



Delays in European aviation – building passenger cost models

Prof Andrew Cook
University of Westminster

Engage summer school, virtual event, 21-25SEP20



Founding Members



Delays in European aviation

Overview

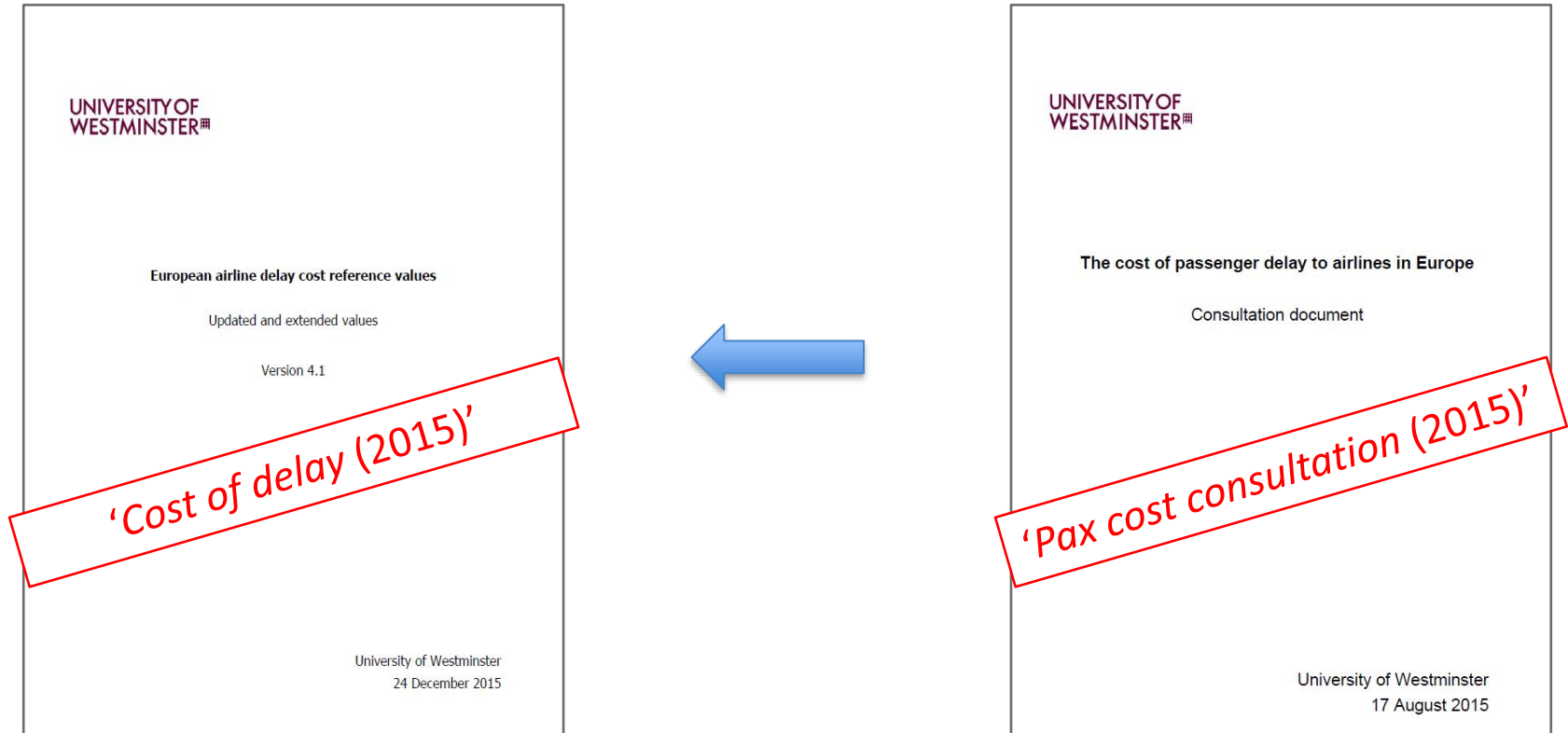


- From 2000, to 2020, and beyond
- Model elements
- Focus on outputs
- Challenges ahead
- Examples of users and projects

Tailored update cf. Engage
summer school 2019

Delays in European aviation

Two main sources (others variously cited)



<https://westminsterresearch.westminster.ac.uk/>
www.eurocontrol.int/library
etc...

Delays in European aviation

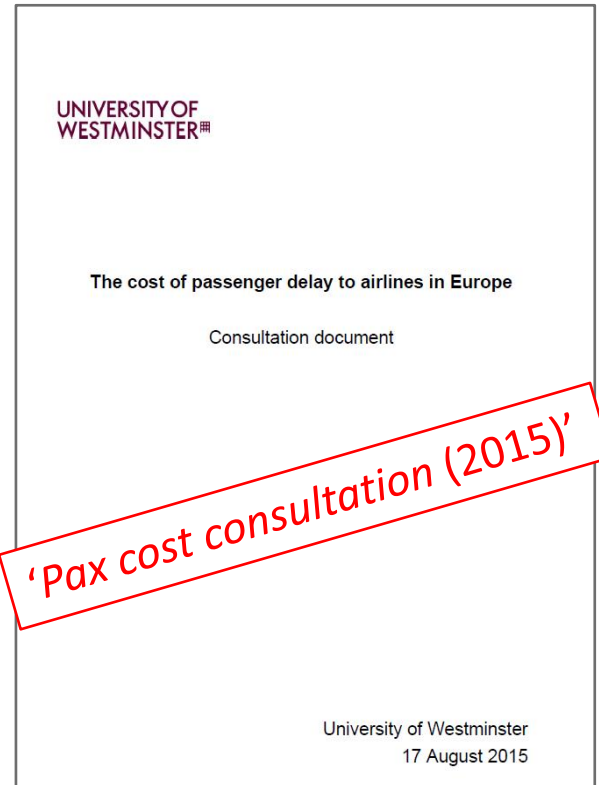
UoW consultation document

Feeding major 2015 update

UoW consultation document AUG-OCT15;
400+ contacts (mostly airlines)

EC Impact Assessment (Reg. 261)
+ limited literature (e.g. claim rates)

8.8% (inflationary) ... pax densities
=> net = 20%



From 2000, to 2020, and beyond

Delays in European aviation

A brief history and context



- Early 2000s
 - cost of delay
 - state of the art not very mature
 - no single, comprehensive study meeting industry needs
 - various values; lack of consensus
 - SES launched by Commission (2000-2004)
 - specifically in response to increasing delays
- University of Westminster framework started from scratch
 - review of method: all minutes are not equal
 - 2002-2004 (260 page ‘summary’)
 - data sources: secondary & primary, extensive interviews

Acknowledgements

The authors would like to thank the following for data provision and advice generously offered during the course of this research. We would especially like to thank the airlines who made particular, and often extensive, efforts to provide the detailed financial and operational data required as inputs to this Study.

Air France
Airbus Industrie
Austrian (Airlines)
Aviation Industry Press
Boeing Commercial Aircraft
Britannia Airways
British Airways
Condor Flugdienst
Cranfield College of Aeronautics
CSA Czech Airlines
Deutsche Flugsicherung
EasyJet
Four (anonymous) aircraft lessors
Four anonymous handling agents
IATA (Geneva & London)
Iberia
KLM Royal Dutch Airlines
Lido GmbH
Lufthansa
The Airline Monitor
The Federal Aviation Authority
Various airport charges' offices

The authors are also heavily indebted to continuous technical support and advice from PRU at all stages of this Study, and to Mr Vittorio Pimpinelli for so ably chairing a valuable workshop held in Brussels to review Edition 2 of this Report.

