Flight prioritisation, delay costs and the passenger – where next?

Cook, A.J.

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Flight prioritisation, delay costs and the passenger – where next?

University of Westminster
Innaxis Foundation & Research Institute

Dr Andrew Cook
Principal Research Fellow

$$e^{i\pi} = -1$$

$$B744\ (60\ mins)_{at-gate\ delay} = €21k$$

Overview

- Background and objectives
- Flight prioritisation
- Delay costs and the passenger
  - passenger context
  - new tool, new data
  - simulation & scenarios
  - selected key results
- Where next?

Background and objectives

Background and objectives

- To build a European network simulation model for flights *and passengers*, which:
  - realistically captures airline decision-making and costs
  - includes a range of new performance metrics we have designed: 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
- Project was design and data front-loaded
- Included stakeholder workshops & two airline case studies

Flight prioritisation

Flight prioritisation

- Where we are now
  - FPFS - fair starting point, but not an optimisation
  - focus is on departure
  - not always coordinated with airport slot
  - usually few/no prior timing constraints en route
  - heavy constraints on routing (RAD)
  - CTOT is quite late in process and subject to change
  - pilot / ATC will often seek tactical change
  - very limited ATFM slot-swapping
- All change – where we go next
  - The ‘Business (4D) Trajectory’
  - SESAR Concept of Operations

Flight prioritisation

- SESAR ConOps
  - Step 1: time-based — 2014-2025 — CTAs
  - Step 2: trajectory-based — ~ 2025++ — full 4D, CTOs
  - Step 3: performance-based — ~ 2025++ — full free-routes
- User Driven Prioritisation Process: a key component
  - AOs request priority order for flights with restrictions
  - previously, only after Demand and Capacity Balancing had failed
  - ConOps 1 extends this scope to all normal situations, all phases
  - greatest applicability during capacity restrictions
  - early emphasis on pre-departure
  - consensus-seeking, although not an optimisation *per se*
- Context; SESAR WP-E – free to explore other options

