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The Hidden Cost of Airline Unpunctuality

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Abstract

The 'soft' cost of delay — for example, loss of market share due to unpunctuality — is a dominant component in the economics of airline delay. Nevertheless, it remains poorly understood, with almost no quantitative costs published. Drawing on primary survey data and the literature, including Kano satisfaction factors, passenger airline-switching propensity is modelled. Using our peer-reviewed estimate of the average soft cost, we newly estimate its *distribution* as a function of delay duration. Policy implications emerging from the economics of punctuality target-setting and disruption management techniques are discussed. A shift in strategy from managing delay *minutes* to delay *costs* is proposed.

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1.0 Introduction

This paper explores airline cost–benefit trade-offs, focusing on a major cost associated with delayed passengers. A cost of passenger delay to an airline may be classified as either a 'hard' or 'soft' cost. Hard costs are due to such factors as passenger rebooking, compensation, and care. Although potentially difficult to ascribe to a given flight owing to accounting complications, these are, in theory at least, identifiable deficits in the airline's bottom line. Soft costs manifest themselves in several ways. Due to a delay on one occasion, a passenger may defect from 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. Even during economic downturn, unpunctuality may thus cause a reduction in market share, since these markets will never be wholly price-driven. These soft costs can only be properly understood through market research, the focus of Sections 2 and 3.

Since we are quantifying airline cost–benefit trade-offs, we are concerned only with the cost *to the airline* — not wider costs of delay, which may be applicable in contexts such as the full societal impact of delay. Whilst passenger 'value of time' is an important consideration in wider transport economics, costs which do not impact on the airline's business are not included in our calculations.

Although the major cost components of airline delay (delayed passengers, crew, maintenance, fuel, and future emissions charges) may be dominated by passenger soft costs (Cook *et al.*, 2004; Cramer and Irrgang, 2007), almost nothing quantitative has been published on this. The primary objective of this paper is to formulate a viable *distribution* for the passenger soft costs as a function of delay duration, derived in the context of an extensive literature review and new survey work. As will be shown, in airline decision-making on when to use 'accelerated fuel burn' for delay recovery,[1] quantifying passenger soft costs is a vital component of the calculation. We have derived the other cost of delay components elsewhere.[2]

Estimates of future emissions charges have also been included. CO_2 from aviation is scheduled for inclusion in the EU emissions trading scheme from 1 January 2012. A flanking policy from the European Commission to address NO_x emissions is still awaited. The Copenhagen Accord of December 2009 has disappointed those hoping to see better progress towards a global policy on emissions to replace the Kyoto Protocol.

2.0 Passenger Delay

2.1 Exploring the response to delay using a Kano model

One approach to customer satisfaction modelling, the Kano model (Kano *et al.*, 1984), is summarised in Table 1. This defines a tiered description of customer satisfaction

[1]Using a higher cost index in the Flight Management System. An introduction to dynamic cost indexing is furnished by Cook *et al.* (2009).

[2]Space does not permit us to present the derivation of these other costs in this paper. The reader is referred to our series of papers produced under work funded by EUROCONTROL. Please see: www.eurocontrol.int/eec/public/standard_page/proj_CARE_INO_III_Dynamic_Cost.html.

Table 1
Kano Customer Satisfaction Requirement Levels

Factor (requirement) level	*Explanation*
Basic factor (Must-be requirement)	Taken for granted. If unfulfilled, generates dissatisfaction, but if fulfilled, does not lead to increased satisfaction. If absent from product/service, customer will have no interest in it.
Linear factor (One-dimensional requirement)	Customer satisfaction is here proportional to the degree of fulfilment. Usually demanded explicitly.
Premium factor (Attractive requirement)	Large influence on satisfaction: fulfilment leads to more than proportional satisfaction. Neither explicitly expressed nor expected by the customer. If not fulfilled, does not generate dissatisfaction.
Indifferent factor	Customer indifferent to this product feature but not willing to spend more for it.

Source: Adapted from Sauerwein *et al.* (1996).

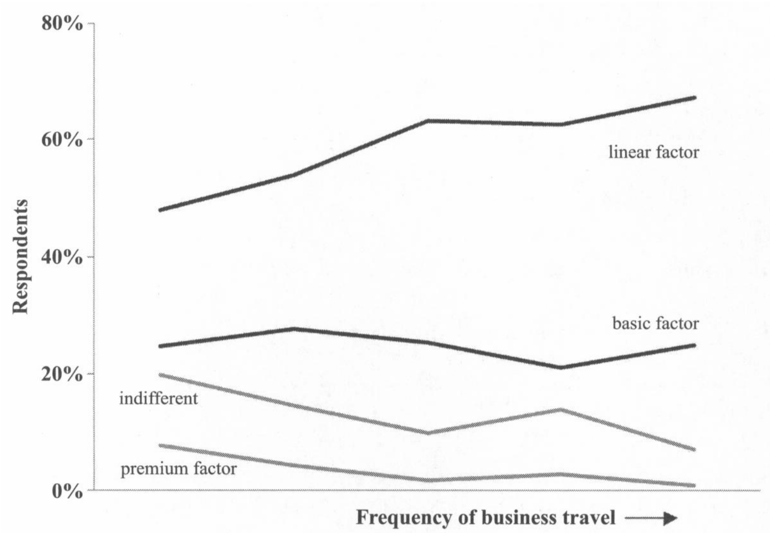
requirements. We have used an alternative terminology with factors instead, with the original terms proposed by Kano given in parentheses under each one. Sauerwein *et al.* (1996) explain in some detail an application of this model for assessing product requirements in terms of customer satisfaction. These authors point out that such requirements are likely to vary by customer segment and that merely satisfying the 'must-be' and 'one-dimensional' requirements will result in a product being perceived as average and therefore interchangeable.