Delays in European aviation

A brief history and context



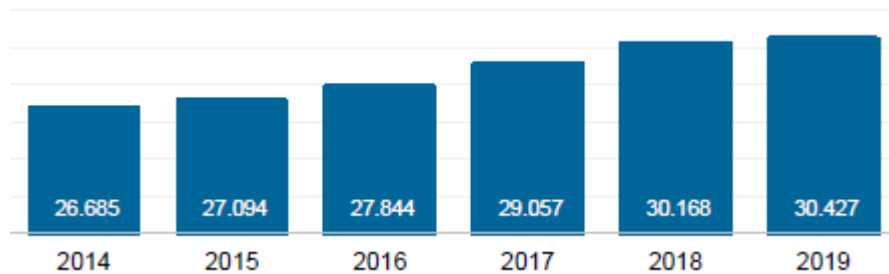
Key objectives of the 'new' framework

- Comprehensive, transparent approach
 - including margins of error
- Consultation and industry agreement
 - common reference values
- Operationally meaningful – aligned with airline mind set
 - bottom line in accounts (very challenging); interviews
- Shifting focus away from fuel-only costs
- Useful at network level, e.g. total and average ATFM delays

So, how have delays developed since? ...

Delays in European aviation

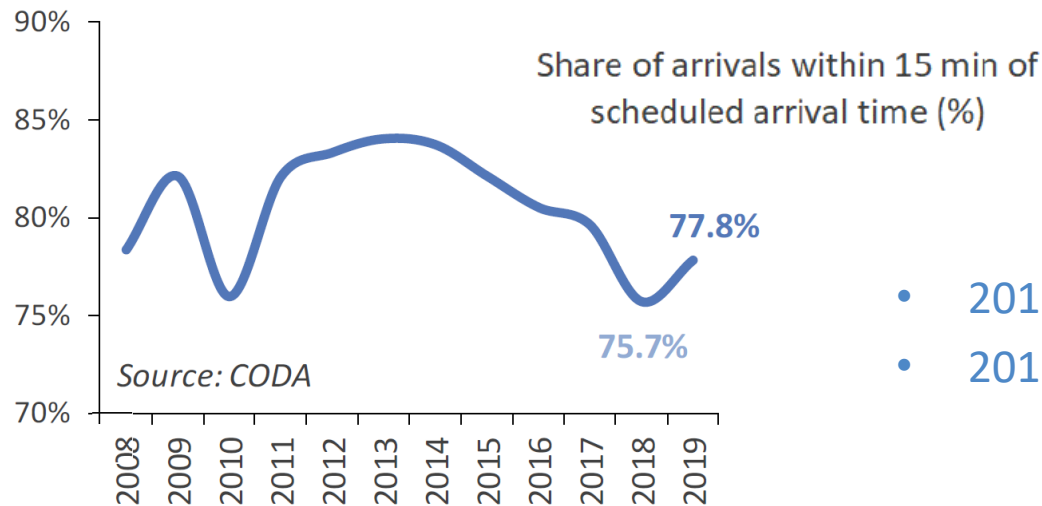
Latest European punctuality performance



Average daily traffic

Source: Network operations report 2019 (EUROCONTROL, 2020)

- Highest-ever traffic levels in 2019 (2016 ≈ back to 2008)
- Six years of growth (from 2014 incl.)
- Lower growth in 2019 (0.9% cf. 2018)



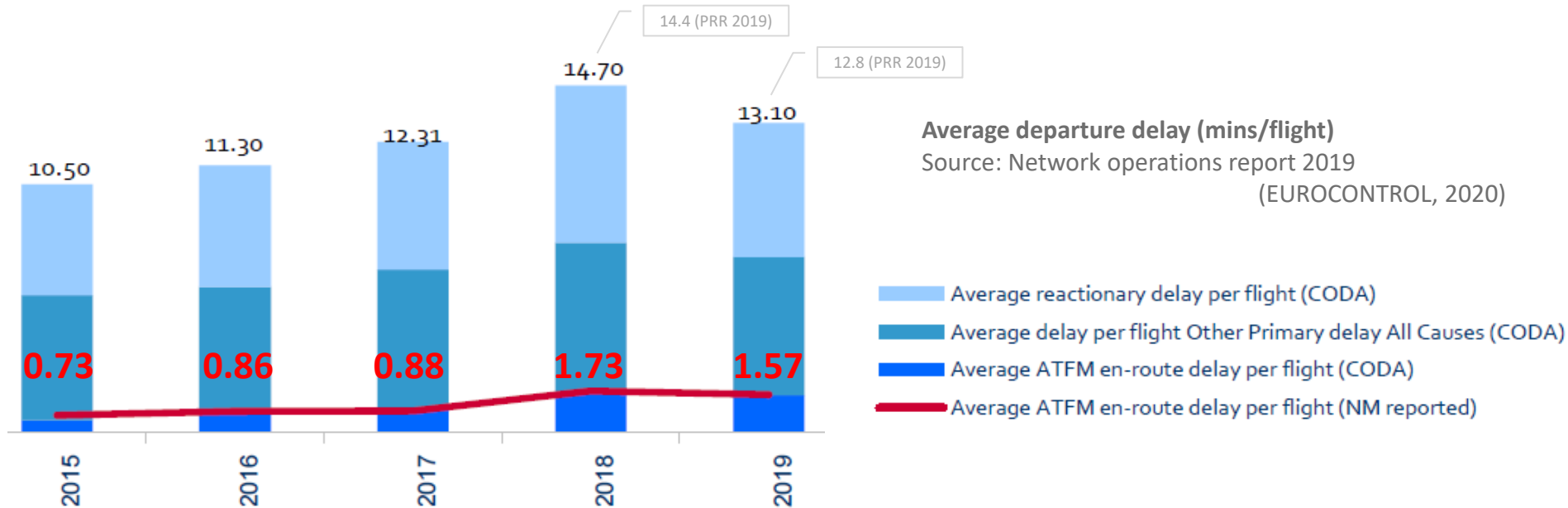
Source: CODA

Source: PRR 2019 (PRC, 2020)

- 2018: fifth consecutive annual fall
- 2019: improved

Delays in European aviation

Latest European punctuality performance



- Average en-route ATFM delay, some recovery in 2019: **1.57** mins/ft
cf. **RP2 target: 0.50** (2015-19)
 - total ATFM delay split about 70% en-route, 30% airport
 - en-route: capacity is main cause; followed by staffing and weather
- **Reactionary** ('knock-on') delay 44% (45-46% previous five years) – fairly **stable ratio**
- Some delay improvements in 2019 due to re-routing measures (with longer routes)
- **SESAR ambition** for 2035: average dep. delay: **6.5-8.5** mins/ft

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Latest European punctuality performance



metric	2000	2019
IFR flights	8.4M	11.1M
% flights arr. > 15 mins late	27%	22%
turnaround delay	33% [?]	33%
reactionary delay	39%	44%
ATFM/ANS delay	23%	21%

