Innovative Cooperative Actions of Research & Development
in EUROCONTROL Programme CARE INO III

Dynamic Cost Indexing

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Technical Discussion Document 6.0

*Airline costs of delayed passengers
and how to estimate full network delay costs*

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1. Overview of this report and of disruption management

1.1 Overview of this report

'Hard' costs borne by airlines as a result of delay comprise such costs as passenger rebooking and compensation costs. Although potentially difficult to ascribe to a given flight due to accounting complications (a point to which we shall return later), these are, in theory at least, identifiable deficits in the airline's bottom line. Due to a delay on one occasion, passengers may defect (and maybe later come back) to an unpunctual airline as a result of dissatisfaction. A passenger with a flexible ticket may arrive at an airport and decide to take a competitor's on-time flight instead of a delayed flight on which they were originally booked. 'Soft' costs, exemplified by these types of revenue loss, are rather more difficult to quantify, but may even dominate the hard costs.

In this report, passenger hard costs will first be derived at the aggregate (European average) level, for three cost scenarios (low, base and high). Previously derived soft costs are compared with these hard costs and subsequently also assigned values for each scenario.

These costs are then distributed according to various lengths of delay. For these types of delay, longer delays have higher associated costs per minute. The hard costs are higher as airlines pay more in recovery and care costs, such as meal vouchers and overnight accommodation. The soft costs are also higher for longer delays, as passengers are more likely to be disgruntled as the result of a longer delay than a shorter one.

These passenger per-minute costs, for each delay range and cost scenario, are then transformed into aircraft per-minute costs, for each of twelve supported aircraft types, representing a range of equipment operated in Europe. To this end, seat allocations used in previous reporting[1] in this research programme were applied, as were appropriate load factors for the low, base and high cost scenarios, differentiating between narrowbody (short-haul) and widebody (long-haul) operations.

Original delays caused by one aircraft ('primary' delays) cause 'knock-on' effects in the rest of the network (known as 'secondary' or 'reactionary' delays). Reactionary delays are generally worse for longer primary delays and for primary delays which occur earlier in the operational day (when the knock-on effects in the network are greater). They also depend on the airlines' ability to recover from the delay, for example due to the extent of schedule padding (buffering). Primary delays do not only affect the initially delayed ('causal') airframe on subsequent legs (rotational reactionary effect), but also other aircraft (non-rotational reactionary effect).

A method is presented for deriving and applying reactionary multipliers which quantitatively differentiate between rotational and non-rotational reactionary delays *and* for the *magnitude* of the primary delay. These are not restricted to passenger costs, but also apply to marginal delay costs such as those associated with maintenance and crew.

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[1] Technical Discussion Document 5.0, Aircraft crewing – marginal delay costs (October 2008).

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Furthermore, different methods are required for allocating the different types of reactionary multipliers to passenger, long-haul crew, short-haul crew and marginal maintenance costs. For non-passenger costs, these calculations depend upon a 'critical level' of primary delay, beyond which the rotational reactionary delay is greater than the primary delay. Based on the model developed and the latest raw data available, this 'critical level' occurs at 58 minutes of primary delay.

1.2 Disruption management

Disruption management is a vital component of airline operations[2]. A major challenge facing the industry is the integration of disruption management techniques into a *centralised* optimisation process, bringing together the various cost centres of an airline. In particular, passenger services and reaccommodation (booking disrupted passengers onto new flights) are rarely integrated with flight operations. Kohl et al. (2007) comment that: "Successful operation of an airline depends on coordinated actions of all supporting functions. However, each group typically operates under its own directive, with its own budget and performance measures ... Generally, in the disruption management literature passengers are given a low priority".

The major cost components which need to be considered are passengers, crew and maintenance. Although customer service coordinators are consulted, as Bratu and Barnhart (2006) comment, passenger disruptions rarely drive operational decision making. Aircraft and crew are often recovered first, with a need to respect aircraft maintenance requirements – especially for 'maintenance critical' aircraft (i.e. which will be grounded if not attended to). If a disruption management solution cannot be generated within a matter of minutes, it may become redundant, which still poses a serious problem for many optimisers.

Only a few disruption management tools are commercially available, which can optimise the reaccommodation of passengers. Full cost accounting for such tools remains a challenge, as exemplified in the next section. This report derives generic passenger costs of delay, which may be used by airlines in the absence of such tools (few airlines have these at present) and advances the understanding of soft costs, which may be included in existing tools.

No such tools are currently integrated with flight planning applications. The dynamic cost indexing prototype tool developed under this research programme has both the hard and soft costs derived in this report already incorporated (in addition to other major cost components – see later). Either the default European values derived for one of three cost scenarios may be selected, or the airline may enter its own costs (if known). In future, an interface could be developed with existing tools. This would have to be designed in such a way as to appropriately handle passenger soft costs. An initial, scoping technical review of such interfacing has been previously reported[3] in this project.

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[2] Substantial reviews of the literature are furnished by Bratu and Barnhart (2006) and by Kohl et al. (2007).
[3] Dynamic Cost Indexing, Deliverable 3.2, 2nd Progress Report (30 May 2008). Working paper available on request: airspace-research@westminster.ac.uk.

2. An aggregate estimate of the cost of passenger delay

2.1 Background and previous research

Harmonising findings from two extensive European airline case studies, using Airclaims and Association of European Airlines data, Cook et al. (2004), in reporting for EUROCONTROL's Performance Review Commission, derive airline hard costs of passenger delay under three cost scenarios. These costs are per average passenger, per average delay minute, per average delayed flight, for 2003. A simplified version[4] of the results is shown in Table 1.

Table 1. **Three scenarios for passenger hard costs to the airline**, **for 2003**

Cost type	Low	Base	High
Hard cost	0.096	0.120	0.144
Relative to base	- 20%		+ 20%

Adapted from University of Westminster reporting for EUROCONTROL's Performance Review Commission, Cook et al. (2004)

Since 2003, a significant change to these costs has likely been brought about by the European Union's air passenger compensation and assistance scheme (Regulation (EC) No 261/2004), introduced on 17 February 2005. In addition to affording passengers with additional rights in cases of flight disruption (denied boarding, cancellation and delay), the Regulation also requires airlines to formally inform passengers of their rights when a flight is disrupted. The Regulation only relates to *departure* delay (nothing is actually due to the passenger for any type of arrival delay or missed connection[5], per se) and it applies to any flight departing from the EU and to all flights operated by EU carriers from or to an EU airport. This prompts two questions, neither of which is easy to answer, due to lack of published data. Firstly, is there any quantitative evidence of how this has increased airline costs, if at all? On the one hand, many traditional carriers may have already been offering levels of service equal to, or exceeding, the provisions of the Regulation, such that its introduction may have impacted their costs relatively little. On the other hand, some carriers may have persisted in not acting in accordance with the Regulation – several airlines have received unwelcome media attention for not being as forthcoming in terms of passenger support as they ought to be. Secondly, have passengers become more aware of these rights, thus increasing the likelihood that they are demanded?

Regarding passenger awareness of such rights, there is almost no published data. Posters and signs promoting awareness of the Regulation are prominent at a number of EU airports. The Regulation requires that contact details are made available to passengers of a body designated by each member state to receive complaints. The Air Transport Users' Council (AUC) is the corresponding UK body. After a marked increase in complaints during the introduction of the Regulation, from 01 April 2006 to 31 March 2007 (the AUC's reporting

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[4] In fact, lower values were applied for delays of up to 15 minutes, see Section 3.1.
[5] An IATA Resolution, binding on member airlines, affords rights to passengers who miss connections between two different IATA carriers, although many airlines do not publish their policies on conjunction/intraline tickets (Air Transport Users Council, 2008).

