The door to door perspective

Delgado, L. and Belkoura, S.

A paper presented at the 8th International Conference on Research in Air Transport (ICRAT), Universitat Politècnica de Catalunya, Castelldefels, Catalonia, Spain, 26 - 29 Jun 2018.

The door to door perspective

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University of Westminster
Innaxis

Overview of presentation

- Introduction
- Metrics for flights vs metrics for passengers
- The door-to-door context
- Passenger profiles
- Modelling

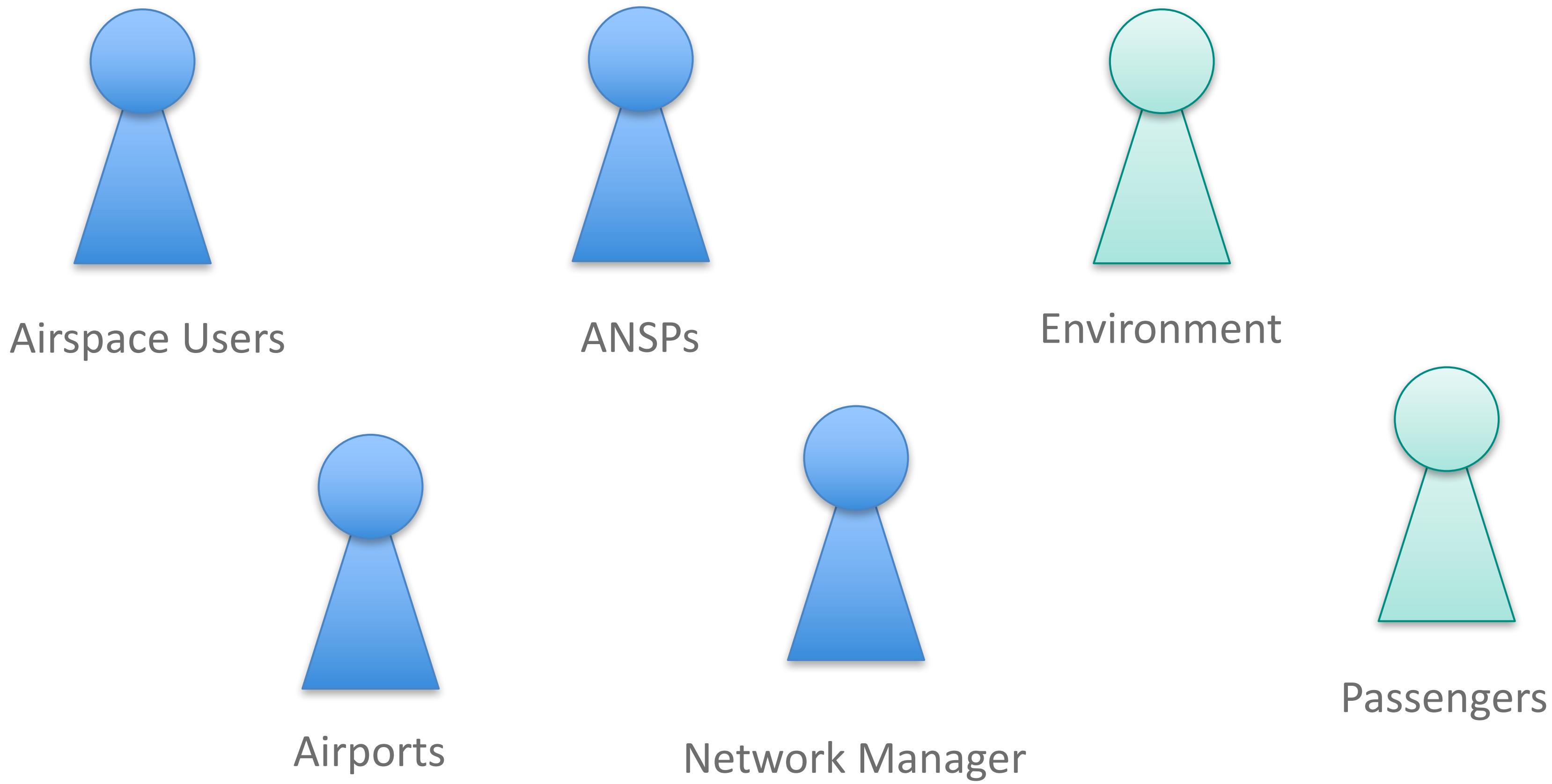
Introduction

Stakeholders

THE ROADMAP FOR DELIVERING HIGH PERFORMING AVIATION FOR EUROPE

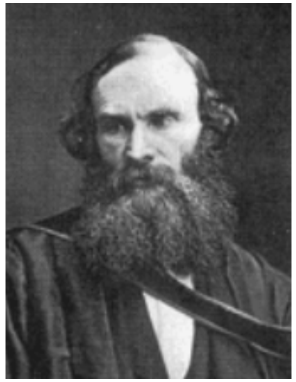
European ATM Master Plan

Executive View — Edition 2015



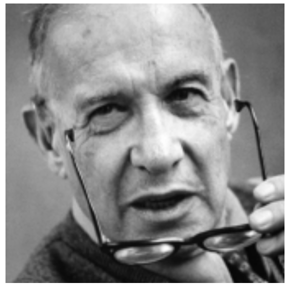
Stakeholders

When you can measure what you are speaking about, and express it in numbers, you know something about it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.



Lord Kelvin
(Sir William Thomson)
1824 – 1907

what gets measured gets managed



Peter Drucker
1909 – 2005

Stakeholders

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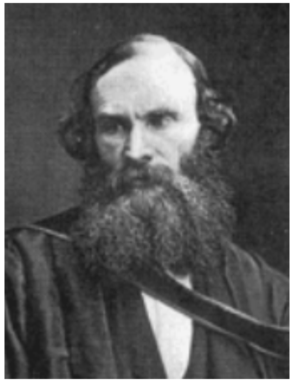
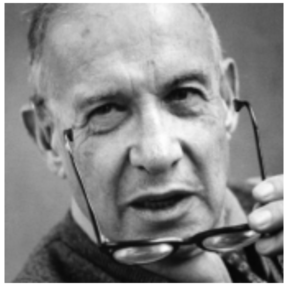


Lord Kelvin
(Sir William Thomson)
1824 – 1907

what gets measured gets managed –
even when it's pointless to measure and manage it, and even if it harms the purpose of the organisation to do so

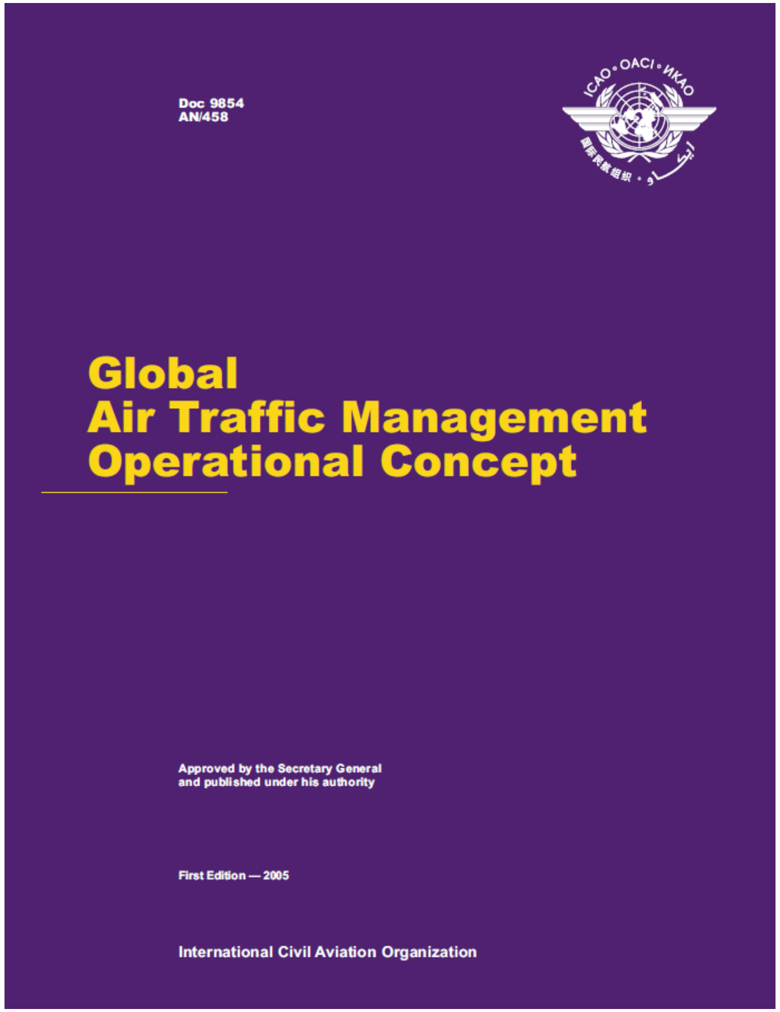


Peter Drucker
1909 – 2005

Single European Sky

- **Key objectives, to:**
  - “restructure European airspace as a function of air traffic flows”
  - “create additional capacity”
  - “increase the overall efficiency of the ATM system”
- **High-level, ambitious goals (“political targets”), aka SES ‘2005 vision’* for 2020:**
  - **x3** increase in capacity (reducing delays)
  - **x10** improvement in safety
  - **10%** reduction of flights’ impact on environment
  - **≥ 50%** reduction in costs of ATM services to airspace users

ICAO Global ATM Operational Concept ('Doc 9854')



ICAO (2005). Global Air Traffic Management Operational Concept (Doc 9854), Ed. 1, International Civil Aviation Organization, Montréal.

(Not updated with second edition.)

A key objective

Presents ICAO vision of an integrated, harmonised and globally interoperable ATM system – agreed levels of safety, optimum economic ops, environmentally sustainable (horizon: up to and beyond 2025)

ICAO Global ATM Operational Concept ('Doc 9854') - KPA

KPA	Name	Meaning
1	Access and equity	
2	Capacity	
3	Cost effectiveness	
4	Efficiency	
5	Environment	
6	Flexibility	
7	Global interoperability	
8	Participation	
9	Predictability	
10	Safety	
11	Security	

ICAO Global ATM Operational Concept ('Doc 9854') - KPA

KPA	Name	Meaning
1	Access and equity	"all airspace users have right of access to the ATM resources needed to meet their specific operational requirements [...] shared use of airspace by different users"
2	Capacity	"meet airspace user demands at peak times and locations while minimizing restrictions on traffic flow [...] resilient to service disruption"
3	Cost effectiveness	"cost of service [...] should always be considered when evaluating any proposal to improve ATM"
4	Efficiency	"airspace users want to depart and arrive at the times they select and fly the trajectory they determine to be optimum"
5	Environment	"contribute to the protection of the environment by considering noise, gaseous emissions and other environmental issues"
6	Flexibility	"ability of all airspace users to modify flight trajectories dynamically and adjust dep. & arr. times"
7	Global interoperability	"uniform principles [...] non-discriminatory global and regional traffic flows"
8	Participation	"ATM community [...] continuous involvement in the planning, implementation and operation"
9	Predictability	"ATM service providers to provide consistent & dependable levels of performance"
10	Safety	"highest priority [...] uniform safety standards [...] applied systematically"
11	Security	"protection against [...] intentional acts (e.g. terrorism) or unintentional acts (e.g. human error, natural disaster) "

