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BEACON

BEHAVIOURAL ECONOMICS FOR ATM CONCEPTS

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Abstract

The cost of delay is a critical input for the assessment of flight prioritisation mechanisms and airspace user decision-making. The University of Westminster produces the standard industry reference work for European cost of delay assessment used, for example, by airspace users, ANSPs, in performance assessment by the Performance Review Unit (PRU) and cost benefit analysis in SESAR. This deliverable includes key updates that will feed these reference values, to update the costs based on market changes since 2015, newly adding important consideration of airport curfew costs, and, *inter alia*, updating the assessment of the passenger cost of delay driven by Regulation 261 trends. After further consulting with the University of Westminster's stakeholder base, these results will be made available to the wider community and shared with the PRU and SESAR.

Table of Contents

List of Tables

List of Figures

1 Introduction

The cost of delay is a critical input for the assessment of flight prioritisation mechanisms and airspace user decision-making. The University of Westminster produces the standard industry reference work for European cost of delay assessment [1] used, for example, by airspace users, ANSPs, in performance assessment by the Performance Review Unit (PRU) and cost benefit analysis in SESAR.

This deliverable includes key updates that will feed these reference values, to update the costs based on market changes since 2015, newly adding important consideration of airport curfew costs, and, *inter alia*, updating the assessment of the passenger cost of delay driven by Regulation 261 trends.

After further consulting with the University of Westminster's stakeholder base, and the BEACON project's Advisory Board, for inputs into, and verification of, the newly proposed values, these results will be made available to the wider community and shared with the PRU and SESAR.

The values herein, after further consultation, will thus be used in two contexts. Firstly, as **'explicit' costs** in the BEACON model. By 'explicit', is meant the case-by-case application of costs in specific circumstances, for example taking into account if a specific delay is airline-attributable and thus associated with a specific passenger compensation payment.

Secondly, the values will be used to generate **'statistical' costs** in a standard reference document, updating [1]. By 'statistical', is meant the generation of probabilistic values for generic reference, e.g. the cost of an average minute of at-gate delay, taking into account delay distribution causes. Examples are given through the text, and this relates primarily to the passenger 'hard' costs and Regulation 261 (see Section 3.4). To some extent, through running repeated simulations in BEACON, the results of the explicit modelling will help to inform the estimates of the probabilistic costs.

Section 2 presents the context of the cost modelling. After presenting updates across all the cost elements, in Section 3, key next steps are identified in Section 4.

2 Context of cost model

2.1 Overall context, note on Covid-19

The costs in this report relate as far as possible to the end of 2019, and thus reflect the pre-Covid-19 situation. Further updates will focus on this same period and/or the post-Covid situation, to provide reference values that are useful for nominal modelling, rather than drawing on costs impacted by the exceptional circumstances of the pandemic.

As a reference when updating some costs from 2015 to 2019, Table 1 shows the annual average rate of inflationary change (%) for the European Union, for 2015 to 2019. The value cited is the Harmonised Index of Consumer Prices (HICP), designed for international comparisons of consumer price inflation. It is used by the European Central Bank for monitoring inflation in the Economic and Monetary Union[1].

Table 1: Average European inflation rates.

Year	Inflation rate (%)	Cumulative rate (%)
2015	0.1	0.1
2016	0.2	0.3
2017	1.7	2.0
2018	1.9	3.9
2019	1.5	5.5

2.2 Cost scenarios

Our costs are typically assigned under three cost scenarios: ‘low’, ‘base’ and ‘high’. These scenarios are designed to cover the likely range of costs for European operators. The ‘base’ cost scenario is, to the greatest extent possible, designed to reflect the typical case. Furthermore, combinations of cost scenarios may be used to represent particular airline types, based on their business model and network structure. As an example, an airline operating long-haul flights with a modern fleet might be assigned ‘low’ maintenance costs, and ‘base’ fleet, crew and passenger costs.

[1] https://ec.europa.eu/eurostat/databrowser/view/tec00118/default/table?lang=en

2.3 Aircraft selection and traffic

A review of the selected aircraft in the 2014 cost model [1] has been undertaken. The 2014 cost model comprises 15 aircraft (expanded from the original 12 used by the earlier cost models) and accounted for almost 63% of flights within the Network Manager (NM) Area. By 2019, the proportion of flights flown by the 15 aircraft had reduced slightly to just under 62%, with the top four aircraft (B738, A319, A320 and A321) increasing their share from 46.8% to 50.4% overall (2014-2019). In contrast, the proportion of flights served by older, less popular aircraft has declined. Whilst only four aircraft now account for half of flights, adjustments to the selected aircraft for the new cost model are required in order to reflect the changing fleet.

Table 2 shows the change in the number of flights per aircraft between 2014 and 2019 (second column from the right). For example, the number of flights served by the B738 has increased by 40% (from 1.55m to 2.17m), whereas the AT72 has decreased by almost -61% (from 114.7k to 44.9k). To maintain comparability with the earlier cost models, it was decided that only the aircraft which have seen the largest decline 2014-2019 should be replaced: B733 (-57.8%), B735 (-60.9%) and AT72 (-60.9%). It is worth noting that significant fleet changes have occurred during the Covid-19 pandemic (2020-2021), such as the accelerated decline in the passenger variant of the B744. This will be addressed in the future, however retaining the B744 serves as a good proxy at the higher end of the range of costs.

Comparable aircraft, in terms of MTOW and typical seat range, have been considered as replacements for the three least popular aircraft. The B733 (122-148 seats) has been replaced by the B737 (116-149 seats); B735 (114-126 seats) by the slightly smaller CRJX (90-100 seats); and a like-for-like change with the AT72 (62-74) swapped for the newer AT76 (68-78 seats). The B737, CRJX and AT76 have taken the positions of the B733, B735 and AT72 in the table, with the original aircraft moved to the bottom for reference.

Table 2. Updated aircraft selection.

Aircraft	Aircraft type	MTOW (tonnes)	Seat range	Seats low scenario	Seats base scenario	Seats high scenario	Chg. in flights 2014-19	Change
B737	B737-700	66.5	116-149	149	135	135	-28.7%	B733 replacement
B734	B737-400	66.3	144-176	176	159	159	+6.6%	
CRJX	CRJ-1000	38.8	90-100	100	90	90	+98.1%	B735 replacement
B738	B737-800	76.2	142-189	189	171	171	+40.0%	
B752	B757-200	108.8	166-235	235	212	212	-25.4%	
B763	B767-300ER	182.6	211-270	270	243	230	-21.7%	
B744	B747-400	392.8	306-455	455	410	387	-27.2%	
A319	A319	67.4	116-156	156	141	141	-10.6%	
A320	A320	74.5	133-188	188	170	170	+23.3%	
A321	A321	87.2	166-235	235	212	212	+30.8%	
AT43	ATR42-300	16.8	44-48	48	44	44	-47.4%	
AT76	ATR72-600	23.1	68-78	78	71	71	+249.5%	AT72 replacement
DH8D	Dash 8 Q400	29.2	72-80	80	72	72	+6.9%	
E190	ERJ 190-100	48.4	96-106	106	96	96	-9.5%	
A332	A330-200	232.7	204-327	327	295	278	+13.5%	
B733	B737-300	61.2	122-148	148	134	134	-57.8%	Replaced by B737
B735	B737-500	57.1	114-126	126	114	114	-60.9%	Replaced by CRJX
AT72	ATR72-200	22.0	62-74	74	67	67	-60.9%	Replaced by AT76

2.4 Strategic costs cf. tactical costs

In our wider reporting [1], the cost of delay is calculated separately for strategic delays (those accounted for in advance) and tactical delays (those incurred on the day of operations and not accounted for in advance). The type of strategic cost usually focused on is adding buffer to the airline schedule. Strategic costs and tactical costs are not independent: reactionary delays depend on the airline's ability to recover from the delay, due to the amount of schedule buffer, for example. If no buffers were used, the reactionary costs would increase markedly and the tactical costs would be significantly higher.

Whilst BEACON does not require the use of strategic costs, these will be updated in the planned 2021 revision of the University of Westminster 2015 report [1], to be produced in due course, also drawing on the values proposed herein.