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period runs from April to March), total complaints and enquiries about delays *fell* because such written complaints decreased markedly: "possibly because there appears now to be less confusion for passengers about their rights under the Regulation following delays" (Air Transport Users Council, 2007). Complaints about delays fell again for the corresponding period in 2007-2008 (Air Transport Users Council, 2008), although 2008-2009 may be expected to see an increase due to the problems associated with the opening of Heathrow's Terminal 5.

Delay complaint rates are a function of actual delay levels, passenger acceptance of delay, the capacity of the receiving organisation (such as the AUC) to receive such complaints, and the way in which the airlines deal with the complaints themselves – passengers tend to complain to the airline first and use the Council as a second resort[6]. If awareness of such rights is indeed reasonably high, and there is no marked increase in onward referral to the AUC, we may somewhat cautiously assume that airlines are incurring increased costs as a result of the Regulation.

Jovanović (2008) cites numerous industry estimates of the cost impact of the Regulation, pointing out that these do not appear to be based on hard evidence, although complaints rates are more transparent: in early 2006, Air France reported an increase of 60%. Only exceptionally rarely can airlines track such costs, however.

Figure 1 illustrates[7] the situation of a delayed JFK-LHR flight with four passengers missing their onward BA flight to Madrid, and six passengers missing their onward BA flight to Frankfurt. On the right-hand side of the figure, BA decides to rebook three (let's say Executive Club 'Premier') passengers onto Lufthansa's flight to FRA.

In-bound flight			Connecting passengers and flights				
DEP JFK	ARR LHR	Flight	Pax	DEP LHR	Flight	Destination	Status
1930	0740 (+1)	BA0176	4	0930	BA0458	MAD	MISSED CONNECTION
	ETA 1000		→ 2	1055	IB3163 BA7055	MAD	RE-BOOK
			→ 2	1305	BA0464	MAD	RE-BOOK
	Time now:		6	1040	BA0904	FRA	MISSED CONNECTION
	0700			1145	BA0906	FRA	SOLD OUT
			→ 3	1150	LH4727	FRA	RE-BOOK
			→ 3	1345	BA0908	FRA	RE-BOOK

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Figure 1. Rebooking passengers with missed connections at Heathrow

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[6] Personal communication from AUC.
[7] This is an illustrative example, not based on British Airways data, but constructed using actual British Airways schedule data. It should not be taken to represent British Airways practice or policy.

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Since the true costs of handling the disruption will not be apparent to an airline's revenue management (or yield control) department until some time after the event[8], they will not typically be costed back against the disrupted service, but rather accounted as centralised / aggregated costs (e.g. for that airport or by type of haul). The same may apply to other delay-related costs, such as care payments (see next section). Disruption management processes directly affect aircraft turnaround times. These times are a key component of overall ATM efficiency: "Air transport delays originate principally from local turn-around delays (76%), i.e. ground processes under local control outside the remit of ATM. This is an area for improvement and there should be consistency in the accuracy of ground and air-side processes in advanced concepts such as SESAR" (EUROCONTROL, 2008).

Although Jovanović (2008) cites an annual European estimate of compensation only, made by IATA, no other industry source (including IATA) directly approached as part of this study was able to provide any quantitative data on delay costs. A particular effort was made to obtain data on rebooking costs, since these are especially difficult to estimate, but no such data were available. In the next section, all such costs will be estimated based on the best available data, where it will be shown that fairly robust models evolve.

2.2 Calculation of 2008 costs for the three scenarios

2.2.1 Hard cost scenarios

Disruption management was briefly introduced in Section 1.2. Kohl et al. (2007) do not quote specific delay costs, and Bratu and Barnhart (2006) use values of time to estimate passenger costs. Jovanović (2008) appears to be the only publication to date specifically addressing the impact of Regulation 261, citing a comprehensive response from a major European, full-service network carrier, and more limited data from another, similar carrier.

The latter airline (henceforth "Airline X"[9]) reported that the costs resulting from meal vouchers, hotel accommodation, tax-free vouchers, frequent-flyer programme miles and phonecards were 25-50% higher compared to the accounting year prior to the Regulation. We will label these costs collectively simply as "care".

The costs of rerouting/rebooking passengers, and ticket reimbursements (which we shall label simply "reaccommodation") were not included in the cost estimates. For both the major European carriers from whom data had been collected, it was reported that of the passengers who were delayed for five or more hours (and thus entitled to a ticket refund by the Regulation), typically fewer than 10% opted for this. The range cited for rebookings onto other carriers was 10-50%. A model estimating these costs as a combined category will be presented later in this discussion.

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[8] Although the interline settlement process can be achieved through a number of systems, it typically takes several weeks (see Annex). Estimating these costs dynamically is therefore at least as difficult, although as early as 0700, it is apparent that there will be a problem at 1000, when BA0176 arrives late, and ten passengers will miss their connection.

[9] The identity of this carrier is in fact known by the authors of this paper, with permission.

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A report from the Institut du Transport Aérien (2000) was the only published source found to give a quantitative indication of the ratio[10] of various passenger costs to the airlines as a result of delay. Comparing 'rerouting and compensation' (reaccommodation) with 'food, drink and miscellaneous' (care) expenditure, gives a value of approximately 30%:70%.

Table 2. Hard cost estimates across a range of reaccommodation:care ratios

Increase in costs (%)		Ratio of reaccommodation:care costs						
Reaccommodation	Care	80:20	70:30	60:40	50:50	40:60	30:70	20:80
20	20			<<<	0.144	>>>		
30	20	0.154	0.152	0.151	0.150	0.149	0.148	0.146
40	20	0.163	0.161	0.158	0.156	0.154	0.151	0.149
50	20	0.173	0.169	0.166	0.162	0.158	0.155	0.151
20	30	0.146	0.148	0.149	0.150	0.151	0.152	0.154
30	30			<<<	0.156	>>>		
40	30	0.166	0.164	0.163	0.162	0.161	0.160	0.158
50	30	0.175	0.173	0.170	0.168	0.166	0.163	0.161
20	40	0.149	0.151	0.154	0.156	0.158	0.161	0.163
30	40	0.158	0.160	0.161	0.162	0.163	0.164	0.166
40	40			<<<	0.168	>>>		
50	40	0.178	0.176	0.175	0.174	0.173	0.172	0.170
20	50	0.151	0.155	0.158	0.162	0.166	0.169	0.173
30	50	0.161	0.163	0.166	0.168	0.170	0.173	0.175
40	50	0.170	0.172	0.173	0.174	0.175	0.176	0.178
50	50			<<<	0.180	>>>		

Table 2 uses a cross-section of such ratios (from 80%:20% to 20%:80%) with independently varying increases in each category, using the range 25-50% (as cited above), to produce 2008 cost estimates from the base cost scenario for 2003 of € 0.12 (see Table 1). The table yields 2008 values in the range € 0.14 – € 0.18, with an average of € 0.16. The sensitivity analysis thus demonstrates a relatively weak dependence on these assumptions, with even the extremes only differing by just under a third. Using the Institut du Transport Aérien (ITA) 'reaccommodation:care' ratio of 30%:70%, and the mid-point of the 25-50% increase range estimate, yields a value which differs by only 3% from this table average value of € 0.16. Therefore, although the ITA airline sampling basis was not clear, the cost ratio produces a value not that different from the average of a rather broader range of assumptions.