Visibility of KPAs

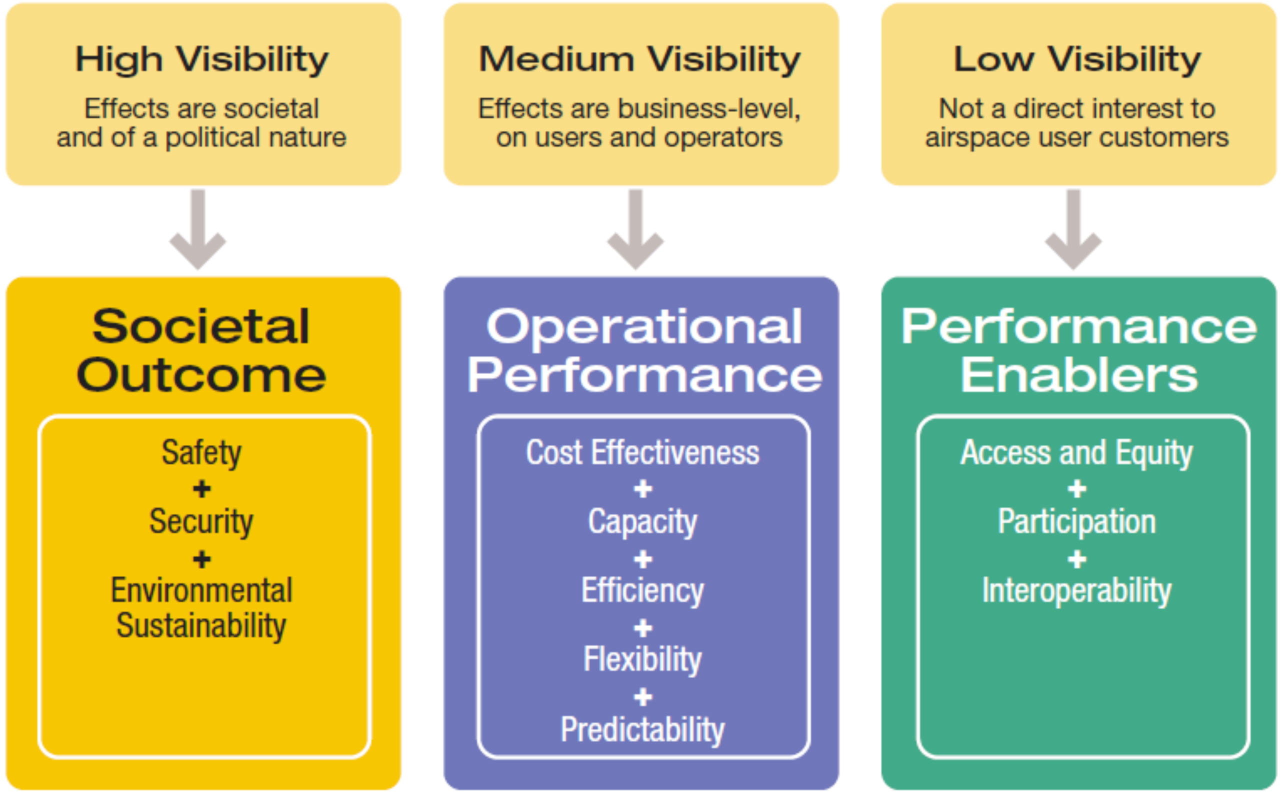
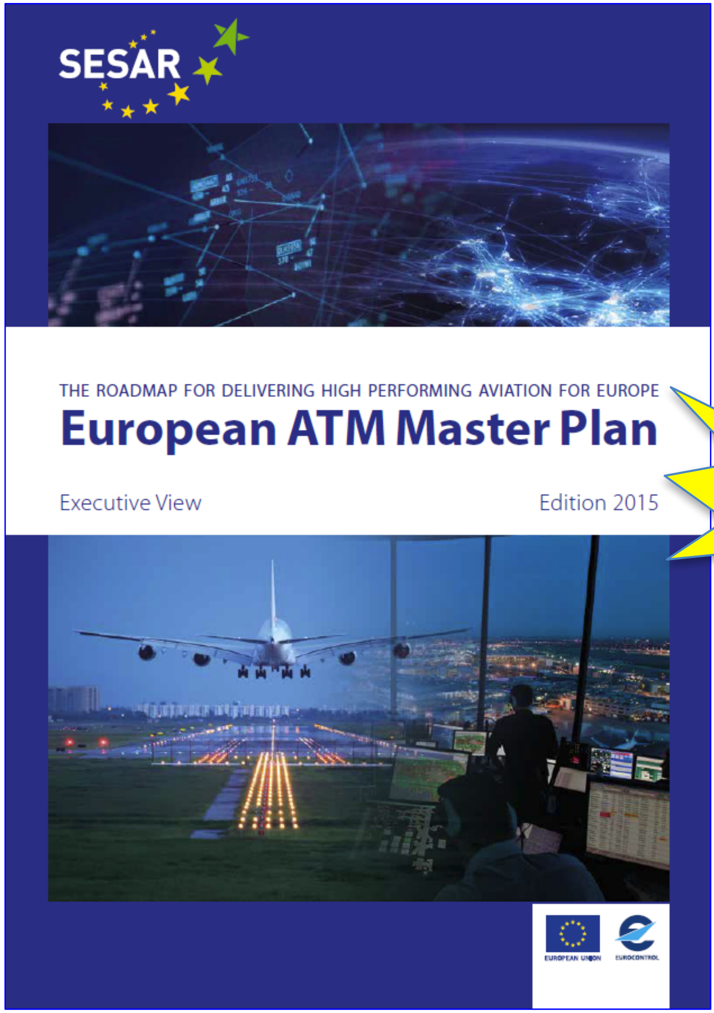


Figure 3-4 Grouping of KPAs

Source: SESAR Performance target ('D2'), 2006.

SESAR European ATM Master Plan



SESAR (2015): European ATM Master Plan, Edition 2015

https://www.atmmasterplan.eu/

Significant step towards alignment with SES Performance Scheme.

Through 'SESAR Solutions'

SESAR European ATM Master Plan

“Operational efficiency” is added to the SESAR Perf. Framework e.g. to be useable by the SES Perf. Scheme under ‘environment’ (as fuel savings)

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

[1] Additional flights that can be accommodated at congested airports, representing 5-10 % of flights at congested airports (~31 % of14,4 (million) flights in 2035).
[2] Additional traffic accommodated in 2035 in comparison with 2012 and associated with ANSP productivity gains, enabled by SESAR. Note: Numbers are rounded.

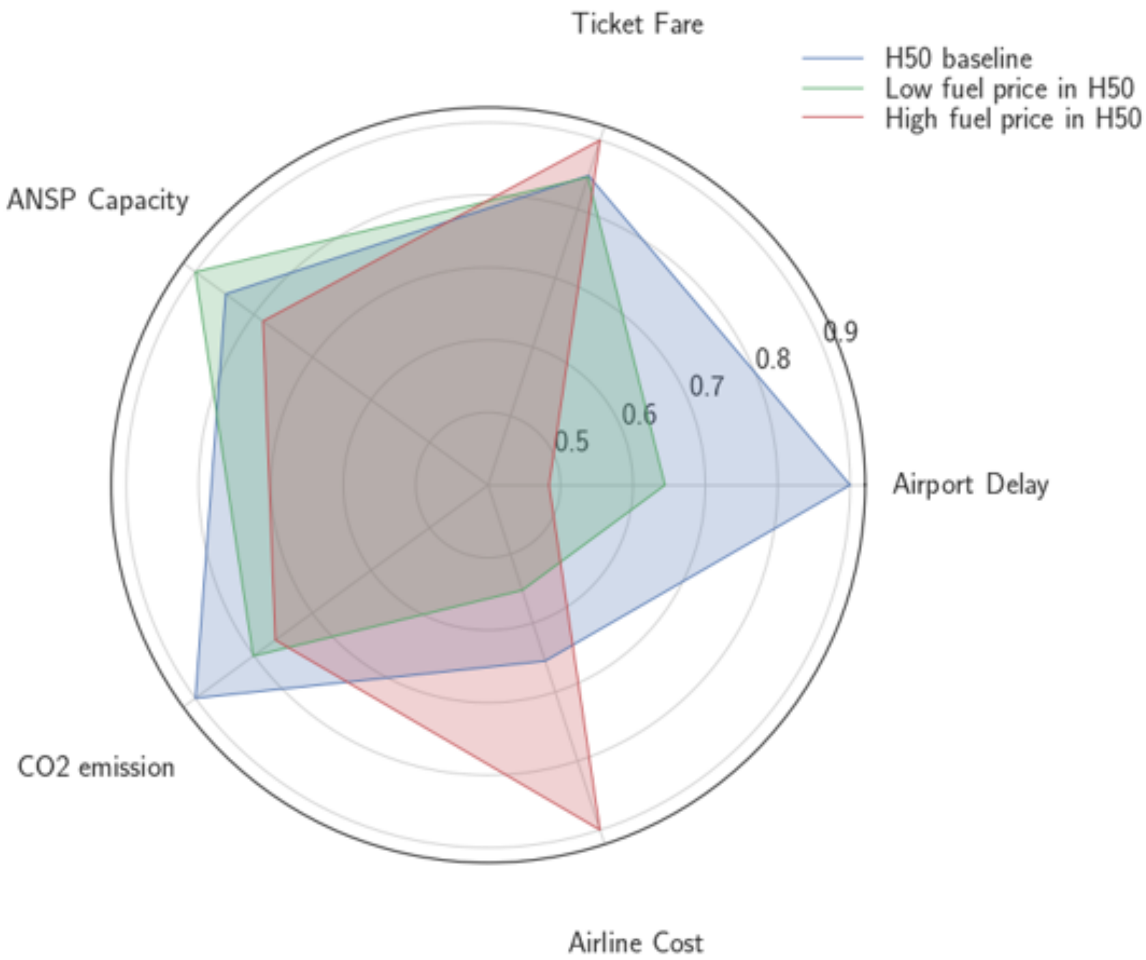
Current performance, wider context
Comparing Europe, US and China

Region	Europe	US	China
Programme	SESAR*	NextGen	ATMB Strategic Development Programme
Programme target year	2035	2025	2030
Baseline year for comparison of relative changes	2005	2009	2015
(ICAO) KPA			
Safety	Improve safety 10-fold	Commercial 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 in core airports throughput	Increase capacity 3-fold
Efficiency	1–3 min. reduction in average delay En-route ATFM average delay 0.5 min	Reduce delays by 27%	Average ATC-attributable delay < 5 min
Environment	10% reduction in impact of flights on environment	Reduce fuel burned per miles flown by $\geq 2\%$ annually	Reduce CO_2 by 10% (kg/km)

Better

Director of Better

Better – Trade offs

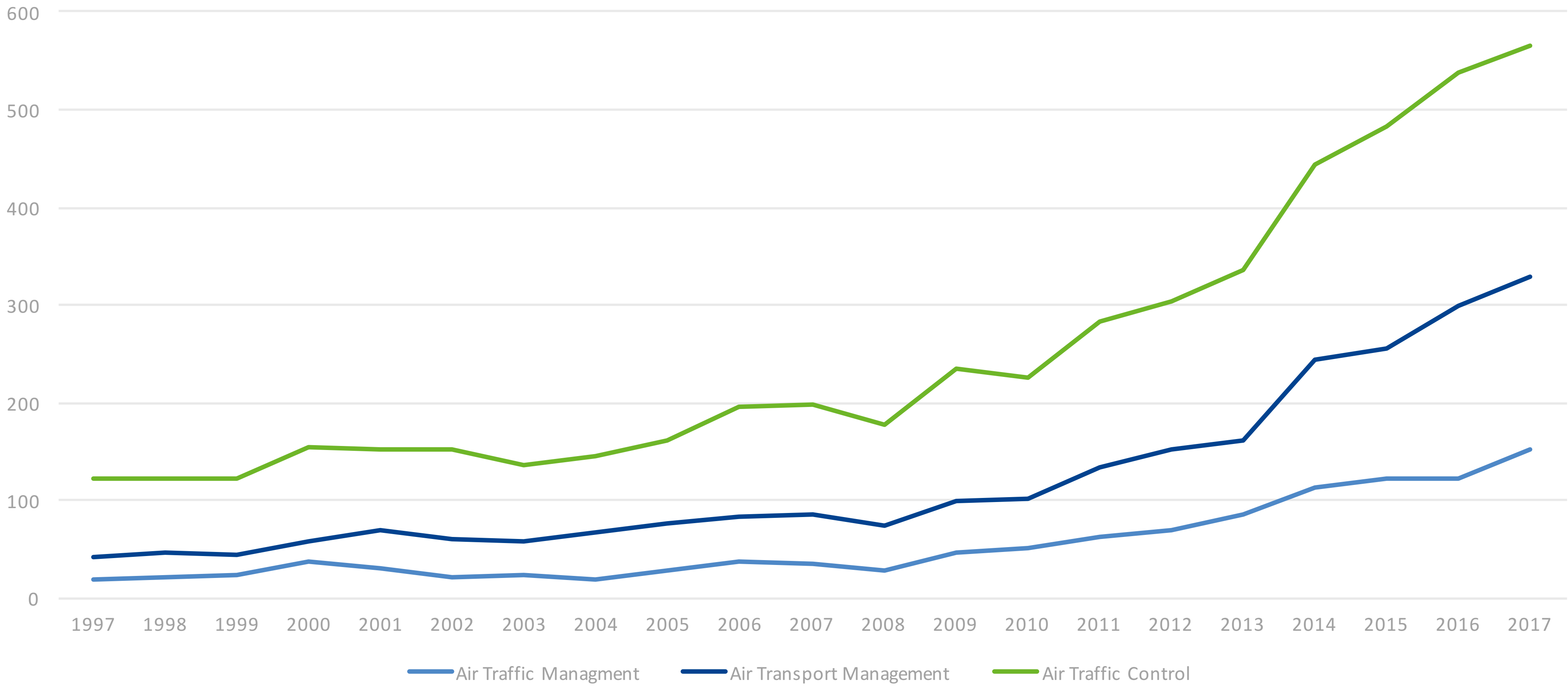


Research in ATM evolution

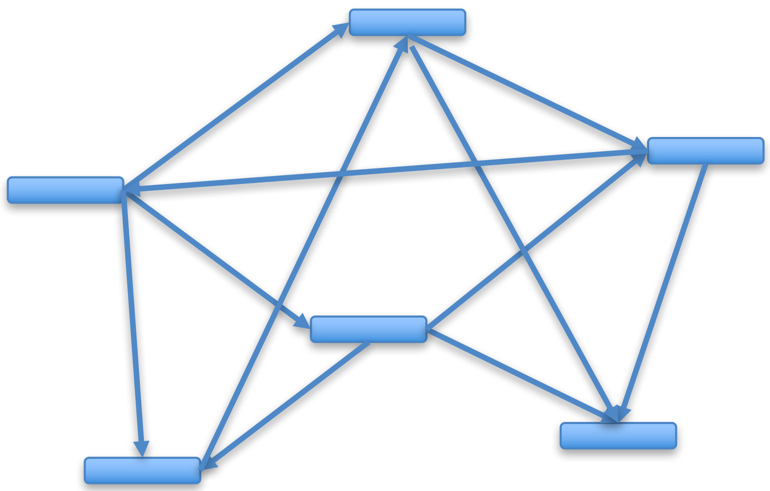
- Broadening the perspective
    - **Air Traffic Control** (separation)
    - **Air Traffic Management** (throughput, delay)
    - **Air Transport Management** (AO costs, pax-centric, multimodality)