Fleet costs refer to the full cost of fleet financing, such as depreciation, rentals and leases of flight equipment. These costs are determined by service hours. Since utilisation has only a very small effect on these costs, they are wholly allocated to the strategic phase and the corresponding tactical delay costs are thus taken to be zero. Fleet costs will be updated as part of the 2019 strategic costs.

2.5 Modelling reactionary costs

Reactionary delays will also be modelled in the wider, planned 2021 update, calculated on a statistical cost basis. In the wider model, they are split over a number of rotations, as it is less likely that all the reactionary delay would occur in a single knock-on event. Different models are used for narrowbodies and widebodies, and for different types of cost (fuel, passenger, crew and maintenance). Whilst BEACON, modelling these costs explicitly, does not require these statistical costs, they will be produced statistically in on-going research being led by the University of Westminster in Clean Sky 2, in which machine learning is applied to model such propagation effects, linking them to curfew impacts. We also present some initial models for curfew-induced reactionary effects in Section 0.

3 Specific cost elements

3.1 Cost of fuel

3.1.1 Costs in 2014

The 2014 'into-plane' fuel cost, also known as the 'all-in rate', is the price paid by airlines and was calculated using published kerosene spot prices and airline financial reports. The high, base, and low scenarios reflecting the cost range.

In a change from earlier editions, the 2014 cost model included fuel burn in the base and high scenario at-gate calculations, capturing auxiliary power unit (APU) usage.

Table 3: Cost of fuel 2014.

Scenario	Cost of fuel / kg (€)
High	0.9
Base	0.8
Low	0.7

3.1.2 Costs in 2019

Figure 1 shows the average kerosene spot price *per month* (per US gallon) alongside average prices paid by several European airlines *per year* since 2017 (all costs in $). EUROCONTROL's published 2019 fuel cost ($1.83/US gallon), derived from IATA jet fuel price analysis and intended for use as the standard input for economic analyses, is also plotted.

Whilst fuel hedging tends to flatten out sudden price changes, the average annual fuel price shown for regional, full-service, and low-cost airlines hides fluctuations in the price airlines pay.

Following a review of kerosene spot prices and airline financial reports during 2018-2019, the into-plane fuel cost has been updated to 2019 values. The blue curve in Figure 2 shows the average unhedged into-plane € price per month (developed in-house). The into-plane price includes estimates for additional fuel charges and fees paid by airlines. The three fuel cost scenarios covering 2019 are also plotted.

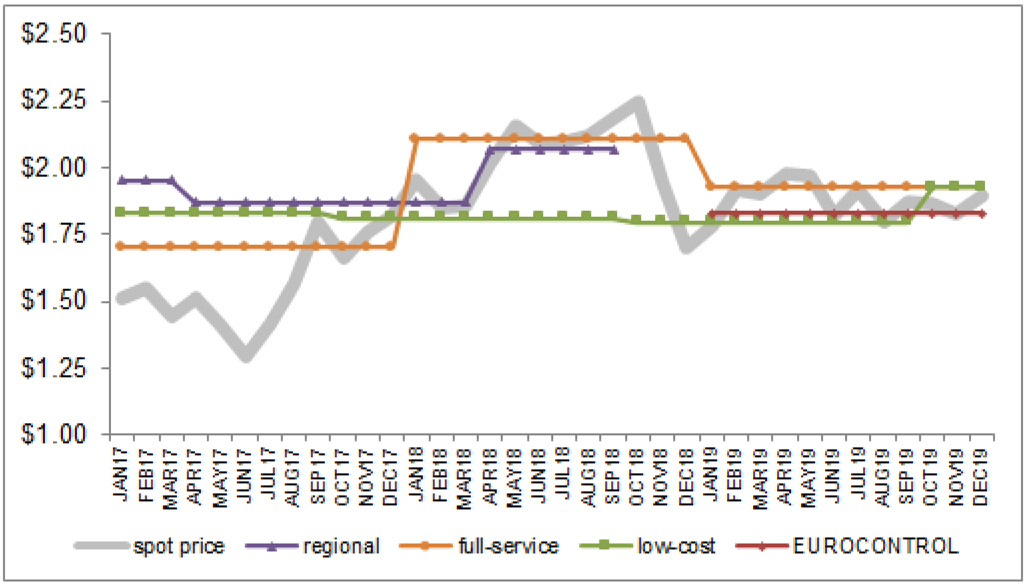

Figure 1. Average Jet A-1 fuel spot prices with examples of average airline prices paid ($/US gallon)

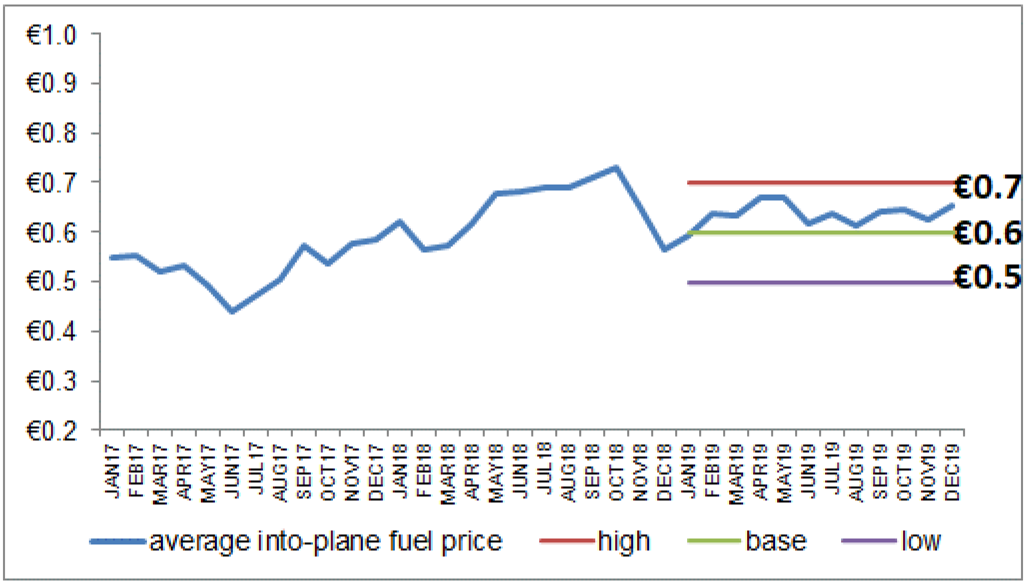

Figure 2. Average into-plane Jet A-1 fuel price and the three 2019 fuel cost scenarios (€/kg)

The three fuel cost scenarios are lower than the 2014 values, with the earlier low value (€ 0.7/kg) now the high value in 2019. The updated base value for 2019 is € 0.6/kg. Note that whilst EUROCONTROL's published standard input fuel cost is slightly lower (€ 0.43/kg), the equivalent into-plane fuel cost, calculated using the cost of delay methodology from the standard input of $ 1.83/US gallon, gives € 0.62/kg.

Please note that the cost model uses explicit fuel burn values per aircraft for each phase of flight, primarily sourced from Lido Flight (Lufthansa Systems) and BADA 3 (EUROCONTROL). A fuel carriage penalty is applied to arrival management. We continue to monitor the impact of environmental policies and emissions taxes, as coupled with the 'effective' cost of fuel.

Table 4: Cost of fuel 2019.

Scenario	Cost of fuel per kg (€)
High	0.7
Base	0.6
Low	0.5

3.2 Cost of maintenance

3.2.1 Costs in 2014

Tactical maintenance costs relate to factors such as the (mechanical) attrition of aircraft waiting at gates, subjected to arrival management, or accepting longer re-routes. Large proportions of maintenance costs are fixed, in terms of overheads, or on a per-cycle basis. The basic principle of these calculations is to estimate marginal, time-based costs from unit costs. This was achieved by removing the appropriate fixed costs and apportioning the remaining costs across marginal delay minutes for the 15 aircraft types. Table 5 shows 2014 tactical maintenance costs that apply at-gate.

Table 5. At-gate, tactical maintenance costs 2014 (€ per minute).

