Assessing European mobility

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Assessing European mobility

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Overview and objectives

- Modelling developments
  - POEM
  - DATASET2050
  - Vista

  'Mercury' mobility model core capability

- Data visualisation
- Discussion
  - 4H D2D revisited …
  - Concluding remarks (but not conclusions!)

Overview and objectives

Project	In a nutshell	Funding & timeframe	Partners	Key scope
POEM	Passenger-centric metrics	SESAR WP-E 2011-13	**University of Westminster** Innaxis	Current **Gate-to-gate** Pax c.f. flights
DATASET2050	Data-driven pax mobility	EU Research & innovation programme (CSA) (H2020) 2014-17 (CSA)	**Innaxis** University of Westminster Bauhaus Luftfahrt EUROCONTROL	Current, ≈2035, ≈2050 **Door-to-door** Pax mobility
Vista	KPA trade-offs	SESAR Research & innovation action (H2020) 2016-18	**University of Westminster** Innaxis Belgocontrol EUROCONTROL Icelandair Norwegian Air Shuttle SWISS	Current, ≈2035, ≈2050 **Door-to-door** Pax mobility Wider stakeholders

POEM
Passenger-Oriented Enhanced Metrics
SESAR Outstanding Project Award

University of Westminster
Innaxis Foundation & Research Institute

Motivation

- To build a European network simulation model for flights and explicit passengers, which:
  - realistically captures airline decision-making and costs
  - includes a range of new performance metrics:
    e.g. passenger-centric and propagation-centric
  - operates under a range of flight and pax prioritisation scenarios
- Key objectives, to investigate under these scenarios:
  - performance (cost and delay) trade-offs
  - propagation of delay through network

  ] related tasks
- Included stakeholder workshops & two (airline) case studies

Motivation

- Policy-driven motivation
  - ultimate performance delivery to the passenger
  - ACARE Strategic Research & Innovation Agenda (Sep. 2012)
  - Commission's new roadmap (2011) to a Single European Transport Area for 2050: pax mobility & network resilience
  - extension of passenger rights (e.g. review of Regulation 261)
- Operational drivers
  - pax dominate *most* AO delay costs and therefore strongly influence AO behaviour in the network (strategically and tactically)
  - currently only using flight-centric metrics (Europe & US), although flight delay ≠ pax delay (US factors of 1.6 – 1.7)
- How can we measure specific progress without metrics?

Passengers and costs

Passengers and costs

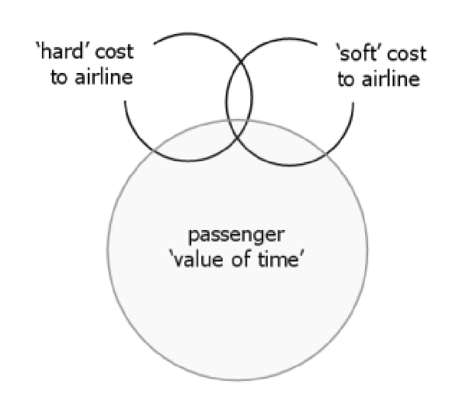
- 2000: SES launched by Commission
  - specifically in response to increasing delays
- Early 2000s: cost of delay
  - state of the art not very mature
  - no single, comprehensive study meeting industry needs
  - various values; lack of consensus
- University of Westminster started from scratch
  - review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

Passengers and costs

- Key objectives of the ‘new’ framework
  - comprehensive & transparent approach
    - including margins of error
  - consultation and industry agreement
    - common reference values
  - operationally meaningful – aligned with AO mind set
    - bottom line in accounts (*very* challenging); interviews
  - shift the focus away from fuel-only costs
  - useful at network level, e.g. total and average ATFM delays

Passengers and costs

- Key features
  - tactical cost of delay
    - § incurred on the day of operations, not planned in advance
    - § mostly marginal costs
    - § e.g. aircraft waiting at-gate
  - strategic cost of delay (then a new concept)
    - § incurred in advance, often difficult to recover later ('sunk' cost)
    - § mostly unit costs
    - § e.g. schedule buffer ('opportunity' cost) & route extension (later)
  - passenger cost of delay
    - 'hard' cost to AO
    - 'soft' cost to AO
    - internalised costs (c.f. US)



Passengers and costs

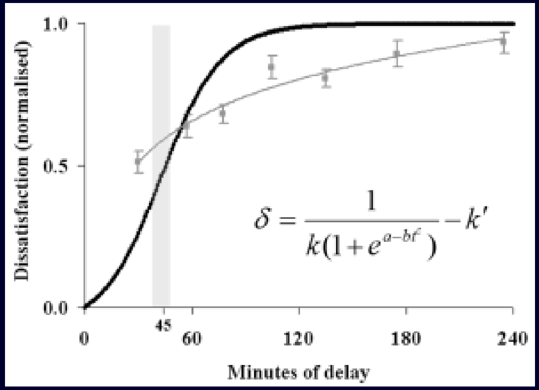
	types of cost (in-house models, except fuel)
fleet	all fleet costs (depreciation, rentals & leases)
fuel	Lido/Flight, BADA, manufacturers
crew	schemes, flight hours, on-costs, overtime
maintenance	extra wear & tear powerplants/airframe
passenger	major update in 2010 …

Passengers and costs

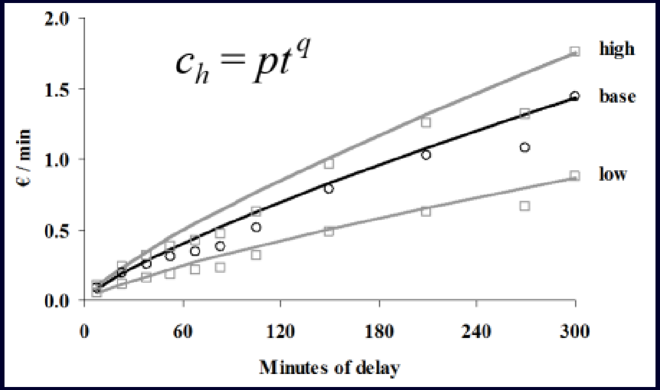
Cost element	2004	2010
Pax hard cost	Treated as zero for <15 minutes of delay	Major update - full cost curves (power curve) derived as function of primary delay
Pax soft cost	Treated as zero for <15 minutes of delay	Major update - full cost curves (logit curve) derived as function of primary delay; scalability now accounted for: small fraction of total now used in most contexts
Crew	Treated as zero for <15 minutes of delay	Extensive new model addressing crew payment schemes and overtime rates; costs assigned to all delay magnitudes
Maintenance	Overheads not fully assessed; costs based on block-hour costs	Overheads fully assessed; cost base extended and re-calibrated on full ICAO data sets
Fleet	Major model developed, based on extensive financial literature	Cost base extended and re-calibrated on full ICAO data sets, supplemented with update from financial literature
Fuel	0.31 EUR/kg	0.60 EUR/kg; carriage penalty now applied to arrival management
Reactionary	Two multipliers: one for below 15 minutes of delay, one for above	Extended model: multipliers fully quantified as function of primary delay magnitude, caps applied using new rotationary models

Passengers and costs

- Passenger costs modelling from 2010 (2nd edition)
  - 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)

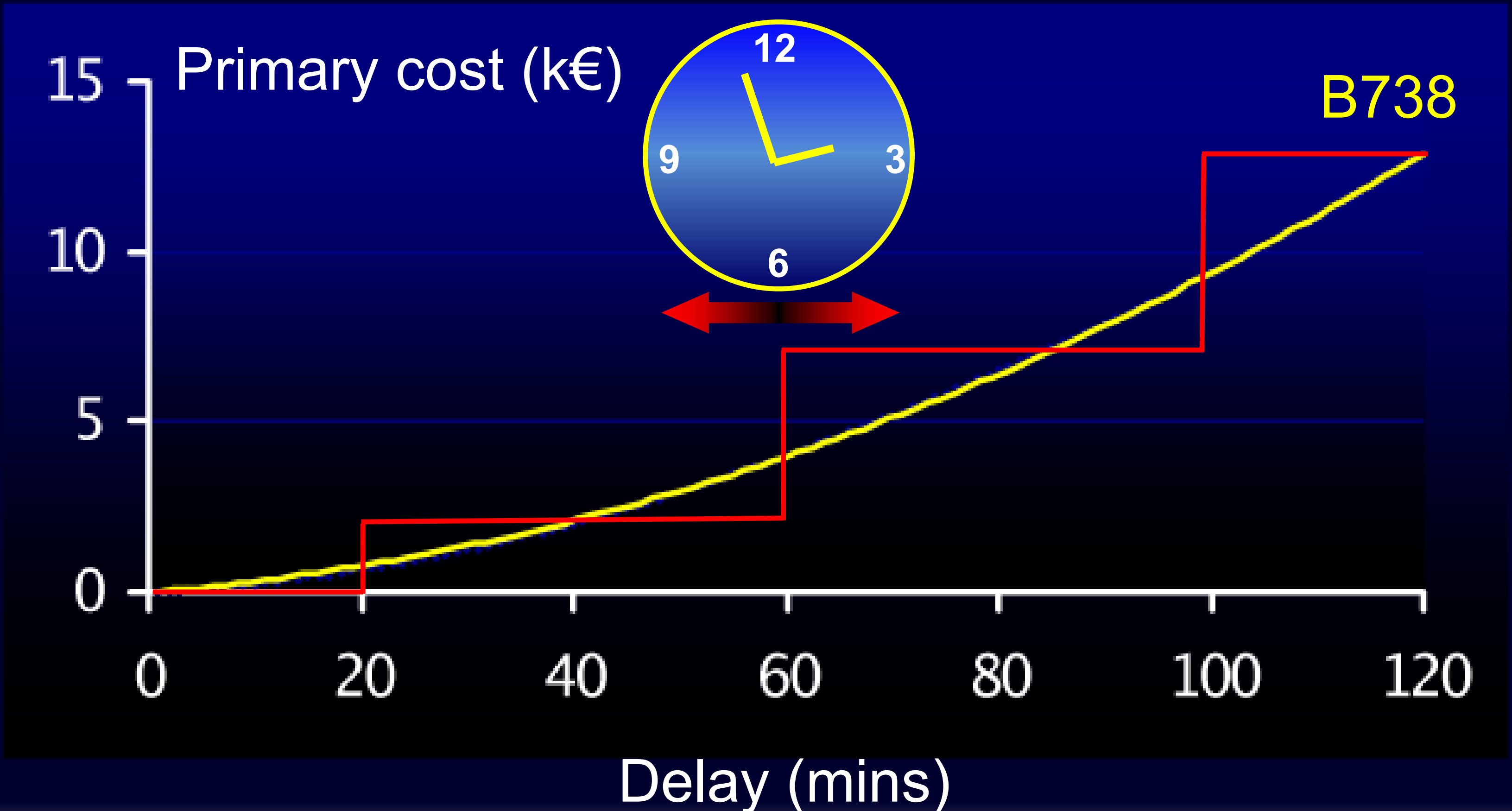


Airline passenger Kano satisfaction model, Wittmer and Laesser (2008).
In-house, bespoke surveys & airline models



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

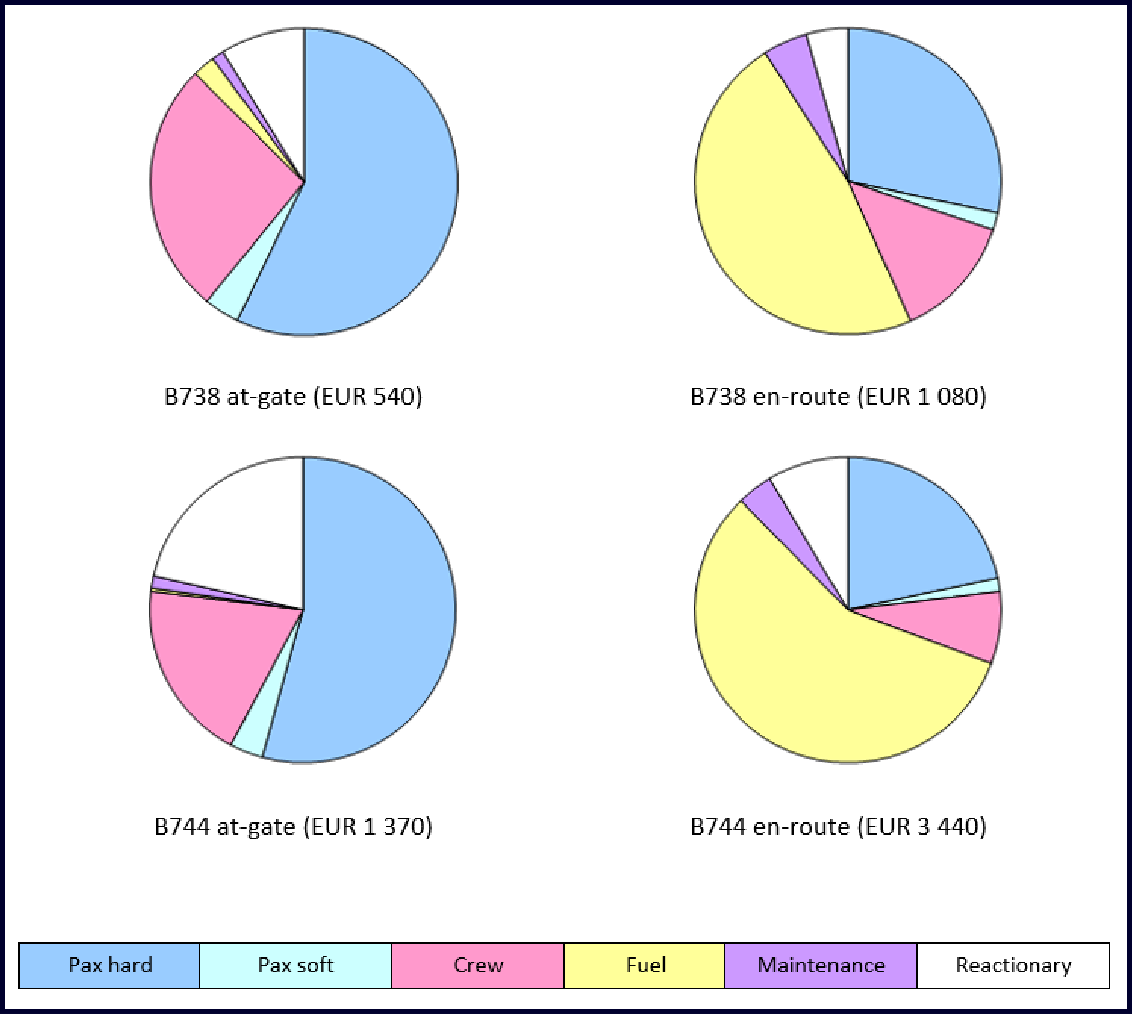
Passengers and costs



Passengers and costs

- Major updates in 2015 (3rd edition) – 2014 cost basis
  - 3 aircraft added (DH8D, E190, A332)
    - now 15 aircraft, 63% coverage of CFMU area
  - rotations per day, service hours, average MTOWs, ATFM delay distributions, seat & load factors; reactionary data – all updated
  - fuel 0.8 €/kg; APU fuel added at-gate (base scenario: 25% running)
  - crew & maintenance:□; fleet: □□ (all continuing 2010 trends)
  - passenger costs: still only limited evidence
    - EC Impact Assessment (Reg. 261) + limited literature (e.g. claim rates)
    - UoW consultation document Aug-Oct15; 400+ contacts (mostly AOs)
    - 8.8% (inflationary) … pax densities => net = 20%