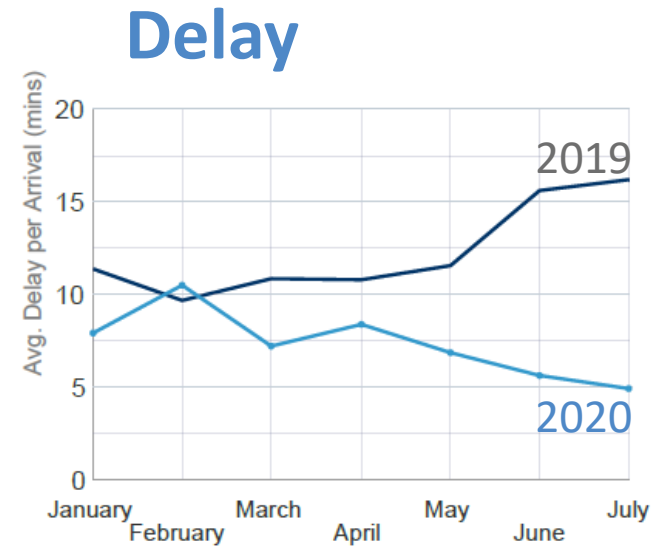
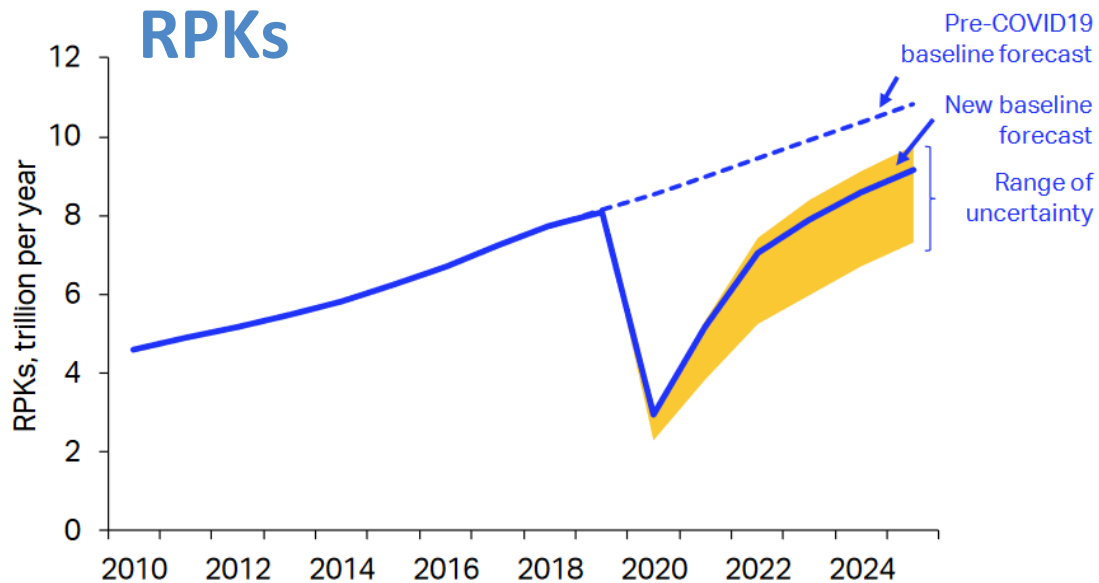
Sources: Performance Review Report 2000 (EUROCONTROL, 2001)
 Performance Review Report 2019 (EUROCONTROL, 2020)

Total cost of ATFM delay to airlines €₂₀₀₉ **1.7bn** in 2018,
 cf. ANSP delay penalties in SES Performance Scheme: €₂₀₀₉ **4m**

Source: Performance Review Body: PRB Monitoring Report 2018 (PRB, 2019)

Delays in European aviation

Traffic and delay as of end July 2020



Source: EUROCONTROL, 26 August 2020
(www.eurocontrol.int)

- Five years to recover to 2019 levels (i.e. by 2024)
- Uncertainty range asymmetric – bias to more negative growth
- Expected: some suppressed VFR re-bounce, less re. leisure & esp. business
- Passenger confidence (complex dimensions) and travel restrictions remain key to growth

Source: IATA Tourism Economics Air Passenger Forecasts, 30 July 2020 (www.iata.org)

Model elements

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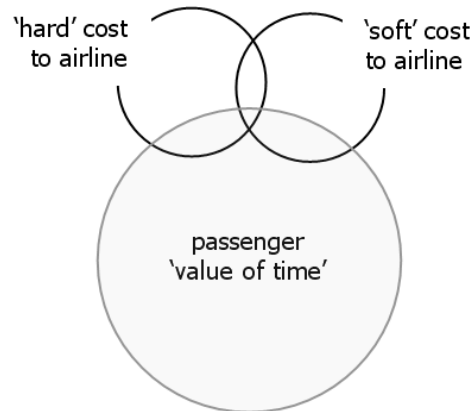
Model elements

Key features

- Tactical cost of delay
 - incurred on the day of operations, not planned in advance
 - e.g. aircraft waiting at-gate
 - mostly marginal costs
- Strategic cost of delay (then a new concept)
 - incurred in advance, often difficult to recover later ('sunk' cost)
 - e.g. schedule buffer ('opportunity' cost) & route extension
 - mostly unit costs

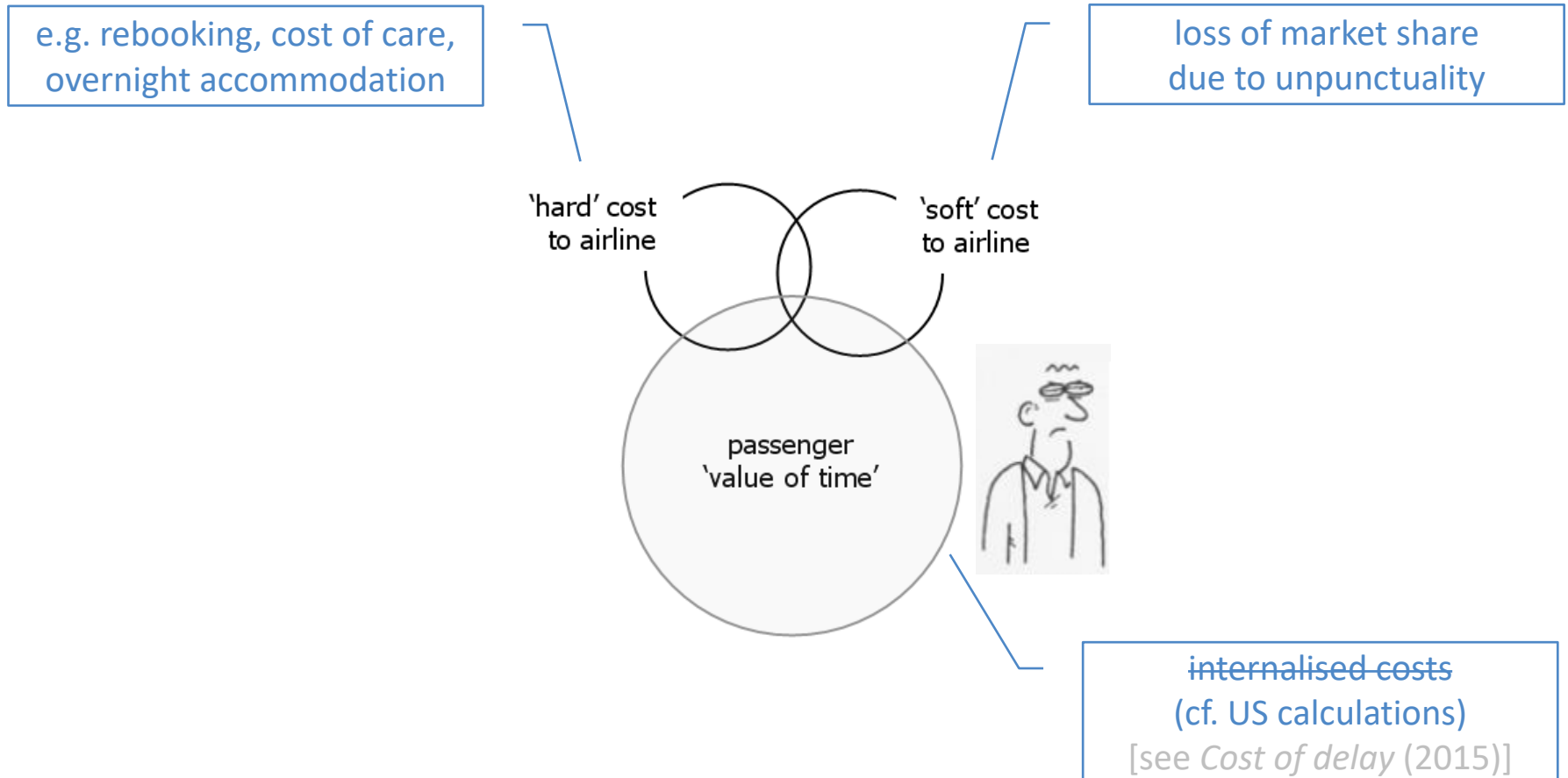
'Reactionary' delays may be defined as all delays which may be directly attributed to an initial, causal or primary delay, be they experienced by the causal aircraft, or by others.