Where does airline delay fit into this picture? Wittmer and Laesser (2008) undertook a survey of 2,834 passengers at Zürich airport over a one-week period in 2006. Respondents were categorised into five groups according to their number of business-related flights per year, to evaluate, using a Kano model, differences in attitudes to delay as a function of the number of such flights taken. If the flight were to be on time instead of having an expected delay[3] of 15 minutes, then for around 25 per cent of travellers this did not create any satisfaction, whereas a greater delay led to dissatisfaction. On-time performance may thus be said to be a basic factor for these passengers. This was quite a flat effect across frequency of travel, as shown in Figure 1. For around half the passengers travelling least often on business (left-hand side of figure), on-time performance was a linear factor in terms of satisfaction, this proportion rising to two-thirds of those travelling most frequently. On-time performance was a premium factor for fewer than 10 per cent of least frequent business travellers and fewer than 1 per cent of most frequent. Responses classified as 'indifferent, questionable or contrary' (labelled indifferent) ranged from 20 per cent (least frequent travellers) to 7 per cent (most frequent).

Indifference and the premium effect both (broadly) fall with frequency of travel. The linear effect increases with frequency of travel, dominating throughout, whilst the basic effect holds at around 25 per cent of respondents. The data for 30 minutes' expected delay are extremely similar to those for 15 minutes, in both magnitude and trend.

[3]Note that expected delays were apparently hypothecated to respondents (rather than allowing them to base responses on their actual expectation of delay) and were not a function of trip length.

Figure 1
Kano Satisfaction Factors for Bettering 15 Minutes of Expected Delay



Note: For definition of terms, please refer to Table 1.

For an expected delay of 45 minutes, if the flight were to be on time, this did not create any satisfaction, whereas a greater delay led to dissatisfaction, for around 15 per cent of travellers. On-time performance may thus be said to be a basic factor for these passengers. This was again quite a flat effect across frequency of travel but notably lower than the 25 per cent for 15 minutes and 30 minutes. At 45 minutes, the dominating effects were (equally) the premium factors and indifference for least frequent travellers, with both of these falling as the linear factor increased, as a function of travel frequency. The picture was broadly similar for 60 minutes' expected delay.

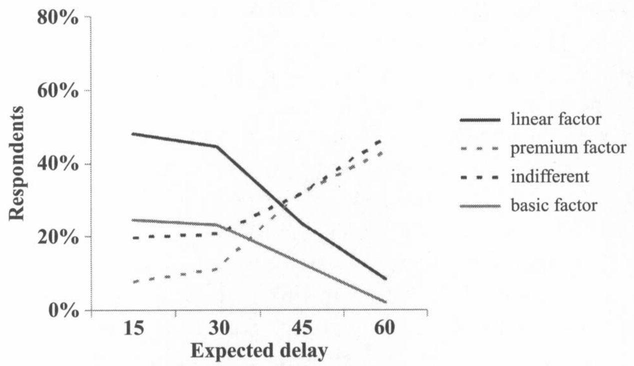
This suggested that the data tabulated by Wittmer and Laesser (2008) could be restructured and plotted for each travel-frequency group as a function of the expected delay. This gave a series of graphs, which demonstrated a smooth transition in pattern, moving successively from the least frequent (Figure 2) to the most frequent (Figure 3) business-purpose travellers. Since the transition was smooth, the intermediate graphs are not shown.

In each plot (all five; three not shown), for expected delays of 15 and 30 minutes, the linear factor dominated, followed by the basic factor. By 60 minutes, in each plot, these effects had fallen off, to be overtaken by the premium factor and indifference. The crossover point, at which the premium factor became the dominant one, by simple interpolation, was later in each of the successive frequency groups (at approximately 42, 48, 49, 51, and 53 minutes, respectively). It is not appropriate to over-interpret the crossover points in an absolute sense, since we do not know the actual power of the premium factor (other than that it exceeds unity). It is clear, however, that as (business) travel frequency increases, the linear effect persists for longer delays.

The premium effect generally falls with increasing frequency of travel for expected delays of 15, 30, and 45 minutes. This could be attributable to relatively substantial delay being already factored in to the travel planning of more frequent travellers or

Figure 2

Kano Satisfaction Factors by Expected Delay, for Least Frequent Travellers



Note: For definition of terms, please refer to Table 1.

more *generalised* disgruntlement at delay levels. The strength of the premium factor at 60 minutes' expected delay for each frequency group, implying that extra delay does not create additional dissatisfaction, indicates that a common saturation of disutility might prevail at such higher levels of delay. (Increased indifference at high delay might be attributable to reduced engagement with the question by some.)

