

New perspectives for air transport performance

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Overview

- Background and objectives
- Flight prioritisation
- POEM – a new simulation tool
 - passengers and costs
 - key model features
- Scenarios and selected results
- Where next?

Background and objectives

Background and objectives

- 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 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

- 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, AO iterations; else Network Arbitration function

POEM – a new simulation tool

- passengers and costs

Passengers and costs

- 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
 - 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 $\neq$ pax delay (US factors of 1.6 – 1.7)
- How can we measure specific progress without metrics?

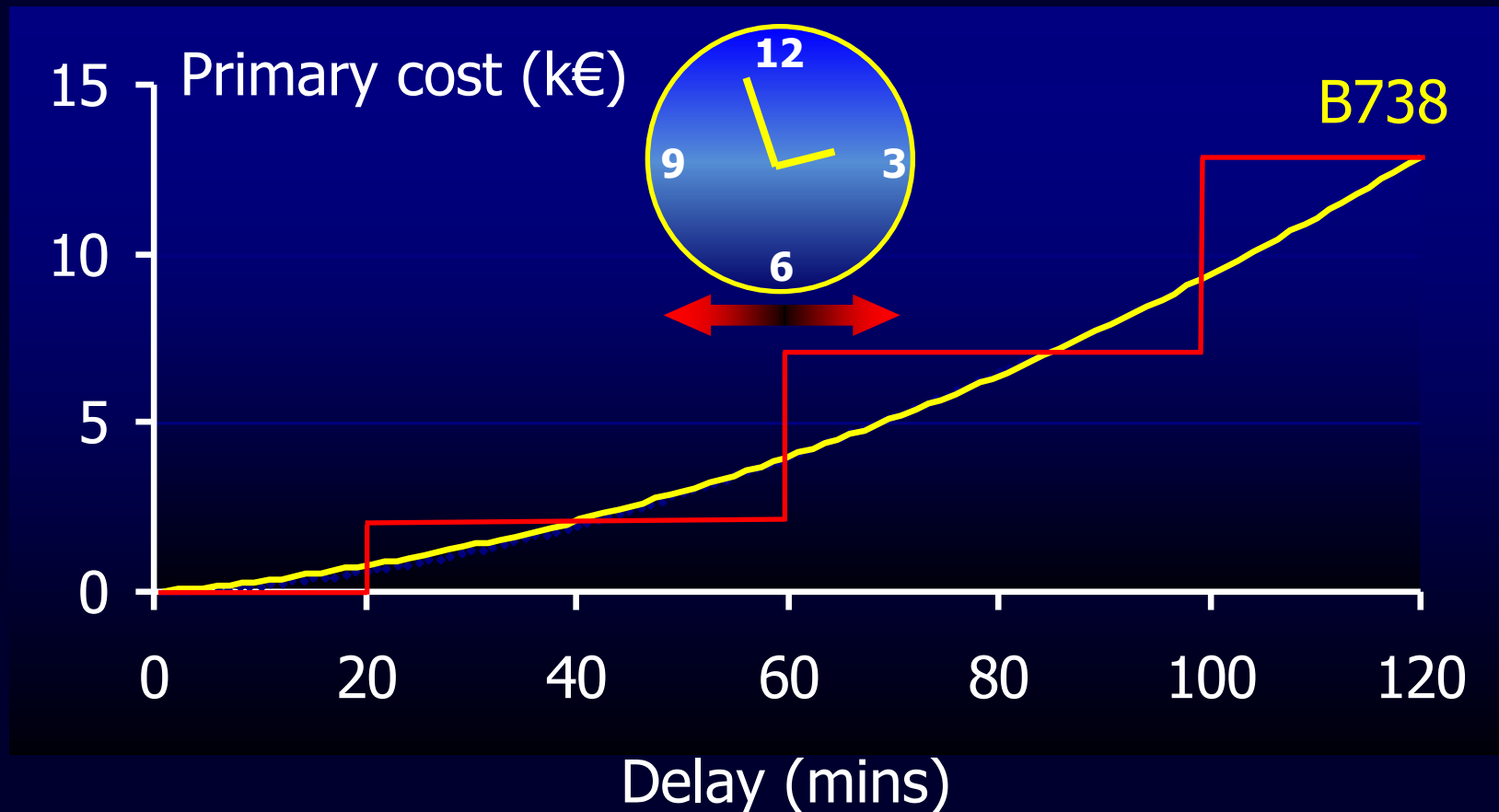
Passengers and costs

types of cost (in-house models, except fuel)

<i>fleet</i>	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)

well-established non-linearity ...