Research in ATM evolution

- Number of research papers in Science Direct with key words



Research in ATM evolution



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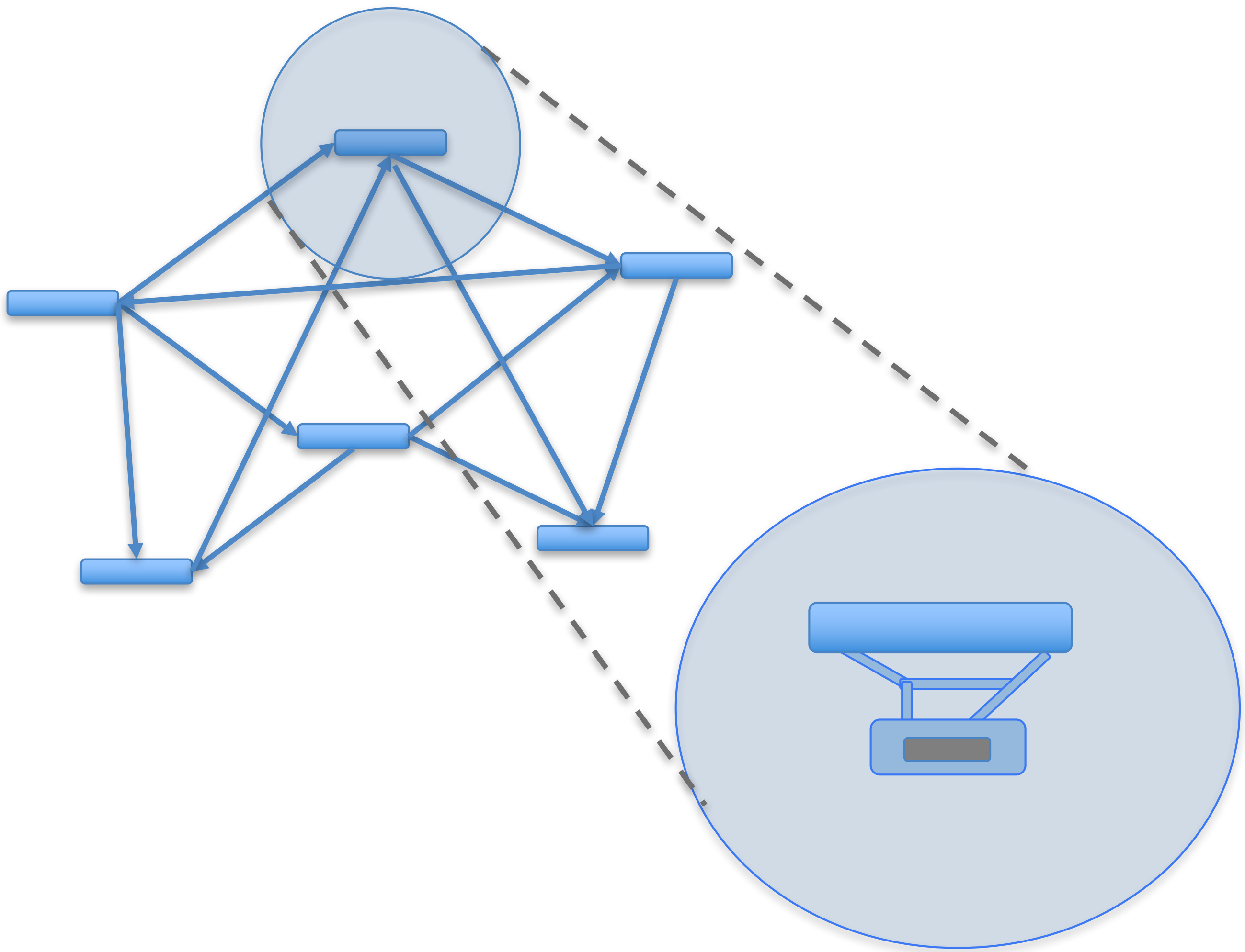
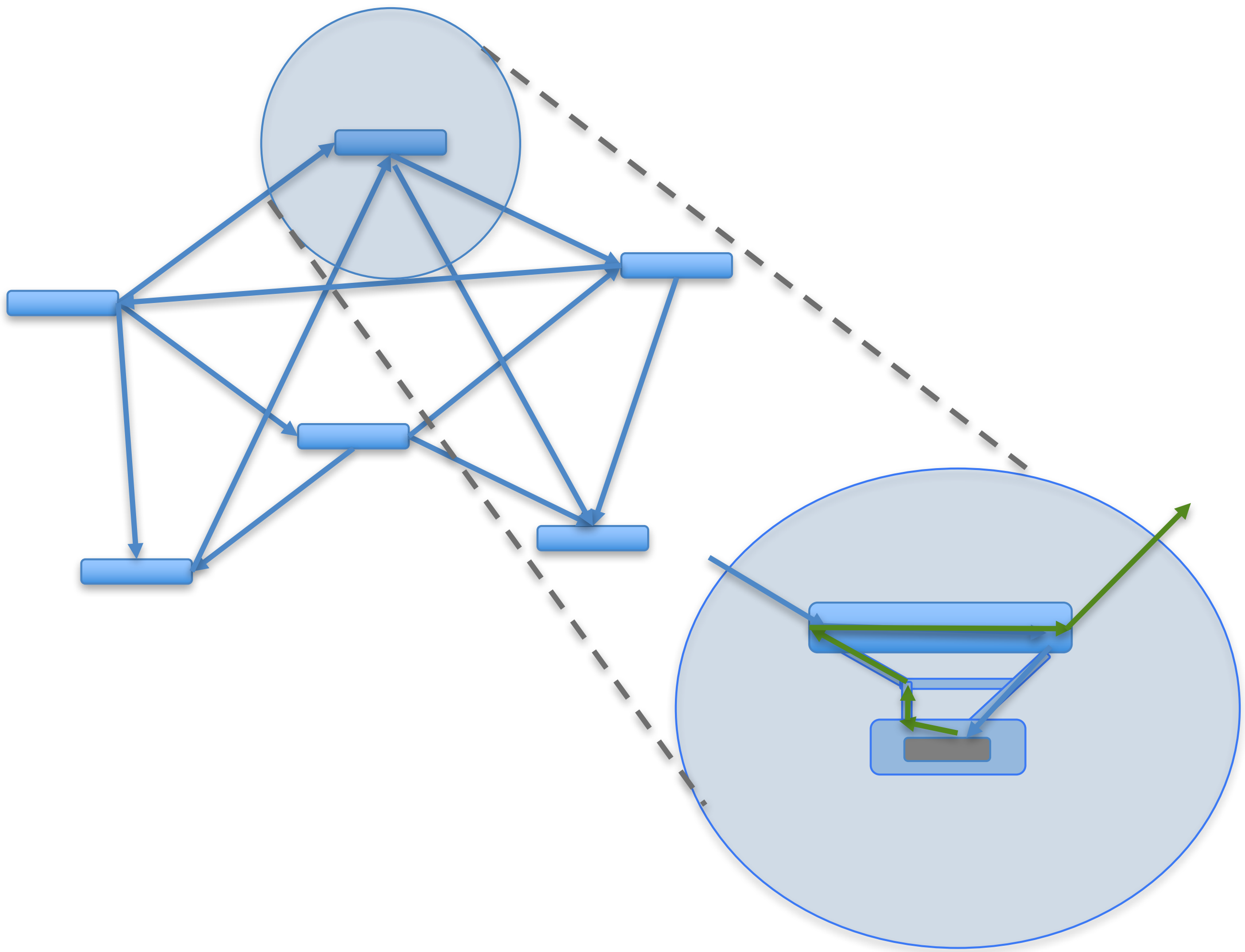


Research in ATM evolution



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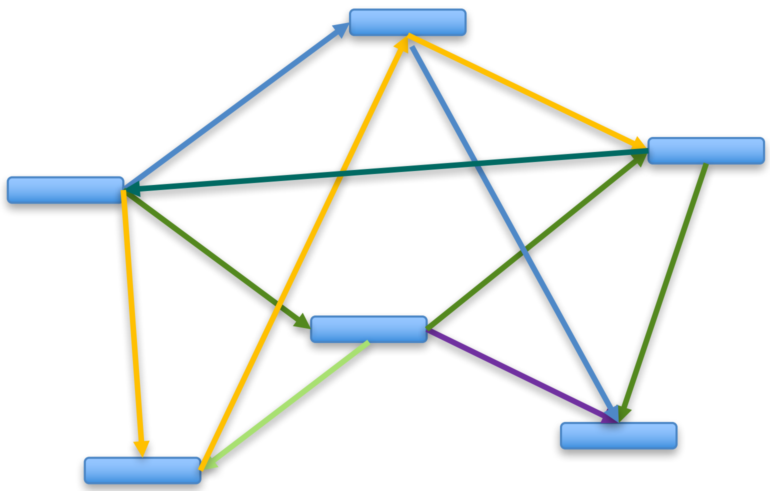

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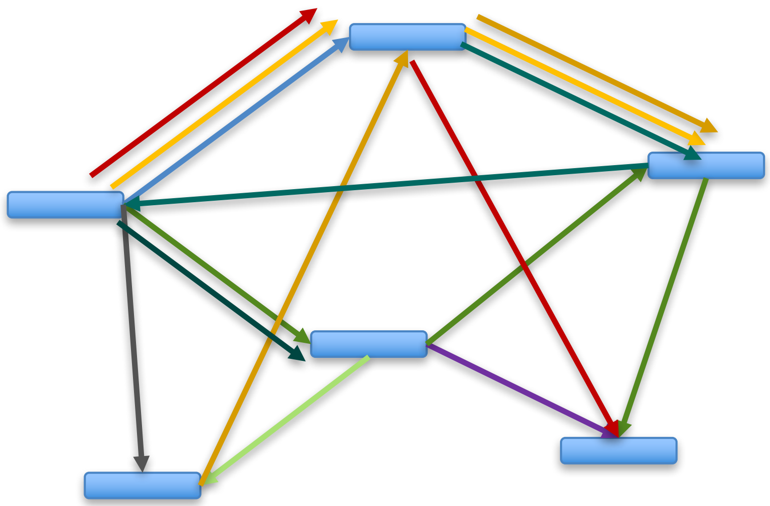

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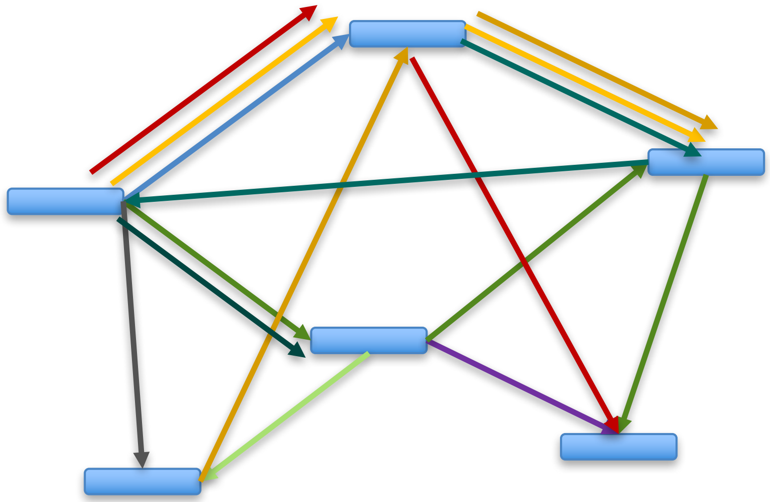
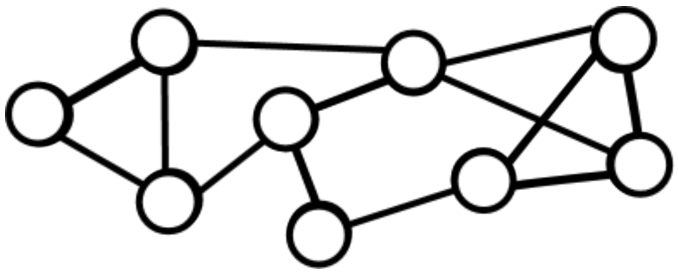


