The challenge of ATM performance measurement

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The challenge of ATM performance measurement

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Overview

- Comparing three regions
- New metrics & sampling insights
- Multiple targets
- Challenges & opportunities

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Submitted paper.
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Comparing three regions

Comparing three regions

	Europe	US	China
Airline liberalisation	▪ within EU: main change - deregulation int. routes, 1993 ▪ beyond EU: series bilaterals and 'open sky' agreements	▪ major industry liberalisation first started in US, 1978 ▪ major EU-US multilateral agreement, 2008	▪ official separation military jurisdiction, 1980 ▪ merged into three large airline groups, 2002 ▪ regionals emerged essentially as supplementary
Major operators, alliances, ownership	Lufthansa Group (Star Alliance) Ryanair (LCC; no global alliance) IAG (**one**world) Air France-KLM (SkyTeam) wholly/majority private holdings	American Airlines (**one**world) Delta (SkyTeam) Southwest (LCC; no global alliance) United Airlines (Star Alliance) public companies	Air China (Star Alliance)* China Eastern (SkyTeam)* China Southern (SkyTeam)* Hainan Airlines (no global alliance)† * majority state shareholdings † largest privately-owned airline
Airport strategic schedule control	yes	no	yes

Comparing three regions

	Europe	US	China
ATFM service provision	41 states (EUROCONTROL) 63 en-route centres	Federal Aviation Administration 20 air route traffic ctrl centres	Air Traffic Management Bureau (CAAC) 7 ATFM regions
Primary management	at-gate	airborne	airborne
MIT	very limited	yes (->TBM)	yes
Special use airspace	core	coast	core
ATFM / AO/ airport CDM	yes	yes	yes

Comparing three regions

- Common
  - mergers into airline groups; global alliance affiliations
- Europe and US
  - established free-markets
  - growth in LCCs; demarcation breaking down in Europe
- China
  - from fully planned, to more market economy
  - competition, e.g. between three largest groups; few LCCs
- ATFM, mainly similarities; key characterising features:
  - Europe: fragmentation
  - US: large weather systems (airport flows)
  - China: special use airspace

Comparing three regions

Data level by region	Europe	US	China
Focus on arrival or departure delay	departure	arrival	arrival
Delay threshold	≥ 5 mins	≥ 15 mins	> 5 mins
Main delay causes reported	airline weather ATFM, weather ATFM, airports ATFM, en-route reactionary	airline weather ATFM reactionary security	airline weather ATFM military

Comparing three regions

(2014)

	Europe	US	China
Total airports			
Total* pax (m)			
Total* flights (m)			
Delayed ≥ 5 mins			
Delayed ≥ 15 mins			
Avg. delay (mins)			
Reactionary delay			
ATFM delay			
Cancelled			

Sorry, table not publicly available just yet

* International and domestic

New metrics & sampling insights

Do the top 30 airports give us 80% of the metric?
What does the shape of the curve look like there?

New metrics & sampling insights

- Primary ATM data sources (don't always agree)
  - pure trajectory (radar track) data
  - network manager (e.g. ATFM) delay data, with causes
  - airline data (e.g. delay & cancellation) (various channels)
- Need to assess in appropriate context
  - exogenous (weather, airport/sector capacities, strikes, military)
  - robustness (schedule, flight scope, range checks, last-filed FPL)
  - reporting protocols (e.g. reactionary ('knock-on') delay)
- Sampling frameworks (Europe c.f. US), carriers:
  - in US required report performance data if ≥ 1% total domestic scheduled service passenger revenues (+ some report voluntarily)
  - in EU operating > 35 000 flights per year within EU airspace
  - in 2014: US = 16, EU = 100; both IFR ≈ 70%