Passengers and costs



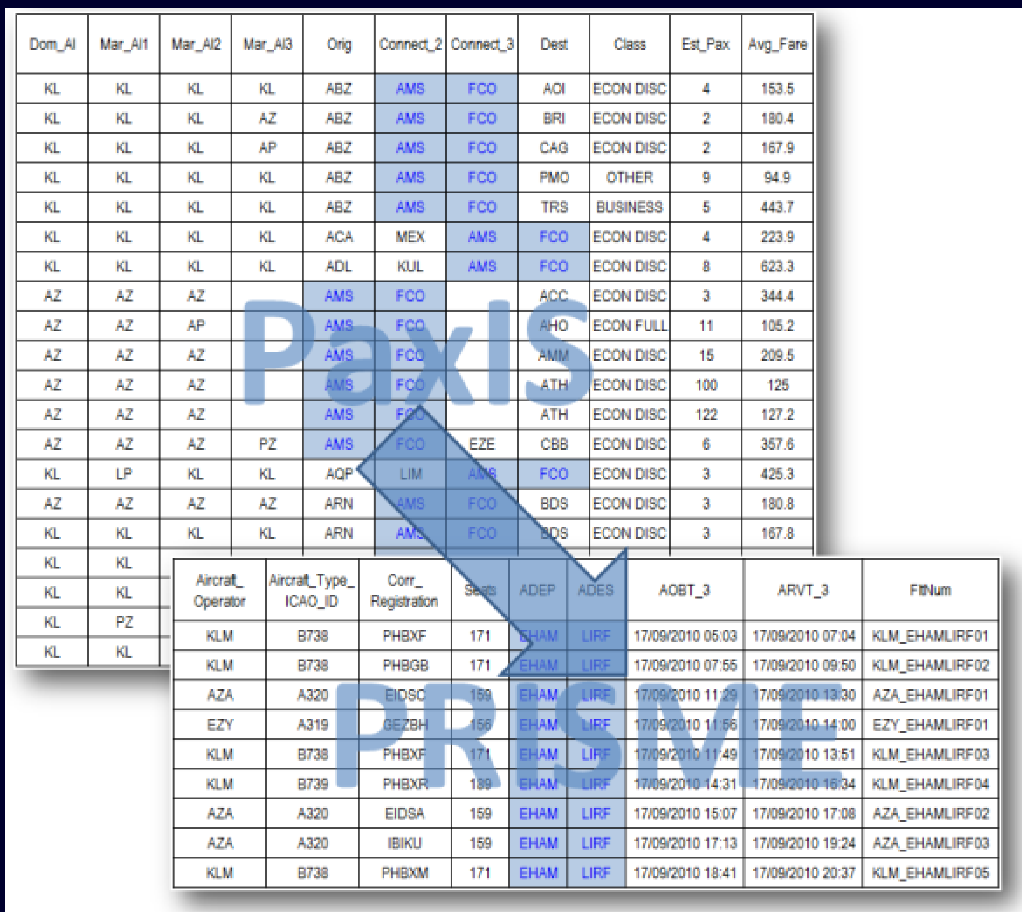
- 2014 15-minute distributions very similar to those for 2010
- Pax costs also dominate en-route at higher delays

Key model features

Key model features

- POEM evaluates different flight & pax prioritisation strategies
- Includes tactical costs to the airline (4 AO types)
- Key data-related characteristics of Mercury core model:
  - runs a busy day and month (September 2010 & 2014)
  - non-exceptional in terms of delays, strikes, weather
  - busiest 200 ECAC airports (e.g. 97% pax & 93% traffic, 2010)
  - 50 non-ECAC airports (based on pax flows in/out Europe)
  - extensive range and logic checks (e.g. speeds, registration seqs)
  - taxi-out unreliable; taxi-in missing; IOBT c.f. schedule
  - calibration (independent sources, e.g. network delays and LFs)
- Unique combination of PaxIS and PRISME data …

Key model features



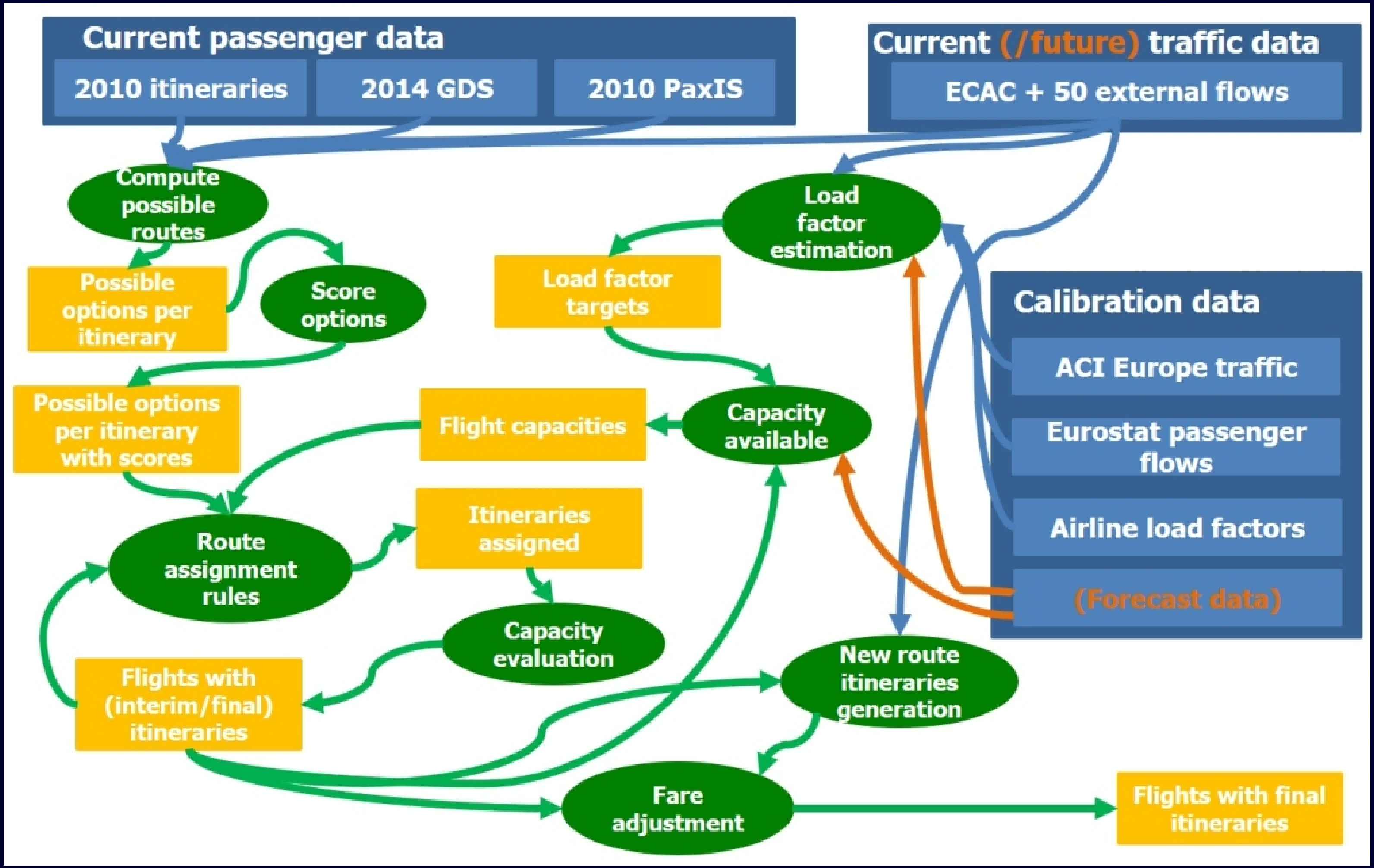
Dom_Al	Mar_Al1	Mar_Al2	Mar_Al3	Orig	Connect_2	Connect_3	Dest	Class	Est_Pax	Avg_Fare
KL	KL	KL	KL	ABZ	AMS	FCO	AOI	ECON DISC	4	153.5
KL	KL	KL	AZ	ABZ	AMS	FCO	BRI	ECON DISC	2	180.4
KL	KL	KL	AP	ABZ	AMS	FCO	CAG	ECON DISC	2	167.9
KL	KL	KL	KL	ABZ	AMS	FCO	PMO	OTHER	9	94.9
KL	KL	KL	KL	ABZ	AMS	FCO	TRS	BUSINESS	5	443.7
KL	KL	KL	KL	ACA	MEX	AMS	FCO	ECON DISC	4	223.9
KL	KL	KL	KL	ADL	KUL	AMS	FCO	ECON DISC	8	623.3
AZ	AZ	AZ		AMS	FCO		ACC	ECON DISC	3	344.4
AZ	AZ	AP		AMS	FCO		AHO	ECON FULL	11	105.2
AZ	AZ	AZ		AMS	FCO		AMM	ECON DISC	15	209.5
AZ	AZ	AZ		AMS	FCO		ATH	ECON DISC	100	125
AZ	AZ	AZ		AMS	FCO		ATH	ECON DISC	122	127.2
AZ	AZ	AZ	PZ	AMS	FCO	EZE	CBB	ECON DISC	6	357.6
KL	LP	KL	KL	AQP	LIM	AMS	FCO	ECON DISC	3	425.3
AZ	AZ	AZ	AZ	ARN	AMS	FCO	BDS	ECON DISC	3	180.8
KL	KL	KL	KL	ARN	AMS	FCO	BDS	ECON DISC	3	167.8
KL	KL									
KL	KL									
KL	PZ									
KL	KL									

Aircraft_Operator	Aircraft_Type_ICAO_ID	Corr_Registration	Seats	ADEP	ADES	AOBT_3	ARVT_3	FltNum
KLM	B738	PHBXF	171	EHAM	LIRF	17/09/2010 05:03	17/09/2010 07:04	KLM_EHAMLIRF01
KLM	B738	PHBGB	171	EHAM	LIRF	17/09/2010 07:55	17/09/2010 09:50	KLM_EHAMLIRF02
AZA	A320	EIDSC	159	EHAM	LIRF	17/09/2010 11:29	17/09/2010 13:30	AZA_EHAMLIRF01
EZY	A319	GEZBH	156	EHAM	LIRF	17/09/2010 11:56	17/09/2010 14:00	EZY_EHAMLIRF01
KLM	B738	PHBXF	171	EHAM	LIRF	17/09/2010 11:49	17/09/2010 13:51	KLM_EHAMLIRF03
KLM	B739	PHBXR	189	EHAM	LIRF	17/09/2010 14:31	17/09/2010 16:34	KLM_EHAMLIRF04
AZA	A320	EIDSA	159	EHAM	LIRF	17/09/2010 15:07	17/09/2010 17:08	AZA_EHAMLIRF02
AZA	A320	IBIKU	159	EHAM	LIRF	17/09/2010 17:13	17/09/2010 19:24	AZA_EHAMLIRF03
KLM	B738	PHBXM	171	EHAM	LIRF	17/09/2010 18:41	17/09/2010 20:37	KLM_EHAMLIRF05

- aggregated PaxIS (IATA ticket) pax data allocated onto individual flights (PRISME traffic data, from EUROCONTROL)
- assignment algorithms respecting aircraft seat configurations and load factor targets
- full pax itineraries built respecting MCTs and published schedules
- 27k flights in scope
- 3.8 million pax
- >150k routings

2014

Key model features

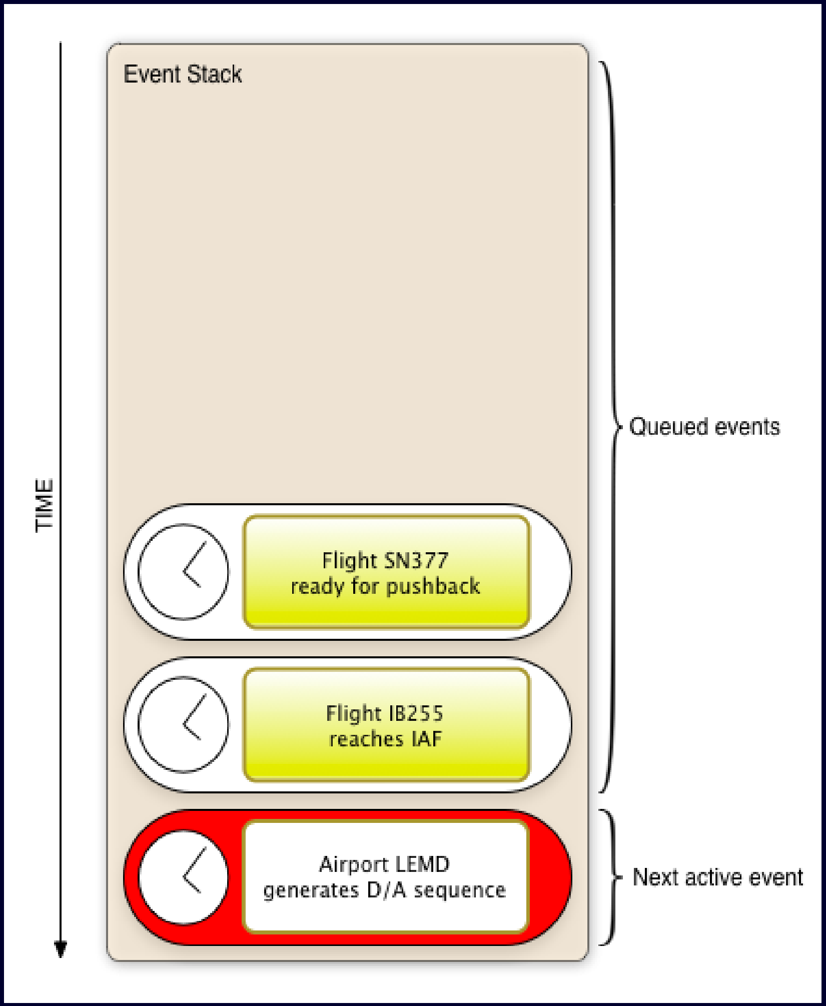


A u t o m a t i o n ?