- Passenger cost of delay
 - 'hard' cost to airline
 - 'soft' cost to airline
 - ~~internalised costs~~



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Passenger cost of delay



Delays in European aviation

Methodology and refinements (2004, Ed.2)



element	types of cost (in-house models, except fuel)
fleet	all fleet costs (depreciation, rentals & leases)
fuel	Lido/Flight, BADA, manufacturers
crew	schemes, flight hours, on-costs, overtime
maintenance	extra wear & tear powerplants/airframe (using the aircraft more)
passenger	'hard' & 'soft' (not internalised costs)
ground handling	aircraft and passengers – penalty if late / delayed at gate
airport charges	various aeronautical charging manuals and policies consulted
en-route ATC charges	requires a significant re-route due to the delay to have a large effect
CO ₂	considered allocated permits and CO ₂ price; small % fuel variation

Delays in European aviation

Methodology and refinements (2004, Ed.2)



element	strategic	tactical
fleet	$= f(\text{service hours})$	$\neq f(\text{utilisation}) = 0$
fuel		$=$ (e.g. no hedging between phases)
crew	unit	marginal (0 ... full overtime)
maintenance	unit	marginal (e.g. fixed LTO cycles)
passenger	0	dominate, non-linear

Delays in European aviation

Methodology and refinements (2004, Ed.2)



Cost types by operational phase.

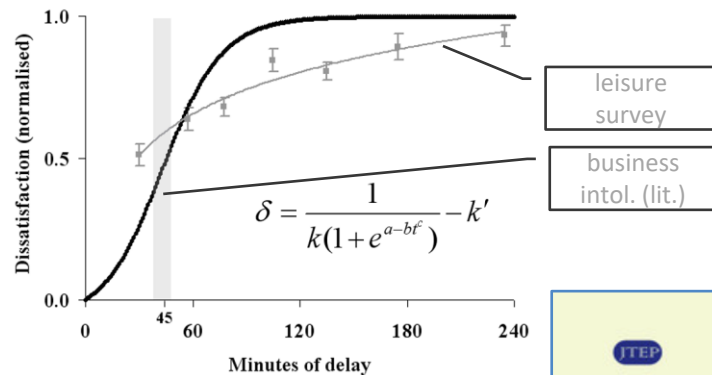
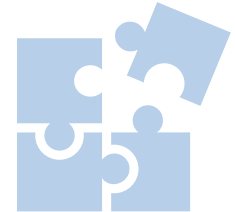
Cost to airline	Strategic	Tactical	Reactionary
Fleet	✓		
Fuel (and carbon)	✓	✓	(✓)
Crew	✓	✓	✓
Maintenance	✓	✓	✓
Passenger		✓	✓

Delays in European aviation

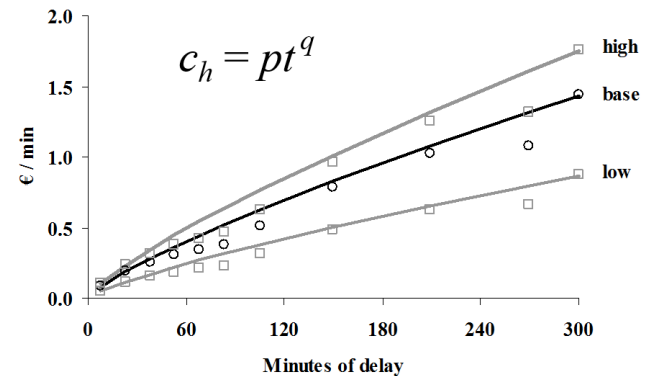
Methodology and refinements (2004, Ed.2)

Passenger costs modelling

- Originally Austrian + 'Airline Z' (very close), single average value
- Regulation (EC) No 261/2004 (17 February 2005)
- Logit curve (soft), power curve (hard) – basic, **but f (duration)**



Airline passenger Kano satisfaction model,
Wittmer and Laesser (2008) [ZRH].
In-house, bespoke surveys & airline models



Regulation 261 + airline policy.
Limited airline data & literature; care
& reaccommodation model

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Methodology – review of elements

- Difficult to establish consistent trends
 - crew and maintenance costs least volatile
 - fleet costs most dependent on particular a/c types
 - pax costs to airline most dependent on legislation
 - fuel prices most volatile
- Cost of fuel
 - Jet A1, into-plane; typical lag cf. spot prices
 - price (EUR/kg): 0.80 (2014), 0.60 (2010), 0.31 (2004)
 - vary strongly by phase (e.g. delay cost recovery – ‘DCI’)

Pre-Covid-19

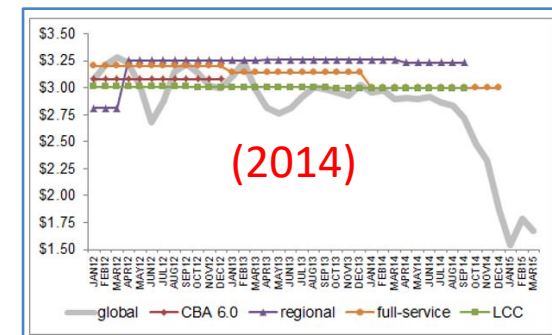
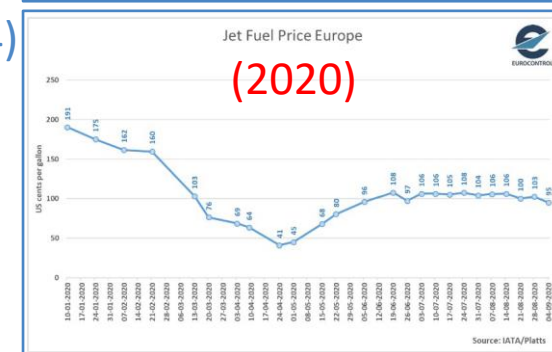


Figure 46. Average Jet A-1 fuel spot prices paid by airlines (\$/US gallon)



Source: IATA/Platts

Focus on outputs

Delays in European aviation

Focus on outputs

Table 26. AT-GATE / BASE / full tactical costs

Delay (mins)	5	15	30	60	90	120	180	240	300
B733	70	430	1 550	7 020	19 160	36 220	49 040	66 480	89 310
B734	80	480	1 740	7 930	21 690	40 960	55 340	74 780	100 040
B735	70	390	1 400	6 280	17 110	32 350	43 900	59 720	80 590
B738	90	540	1 940	8 860	24 270	45 750	61 740	83 220	110 920
B752	100	620	2 290	10 620	29 250	55 150	74 240	99 700	132 200
B763	170	900	3 200	14 780	39 960	85 300	121 880	152 860	191 990
B744	240	1 370	5 000	23 430	63 710	136 330	194 330	242 440	302 200
A319	70	440	1 600	7 320	20 040	37 850	51 240	69 420	93 180
A320	80	500	1 820	8 350	22 920	43 250	58 420	78 890	105 380
A321	100	580	2 160	10 010	27 580	51 990	70 060	94 250	125 240
AT43	30	180	610	2 610	6 960	13 290	18 550	26 360	37 610
AT72	40	240	820	3 600	9 690	18 430	25 380	35 350	49 210
DH8D	40	250	890	3 900	10 530	19 990	27 480	38 120	52 780
E190	60	320	1 150	5 140	13 970	26 440	36 060	49 420	67 340
A332	180	990	3 550	16 480	44 620	95 330	136 120	170 480	213 660

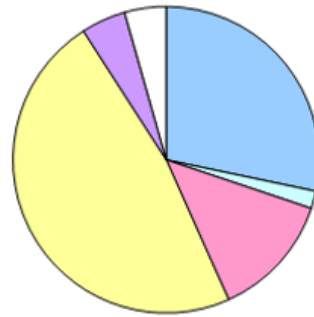
With reactionary costs.