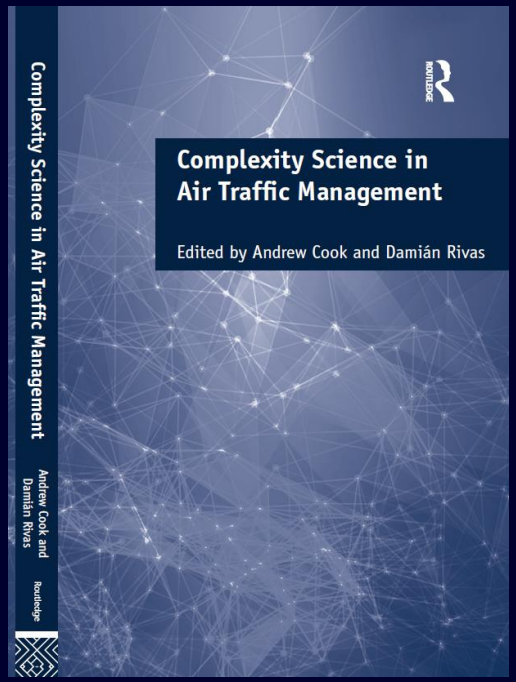
New metrics & sampling insights

Data level by region	Europe	US	China
Lower delineation (no aircraft types or delay data)	OpenFlights*		
No. of airports	497	595	185
No. of airlines	153	81	17
Higher delineation (with aircraft types and delay data)	ALL-FT+†	RITA¶	N/A
No. of airports	1854	286	–
No. of airlines	100	16	–

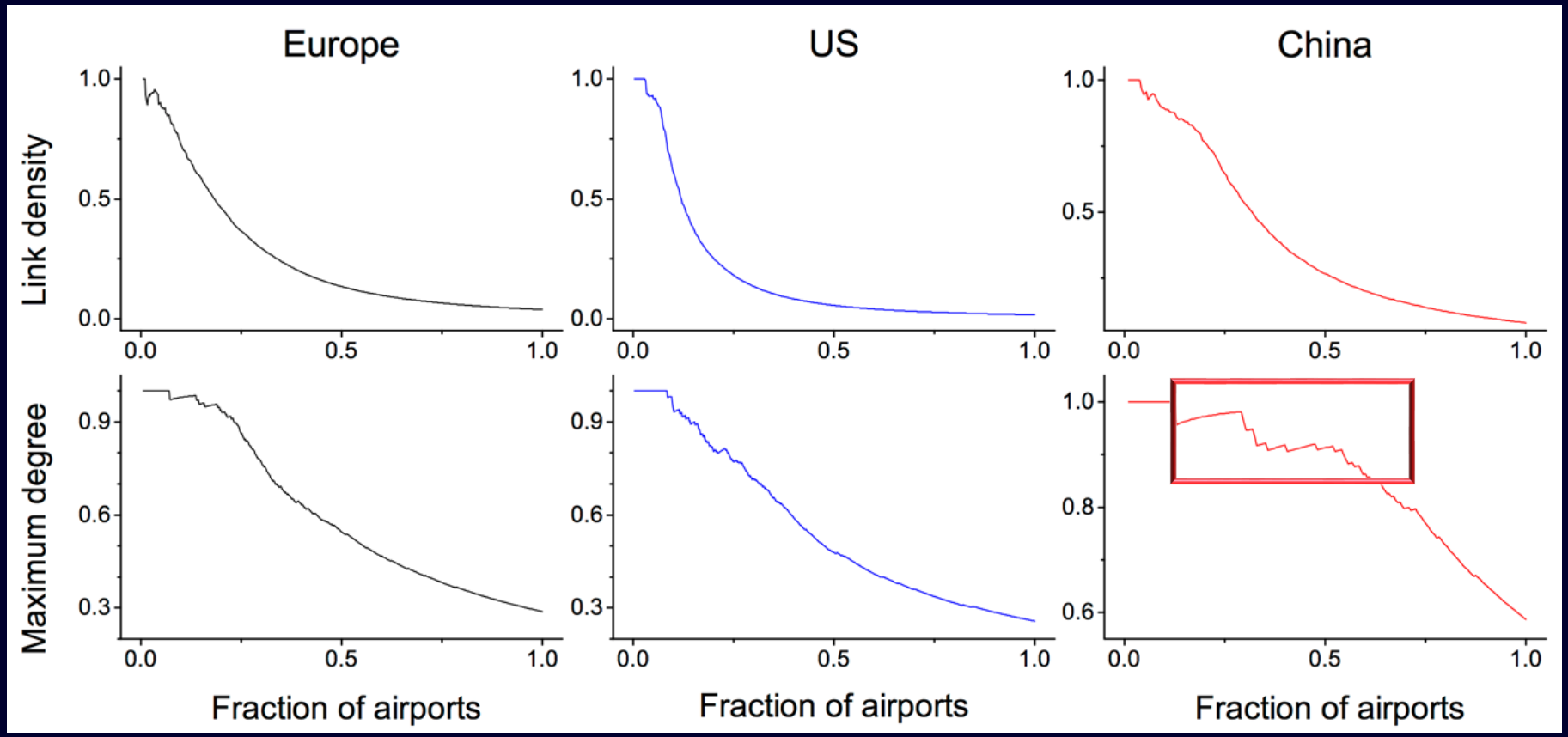
* Open source repository, flights and airport data, worldwide coverage. Flights for June 2015.
† EUROCONTROL; all intra-European IFR flights, March through December, 2011.
¶ OTP data, Research and Innovative Technology Administration (RITA), US DoT. Intra-US flights, March through December, 2011.