Key model features

- Modular structure, can adapt and add new functionalities
- Varying levels of fidelity, for example:
- Rule 23: en-route recovery (was very basic, now DCI uptake!)
- Rule 33: passenger reaccommodation
  - Regulation (EC) 261/2004; IATA (involuntary rerouting & proration rules)
  - trigger: pax late at gate (a/c not wait); cancellation; (*denied boarding)*
  - aircraft seat configuration data used with routing sub-rules
  - passenger prioritisation sub-rules (alliances, ticket flexibility, ties)
  - hard costs (rebooking, cost of care, overnight accommodation)
  - soft costs (dissatisfaction, market share; capped at 5 hours)
  - (passenger value of time)
  - multiple sources, including airline input and airline review

Key model features



- event-driven: event stack, ordered sequence of events, each with a stamp
- dynamic tracking of costs for each a/c & passenger
- some pre-computed cost functions: recursive (from end of day backwards along propagation tree); discrete dly
- stable after appx. 10 runs
- MATLAB (R2016b)
- 5-20 minutes to run one day (depends on complexity)
- Amazon-cloud grid of five super-computers

CC

Key model features

[…] (17-Sep-2010 12:25:00) 47 out of 49 of pax (95.92 pct.) of DLH_EDDLEGBB02:15877 were ready, flight over 80 pct. occupancy, no more delay added

(17-Sep-2010 12:25:00) Total cost of flight DLH_EDDLEGBB02:15877 departing at 17-Sep-2010 12:25:00 now estimated at 127.15 euros (DUS-BHX)

(17-Sep-2010 12:25:00) No further pax delay will be introduced, thus flight DLH_EDDLEGBB02:15877 is now pushback ready, reaccommodating connecting pax

(17-Sep-2010 12:25:00) Pax group DLH1815:37550 of 2 inflex pax coming from DLH_EDDHEDDL06:12246 to EGBB did not make it to DLH_EDDLEGBB02:15877 (no more connections afterwards) and need to be reaccommodated

(17-Sep-2010 12:25:00) 2 inflex pax of group DLH1815:37550 of DLH_EDDHEDDL06:12246 that missed DLH_EDDLEGBB02:15877 were successfully reaccommodated in DLH_EDDLEGBB03:23396 same alliance, DLH1815/1:145607 Arrival: 17-Sep-2010 17:50:00 delay: 04:00'00" (airport wait 03:01'51")

(17-Sep-2010 12:25:00) Trying to reaccommodate the 80 pax waiting at EDDL:10 (DUS)

(17-Sep-2010 12:25:00) A total of 2 pax of DLH_EDDLEGBB02:15877 were left behind and all of them were successfully reaccommodated

(17-Sep-2010 12:25:00) Flight SAS_ENKBENGM03:15843 loading 67 pax and all of the 67 pax are not coming from a previous flight. There are NO connecting pax

(17-Sep-2010 12:25:00) There are 29 pax groups in SAS_ENKBENGM03:15843 connecting with another flight afterwards (SAS3310:87574, SAS3311:87575, SAS3312:87576, SAS3313:87577, SAS3314, […]

(KSU-OSL)

Scenarios and selected results

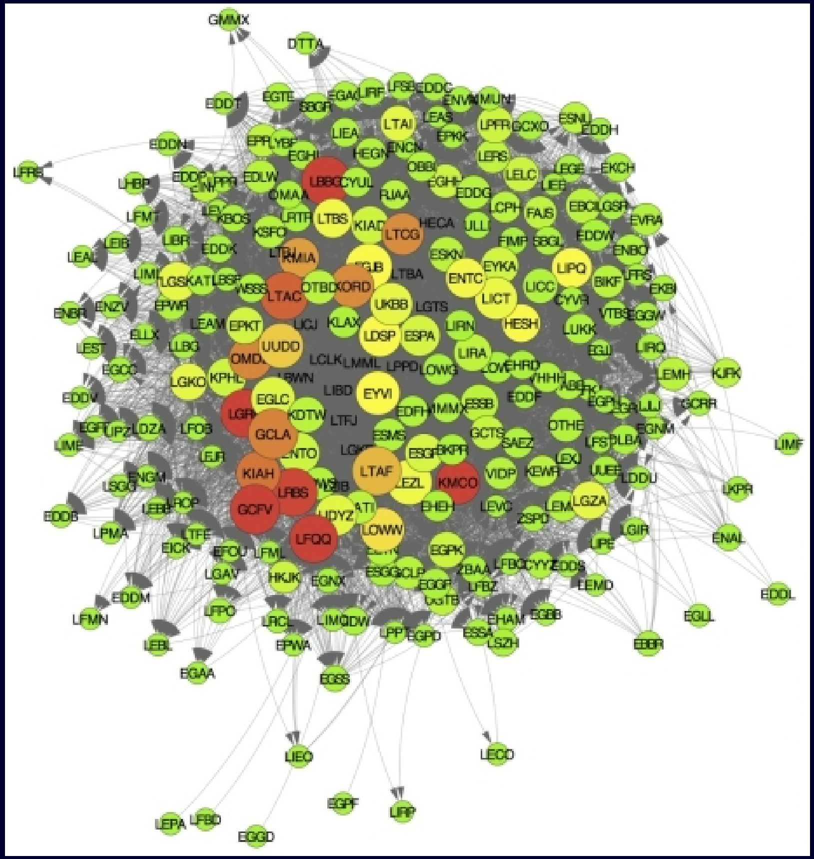
Scenarios and selected results

Type, and level	Designator	Summary description
No-scenario, 0	S_0	No-scenario baselines (reproduces historical operations for baseline traffic day)
ANSP, 1	N_1	Prioritisation of inbound flights based on simple passenger numbers
ANSP, 2	N_2	Inbound flights arriving more than 15 minutes late are prioritised based on the number of onward flights delayed by inbound connecting passengers
AO, 1	A_1	Wait times and associated departure slots are estimated on a cost minimisation basis, with longer wait times potentially forced during periods of heavy ATFM delay
AO, 2	A_2	Departure times *and* arrival sequences based on delay costs – A_1 is implemented *and* flights are independently arrival-managed based on delay cost
Policy, 1	P_1	Passengers are reaccommodated based on prioritisation by final arrival delay, instead of by ticket type, but preserving interlining hierarchies
Policy, 2	P_2	Passengers are reaccommodated based on prioritisation by final arrival delay, regardless of ticket type, and also relaxing all interlining hierarchies

Scenarios and selected results

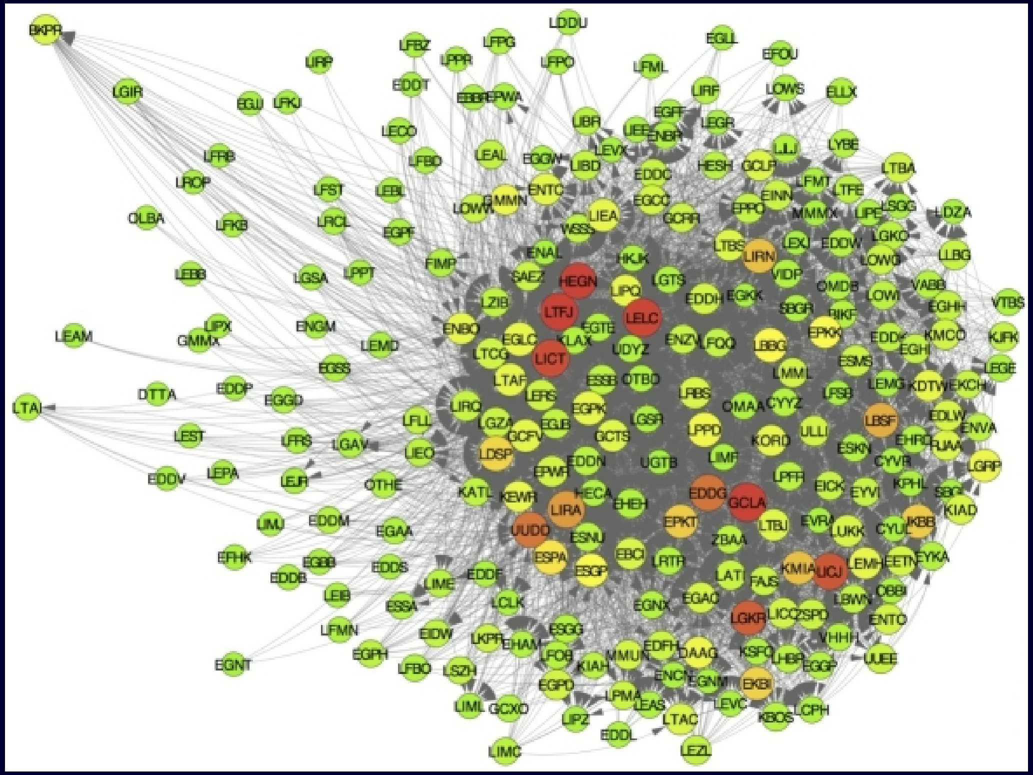
- A_1 and reactionary delay
  - increases from 49% (S_0) to 51% as a proportion of all dep. delay
  - … but focused on relatively few (waiting) aircraft (purposefully)
  - … saving in total costs wholly due to reduction in hard costs
  - explicit estimations of reactionary delay: a significant advance
- Smaller airports implicated in delay propagation
  - more than hitherto commonly recognised
  - expedited turnaround; spare crew *(& a/c)*; connectivity & capacity
- Back-propagation important in persistence of network delay
  - CDG, MAD, FRA, LHR, ZRH, MUC: all > 100 hours (baseline day)
  - most delay distributed between a relatively limited no. of airports
- Granger causality in complex network theory context …

Flight delay causality network for S_0



redder => higher connectedness (E$_C$)   larger => more nodes ‘forced’ (out-degree)

Flight delay causality network for A_1



Scenarios and selected results

- Main conclusions of Granger causality analyses
  - all four layers *very* different, i.e. airports play different roles in terms of flight and passenger delay propagation, and different again under A_1
- Main effects of A_1 (cost-minimising aircraft wait rules)
  - delay propagation contained within smaller airport communities
  - … but these communities more susceptible to such propagation

  trade-off
  - largest persistent airports: Athens, Barcelona & Istanbul Atatürk
  - all scenarios: no stat. signif. changes in current flight-centric metrics!

□ €39 avg. cost / flight

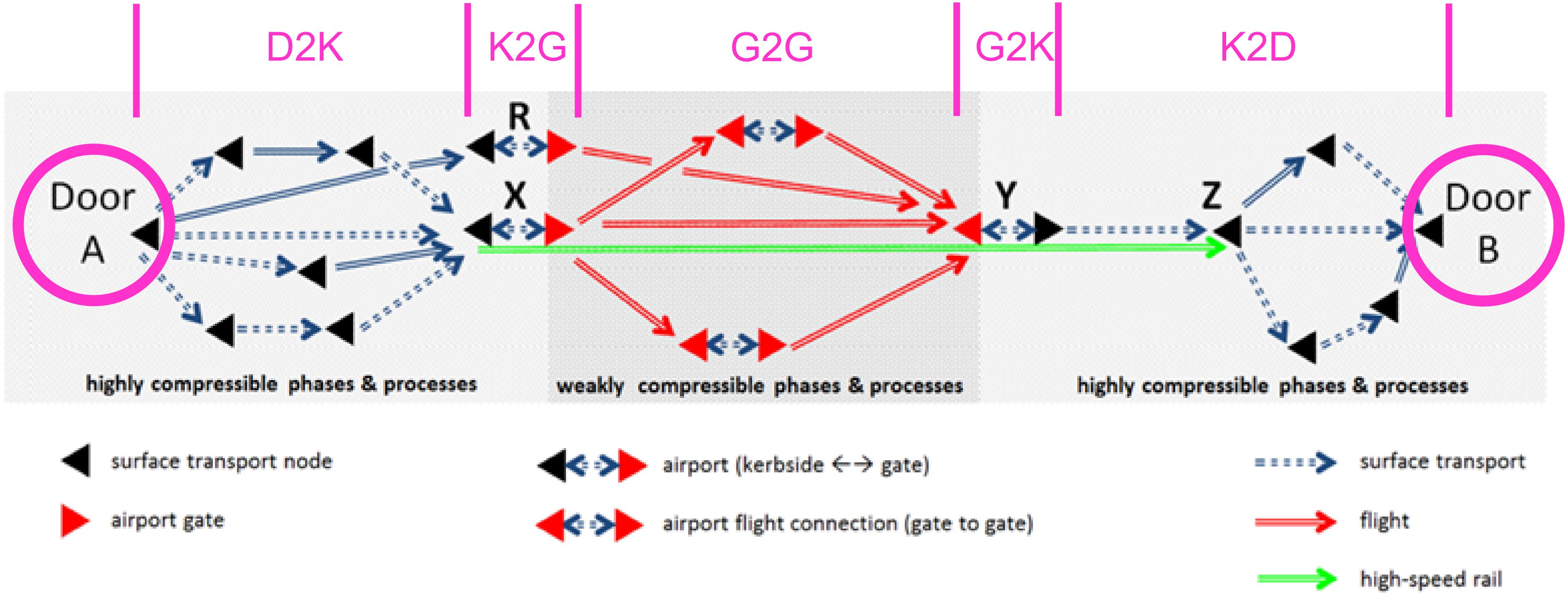
□ 9.8 mins avg. arr. / dlyd pax

□ 2% reactionary delay

DATASET2050

Data-driven approach for seamless, efficient European travel in 2050

University of Westminster
Innaxis Foundation & Research Institute



mins/flt (2015-19)

Key questions

- What is the current D2D time?
  - how can we improve without quantifying appropriate metrics?
- How achievable is the 4H D2D ambition by 2050?
  - demand? (more later …) supply-driven?
  - where is the key compressibility? regulatory (e.g. Reg 261) role?
  - disruptive change required? – e.g. journey ownership, pax data mgt
- EU 28 and EFTA, plus extra-European flows
- What is the cost/benefit ratio? What if we do nothing?