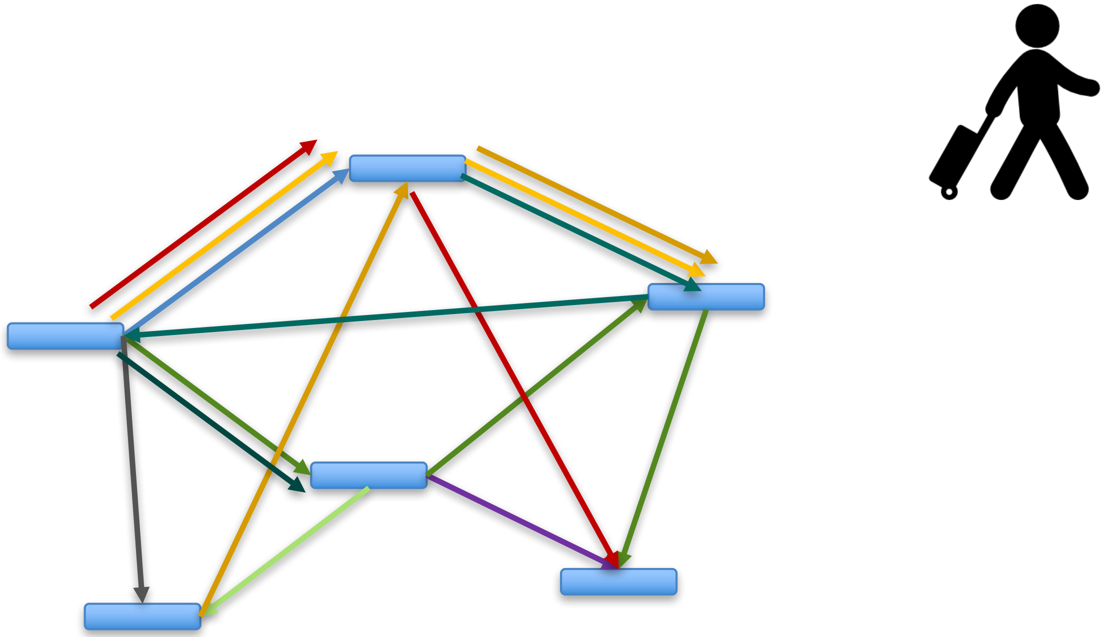
DOMINO

Flight

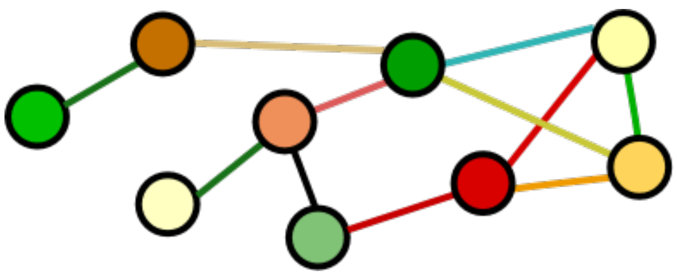
Passenger



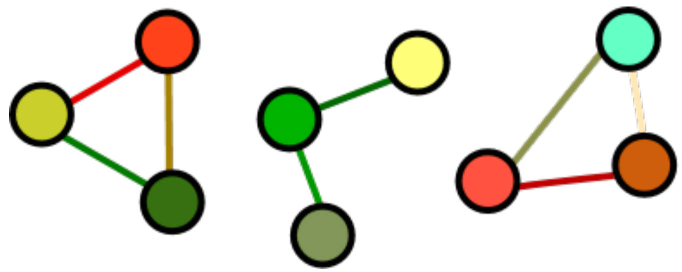
Research in ATM evolution



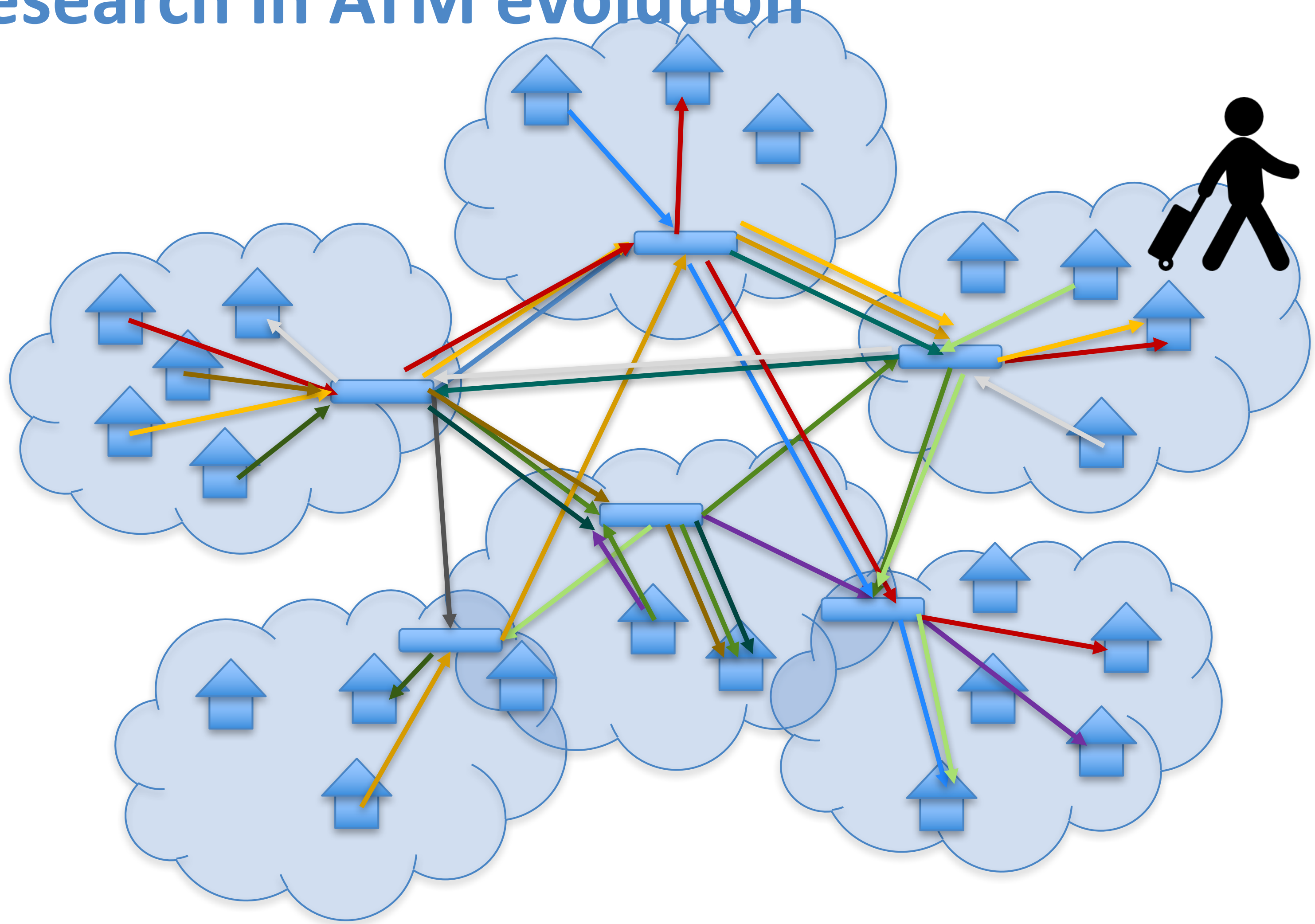
Flight
Network Analysis



Passenger
Network Analysis



Research in ATM evolution



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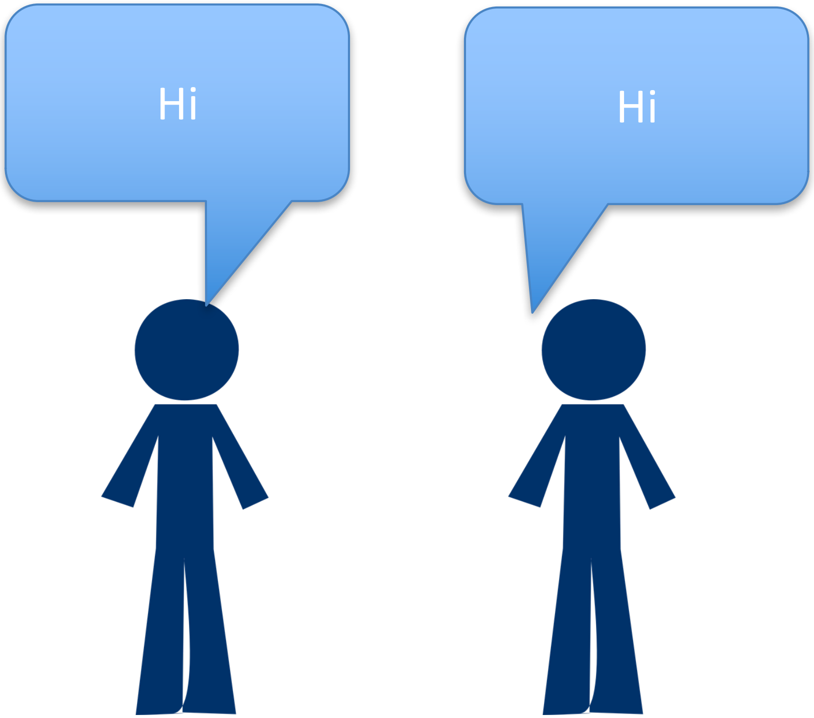

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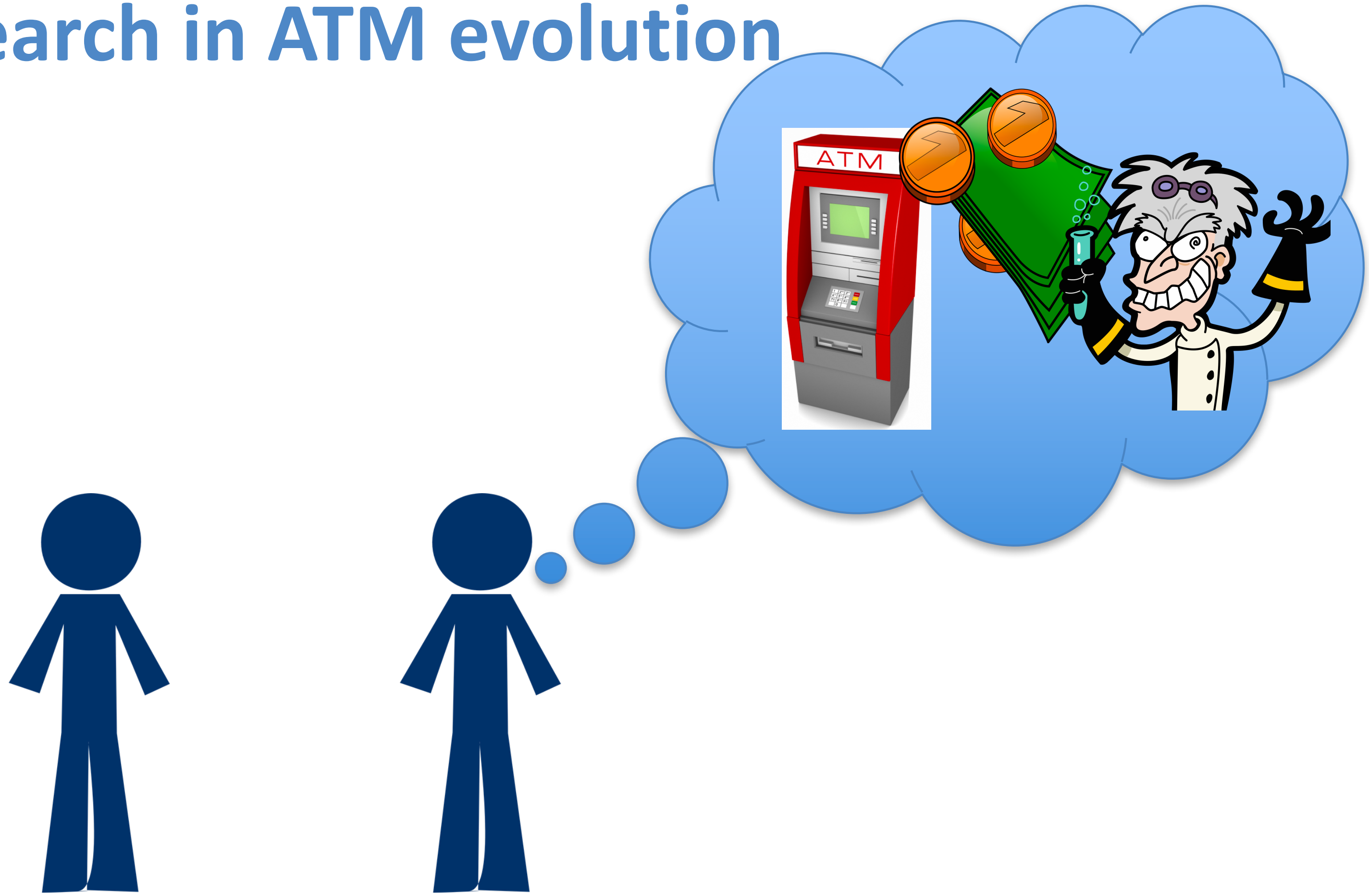