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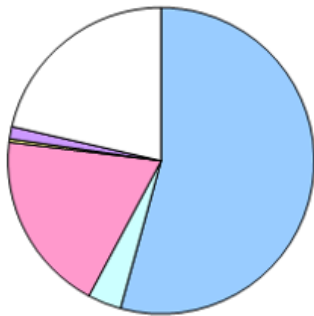
Pax cost contributions – 15-minute delays



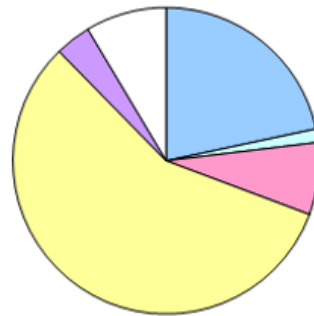
B738 at-gate (EUR 540)



B738 en-route (EUR 1 080)



B744 at-gate (EUR 1 370)



B744 en-route (EUR 3 440)

15-minute delay distributions (2015; very similar to 2010)

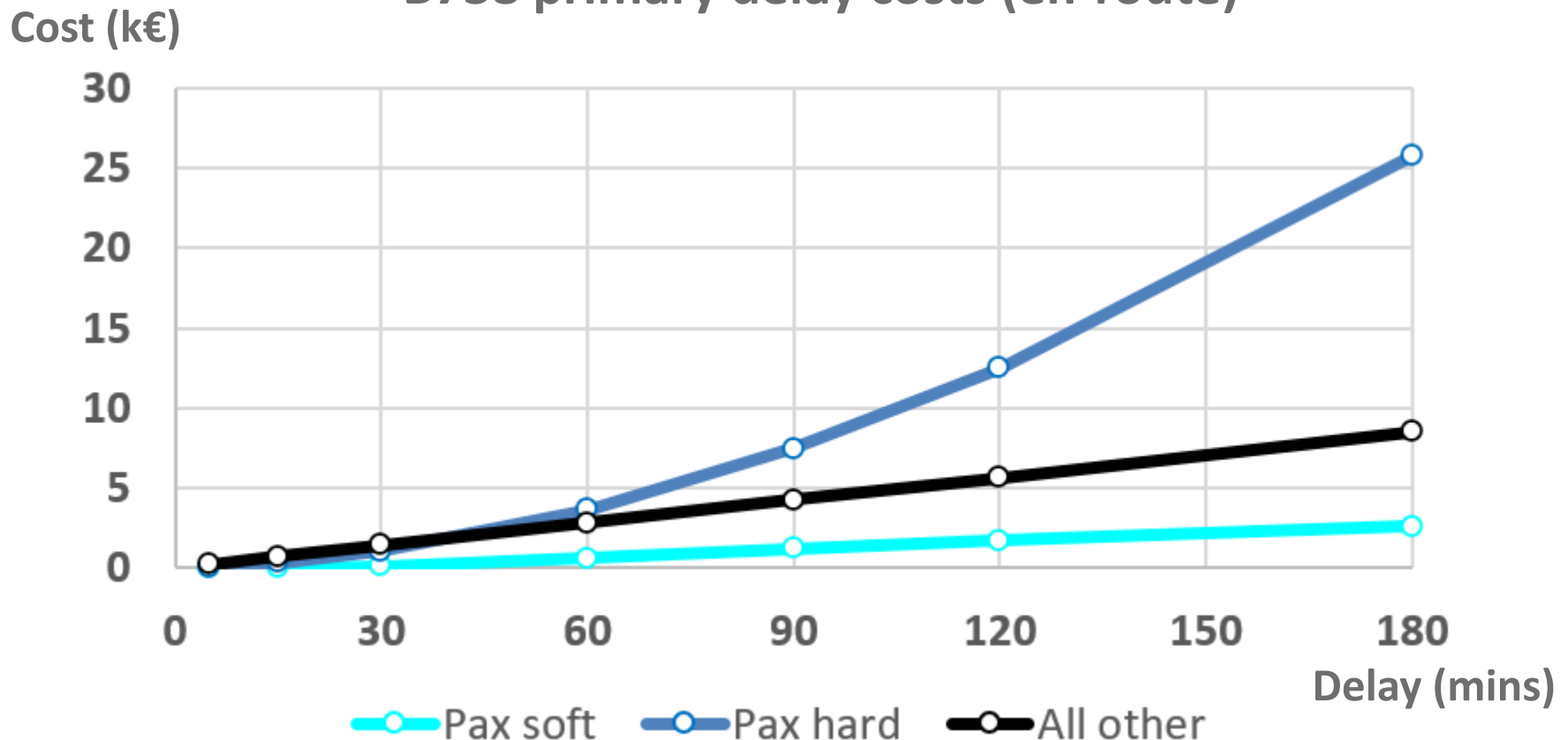
Pax costs also dominate en-route at higher delays



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Pax cost contributions – higher delays en-route

B738 primary delay costs (en-route)

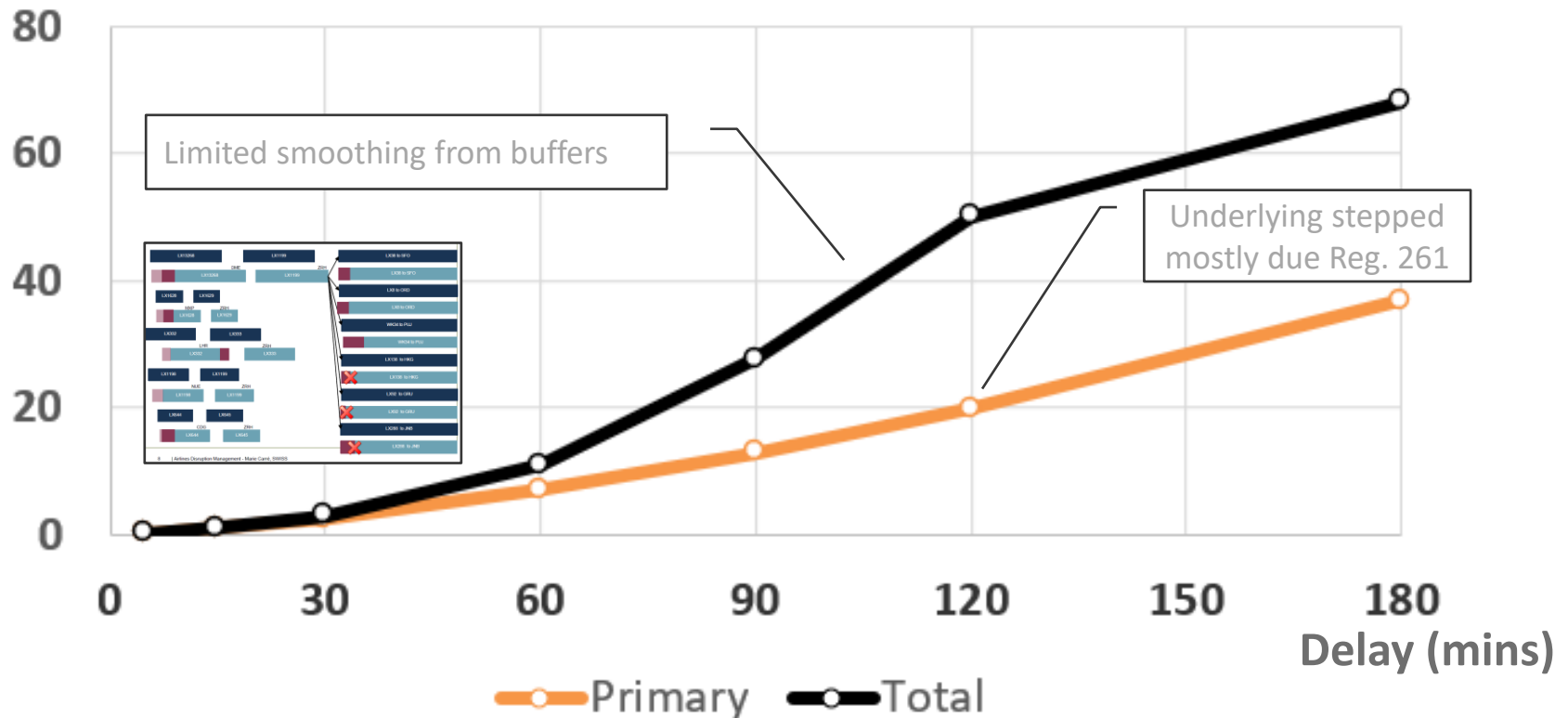


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Primary cf. total cost – higher delays en-route

B738 primary cf. total cost (en-route)

Cost (k€)



Delays in European aviation

Pax hard costs – illustrative numbers



Illustration (not how the value is actually calculated!)