Key trade-offs

Opportunities

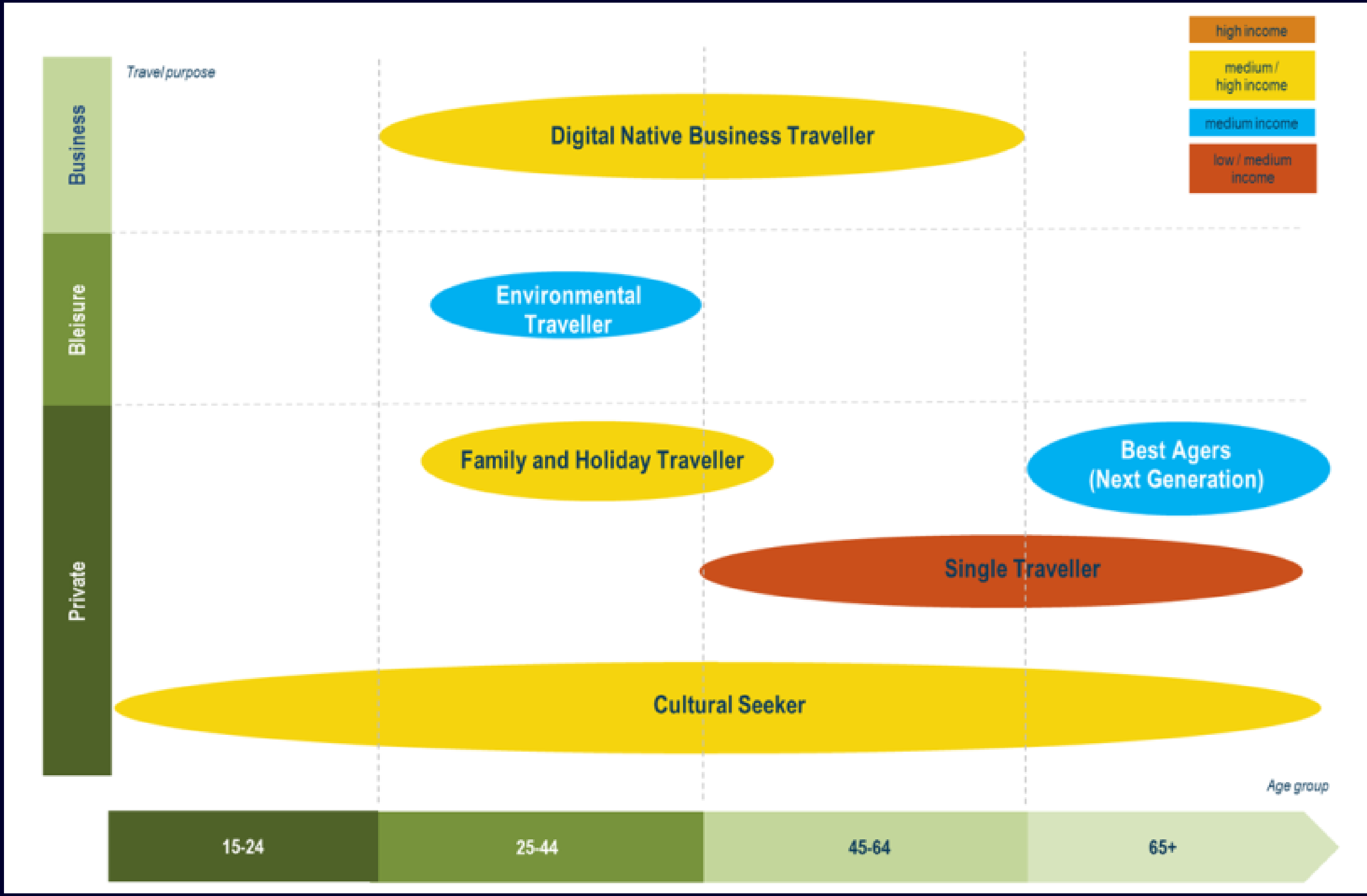
Large spend	Small spend
90%	10% (shape & metrics)
Travel	Technology (+&-) & env.
Competition	Cooperation & responsibility
Airline profitability (LFs)	Network resilience
Airport profitability (non-aero)	Pax dwell times

Building a picture for 2050

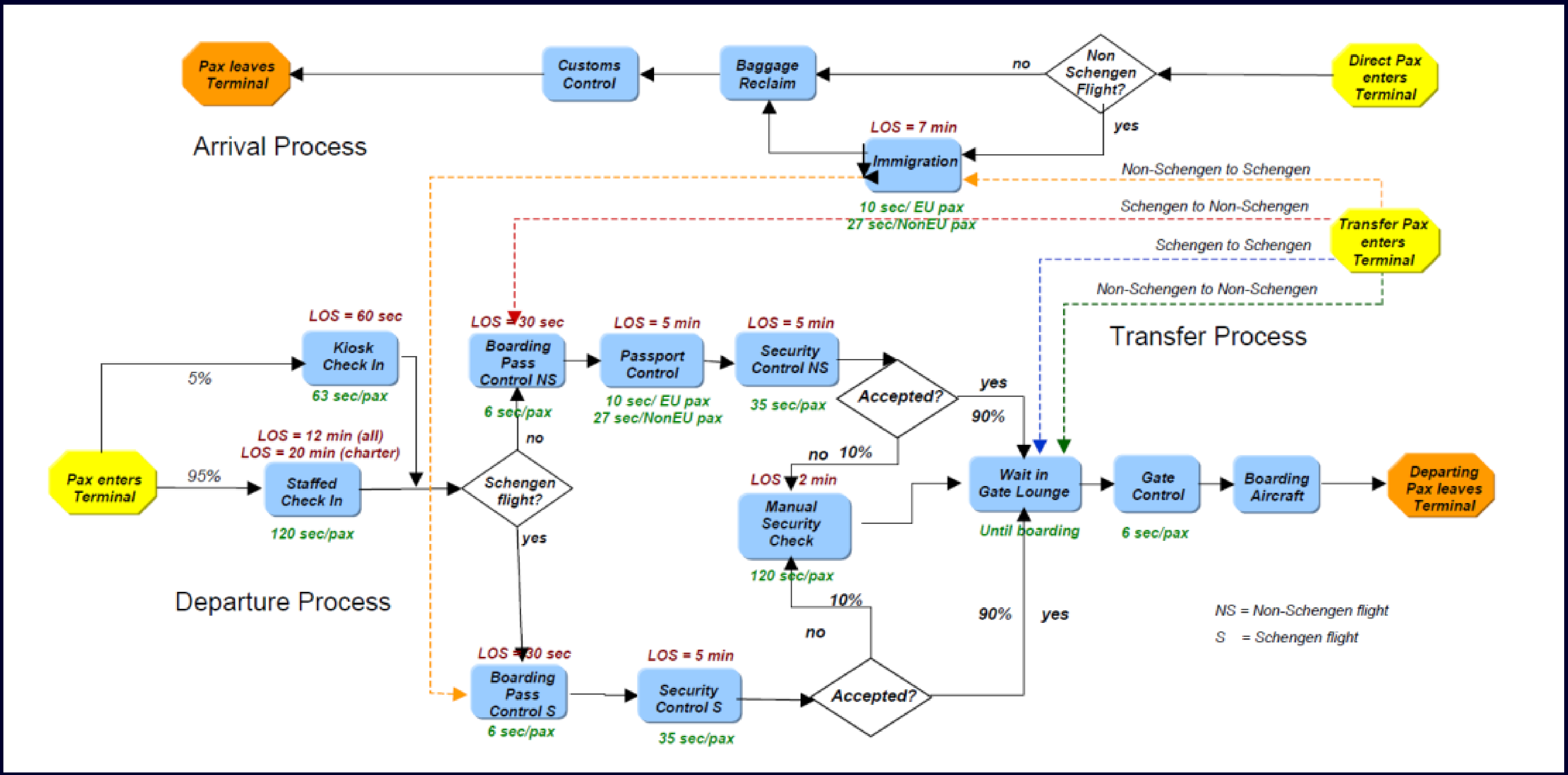
- Model framework: high-level factor groups
  - H1. Traffic / demand
  - H2. Market forces / technologies / supply
  - H3. Policy / regulation
- Populate with: future European passenger archetypes
  - data-driven, evidence-based (better availability for 2035)
  - multiple data sources & factors considered (e.g. ICT use, education)
  - 65+ group around 25% of population in 2035 (‘Best Agers’)
  - passengers may belong to more than group

Building a picture for 2050

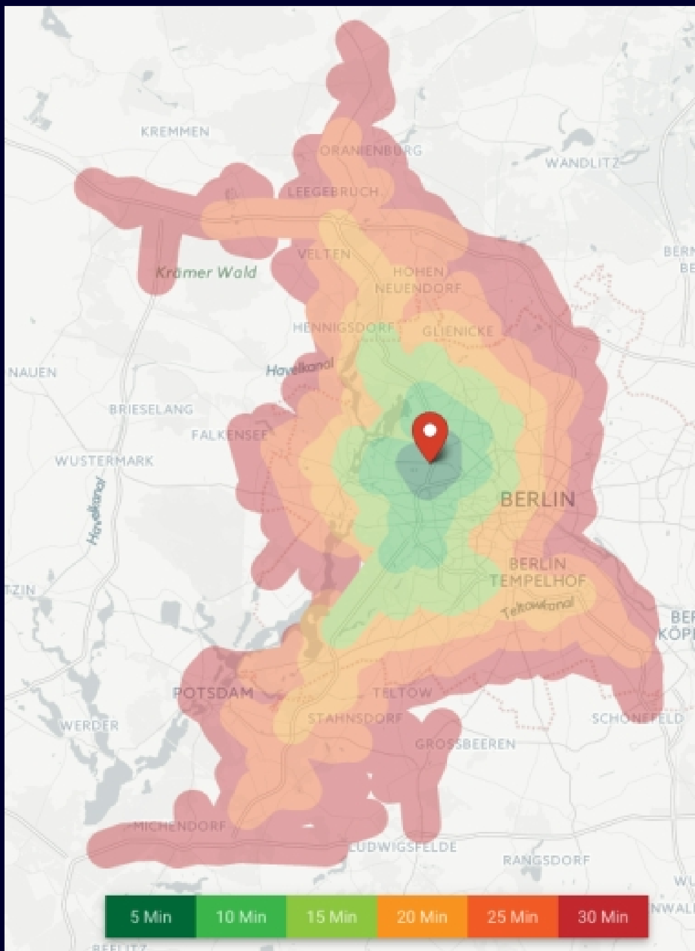
Building a picture for 2050

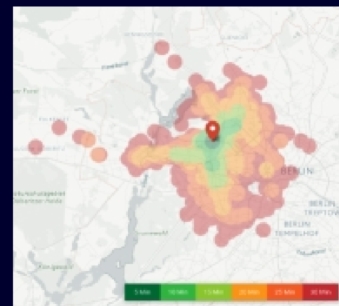


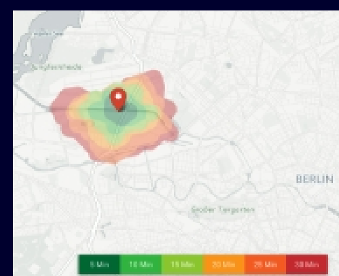
Building a picture for 2050

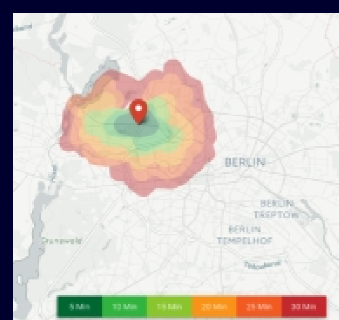


Building a picture for 2050









- Access and egress
  - by mode
  - by time of day
  - OpenStreetMap; Google; other aps
  - websites (incl. airport access tools)
  - timetables (primary data)
  - market research
  - wider literature (journals, reports, accessibility plans)

High-level factor group		Model scenario 1: WEAK supporting changes	Model scenario 2: EXPECTED supporting changes	Model scenario 3: STRONG supporting changes
H1. Traffic / demand				
Door-to-kerb	NET	LOW	LOW	MEDIUM
...	Future traffic	Low	Low	Low
...	HSR substitution	Low	Medium	High
Kerb-to-gate	NET [...]	LOW	MEDIUM	MEDIUM
Gate-to-gate	NET [...]	LOW	MEDIUM	MEDIUM
H2. Market forces / technologies / supply				
Door-to-kerb	NET [...]	LOW	MEDIUM	HIGH
Kerb-to-gate	NET	LOW	MEDIUM	MEDIUM
...	Seamless ticketing	Low	Low	Medium
...	Self-service take-up	Low	Low	Medium
...	Baggage handling	Low	Medium	High
...	Security processes	Low	Medium	High
Gate-to-gate	NET [...]	LOW	MEDIUM	MEDIUM
H3. Policy / regulation				
Door-to-kerb	NET [...]	LOW	MEDIUM	HIGH
Kerb-to-gate	NET [...]	MEDIUM	MEDIUM	HIGH
Gate-to-gate	NET [...]	LOW	MEDIUM	MEDIUM

Building a picture for 2050

- Two largest effects (??)