Passengers and costs



POEM – a new simulation tool

- key model features

Key model features

- Evaluates different flight and pax prioritisation strategies
- Includes tactical costs to the airline (4 AO types)
- Key data-related characteristics
 - 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 (ind. sources, e.g. network delays 13.9 ± 0.1) and LFs)
- Unique combination of PaxIS and PRISME data ...

Key model features

Dom_AI	Mar_AI1	Mar_AI2	Mar_AI3	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									

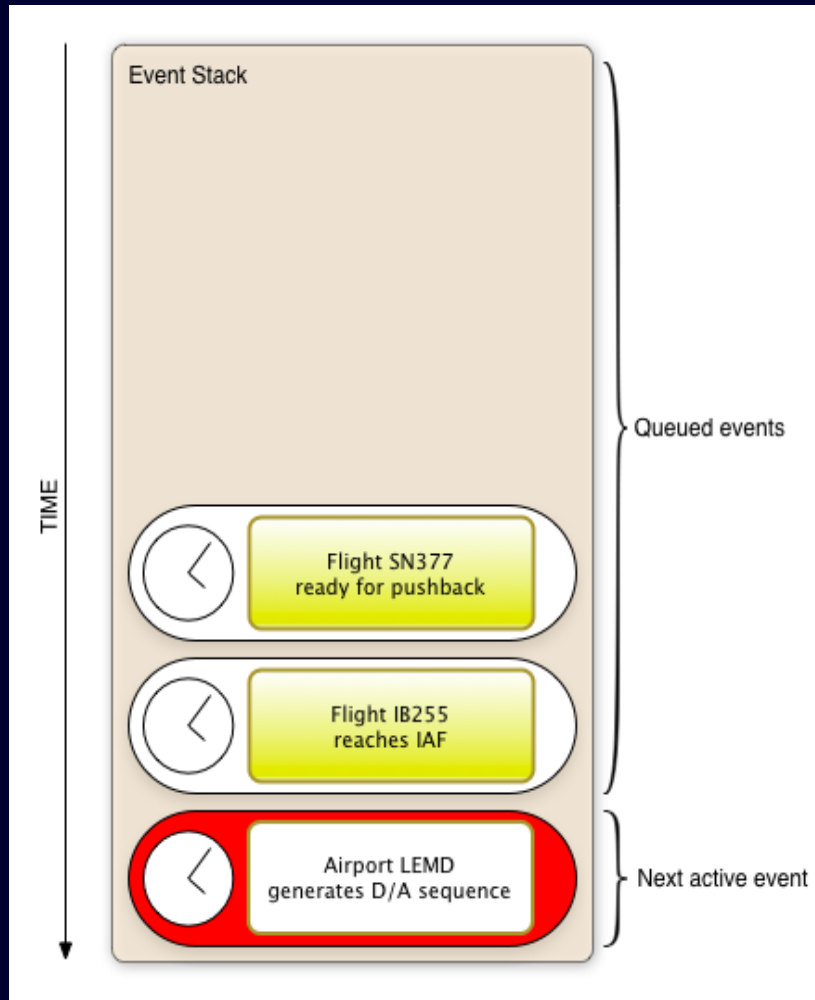
Aircraft_Operator	Aircraft_Type_ICAO_ID	Corr_Registration	Seats	ADEP	ADES	AOBT_3	ARVT_3	FltNum
KLM	B738	PHBXF	171	EHAM	LIRF	17/09/2010 05:03	17/09/2010 07:04	KLM_EHAMLIRF01
KLM	B738	PHBGB	171	EHAM	LIRF	17/09/2010 07:55	17/09/2010 09:50	KLM_EHAMLIRF02
AZA	A320	EIDSC	159	EHAM	LIRF	17/09/2010 11:29	17/09/2010 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

Key model features

- 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

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: 0, 5, 10, ...)
- single-processor: 25-50 minutes to run one day
- cloud-computing platform: approximately 2 minutes
- stable after appx. 10 runs

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

(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 <i>and</i> arrival sequences based on delay costs – A ₁ is implemented <i>and</i> 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

N_1 & N_2 P_1 P_2 A_1
scenarios

flight-
centric

new
metrics

?