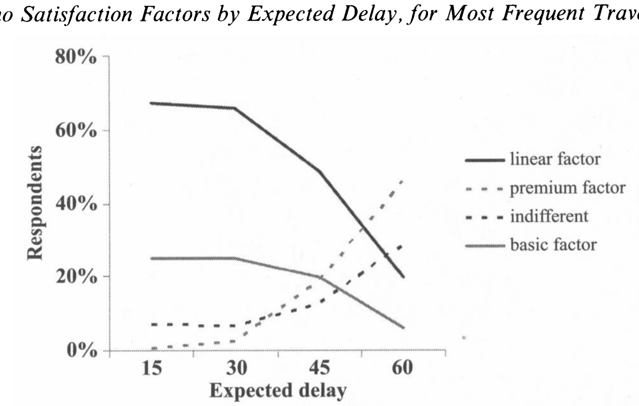
2.2 Punctuality and market share

Flights that are delayed beyond a passenger's tolerance limit are likely to shift the perception of that service into the interchangeable category identified by Sauerwein *et al.* (1996). Switching behaviour, from one airline to another, or from a flight to a different mode or action, is a determinant of airline market share, and hence profitability.

There is, however, little evidence in the literature on how punctuality drives airline markets. Sultan and Simpson (2000) have shown that Americans and Europeans concur on some aspects of service delivery priorities but differ on others. They observed that

Figure 3

Kano Satisfaction Factors by Expected Delay, for Most Frequent Travellers



Note: For definition of terms, please refer to Table 1.

reliability is the common, most important quality aspect. Bieger *et al.* (2008) compared service priorities for passengers flying with traditional carriers and low-cost carriers (LCCs), with punctuality being ranked similarly by both. In a stated preference survey, Teichert *et al.* (2008) interviewed frequent-flyer programme (FFP[4]) members on European short-haul routes, demonstrating punctuality to be a dominating factor across the analytical segmentations.

Suzuki *et al.* (2001) modelled US domestic airline market share as a function of service quality. Previous studies all assume no sudden change of gradient for functions modelling passenger demand as a function of service quality, it is asserted, whereas the utility function *should* be steeper for losses. Only in the authors' asymmetric-response model (based on loss aversion theory) were service quality effects significant at the 5 per cent level. They concluded that if an airline's service quality falls below the market reference point (such as expected service), market share will decrease significantly, whereas a comparable service increase may not correspondingly increase market share. This clearly echoes Wittmer and Laesser (2008).

Dresner and Xu (1995) examined, using two-stage least-squares regression for thirteen major US carriers, the two links ('→') in the relationship:

customer service → customer satisfaction → corporate performance.

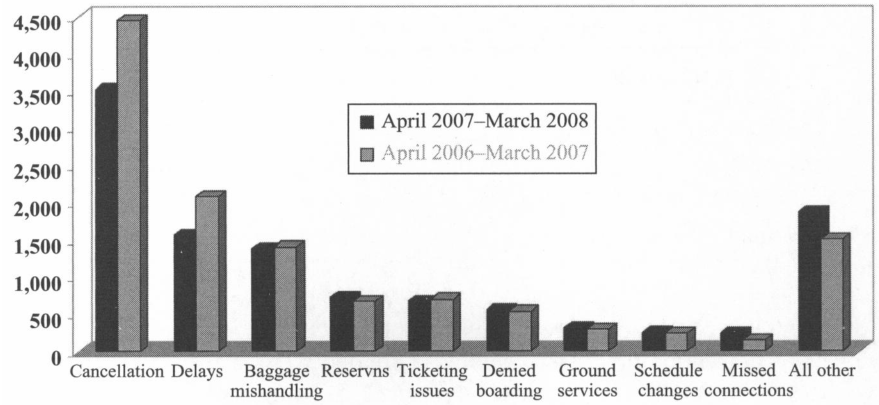
Customer service was assessed based on published statistics for 'on-time performance',[5] mishandled baggage reports, and denied boarding rates. Customer satisfaction was based on aggregated, total complaints data. Corporate performance was measured as a profitability ratio, thus off-setting differences in accounting practices and scale effects. An increase in customer service levels will, it is argued, only increase profits if the (indirect) revenue effect through increased satisfaction outweighs any (direct) cost effect associated with actually improving or maintaining the service delivery.

Ceteris paribus, airlines that achieved higher on-time performance had significantly fewer customer complaints ($p < 0.05$). (Analogously, Oldfield, 2009, demonstrates how United Airlines customer satisfaction scores are strongly correlated with on-time performance.) The greater the number of customer complaints, the lower the airline's profitability ratio ($p < 0.01$). However, increasing on-time performance significantly (and directly) contributed to reduced profitability ratios ($p < 0.01$), which was likely due to higher costs. Further examination of the data for Continental Airlines for 1988 suggested that these increased costs were not offset by the positive effect of the associated reduction in customer complaints.