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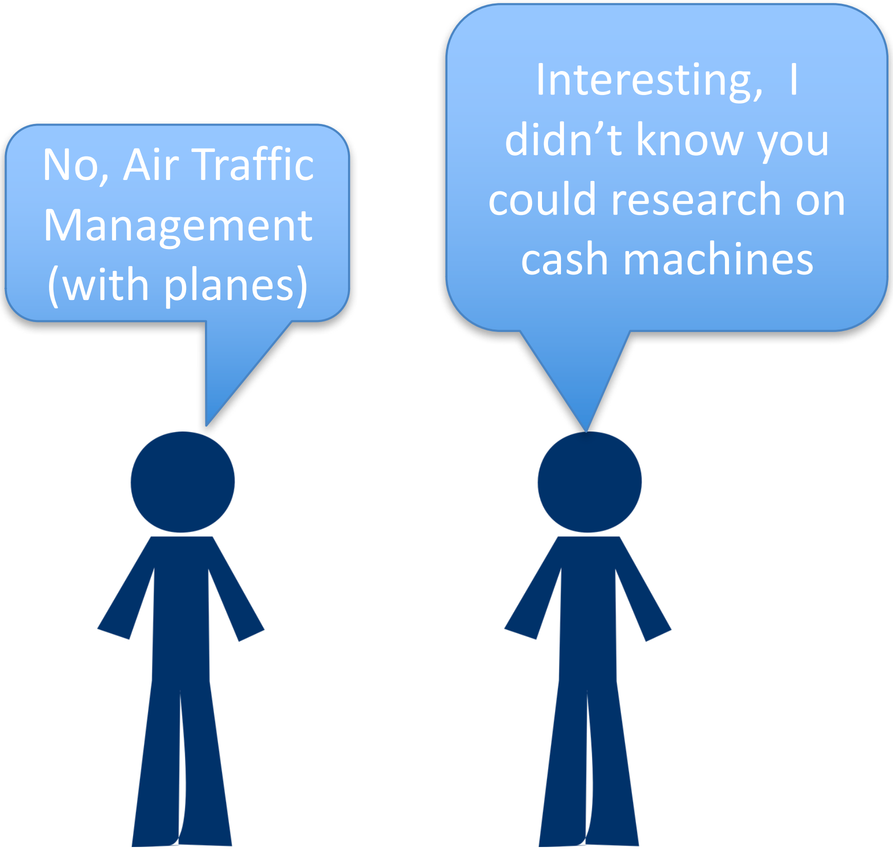
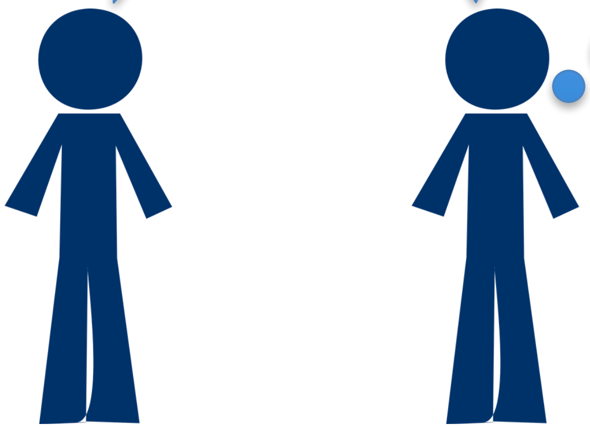


Research in ATM evolution

No, that's Air Traffic Control

Ah, with the tower and the controllers



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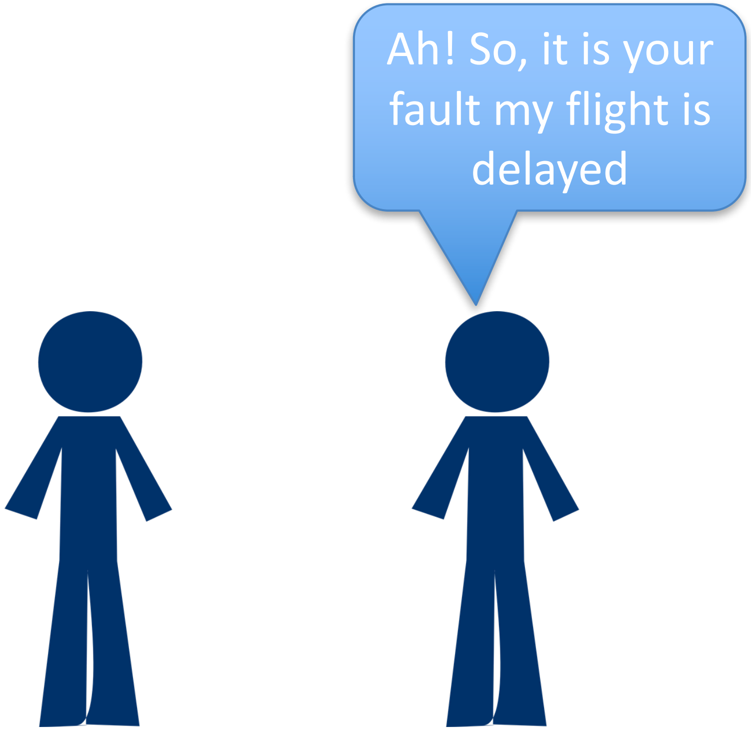

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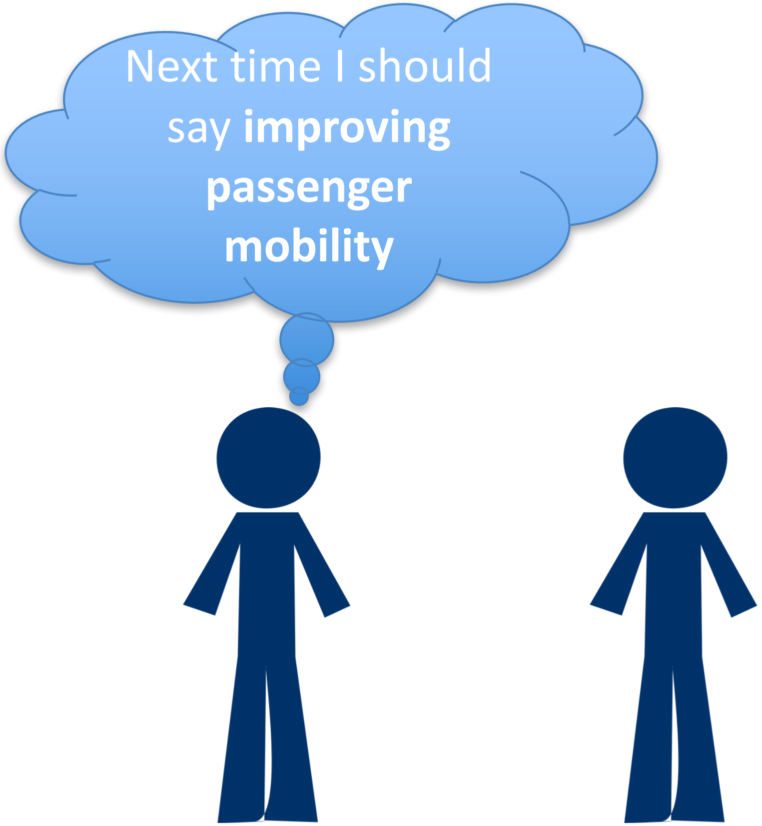
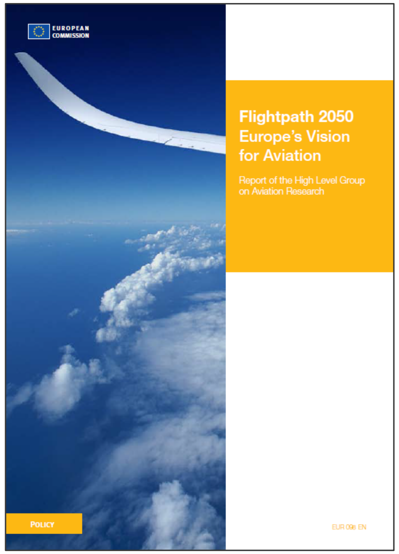


Door-to-door context

- Flightpath 2050 (ACARE, 2011)
  - “highly ambitious goals” (x5)
  - “90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours”



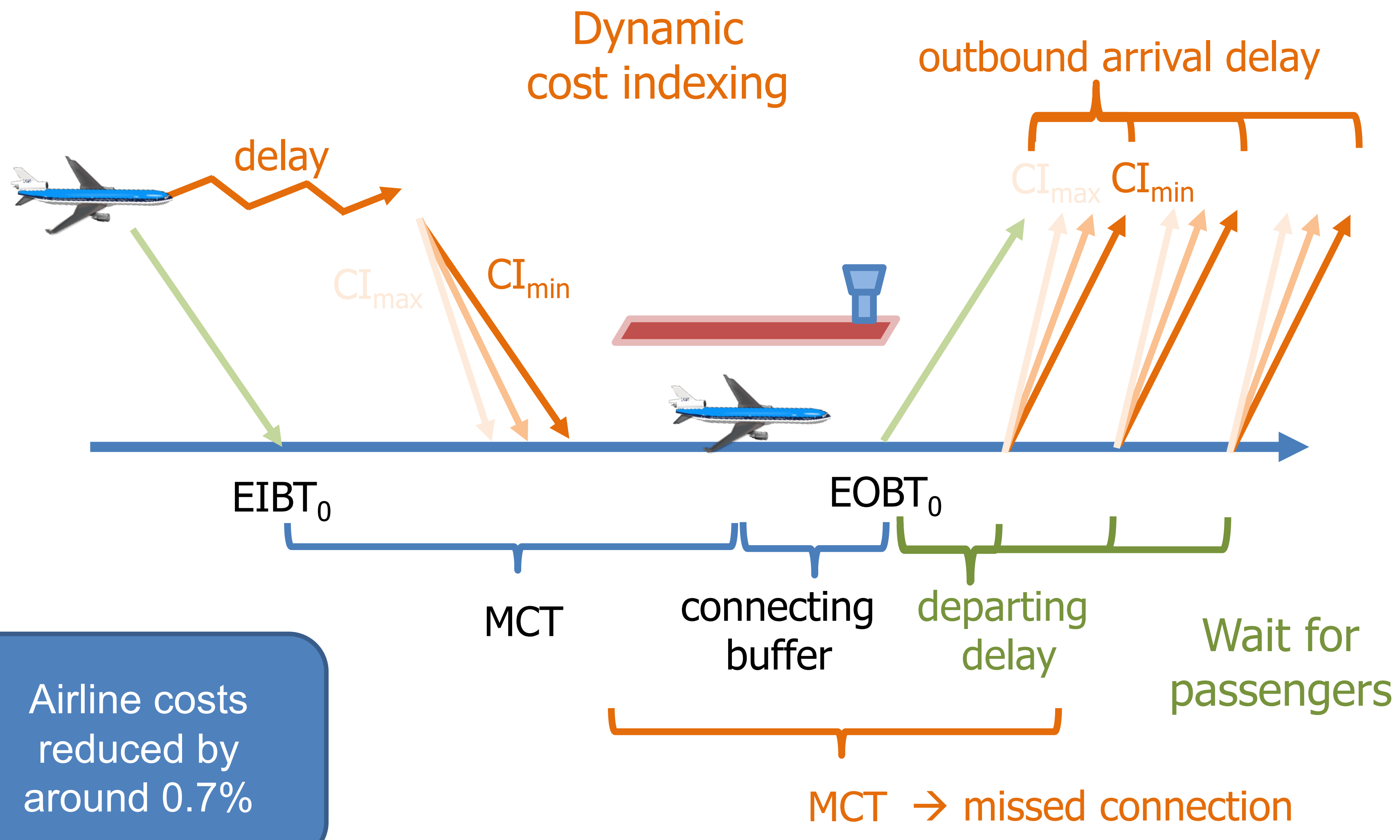
Door-to-door context

- **Open questions**
  - How measure progress without the right metrics? (Currently G2G)
  - New metrics needed – new trade-offs apparent
  - Impacts of intermodal factors (e.g. regulated ticketing; HSR; airport access), on, e.g.:
    - Essential Operational Changes, such as UDPP
    - ATM Technology Changes, such as A-CDM
  - Is faster better? What should we measure? – ‘slow’ & ‘green’ travel paradigms

Metrics

- Flight-centric → pax-centric metrics
    - can’t always detect changes with flight-centric metrics

CASSIOPEIA – Hub optimisation

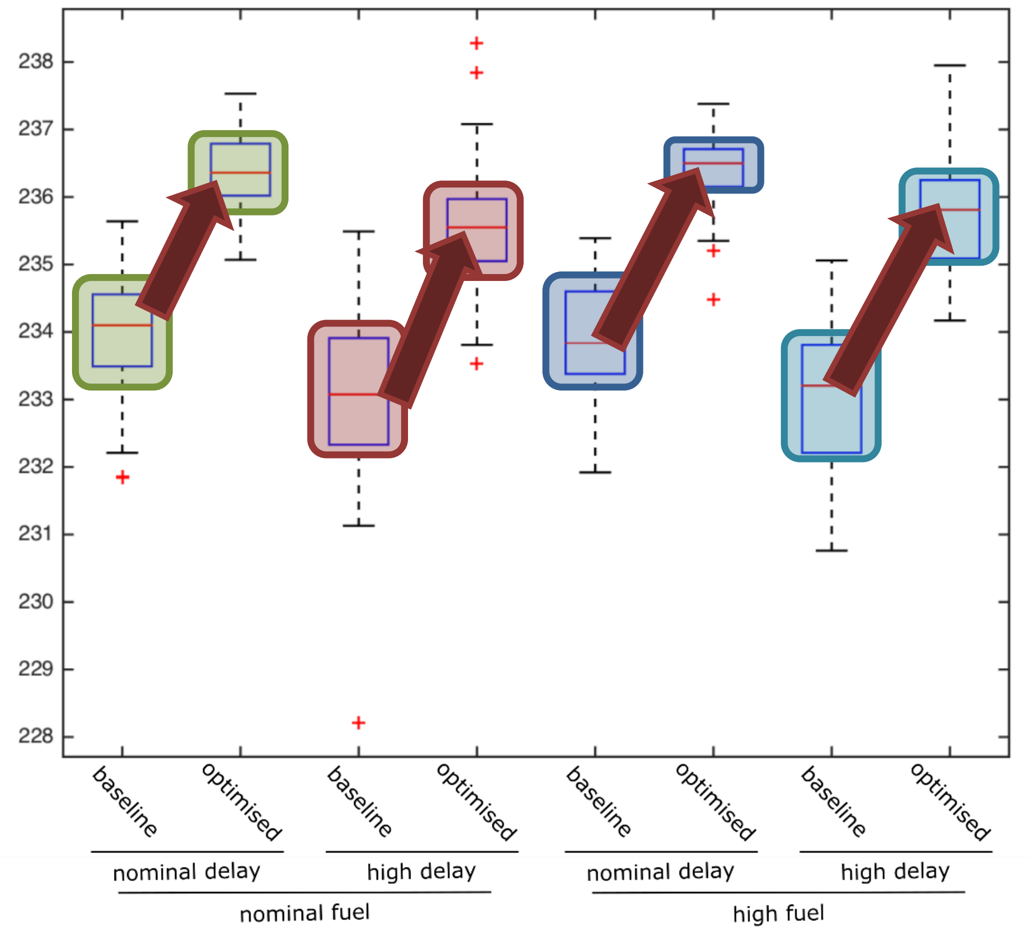


Airline costs reduced by around 0.7%

L. Delgado, J. Martin, A. Blanch and S. Cristobal, Hub operations delay recovery based on cost optimisation, SESAR Innovation Days 2016