?

?

?

?

?

?

?

flight-
centric

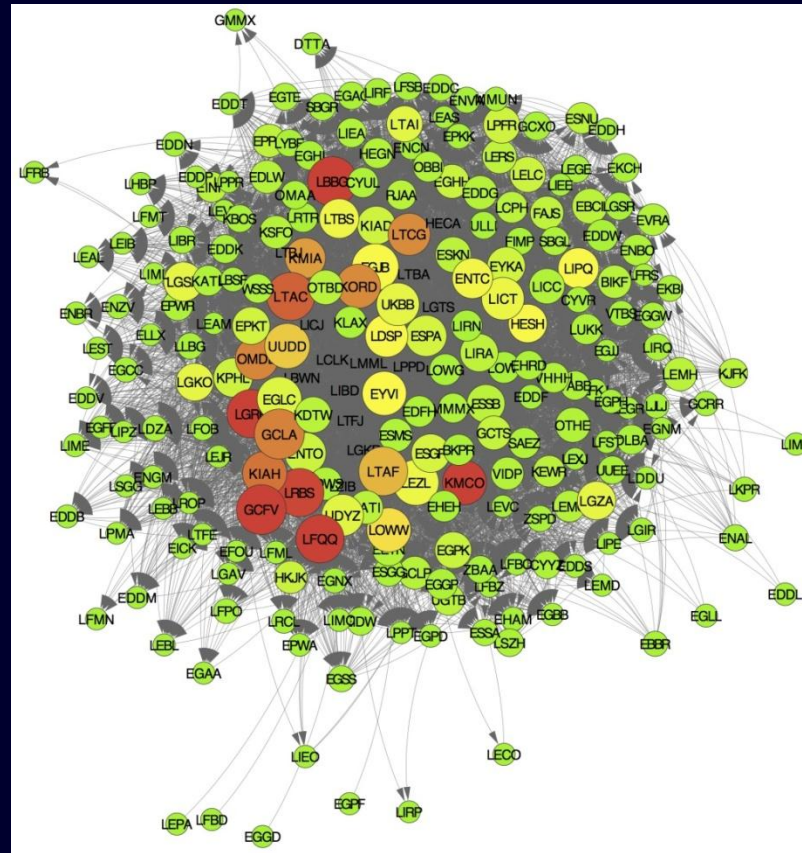
new
metrics

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	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%

