Abstract

Employing primary and secondary data, a European, aggregate ‘hard’ cost model is developed for the airline cost of passenger delay. These costs are then newly modelled as a function of delay duration, quantifying how longer delays have higher per-minute costs. Passenger ‘hard’ plus ‘soft’ costs of delay typically dominate other delay costs (e.g. associated with crew and maintenance). Integrating disruption management techniques into flight planning presents major cost-saving opportunities. A shift in air traffic management strategy from managing delay minutes to delay costs, including those of emissions, is required if true 4D/‘business’ trajectories are to be realised.

Keywords: cost of delay, passenger, disruption management, 4D trajectories, emissions

1 Introduction

1.1 Components of the cost of delay

The cost of delay severely impacts airline profitability. As will be demonstrated, the major component is typically that associated with delayed passengers, although it is generally poorly quantified. This paper focuses on the ‘hard’ airline costs resulting from passenger delay, such as those due to passenger rebooking, compensation and care. Although potentially difficult to ascribe to a given flight due to accounting complications, these are, in theory at least, identifiable deficits in the airline’s bottom line.

‘Soft’ costs manifest themselves in several ways. Even with no experience of an airline, a passenger may perceive it to be unpunctual and choose another, instead. Due to a delay on one occasion, a passenger may defect from an unpunctual airline as a result of dissatisfaction (and maybe later come back). 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 (Cramer and Irrgang (2007), Cook et al. (2004)).

This paper will derive passenger hard cost models, drawing on a combination of primary and secondary data, and then compare these with other delay costs, which we have reported elsewhere – i.e. soft costs of passenger delay, crew and maintenance costs, plus fuel costs and future emissions charges. For passenger 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 dissatisfied as the result of a longer delay than a shorter one.

1.2 Managing delay costs

Airlines have windows of opportunity for mitigating against, and managing, delay costs, as illustrated in Table 1.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic</td>
<td>Resources committed at planning stage: advance contingency for delays</td>
<td>Buffers in schedules: large enough to absorb tactical delays, but without over-compromising utilisation of aircraft/crew</td>
</tr>
<tr>
<td>Pre-departure</td>
<td>Slot management process. (Also decision point for fuel uplift.)</td>
<td>Re-route: accepting/filing a longer route to bring a departure slot forward</td>
</tr>
<tr>
<td>Airborne</td>
<td>Speed/route adjustment; depends on: ATC, weather, fuel uplifted</td>
<td>Change of cost index(^1); request to ATC for change to filed plan</td>
</tr>
<tr>
<td>Post-flight</td>
<td>Aircraft, crew and passenger delay recovery</td>
<td>Re-booking delayed passengers. (Potential of associated ‘soft’ costs.)</td>
</tr>
</tbody>
</table>

Disruption management is a vital component of airline operations\(^2\). It may focus on the ground-based recovery of operations, which have become misaligned from the strategic plan, and rarely extends to a properly costed recovery in the airborne phase. A major challenge facing the industry is the integration of disruption management techniques (and the supporting tools that are commercially available) 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”. Narasimhan (2001) also offers a succinct summary of the challenge: “In most airlines … applications are not deeply integrated. This implies that two groups doing their individual best could actually be working against each other.”

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1 The cost index is a parameter set in the cockpit, which determines how the flight management system will control the aircraft. It quantifies the choice to fly faster to recover delay, or to fly slower to conserve fuel.

2 Substantial reviews of the literature are furnished by Bratu and Barnhart (2006) and by Kohl et al. (2007).
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.

In the next sections, aggregate hard costs are first derived for the cost of passenger delay to airlines. These costs are next distributed, using new models, as a function of delay duration. Consideration is then given to these costs in the wider cost of delay context, and, finally, regarding delay recovery and cost management.

2 Estimating the hard 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 of the results is shown in Table 2.

Table 2. Three scenarios for passenger hard costs to the airline, for 2003

<table>
<thead>
<tr>
<th>Cost type</th>
<th>Low</th>
<th>Base</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard cost</td>
<td>0.096</td>
<td>0.120</td>
<td>0.144</td>
</tr>
<tr>
<td>Relative to base</td>
<td>-20%</td>
<td>+20%</td>
<td></td>
</tr>
</tbody>
</table>

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

Costs are Euros (2003) per average passenger, per average delay minute, per average delayed flight

Since 2003, however, a significant change to the way these costs are addressed by regulation has 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, per se. It applies to any flight departing from the EU and to all flights operated by EU carriers from or to an EU airport. As will be discussed, the Regulation affects both hard and soft costs of passenger delay to the airlines.