Aircraft	Low scenario	Base scenario	High scenario
B733	0.2	0.5	0.7
B734	0.2	0.5	0.7
B735	0.2	0.5	0.6
B738	0.2	0.5	0.7
B752	0.3	0.6	0.8
B763	0.4	0.8	1.3
B744	0.8	1.2	1.4
A319	0.2	0.6	0.8
A320	0.2	0.5	0.8
A321	0.3	0.6	0.8
AT43	0.1	0.2	0.3
AT72	0.1	0.3	0.4
DH8D	0.1	0.3	0.4
E190	0.2	0.4	0.6
A332	0.4	0.9	1.4

3.2.2 Costs in 2019

To facilitate an update to 2019 values, maintenance costs published annually in airline financial returns have been reviewed covering 2014-2019. These figures show the general trend in maintenance costs, reflecting fleet changes over time. Note that annual costs affected by exceptional costs, such as maintenance costs triggered by the return of a large number of leased aircraft, have been excluded. Drawing on these published costs, a 20% increase has been applied to maintenance block-hour costs per scenario as an input to the calculation of 2019 values (other inputs have been updated, such as rotations per day per aircraft type in 2019). In summary, a 20% increase is consistent with the maintenance reserve escalation rate of approximately 3% - 4% per year used in typical lease contracts [2] which would imply a 22% increase over the same period (i.e. 4% compounded over five years). Table 6 below shows provisional 2019 tactical maintenance costs that apply at-gate. The corresponding taxi and en-route maintenance cost tables are available in Appendix C.

Table 6. At-gate, tactical maintenance costs 2019 provisional (€ per minute).

Aircraft	Low scenario	Base scenario	High scenario
B737	0.2	0.5	0.8
B734	0.3	0.6	0.8
CRJX	0.2	0.5	0.7
B738	0.2	0.5	0.9
B752	0.4	0.8	1.1
B763	0.5	1.0	1.6
B744	1.0	1.4	1.7
A319	0.3	0.7	0.9
A320	0.3	0.6	1.0
A321	0.4	0.8	1.0
AT43	0.1	0.2	0.3
AT76	0.2	0.4	0.5
DH8D	0.2	0.3	0.5
E190	0.2	0.5	0.7
A332	0.5	1.1	1.7

3.3 Cost of crew

3.3.1 Costs in 2014

Crew costs cover the cost of flight and cabin crew, i.e. captain, first officer and flight attendants. Pilots' salaries increase by size of aircraft, although commonality can be seen within aircraft families (e.g. the A320 family). In contrast, flight attendants' salaries are more consistent across all aircraft types.

Crew tactical costs relate to the cost of crewing a flight for additional minutes over and above those planned at the strategic phase. The 2014 costs were derived from a detailed examination of payment mechanisms for flight and cabin crew from which strategic unit costs were calculated using realistic annual block/flight duty hours, sectors flown, overnight stopovers and crewing levels per aircraft type. For the tactical cost calculation, cycles-based allowances were removed. Whilst the high and base cost scenarios take account of overtime rates, the low scenario was assigned zero cost as delays can have no effect on the cost of crew when a large proportion of pay is fixed as basic salary, with *per diem* allowances. For example, an at-gate delay would have no effect on the cost of crew paid by block hours worked as this payment mechanism is triggered off-blocks, whereas an airborne delay will have no effect on the cost of crew paid by sectors flown as this payment mechanism is cycles-based. The costs shown in the following table apply to ground and airborne phases.

Table 7. Tactical crew costs 2014 (€ per minute).

Aircraft	Low scenario	Base scenario	High scenario
B733	0	8.9	19.5
B734	0	9.2	20.6
B735	0	8.4	19.0
B738	0	9.5	21.5
B752	0	9.9	20.9
B763	0	13.0	38.0
B744	0	17.5	49.5
A319	0	7.7	16.7
A320	0	8.2	17.7
A321	0	8.2	17.7
AT43	0	5.9	12.7
AT72	0	6.4	14.3
DH8D	0	6.4	14.2
E190	0	7.1	16.6
A332	0	13.8	39.7

3.3.2 Costs in 2019

Pilot and flight attendant salary changes 2014-2019 have been reviewed using informal sources and other grey literature, revealing a range of salary scales offered by airlines. These pre-Covid-19 changes range from reduced salaries (i.e. reflecting new contract conditions for starters), through unchanged salaries to large pay rises. Overall, there have been modest pay increases for pilots, except for widebody pilots (already the highest paid pilots), whereas flight attendants have received proportionally higher pay increases at the lower end of their salary scales, and relatively small changes at senior grades.

The low scenario remains zero for the updated 2019 tactical crew costs. Driven by the modest pilot pay increases and larger flight attendant pay increases, with four exceptions, tactical crew costs have been increased for the base and high cost scenarios, respectively:

- narrowbodies +5% and +3%;
- turboprops +4% and +5%;
- widebodies +2% and unchanged.

The four exceptions include the three replacement aircraft (B733, B735 and AT72) since like-for-like costs are not comparable, and the A321 that required one extra member of cabin crew due to the increased seating capacity (212 seats in 2019 cf. 198 in 2014) assigned to the base and high cost scenarios – note that the minimum number of cabin crew is determined by seats not passengers. The provisional costs shown in the following table (Table 8) apply to ground and airborne phases.

Table 8. Tactical crew costs 2019 provisional (€ per minute).

Aircraft	Low scenario	Base scenario	High scenario
B737	0	9.0	20.6
B734	0	9.6	21.3
CRJX	0	7.3	17.4
B738	0	10.0	22.2
B752	0	10.4	21.5
B763	0	13.2	38.0
B744	0	17.9	49.5
A319	0	8.1	17.2
A320	0	8.6	18.2
A321	0	9.1	19.2
AT43	0	6.2	13.1
AT76	0	6.7	14.7
DH8D	0	6.7	14.6
E190	0	7.4	17.2
A332	0	14.1	39.7

3.4 Cost of passenger delay – 'hard' costs

Regulation (EC) No 261/2004[2] establishes the rules for compensation and assistance to airline passengers in the event of denied boarding, cancellation or delay. The objective of this section is to review the costing of the hard cost of delay, by delay duration, drawing in large part on the impact of Regulation 261 – since this significantly drives the airline hard costs of passenger delay. We examine whether there is evidence to substantially adjust previously adopted values, as described in "The cost of passenger delays to airlines in Europe" [3]. This study (*ibid.*) examined Regulation 261 and of major legal rulings thereon to assess the broader cost impacts on airlines. The European Commission proposed a revision of Regulation 261 in March of 2013, based on a study in support of a Commission Impact Assessment of the Regulation [4] that was finalised by Steer Davies Gleeve[3] (SDG) [5], and which studied the prevalent market situation, quantitatively assessing the impacts of numerous policy measures. However, the proposal has been on hold since November 2015. The latest assessment on the current level of passenger rights protection was performed by Steer on behalf of the European Commission [6], covering the period from 2011-2018. The study triggered various (further) proposals for revision of the Regulation, which was halted, in part, by the Covid-19 pandemic's impact on aviation. Thus, the provisions of the Regulation 261 and the impact of major legal rulings on the Regulation have not changed from the provisions described in 2014. Table 9 summarises the provisions of Regulation 261 for care, reimbursement of ticket, and compensation, with respect to delay duration and the type of delay (on arrival or at departure).

Table 9. Delay duration and current Regulation 261 estimated costs and cost categories.

Haul[4]	≥ 2 hours	≥ 3 hours	≥ 4 hours	≥ 5 hours	≥ 10 hours
Short haul		€250	€250	€250	(accommodation)
Medium haul		€400	€400	€400	(accommodation)
Long haul		€300	€600	€600	(accommodation)

Care (e.g. reasonable meals and refreshments), refers to departure delay

Reimbursement of ticket

Compensation, refers to arrival delay

[2] Henceforth: "Regulation 261".

[3] Now named Steer.

[4] Short haul <1500km; medium haul 1500-3500km; long haul >3500km.