Scenarios and selected results

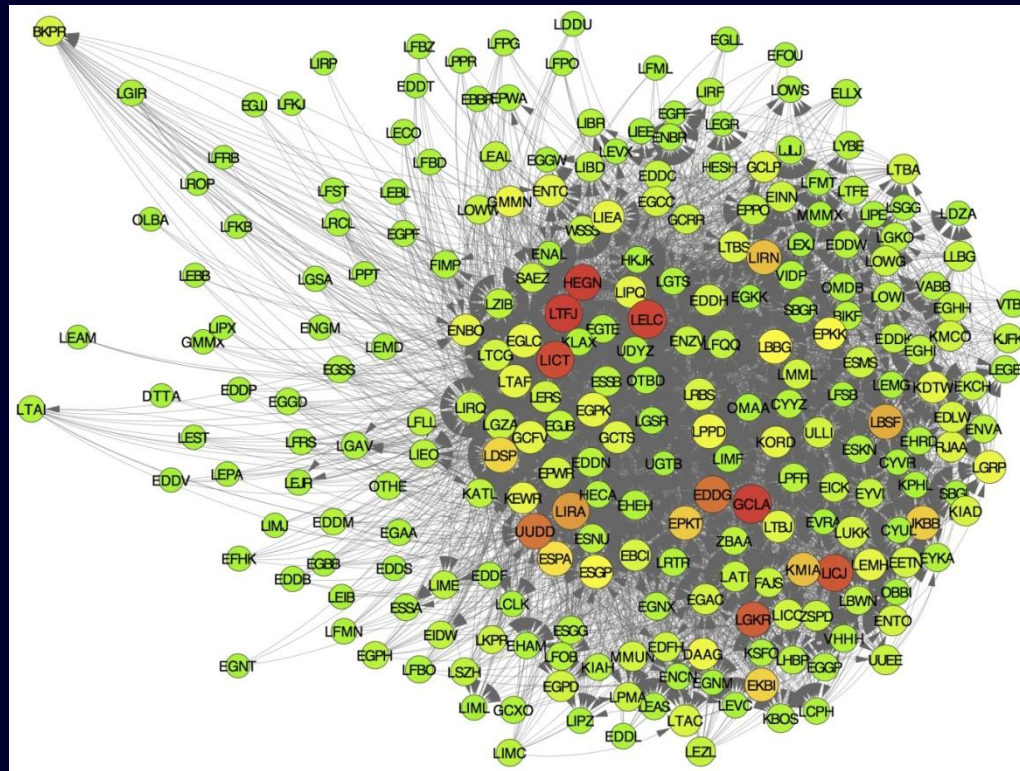
- A_1 and reactionary delay
 - increases from 49% (S_0) to 51% as a proportion of all dep. delay
 - ... but focused on relatively few (waiting) aircraft (purposefully)
 - ... saving in total costs wholly due to reduction in hard costs
 - explicit estimations of reactionary delay: a significant advance
- 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; larger => more nodes 'forced'

Flight delay causality network for A_1

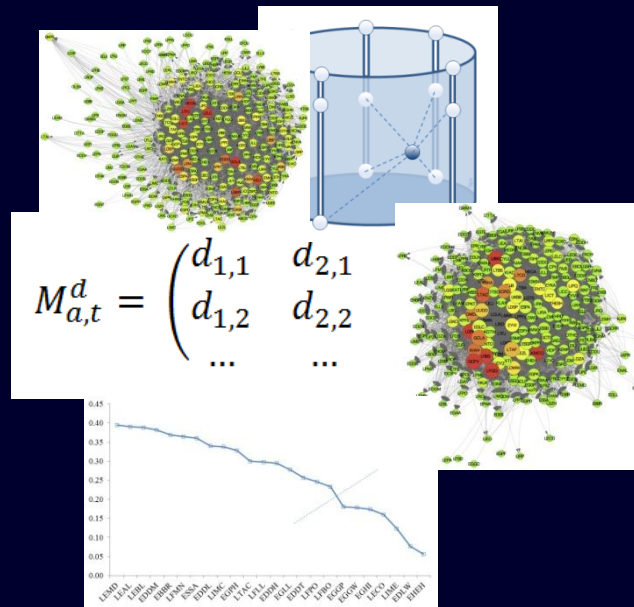


Scenarios and selected results

- Main conclusions of Granger causality analyses
 - comparing eigenvector centrality rankings through Spearman rank correlation coefficients: all four layers almost completely 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
 - delay propagation contained within smaller airport communities
 - ... but these communities more susceptible to such propagation
 - largest persistent airports: Athens, Barcelona & Istanbul Atatürk
 - similar findings earlier vulnerability analysis & by Fleurquin *et al.* (2013)

trade
-off

Scenarios and selected results



Where next?

Where next?

- Model enhancements
 - en-route: more sophisticated delay recovery rules (4DT; DCI)
 - higher fidelity ATFM modelling
 - cost recoveries (e.g. crew hours; cancelled flights)
- Schedule robustness
 - +1 minute of delay (avg: 14.9); +1% cancellations (morning); ...
 - greater disruption: more localised or more severe & widespread
- Adaptive features, ability to investigate:
 - other metrics (e.g. RP2(/3) delay targets) & rules (e.g. UDPP)
 - future traffic levels, aircraft sizes, LFs, frequencies & wave structures
 - new AO policies / EU regulation impacts (re. pax and emissions)
 - performance of particular airlines or routes (c.f. network)
- Integration with other tools (tactical and strategic)

Thank you