New metrics & sampling insights

- Complexity science: networks (CNT)
  - multiple components; uncertainty
  - non-linear dynamics: emergent behaviour
  - non-analytical models, e.g. ABM
  - metrics & methods (community detection)
- ComplexWorld network
  - SESAR ER (NEXTOR)
- Some simple metrics
  - link density: active links in the network / all possible links
  - maximum degree: degree of the most connected node
  - assortativity (degree correlation): correlation coefficient between the degrees of pairs of nodes connected by a link
  - -1 => all nodes connected to nodes of different degree

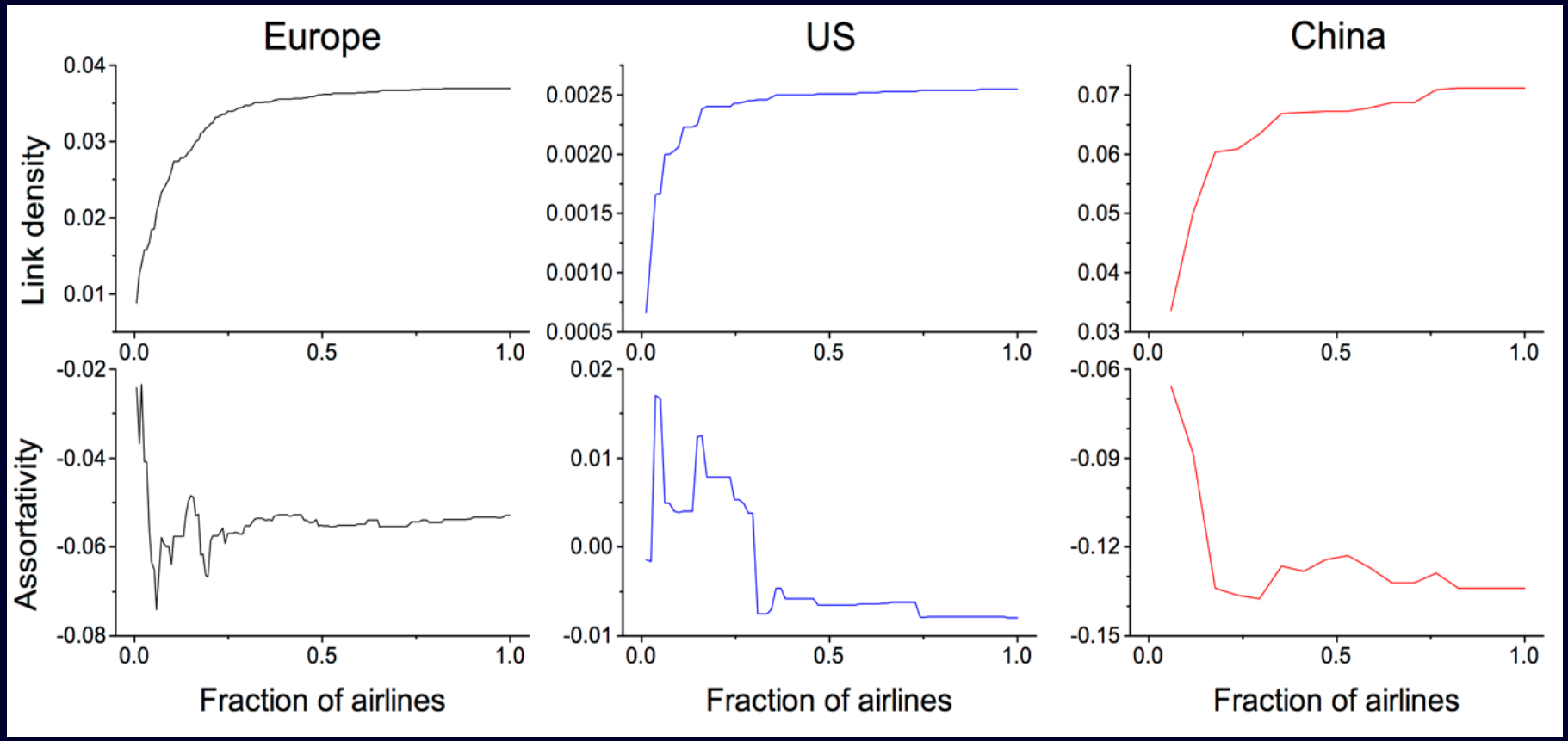


New metrics & sampling insights



(OpenFlights data)