Note that these rights are conferred on the passenger regardless of the cause, except for **compensation, which is only due to the passenger in the case of airline-attributable delay**. This thus excludes compensation payments being required under conditions declared to be 'extraordinary circumstances', which includes certain types of weather, for example. Whilst these costs are assigned explicitly (case by case) in the Mercury[5] (BEACON) model, when generating the statistical costs of delay, care must be taken to avoid over-counting. For example, regarding compensation payments only being due for airline-attributable delay, the 2020 Steer study [6] cites that these rates were around 70% in 2017 and 2018. Whilst the rates indicated in the tables that follow are successful claim rates[6] for eligible passengers, as should be deployed in explicit cases in models (i.e. when the eligibility is known), for statistical estimations they need to be factored down by the attributability rate (70%).

3.4.1 Costs in 2014

The objective of the 2015 report [3] was to produce passenger cost reference values for industry use, which accurately reflect airline delay costs. These were produced for 15 aircraft types, across a range of delay durations, according to 'low', 'base' and 'high' cost scenarios, for the year 2014. To facilitate the calculations, several assumptions were made:

- a refreshment is offered at the first stipulated threshold, and every five hours thereafter;
- meals are offered after five hours of delay, and every subsequent five hours;
- delays of ≥10 hours of delay are aggregated, and a further refreshment and meal is assumed;
- costs were based on 2012 airport averages calculated by Steer [4] inflated to 2014 prices;
- hotel accommodation is triggered at 10 hours of departure delay;
- seats, and load factors that lead to passenger allocations per aircraft type were assigned for low, base and high cost scenarios, based on distributions of aircraft movements by length of haul.

The superscript values in the following tables indicate the assumed uptake (or claim rate) of the various costs. Where absent, a 100% value is assumed, or the rate is already included in the estimate. Table 10 assumes that the passengers associated with these costs wait for an onward flight (be that the delayed flight or as a rebooking). Regulation 261 allows for a reimbursement to be made when the delay is at least five hours, according to Article 8(1)(a). Table 11 assumes the associated passengers abandon their trip and are reimbursed. For simplicity, we use common values (shown in green) as the basis of reimbursement and rebooking costs. Passengers in the Mercury (BEACON) model, as in actual situations, will either wait for a late flight or subsequent connection, or opt for reimbursement. These generate explicit costs in the BEACON model. In the statistical model, an assumption is made regarding the ratio of passengers who wait compared to those who opt for reimbursement. This was previously

[5] As explained in other BEACON deliverables, Mercury is the in-house simulator for flights and passengers that will be at the core of the BEACON simulations. It has fully integrated cost functions.

[6] Where a successful claim rate can be expressed as: (eligible for and received compensation)/all eligible pax.

[3] set at 80:20%, respectively, for the base cost scenario, and this will be retained in the statistical values for 2019, and form the basis of the explicit decisions in the BEACON model.

Table 10. Departure delay duration base scenario estimated costs – pax wait for flight.

	Departure delay duration				
Haul	≥ 2 hours	≥ 3 hours	≥ 4 hours	≥ 5 hours	≥ 10 hours
Short haul	€6$^{80\%}$	€6$^{80\%}$ €250$^{11\%}$	€6$^{80\%}$ €250$^{11\%}$	€265$^{10\%}$€15$^{80\%}$ €250$^{11\%}$	€265$^{50\%}$ €21 €250$^{11\%}$ €65
Medium haul		€6$^{80\%}$ €400$^{11\%}$	€6$^{80\%}$ €400$^{11\%}$	€345$^{10\%}$€15$^{80\%}$ €400$^{11\%}$	€345$^{50\%}$ €21 €400$^{11\%}$ €65
Long haul		€300$^{11\%}$	€6$^{80\%}$ €600$^{11\%}$	€1170$^{10\%}$€15$^{80\%}$ €600$^{11\%}$	€1170$^{50\%}$ €21 €600$^{11\%}$ €65

Key: Care, rebooking, compensation, accommodation

For passengers opting to wait for an onward flight (see Table 10 for values), three types of costs can be incurred. First, care and assistance is given to passengers incurring departure delay of two hours or more. Second, for arrival delay of the magnitude indicated in the common column headers[7], and where the delay is airline-attributable, passengers can claim compensation (blue values). Third, airlines are obliged to provide passengers who are delayed for more than five hours with the choice of either a rebooking with the same airline or a re-routing on either alternative transport or on an alternative airline. These are the costs of rebooking shown in green. For delays of less than 10 hours, we assume that most passengers are rebooked on the same carrier or using a within-alliance reciprocal agreement, with only 10% of passengers thus generating a rebooking fee for the carrier. For delay durations greater than this, across all lengths of haul, in the base cost scenario it is assumed that after such high durations (and with an overnight stay assumed), 50% of passengers are booked on the same carrier (i.e. at no extra cost), thus with 50% of the cost statistically (probabilistically) applied as a cost to the airline. In explicit models, this could be refined to reflect estimated capacities/availabilities on specific carriers (e.g. with higher rebooking on other airlines for long haul, whereby flights provided by the same carrier are likely to be fewer), and used in future as evidence to adjust the cruder statistical assumptions.

Table 11. Departure delay duration base scenario estimated costs – pax opt for reimbursement.

	Departure delay duration				
Haul	≥ 2 hours	≥ 3 hours	≥ 4 hours	≥ 5 hours	≥ 10 hours
Short haul	€6$^{80\%}$	€6$^{80\%}$ ~~€250~~	€6$^{80\%}$ ~~€250~~	€265$^{90\%}$€15$^{80\%}$ ~~€250~~	€265$^{90\%}$ €21 ~~€250~~ €65
Medium haul		€6$^{80\%}$ ~~€400~~	€6$^{80\%}$ ~~€400~~	€345$^{90\%}$€15$^{80\%}$ ~~€400~~	€345$^{90\%}$ €21 ~~€400~~ €65
Long haul		~~€300~~	€6$^{80\%}$ ~~€600~~	€1170$^{90\%}$€15$^{80\%}$ ~~€600~~	€1170$^{90\%}$ €21 ~~€600~~ €65

Key: Care, reimbursement, compensation, accommodation

[7] This is our working assumption statistically – departure and arrival delay are of the same magnitude.

Table 11 details the costs for passengers who choose to abandon their trip. The care and assistance costs apply as in the previous table. The reimbursement cost applies here, since these passengers opt for abandoning their trip, which they are entitled to for departure delays of more than five hours. It is unlikely that many passengers would reach delays of 10 hours and above, and thus receive the care payments in the final column. Where the fares are reimbursed to the passenger, we assumed that the airlines recover some of the taxes. Compensation of some form *could* be offered to some passengers (consider a high-yield business-class passenger who is delayed by 5 hours and then abandons the trip) but since this is determined in Regulation 261 by *arrival* delay, and the passengers are, by definition, not completing their trip, there is no legal obligation to offer compensation in such cases.

For detailed explanations of these calculations see Section 3.1 of [3]. It is explained therein that the reimbursement and rebooking values shown in green are higher than corresponding values of [4].

3.4.2 Costs in 2019

The 2020 study by Steer [6] assesses the issues around the application of Regulation 261 that have arisen since 2011. In this section, we use several of these cost estimates. Compensation values that *may* be claimed (blue numbers) are dictated by Regulation 261 and are unchanged. However, a **significant change** since the reporting in the previous section, is the **compensation successful claim rate** for delay, growing from 11% in 2014 to **58% in 2018**[8]. As noted, for *statistical* estimations this needs to be factored down by the attributability rate (70%), i.e. to **approximately 41%**.

Care numbers (for the first four columns) are updated to match the latest figures given in Table C.1 of the Steer report [6]. The values reflect inflation from 2012 to 2018 and other changes in prices. However, the main difference compared to the 2013 (SDG) study is the consideration of a €50 payment for overnight subsistence, cf. the €18 care values in the "≥ 5 hours" category, as a more substantial meal is foreseen for long delays. The derivation of the overnight accommodation and care rates is fairly involved and is thus presented in Appendix A to avoid cluttering the text here. In brief, we have adopted a value of €106 for the overnight accommodation and €45 for the care in the "≥ 10 hours" category.