Delay costs and the passenger

- passenger context

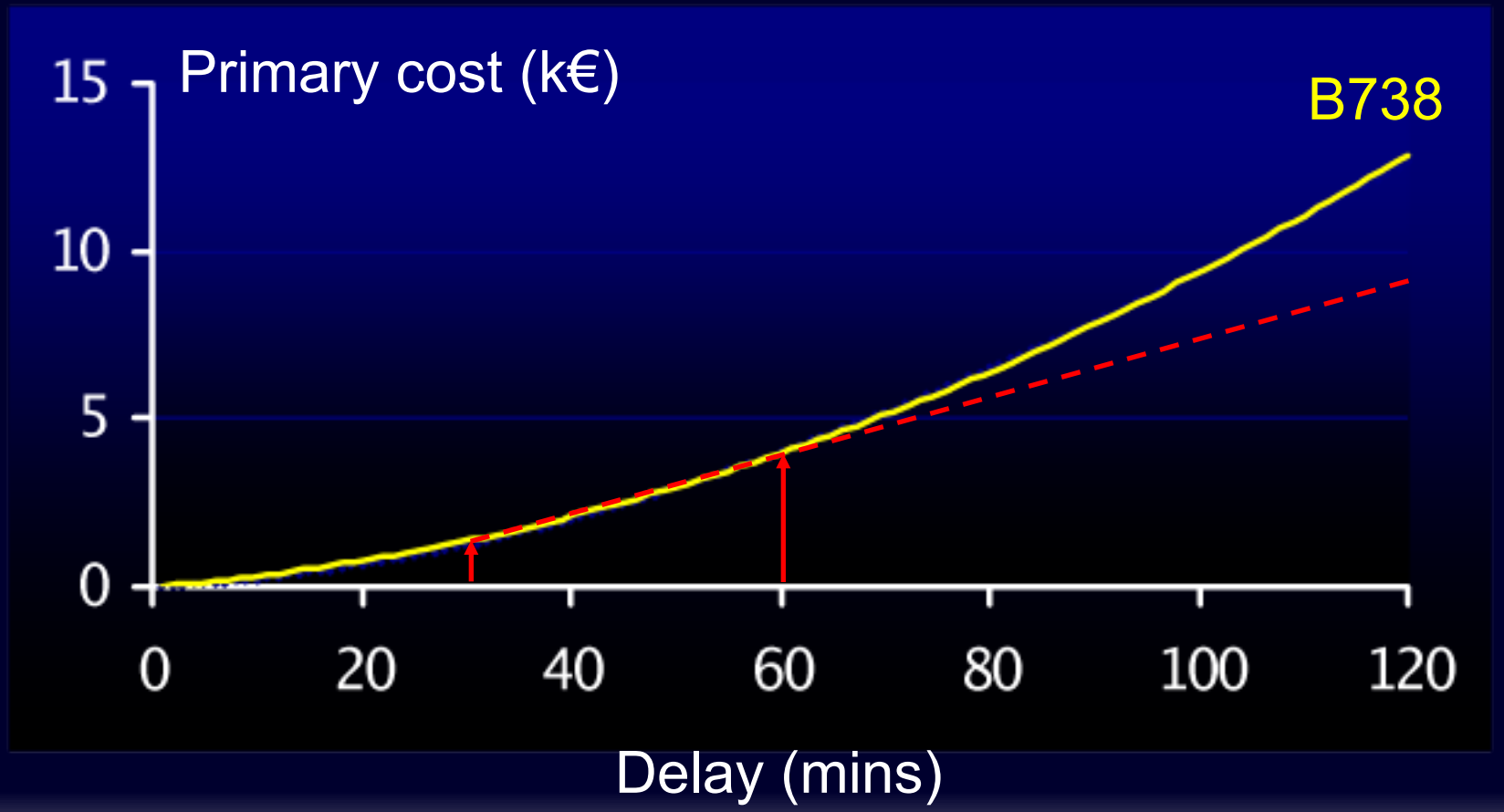
Passenger context

- Policy-driven motivation
  - ultimate performance delivery to the passenger
  - 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)
  - ACARE Strategic Research & Innovation Agenda (Sep. 2012)
- Operational drivers
  - 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 (factor of 1.6 – 1.7)
- How can we measure specific progress without metrics?