3 Lower values were applied for delays of up to 15 minutes.
4 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).
5 For a calculation of soft costs in general, including a discussion of the impact of the Regulation on these, and of passenger awareness of delay, see Cook et al. (2009).
What of the quantitative evidence of how this has affected hard costs? 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. Jovanović (2008) cites numerous industry estimates of the cost impact of the Regulation, pointing out that these do not appear to be evidence-based (complaints rates are more transparent, however: in early 2006, Air France reported an increase of 60%). Only exceptionally rarely can airlines track such costs.

The true costs of handling a disruption will not be apparent to an airline’s revenue management (or yield control) department until some time after the event, and 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). Whilst Jovanović (2008) cites an annual European estimate made by IATA, specifically of compensation, no general industry source (including IATA, but excluding the airlines – see next section) directly approached as part of this study was able to provide any more specific quantitative data on delay costs.

2.2 Building the aggregate hard cost scenarios

In the context of disruption management, 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 former (henceforth “Airline X”) reported that the costs resulting from meal vouchers, hotel accommodation, tax-free vouchers, frequent-flyer programme miles and phonecards were 25-50% higher just after the Regulation, as compared with the accounting year prior to the Regulation. We will label these costs collectively simply as “care”. The costs of rerouting/rebooking passengers (possibly with upgrades), ticket reimbursements and compensation (which we shall collectively label simply “reaccommodation”) were not included in these cost estimates, although frequent-flyer miles and ticket discount voucher costs were included.

2.2.1 The base cost scenario

Whilst the 25-50% increase cited by Airline X refers to care costs, in the absence of further data it is difficult to estimate the effects on the other hard cost category, “reaccommodation” (which includes reimbursement). With regard to delay, Regulation 261 offers rights relating both to care and also to reimbursement, the latter applying if a flight is delayed by five hours or more and the passenger decides not to fly (a flight back to the point of origin, if applicable, is also required). With the Regulation directly conferring reimbursement rights, it might be reasonably expected that such costs (or those of alternative airline action) have similarly increased. For both major European carriers from whom data were collected by Jovanović (2008), it was reported that of the passengers who were delayed for five or more hours (and thus entitled to reimbursement), typically fewer than 10% opted for this, whereas the range cited for rebookings onto other carriers (not required by the Regulation) was 10-50%.

This may reflect a tendency by many airlines to get passengers to their destination rather than reimbursing them (the Regulation does not confer compensation rights as a result of delay, as

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6 Although the interline settlement process can be achieved through a number of systems, it typically takes several weeks.
7 The identity of this carrier is known by the authors of this paper, with permission.
an alternative). This tendency is doubtless driven by passenger preference, having already committed to the journey. On the assumption that Regulation 261 (or, more specifically, the airlines’ response to such improved passenger rights) has increased both care and reaccommodation costs, without a disproportionate increase in one over the other, these calculations will apply a common increase across all hard costs. Future research may justify an adjustment to this assumption.

Therefore, to produce 2008 cost estimates from the base costs scenario for 2003 of €0.12\(^8\), rounding off the range of 25-50% calculated by Airline X to 20-50% produces crude 2008 values of €0.14 – €0.18, with an average of €0.16. Adopting this average value of €0.16 as a base cost, a correction for inflation (see footnote 9) should also be applied, before and after the two years to which the 20-50% range relates, for the overall period 2003-2008. This produces a final value of €0.18 for the 2008 base cost scenario.

2.2.2 The high cost scenario

As a first step towards estimating a high cost scenario value, taking the upper value of €0.18 (from the €0.14 – €0.18 range), and making a similar correction for inflation either side of the 20-50% 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 had a higher average cost increase than this 50%. 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 Regulation 261 came into force. As alliance and code-share structures have deepened, and interline ticketing agreements along with them, the ability to effect 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), many of these factors combine to mitigate costs from prescribed programmes of customer care and the increased likelihood of departure delays resulting from the operation of a complex network. The latter does not generally apply to the business model of low-cost carriers.

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. Adopting this 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 2.

2.2.3 The low cost scenario

For the low cost scenario, it is proposed that the 2003 value of €0.096 (see Table 2) be more simply factored up to a 2008 value. EUROSTAT compounded ‘Euro area’ inflation\(^9\) for the

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\(^8\) See Table 2: per average passenger, per average delay minute, per average delayed flight. This full qualification of the cost is not repeated after each value to avoid undue clutter in the text.

\(^9\) ‘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 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”.
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 midpoint 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% less than the lower value in the original range of €0.14 – €0.18, 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. 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 (see Table 1); the opposite effect is generally seen in Europe, however (see Section 4.1.1).