Delay (mins)	5	15	30	60	90	120	180
B733	34	239	820	2 840	5 850	9 770	20 150
B734	38	272	940	3 230	6 670	11 140	22 970
B735	30	212	730	2 520	5 190	8 680	17 890
B738	43	306	1 050	3 630	7 490	12 510	25 800
⋮							

...

After a 3-hour delay, some 47% of passengers are paid the €400 compensation.

The real calculation is a mixture of compensation and duty of care, plus some reimbursements/rebookings.

€₂₀₁₄ costs (Excerpt from *Pax cost consultation* (2015))



- Regulation 261 – rules for compensation and assistance re. denied boarding, cancellation or delay (see [Annex](#), with *up to date* refs)
- 2013 proposed changes still on table; several hot issues, e.g. 90 minute missed connections cf. existing (IATA) interlining rules
- Other rights exist (e.g. Montreal Convention, ICAO – typically used for baggage)
- **Airline may be more generous than Reg. 261**
- UoW consultation document AUG-OCT15
- **Claim rates and seat densities (plus inflation) drove cost changes**

Delays in European aviation

Pax soft costs – illustrative numbers



Illustration (not how the value is actually calculated!)

Delay (mins)	5	15	30	60	90	120	180
B733	1	16	90	480	950	1 340	2 030
B734	2	18	100	550	1 080	1 520	2 310
B735	1	14	80	430	840	1 190	1 800
B738	2	20	110	620	1 220	1 710	2 600
⋮							

...

€₂₀₁₄ costs (Excerpt from *Pax cost consultation* (2015))

After a 3-hour delay, around 10% of passengers fly with another airline next time

Based on average load factors and average (marginal) revenue per pax across IAG (BA, IB, VY) in 2014

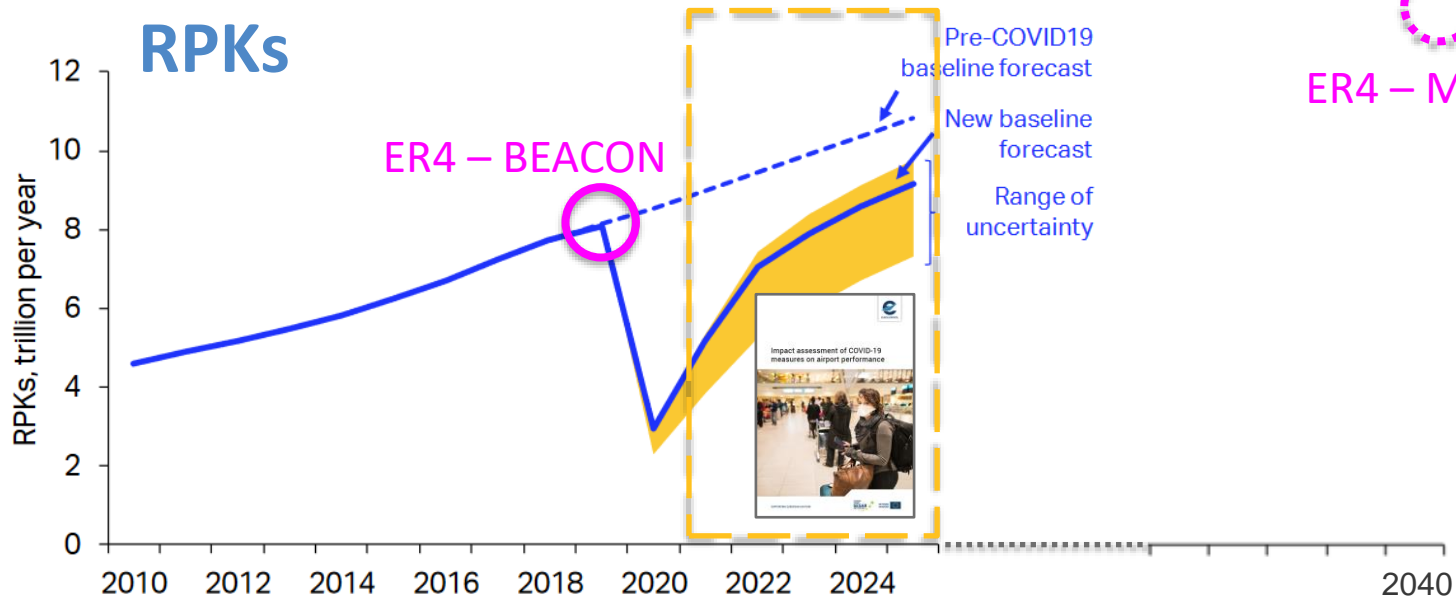


- Delay may impact directly (above) and indirectly (perception *only*)
 - poor punctuality -> poor perception -> loss of market share
- Consolidation of Austrian + 'Airline Z' research, *inter alia*
 - these related to short-run costs
 - usually want network, long-run costs
- Almost no published costs, but several papers in *Cost of delay* (2015)
- UoW consultation document AUG-OCT15
 - debatable arguments for small increase or decrease
 - just applied inflationary increase

Challenges ahead

Delays in European aviation

Pre- and post-Covid-19 models



- Very difficult modelling anything inside the volatile ‘amber’ area
 - indeed, even knowing the duration and content of the amber area
 - pax confidence (complex) and travel restrictions key to growth
- Raises questions from a passenger cost perspective (examples on next slides)
 - <https://beacon-sesar.eu>
 - <https://modus-project.eu/> } how to deal with cost of delay and behavioural impacts?

Delays in European aviation

Pax hard costs – challenges ahead

Haul	Delay duration					
	≥ 90 mins	≥ 2 hours	≥ 3 hours	≥ 4 hours	≥ 5 hours	≥ 8 hours
Short haul	Ⓢ	Ⓢ 🍷	Ⓢ 🍷 €250	Ⓢ 🍷 €250	Ⓢ 🍷 🍷 €250	+Ⓢ
Medium haul	Ⓢ	Ⓢ 🍷	Ⓢ 🍷 €400	Ⓢ 🍷 €400	Ⓢ 🍷 🍷 €400	+Ⓢ
Long haul	Ⓢ	Ⓢ 🍷	Ⓢ 🍷 €300*	Ⓢ 🍷 €600	Ⓢ 🍷 🍷 €600	+Ⓢ

Key

- 🍷 Care (e.g. reasonable meals and refreshments)
- 🍷 Reimbursement of ticket
- € Compensation (refers to arrival delay)
- Ⓢ Rights re. missed connecting flights
- +Ⓢ Better rights re. re-routing on other airlines
- * For delays of three to four hours (CJEU ruling, 2009)

orange: 2005
blue: 2009
red: ??