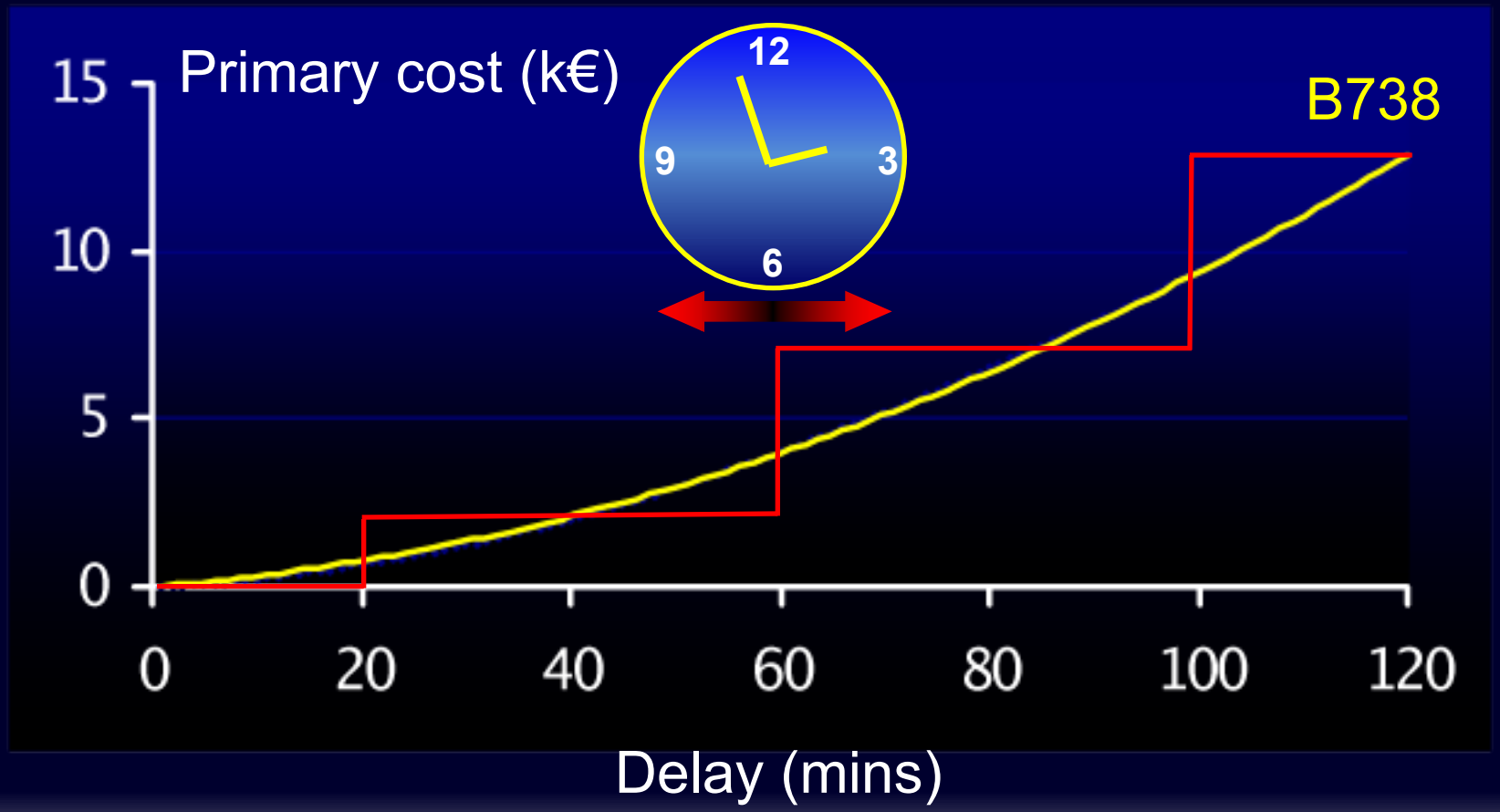
Passenger context

	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	‘hard’ & ‘soft’ (not internalised costs)