New metrics & sampling insights



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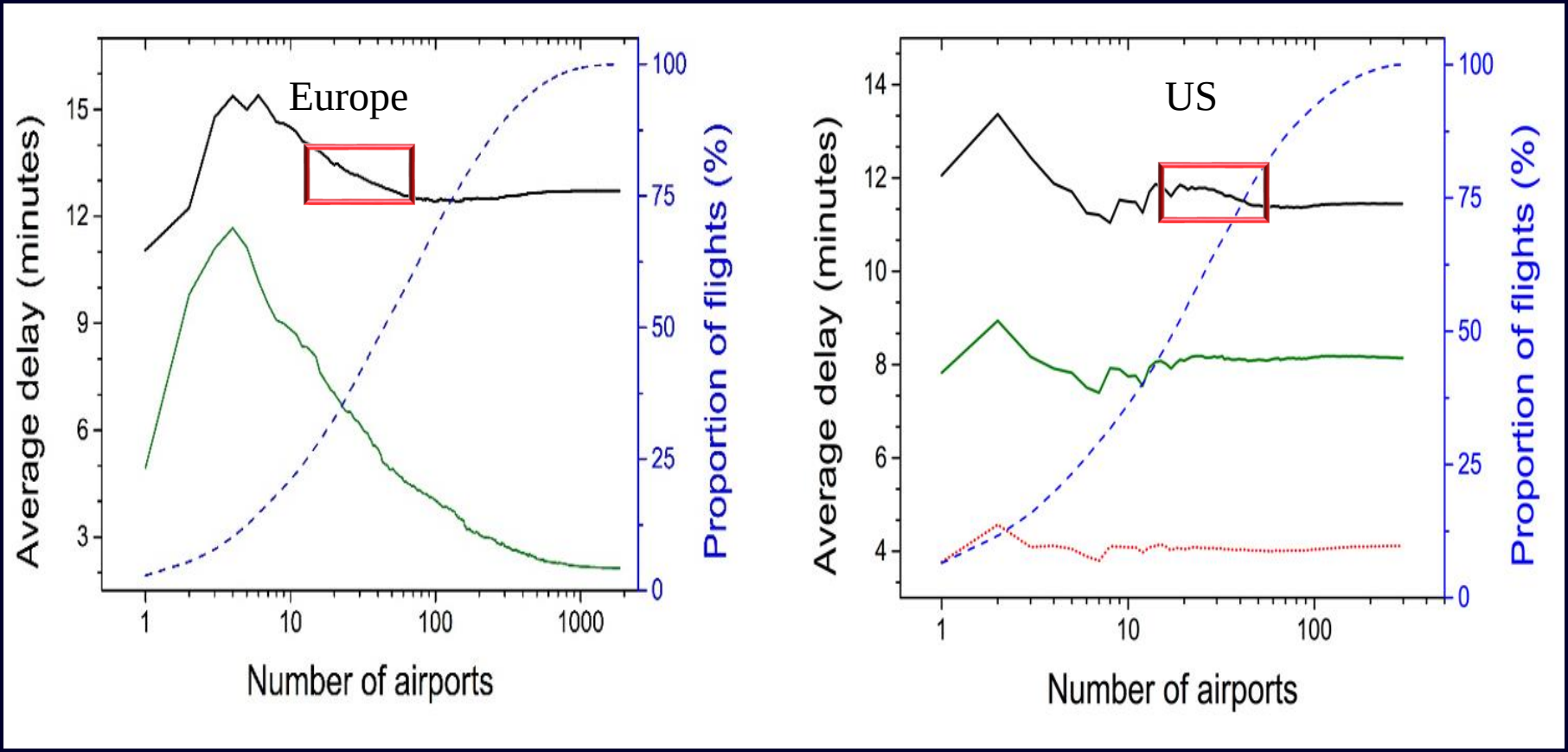
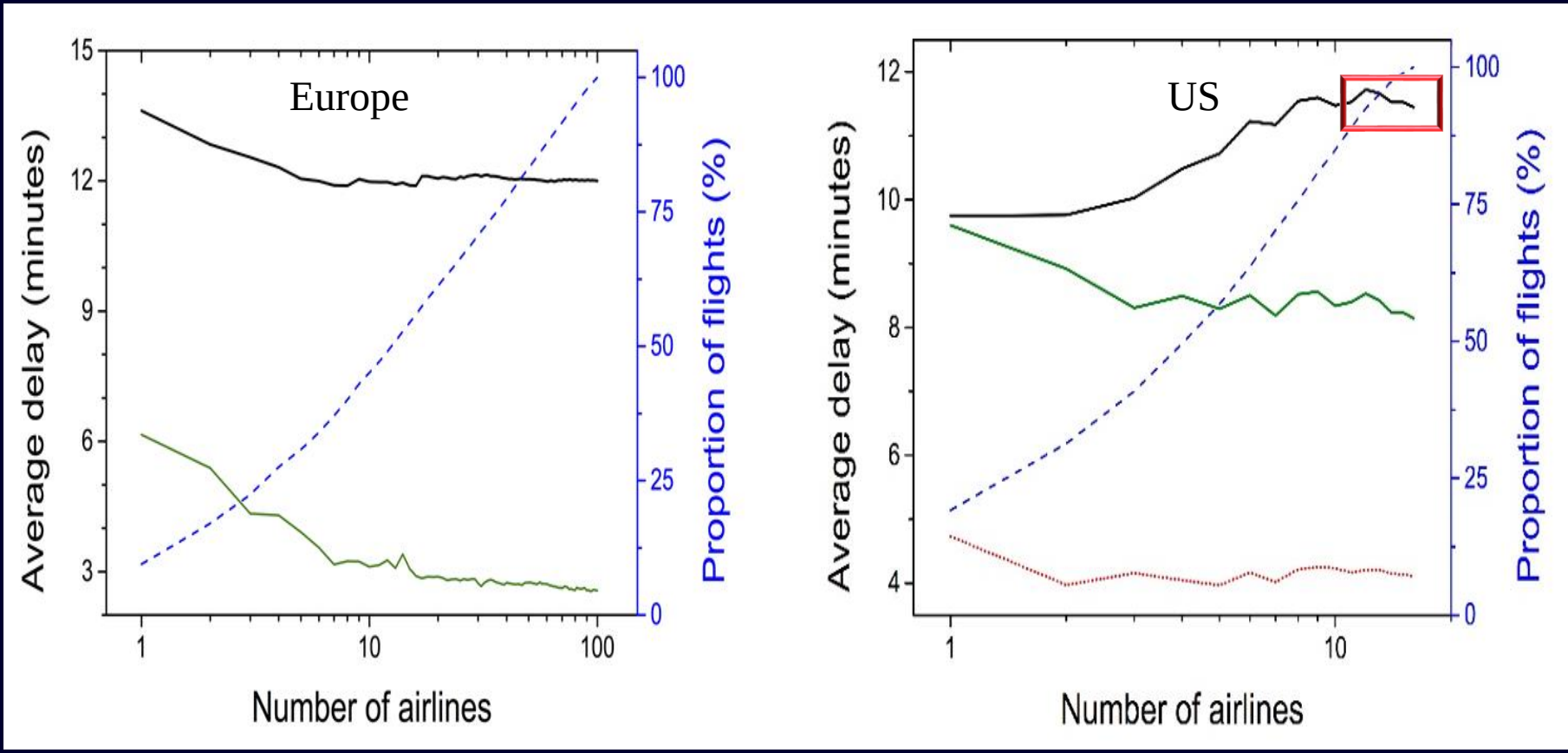
New metrics & sampling insights