Furthermore, the Steer report states that: "Based on IATA airline economics data, the average yield for European airlines has fallen from €206 in 2012 to €148 in 2017 (probably 2018), with a CAGR of -5.4%, reflecting increasing airline competition and capacity provision, as well as an increased market share for LCCs, which are able to offer lower fares than network carriers on many routes (therefore further reducing the industrywide average yield)." Changes in the US are similar[9].

[8] The rate calculated by Steer [6] is the result of the analysis of data provided by airlines, claim agency stakeholders. It was also compared with disaggregated data presented in *Which*? (https://www.which.co.uk/news/2017/07/flight-compensation-and-the-airlines-that-wont-pay/), based on data provided by the UK Civil Aviation Authority.

[9] https://www.bts.gov/content/annual-us-domestic-average-itinerary-fare-current-and-constant-dollars

Table 12. Relative average per pax reimbursements and re-routing costs due by length of haul.

Length of haul	Average total reimbursement due, % change 2020 (Steer) / 2013 (SDG)	Re-routing same airline, as % of reimbursement due, 2020 (Steer)	Re-routing other airline, as % of reimbursement due, 2020 (Steer)
Short haul	-23%	10%	133%
Medium haul	-23%	10%	133%
Long haul	-23%	10%	133%

(Values rounded to nearest whole percentage.)

The average yield is per passenger. In Figure 4.9 (*ibid.*) the **average yield falls by about 23%** over the period 2014 to 2018, such that we have applied this reduction in our previously simulated values for 2014 to 2019. This is reflected in Table 12. Pending further in-house data and simulations, the common rebooking and reimbursement values in Table 13 and Table 14 are thus 23% lower than those in Table 10 and Table 11. The 'same airline re-routing' value in Table 12 aligns with the 10% applied in Table 10 and Table 13 for delays in the "≥ 5 hours" category, although the 33% uplift for 're-routing other airline' (of Table 12) is not deployed therein, this being more crudely captured in the 50% of the "≥ 10 hours" delay category.

Table 13. Departure delay duration base scenario estimated costs – pax wait for flight.

	Departure delay duration				
Haul	≥ 2 hours	≥ 3 hours	≥ 4 hours	≥ 5 hours	≥ 10 hours
Short haul	€7$^{80\%}$	€10$^{80\%}$ €250$^{58\%}$	€13$^{80\%}$ €250$^{58\%}$	€205$^{10\%}$€18$^{80\%}$ €250$^{58\%}$	€205$^{50\%}$ €45 €250$^{58\%}$ €106
Medium haul		€10$^{80\%}$ €400$^{58\%}$	€13$^{80\%}$ €400$^{58\%}$	€265$^{10\%}$€18$^{80\%}$ €400$^{58\%}$	€265$^{50\%}$ €45 €400$^{58\%}$ €106
Long haul		€300$^{58\%}$	€13$^{80\%}$ €600$^{58\%}$	€900$^{10\%}$€18$^{80\%}$ €600$^{58\%}$	€900$^{50\%}$ €45€600$^{58\%}$ €106

Key: Care, rebooking, compensation, accommodation

Table 14. Departure delay duration base scenario estimated costs – pax opt for reimbursement.

	Departure delay duration				
Haul	≥ 2 hours	≥ 3 hours	≥ 4 hours	≥ 5 hours	≥ 10 hours
Short haul	€7$^{80\%}$	€10$^{80\%}$ ~~€250~~	€13$^{80\%}$ ~~€250~~	€205$^{90\%}$€18$^{80\%}$ ~~€250~~	€205$^{90\%}$ €45 ~~€250~~ €106
Medium haul		€10$^{80\%}$ ~~€400~~	€13$^{80\%}$ ~~€400~~	€265$^{90\%}$€18$^{80\%}$ ~~€400~~	€265$^{90\%}$ €45 ~~€400~~ €106
Long haul		~~€300~~	€13$^{80\%}$ ~~€600~~	€900$^{90\%}$€18$^{80\%}$ ~~€600~~	€900$^{90\%}$ €45 ~~€600~~ €106

Key: Care, reimbursement, compensation, accommodation

Again, on a statistical basis, it is unlikely that many passengers would reach delays of 10 hours and above, and thus receive the care payments in the final column.

3.5 Cost of passenger delay – 'soft' costs

Soft costs "refer to a loss in revenue to one airline as a result of a delay on one occasion, this loss may be considered to be largely the gain of another airline, gaining a passenger who has transferred their custom. When scalable costs (multiplied over a period of time or a network) are assessed, only some net loss to the airlines of the soft costs is likely (e.g. due to trip mode substitution, trip consolidation, trip replacement (e.g. teleconference) or cancellation)." [3]

3.5.1 Costs in 2014

Table 15. Soft costs by delay duration and aircraft type (base cost scenario), for 2014 (€).

Delay (mins)	5	15	30	60	90	120	180	240	300
B733	1	16	90	480	950	1 340	2 030	2 710	3 380
B734	2	18	100	550	1 080	1 520	2 310	3 090	3 860
B735	1	14	80	430	840	1 190	1 800	2 400	3 000
B738	2	20	110	620	1 220	1 710	2 600	3 470	4 330
B752	2	24	140	750	1 480	2 090	3 170	4 220	5 280
B763	3	30	170	940	1 840	2 590	3 920	5 240	6 540
B744	4	49	280	1 510	2 970	4 170	6 330	8 450	10 560
A319	1	16	90	510	1 000	1 410	2 140	2 860	3 570
A320	2	19	110	590	1 150	1 620	2 460	3 290	4 110
A321	2	23	130	710	1 400	1 970	3 000	4 000	5 000
AT43	0	5	30	160	320	450	680	910	1 140
AT72	1	8	40	230	460	650	990	1 320	1 640
DH8D	1	8	50	260	510	710	1 080	1 440	1 800
E190	1	11	60	350	680	960	1 460	1 950	2 430
A332	3	34	190	1 050	2 060	2 900	4 400	5 870	7 330

3.5.2 Costs in 2019

We have reviewed the literature since the previous reporting [3] and found no direct, substantive evidence as a basis for which to adjust the soft costs. New literature explores the changes in airlines' business models, and demonstrates that there is increasing convergence between the low-cost and the full-service network airlines' business models [7] [8]. Further work that links competition with on-time-performance, delays and cancellations is presented by Cao et al. [9]. The authors found that worse quality of service can be linked to less competition in a market, where average flight delay and cancellations tend to increase in markets exhibiting less competition.

Regarding passenger expectation on delay in the European context, if passengers expect departure delay and delay on arrival is avoided through airline's operations management, the "passengers accept it without causing soft costs to the airline." [10]. In other recent work [11] analysed the influence of on-time performance (OTP) in the USA air travel market. Their empirical analysis further confirms that passengers value punctuality and are willing to pay for it. The authors estimate that passengers are willing to pay $1.56 per minute of delay to avoid it. Furthermore, the analysis shows that by reducing minutes of delay by 10%, an airline can increase variable profit by 3.95% (on average), which is mainly driven by increase in travel demand, less than by the price markup. Yimga [12] extended this work, with several findings. The author confirmed that delays impact passengers' utility in a negative manner. The presented results suggest that passengers "are willing to pay $0.78 on average for each additional minute of flight arrival delay to avoid delay. [12]". The worsening of on-time performance "has a strong negative effect on the market price."

All in all, our contention is that significantly increasing passenger information and awareness of Regulation 261 rights, as mentioned in Section 3.4 and as reflected in the highly elevated compensation claim rate in 2018 (58%, [6]) is probably the most compelling reason to increase the soft cost of delay to the airlines. Whilst erosion of differentiation of business models (cited above) might suggest a narrowing of the low-high cost separation, and increased competition and pressure on fares might drive down the soft costs, there is no quantitative evidence to support such a calculation. As in 2014, we have again simply increased the soft costs relative to 2014 by the compound inflation of 5.5% cited in Section 2.1, to contribute to the values of Table 16. Note also that the seats cited in Table 2 are also used in the calculation, such that several values have increased by more than 5.5% (e.g. for the A332).

It is stressed that further market research is still required in this field to build better and updated estimates of these soft costs.