CASSIOPEIA – Hub optimisation

Gate-to-gate trip time (min)



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CASSIOPEIA – Hub optimisation

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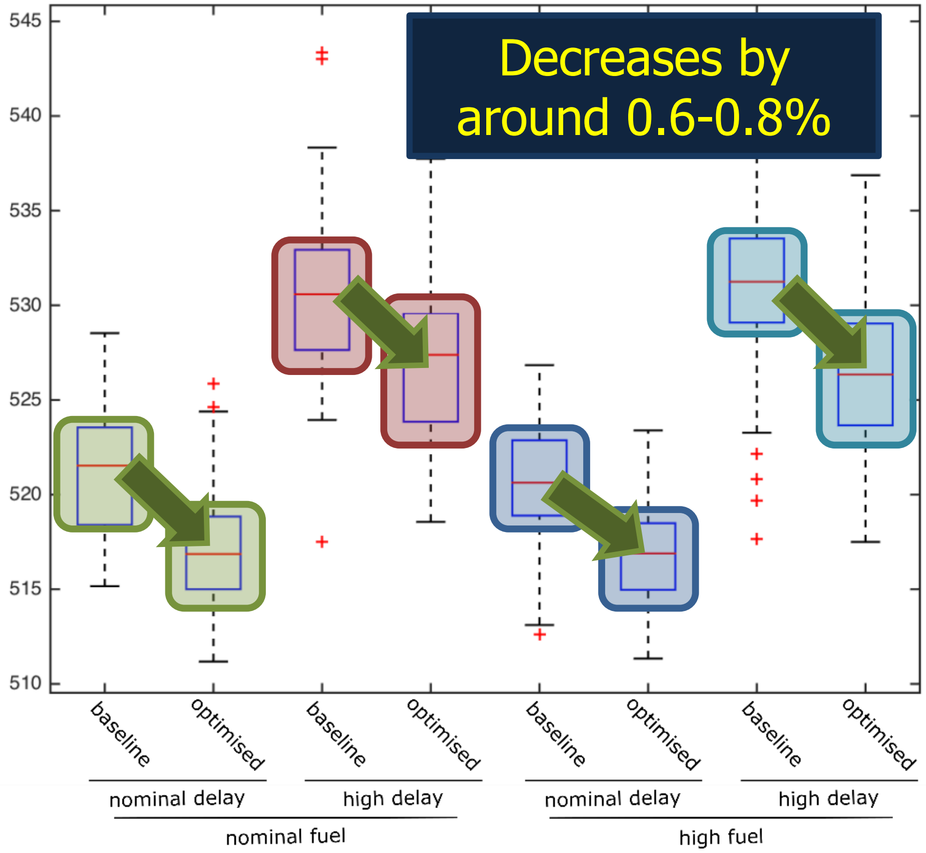
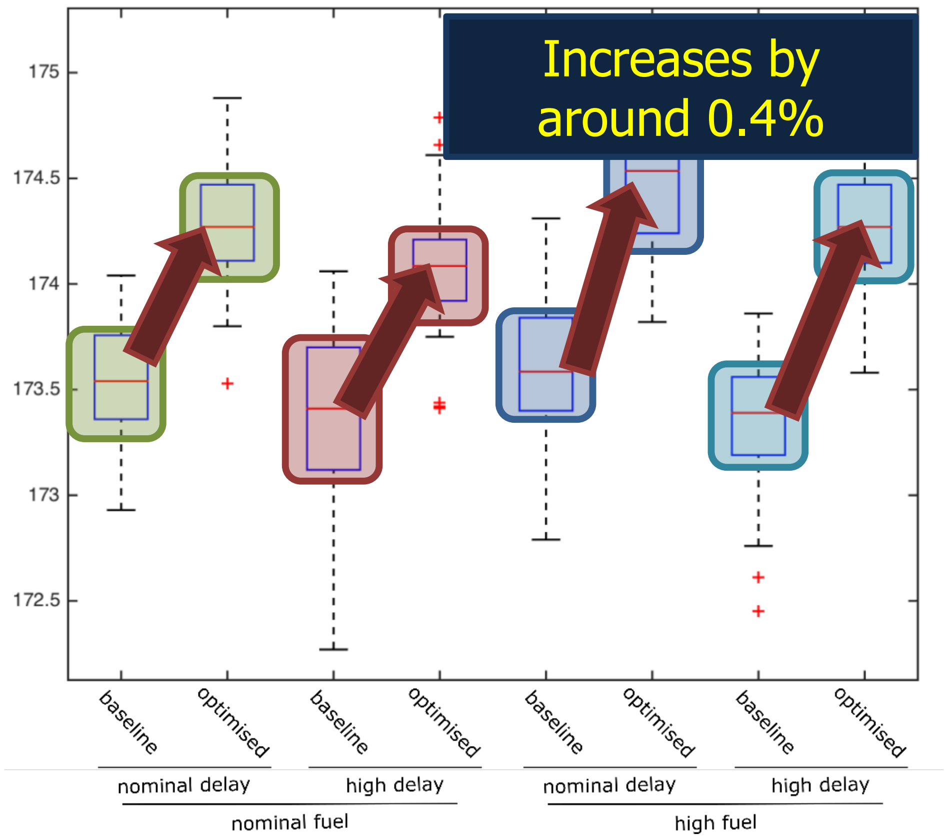


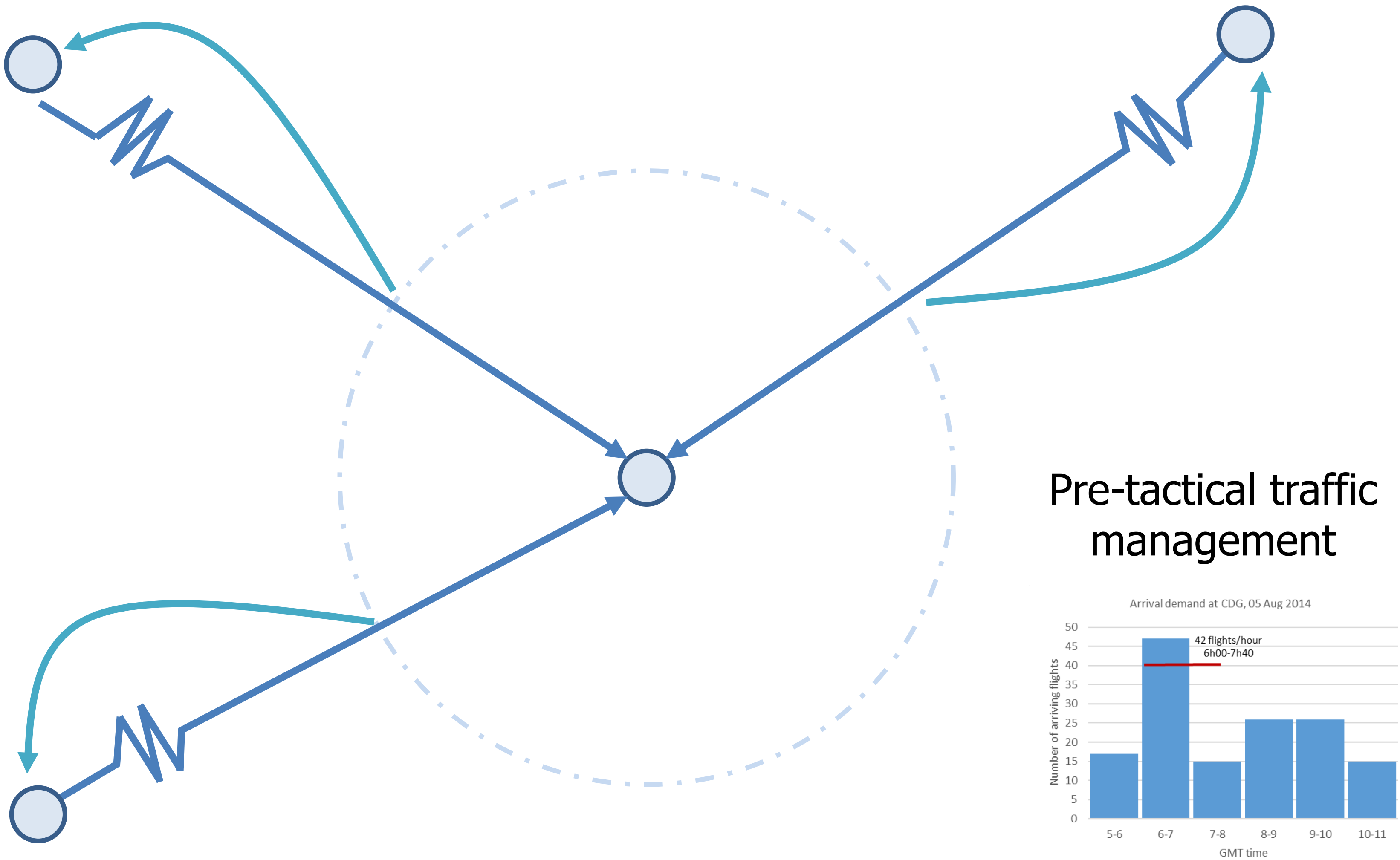
Connecting passengers



Non-connecting passengers

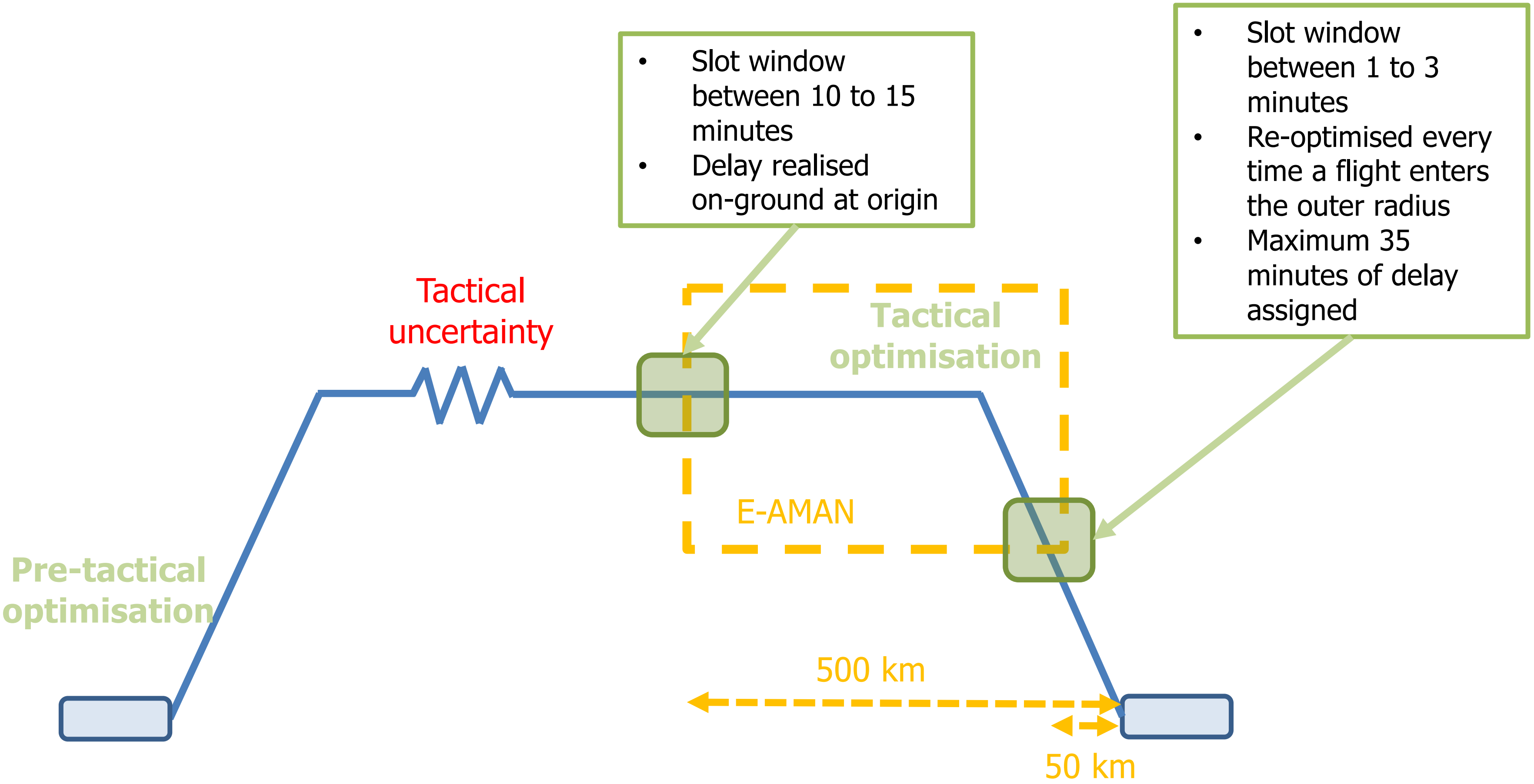
L. Delgado, J. Martin, A. Blanch and S. Cristobal, Hub operations delay recovery based on cost optimisation, SESAR Innovation Days 2016