(ALL-FT+ & RITA data)

New metrics & sampling insights



(ALL-FT+ & RITA data)

New metrics & sampling insights

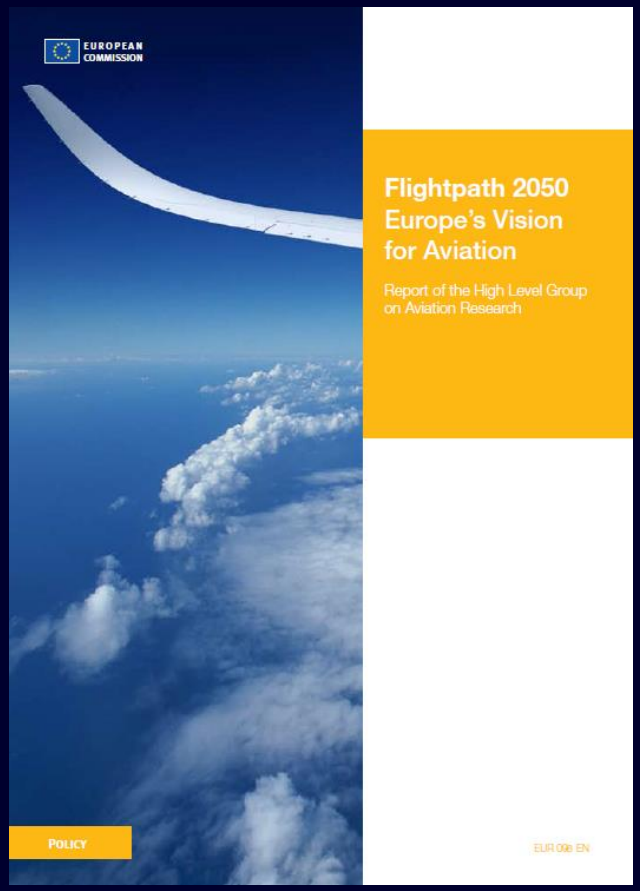
- Literature demonstrates many sampling constraints
  - purposive, e.g. most connected airports / region of airspace
  - limited to data from (a) given airline(s) (or alliance)
  - data quality/availability for smaller airports / smaller airlines/LCCs
  - data purchase cost
  - computational cost (including data cleaning; 14%)
- Larger airports and airlines are often over-represented
- Non-saturation => often no obvious sampling threshold by which nodes may be safely discarded
- Top 34 airports (Europe & US) => ≈2% error
  - caution thus advised regarding changes of this order

Multiple targets

	Europe	US	China
Programme	SESAR	NextGen	ATMB Strategic Development Programme
Target year	2035	2025*	2030
Baseline year (for relative changes)	2005	2009	2015
(ICAO) KPAs (11)			
Safety	Improve safety 10-fold	Comm. carrier fatalities ≤ 6.2 per 100 million pax	Reduce ATC-attributable accident rate by 20% by flight volume
Capacity	Increase capacity 3-fold	12% increase, core airports	Increase capacity 3-fold
Efficiency	Reduce avg dly by 1-3 min† En-route ATFM avg dly 0.5 mins¶	Reduce delays by 27%	Average ATC-attributable delay < 5 mins
Environment	10% reduction in impact of flights on environment	Reduce fuel burned per km by ≥ 2% annually	Reduce CO_2 by 10% (kg/km)