Adopting this average value of € 0.16 as the basis for the base cost scenario, it remains only to correct for inflation before and after the two years to which the 25-50% range relates, for the periods 2003-08 (see footnote 13). This produces a final value of € 0.18 for the base cost scenario.

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[10] Although corresponding actual costs were not given.

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In research cofinanced by EUROCONTROL under its CARE INO III programme, undertaken by the University of Westminster with Consumerdata Ltd, Cook et al. (2008) propose a soft cost of delay of € 0.18 per average passenger, per average delay minute, per average delayed flight. Also in 2008, another full service European carrier[11] operating several hubs, and one of only a very small number of airlines known to be modelling these costs, disclosed to the research team an estimate that its hard and soft costs were approximately equal, which is consistent with both the hard and soft values proposed of € 0.18. This is also in line with previous (1999) estimates from Austrian[12] of soft costs being 60% of total passenger costs: the increasingly price-driven marketplace likely to have at least equalled this ratio out.

For the high cost scenario value, the upper value of € 0.18 from Table 2, with a similar correction for inflation either side of the 25-50% period, produces a value of € 0.20. This is based on the upper bound of the increase experienced by Airline X. The issue then is whether another European airline is likely to have a higher average cost than that based on this upper bound of 50%. The balance of probability is that it is unlikely that a European carrier would have suffered a doubling of such costs as a result of Regulation 261. With airlines facing severe financial challenges due in particular to high fuel costs, it is unlikely that a carrier could simultaneously bear a doubling of disruption costs. Furthermore, most carriers, i.e. those typical of the base cost scenario, already had substantial procedures in place for looking after and reaccommodating disrupted passengers, before the Regulation came into force. There is also a limit at which the reaccommodation and care costs can grow, since there is a dependency between the two – if more money is spent on rebooking and rerouting, then less would need to be spent on care, particularly overnights in hotels. As alliance and code-share structures have deepened, and interline ticketing agreements along with them (see Annex), the ability to manage rebookings and reroutings has doubtless improved. Such ability is also improved through hub operations, although offset somewhat by increasing load factors. Thus, for full-service, hubbing airlines such as Airline X (also a large alliance member), these factors combine to offset costs from its prescribed programme of customer care and the increased likelihood of departure delays resulting from the operation of a complex network. The latter does not apply to the business model of the low-cost carriers.

The care costs are a function of both the actual cost of delivering such care (which will often be limited to refreshments) and the number of passengers to whom it is given. Either assuming that these costs have increased by the upper limit of 50% and at twice the rate of inflation for the periods either side of this, or that they have increased by 65% plus average inflation, yields a high cost estimate of € 0.22. In fact, to the two decimal places quoted, the inflationary factor could be up to 2.35, or the percentage increase 69%, still producing a result of € 0.22. Adopting a high cost scenario value of € 0.22 renders the upper estimate approximately 22% higher than the base scenario, thus in line with the principles of Table 1.

For the low cost scenario, it is proposed that the 2003 value of € 0.096 (see Table 1) be more simply factored up to a 2008 value. EUROSTAT compounded 'Euro area' inflation[13] for

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[11] This airline also preferred not to disclose its identity.
[12] Personal communication with Austrian (Airlines) following reporting by Nichols and Kunz (1999).
[13] 'Euro area' data sourced from EUROSTAT. 2003-2007 based on annual values; 2008 value based on rolling average to October 2008. As defined by EUROSTAT: "Euro area inflation is measured by the MUICP ("Monetary

the period 2003-2008 is 13.03%, although considering the reach and impact of Regulation 261, it seems unlikely that these costs will have increased only by the rate of inflation. The mid-point between this inflationary increase and the lower end (25%) of the range cited by Airline X, gives a factor of 19%, and a low cost estimate of € 0.11. This is 20% lower than the *lowest* value in Table 2, and may be seen as representing the lowest extent to which it might be expected that carriers can drive down these hard costs.

This could be through one of two primary mechanisms. Some carriers might avoid fulfilling the requirements of Regulation 261 to anything like the extent of Airline X, with its systematic policy in place. Negative examples of such cases have been reported in the media. However, it is not the purpose of this paper to identify such cases but rather to identify the principle, which results in lower hard costs. Other carriers might seek to avoid these costs through operating schedules with large buffers, thus effectively displacing these tactical hard costs into the strategic phase, for example due to decreased aircraft utilisation. The opposite effect is seen in Europe, however – see Section 3.2.1.

These hard costs are summarised in Table 3, at the start of the next section, in which corresponding soft costs are estimated for the low and high scenarios, based on an existing estimate for the base scenario.

2.2.2 Soft cost scenarios

Table 3. **Three cost scenarios for passenger hard and soft costs to the airline**

Cost type	Low	Base	High
Hard cost	0.11	0.18	0.22
Soft cost	0.05	0.18	0.20
Total	0.16	0.36	0.42

All costs are Euros (2008) per average passenger, per average delay minute, per average delayed flight

In order to take these calculations forward, it is necessary to assign corresponding soft costs for the low and high cost scenarios – the base scenario value has already been given as € 0.18 – in order to determine the total passenger cost of delay to the airline. In the absence of any appropriate quantitative findings published in this area, this is a matter of judgement. For the high cost scenario, it may be considered whether to increase the soft cost of € 0.18 in proportion to the hard cost (yielding a soft cost estimate of € 0.22), less than this, or more than this.

Union Index of Consumer Prices" as defined in Council Regulation (EC) No 2494/95 of 23 October 1995) which is the official euro area aggregate … New Member States are integrated into the MUICP using a chain index formula".
http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/prc/prc_hicp&language=en&product=EU_MASTER_prices&root=EU_MASTER_prices&scrollto=0

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The European market for air travel has become increasingly price-driven. Increased distribution through the internet has helped to keep fares down and competition up. Many 'traditional' airlines no longer provide free catering on shorter hauls, and low-cost carriers continue to enjoy a considerable share of the business-purpose market. Teichert et al. (2008) remark that the correlation between non-price-sensitive business passengers and frequent-flyer programme passengers has become rather less marked over recent years: more frequent fliers now belong to more programmes. The effect of this on switching rates is not clear: flexibility between carriers may be off-set by an increased desire to accumulate points with a preferred programme. Despite a worsening of actual delays experienced, the discussion on the AUC complaints data (Section 2.1) supports the view that there has been no recent marked increase in delay sensitivity.

Strong service competition may increase switching rates (although likely dampened in many cases by loyalty programmes), but also promote faster rates of return patronage. For the high cost scenario for the soft cost, the mid-point is taken between a proportional increase and no increase at all, yielding a value of € 0.20. This allows the value to increase relative to the base cost scenario, such that a carrier with a higher cost base might also be impacted by higher soft costs (losses of revenue) as a result of unpunctuality, but allowing the higher 'investment' in hard costs to off-set such soft costs: the more the airline spends looking after the disrupted passengers, the less likely they are to defect. A review of the literature in this area may be found in Cook et al. (2008).