Isolating pure satisfaction variables is non-trivial. Morash and Ozment (1996) hypothesised that although most of an airline's network qualities remain hidden from the passenger, if the network appears to be extensive and offers fast and easy access, such value delivery to the passenger may in itself increase customer satisfaction. This is the 'halo' effect, as originally proposed by Thorndike (1920): a '... tendency to think ... in general ... and to color the judgments of the qualities by this general feeling'. Similarly, airline attributes may be conflated by respondents, such as service frequency and flexibility, or higher fares and flexibility — see Proussaloglou and Koppelman (1999).

[4]For other analyses of FFPs as choice determinants, see Nako (1992) and Proussaloglou and Koppelman (1999).
[5]Percentage of arrivals within 15 minutes of the scheduled time.

Figure 4
Total Complaints and Enquiries by Category, Received by AUC



Source: Compiled from AUC Annual Report 2007–8.

2.3 European legislation and passenger complaints

On 17 February 2005, the European Union's air passenger compensation and assistance scheme (Regulation (EC) No 261/2004) was introduced. In addition to affording passengers additional rights in cases of flight disruption (denied boarding, cancellation, and delay), the Regulation also requires airlines to inform passengers of their rights when a flight is disrupted. This includes giving the contact details of a body designated by the member state to receive complaints. In the UK, this is the Air Transport Users' Council (AUC).

In 2005–6, the UK's AUC received nearly three times as many written complaints as the year before. In 2007, the number of complaints in many member states was increasing (Steer Davies Gleave, 2007). However, in 2006–7, total UK complaints and enquiries about delays fell because written complaints decreased markedly (Air Transport Users Council, 2007). Figure 4 shows a similar effect for 2007–8.

Such data on delay complaints are not trivial to interpret. They are a function of the capacity of the receiving organisation (such as the AUC) to receive such complaints, the way in which the airlines deal with the complaints themselves, actual delay levels, and passenger acceptance of delay. Based on the AUC data, we may cautiously postulate that there has at least not been a marked increase in delay complaints in more recent years in the UK. Even if the airlines are absorbing increases in such complaints, these are presumably being dealt with to the reasonable satisfaction of passengers, with no marked increase in onward referral. We shall return to this in Section 4.2.

3.0 In-house Passenger Survey Results

This section reports on analyses of the UK Customer Care Alliance (CCA) survey and on a dedicated follow-up survey undertaken for this paper. The on-line annual CCA survey was conducted in July–September 2008. Invitations were e-mailed to a proprietary

Table 2
Travel Causing Most Serious Passenger Problem

Air travel sector causing most serious problem	*Respondents*
Traditional carriers	219
LCCs	144
Package/charter carriers	196
Sub-total	**559**
Other (such as airport)/missing	112
Total	**671**

database of consumers who had previously completed customer satisfaction surveys. The objective was to determine how customers were treated when a problem arose, across all industry sectors. Of 10,102 respondents, across the full range of industry sectors, 2,229 reported no problems at all in the previous 12 months; 671 respondents declared that their worst problem had been associated with a flight (see Table 2 for distribution).

These passengers were asked how long prior to the interview they had experienced the problem. Removing the unsure and missing categories, and plotting responses against which statements best described how upset the respondents were as a result of the problem (from 1 to 5: not at all to extremely), furnishes Figure 5. Significantly higher (Mann-Whitney U test, $p < 0.001$) distress was declared relating to problems that occurred more than six months ago, compared with more recent ones, although the plot (note truncated scale) is actually pretty flat. The degree of distress declared across the three airline segments of Table 2 was almost identical.

Consider the following key variables:

(a) satisfaction with the way the problem was resolved;
(b) satisfaction with the airline finally, overall;

Figure 5
When Problem Experienced as a Function of Passenger Distress ($n = 546$)

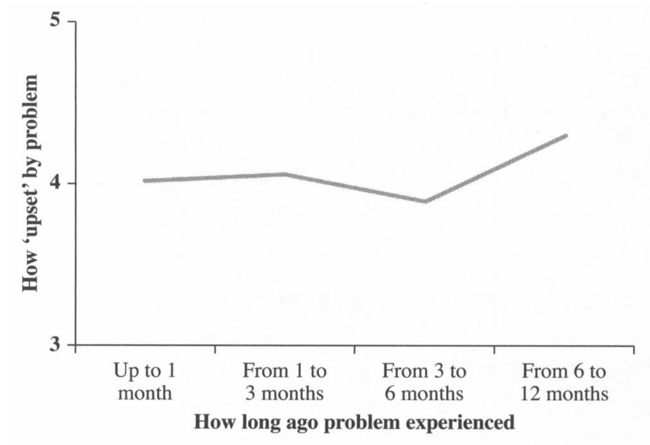
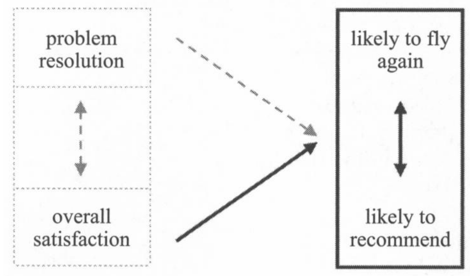


Figure 6
Simplified Summary of Repeat Business Drivers



(c) likelihood of recommending the airline to others;
(d) likelihood of flying with the same airline again.