- Access times
  - driven by technology (travel supply) & regulation
- Dwell (buffer) times
  - driven by airport policy (revenue) & regulation (?)

] passenger attitudes

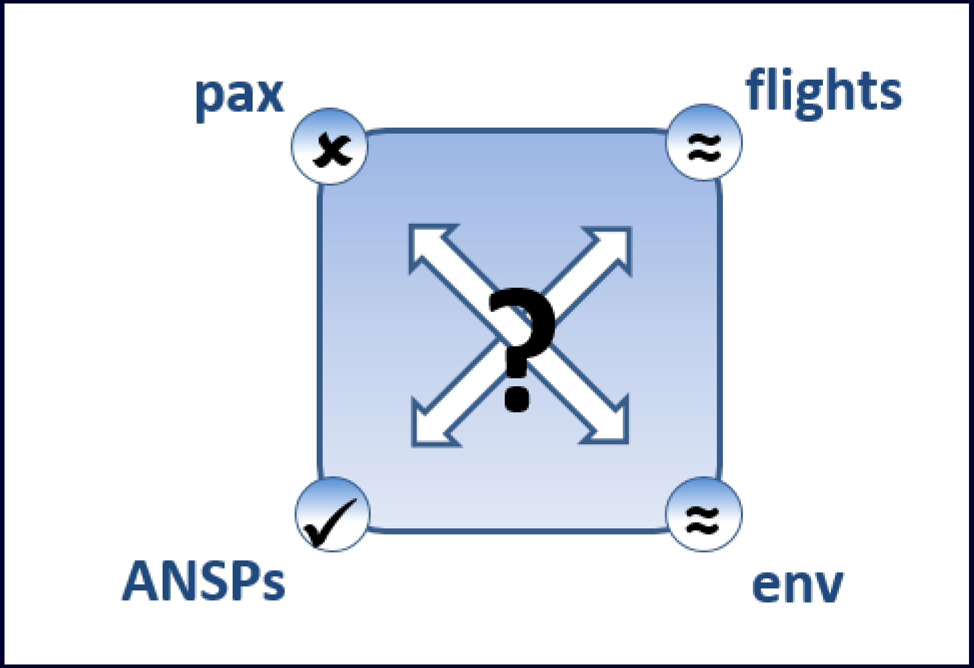
- Policy implications

Vista

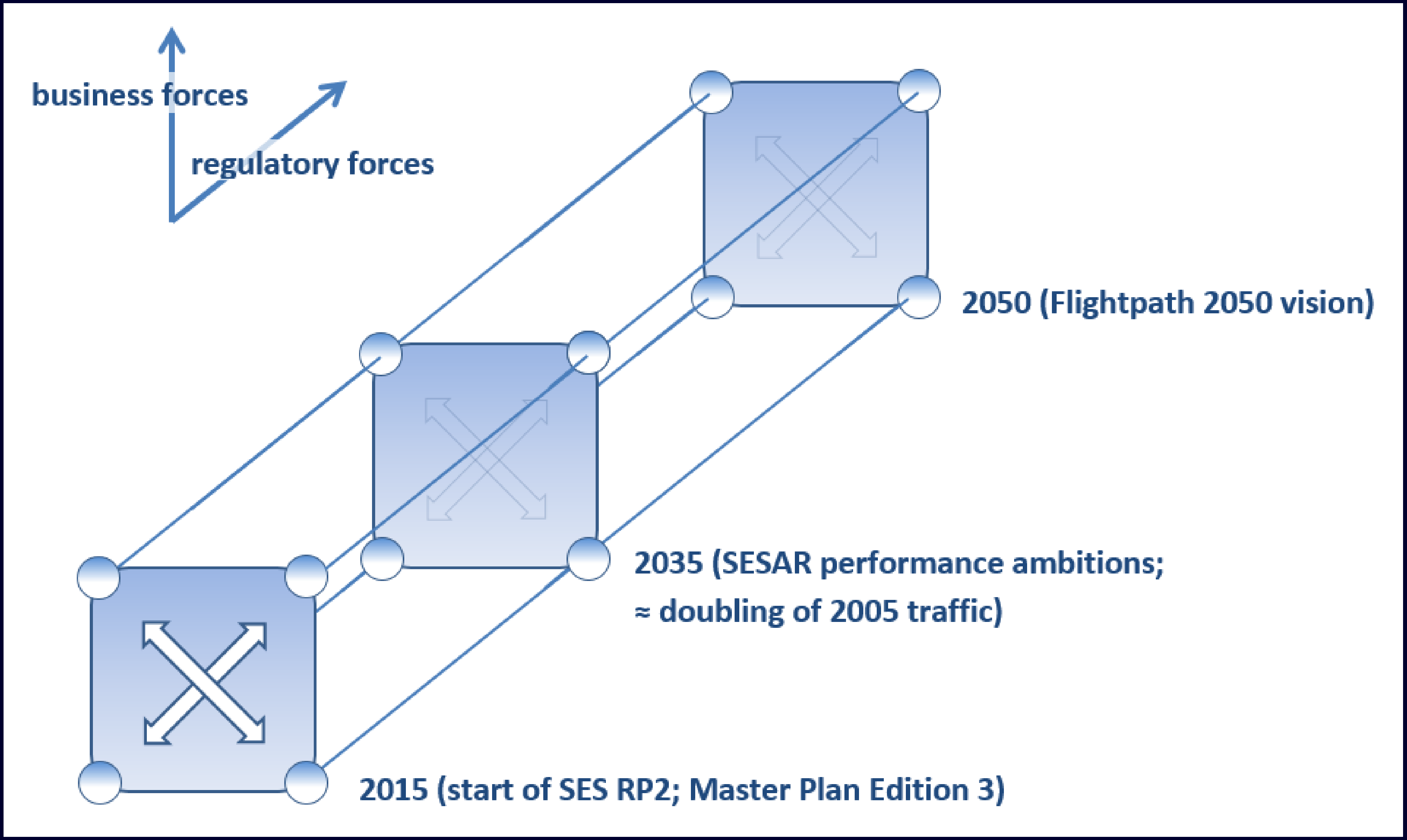
Examines effects of conflicting market forces on European performance, through evaluation of fully monetised & quasi-cost impact metrics on four stakeholders, and the environment

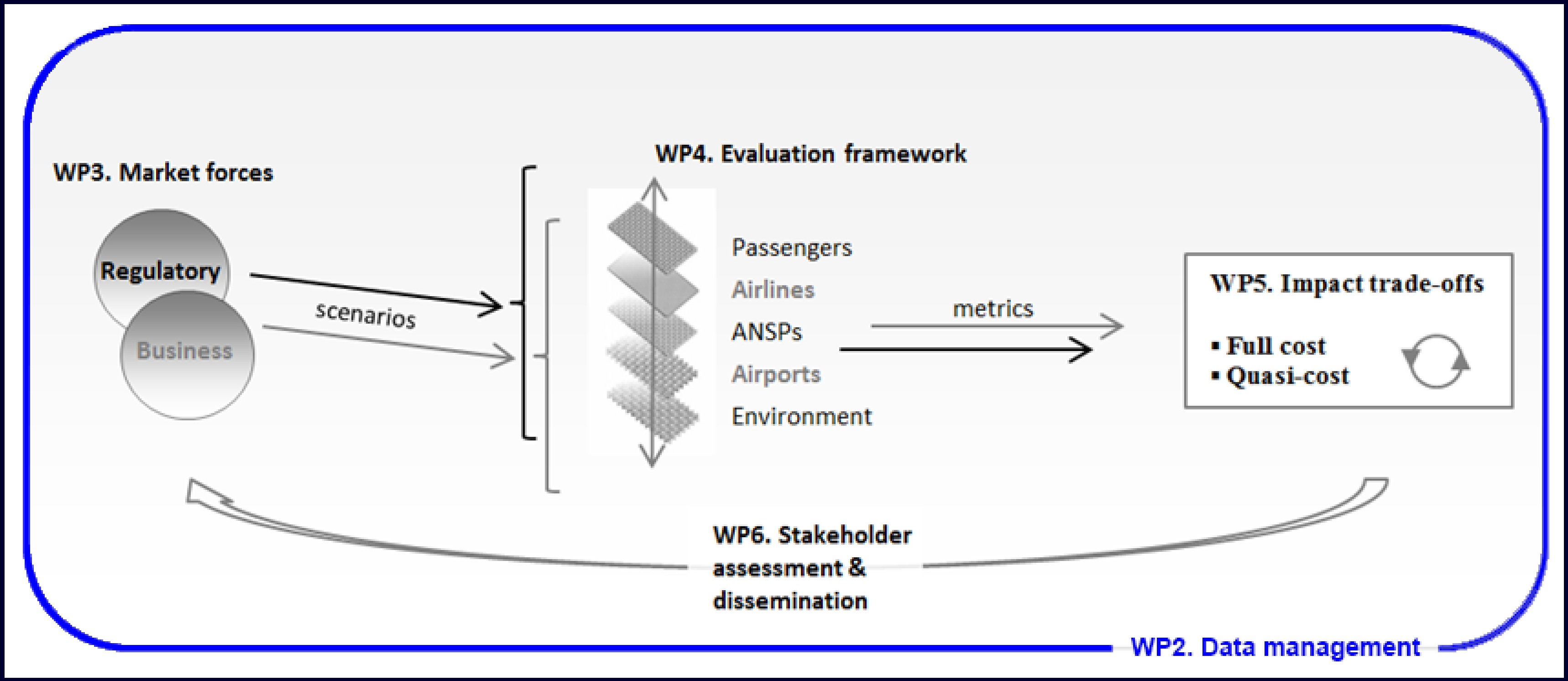
Assessing impacts

- Business (market) factors (incl. tools & technologies) may conflict with (new) regulations (and instruments) [review]
- Exploring unintended consequences, such as:
  - cheaper to cancel a flight? (Reg. 261)
  - delay recovery v. emissions impact? (ETS; Directive 2008/101)
  - ANSP delay levels driven too low? (SES PS; Reg. 549/2004)
- Impact metrics
  - classical (e.g. average delay) & complexity (e.g. community detect^{N})
  - monetised (e.g. cost of delay; ATCOs) & quasi-cost (NO_x, σ^2_{arr})
- Stakeholders
  - passengers, airlines, ANSPs, airports; environment



KPIs established for 2015 (all in SES PS, RP2)


business forces
regulatory forces
2050 (Flightpath 2050 vision)
2035 (SESAR performance ambitions;
≈ doubling of 2005 traffic)
2015 (start of SES RP2; Master Plan Edition 3)



‘Mercury’ model:	at core of evaluation framework
Ambition:	TRL2 (technology concept and/or application formulated; applied research)
Trade-off analysis:	Pareto frontier; expected utility; Granger causality; precursor-successor analysis

Assessing impacts

- Better understanding of future KPA roadmap & interactions
- Supporting industry to better adapt to change
- Reducing the risk of future performance misalignment and unintended consequences
- Improving the potential of implementing synergistic targets and cost-efficient policy and regulatory measures
- Supporting specific initiatives, such as:
  - improving the gap analysis set as a goal of Network Strategy Plan
  - driving quantified rather than reportedly "conceptual" trade-off assessments in FAB Performance Plans (required by Perf. Reg.)
  - providing extended insights into metric trade-offs for future editions of ATM Master Plan & SES PS planning horizons
  - highlighting further research needs towards ACARE 4H D2D goal

Regulatory example

- Regulation (EC) No 261/2004
  - 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 passed first reading in European Parliament; awaiting European Council (member states) agreement
- Complicated in practice, especially regarding ‘extraordinary circumstances’, and reactionary delays – legal advice