Passenger context



Passenger context



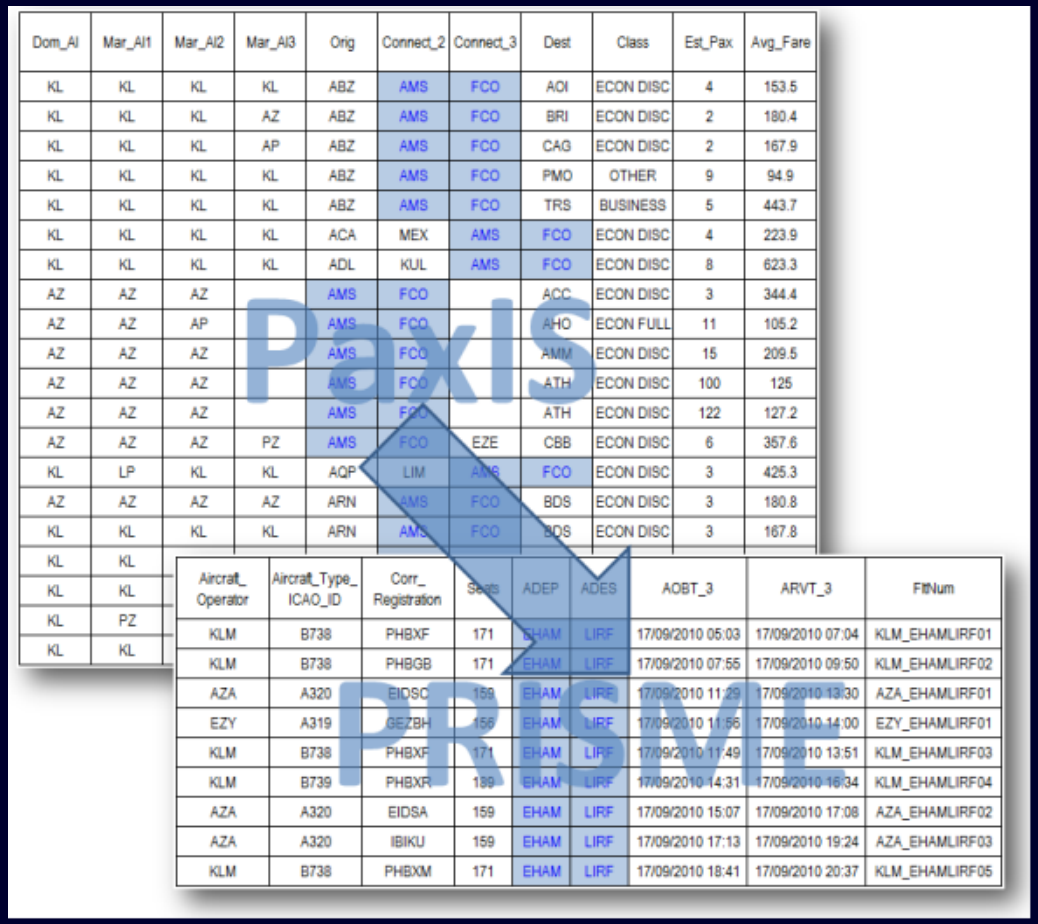
Delay costs and the passenger

- new tool, new data

New tool, new data

- Evaluates different flight and pax prioritisation strategies
- Includes tactical costs to the airline (4 AO types)
- Incorporates new metrics using complexity science
- Key characteristics of the model
  - currently running 17SEP10 (busy day & month; 2010 c.f. 2012)
  - non-exceptional in terms of delays, strikes, weather
  - busiest 199 ECAC airports (cover 97% pax & 93% traffic for 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 …

New tool, new data



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
- 30 000 flights
- 2.5 million pax
- 150 000 routings

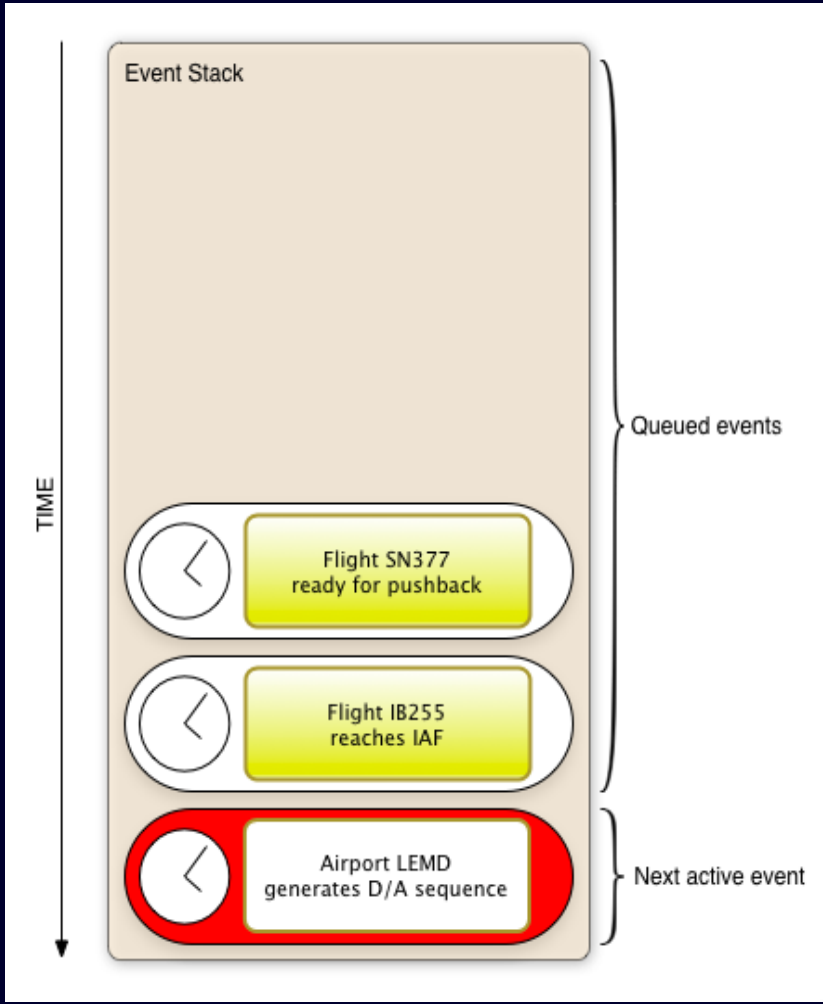
Delay costs and the passenger

- simulation & scenarios

Simulation & scenarios

- Gate-to-gate aircraft rules, and pax connection rules
- Varying levels of fidelity, for example:
- Rule 23: en-route (some recovery, 5 min residual, wind; later …)
- 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

Simulation & scenarios



- event-driven: event stack, ordered sequence of events, each with a stamp
- dynamic tracking of costs for each a/c & passenger
- pre-computed cost functions: recursive (from end of day backwards along propagation tree); discrete (dly: 0, 5, 10, …)
- single-processor: 25-50 minutes to run one day
- cloud-computing platform: approximately 2 minutes

Simulation & scenarios

[…](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

(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)

Simulation & scenarios

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

Delay costs and the passenger

- selected key results

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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	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. →	=	+0.4
Pax arrival delay	mins / pax			-0.4	-1.6
Departure delay of departure-delayed pax	mins / pax			=	=
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%

Selected key results

- With regard to A_1
  - saving in total costs wholly due to reduction in hard costs
  - explicit estimations of reactionary delay: a significant advance
    - § increases from 49% (baseline) to 51% as a proportion of all dep. delay
    - § reactionary delay focused on relatively few (waiting) aircraft
    - § c.f. baseline: contained in smaller, but more susceptible, communities
- 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

Where next?