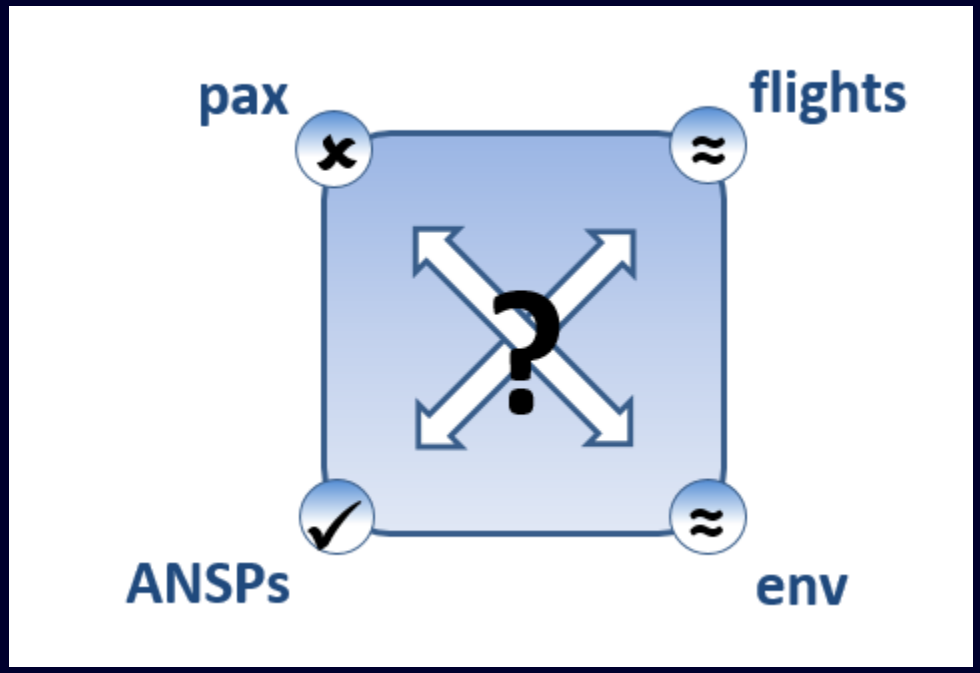
* Selected targets shown relate to intermediate target year 2018. Delay reduction allocated to efficiency KPA for ease of comparison.
† Declared within SES Performance Scheme within capacity KPA; target relative to 2012.
¶ Corresponding target set within SES Performance Scheme for 2015-2019.