Table 5. Departure delay duration base scenario estimated costs – 80% of pax wait for flight

Haul	Departure delay duration				
	≥ 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

Table 6. Departure delay duration base scenario estimated costs – 20% pax opt for refund

Current rules, and changes proposed in 2013

Multiple explicit cost tables – DIY



- Heavily driven by Reg. 261 (see [Annex](#)):
 - add costs of downstream hubs (2019)
 - UK probably not excluded post-Brexit (written into UK law)
 - impact on current rules of Covid-19 (already issues raised)
 - pending proposed changes (2013)
 - auto-compensation in future (rail precedents)
- Impact of emerging ENV and intermodal (integration and) regulations
- Some of these issues tackled in e.g. ER4 BEACON and Modus

time order ↓

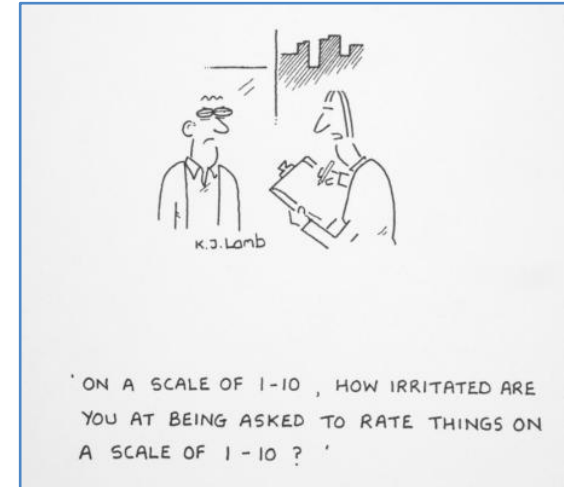
To be covered by EU law, flight must be operated by an EU airline into EU airport OR operated by any airline from EU airport. (EU airports incl. Iceland, Liechtenstein, Norway & Switzerland.)

Delays in European aviation

Pax soft costs – challenges ahead

(Excerpt from SESAR ER3 project Domino, D5.3)

Metric	Baseline			4DTA Level 2	
	Mean	1st Quartile	3rd Quartile	Mean	1st Quartile
Average excess cost of fuel	128	127	130	103	102
Average cost of compensation	56.6	53.7	59.1	57.1	53.5
Fraction of flights paying compensation ($\times 10^{-3}$)	17	16	18	17	17
Average cost of transfer	1.1	0.5	1.2	1	0.6
Fraction of flights paying transfer ($\times 10^{-5}$)	83	70	92	86	70
Average duty of care cost	122	114	126	121	114
Fraction of flights paying duty of care	0.092	0.087	0.096	0.092	0.086
Average soft costs	8.5	3.6	14.2	9.9	3.7



Epecially stochastic

- Incorporating more into event-driven (cf. statistical) models
 - ABMS for ATM mechanism assessment (Uni. Westminster, Domino)
 - ABMS for UDPP mechanism assessment (Nommon, Engage CF)
 - Stochastic control of tactical airline ops (TU Dresden, Engage PhD)
- Focus on consideration of uncertainty on cost models (e.g. UoW, TUD, ...)
- Soft cost primary evidence remains somewhat tentative
 - very expensive to resolve
- Effect of other factors (e.g. hygiene measures, ENV) on pax delay sensitivity

scale
↓

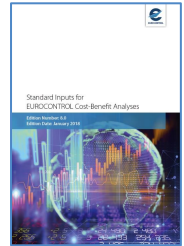


Same challenges for hard

Delays in European aviation

Wider challenges ahead

- Further research needed
 - 2004, 2010, 2015 ... next edition (BEACON)?
 - reactionary delay and propagation; slot and aircraft swaps; cancellation costs
 - curfew costs (may dominate P2P costs, even at start of day); crew costs
 - mitigation/recovery costs (strategic/tactical); resilience metrics
- Applications
 - *Standard Inputs for EUROCONTROL CBA* (etc.) – updated web tools?
 - integration with strategic and tactical tools
 - ANSP rostering – better predictions of airline demand w.r.t. route charges
 - airlines – scheduling, routing choices, airborne delay recovery
 - SESAR Solutions – cost-saving evaluations, e.g. for flight prioritisation tools
 - EU policy – supporting evidence-led decisions for planned Reg. 261 changes



Examples of users and projects

Delays in European aviation

Examples of users and projects

Standard reference

“The University of Westminster (UoW) report ... represents the most recent and comprehensive appraisal of the cost of delays in the air traffic management system in Europe”



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- Press releases

European airline delay cost reference values

24 December 2015

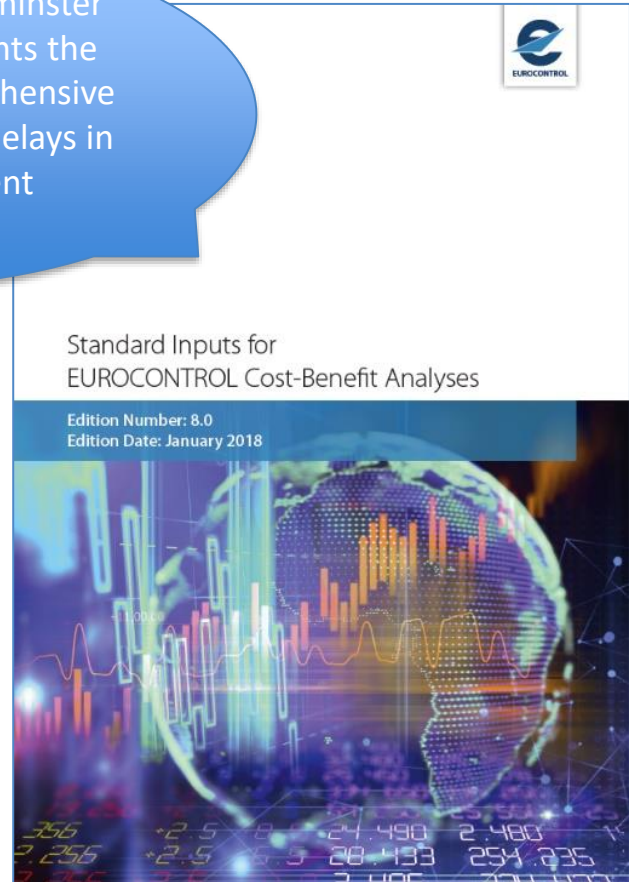
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[DOWNLOAD REPORT](#)

This report, produced by the University of Westminster, is designed as a reference document for European delay cost incurred by airlines, both at the strategic (planning) and tactical stages.

It presents updated values for the cost of delay to European airlines for the reference year 2014. The methodology is substantially unchanged compared to the previous reporting of the 2010 delay costs. Methodological points are only highlighted where they differ from the 2010 reporting.


Document	Size
European airline delay cost reference values report for 2014, version 4.1	1.59 MB



EUROCONTROL

Standard Inputs for EUROCONTROL Cost-Benefit Analyses

Edition Number: 8.0
Edition Date: January 2018



Delays in European aviation

SES Performance Scheme – RP2 dashboard (2019 provisional)



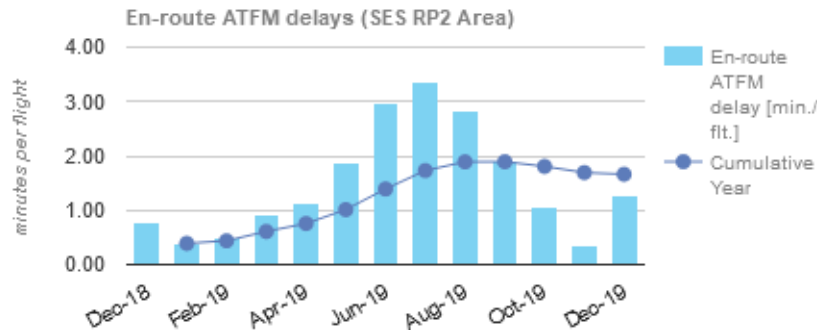
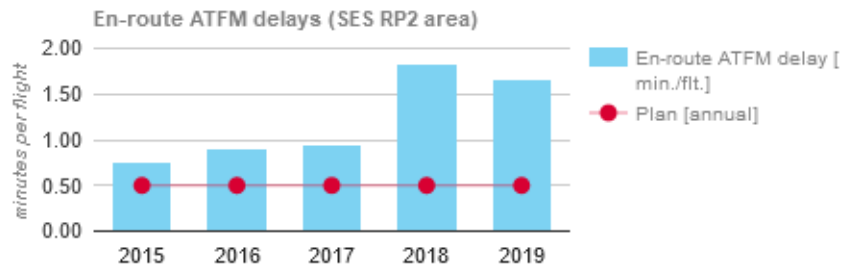
Capacity KPI #1: En-route ATFM delay per flight [minutes per flight]

Period: January-December

[\[Download data\]](#)

Source: Network Manager

[\[Meta data\]](#)



FAB (based on FIR)	Plan [2019]	Actual [2019]	[act. vs. plan]
Baltic FAB	0.22	0.17	-0.05
BLUE MED FAB	0.38	0.33	-0.05
DANUBE FAB	0.04	0.08	0.04
DK-SE FAB	0.09	0.07	-0.02
FAB CE (SES RP2)	0.27	1.71	1.44
FABEC*	0.43	1.55	1.12
NEFAB	0.13	0.01	-0.12
SW FAB	0.30	0.69	0.39
UK-Ireland FAB	0.26	0.22	-0.04

* Functional Airspace Block Europe Central: Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland.