Where next?

- Enhancements to the simulation
  - en route: Dynamic Cost Indexing (CASSIOPEIA), e.g. c.f. ‘rule of thumb’
  - cost recoveries (e.g. crew hours, cancelled flights)
- Schedule robustness
  - +1 minute of delay (avg: 14.9); +1% cancellations (morning); …
  - larger scale disruptions, localised or widespread
- Adaptive features
  - other dedicated metrics and (prioritisation) rules
  - new AO policy / EU regulation impacts
  - different traffic assumptions (e.g. STATFOR forecasts)
  - focus on performance of given airline or flights (c.f. network)
  - integration with other tools (tactical and strategic)

Where next?

Acronym	Full title
SAFECORAM	Sharing of authority in failure/emergency conditions for resilience of ATM
ALIAS II	Addressing liability issues of automated systems
MOTA	Exploring a gradual transition towards modern taxiing
TREE	Data-driven modelling of network-wide extension of the tree of reactionary delays in ECAC area
ACCESS	Application of agent-based computational economics to strategic slot allocation
ACCHANGE	Accelerating change by regional forerunners (how to best implement innovation via selected market leaders)
SATURN	Strategic allocation of traffic using redistribution in the network (by means of route charging strategies)
ComplexityCosts	The true costs of complexity (investigated via different investment mechanisms)
ACF	Airport capacity forecast (to allow better airport planning for all stakeholders)
IMET	Optimal approach for future trajectory prediction systems to use meteorological uncertainty information

- SESAR WP-E

Long-term & innovative research

- Stockholm, 26-28NOV13

KTH Royal Institute of Technology

http://www.sesarinnovationdays.eu

(free of charge)

- Questions / contact

airspace-research@westminster.ac.uk

Thank you

Stand-bys

2010 c.f. 2012 – key statistics

Metric	2010	2012
IFR flights (million)	9.5	9.6
Total pax (million, EU27)	777	734
Average dep. delay (mins)	14.8	9.5
Arrival delays > 15 mins	24.2%	16.7%
Reactionary delays	46.7%	45.5%

Simulation & scenarios

Designator	Rule 13 Wait for boarding	Rule 26 Airborne arrival management	Rule 33 Passenger reaccommodation
N_1		●	
N_2		●	
A_1	●		
A_2	= A_1	●	
P_1			●
P_2			●