2.2.4 Summary of hard cost scenarios

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

<table>
<thead>
<tr>
<th>Cost type</th>
<th>Low</th>
<th>Base</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard cost</td>
<td>0.11</td>
<td>0.18</td>
<td>0.22</td>
</tr>
</tbody>
</table>

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

Table 3 summarises the aggregate hard cost scenarios. The high cost scenario adopted is 2.0 times the value of the low cost value. In other ‘hard’ cost calculations on the effect of crew delay costs (summarised in Section 4.1.2), the European ratio for high to low cost scenarios averaged over captains and first officers over twelve aircraft types was also 2.0, lending some further support to the general plausibility of this ratio. The asymmetry around the base value is intentional, and will be echoed in the soft scenarios summarised next.

2.2.5 Soft cost scenarios

This section sets aggregate soft costs in the context of the corresponding hard costs developed in the previous section, such that a total cost of passenger delay to the airline may be produced. In 2008, another full-service, European carrier operating several hubs, and one of only a very small number of airlines known to be modelling passenger delay costs, disclosed to the research team an estimate that its hard and soft costs were approximately equal. The base cost scenario for the soft cost is thus set at €0.18 per average passenger, per average delay minute, per average delayed flight, i.e. equal to the corresponding hard cost. This is also in line with previous (1999) estimates from Austrian, of soft costs being 60% of total passenger costs: the increasingly price-driven marketplace likely to have at least levelled this ratio out. In the absence of any appropriate quantitative findings published, assigning soft costs for the low and high cost scenarios is more a matter of judgement.

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10 This airline also preferred not to have its identity disclosed.
11 Personal communication with Austrian (Airlines) following reporting by Nichols and Kunz (1999).
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. The European market for air travel has become increasingly price-driven. Increased distribution through the internet has helped to keep fares low and competition high. 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) review such changes and investigate superior methods now required for customer segmentation, also noting that “there is reason to believe that the once believed match between [frequent-flyer programme] and business passengers is at least partly diluted”. Furthermore, despite a worsening of actual delays experienced, in their discussion on UK Air Transport Users’ Council complaints data, Cook et al. (2009) support the view that there has been no recent marked increase in passenger sensitivity to delay.

Routes with strong competition may encourage high switching rates yet 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 (relative to the hard cost) and no increase at all: yielding a value of € 0.20. This sets a higher value than the base cost scenario, allowing for a carrier with a higher cost base to be more heavily impacted by soft costs. Not setting a fully proportional increase relative to the hard cost allows higher ‘investment’ (voluntary or regulation-induced) in hard costs to off-set such soft costs: the more the airline spends looking after disrupted passengers, the less likely they are to defect.

The low scenario for hard costs 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 rather lower than the soft cost base scenario, for example through effects such as those suggested by Wittmer and Laesser (2008): 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. Low-cost carriers may act as a type of low-cost ‘sink’ in the short-haul market, operating out of less congested (more punctual) secondary airports. Also, carriers with low cost bases are likely to be impacted relatively less in terms of gross revenue loss per defection. In conclusion, selecting as a low scenario value for the soft cost a mid-point between half the high cost and the unlikely zero-cost option, gives € 0.05.

2.2.6 Summary of the aggregate passenger costs

Table 4. Three cost scenarios for passenger hard and soft costs to the airline

<table>
<thead>
<tr>
<th>Cost type</th>
<th>Low</th>
<th>Base</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard cost</td>
<td>0.11</td>
<td>0.18</td>
<td>0.22</td>
</tr>
<tr>
<td>Soft cost</td>
<td>0.05</td>
<td>0.18</td>
<td>0.20</td>
</tr>
<tr>
<td>Total</td>
<td>0.16</td>
<td>0.36</td>
<td>0.42</td>
</tr>
</tbody>
</table>

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

As per the hard cost high:low ratio of 2.0.
In summary, the base cost scenarios presented in Table 4 are derived from independently concurring sources (two European airlines) on total passenger costs for a 2003 reference base. Two airline sources have also been used to rationalise the equal (base scenario) 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. 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.

Overall, the total 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 Distributing the hard costs as a function of delay duration

Having derived the hard and soft aggregate costs, it is now necessary to distribute these as a function of duration of delay. Longer delays will tend to have higher per-minute costs than shorter ones. This paper derives new distribution models for hard costs. Previous work on soft cost distribution is summarised for comparison.

In this section, care costs reported from one airline as a function of delay duration will be consolidated with a theoretical distribution of reaccommodation costs, in the absence of any previous model or appropriate data for the latter. The primary constraint applied is that the aggregate hard costs of Section 2.2 are respected. Two indicators of the integrity of the unified model developed are the magnitude of a ‘corrective weighting’ factor required to consolidate the care and reaccommodation costs, and also the ratio of these two costs – such that one does not too heavily dominate the other.

3.1 Care costs by delay duration

Table 5 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 gives an initial estimate of costs per minute (final column).