Table 16. Soft costs by delay duration and aircraft type (base cost scenario), for 2019 (€).

Delay (mins)	5	15	30	60	90	120	180	240	300
B737	1	17	90	510	1 010	1 420	2 160	2 880	3 600
B734	2	20	110	610	1 190	1 670	2 540	3 390	4 240
CRJX	1	11	60	340	670	950	1 440	1 920	2 400
B738	2	21	120	650	1 280	1 810	2 740	3 660	4 570
B752	2	26	150	810	1 590	2 240	3 400	4 540	5 670
B763	3	32	180	990	1 940	2 730	4 140	5 520	6 900
B744	5	54	300	1 660	3 270	4 600	6 980	9 310	11 640
A319	2	17	100	540	1 060	1 490	2 260	3 020	3 770
A320	2	21	120	650	1 270	1 790	2 720	3 630	4 540
A321	2	26	150	810	1 590	2 240	3 400	4 540	5 670
AT43	0	5	30	170	330	460	700	930	1 170
AT76	1	9	50	270	530	750	1 140	1 520	1 900
DH8D	1	9	50	280	540	760	1 160	1 550	1 930
E190	1	12	70	370	720	1 010	1 540	2 050	2 570
A332	3	39	220	1 200	2 350	3 310	5 020	6 700	8 370

3.6 Cost of curfew breach

3.6.1 The terminology of curfews and bans

There is a somewhat **variable terminology** on the topic of night 'curfews', 'bans', 'quotas', 'surcharges' and 'fines'. Essentially, a number of European airports have restrictions on the number of aircraft that arrive or depart during a designated night-time period (e.g. 2300 – 0600, local time), which are normally driven by locally imposed/agreed regulations and motivated by reducing noise disturbances to local residents. (Several airports also operate peak or 'shoulder' rates, to encourage dilution of the noise intensity by shifting the demand.) Practice, rules, quotas and exceptions vary from airport to airport, and are often highly complex. Even an essential night ban will have some exceptions.

Many airports operate a **quota system**, which limits how many aircraft are allowed/scheduled to arrive or depart during such a curfew period, accumulated over a season. These restrictions often ban flights from being scheduled during the curfew, and apply penalties and quotas to unscheduled operations during the curfew period. Quotas may refer to movements and/or accumulated noise impacts. Landings or departures during this period are often subject to a significant increase in the noise charge associated with the landing or departure. This may be referred to as a 'surcharge' or 'fine', but is usually noise-related. (It may be shared or paid in full to a local community fund, for example.) Exemptions may be made for aircraft below a certain noise threshold, for flights associated with essential airport safety checks (e.g. ILS calibrations), and for emergencies. Practice will also vary by location (for example the cargo and freight operations at East Midlands airport).

The planning document issued by the UK Department for Transport [13] relating to Heathrow, Gatwick and Stansted Airports refers not only to schedule bans but also "sufficient headroom to ensure the limits can still be complied with in the event of unplanned disruption". The disincentive to arrive or depart during the night quota period is exemplified for Heathrow by the statement that: "For any arriving/departing movements that are unscheduled during the Night Quota Period ... Noise Charges are 5 times the normal charges. We may, at our sole discretion, waive these additional charges in exceptional circumstances" [14].

More exceptionally, airports may essentially operate a **total night ban**. An example is the "nachtflugverbot" ('night flight ban') operated at Frankfurt, whereby arrivals/departures cannot be planned 2200-0600, although departures are allowed 2200-2300 and 0500-0600 subject to prior agreement and a quota system, and arrivals are allowed 2300-2400, again with explicit permission and only if the reasons for delay are not within the scope of the airline (e.g. due to weather), and must otherwise divert. Only emergencies are handled 2400-0500. Fuller details are published by Fraport[10] (in German) and the corresponding policy summary document is published (in German) by the corresponding ministry of Hessen [15].

[10] https://www.fraport.com/de/umwelt/schallschutz/flugbetrieb--verfahren/bahnensystem-und-betriebszeiten.html

A similar situation pertains at Zürich, with a strict ban in place 2330-0600[11]. Arrivals are only permitted for emergencies (and in such cases noise charges are actually *lower* than the standard fees). Such emergencies may rarely include a late snow clearance for an inbound SWISS flight, for example, but these flights are otherwise forced to divert (with some airports, such as Basel, not accepting landing for diverted flights if the reason for diversion is the night ban at Zürich, which may thus result in an expensive cancellation). Regarding *departures* from Zürich, these may be planned up to 2245. Delayed flights are still permitted after this time but with a heavy increase in fees, but these are usually less than the anticipated hard and soft passenger costs of a cancelled departure, and are only permitted up to 2330. Sometimes, constraints such as this, after 2245, are referred to as 'soft' curfews, and after 2330 as a 'hard' curfew (although these terms do not correspond to the passenger hard and soft costs.) Again, it is to be stressed that these strict bans at Frankfurt and Zürich are exceptions. More common practices at larger airports are noise surcharges (subject to quotas).

3.6.2 Costs in 2014

The 2015 report did not include curfew cost calculations. These will be a new feature of the 2021 report on the costs for 2019.

3.6.3 Costs in 2019

Table 17 illustrates different types of curfew breach and the corresponding (cost) consequences. It is important to avoid double-counting, e.g. if flight flies in and out of a curfew (case [6]) the inbound and outbound passenger and crew costs are already counted due to the 30 minutes delay (assuming the curfew does not *additionally* affect the turnaround time). Likewise, only any *additional* parking costs are included for a flight breaching a curfew and then overnighting at the airport (instead of flying a subsequent leg as planned). The explicit curfew costs in BEACON will include additional landing and/or departure fees, and additional parking charges (see later). Accelerated fuel burn to meet an arrival curfew is not included in the table. It will also be modelled explicitly in Mercury (and may be added to the statistical costs in future).

Expanding in detail on the more complex example of case [4], Table 18 illustrates costs for an unplanned overnight at an outstation. (A similar table with adapted assumptions would describe an unplanned overnight at a home station. Both types of scenarios will be explicitly modelled in BEACON). The table demonstrates the complexity and variability in the assumptions that need to be made in order to make estimates of the costs associated with a curfew breach. This may be challenging in attempting to generate corresponding statistical costs for curfew breaches. Indeed, we do not propose to calculate 'per minute' costs of delay for curfew breaches.

[11] https://www.zurich-airport.com/the-company/media/current-topics/night-flight-ban

Table 17. Modelled curfew breach costs, by scenario.

Events			Modelled costs				
Curfew initial event	**[Case] Subsequent action**	**Out-of-position event**	**Noise penalty**	**Fuel burn and maintenance**	**Passenger**	**Crew**	**Parking**
Aircraft **arrives early** (e.g. arrives 0530, curfew until 0600)	**[1]** Breaches curfew	No	Arrival	N/A	N/A	N/A	N/A
	[2] Holds (e.g. in stack) until no curfew[12]	No	N/A	Holding (airborne)	N/A	N/A	N/A
Aircraft **arrives late** (e.g. arrives 2330, curfew from 2300)	**[3]** Aircraft diverts to alternate	Not modelled in BEACON due to complexity and *relative* rarity					
	[4] Planned to fly on, but overnights	Yes	Arrival	N/A	***Unplanned overnight***		
	[5] Not planned to fly on, overnights	No		N/A	N/A	N/A	N/A
	[6] Planned to fly on, and does so	No	Arrival and departure	N/A	N/A	N/A	N/A
Aircraft **departs late** (e.g. departs 2330, curfew from 2300) (or assesses this option)	**[7]** Breaches curfew	No	Departure	Waiting (at-gate)	N/A	N/A	Any additional, or reduced, costs
	[8] Cannot depart due to ban at destination	Yes	N/A	N/A	***Unplanned overnight***		
Aircraft **departs early** (e.g. departs 0530, curfew until 0600)	**[9]** Breaches curfew	Not modelled in BEACON (relatively rare event)					

[12] NB. This is usually an ATC decision, not left to the airspace user. E.g. see NATS example.