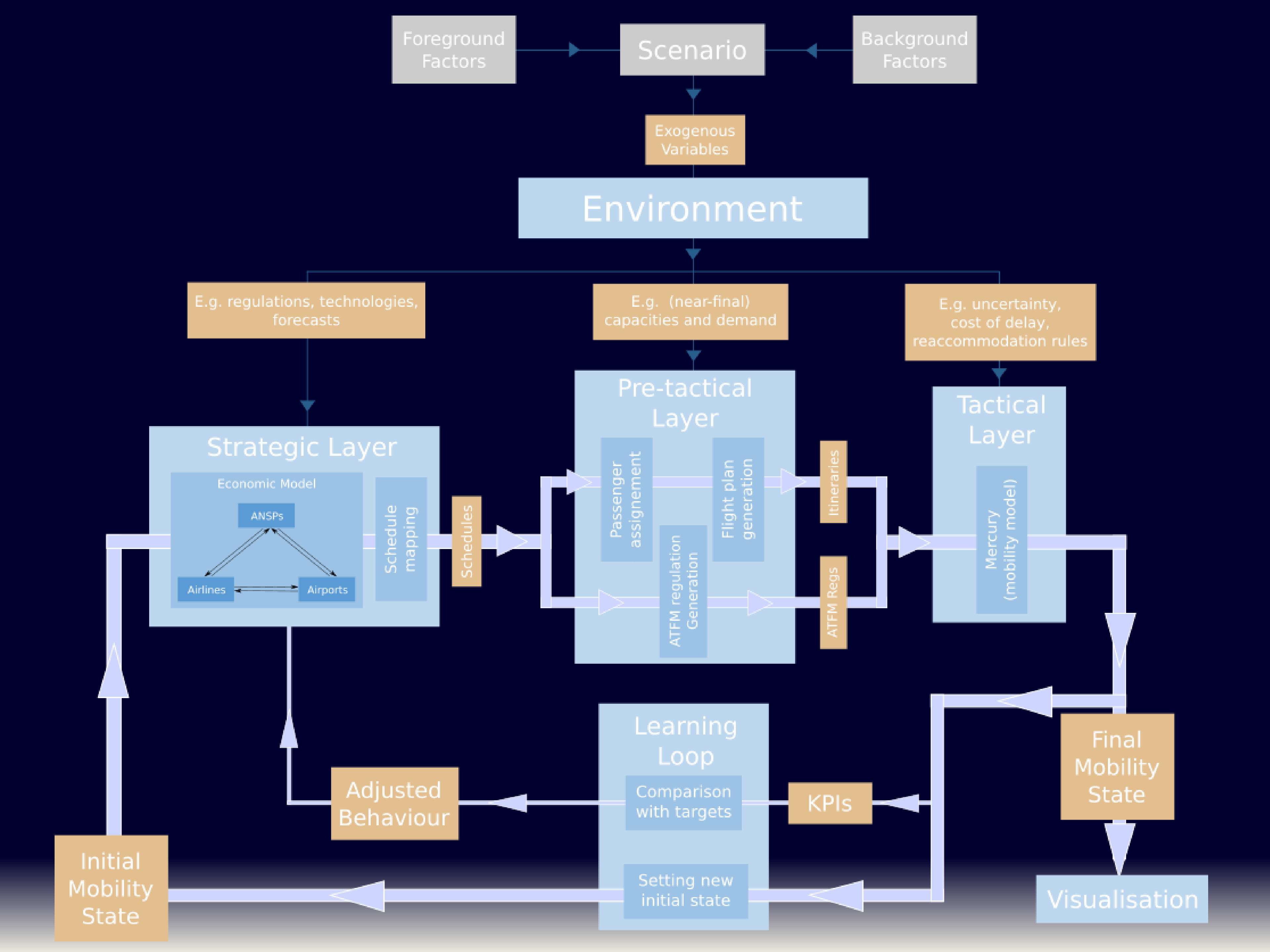
Regulatory example

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	+®

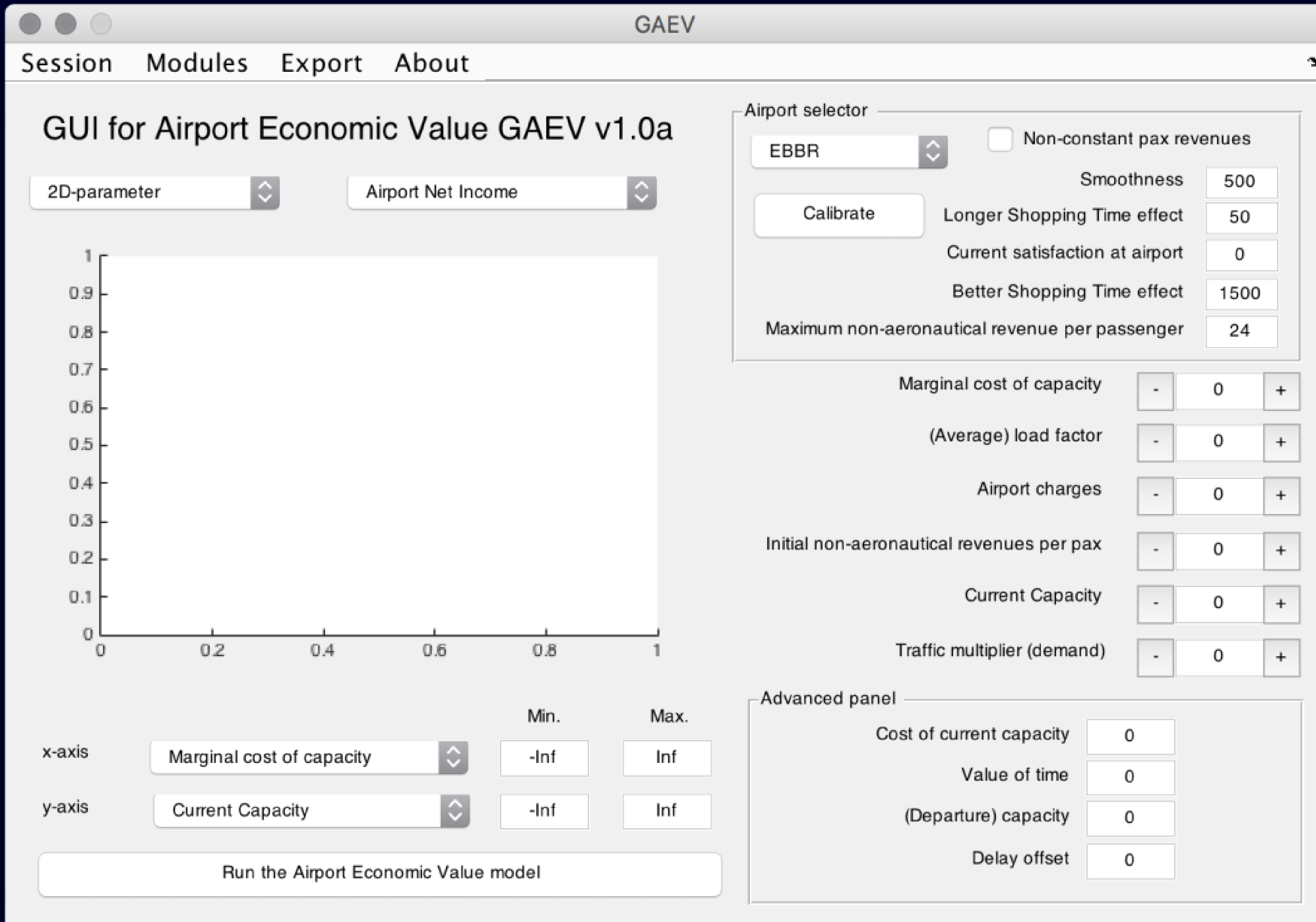
Key

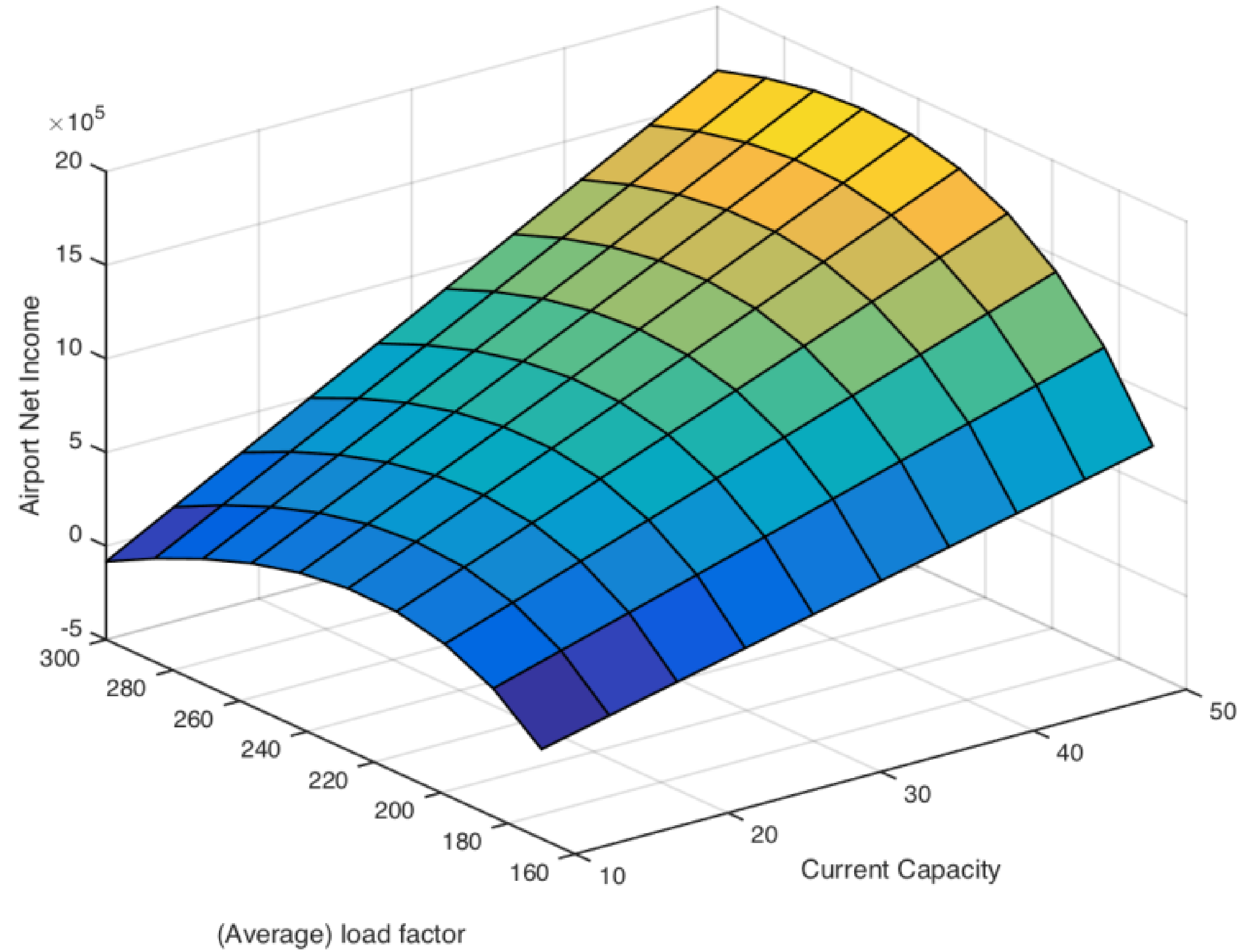
🍽	Care (e.g. reasonable meals and refreshments)		
🗎	Reimbursement of ticket		
€	Compensation (refers to *arrival* delay)		
©	Rights re. missed connecting flights	orange:	2005
®	Better rights re. re-routing on other airlines	blue:	2009
*	For delays of three to four hours (CJEU ruling, 2009)	red:	??

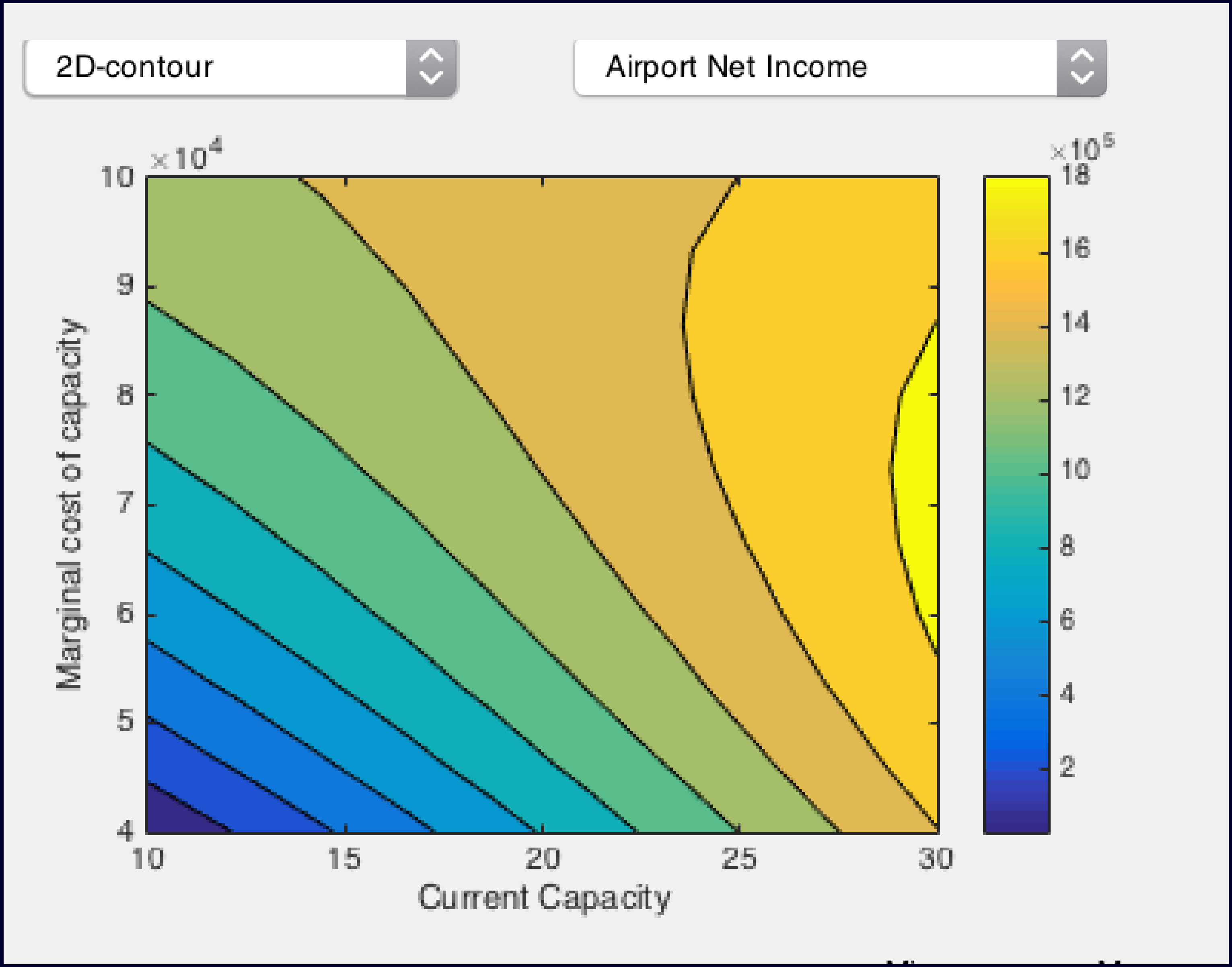
- Benefit of more radical regulatory change, beyond 261?