As a further trend to be remarked upon again later, it is noted that the data in the final column of Table 5 give a good linear fit against delay duration ($r^2 = 0.95$; Figure 1). Although only triggered at higher delays (first range in Figure 1 is 90-120 minutes), these costs still contribute to the grand mean of €0.18 / min (base scenario, Table 3) per average passenger, per average delayed flight.

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13 Using the mid-point of each range (lower limit of 90 minutes assumed) and 5 hours for upper limit.
Table 5. Average care costs per delayed passenger

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 2 hours</td>
<td>Refreshment (bottle of water)</td>
<td>1.5</td>
<td>0.02</td>
</tr>
<tr>
<td>2 – 3 hours</td>
<td>Tax-free voucher and phonecard</td>
<td>7.0</td>
<td>0.05</td>
</tr>
<tr>
<td>3 – 5 hours</td>
<td>Tax-free voucher, meal voucher, phonecard &amp; frequent-flyer miles</td>
<td>17.2</td>
<td>0.08</td>
</tr>
<tr>
<td>Over 5 hours (no hotel)</td>
<td>Tax-free voucher, meal voucher, phonecard, frequent-flyer miles &amp; ticket discount voucher</td>
<td>19.2</td>
<td>0.13</td>
</tr>
<tr>
<td>Over 5 hours (with hotel)</td>
<td>Tax-free voucher, meal voucher, phonecard, frequent-flyer miles, ticket discount voucher &amp; hotel accommodation</td>
<td>75.0</td>
<td></td>
</tr>
</tbody>
</table>

Primary source: Jovanović (2008).

When the values in Figure 1 are weighted by the delay probabilities for each category, their contribution to the grand mean is very small, since delays above 90 minutes constitute only approximately 5% of all delays in Europe (as may be seen later, in Table 6).

![Graph of 'Simple' costs of care provision per minute by duration of delay](image)

Figure 1. ‘Simple’ costs of care provision per minute by duration of delay

It is unlikely that either these care costs, or reaccommodation costs, will dominate the overall airline hard costs too heavily. Exploring the potential consolidation of the cost models of this paper into a unified model, a lower value of 20% is proposed for the contribution of care to the total hard cost. (This will vary from airline to airline, but is unknown for Airline X.) The primary modelling constraint applied is that the grand mean values generated for the hard costs, when costs in various delay ranges (e.g. Table 5) are weighted by their respective delay probabilities, are the same as those of Table 3 (e.g. € 0.18 / min for the base scenario).

To satisfy this set of constraints, a ‘corrective weighting’ needs to be applied to the care costs of Table 5. If this ‘corrective weighting’ is applied across each delay band of Table 5 at a flat rate, the value required is 2.6. How can this value be interpreted? It may be described as the 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.

Of course, Airline X records the correct level of delay for such passengers, such that the values in Table 5 remain valid. However, multiplying the “simple” per-minute values (final column) by the corresponding number of delayed flights in each delay range will underestimate the correct grand mean, without the use of the appropriate ‘corrective weighting’.

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. These 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. Sherry et al. (2008) concur that “flight delay data is a poor proxy for measuring passenger trip delays”. Based on a model using 2005 US data, they conclude that the average passenger trip delay is 34 minutes longer than the average flight delay (53 minutes). This suggests a factor of just over 1.6. This is a single-segment model, i.e. connecting flights are not (yet) included. This may have led to an underestimate of the true value. Combined with decreasing buffers in airline schedules in Europe (see Section 4.1.1), the value of 2.6 for the passenger-centric ‘corrective weighting’ factor above, appears to be plausible. The general superiority of passenger-centric metrics is of significance for delay measurement, although flight delays are still the only commonly-reported type of metric in both the US and Europe. The former also better capture the true impact of diverted and oversold flights.

### 3.2 Adding in the reaccommodation costs by delay duration

Turning next specifically to the modelling of reaccommodation costs as a function of delay duration, a form of distribution is required that starts off at a very low value and then rises as a cost per minute at higher delays. 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 5), a peak could be expected at 5 hours. Before or after this limit, it may be decided that some passengers will require overnight accommodation; they may actually be rebooked the next morning, or overnight. In any case, the rebooking cost itself may be notionally allocated to a cut-off point of 5 hours, costs still thus increasing towards this point, then saturating. The simple theoretical function as shown in Equation 1 has been used.
Equation 1

\[ c_R = k \cdot \ln t_D^2 \]  

\( c_R \): reaccommodation cost (€/min)  
\( t_D \): time (delay, mins)

In Figure 2, the value of \( k \) is chosen such that: (i) the contribution of the care costs to the total is 20% (as in the previous section); (ii) the flight-proportion-weighted grand mean is € 0.18 / min (required for all base scenario cases).