Multiple targets



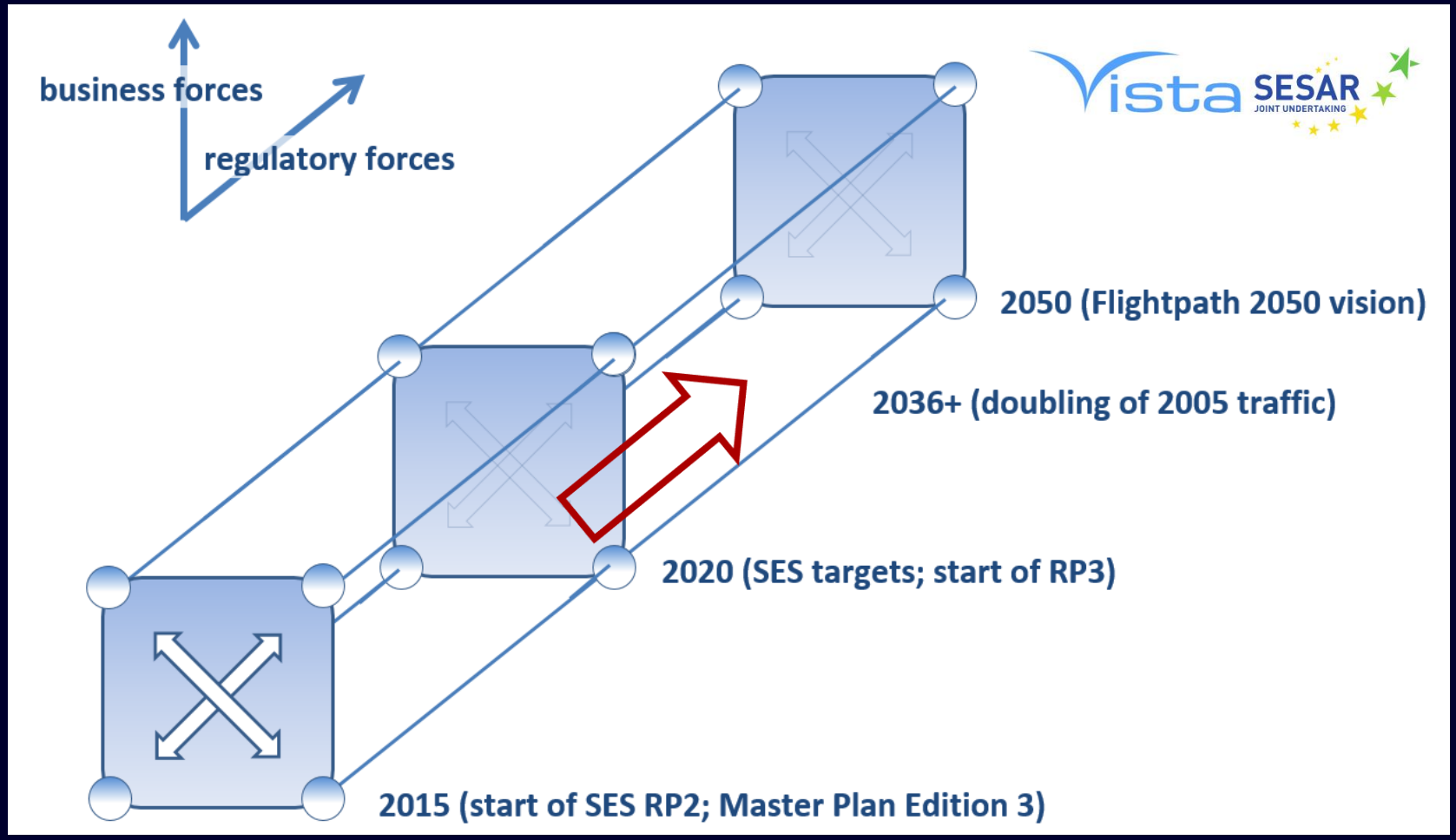
- Passenger context: ultimate customer
  - Advisory Council for Aeronautics Research in Europe; and White Paper (both 2011)
  - "highly ambitious goals" (x5)
  - "90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours."
  - 'Destination 2025' (FAA, 2011) – qualitative
- Pax delay > flight delay
  - often dominates delay costs & behaviour
  - 1.6 – 1.7 (US); 1.3 – 1.9 (Europe)
  - flight-centric assessment only (x3)
  - how measure progress?

Multiple targets



KPIs established for 2015
(all in Single European Sky Performance Scheme, RP2)

Multiple targets



Challenges & opportunities

Challenges & opportunities

- Metrics – methods
  - more focus: costs (cancellation), propagation, predictability
  - often cannot see differences in flight-centric metrics only
  - US analyses more advanced; several pax-centric metrics proposed
  - complementarity: complexity & classical – metrics & methods
- Metrics – trade-offs
  - 'basic' (e.g. flexibility and predictability)
  - monetised v. non-monetised (resilience)
  - regulatory v. market forces
  - KPAs, stakeholders: horizontal & vertical
  - local v. network (resilience engineering: polycentric governance best)
  - capture of non-linearity effects in models

Challenges & opportunities

- Data
  - how much of a network is 'enough'?
  - more work ahead on sampling protocols; clearly need smaller airports
  - focus on particular airlines or routes is fine, but not a network proxy
  - accessibility: still a challenge in Europe
  - performance assessment advances: mandate- and data-driven
  - big data: diversity / open architectures, integrity – dynamic metrics?
- Standardisation and collaboration
  - EU-US harmonised KPI reporting, in coordination with ICAO
  - collaborations between China and US, China and EUROCONTROL
  - ATFM delay established as a proven leading indicator
- Performance assessment harmonisation across regions
  - account for different operational /market / regulatory contexts
  - balance between standardisation and adaptability
  - mutual international learning and research

Thank you

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