For the low scenario for hard costs, it has already been stated that this may be the result of lower spending on passenger care and/or reaccommodation, or, of being particularly punctual, the former being the more likely. It might be expected that soft costs, particularly defection rates, would also be lower than the soft cost base scenario, for example through effects such as those suggested by Wittmer and Laesser (2008) in their analyses, declaring that airlines known for delay may find it easier to generate customer satisfaction by reducing such delays than airlines with a reputation for being punctual. With hard costs under the low cost scenario half those of the high cost scenario, it seems reasonable that the soft cost under the low cost scenario will be relatively lower still, although not zero. Carriers with lower cost bases, marketing significantly lower fares, are arguably relatively less likely to lose custom to a competitor as a result of unpunctuality. Furthermore, such customers are, on average, less likely to stay with that competitor, unless it offers an approximately equivalent service at a lower price, which makes the selection of the original carrier less likely in the first place. Finally, carriers with low cost bases are likely to be impacted relatively less in terms of gross revenue loss per defection. For the low scenario for the soft cost, a mid-point between half the high cost and the zero-cost option (unlikely in practice: low cost markets are also competitive) gives a value of 0.05.

2.2.3 Critical review of the adopted costs

In review of the 2008 costs presented in Table 3, the base cost scenarios are derived from independently concurring sources (two European airlines) on total passenger costs for a 2003 reference base. Two further airline sources have been used to rationalise the equal split between hard and soft costs. The values set for the high and low cost estimates are more a matter of informed judgement, in particular subject to further research, but nonetheless based on a semi-quantitative argument.

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For the hard costs, the high cost scenario adopted is 2.0 times the value of the low cost value. In previous reporting[14] within this research programme, the cost ratio for high to low cost scenarios averaged over captains and first officers over twelve aircraft types is also 2.0. For unit maintenance costs, which are often substantially outsourced from home bases, the ratio is lower, averaging 1.3 over the twelve aircraft[15]. Soft costs, it is argued, are relatively less impacting for carriers with a low cost base, such that the ratio between the high and low scenarios is 4.0, although much closer for base and high scenarios. This asymmetry is intentional and reflects soft costs saturating out at higher total costs.

For the total costs, the high cost scenario is just under 20% higher than the base cost, and the low cost is around 45% of the base cost. Around two-thirds of the latter difference is explained by the soft cost differential. The total high cost scenario is 2.6 times the low cost scenario, again mostly driven by the soft cost differential. The relatively low value for the low cost scenario reflects the potential for some delay minutes to have rather lesser cost impacts than the typical, base case. Unlike the situation for crew costing, however, it is considered very unlikely that these could average out to zero over a range of delay durations (see Section 3.1).

Overall, the base cost scenario for 2008 is 20% higher than the 2003 value previously reported. Inflation and the impact of Regulation 261 have been cited as incrementing factors, whilst increasingly cost-driven markets have been cited as a capping effect through soft costs.

3 Temporal and network effects

Having derived the hard and soft aggregate costs, it is now necessary to distribute these as a function of duration of delay, as longer delays will tend to have higher per-minute costs than shorter ones. Finally, account needs to be taken of the reactionary ('knock-on') effects of delays in the rest of the network. Methods for distributing the costs by duration of delay and then scaling them up for the network, are presented in the next two sections.

3.1 Costing by duration of delay

Table 4 shows the average costs per passenger quoted by Airline X, for its applied levels of care provision according to Regulation 261. (In fact, not only are temporal rules specified by the Regulation, but also rules in relation to the distance of the flight). In the final column, a simple additional calculation has been made. Assuming a typical airport operation from 0700-2200 (fifteen hours), it could be estimated that of all five-hour delays, approximately one-third would delay passengers later than 2200, such that overnight accommodation would be required/supplied. This gives a simplified, combined estimate for the 'over 5 hours' category, of around €40. Increasing each of these costs by inflation and dividing by the number of minutes[16] gives an initial estimate of costs per minute (final column).

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[14] Technical Discussion Document 5.0, Aircraft crewing – marginal delay costs (October 2008).
[15] Technical Discussion Document 9.0, Aircraft maintenance – marginal delay costs (June 2008).
[16] Using the mid-point of each range (lower limit of 90 minutes assumed) and 5 hours for upper limit.

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Table 4. **Average care costs per delayed passenger**

Delay duration	Care provision	€ (2005-6)	'Simple' € /min (2008)
Up to 2 hours	Bottle of water	1.5	0.02
2 – 3 hours	Tax-free voucher and phone card	7.0	0.05
3 – 5 hours	Tax-free voucher, meal voucher, phonecard & frequent-flyer miles	17.2	0.08
Over 5 hours (no hotel)	Tax-free voucher, meal voucher, phonecard, frequent-flyer miles & ticket discount voucher	19.2	0.13
Over 5 hours (with hotel)	Tax-free voucher, meal voucher, phonecard, frequent-flyer miles, ticket discount voucher & hotel accommodation	75.0	0.13

The data in the final column of Table 4 give a good linear fit against delay duration (r^2 = 0.95; Figure 2). The costs in Figure 2, although not triggered until delays greater than 90 minutes occur, still contribute to the grand mean of € 0.18 / min (base scenario) per average passenger, per average delayed flight, as derived in Section 2.2.1. When the values in Figure 2 are weighted by the delay probabilities for each category, their contribution to the grand mean is very small, since all delays above 90 minutes constitute only approximately 5% of all delays.
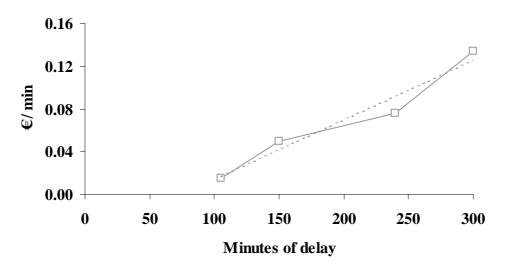

Figure 2. **'Simple' costs of care provision per minute by duration of delay**

In Table 2, the grand mean value of € 0.18 / min was derived from the costs of care ranging from 20% upwards in proportion to the cost of reaccommodation, although this will vary by airline to airline, and is unknown for Airline X. Instead of a simple weighting by the low probability of the flights with delays longer than 90 minutes, an additional weighting may be derived such that these care costs contribute approximately 20% of the total hard costs.

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The higher the weighting factor, the higher the percentage of the care costs (a point to which we shall return later). To render a value of exactly 20% the weighting is 2.6. How can this value be interpreted?

Subject to the several constraints of the grand mean value of € 0.18 / min, the contribution of care costs of 20%, and that we shall require costs in various delay ranges to be weighted by their respective delay probabilities back to the grand mean, the factor may be described as a rate at which costs are incurred *higher than their flight delay probability*.

For example, although approximately 0.5% of *flights* are delayed for 4-5 hours or more, many *passengers* on such flights may be delayed by a lot more than this, relative to their original schedule, such that the net effect is that higher care costs are incurred than flight delays alone suggest. Such effects may be compounded by hub-and-spoke connections, for example whereby a flight delay of a short-haul feeder flight of 45 minutes, may cause the passenger to be delayed by 4 hours, waiting for the next long-haul onward connection.

Airline X would still record the correct level of delay for such passengers, such that the absolute averages per passenger in Table 4 (third column) are valid, although it is necessary to multiply these values by more than the corresponding number of delayed flights in each delay range to obtain the correct grand mean. Therefore, the values per minute in Table 4 (final column), are too low, if they are to be used in the delay ranges in which they currently reside.