With this theoretical function for the reaccommodation costs, we are at liberty to specify points across evenly distributed delay ranges (explicitly given later, in Table 6). The four bands in Table 5 are used to populate the care costs, two of these being equal in the 3-5 hours range, giving five points in all.

Setting care costs at 50% of the total hard costs\(^{14}\) gives the cost distribution shown in Figure 3. Under these constraints, the weighting factor necessary for the Table 5 data is around 9, which is, prima facie, too high. This could be attributable to a number of reasons. It could suggest that the data of Table 5 are not consistent with care costs contributing 50% to the total of the hard costs. It could suggest that the data of Table 5 are not consistent with a flight-proportion-weighted grand mean of € 0.18 / min for Airline X. It could suggest other incompatibilities between the models. Regarding the (too high) weighting factor required under these constraints, we are reminded that the application of a common weighting factor across all care costs is rather crude, particularly as marked non-linearities may arise with higher delays. Much more detailed data would be needed before this could be addressed, however.

A report from the Institut du Transport Aérien (2000) was the only published source found to give a quantitative indication of the ratio\(^{15}\) of various passenger costs to airlines as a result of

\(^{14}\) Increasing the passenger-centric corrective weighting factor and reducing \( k \), but still fixing the flight-proportion-weighted grand mean at € 0.18 / min.

\(^{15}\) Actual costs and airline sampling basis not specified.
Comparing ‘rerouting and compensation’ (‘reaccommodation’) with ‘food, drink and miscellaneous’ (‘care’) expenditure, gives a ratio of approximately 30%:70%. It is unclear, however, how the 70% care value may have changed over the past decade or so, or how representative it is of European operations.

In Figure 2, reaccommodation dominates the costs at high delay; in Figure 3, care costs dominate. Each airline will have its own cost curves, which will 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 at some other hub, which may be able to rebook passengers onto alliance partner flights, for example.

### 3.3 Selecting the final hard costs for each scenario

In Figure 4 these total hard costs are explored further, plotting a number of curves together for comparison, to aid the selection of the best options for final adoption. Care costs at a maximum of 50% are used as a compromise towards the (older) value of 70% suggested by the Institut du Transport Aérien, yet still mindful of the uncertain implications for the weighting factor. On the one hand, this weighting factor reflects the cohesion of the various cost models we are attempting to consolidate, on the other hand, we cannot dismiss a value of 50% without further research, as discussed. The minimum care percentage of 20% is used, as before.

The plots of figures 2 and 3 are based on the base cost scenario. Both of these care assumptions (20% and 50%) are re-plotted in Figure 4 (dashed lines). To reduce clutter, curves for the low\(^{16}\) and high\(^{17}\) cost scenarios are plotted as the average of the ‘care at 20%’ and ‘care at 50%’ calculations. This average is also shown for the base scenario.

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\(^{16}\) Grand mean of € 0.11 / min, Table 3.

\(^{17}\) Grand mean of € 0.11 / min, Table 3.
At higher delay, the base scenario with care costs forming 50% of the total hard costs (upper, dashed black line), follows closely the care-averaged distribution for the high cost scenario (upper grey line). This ‘care at 50%’ base scenario is thus probably rather too high to be used as the adopted base scenario. The care-averaged base scenario distribution (solid black line), however, seems to be a suitable choice for the adopted base scenario. By similar inspection, the care-averaged low and high scenario distributions are selected as appropriate to take forward to the next stage of these calculations, in the following section. The ratios of these adopted sets of care-averaged base, high and low values are the same as the ratios of the hard costs in Table 3.

In summary, in order to distribute the hard costs of passenger delay to the airline as a function of delay duration, an empirical source of care costs (Table 5) has been combined with a theoretical distribution of reaccommodation costs (Equation 1). Within the limitations of the available data, attention has been paid regarding the credibility of the associated passenger-centric corrective weighting factor, and that neither care nor reaccommodation costs dominate too heavily.

The adopted costs per minute for each of the scenarios, over a range of delay periods, are given in Table 6. 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 values closest to the respective grand means.

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

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17 Grand mean of € 0.22 / min, Table 3.
Table 6. Passenger hard costs of delay per minute, by three scenarios

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

Costs are Euros per minute (2008)


However, it is neither desirable, nor realistic, for modelled 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, linear interpolations between the mid-points of each range, thus lying on the individual (linear) segments of the distributions plotted in Figure 4, are suggested as the best point-estimates for a given delay duration. This allows very small costs to be assigned to very small delays, e.g. € 0.053 / min for a 5-minute delay.

Although minimum connection times at an airport are likely to 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 the zero-cost baseline assumed.