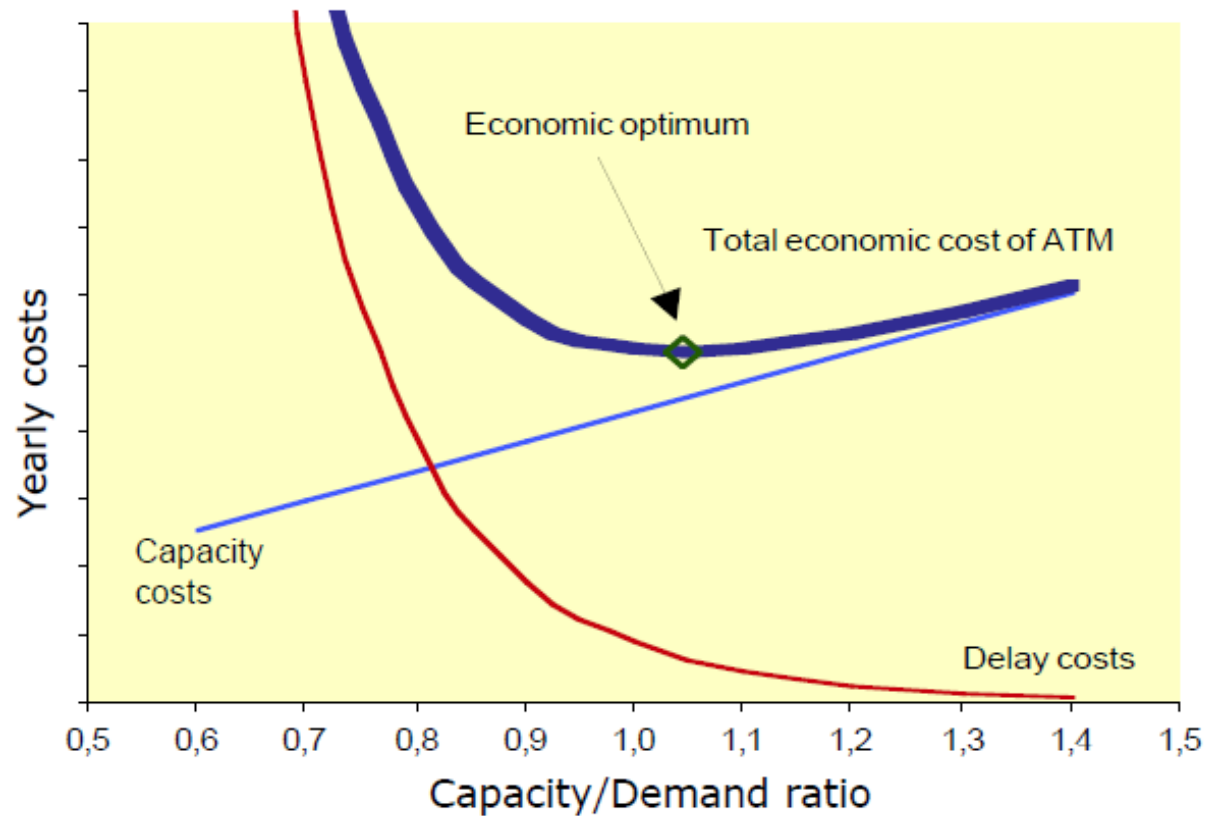
Note 1. Various FAB performance plans have different planned contributions to the EU target.

Note 2. PRB calculated (2010) that the economic optimum for delay is appx 0.35 min/flight.

Delays in European aviation

Examples of users and projects

Standard reference



Delays in European aviation

Examples of users and projects

- EUROCONTROL (Brussels (HQ), Experimental Centre, MUAC) and SESAR
 - tactical and strategic, planning and assessment levels; cost-benefit analyses; evaluating SESAR essential operational changes (e.g. UDPP)
- Airlines (2-way process): delay recovery & buffer calcs
- ANSPs, airports, national government
 - expansion and privatisation cases
- Legal cases (large delay compensation claims)
- Industry (e.g. aircraft delay management software)
- Academia (more global reach cf. above); UoW project examples:



- previous: POEM, SATURN, ComplexityCosts, Airport Economic Value, Vista
- current/recent: Domino, ADAPT, CAMERA, Pilot3, Dispatcher3, BEACON, Modus



Delays in European aviation – building passenger cost models

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Thank you



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Founding Members



The opinions expressed herein reflect the author's view only.

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Annex

Further resources on Reg. 261

Delays in European aviation

Regulation 261 – background



- Establishes the rules for compensation and assistance to airline passengers in the event of denied boarding, cancellation or delay
- Came into effect on 17 February 2005; implementation across Europe not consistent
- Case law and national rulings have a decisive impact; legally binding European Court of Justice rulings (also interpretive guidelines)
- Consultation: but lack of agreement on proposed changes
- 2014: proposed strengthening (in 2013) passed first reading in European Parliament; still awaiting European Council (member states) agreement
- 2019: ECJ stated that connecting flights (e.g. *outside EU*) on a single reservation originating from an EU airport, are subject to 261 as if they were one flight inside EU
- Complicated in practice, especially regarding ‘extraordinary circumstances’, and reactionary delays – legal advice case law consultation often required

References

<https://eur-lex.europa.eu/> and search “261” for original Regulation

<https://westminsterresearch.westminster.ac.uk/> and search “passenger consultation” for major updates through to 2015

Delays in European aviation

Regulation 261 – updates and future proposals



- **Enforcement:** strengthening the oversight of airlines by national and European authorities, with more effective sanctions;
- **Right to care:** introduction of a right to care for passengers after a delay of two hours, for all flights irrespective of distance (thereby removing the current dependency on flight distance);
- **Complaint handling:** the introduction of a common complaint form; ensuring that passengers have a right to receive an acknowledgement within a week and a response to their complaint within two months (currently no time limit);
- **Right to information:** ensuring passengers have a right to information about their situation 30 minutes after a scheduled departure (currently no time limit); contact points in airports to inform passengers on the circumstances of their travel disruption and their rights;
- **Re-routing:** ensuring passengers have a right to be re-routed by another airline or transport mode in case of cancellation when the carrier cannot re-route on its own services; Parliament additionally suggested a lower limit of 8 hours compared with 12 hours proposed by the Commission;
- **Connecting flights:** clarifying that rights to assistance and compensation apply if connecting flights are missed because the previous flight was delayed by at least 90 minutes;
- **Other rights:** the right for passengers to correct spelling mistakes in their name without charge and giving national authorities enforcement powers over lost luggage rules.

Source: *Pax cost consultation* (2015)

References

<http://www.eraa.org/policy/passenger-rights/passenger-rights> – good at keeping an up to date list of key progress

<https://www.caa.co.uk/Passengers/> – good on detailed rules, incl. for connection rights

<https://www.moneysavingexpert.com/travel-reclaiming/> – good on detailed rules, incl. Covid-19 and beyond EU (Montreal Convention etc.)