There are two mathematically equivalent ways of resolving this. Either the proportion of flights in each range could be increased, to give an 'effective proportion', in order to obtain the correct grand mean, or, the costs per minute can be increased, to give an 'effective cost per minute'. The latter is clearly more desirable, allowing an effective cost to be assigned in actual delay ranges. (If 'effective proportions' of flights were to be used, instead of actual ones, it would make combining these hard costs with soft costs, as will be necessary later on, confusing to present). An airline could suffer from various delay ranges at rather higher rates than those of the European averages applied in this analysis – see second row of Table 5 – which may render the use of a weighting factor unnecessary if these were to be employed. This was unlikely to be the case for Airline X.

Using large data sets for passenger booking and flight operations from a major US airline, Bratu and Barnhart (2004) show how passenger-centric metrics are superior to flight-based metrics for assessing passenger delays, primarily because the latter do not take account of replanned itineraries of passengers disrupted due to flight leg cancellations and missed connections. The authors conclude that flight leg delays severely underestimate passenger delays for hub-and-spoke airlines, with their specific analysis for (August 2000) demonstrating that the average passenger delay is 1.7 times greater than the average flight leg delay, with average disrupted passenger delay growing exponentially with load factors. Combined with decreasing buffers in airline schedules in Europe (see Section 3.2.1), the value of 2.6 derived above appears to be easily plausible. Of course, its application as a common weighting factor across all care costs is rather crude, particularly as marked non-linearities may arise with higher delays and overnight stays paid for by the carrier.

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Turning specifically to the modelling of reaccommodation costs as a function of delay duration, a form of distribution is required which starts off at a very low value (e.g. at 1-15 minutes of delay such costs are likely to be very small) and then rises as a cost per minute at higher delays, before levelling off at higher values. In fact, if these costs are modelled from 1 minute to 5 hours (the threshold set by Regulation 261 for additional rights to be granted – see Table 4), a peak could be expected at 5 hours. Just before this limit, it may be decided that some passengers will require overnight accommodation, and these may even be rebooked the next morning, or overnight. In any case, the rebooking cost itself may be notionally allocated to the point in time at which the decision is taken that the passenger will be rebooked, thus still increasing towards the 5 hour point. The simple theoretical function as shown in Equation 1 has been used.

Equation 1

$$c = k.\ln t_D{}^2$$

c: cost (€/min)
t_D: time (delay, mins)

The value of k is chosen such that: (i) the contribution of the reaccommodation costs to the total is 80% (in this case); (ii) the flight-proportion-weighted grand mean is € 0.18 / min (in all base scenario cases). A plot of this is shown in Figure 3.
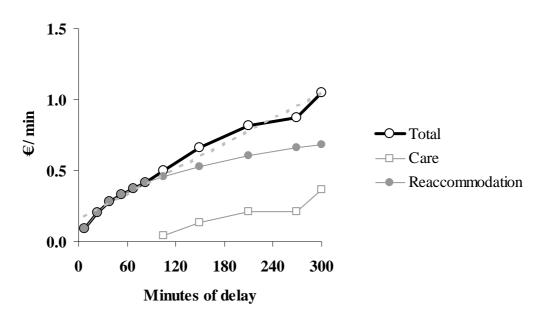

Figure 3. Modelled distribution of hard costs, with care 20% of total

Allowing the care costs to contribute 50% to the total of the hard costs (increasing the weighting factor and reducing k, but still fixing the flight-proportion-weighted grand mean to € 0.18 / min) gives the cost distribution shown in Figure 4. This represents the mid-point situation described in Table 2.
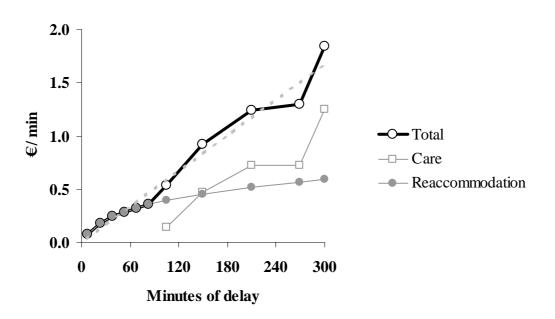
Figure 4. Modelled distribution of hard costs, with care 50% of total

The distributions of hard costs in both Figure 3 and Figure 4 are based on the base case scenario, i.e. producing a flight-proportion-weighted grand mean of € 0.18 / min. In Figure 5, the same calculations are performed for the low cost scenario (grand mean of € 0.11 / min, see Section 2.2.1) and the high cost scenario (grand mean of € 0.22), in each case the distribution plotted being the average of the 'care at 20%' and the 'care at 50%' scenarios. The base distribution with care costs forming 50% of the total costs (upper, dashed black line), follows closely the averaged distribution for the *high* cost scenario (upper grey line), such that the former is probably rather too high to be used as the base scenario. The average base distribution, however, seems to be a pertinent choice, relative to both the average high and low cost scenarios. The proportions of the base (average) values to the corresponding high (average) and low (average) values plotted in Figure 5 are, of course, the same as those of the hard costs in Table 3.

Each airline will have its own cost curve, which may even vary from flight to flight and from day to day. The curves will be a function of the network (e.g. point-to-point or hub-and-spoke) and the way it is operated. An airline with many feeder flights into a hub with the only onward connections being its own flights will have lower rebooking costs but higher overnight accommodation costs if a feeder flight for the last wave is too late for the onward connections, compared with another carrier and another hub, which may be able to rebook passengers onto alliance partner flights, for example. The model developed here is for generalised cases but should furnish a robust estimate for the range of expected costs (notwithstanding exceptions that arise in any operation). The costs per minute for each of the scenarios, over a range of delay periods, are given in Table 5.
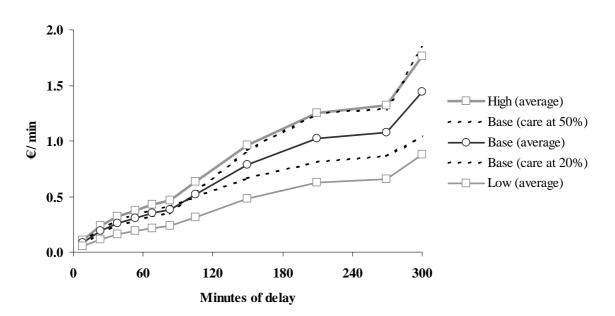
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Figure 5. Modelled distribution of hard costs, for three scenarios

For the low, base and high cost scenarios, the grand mean values, weighted by the proportions of flights in each delay range, are € 0.11 / min, € 0.18 / min and € 0.22 / min, respectively (see Table 3). Note how, as would be expected by the methodology used, the delay range for which delays are most common (16-30 minutes) has the values which are closest to the respective grand means.

Table 5. Passenger hard costs of delay per minute, by three scenarios

Delay minutes range	1 -15	16 -30	31 -45	46 -60	61 -75	76 -90	91 -119	120 -179	180 -239	240 -299	300+
Proportion of flights[a]	0.608	0.194	0.084	0.040	0.019	0.011	0.005	0.011	0.010	0.005	0.014
Low cost scenario	0.05	0.12	0.16	0.19	0.21	0.23	0.32	0.48	0.63	0.66	0.88
Base cost scenario	0.08	0.19	0.26	0.31	0.35	0.38	0.52	0.79	1.02	1.08	1.44
High cost scenario	0.10	0.24	0.32	0.38	0.43	0.47	0.63	0.97	1.25	1.32	1.76

All costs are in Euros per minute (2008)

(a) EUROCONTROL (2007b) (CODA STATFOR series), EUROCONTROL (2008), Jovanović (2008).