3.4 Adding in the soft costs: producing passenger costs per-aircraft

For soft costs of delay to the airline a different type of distribution (a logit function) is used by Cook et al. (2009) to express the propensity, ‘Π’, of a passenger switching from a given airline, to some other choice, after trips with delay experiences from 1 to 300 minutes (as per Table 6). Quantification of the saturation of delay inconvenience and crossovers in Kano satisfaction factors\(^{18}\) contribute towards the model. Relationships between market share, punctuality and customer satisfaction are also examined.

This distribution (see Figure 5) is used to assign the three (aggregate) soft cost scenarios of Table 4 across the delay ranges of Table 6 in the same manner applied to the hard costs. For the low, base and high cost scenarios, the grand mean values, weighted by the proportions of flights in each delay range, are therefore € 0.05 / min, € 0.18 / min and € 0.20 / min, respectively.

\(^{18}\) Kano et al. (1984) defines a multi-tier approach to customer satisfaction, using “must-be”, “one-dimensional” and “attractive” requirements.
In Table 7, the hard and soft costs are combined, scenario with like scenario, to give the total passenger costs of delay per minute. In practice, an airline might wish to mix and match these scenarios in delay cost management (see Section 4.2), e.g. assigning the low scenario soft costs and base scenario hard costs to a given flight.

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

<table>
<thead>
<tr>
<th>Delay minutes range</th>
<th>1</th>
<th>16</th>
<th>31</th>
<th>46</th>
<th>61</th>
<th>76</th>
<th>91</th>
<th>120</th>
<th>180</th>
<th>240</th>
<th>300+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost scenario</td>
<td>0.06</td>
<td>0.17</td>
<td>0.26</td>
<td>0.35</td>
<td>0.42</td>
<td>0.47</td>
<td>0.58</td>
<td>0.75</td>
<td>0.89</td>
<td>0.92</td>
<td>1.15</td>
</tr>
<tr>
<td>Base cost scenario</td>
<td>0.13</td>
<td>0.36</td>
<td>0.63</td>
<td>0.89</td>
<td>1.11</td>
<td>1.24</td>
<td>1.47</td>
<td>1.75</td>
<td>1.98</td>
<td>2.03</td>
<td>2.40</td>
</tr>
<tr>
<td>High cost scenario</td>
<td>0.15</td>
<td>0.43</td>
<td>0.72</td>
<td>1.03</td>
<td>1.27</td>
<td>1.42</td>
<td>1.69</td>
<td>2.03</td>
<td>2.31</td>
<td>2.38</td>
<td>2.82</td>
</tr>
</tbody>
</table>

Costs are Euros per minute (2008)

Table 8 shows these values translated into per-aircraft costs for each of twelve supported aircraft types, selected to represent a range of equipment operated in Europe. Drawing on typical seat allocations, using ICAO 2006 fleet data with a sample of over 4000 aircraft, load factors of 60%, 75% and 90% are applied to the low, base and high cost scenarios, respectively, for narrowbodies (short haul). For widebodies (long haul), the load factor applied is 80%. Costs in Table 8 are shown only for the first three delay ranges to save space. These are mid-range values, whereas exact, interpolated values are used in delay cost management computations such as those of Section 4.2; airlines might also wish to mix and match these scenarios by cabin in such calculations.
Table 8. Per-aircraft passenger costs of primary delay, by delay range and scenario

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>1-15 minutes of delay</th>
<th>16-30 minutes of delay</th>
<th>31-45 minutes of delay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Base</td>
<td>High</td>
</tr>
<tr>
<td>B737-300</td>
<td>6</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>B737-400</td>
<td>7</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>B737-500</td>
<td>5</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>B737-800</td>
<td>7</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>B757-200</td>
<td>9</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>B767-300ER</td>
<td>13</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>B747-400</td>
<td>18</td>
<td>41</td>
<td>49</td>
</tr>
<tr>
<td>A319</td>
<td>6</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>A320</td>
<td>7</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>A321</td>
<td>8</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>ATR42-300</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>ATR72-200</td>
<td>3</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

Costs are Euros per minute (2008)

4 The wider context and delay cost management

In terms of disruption management, the principle costs to manage are the passenger costs, which have been derived in sections 2 and 3. To illustrate the dominance of the passenger costs, this section will set these in the context of other delay costs (crew, maintenance, fuel and future emissions charges), which we have derived elsewhere. Such calculations were also undertaken for three cost scenarios (low, base and high) and needed to differentiate between delays in different phases of flight, e.g. at-gate or airborne. Whilst many delay costs differ by phase of flight, passenger costs are a notable exception, since these are only a function of arrival delay. Furthermore, such costs need to be scaled up to the network level, since original delays caused by one aircraft (‘primary’ delays) cause ‘knock-on’ effects in the rest of the network (known as ‘secondary’ or ‘reactionary’ delays). These need to be factored in to any comprehensive assessment of delay costs. Space does not permit us to present the derivation of these other costs in this paper, nor of the detailed calculations of the reactionary costs. Instead, these are briefly summarised in Section 4.1, and the reader is referred to a series of papers produced under work funded by EUROCONTROL, for further information. Section 4.2 then concludes with examples of how these calculations may be used in delay cost management.