Arrival manager optimisation



Montlaur, L. Delgado, Flight and passenger delay assignment optimization strategies, Transportation Research Part C: Emerging Technologies Volume 81, August 2017, Pages 99-117

Arrival manager optimisation



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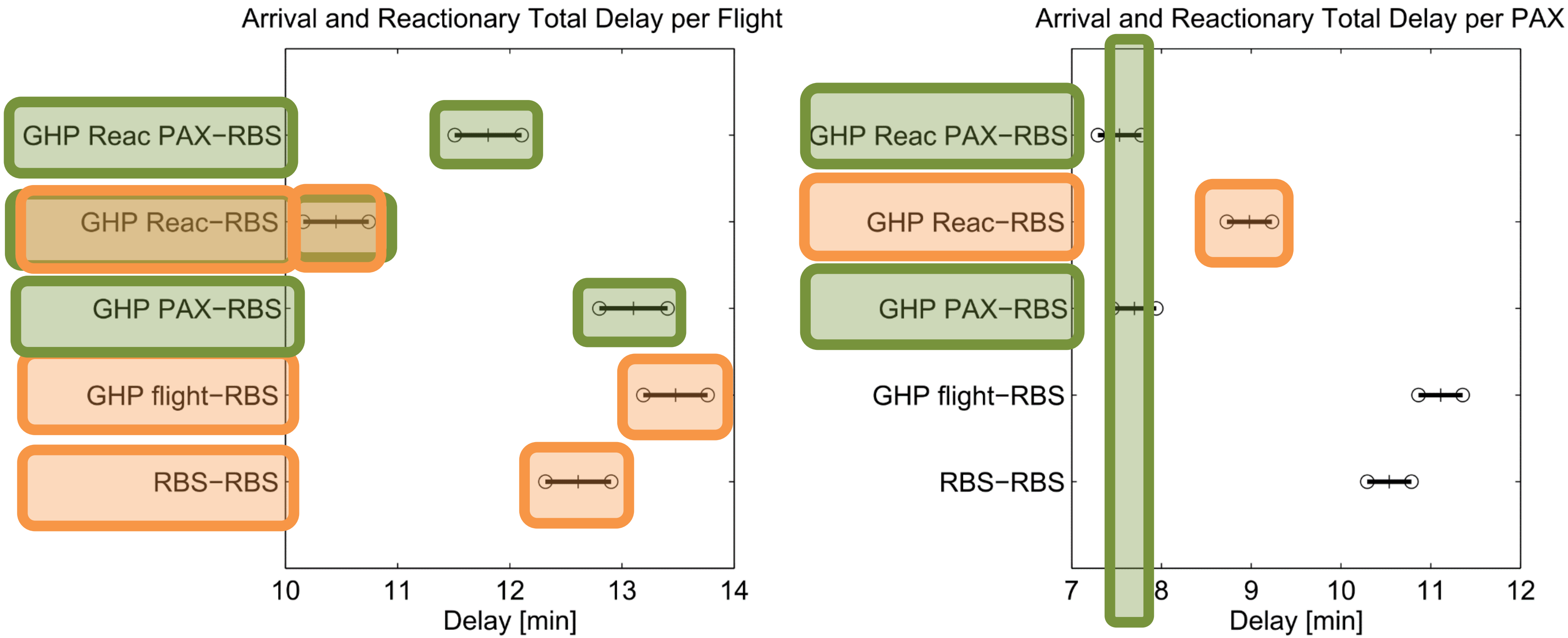
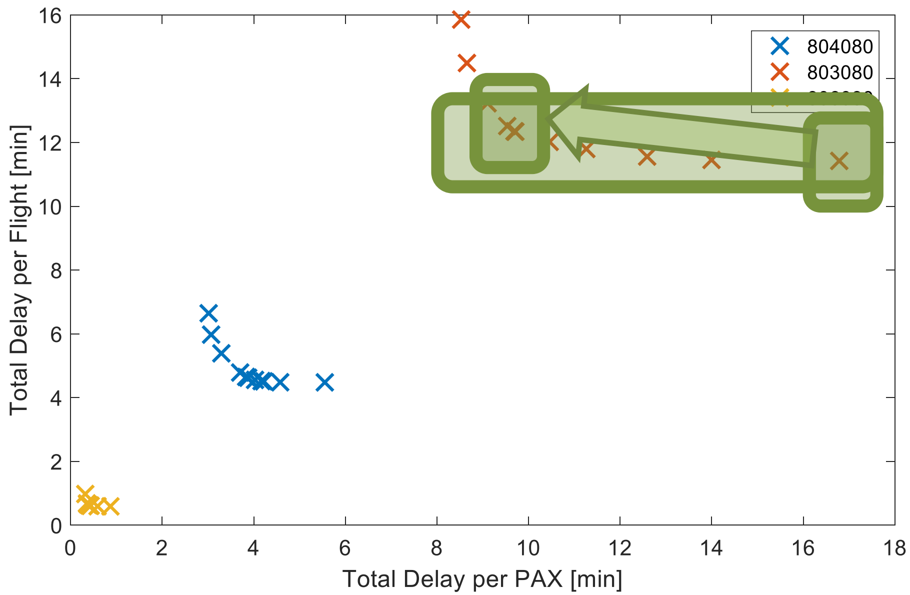
Arrival manager optimisation

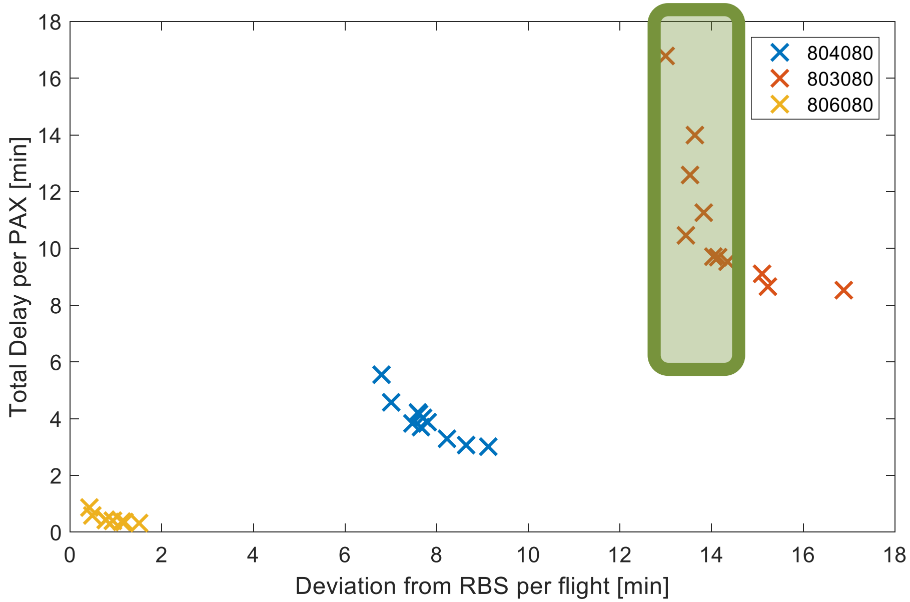


Montlaur, L. Delgado, Flight and passenger delay assignment optimization strategies, Transportation Research Part C: Emerging Technologies Volume 81, August 2017, Pages 99-117

Arrival manager optimisation

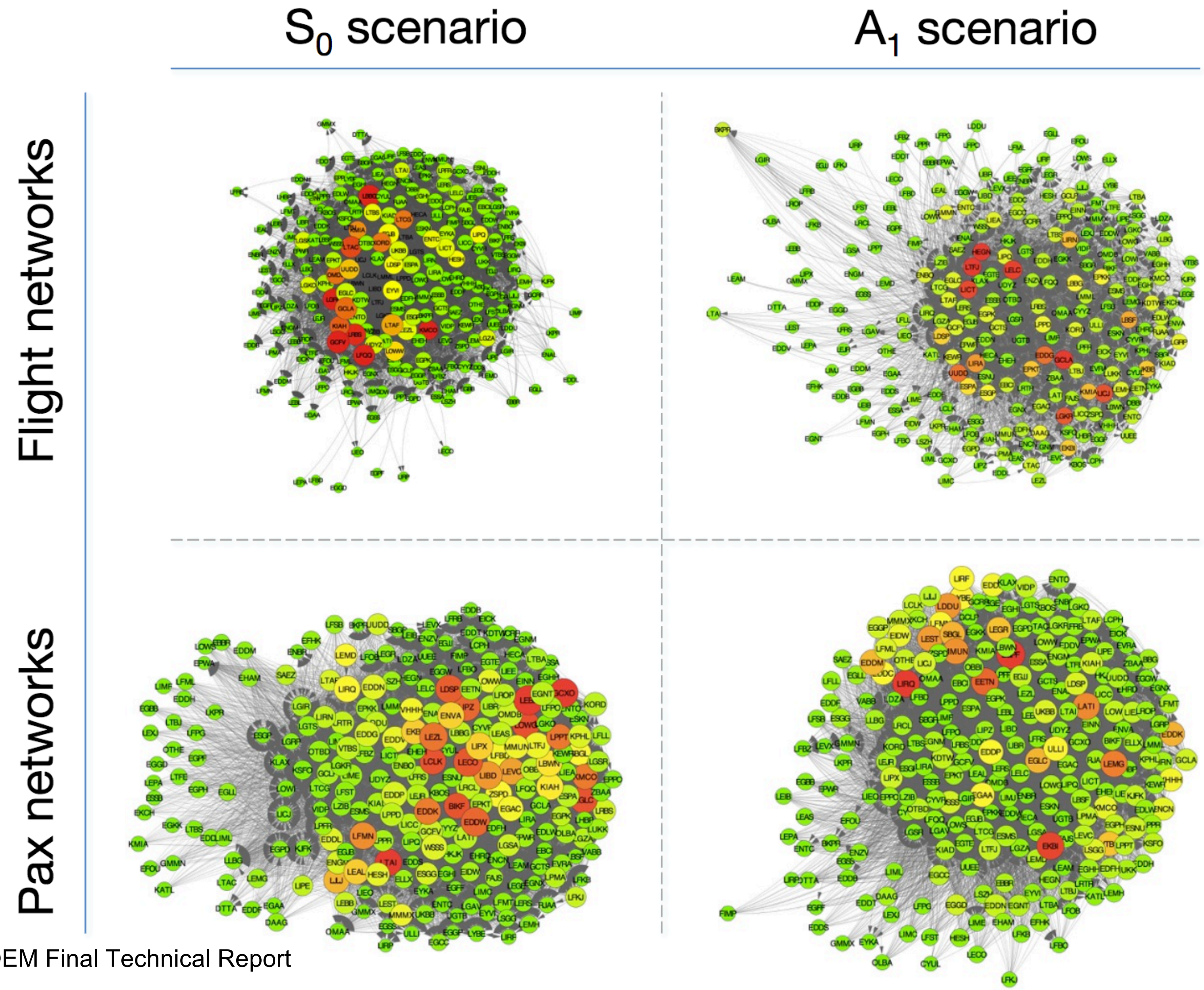
Obj = α Total delay per flight + (1-α) Total delay per passengers