Analysing these for correlations,[6] problem resolution, and overall satisfaction — (a) and (b) — had only a medium correlation ($r_s = 0.66$, $p < 0.001$), whilst (c) and (d), often used as mutual proxies, were indeed strongly correlated ($r_s = 0.83$, $p < 0.001$). Notwithstanding these collinearities,[7] both likelihood of recommendation and likelihood of flying again with the same airline were fairly weakly correlated with problem resolution (respectively: $r_s = 0.57$, $p < 0.001$; $r_s = 0.49$, $p < 0.001$) and rather strongly correlated with overall satisfaction (respectively: $r_s = 0.83$, $p < 0.001$; $r_s = 0.72$, $p < 0.001$). These relationships are represented in Figure 6.

To explore such findings further, a sub-sample of those invited to complete the CCA survey, known to have flown at least once in the past few years but not necessarily reporting their worst problems with air travel, participated in a dedicated, on-line flight delay survey, in October 2008. Questions were asked based on the most recent delay recalled on a direct flight since January 2007. Inviting respondents to complete a survey about flight delays clearly introduced a bias towards longer delays, the average delay at the destination airport being 5 hours 40 minutes, across the 507 respondents (range: 10 minutes to 48 hours 30 minutes). The purpose of the survey was to gain insights into the disutility of airline delay: having delays that were representative of actual delay durations encountered in Europe (peaking below 15 minutes; see Table 4) would not have been useful. Approximately 20 per cent of the surveyed cases related to delays of one hour or less. Dominant trip purposes over the preceding 12 months were: 8 per cent business, 88 per cent leisure/non-work, and 4 per cent equally frequent for these two.

Table 3 shows whether the experience of the delay had directly led to changes in travel behaviour. (Of the 'other' category, most free-text responses indicated that the respondent would not use the same airline or airport again.) This sample was strongly dominated by the leisure market. It is likely that in a more representative sample, the 'not travelled since anyway' responses would be fewer.

[6]All such results quoted are Spearman rank correlation coefficients and use two-tailed tests.
[7]Principal components analysis may be applied in future research.

Table 3
Effects of Delay on Subsequent Travel Behaviour

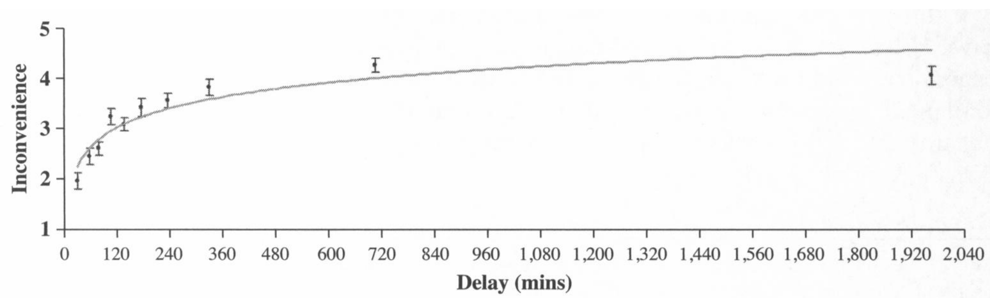
Direct effect of delay since delay event	*Respondents*
Had not affected travel plans	298
Had not travelled since, anyway	116
Made some flights with another airline	41
Made some journeys by train/other	4
Made fewer journeys	2
Other	20
Missing response	26
Total	**507**

Figure 7 is a plot of the delay minute deciles experienced, against the stated inconvenience of the delay on a five-point scale, with standard errors of each group mean. The first decile is for 10–50 minutes, each point being plotted for the range mid point. The logarithmic fit shown ($r^2 = 0.86$) indicates a rapidly rising disutility, which flattens out at higher delay.

In this sample, the lowest delay for a respondent who consequently switched to another airline was 60 minutes. Forty-one respondents had flown with at least one other airline as a result of the delay (switchers); for 298 respondents, subsequent plans had not been affected by the delay, although they had travelled since (non-switchers). As a result of the delay, the forty-one switchers had since made an average of 3.7 flights (0.6 per month) with other airlines.

The ratio of switchers to non-switchers did not change as a function of compensation received (in cash or kind), but increased reasonably uniformly with each delay decile, maximising at around 1 in 3. This value seems, *prima facie*, rather low, especially in view of the rate at which inconvenience saturated (Figure 7). Indeed, Cramer and Irrgang (2007) suggest that after experiencing a 5-hour delay, *all* passengers will switch. The lower value from our survey may be explained by the strongly dominating leisure-purpose passengers, quite probably in combination with fare and/or single-operator route constraints.