4.1 Reactionary effects and non-passenger costs

4.1.1 Reactionary effects

Reactionary delays are generally worse for longer primary delays and for primary delays that 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 not only affect the initially delayed
('causal’) airframe on subsequent legs (rotational reactionary effect), but also other aircraft (non-rotational reactionary effect).

The 2007 European reactionary to primary delay ratio of 0.8 means that for each minute of primary delay, on average, another 0.8 minutes of reactionary delay are generated in the network. (This is often expressed in the literature as a multiplier, 1.8.) This ratio has worsened year-on-year since 2003. EUROCONTROL (2008) suggests that this increased sensitivity to primary delays 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 (previously) strong traffic growth. Increased unpredictability has further compounded the problem.

Rather than multiplying all delay costs by a common factor (e.g. 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 delay trees with schedule buffers included in the delay-tree scenarios. Based in part on this model, the multipliers we have developed quantitatively differentiate between rotational and non-rotational reactionary delays and also take into account the magnitude of the primary delay, thus producing multipliers for each delay range in Table 7 (multipliers not shown).

The use of these reactionary multipliers is not restricted to passenger delay costs, but also applies to marginal delay costs such as those associated with crew and maintenance. Separate methods are required for applying the different types of reactionary multipliers to passenger, long-haul crew, short-haul crew and marginal maintenance costs.

Non-rotational reactionary costs are more straightforward to calculate than rotational reactionary costs. It is assumed that non-rotational delays 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, however. Each non-rotational reactionary delay is thus treated as a new, at-gate delay. These costs are based on European aircraft movement weightings, derived from EUROCONTROL data on flights controlled in 2006 (EUROCONTROL (2007a)).

4.1.2 Crew, maintenance, fuel and emission charges

For crew costs associated with delay (i.e. paying delayed crew more in certain cases), a detailed examination of payment mechanisms for aircraft crew was undertaken. This drew on salary ranges in 2008 and a review was made of flight and cabin crew payment mechanisms for a wide range of airlines. Typical pilot and cabin crew salaries were calculated for various European airlines, using their corresponding payment schemes with typical annual block/flight duty hours, sectors flown and overnight stopovers. Since these calculations relate to delay costs incurred by the airline, on-costs (such as company contributions to crew pension schemes) were included. The base scenario costs derived were proxy rates. These were not the rates at which crew would actually be paid, but instead allowed the determination of an equivalent marginal (block-) hour crew cost to the airline, based on typical operational conditions. These base scenario costs were averaged back over the whole year, allowing typical delay costs to be proportionately spread over crew paid at basic and overtime rates.
For maintenance costs associated with delay (i.e. the mechanical attrition of aircraft waiting at gates, subjected to arrival management, or accepting longer re-routes in order to obtain a better departure slot), marginal, time-based costs were computed from unit costs. These unit costs were derived from in-house data, plus ICAO and Airline Monitor sources. Selected unit (block-hour) costs were processed through a gate-to-gate workload model into marginal at-gate and cruise costs. Fixed costs (such as overheads) were first removed and appropriate cycles-based costs were apportioned across marginal delay minutes, by phase of flight. Per-cycle costs incurred during the highest intensity phases of flight were excluded from the calculations. Fuel burn rates were used as a proxy for workload to apportion the powerplant costs across the phases.

Fuel burn cost calculations were undertaken (in 2008) using the flight planning application Lido OC (Lufthansa Systems Aeronautics), based on operational flight plans. In addition to these direct fuel costs, the future costs of emissions charges were considered. CO₂ from aviation is scheduled for inclusion in the EU emissions trading scheme from 01 January 2012. In its current form, the legislation requires all airlines operating to or from EU airports to surrender permits for the CO₂ emitted. For the airlines, this will result in all fuel use being associated with an additional carbon permit cost. The European Commission has also committed to developing a flanking policy to address NOₓ emissions from aviation by November 2009. Emissions are estimated using the product of the fuel consumed and the emission index (emission per unit mass of fuel). For CO₂, the emission index is a function only of the fuel and can be considered constant across an aircraft fleet. Fuel consumption above 3000 ft was used for the NOₓ calculations; below this level NOₓ emissions are important for air quality considerations but not for climate impact. Estimates of NOₓ emissions took into account aircraft type and route length. For illustration only, costs were sourced from ENVISA (2006), which assigns the climate impacts of CO₂ emissions at € 37 / tonne and those of NOₓ at € 6414 / tonne, for a base case scenario.