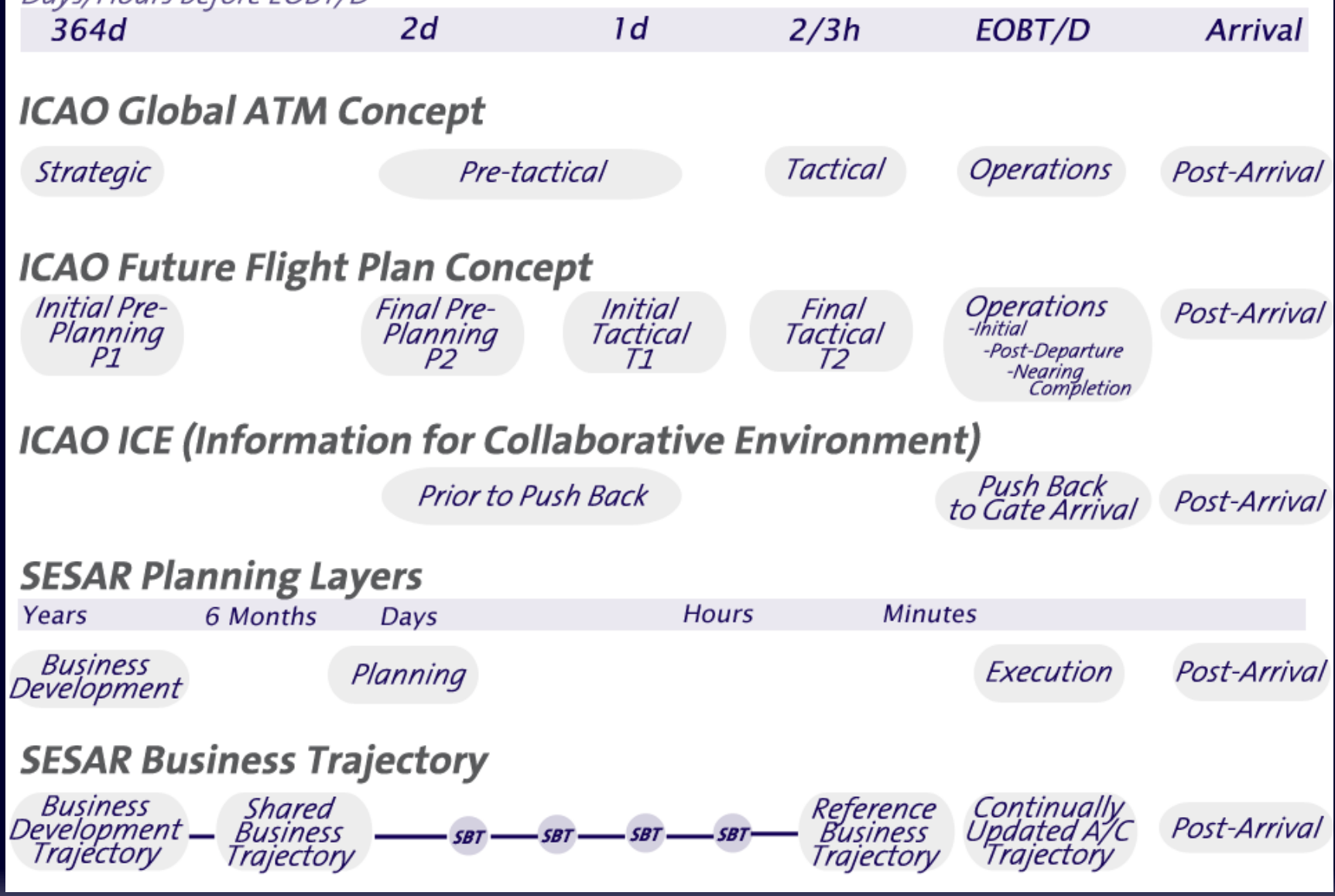
Hierarchy of interlining

Carrier type	Ticket type	Rebooking onto next available flight according to departure delay of:		
		up to 2 hours	2 – 5 hours	> 5 hours
full-service	flexible (first/bus.)	any carrier	any carrier	any carrier
full-service	business inflexible	booked/alliance only	any carrier	any carrier
full-service	all other tickets	booked/alliance only	booked/alliance only	any carrier
all other	all tickets	booked carrier only	booked carrier only	booked carrier only

- Rule 33 (sub-rules)
  - most airlines will try to rebook onto their own flights first
  - if LH wants to rebook onto LH1234, no other AO may claim seat
  - on reaccommodation, fare of remaining legs transferred to new carrier (if applies), according to IATA rules

Flight Plan Phases

Source: Innaxis

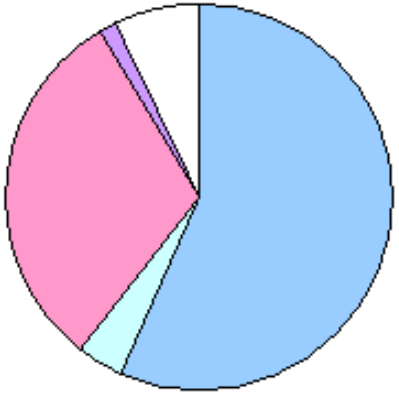


Introducing the business trajectory

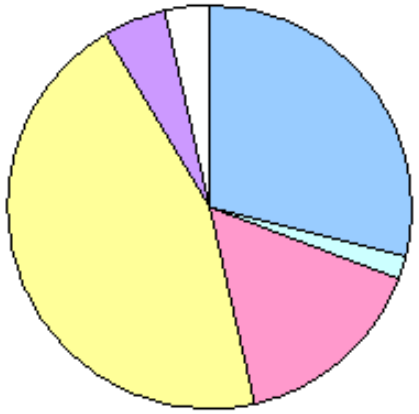
- The ‘Business (4D) Trajectory’
- Negotiated ‘contract’ with time constraints (hence 4D)
- Shared Business Trajectory (SBT)
  - Firstly, a trajectory is negotiated which represents the business intentions of the airline and takes account of Air Navigation Service Provider, ATFM and airport constraints
- Reference Business Trajectory (RBT)
  - Negotiation complete: trajectory which airline agrees to fly and ANSP + airport agree to provide; c.f. current practice, from both providers and users, of pre-tactical and tactical changes: new concept designed to minimise changes to trajectories & achieve ‘best business outcome’ for all users
- A key business outcome is reduction of delay