Figure 7
Inconvenience as a Function of Delay Experienced



4.0 Deriving and Using the Cost of Delay as a Function of Duration

4.1 Distributing the soft cost as a function of delay duration

Hitherto, the state of the art regarding the assignment of soft costs for airline delay has been limited to a simple linear model. Using Airclaims and Association of European Airlines data to harmonise findings from two extensive European airline case studies, Cook *et al.* (2004) derive a peer-reviewed soft cost of passenger delay of €0.18 per average passenger, per average delay minute, per average delayed flight, for 2003.

We here make a distribution of these costs, as a function of delay length, drawing on the survey data above and existing literature. The required qualities of such a distribution are as follows. First, the cost per minute must increase as a function of delay duration. Passengers are more likely to transfer their custom to another airline following a longer delay than a shorter one (or, indeed, this may result in subsequent trip mode substitution, consolidation, replacement (for example, teleconference), or cancellation). Second, for a given delay range (for example, 1–15 minutes), the cost per minute needs to be weighted by the proportion of delays in that range. The weighted average must equal the aggregate value used at the start of the calculation — the new distribution of the cost cannot increase or decrease the total cost.

For distributing the soft cost of delay as a function of delay duration, a form of the logit function, such as equation (1), may be used to describe passenger dissatisfaction (δ; normalised) at various levels of delay. This may be thought of as a proxy for the propensity of a passenger to switch from a given airline to some other choice, after trips with given delay experiences of duration t:

$$\delta = \frac{1}{k(1+e^{a-bt^c})} - k'. \tag{1}$$

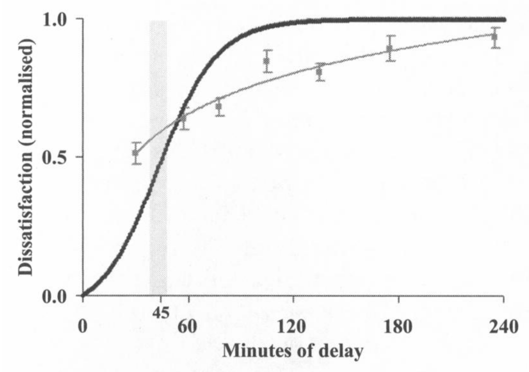
In their analysis of schedule delay[8] and total carrier share, Koppelman *et al.* (2008) found that adding an S-shaped schedule delay penalty improved the overall goodness of fit with empirical data and suggested that this makes sense behaviourally. Suzuki *et al.* (2001) adapt a simple binary logit equation to form a function similar to equation (1), but with a detailed treatment for dealing with the asymmetries of loss aversion (as discussed earlier). The familiar S-curve produced (the black curve in Figure 8) has the desirable characteristics of increasing through a zone of intolerance, before levelling off. If the plot in Figure 8 were of disutility *per se*, it is arguable that the curve would have a more complex shape on the right; for example, oscillating as different onward connections were made and lost, or the delay involved an overnight stay at an airport.

Selecting an appropriate set of constants ($a=3.0$, $b=0.1$, $c=0.9$; $k=e^a/(1+e^a)$; $k'=e^{-a}$) through manual iteration, it is possible to produce a judgemental fit that accords in a semi-quantitative manner with several key findings of this paper.

The grey markers of Figure 8 are the inconvenience scores from Figure 7 (that is, using the 507 passengers of Table 3), normalised to the eighth decile (mid-point: $5\frac{1}{2}$ hours' delay), which was, it should be noted, 0.94 of the value of the tenth decile (mid-point:

[8] A term used to describe the difference between a desired departure (or arrival) time and the closest option (realistically) available to the passenger.

Figure 8
Passenger Dissatisfaction as a Function of Delay Duration



approximately 33 hours' delay). This rescaling reflects the assumption of dissatisfaction saturation at 5 hours, which may be compared with the suggestion previously mentioned, from Cramer and Irrgang (2007), that after experiencing a 5-hour delay, *all* passengers will switch.[9] As discussed in Section 3, however, it seems likely that for a more representative cross-section of passengers (with more business-purpose trips), saturation would actually occur at rather lower delay than the Figure 7 markers. The constants in equation (1) have been chosen such that the S-curve runs higher than a log-fit (grey curve) through the Figure 7 markers. The constants have also been chosen such that the S-curve falls off far more sharply towards the origin than the log-fit of the grey curve suggests, as the latter would result in high dissatisfaction at 0 minutes of delay.

Although the Wittmer and Laesser (2008) data were dominated by high-frequency business-purpose passengers, many of the distinctions between business- and leisure-purpose passengers have been eroded over recent years. For example, average fares have been falling and business-purpose passengers are more often choosing tickets based on price and making extensive use of LCCs (see discussion in Teichert *et al.*, 2008). This is, to some extent, supported by similarities across the business-purpose frequency groups in the data. (a) The Kano basic factor is quite flat across frequency of travel. (b) Figures 2 and 3 suggest crossover points, where the Kano premium factor becomes dominant, which spans only an 11-minute interval between the highest- and lowest-frequency groups. This occurs in the range of approximately 40–50 minutes. The shaded strip in Figure 8 shows this delay range and the S-curve passes the 50 per cent point at $t = 45$ minutes. (c) By 60 minutes, for each frequency group, the premium factor dominates, indicating common saturation of disutility at such higher levels of delay. The S-curve passes 70 per cent at $t = 60$ minutes — where it nearby intersects the grey inconvenience curve. In earlier reporting from the US perspective, Narasimhan (2001) comments that: 'Delays have an average level of impact on repurchase intent but customer tolerance decreases significantly when delays exceed 30 minutes'.