4.2 Delay cost management

Figure 6 shows how these calculations may be used to compare at-gate costs with cruise extension costs for a given delay duration, aircraft and cost scenario. In this case, the at-gate (auxiliary power unit and engines off) cost is € 1109, whilst the cruise extension cost is € 1948. The latter is higher primarily due to fuel burn and emissions charges.

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20 Emissions costs can only be an estimate at this time, as the price will depend on the design and implementation of emissions policy.
21 Base cost scenarios are shown, including the reactionary delay costs outlined in Section 4.1.1; cost of fuel (2008): € 0.7 / kg.
The key application of comparisons such as these is for pre-departure operations, e.g. trading the costs of bringing a delayed take-off slot $x$ minutes forward against a re-route that is $y$ minutes longer\textsuperscript{22}, and for informing the process of airspace design. In decision-support for airborne delay recovery, it is necessary to trade accelerated fuel burn costs (and, from 2012, emissions charges) against these costs of delay. Since many airlines have significant barriers to quantifying such delay costs, they may use simple ‘rules of thumb’ to set the value of the cost index (see Table 1). Of the (non-fuel/emissions) components of delay cost (i.e. passenger delay, crew and maintenance costs), it is clear from Figure 6 that the passenger cost dominates (this is usually the case, except for very small delays).

![Figure 7. Net benefit of recovered minutes for a B738 with a 22-minute delay](image)

Figure 7 shows a quantitative example of such a cost trade-off for a B738, which has incurred 22 minutes of delay on a flight from Lisbon to Helsinki. The dashed vertical line (right) represents the maximum number of minutes (19) that may be recovered by employing the cost index at its upper operational setting. The net benefit plotted is the difference between [(cost of delay) – (cost of fuel + emissions)], before and after the delay recovery applied (x-axis). Each curve represents different cost assumptions (from top to bottom: without emissions charges, fuel at € 0.5 / kg; without emissions charges, fuel at € 0.7 / kg; with emissions charges, fuel at € 0.7 / kg). The optimised number of recovered minutes is 12, 11 and 10 for the respective cost assumptions. The plot illustrates, for example, that when fuel is cheaper, it is optimal to recover more time and that recovering the full 19 minutes when fuel is more expensive and emissions charges apply, actually generates a net loss. For the latter assumption, recovering 19 minutes instead of the optimal 10 minutes, for twenty such B738 flights a day, would cause an estimated, relative annual loss of approximately € 6.7 million.

### 5 Conclusions and future work

The cost of delay severely impacts airline profitability. Although the major component is typically that associated with delayed passengers, this is generally poorly quantified. A major challenge, and opportunity, facing the airline industry is the integration of disruption management techniques into flight planning.

\textsuperscript{22} In Figure 6, $x = y = 20$ minutes, as a simple comparison. See Cook et al. (2004) for proper worked examples.
Generic European costs (for 2008) of passenger delay have been derived in this paper to illustrate the magnitude of these costs and their use in delay cost management calculations. The costs estimated could be used, for example, for improved decision-making in delay recovery, superior to many ‘rules of thumb’ currently employed by many airlines. A superior solution would be the calculation of such hard costs dynamically, through the enhancement of existing passenger reaccommodation tools to interface with airborne delay recovery – this could furnish airlines with large savings.

Soft costs of passenger delay are not tractable dynamically. Estimates have been presented in this paper for such costs, although more research needs to be undertaken in this area. This can only be addressed through passenger surveys, ideally using the technique of ‘stated preference’ (conjoint analysis).

There is also a need for further work on reactionary effects, addressing in particular the connection between reactionary multipliers and passenger-centric corrective cost weightings, and higher-order effects in the network. These might be addressed through tail-specific models, which would also ideally examine passenger and crew dependencies between delay-impacted aircraft.

Disruption management processes, including passenger reaccommodation, directly affect aircraft turnaround times. These are a key component of overall air traffic management (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).

The general superiority of passenger-centric metrics is of significance for delay measurement, although flight delays are still the only commonly-reported type of metric in both the US and Europe. Furthermore, a shift in thinking from managing delay minutes to delay costs, including those of emissions, is required. If 4D (or ‘business’) trajectories – flight intentions in position and time being shared by stakeholders – are to be realised through SESAR’s ATM Master Plan, these types of cost, dominated by delayed passenger costs, need to be integrated into future air traffic management.

Acknowledgement

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23 The Single European Sky ATM Research programme, the European analogue of NextGen in the US.
References