Current & future principles

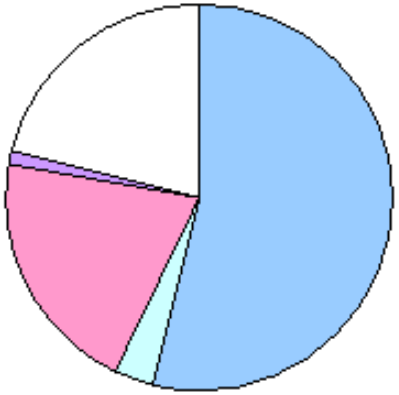
Aspect	Current	Future
prioritisation principle	first planned, first served	tbd
slot calculation	ETFMS (multiple, independent constraints)	ETFMS + CDM (collaborative & dynamic …)
control process	CTOT (focus on departure)	CTOT + CTA + CTOs
route choice	RAD	Free
optimisation?	no - preserves planned sequence	capacity, environment, cost (single flight c.f. network)
result	equity	“best business outcome”



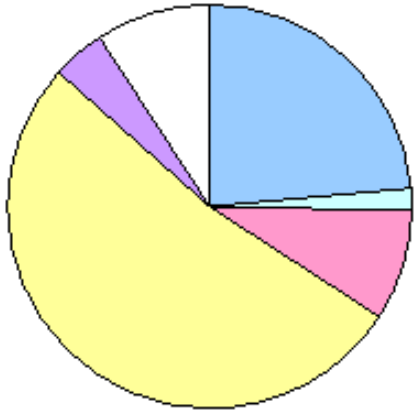
B738 at-gate (EUR 440)



B738 en-route (EUR 860)



B744 at-gate (EUR 1 230)



B744 en-route (EUR 2 800)

Tactical cost distributions for 15 mins (base scenarios)

Pax hard	Pax soft	Crew	Fuel	Maintenance	Reactionary

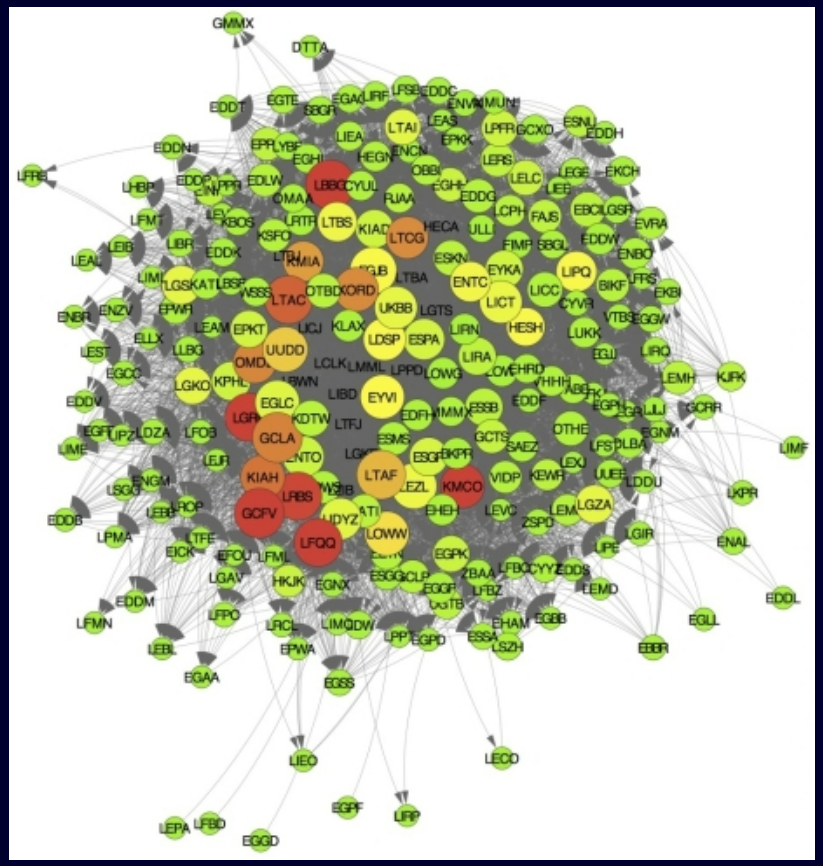
ConOps Step	Operations	Document release	Deployment phase	UDPP implementation status	Other example implementations
1	Time -based	2012	2014 - 2025	UDPP initial steps - airport slot swapping and consistency of airport slots with flight plans. (Enhanced ATFCM and DCB processes are part of the Deployment Baseline.)	Network Operations Planning; CTAs; initial SWIM; airport surface management integrated with AMAN and DMAN; some free routes
2	Trajectory -based	2013	~ 2025++	Network Operations Planning based around 4D trajectories driven through collaborative process where users define their priorities; full integration of AMAN, DMAN and surface management linked to UDPP and (dynamic) DCB	Full 4D trajectories; multiple CTOs /CTAs (including on non-published waypoints)
3	Performance -based	2016*	~ 2025++	Full SWIM and collaboratively planned network operations with UDPP	Two airspace categories (civil and military); specific separation tasks delegated to flight deck; free routes implemented from TMA exit to entry; Dynamic Mobile Areas