Table 18 is based on a B738 and B744 and presents a number of assumptions regarding the primary and reactionary costs for a late in-bound aircraft at an outstation, that was planned to make a further, onward rotation. It is built from multiple tables in the previous sections, drawing in each case on the *base* cost scenarios. The low-base-high curfew scenarios are thus actually driven by the assumptions presented on the number of connecting passengers awaiting a flight the following day and the number of hours' delay modelled in each case, as captured primarily in the first data row. The calculations **assume that the airline is liable** for the delay that causes the curfew to be breached, and hence for subsequent compensation payments to the passengers, including for reactionary delays.

On the inbound flight, it assumes that (only) 20% or 10% of passengers are significantly delayed until the next day. The same applies to the original crew, with extra hours costed to their delayed return (but not to their return leg *per se*, which is not an *additional* cost). The crew would need to attain the minimum resting time before being allowed to fly back the aircraft. Alternatively, a deadhead crew (DHC) may be flown (in passenger seats) out to the outstation to operate the aircraft on its next leg (often back to the home station). The base cost scenario includes operating a DHC. The return flight times, with turnaround, are based on average *intra-European* rotations (i.e. filtered for the B744), giving totals of 350 minutes for the B738 and 400 minutes for the B744, for costing the corresponding DHC salary hours (but neglecting any DHC fares when carried as passengers, if even applicable).

RDC Aviation[13] were tasked with calculating overnight parking charges for the 15 selected aircraft types at 30 airports. Drawing on ACI EUROPE airport size categories [16], ten airports were each selected from Group 1 (over 25m passengers), Group 2 (10-25m) and Groups 3 and 4 (5-10m and less than 5m passengers, respectively) – to ensure a range of parking charges at 10 'large', 10 'medium' and 10 'small' airports. Note that airport charge calculations (such as landing, parking and other charges) vary between airports and are highly time consuming to work out. Taking MTOW-based parking charges as an example, tariffs at Zürich vary across nine MTOW classes, at Madrid Barajas by actual MTOW, whereas Frankfurt groups aircraft by their dimensions (length and wingspan) rather than MTOW. These will all be used in the explicit Mercury model for BEACON, but cannot be shown here in order to protect the rights on RDC Aviation's work.

However, for Table 18 comparable parking charges across these airports were calculated for two six-hour time periods: 00:01-06:00 and 06:01-12:00 (local time). RDC Aviation calculated these with September 2019 data from their 'AirportCharges' tool, converting all costs to euros. The calculation of charges at some airports required basic assumptions, e.g. using their in-house standard MTOWs[14] and specifying parking at the stand rather than remotely. A dataset of 900 parking charges (i.e. 30 airports, 15 aircraft types and two time periods) was prepared as an input to these calculations. The results of these are shown under the **parking cost scenarios** in Table 18, using the 'large' airport averages for the high and base scenarios, and the 'medium' airport averages for the low scenario. It will be noted that although such charges will be included explicitly in the BEACON model, they are **very small** compared with the other costs associated with a curfew breach. After the primary costs of delay, the reactionary cost assumptions are shown in Table 18. The final (lower) part of the table shows the allocation of further costs in the network allocated to short-haul flights as a result of the aircraft

[13] RDC Aviation Ltd, will be used as RDC Aviation in the text.

[14] Similar to the MTOWs shown in Table 2.

delayed at the outstation causing further knock-on effects to other aircraft (non-rotational delays). These 5-hour charge blocks comprise passenger compensation, the cost of care and (capped) soft costs, all allocated as narrow-body (B738) short-haul delays. Note that the DHC operation is assumed to mitigate these somewhat. Overall, the **reactionary costs are much higher** than the primary cost: an effect indeed reported in practice by airlines.

Table 18. Costing schema for curfew breach and unplanned overnight at outstation.

Passenger cost scenarios			Crew cost scenarios			Parking cost scenarios		
20% pax delayed 12 hours	10% pax delayed 8 hours	10% pax delayed 6 hours	Orig. crew overtime 12 hours + DHC	Orig. crew overtime 8 hours	Orig. crew overtime 6 hours	Extra 12 hours (€)	Extra 8 hours (€)	Extra 6 hours (€)
High	Base	Low	High	Base	Low	High	Base	Low
Primary costs								
Overnight, + compensation, + half pax (above) rebooked			Original crew overnight, + overtime			B738: 710 B744: 1660	B738: 405 B744: 965	B738: 280 B744: 510
Soft cost (capped)			-	DHC	-	-	-	-
					<u>Total</u> primary costs (k€)	B738: **23** B744: **66**	B738: **17** B744: **44**	B738: **12** B744: **34**
Reactionary costs (rotational and non-rotational)								
Next rotation delayed by:			(Covered above)			(Covered above)		
12 hours	6 hours (DHC)	6 hours						
20% pax opt for reimbursement								
Overnight + compens.	Overnight + compens.	Care + compens.						
Soft cost (capped)								
+ 5-hour further non-rotational short-haul delay in network:			(Considered as absorbed / quasi-zero)			(Negligible)		
x 2	**x 1**	**x 1**						
					<u>Total</u> reactionary costs (k€)	B738: **105** B744: **232**	B738: **79** B744: **206**	B738: **64** B744: **169**

Table 19. Costing results for curfew breach and unplanned overnight at outstation.

Total costs (k€)	High	Base	Low
Sum from previous table (generic, but reasonably representative)	B738: **129** B744: **299**	B738: **95** B744: **250**	B738: **76** B744: **203**
Noise surcharge *example* (LHR) (landing 30 minutes after curfew)		B738: **35** B744: **35**	
Total	B738: **164** B744: **334**	B738: **130** B744: **285**	B738: **111** B744: **238**

Table 19 brings these results together with a specific noise surcharge example from London Heathrow. Note that total values such as these will be highly variable in explicit cases, based not only on the variability of the previous, generic assumptions, but also on the high variation of noise surcharges across Europe.

Table 20 shows cancellation costs and corresponding aircraft seat numbers published in 2020 by EUROCONTROL (see [17], and Appendix B). These are matched *post hoc* to the nearest aircraft in our set, and their MTOWs, in the left-hand columns. (In passing, the seats and MTOWs give reasonable fits, $r^2 > 0.75$, against the costs, for future interpolation/extrapolation to other aircraft.) It would be of interest to further discuss with airlines (notably those in the BEACON Advisory Board) to assess the trade-off between cancelling a flight and operating a flight into a known curfew breach. *Prima facie* (examining the costs in Table 19 and Table 20) it would be cost effective to cancel in many cases, although wider issues such as public image and passenger loyalty (i.e. soft cost considerations) need to be taken into account when cancelling a flight for economic reasons.

Table 20. Cost of cancellation.

(Aircraft)	(MTOW)	Seats	Base scenario cost (k€)
(B733)	(61.2)	50	6.5
(B734)	(66.3)	120	16
(B735)	(57.1)	180	25
(B738)	(76.2)	250	83
(B752)	(108.8)	400	120

4 Conclusions and next steps

4.1 Overall cost changes 2014 to 2019

The overall cost impacts of the updated values in this deliverable will become finally apparent when the statistical reporting is finalised for the update to the 2015 reference document [1]. However, it is likely that the two most significant effects will be the 25% drop in the fuel price (see Section 3.1.2) and the significant increase in the compensation successful claim rate for delay, growing from 11% in 2014, to 58% in 2018 (see Section 3.4.2; as noted, for statistical estimations this needs to be factored down by the attributability rate (70%), i.e. to approximately 41%). These will work in opposite directions, with the fuel price change driving delay costs down (especially those off-gate), supported by the reduced passenger rebooking and reimbursement rates (Section 3.4.2), and the compensation claim rate certainly driving delay costs up (as more compensation is paid as a function of arrival delay). Further analysis will be compiled as the reference document is updated.

4.2 Next steps

This deliverable will be opened up for further consultation, as introduced in Section 1. In particular, further dialogue is anticipated with the airlines active in the BEACON project on the Regulation 261 and curfew modelling, the latter is also planned for consultation with EUROCONTROL teams active in this area. As flagged, statistical estimates face the real challenge of complex and high variabilities across such curfew models.