Foreground Factors
Scenario
Background Factors
Exogenous Variables
Environment
E.g. regulations, technologies, forecasts
E.g. (near-final) capacities and demand
E.g. uncertainty, cost of delay, reaccommodation rules
Strategic Layer
Economic Model
ANSPs
Airlines
Airports
Schedule mapping
Schedules
Pre-tactical Layer
Passenger assignement
Flight plan generation
ATFM regulation Generation
Itineraries
ATFM Regs
Tactical Layer
Mercury (mobility model)
Learning Loop
Comparison with targets
Setting new initial state
Adjusted Behaviour
KPIs
Final Mobility State
Initial Mobility State
Visualisation

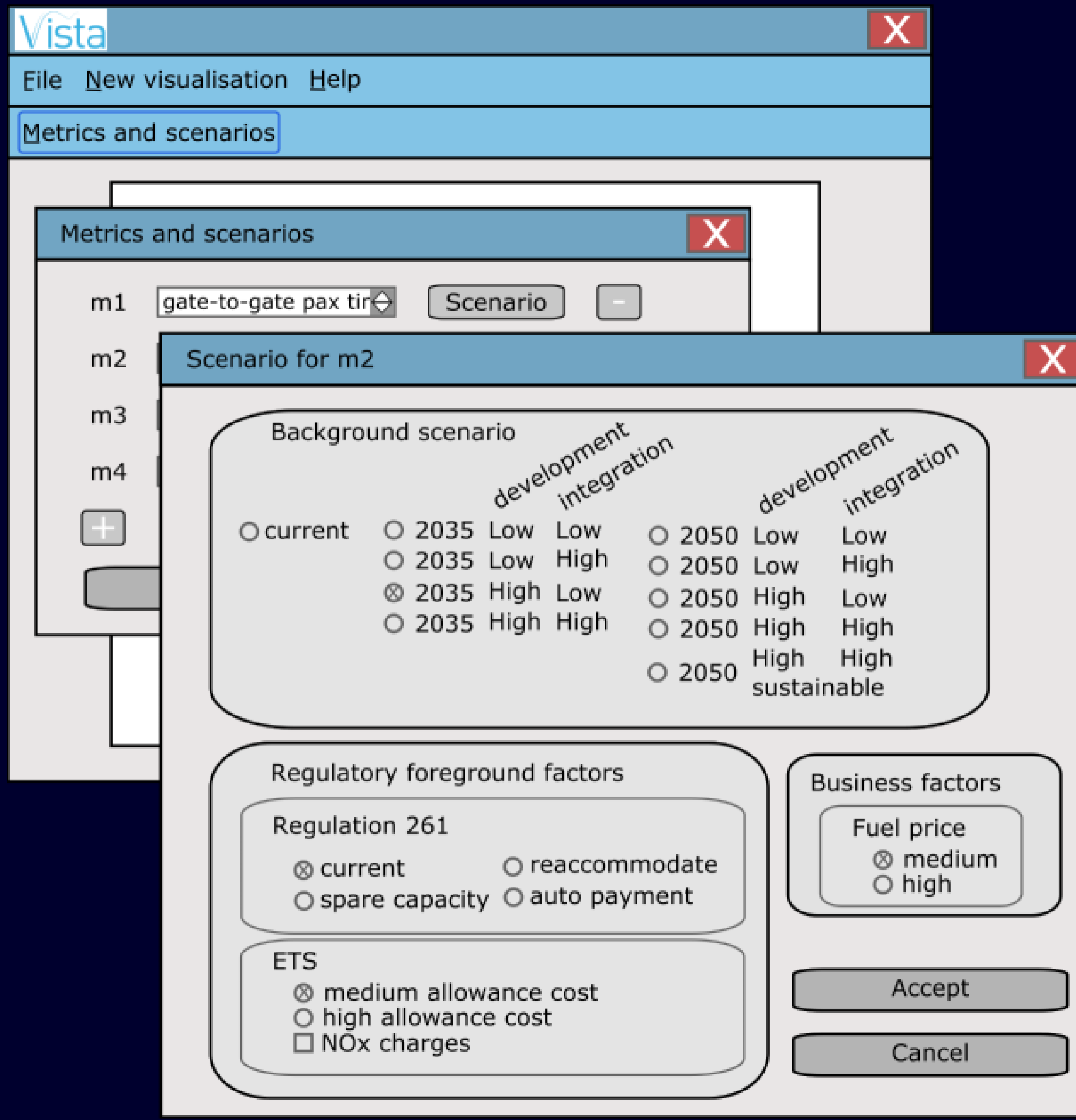
Data visualisation

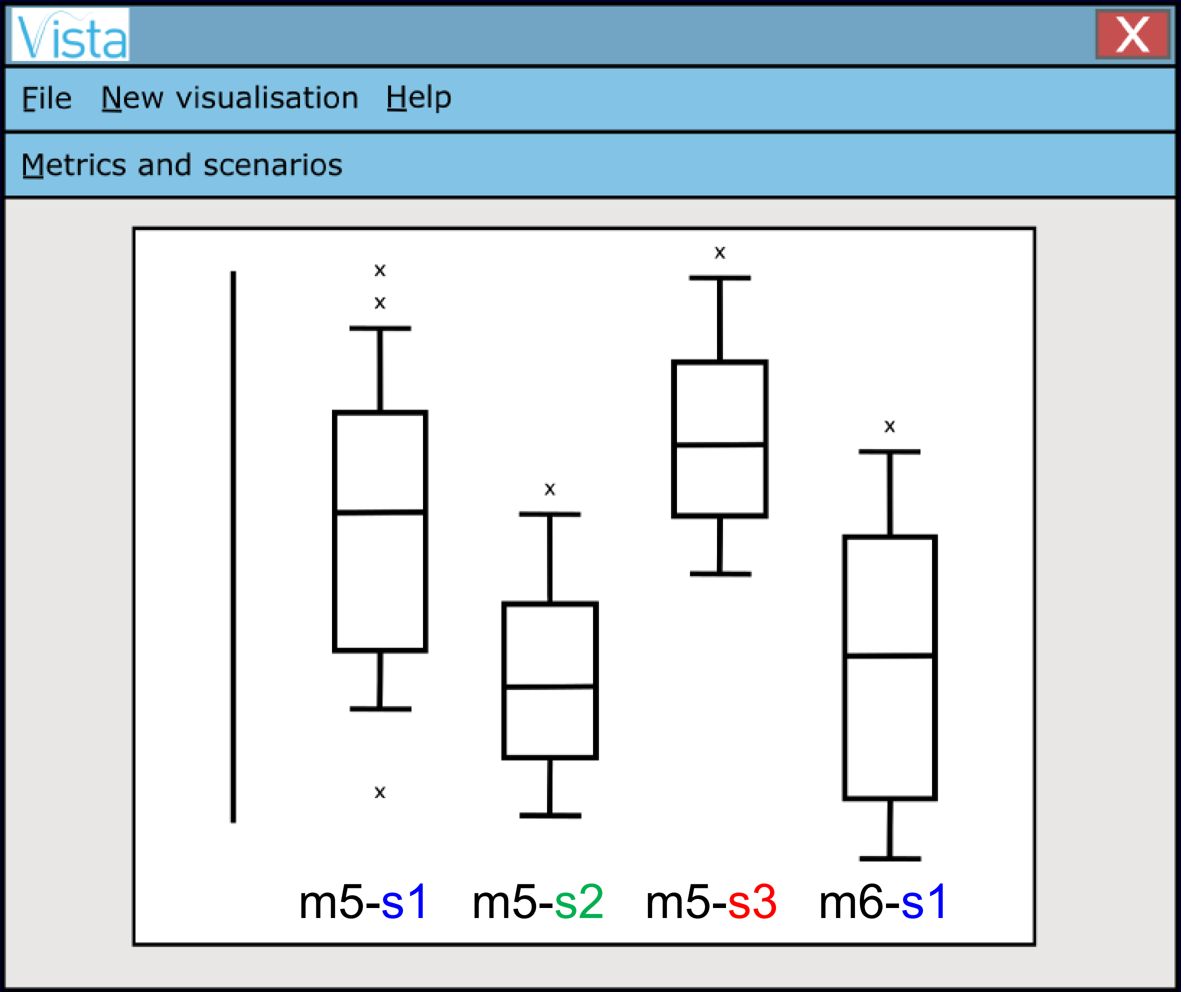

GAEV
Session
Modules
Export
About
GUI for Airport Economic Value GAEV v1.0a
2D-parameter
Airport Net Income
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
Min.
Max.
x-axis
Marginal cost of capacity
-Inf
Inf
y-axis
Current Capacity
-Inf
Inf
Run the Airport Economic Value model
Airport selector
EBBR
Non-constant pax revenues
Calibrate
Smoothness 500
Longer Shopping Time effect 50
Current satisfaction at airport 0
Better Shopping Time effect 1500
Maximum non-aeronautical revenue per passenger 24
Marginal cost of capacity - 0 +
(Average) load factor - 0 +
Airport charges - 0 +
Initial non-aeronautical revenues per pax - 0 +
Current Capacity - 0 +
Traffic multiplier (demand) - 0 +
Advanced panel
Cost of current capacity 0
Value of time 0
(Departure) capacity 0
Delay offset 0

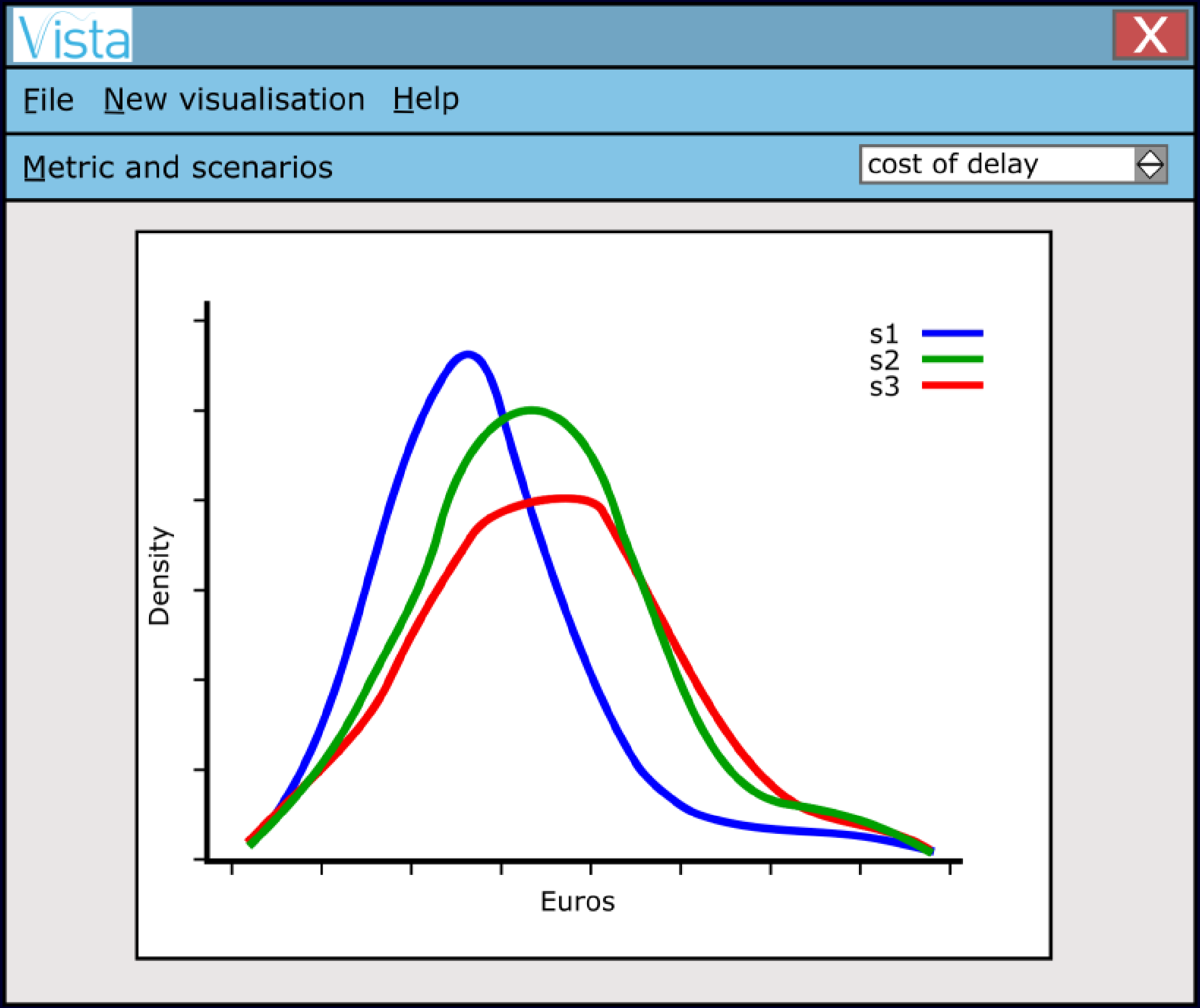

×10^5
20
15
10
5
0
-5
Airport Net Income
300
280
260
240
220
200
180
160
10
20
30
40
50
Current Capacity
(Average) load factor