Although each of these gives a very good linear fit (r^2 = 0.98, x3; see also linear fits shown by dashed lines in Figure 3 and Figure 4, each with r^2 = 0.97) these linear fits overestimate the costs in the low(est) delay range(s), by around 30%, which is a particularly undesirable feature of such a fit, since trade-offs are particularly sensitive to the values assigned to these very common delay values. Similar problems arise with various non-linear fits.

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It is neither desirable, nor realistic, for delay costs to remain at exactly one value over the range 1-15 minutes (e.g. € 0.08 / min for the base cost scenario) then to immediately jump to a higher value (€ 0.19 / min, in this case) on reaching 16 minutes, etc. In the absence of an overall suitable fit, values are therefore proposed which are linear interpolations between the mid-points of each range, thus lying on the individual (linear) segments of the distributions plotted in Figure 5. This allows very small values to be assigned to even very small delays, e.g. € 0.053 / min for a 5-minute delay. The reader is respectfully reminded that these costs are, so far, per passenger.

Although minimum connection times are likely to very comfortably allow for a 5-minute delay, there is a finitely increased probability that a cost will be incurred as a result of even a small delay. Passengers might even miss connections with no delay, for example by not showing at the onward gate in time due to a delay in immigration clearance or passing through security checks, although zero delay is implicitly our zero-cost baseline in this model.

Finally, in Table 6, the soft costs from Table 3 are distributed across the same delay ranges, for each scenario, then added to the hard costs of Table 5 to give the final, total passenger costs of delay, in Table 7 (all values are to two decimal places and thus some values in Table 7 differ from the apparent sum of the other two tables by ±0.01). The soft costs saturate above 90 minutes, as explained in Cook et al. (2008). For each row of Table 6 and Table 7, when the values are weighted by the proportions of delayed flights shown in Table 5, the grand means in Table 3 are produced. Although, for simplicity of presentation in this treatment the hard and soft costs are treated together under one of the three selected cost scenarios, as in Table 7, in practice an airline might wish to assign the low scenario soft costs and base scenario hard costs, and this functionality is enabled in the design of the prototype tool.

Table 6. Passenger soft costs of delay per minute, by three scenarios

Delay minutes range	1 -15	16 -30	31 -45	46 -60	61 -75	76 -90	91 -119	120 -179	180 -239	240 -299	300+
Low cost scenario	0.01	0.05	0.10	0.16	0.21	0.24	0.27	0.27	0.27	0.27	0.27
Base cost scenario	0.04	0.17	0.37	0.58	0.76	0.86	0.96	0.96	0.96	0.96	0.96
High cost scenario	0.05	0.19	0.41	0.65	0.84	0.96	1.06	1.06	1.06	1.06	1.06

All costs are in Euros per minute (2008)

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Table 7. Total passenger costs of delay per minute, by three scenarios

Delay minutes range	1 -15	16 -30	31 -45	46 -60	61 -75	76 -90	91 -119	120 -179	180 -239	240 -299	300+
Low cost scenario	0.06	0.17	0.26	0.35	0.42	0.47	0.58	0.75	0.89	0.92	1.15
Base cost scenario	0.13	0.36	0.63	0.89	1.11	1.24	1.47	1.75	1.98	2.03	2.40
High cost scenario	0.15	0.43	0.72	1.03	1.27	1.42	1.69	2.03	2.31	2.38	2.82

All costs are in Euros per minute (2008)

Table 8 shows the per-aircraft costs for the twelve supported aircraft, based on the seat allocations used in previous reporting[17] and with load factors of 60%, 75% and 90% applied to the low, base and high cost scenarios, respectively, for narrowbodies (short haul). For widebodies (long haul), the base scenario load factor is 80%, the others are the same. Values in Table 8 are shown for only the first three delay ranges to save space. (Furthermore, exact, interpolated values are used in the prototype tool, not the range averages shown). Having derived such costs, the final calculation required is the estimation of the corresponding reactionary (network) effects caused by such delays, and how these affect the total costs.

Table 8. Per-aircraft passenger costs of delay, by delay range and scenario

Aircraft	1-15 minutes of delay			16-30 minutes of delay			31-45 minutes of delay		
	Low	Base	High	Low	Base	High	Low	Base	High
B737-300	6	12	17	15	35	49	23	60	83
B737-400	7	14	20	17	40	56	27	68	94
B737-500	5	11	15	13	31	43	21	53	74
B737-800	7	16	22	19	44	62	30	76	105
B757-200	9	19	27	23	55	77	37	94	130
B767-300ER	13	29	34	33	81	94	51	140	160
B747-400	18	41	49	47	117	136	74	202	232
A319	6	13	18	15	36	51	24	62	87
A320	7	15	21	18	42	59	28	72	100
A321	8	18	26	22	51	72	34	88	122
ATR42-300	2	4	6	5	12	16	8	20	28
ATR72-200	3	6	8	7	16	23	11	28	39

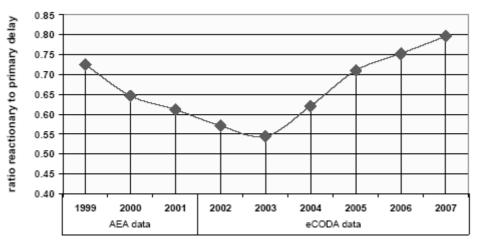All costs are in Euros per minute (2008)

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[17] Technical Discussion Document 5.0, Aircraft crewing – marginal delay costs (October 2008).

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3.2 Scaling up to the rest of network

3.2.1 Deriving the reactionary multipliers

Original delays caused by one aircraft ('primary' delay) cause 'knock-on' effects in the rest of the network (known as 'secondary' or 'reactionary' delays). Figure 6 shows the ratio of these delays from 1999 to 2007. The value of 0.8 in 2007 (often expressed in the literature as 1.8) means that for each minute of primary delay, on average, another 0.8 minutes of reactionary delay are generated in the network. Reactionary delays are generally worse for longer primary delays and for primary delays which occur earlier in the operational day (when the knock-on effects in the network are greater). They also depend on the airlines' ability to recover from the delay, for example due to the extent of schedule padding (buffering). EUROCONTROL (2008) suggests that the increased sensitivity to primary delays shown in Figure 6 is likely to be as a result of higher levels of aircraft and airport utilisation, the former manifested as tighter airline schedules and turnaround times due to strong traffic growth. Increased unpredictability has further compounded the problem.

Source: EUROCONTROL (2008).

Figure 6. Reactionary delay multipliers

Rather than multiplying all delay costs by 1.8 in order to get a value corresponding to the total network cost (primary plus reactionary cost), Beatty et al. (1998) studied delay propagation using American Airlines' schedule data, building up delay trees with schedule buffers included in the delay-tree scenarios. After sampling from the distributions modelled, and performing various regression models on the sample data, then smoothing the resulting output, linear fits are produced relating length of delay and the value of the reactionary delay multiplier. In the absence of any corresponding European data for such a calculation, this fit was re-scaled to produce the 2007 value quoted by EUROCONTROL (2008) of 1.80, using Equation 2.

Equation 2

$$M_R = m.t_D + k$$

M_R: multiplier (reactionary)
t_D: time (delay, mins)
m, k: 0.017, 1.348 (3 d.p.)