The markedly increased attributability rate for compensation payments under Regulation 261 will render certain previous simplifications to the statistical costs more complicated, and this will require further enhancements to the statistical models (e.g. taking close account of delay cause distributions) to protect the integrity of future estimates.

Despite these challenges with regard to the statistical (reference) models, these will not impact the explicit models of BEACON in the same way, and values in this deliverable may be fairly readily incorporated into BEACON cost functions, helping to drive flight prioritisation algorithms and to estimate subsequent cost impacts in the model, alike. The extensive datasets obtained from RDC Aviation (outlined in Section 3.6.3) will be invaluable in this respect.

4.3 Recommendations beyond BEACON

As explained, the values in this deliverable will be used to furnish updates to the standard reference (statistical) values published by the University of Westminster. This will be achieved in consultation with key stakeholders to maximise the value thereof. The need for further work (market research) to build better and updated estimates of the soft costs is again flagged, as there is insufficient literature or data to fully support this activity. It is hoped that the new reference values will furnish a useful contribution to wider delay assessment for stakeholders such as the PRU and SESAR, as the industry emerges from the pandemic and SESAR 3 research gears up.

5 Glossary and acronyms

Acronym	Definition
AB	Advisory Board
ANSP	Air navigation service provider
ATFM	Air traffic flow management
APU	Auxiliary power unit
AU	Airspace user
BADA	Base of Aircraft DAta
BE	Behavioural economics
CAGR	Compound annual growth rate
DHC	Deadhead crew
ECTL	EUROCONTROL
EU	European Union
Explicit (costs)	Case-by-case application of costs in specific circumstances, for example taking into account if a specific delay is airline-attributable and thus associated with a specific passenger compensation payment, cf. “statistical (costs)”
HICP	Harmonised Index of Consumer Prices
ILS	Instrument Landing System
MTOW	Maximum take-off weight
NM	Network Manager
OTP	On-time performance
Pax	Passenger
PRU	Performance Review Unit
RDC	RDC Aviation Ltd
SDG	Steer Davies Gleeve
Statistical (costs)	Probabilistic values for generic reference, e.g. the cost of an average minute of at-gate delay, taking into account delay distribution causes, cf. “explicit (costs)”
SWISS	SWISS International Air Lines
UoW	University of Westminster

6 References

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Appendix A Passenger overnight accommodation and care rates

(a) Overnight accommodation rate

(i) Reflecting Steer report: €118

The base scenario accommodation value in the UoW 2014 report (see Section 3.4.1) was €65, derived from the European Commission's impact assessment [4]. The assessment study included a distribution of accommodation values across different carrier types and passenger trip purposes. The average accommodation rate for a business trip was cited as €96. The value adopted for 2014 incorporated an accommodation rate for a regional carrier (€53), inflation (from 2012-2014) and transport to the accommodation (€10). The latest study [6], contains only the weighted average accommodation rate, weighted towards more costly states in the EU, with the value of €157 (applied to 20% of passengers with a delay of over 5 hours). This value is about 60% higher than the average business hotel rate in 2012 (€96). To adjust the 2014 rate to a 2018 (2019) value, a simple proportion could be applied to the 2018 rate. The adopted room rate value in 2014 was 55% of the average business travel hotel rate. Applying the same percentage to the 2018 value (€157) and including the cited transportation costs of €30, yields €118.

(ii) Simple inflationary approach: €69

The UoW accommodation rate for 2014 (€65), incorporated accommodation (€53), inflation from 2012-2014 and transport to the accommodation (€10). Adopting a simple inflationary approach, increasing the €65 by the cumulative inflation rate of 5.5% (see Table 1), would yield a value of €69.

(iii) Adopted value: €106

Whilst the Steer rate (i) is rather higher than the UoW-inflated value (ii), the former reflects a significant corpus of further research. We have adopted a value using a weighting of 75:25 of the values (i):(ii) above, respectively, resulting in €106, and note that this may be subject to further review following feedback from various advisory body members, including airlines active in the BEACON project.

(b) Overnight care rate

(i) Reflecting Steer report: €68

Regarding overnight care rates, the main difference in the 2020 Steer report (Kouris, 2020), compared to the 2013 (SDG) study, is the addition of a €50 payment for overnight subsistence to the €18 care values, as a more substantial meal is foreseen for long delays. Adding this for delays over 10 hours, would raise the cost of care from €21 (UoW 2014 value) to €68 (SDG €18 + €50 values) in this category.

(ii) Simple inflationary approach: €22

Adopting a simple inflationary approach, increasing the UoW 2014 value (€21) by the 5.5% of Table 1, would yield a value of €22.

(iii) Adopted value: €45

Whilst the Steer rate (i) is again rather higher than the UoW-inflated value (ii), the former reflects a significant corpus of further research. In consideration of the fact that (a) and (b) will be added together for overnight costs used in the calculations, and the higher value was erred towards in (a), we have adopted a value using a weighting of 50:50 of the values (i):(ii) above, respectively, resulting in €45. We again note that this may be subject to further review following feedback from various advisory body members, including airlines active in the BEACON project.

Appendix B Cost of cancellation

<table>
<tr><td>Value 1</td><td>
<table>
<tr><th rowspan="2">Cost of cancellation (€)</th><th colspan="4">Narrow-body</th><th colspan="2">Wide-body</th></tr>
<tr><th colspan="3">Traditional network carrier[22]</th><th>Low-cost carrier</th><th colspan="2">Traditional network carrier</th></tr>
<tr><td>Seats</td><td>50</td><td>120</td><td>180</td><td>189</td><td>250</td><td>400</td></tr>
<tr><td>Value (€)</td><td>6 540</td><td>16 040</td><td>24 900</td><td>19 420</td><td>82 730</td><td>120 830</td></tr>
<tr><td>Of which passenger care and compensation (€)</td><td>3 280</td><td>8 020</td><td>13 090</td><td>18 470</td><td>42 740</td><td>68 390</td></tr>
</table>
(adjusted from 2014 prices)</td></tr>
<tr><td>Value 2</td><td>System-wide average cancellation cost (adjusted from 2014 prices): € 18 570</td></tr>
<tr><td>Source</td><td>Data supplied by the airline members of the SESAR CBA team
Expert judgment derived from an analysis of 2012 total flights carried out in Europe</td></tr>
</table>

This extract is taken from EUROCONTROL's *Standard inputs for economic analyses*, Ed. 9.0, December 2020 [17]. Further discussion with the EUROCONTROL team would be of value to discuss the extent to which certain cost factors are taken into account, to allow a more informed comparison of these costs and the curfew costs presented in the main text.

Appendix C Taxi and en-route tactical maintenance costs 2019 (provisional)

The following pair of tables accompanies the provisional at-gate tactical maintenance cost table (refer to Table 6 in Section 3.2.2).

Table 21. Taxi, tactical maintenance costs 2019 provisional (€ per minute).

Aircraft	Low scenario	Base scenario	High scenario
B737	1.3	3.0	4.8
B734	1.6	3.6	4.8
CRJX	1.3	2.9	3.9
B738	1.4	3.2	5.1
B752	2.2	4.8	6.4
B763	2.9	5.9	9.3
B744	5.7	8.0	9.7
A319	1.7	4.0	5.4
A320	1.8	3.8	5.9
A321	2.0	4.4	5.9
AT43	0.8	1.8	2.4
AT76	1.1	2.4	3.2
DH8D	1.0	2.2	2.9
E190	1.4	3.1	4.2
A332	3.1	6.3	9.9

Table 22. En-route, tactical maintenance costs 2019 provisional (€ per minute).

Aircraft	Low scenario	Base scenario	High scenario
B737	1.8	4.1	6.5
B734	2.2	4.7	6.4
CRJX	1.8	4.0	5.3
B738	1.8	4.1	6.6
B752	2.7	5.9	8.0
B763	3.7	7.5	11.9
B744	7.5	10.4	12.7
A319	2.2	5.2	7.2
A320	2.2	4.8	7.4
A321	2.6	5.8	7.8
AT43	0.9	2.0	2.7
AT76	1.3	2.8	3.8
DH8D	1.2	2.7	3.6
E190	1.8	4.0	5.4
A332	3.9	7.9	12.5