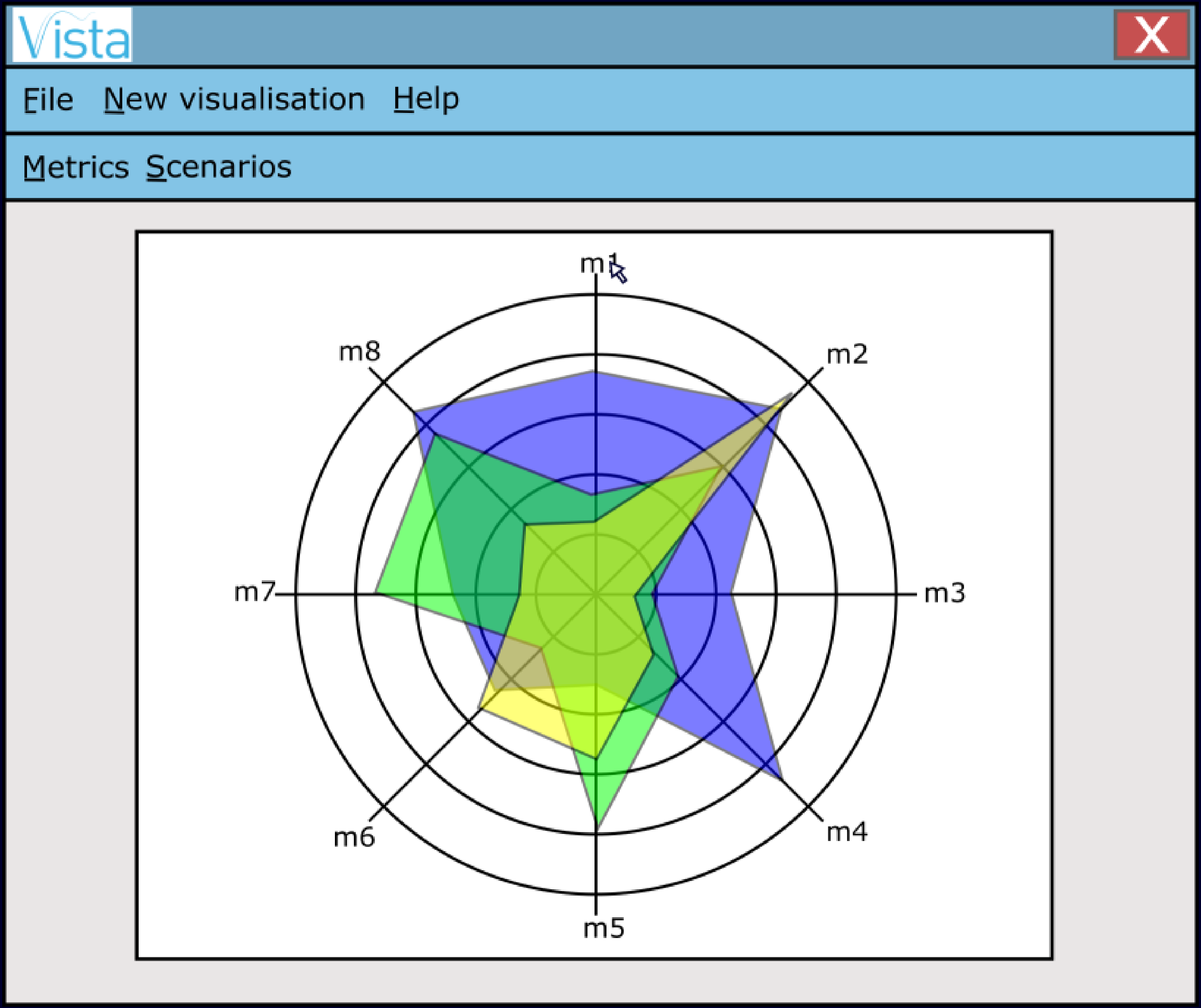


2D-contour
Airport Net Income
×10^4
10
9
8
7
6
5
4
Marginal cost of capacity
10
15
20
25
30
Current Capacity
×10^5
18
16
14
12
10
8
6
4
2


Vista
File New visualisation Help
Metrics and scenarios
Metrics and scenarios
m1
gate-to-gate pax tir
Scenario
m2
m3
m4
Scenario for m2
Background scenario
development
integration
development
integration
current
2035 Low Low
2035 Low High
2035 High Low
2035 High High
2050 Low Low
2050 Low High
2050 High Low
2050 High High
2050 High High sustainable
Regulatory foreground factors
Regulation 261
current
spare capacity
reaccommodate
auto payment
ETS
medium allowance cost
high allowance cost
NOx charges
Business factors
Fuel price
medium
high
Accept
Cancel


Vista
X
File New visualisation Help
Metrics and scenarios
m5-s1
m5-s2
m5-s3
m6-s1


Vista
X
File New visualisation Help
Metric and scenarios
cost of delay
s1
s2
s3
Density
Euros



Vista
X
File New visualisation Help
Metrics Scenarios
m1
m2
m3
m4
m5
m6
m7
m8

Discussion

4H D2D revisited …

- Just a minute … will 90% of travellers actually *want* 4H D2D in 2050?
- More speed => more stress? Changing social norms?
- Current Call: how will ICT applications (e.g. wifi) tend to reduce the perceived cost of travel time? Examine the potential shift *away* from the ‘speed paradigm’. Segmentations, and transport project CBA impacts …

Topic: mobility for growth; pillar: societal challenges; work programme part: smart, green and integrated transport

Discussion

Concluding remarks (but not conclusions!)

Concluding remarks

- Early mobility modelling has established the need for passenger-centric and cost-centric metrics
- Capabilities and plans regarding the most developed European model (‘Mercury’) have been presented; this model is laying foundations for further development
- There is still a lot to be done, in particular to:
  - build a full, mature, intermodal European mobility model
  - develop new mobility metrics for the future (RP3 and beyond)
  - move closer towards data-driven policies (e.g. pax-resilient networks)
  - integrate such models and metrics with SESAR (e.g. UDPP, A-CDM)
  - use these to help (e.g.) airlines to develop better strategies
  - examine performance of particular airlines, routes, airports (c.f. network)
  - integrate such models with industry tools (tactical and strategic)

Thank you

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David: dp@innaxis.org

Stand-bys

Cost of delay

Trends and headlines

- Primary at-gate increase: 18%; en-route: 22% (c.f. 2010)

Table 30. European ATFM delay cost estimates

Factor	2014 value	2010 value
Average cost of delay of an ATFM-delayed aircraft	**1 970**	1 660
ATFM delay cost averaged over all flights	**103**	130
Network average cost of ATFM delay, per minute	**100**	CARE! 81

Costs in Euros. 2014 delay weights use 2014 ATFM data.

NB. The decrease in the ATFM delay cost averaged over all flights is driven by a decrease in the *number* of flights with ATFM delay as a percentage of all flights, from 7.9% in 2010 to 5.2% in 2014.

Users and example SESAR projects

- EUROCONTROL (EHQ & EEC); SESAR
  - tactical and strategic, planning and assessment levels
- Airlines (two-way process); Working Group
- ANSPs, airports, national government
  - expansion and privatisation
- Legal cases (large delay compensation claims)
- Industry (e.g. delay management software)
- Academia (more global reach c.f. above)

POEM

Core metric*	Units	Definition	Threshold
Flight departure delay	mins / flight	Delay from the gate relative to schedule	0.2
Flight arrival delay	mins / flight	Delay at the gate relative to schedule	0.2
Departure delay of departure-delayed flights^	mins / flight	Delay from the gate relative to schedule	1.0
Arrival delay of arrival-delayed flights^	mins / flight	Delay at the gate relative to schedule	1.0
Pax departure delay†	mins / pax	Delay from the gate relative to schedule	0.2
Pax arrival delay†	mins / pax	Delay at the gate relative to schedule	0.2
Departure delay of departure-delayed pax^	mins / pax	Delay from the gate relative to schedule	1.0
Arrival delay of arrival-delayed pax^	mins / pax	Delay at the gate relative to schedule	1.0
Passenger hard cost	Euros / pax	Hard costs (see Appendix A) averaged per passenger	0.2
Passenger soft cost	Euros / pax	Soft costs (see Appendix A) averaged per passenger	0.2
Passenger value of time	Euros / pax	Pax value of time (see Appendix A) averaged per passenger	0.2
Non-passenger costs	Euros / flight	Fuel, crew and maintenance costs averaged per flight	10
Per-flight pax hard cost	Euros / flight	Passenger hard costs to airline averaged per flight	10
Per-flight pax soft cost	Euros / flight	Passenger soft costs to airline averaged per flight	10
Total flight cost‡	Euros / flight	Passenger plus non-passenger costs per flight	10
Total flight cost per minute of departure delay¶	Euros / min	Pax plus non-pax costs per minute of departure delay	2.0
Reactionary delay ratio	ratio	Reactionary delay (see Section 2.5) / flight departure delay	n/a
Arrival-delayed passenger / flight ratio	ratio	Arrival delay of: arrival-delayed pax / arrival-delayed flights	n/a

flight-centric

new metrics

Core metric	Units	N_1 & N_2	P_1	P_2	A_1
		Inbound prioritisation based on: simple pax numbers, or on onward flights delayed	Passenger reaccommodated based on delay at final destination … … preserving interlining hierarchies	… **relaxing interlining hierarchies**	Departures times based on **cost minimisation** (& consideration of ATFM delay)
Flight departure delay	mins / flight	no significant changes in current flight-centric metrics: stresses need for passenger-centric metrics			
Flight arrival delay	mins / flight				
Departure delay of departure-delayed flights	mins / flight				
Arrival delay of arrival-delayed flights	mins / flight				
Pax departure delay	mins / pax			=	+0.4
Pax arrival delay	mins / pax			-0.4	-1.6
Departure delay of departure-delayed pax	mins / pax	no significant changes under simple inbound scenarios driven by passenger numbers, or by numbers of delayed onward flights	revised passenger re-booking rules produce only weak improvements whilst current airline interlining rules are preserved, c.f. ⟶	=	=
Arrival delay of arrival-delayed pax	mins / pax			-2.2	-9.8
Passenger value of time	Euros / pax			-0.2	-0.7
Non-passenger costs	Euros / flight			=	=
Per-flight pax hard cost	Euros / flight			+26	-40
Per-flight pax soft cost	Euros / flight			=	=
Total flight cost	Euros / flight			+26	-39
Total flight cost per minute of departure delay	Euros / min			=	-7.8
Reactionary delay ratio	ratio			49%	51%

Granger causality

- Key features and results
  - time series, q, is considered to Granger-cause another time series, p, if inclusion of past values of q can improve forecasting of p
  - two time series with a high correlation
  - two time series ‘forced’ by a third system

  usually fail, as q doesn’t add new info for p

  - built flight and pax networks for S_0 and A_1
  - time series of arrival delay for node pairs (unweighted directed network)
  - for each node, calculated eigenvector centrality: delay connectedness
  - comparing eigenvector centrality rankings through Spearman rank correlation coefficients: all four layers almost completely different

Selected key results

A_2

A_1	Wait times and associated departure slots are estimated on a cost minimisation basis, with longer wait times potentially forced during periods of heavy ATFM delay
A_2	Departure times *and* arrival sequences based on delay costs – A_1 is implemented *and* flights are independently arrival-managed based on delay cost

- Scenario A_2
  - addition of independent, cost-based arrival management apparently foiled the benefits of A_1 due to lack of coordination between departures and arrivals
  - reflected in higher dispersion (σ) of all core metrics and the highest reactionary delay ratio (58%)
  - arrival queuing may have non-linear delay multiplier effects in the network (Kwan and Hansen (2011))

Vista

ATM Master Plan (Edition 2015

Figure 5 **SESAR performance ambitions for 2035 (categorised by KPA)**

Key performance area	SES High-Level Goals vs. 2005	Key performance indicator	SESAR ambition vs. baseline 2012: Absolute saving	SESAR ambition vs. baseline 2012: Relative saving
Cost efficiency: ANS productivity	Reduce ATM services unit cost by 50% or more	• Gate-to-gate direct ANS cost per flight - Determined unit cost for en-route ANS* - Determined unit cost for terminal ANS*	EUR 290-380	30-40%
Operational efficiency	-	• Fuel burn per flight (tonne/flight) • Flight time per flight (min/flight)	4-8 min 0.25-0.5 tonne	3-6 % 5-10 %
Capacity	Enable 3-fold increase in ATM capacity	• Departure delay (min/dep) - En-route air traffic flow management delay* - Primary and reactionary delays all causes • Additional flights at congested airports (million) • Networkthroughput additional flights (million)	1-3 min 0.2-0.4 (million) 7.6-9.5 (million) Additional flights, not saving	10-30 % 5-10 %[1] 80-100 %[2]
Environment	Enable 10 % reduction in the effects flights have on the environment	• CO_2 emissions (tonne/flight) - Horizontal flight efficiency (actual trajectory)* - Vertical efficiency - Taxi-out phase	0.79-1.6 tonne	5-10 %
Safety	Improve safety by factor 10	• Accidents with ATM contribution	No increase in accidents	Improvement by a factor 3-4
Security	-	• ATM related security incidents resulting in traffic disruptions	No increase in incidents	

Metrics with monetary value in business view

* Targeted by the Performance Scheme

Regulation 261 - practice

Summary of Regulation 261 compensation payments assigned by delay types

Delay code	Type of delay	Approximate percentage [(a)]	Compensation paid for primary delay	Compensation paid for reactionary delay
'A'	ANS / ATFM (mostly)	13%	✗	✗
'TW'	Turnaround and (non-ATFM) weather [(b)]	40%	✓	✓
'R'	Reactionary	47%	If type 'TW'	If type 'TW'

(a) Estimates based on EUROCONTROL (2014) and EUROCONTROL (2015a). (Strikes are subsumed across these categories (data not explicitly shown in reports), probably mostly as 'A'.)

(b) Mostly aircraft turnaround; this will include *some* exempted (exceptional) weather, but this is likely to be a rather low proportion and thus neglected, and even this sub-category still triggers reactionary compensation in any case.