Primary delays do not only affect the initially delayed ('causal') airframe on subsequent legs (rotational reactionary effect), but also other aircraft (non-rotational reactionary effect). Estimates cited in Cook et al. (2004) based on CODA data, set these at 75% and 25%, respectively. The three multipliers are shown in Table 9, averaged over each delay category: in the prototype tool itself, specific numbers are used for each value of the number of minutes of delay, as described by Equation 2. Although the upper limit of 6.47 may appear high, values higher than this were derived in the original research by Beatty et al. (ibid.) for even lower magnitudes of delay than 300 minutes, for early rotations in the day (whereas the values used in Table 9 are averaged over the whole day).

Table 9. **Reactionary multipliers averaged over delay ranges**

Delay minutes range	1 -15	16 -30	31 -45	46 -60	61 -75	76 -90	91 -119	120 -179	180 -239	240 -299	300+
Gross basic	1.48	1.74	2.00	2.25	2.51	2.77	3.14	3.90	4.93	5.95	6.47
Additional rotational	0.36	0.56	0.75	0.94	1.13	1.32	1.61	2.18	2.95	3.72	4.11
Additional non-rotational	0.12	0.19	0.25	0.31	0.38	0.44	0.54	0.73	0.98	1.24	1.37

3.2.2 Using the reactionary multipliers

In this section, a method is presented for applying the reactionary multipliers exemplified by Table 9 to the actual costs incurred as a result of delay. These are not restricted to passenger costs, but also apply to marginal delay costs such as those associated with maintenance and crew.

3.2.2.1 Rotational reactionary costs

Basing an example on Table 9, for an aircraft with a primary delay of 53 minutes (mid-point of the 46-60 range), a gross total of 2.25 x 53 = 119 minutes[*] of delay would be generated on average, i.e. as result of the combined primary and reactionary delay.

Of this total, (2.25-1) x 53 = 66 minutes[*] of additional, reactionary delay would be generated: 0.94 x 53 = 50 minutes[*] experienced by the 'causal' aircraft (rotational reactionary delay: during subsequent rotations of the day) and 0.31 x 53 = 16 minutes[*] experienced by other aircraft (non-rotational reactionary delay: primarily aircraft waiting for the 'causal' aircraft on the primary delay leg, e.g. waiting for connecting passengers or crew).

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[*] Rounded to nearest minute.

On average, it is apparent that for this level of delay, a small proportion of the 53 minutes of delay will be recovered, e.g. by quicker turnarounds/buffers, such that the rotational reactionary delay is 'only' 50 minutes, and not another 53 minutes (or worse). The values in Table 9 suggest a 'critical level', beyond which the rotational reactionary delay is actually worse than the primary delay. This occurs at 58 minutes, in fact. Beyond this level of delay, for each minute experienced by the causal aircraft during the primary delay, more will be added during subsequent reactions (on average). The additional (50) rotational minutes should be multiplied by the cost per minute for the new passengers on (the) subsequent rotation(s) of the causal aircraft, and added to the total cost of delay as reactionary costs.

To calculate the rotational reactionary maintenance costs, for primary delays less than the critical level, the delay minutes encountered during the rest of the operational day are less than the primary delay (implying some turnaround/buffer recovery, any cost benefit of which has not been assessed in this paper). The marginal maintenance costs are thus limited to the original delay (probably encountered at the previous gate).

For delays *greater* than the critical level, additional minutes will be encountered during the rest of the day. For an aircraft with a primary delay of 68 minutes (mid-point of the 61-75 range), approximately 77 minutes (1.13 x 68) of rotational reactionary delay will be encountered, i.e. an *additional 9* minutes relative to the original (inbound) delay. This means that, on average, an extra 9 minutes of maintenance at-gate costs should be added to the reactionary costs. (In theory, these minutes could be incurred during the airborne phase, but this is rather less likely).

For crew costs, a further complication arises, regarding on which subsequent rotation(s) reactionary delays are encountered, and when crew changes occur. In order to simplify the crew calculation somewhat, it will be assumed that all the reactionary delay occurs during the first turnaround after the (inbound) primary delay, and that the crew on short-haul (narrowbodies) are the same on both legs but crew on long-haul (widebodies) are changed.

For delays below the critical level, narrowbody crew costs are set according to the rotational reactionary delay cost only (i.e. taking into account the recovery – thus based on a value of 50 minutes only in the first example), whereas for widebody crew, the costs are the sum of the primary and the rotational reactionary costs (53 + 50 minutes[18]). For delays above the critical level, the same costing mechanism is applied, the resulting difference being that in this case the reactionary delay cost applied for crew on narrowbodies is *greater* than the primary cost (77 minutes applied instead of 68 in the second example; 68 + 77 being applied for widebodies[19]).

3.2.2.2 Non-rotational reactionary costs

The non-rotational reactionary costs are more straightforward to allocate. Returning to the example of the 53 minute primary delay, it was detailed how 66 minutes of additional, reactionary delay would be generated in total. 50 of these 66 minutes are rotational

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[18] In practice, costs on some of these 50 minutes of crew may be avoided, for example by crew being clocked-on later for duty. This is beyond the scope of the current discussion, such that the simplifying assumption is made of allocating the full cost.

[19] The same principle applies for these 77 minutes as for the 50 minutes in the previous example.

reactionary delay. 16 of these 66 minutes are experienced by other aircraft: non-rotational reactionary delay. In this cost estimation, it will be assumed that these are all experienced by secondary aircraft waiting at gates for the causal aircraft. No modelling of passenger or crew dependencies between the secondary and causal aircraft is included. Each non-rotational reactionary delay is thus treated as a new, at-gate delay.

In terms of estimating typical aircraft connectivities in Europe, two approaches suggest themselves. One is to examine permutations of origin and destination via all possible airports with agreed Minimum Connection Times (MCTs), using OAG data. This would be a very large computational task, however. The case of Heathrow to Schiphol, then onward to any point in Europe, with a three hour MCT at Schiphol, alone generates over 4000 possibilities[20]. Obtaining actual booking data from Global Distribution Systems (see Annex) would be equally time consuming and prohibitively expensive.

Table 10. Non-rotational reactionary aircraft connectivities

Aircraft	Percentage of connections
B737-300	11.5
B737-400	3.0
B737-500	7.9
B737-800	18.8
B757-200	2.2
B767-300ER	1.6
B747-400	1.6
A319	16.3
A320	24.9
A321	8.4
ATR42-300	1.1
ATR72-200	2.7

Table 10 shows the result of a rather more straightforward approach, whereby the twelve aircraft selected for this research, have each been assigned a relative percentage connectivity rate for Europe. These aircraft actually represented 46.7% of all IFR flights in EUROCONTROL-controlled airspace in 2006, EUROCONTROL (2007a). Taking the top-half of these aircraft in terms of flight frequencies (A320, B737-800, A319, B737-300, A321 and the B737-500, in order), these were re-weighted to make up the total distribution to 100%, thus avoiding undue domination by the less common aircraft of Table 10.

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[20] Personal communication, OAG.

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Whilst such flight frequencies cannot be guaranteed as a representative estimate of connection frequencies, this seems to be a reasonable approach. Of course, reactionary costs may be experienced by other aircraft in the system than those with connecting passengers from the causal aircraft, which further complicates matters, but strengthens, rather than weakens, this method. For non-rotational reactionary costs, the costs are thus derived as the appropriate per-minute, at-gate costs proportioned over the distribution of aircraft in Table 10.