[9]Using a 1988 study from American Airlines. A simple (exponential) cost-versus-delay curve is presented, flatter at lower delay than the curve in Figure 8.

Table 4
Per-passenger Soft Costs of Delay, Summarised by Ranges of Primary Delay

Primary delay range (minutes)	*1–15*	*16–30*	*31–45*	*46–60*	*61–75*	*76–90*	*90+*
Proportion of flights[a,b]	0.61	0.19	0.08	0.04	0.02	0.01	0.05
Cost per minute (Euros)	0.05	0.17	0.37	0.58	0.75	0.86	0.92

[a]*Source*: EUROCONTROL (2007) — CODA STATFOR series.
[b]*Source*: EUROCONTROL (2008).

4.2 Assigning the costs to delay ranges

Having established that equation (1) furnishes a reasonable basis for making a new and more operationally useful distribution of the soft cost of delay as a function of delay duration, it is necessary to decide upon the average cost to be used. The value of €0.18 per average passenger, per average delay minute, per average delayed flight, introduced at the start of this section, will be retained. Whilst there is some evidence (Jovanović, 2008) that Regulation 261 has increased the hard costs of passenger delay to the airline, there is no corresponding direct evidence for changes in the soft costs, where more research is required.

However, the foregoing discussion of the AUC complaints data supports the view that there was no marked increase in delay sensitivity during a period of increasing delays in Europe (EUROCONTROL, 2008). Combined with the fact that European airline markets have become increasingly price-driven, an argument could be presented to reduce the €0.18 value. Increased competition and the ease for passengers to find alternative routings through Internet search engines arguably make switching easier and push the value up. Although a status quo is adopted, the constants of equation (1) may be easily adapted to accommodate any forthcoming, alternative evidence.

For each delay range in Table 4, the corresponding cost per minute of delay is derived[10] using two simultaneous sets of weights: both the normalised dissatisfaction values of equation (1) and the actual proportion of delays in each range. Thus, when the costs are weighted by the delay proportions, the average value of €0.18 is obtained.

We close this section by demonstrating that these soft costs appear to be reasonable in a practical context. As Figure 8 shows, by 120 minutes the per-minute soft cost has effectively saturated (the net cost continues to increase with total length of delay). If we take a British Airways Boeing 747-400 on a return flight from London to New York, with an average four-class configuration and 80 per cent load factor, this would typically generate revenue of the order of €300k. The soft cost of a 5-hour delay from equation (1) is €94k — this equates approximately to the loss in revenue of one in three passengers taking their custom to another airline for one London–New York return trip.

4.3 Next steps for the model

In future, refinements of the model may take account of more specific effects. Although trip-end constraints typically dominate, the length of the delay as a proportion of the

[10]The cost per minute is the average of the upper and lower bound of each range, except for the 90+ column, which uses 91–240 minutes. Work in progress is refining the breakdown at higher delay durations.

total journey length is likely to be significant. For example, it is less likely that a passenger would schedule a meeting within 60 minutes after a long-haul flight, compared with a short-haul flight, so absolute delay sensitivities with regard to longer flights may well be lower.

In-trip experience may also affect future switching: initial delays may increase, or be recovered (see next section). A delay of 45 minutes on the first leg of a journey could mean a missed connection and a final arrival delay of four hours, after waiting for the next onward flight with the same airline, if the passenger is not otherwise rebooked.

Regarding accumulated experience, an effect which the Kano model incorporates, frequent flyers are of particular interest. They will, on average, experience more delay and be able to make better estimates of likely future delay (and probably form a higher proportion of short-haul passengers than long-haul). They may become more sensitised *or* more tolerant/adjusted than typical passengers. Their higher travel frequencies may cause their switching behaviour to have a greater effect on airlines despite potentially reverting to the original airline sooner. These effects are not indefinite and adjustments need to be applied when multiplying these costs over longer periods of time or whole networks (an issue we are currently exploring further).

Each flight, route, or network will have its own curve, corresponding more or less to that of Figure 8, and net switching may well be affected by the proportion of delayed passengers that are frequent fliers. A curve representative of a particular segment should be correctly weighted by the joint trip-traveller effects.[11] Such future refinements would require considerable data collection. This paper's formulation of a non-linear distribution by delay duration is still sufficient, however, to allow operational implications to be examined, as explored in the next section.

