value up to approx. 60 seconds by implementation of this system.
These scientific examinations offer a valid basis for the definition of the interval above. Therefore values of approx. 24 seconds as well as 60 seconds are considered a lower and upper temporary barrier for the potential cost reduction. It is assured by this procedure that the given interval of the potential delay reduction is based on a realistic and furthermore scientifically verifiable basis.

Moreover a number of flights carried out have to be specified. For the following calculations an average value of approx. 30.000 movements applying to B737 and approx. 35.000 movements of B747-400 per year are assumed[7].

Possible savings according to this data are presented in the following Figure 8.

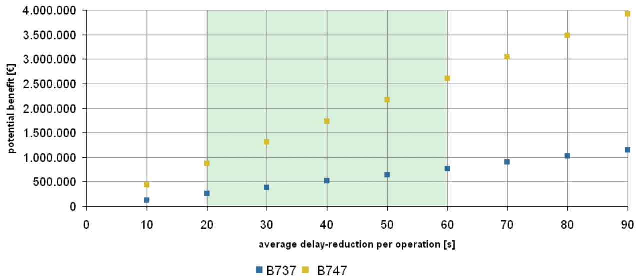

Fig. 8 Cost saving potential at marginal delay reduction

In accordance with this Figure 8 savings of up to approx. 1 million Euros can be expected for B737 and approx. 2,5 million Euros if an average delay reduction by 60 seconds per flight can be reached over a period of a year. The highlighted area represents the interval with its highlighted temporary boundaries mentioned above. It is important to express that the values shown in Figure 8 only apply for the operative costs calculated in chapter 4 and the low number of flights taken into account.

In accordance with the traffic mix and in consideration of all movements at a typical hub airport even higher savings would be obtained, if the determined additional costs of B737 are taken as realistic average costs for typical medium jets and costs of B747 as the upper limit for heavy jets[8].

[7]Data result from own examinations and do not include cargo flights carried out with B747

[8]Classification of aircrafts to the wake vortex categories «Light», «Medium» und «Heavy» is based upon the MTOM [13].

Furthermore it is assumed that approx. 70 % of total traffic is carried out by medium jets and consequently 30 % by heavy jets[9].

On basis of these data a potential benefit of up to 20 million Euros per year per hub can be expected.

Taking further operating and non-operating costs into account, the potential cost reduction could be increased even further.

6 Conclusion

This paper aimed to analyze the cost structure of airlines in order to determine additional operating costs in case of delays in the air traffic system. On the basis of information gained by scientific sources as well as own examinations changes in operating costs are estimated. In order to generate realistic results two different scenarios representing the difference in business models and especially cost structures between LCC and network airlines were developed respectively.

In chapter 6 an interval of potential cost reduction could be evaluated on basis of calculations done in chapter 4. This paper therefore may function as a kind of impulse to sensitize airlines to the amount of potential cost reduction. Such considerations are of great importance, especially in times of econmic recession and increasing consolidation trends in air traffic market since airlines make large effort to cut costs in order to remain competitive in the global market.

[9]The amount of light aircrafts at major European hub airports can be neglected.

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