3.2.3 Concluding note on reactionary multipliers

It is suggested that the method proposed in this paper for calculating reactionary costs be further enhanced in future research. Whilst reasonably robust, further analysis using CODA data would be of benefit. Second-order effects (rotations of aircraft after the first reactionary rotations) also need to be examined in more detail and the opportunity remains to study the passenger and crew dependencies between delay-impacted aircraft.

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Annex

Interline settlements and involuntary reroutes

When it becomes necessary to reaccommodate passengers in response to disrupted operations, a number of special rules come into play. These relate to:

- transferability of tickets between carriers, which are not transferable during normal operational conditions;

- interline settlement of revenues which are due to the new receiving carrier – a complicated and often time-consuming process which makes dynamic assessment of rebooking costs very difficult;

- physical processes of rebooking passengers onto new receiving carriers.

Airlines involved in the interlining[21] of passengers depend on IATA's settlement agreements to determine the revenues accrued, this being known as the Multilateral Prorate Agreement. Manual settlement on interline ticket coupons is carried out by IATA. These interline settlements go through the IATA 'clearing house', with quite a high offset ratio[22] – in 2006, this was 78% (IATA, 2007). Interline revenues account for around 15% of carriers' revenues (Airline Solutions, 2008). A number of non-IATA carriers also use this settlement system. A faster process is offered by the Interline Data Exchange Centre (IDEC), which was established by IATA in 1981. It is operated by the Airline Tariff Publishing Company (ATPCO), using standardised, electronic versions of flight coupons, now with a focus on processing e-tickets.

Complete transition to weekly clearance cycles commenced in June 2007, having previously been monthly. An analogue of this, the Billing and Settlement Plan, interfaces between IATA-accredited travel agents and the airlines, with gross sales volumes of USD 187 billion in 2006 (IATA, 2007) through 80 'BSP' centres. An internet-based system, called 'BSP*link*', also operates.

As opposed to voluntary reroutes, discussed above, 'involuntary reroutes' describe the situation whereby a passenger is obliged[23] to travel on a different flight because the original service is delayed at its origin, because an onward connection is missed, or because a flight is cancelled. Since most tickets sold are on a restricted fare basis, they need to be endorsed by the original carrier to the receiving carrier before the passenger can check in with the new carrier. Such endorsement can only be made if the new receiving carrier accepts the change (see also discussion of 'endorsement waivers', below).

The basic principles laid down by IATA (2002) are that the new receiving carrier will receive the value of the flight coupon of the original carrier (for that segment, by proration). In

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[21] Whereby one carrier issues the ticket and collects the (initial) revenue, with one or more other airlines involved in the transportation.
[22] Whereby transactions are cancelled out without any actual cash transfer.
[23] If still wishing to make the journey. The passenger may, of course, decline any offer made.

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'Declared Interline Prorate Values – a concept for a new prorate methodology' (IATA, 2006) a new method for proration is proposed, using pre-declared interline prorate values. The principles would extend to involuntary reroute settlements, the main difference from the current system being that settlement amounts would no longer be linked to the fare level but be based on pre-agreed flat-rate values for individual segments, used to apportion the fare residual after the first (undisrupted, flown) segment has been accounted for. In essence, the new system is designed to "take the guesswork out of pricing decisions" and to formalise practices already common between airlines. Indeed, interline agreements, such as endorsement waivers (see below), may already extend to agreeing amounts to be paid to the receiving carrier in the case of an involuntary reroute, which will affect the way the coupons are treated when the interline settlement is made (including if this involves processing a Flight Interruption Manifest).

Involuntary reroutes often involve the issue of a Flight Interruption Manifest (FIM). This is a substitute ticket issued when the original coupon is not available, detailing one or more passengers to be transferred from one airline's flight to that of another, usually due to a disruption such as a delay. Use of FIMs when the original coupon is available is strongly discouraged by IATA (the system is considered by some to be open to misuse).

This situation is becoming ever more impractical with the increasing prevalence of e-tickets, which already heavily dominate many markets. In numerous cases, these still have to be first converted into a paper coupon, before they can be processed into an FIM (the original routeing and ticket numbers are needed for settlement, as well as the new details).

The issue of involuntary reroutes is such an important one that IATA publishes its own guidance for airlines on how to handle such situations – 'Airline Guide to Involuntary Rerouting' (IATA, 2002). Appendix A of the guide (Resolution 735d), describes how a receiving carrier is compelled to accept an endorsed ticket, regardless of whether it was originally marked as non-endorsable. However, the terms and conditions of carriage of many carriers clearly do not extend this far – it is more likely that the passenger will have to wait for space on a subsequent flight of the original carrier, or may be reaccommodated by a code-share or alliance partner.

In addition to this level of complexity, the carrier affected by a disruption may simply opt to re-ticket the passenger (especially high-yield passengers, such as members of a frequent flyer programme), or the passenger could elect for a 'voluntary' reroute, i.e. unilaterally decide to board another plane, if their ticket will allow it (as discussed above). In any case, the endorsement (or new booking) could be with a confirmed seat, or only on a standby basis. The Passenger Name Record (PNR) must be updated, with the original segment cancelled and the new one entered, including the new fare calculation[24].

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[24] Governing booking processes in general, it is worth noting that there are two types of interline agreement: the multilateral interline traffic agreement (MITA) and the interline traffic *participation* agreement (known as 'MITA one-way'). MITAs allow carriers to sell transportation over the routes of other airlines that are members of the MITA. A carrier can either be a MITA one-way issuing airline, or a MITA one-way participating airline. An 'issuing' airline can sell the tickets of a 'participating' airline over their routes; a 'participating' airline accepts an 'issuing' airlines' passengers for transportation. The agent can see the pairs of agreements between airlines in the GDS, including whether these extend to e-ticketing and if exceptions apply. An issued ticket will always show the validating carrier.

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Whilst practice varies from airline to airline (indeed, it may vary according to who is on duty in the transit area; airline staff are not always fully conversant with all the rules), small numbers of rebookings may reliably be made through a Global Distribution System (GDS), whereas for the reaccommodation of larger numbers of passengers the airline is more likely to telephone the receiving carrier first to protect/check the seats, rather than rely upon system availability[25]. As will be discussed later, the receiving flight might already be under 'airport control', such that making new bookings externally may be difficult.

Facilitating this process, 'endorsement waivers' often exist between code-share partners and/or within alliance networks, such as that established within the Star Alliance, specifically in respect of IATA Resolution 735d for practically[26] all types of ticket, including restricted and even frequent-flyer redemption tickets. This will often mean that the rebooking of delayed passengers within an endorsement waiver context can be carried out using a GDS, whereas endorsements and FIMs also require manual intervention. Progress is being made towards making FIM and (e-ticket) endorsement processes fully electronic. In the absence of such complete automation, the complexities of both rebooking cost estimations and the physical process of reaccommodating passengers is apparent.

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[25] IATA recommends ('Airline Guide to Involuntary Rerouting', Para 3.4.1 (c)) that airlines should not use CRSs / GDSs for transferring passengers in an "irregular operation" such as involuntary reroute. Verbal confirmation should instead be sought, to prevent these abnormal booking patterns from causing the receiving carrier's flight to become oversold, it is stated.

[26] The Star Alliance only excludes industry discount ('ID') tickets.