* Provisional

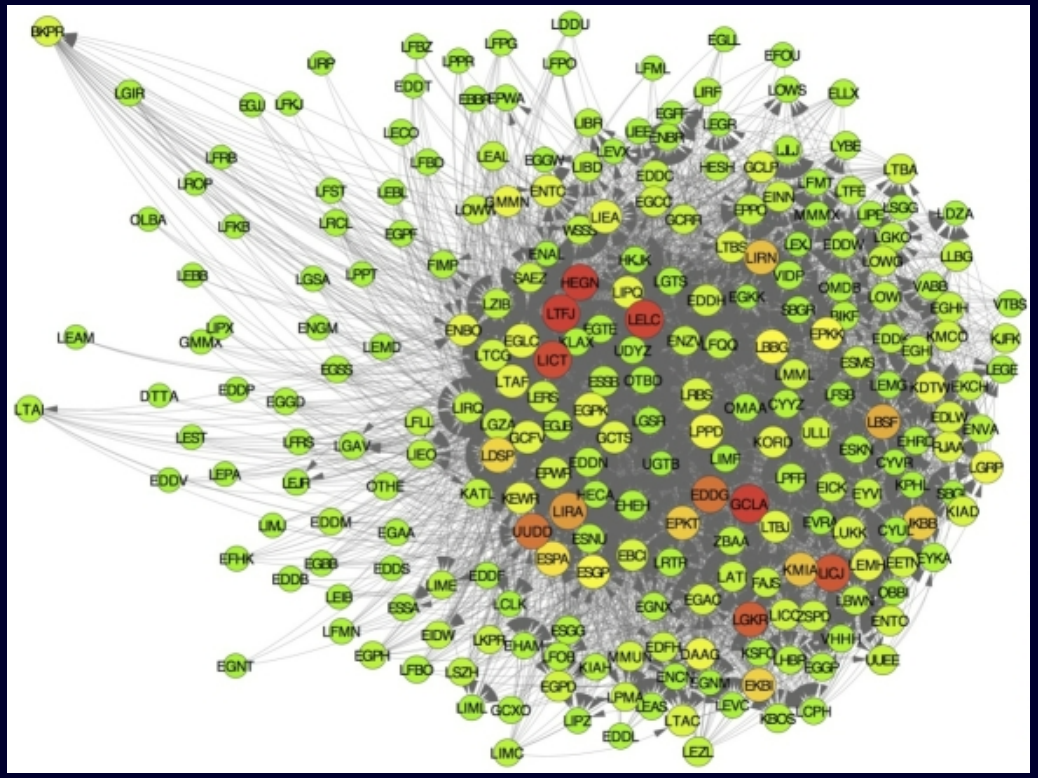
Main source: European ATM Master Plan (Ed. 2), October 2012.

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 delay causality network for S_0



Flight delay causality network for A_1



Highly heterogeneous between <u>all</u> the layers