4.4 Cost–benefit of delay recovery: an example

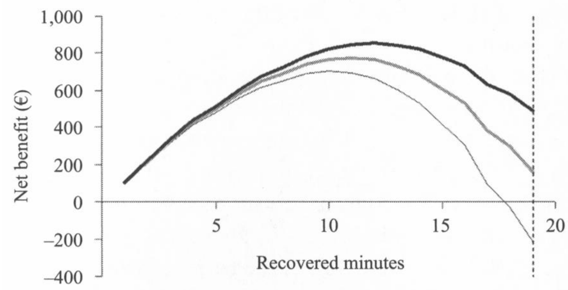
In the introduction, it was mentioned that in airline decision-making on when to use accelerated fuel burn for delay recovery, quantifying passenger soft costs is vital. Figure 9 shows a quantitative example of such a cost trade-off for a Boeing 737-800, which has incurred 22 minutes of delay on a flight from Lisbon to Helsinki. Fuel-burn cost calculations were undertaken (in 2008) using the flight planning application now known as Lido/Flight (from Lufthansa Systems Aeronautics), based on operational flight plans.

The dashed vertical line (right) in the figure represents the maximum number of minutes (19) that may be recovered (ATC- and weather-permitting) 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). The cost of delay component includes the passenger soft costs derived in this paper (see Table 4), plus the marginal crew and maintenance costs, and appropriate passenger hard costs. These calculations also include reactionary costs: the effects of knock-on delay in the rest of the network (see footnote 2 for source).

The soft cost curve of Figure 8 is just starting to pick up at 20 minutes' delay: for a Boeing 737-800, the passenger soft cost contributes approximately two-fifths of the cost of delay, with passenger hard costs totalling just under one-half. As the length of delay

[11] Including sampling bias, for example, whereby frequent flyers are more likely to be sampled by in-trip surveys, compared to, say, a household survey.

Figure 9
Net Benefit of Recovered Minutes for a Boeing 737-800 With a 22-minute Delay



Note: Cost assumptions. Upper curve: no emissions charges, fuel €0.5/kg; middle: no emissions charges, fuel €0.7/kg; lower: with emissions charges, fuel €0.7/kg. CO_2 €37/tonne, NO_x €6,414/tonne.
Source: ENVISA (2006). (Emissions costs can only be an estimate at this time, as values will depend on the design and implementation of policy.)

increases, the passenger costs proportionally increase, to the point where they dominate the total costs (as used in Figure 9) for all aircraft types.

The optimised number of recovered minutes is 12, 11, and 10 for the upper, lower, and middle curves, respectively. 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 Boeing 737-800 flights a day, would cause an estimated, relative annual loss of approximately €6.7 million.

5.0 Policy Conclusions

It cannot be economic best practice to arbitrarily set punctuality targets, such as '99 per cent of flights within 5 minutes of schedule'. If used at all at this generic level, such targets need to be set within the context of cost–benefit analyses. For example, what is the alternative bottom-line impact of targeting 98 per cent of flights within 10 minutes of schedule? Airline use of rules of thumb (described to us during airline interviews and workshops, such as recovering all the delay when it exceeds 15 minutes) can cause severely negative financial impacts. Particularly in times of economic challenge, as legacy business models are increasingly challenged, few carriers still have the luxury of committing resources to targets that are not firmly founded economically. Whilst many, if not most, network airlines recognise that the passenger component is the main driver of their delay costs, relatively few have been able to invest in quantifying this, and only a handful have been able to commit resources to understanding the soft component of these costs — thus appreciating the importance of this hidden factor on the bottom line. Values we have developed for LCCs[12] reflect the fact that these effects are typically rather less

[12]See footnote 2.

pronounced under this model. However, for all carriers, any investment in customer service levels, including punctuality, will only increase profits if the revenue effect outweighs such investment (strategically *and* tactically).

There remains an important opportunity to develop such cost models using primary airline passenger satisfaction measurements with comprehensive attribute sets, since, as we have discussed, most existing work has used either service quality statistics or complaints data. The latter are actually using a proxy for *dis*satisfaction, which cannot be assumed to be a linear (negative) extrapolation of satisfaction. As remarked upon by Wittmer and Laesser (2008), airlines perceived as being punctual may be hostage to their own reputation: delays of less-than-expected levels may only prevent dissatisfaction, without generating increased satisfaction *per se*. Furthermore, determining policy on the provision of punctuality data to passengers is not straightforward, as conveying punctuality concepts to the public is problematic (Bates *et al.*, 2001). It would also be interesting to investigate to what extent passengers allow for delays that are beyond the control of the airline. Collinearities of service attributes, notably frequency and punctuality, along with other frequency effects discussed, need to be taken into account.

Instead of a one-size-fits-all approach to disruption management and target-setting alike, it is better to recognise that the economics of delivering punctuality vary not only from airline to airline, but from flight to flight, and minute to minute. An example of airborne delay recovery was presented in the previous section. During pre-departure slot management in Europe, airlines have the opportunity to trade-off a delayed slot against (usually) a less desirable (longer) route. Cost calculations such as those presented in this paper thus not only have implications for tactical trade-offs but also inform strategic decision making (such as airspace design and flow-management principles).

For airlines and air navigation service providers alike, our research is geared to supporting a shift in strategy from managing delay minutes to delay costs. Investment in better data collection and tools is as much a challenge for airlines as it is the integration of existing disruption management tools with flight-planning applications. However, building step-by-step on some existing successes in this field, and not trying to resolve all these challenges at once, more airlines could make significant progress towards better real-time cost management.

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