A. Montlaur, L. Delgado, Trade-off on arrival optimization (Current work)

POEM – Delay propagation networks

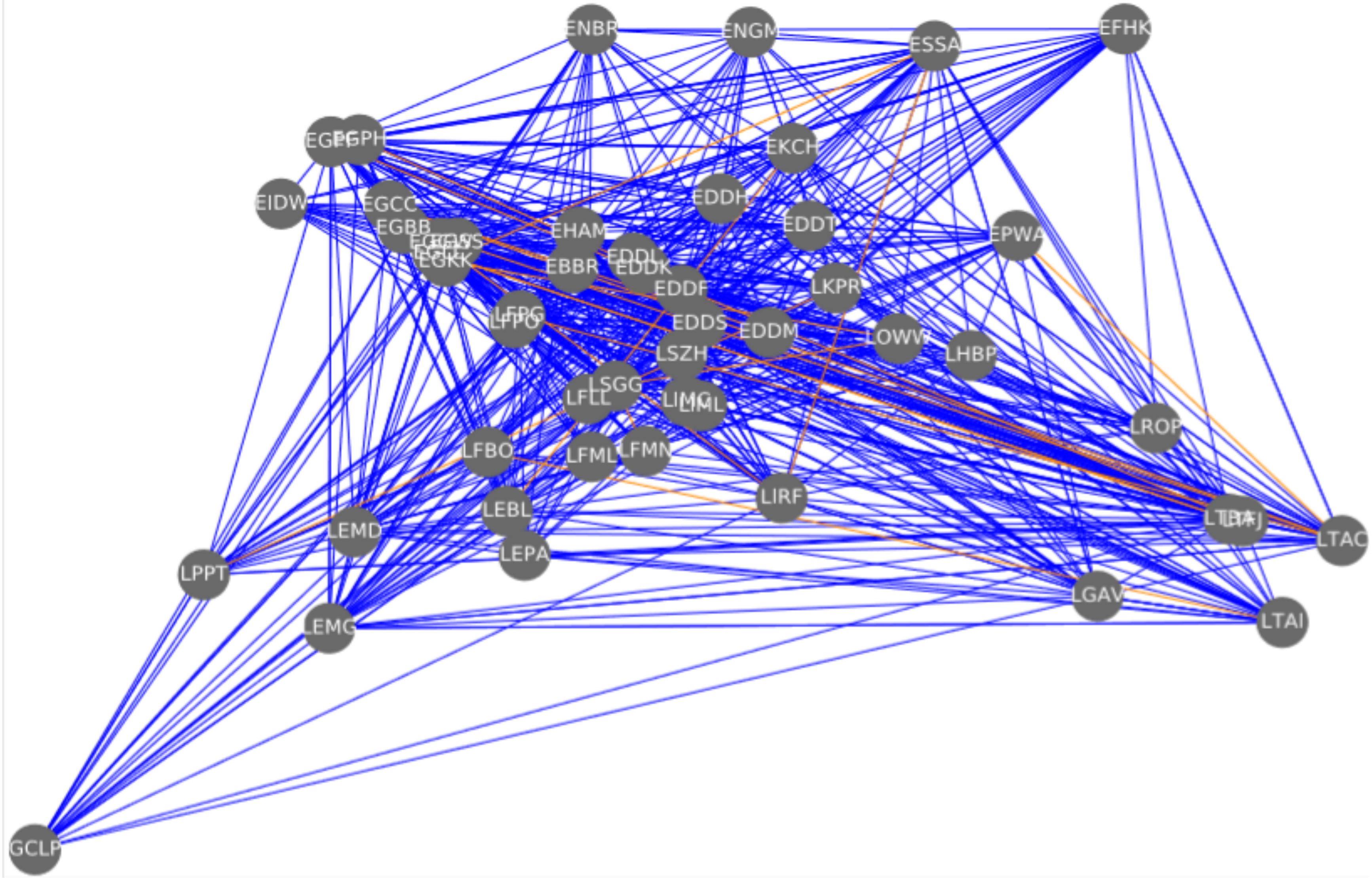


D6.2 – POEM Final Technical Report

POEM – Delay propagation networks

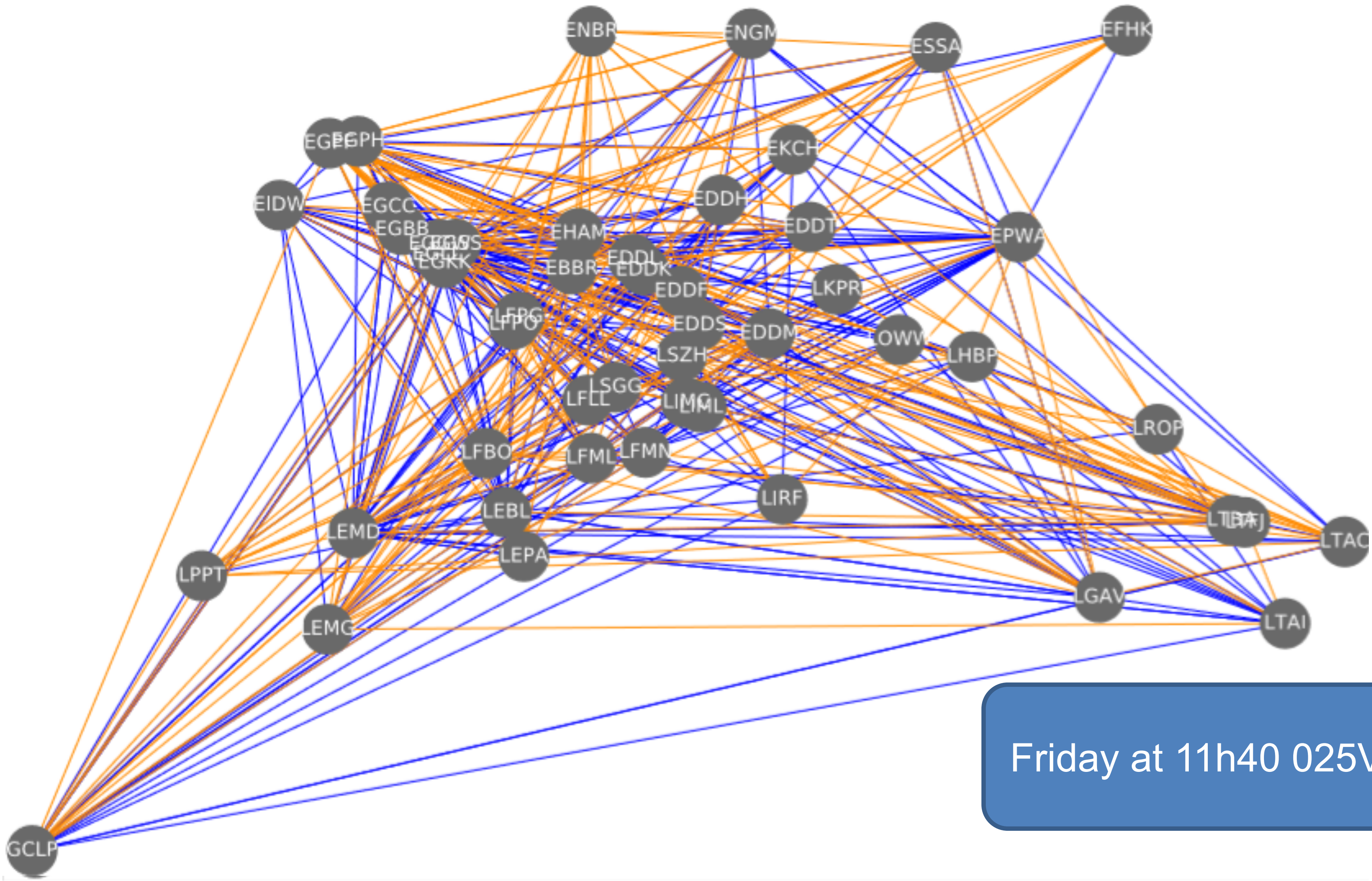
	S_0	A_1
Flight arrival delay	13.8	14.3
Pax arrival delay	16.3	14.6

Delay propagation networks



Seddik Belkoura and Samuel Cristobal, New Insights on Nonlinear Delay Causation Network for Passengers and Flights in Europe, ICRAT 2018

Delay propagation networks



Seddik Belkoura and Samuel Cristobal, New Insights on Nonlinear Delay Causation Network for Passengers and Flights in Europe, ICRAT 2018

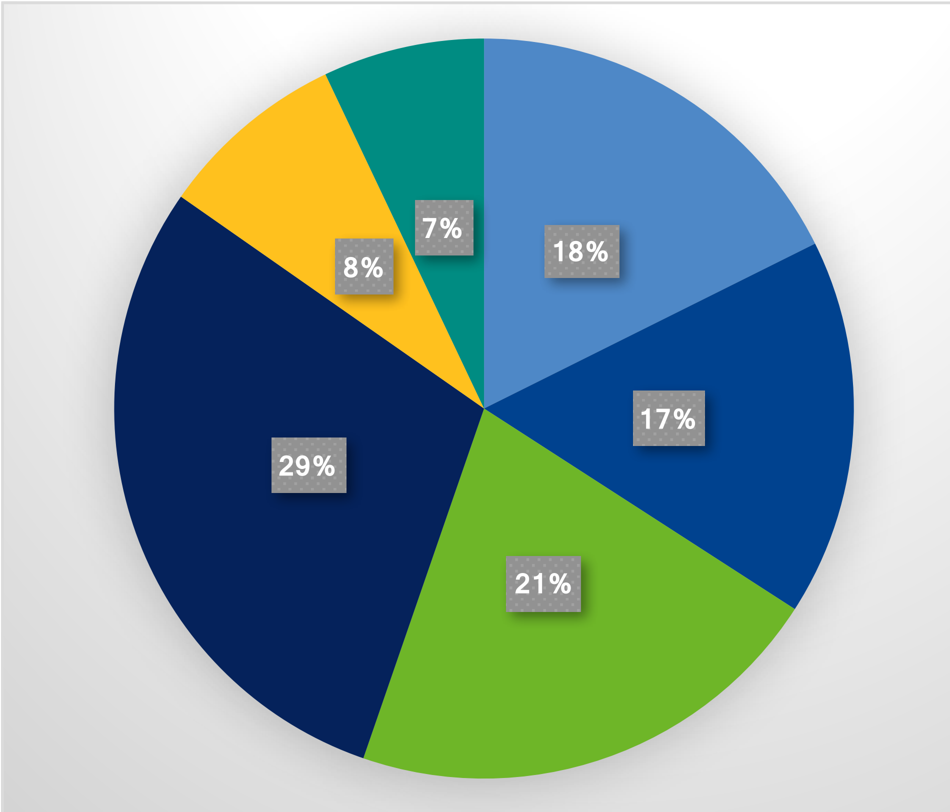
The door-to-door context

From gate-to-gate to total travel

- London – Castelldefels (via Gatwick)

From gate-to-gate to total travel

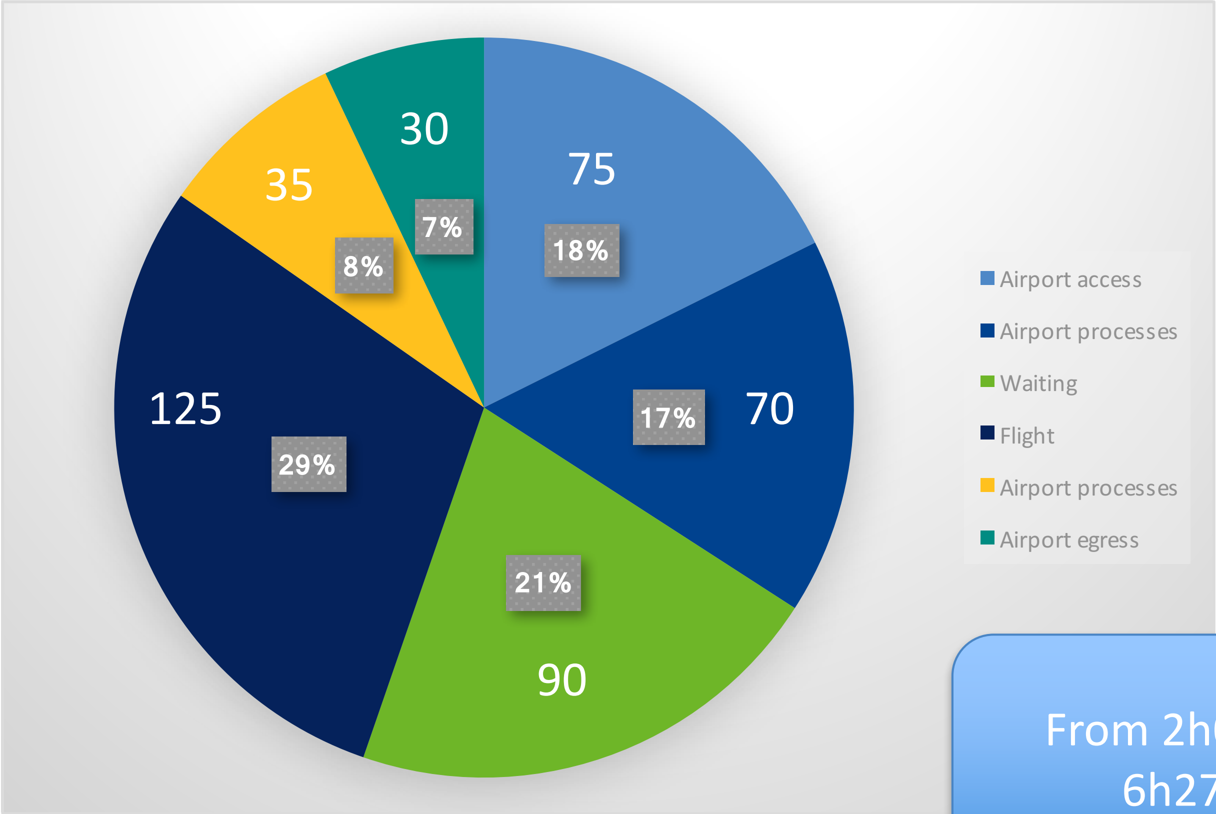
- London – Castelldefels (via Gatwick)



- Access to airport
- Egress airport
- Airport processes departure
- Airport processes arrival
- Flight
- Waiting

From gate-to-gate to total travel

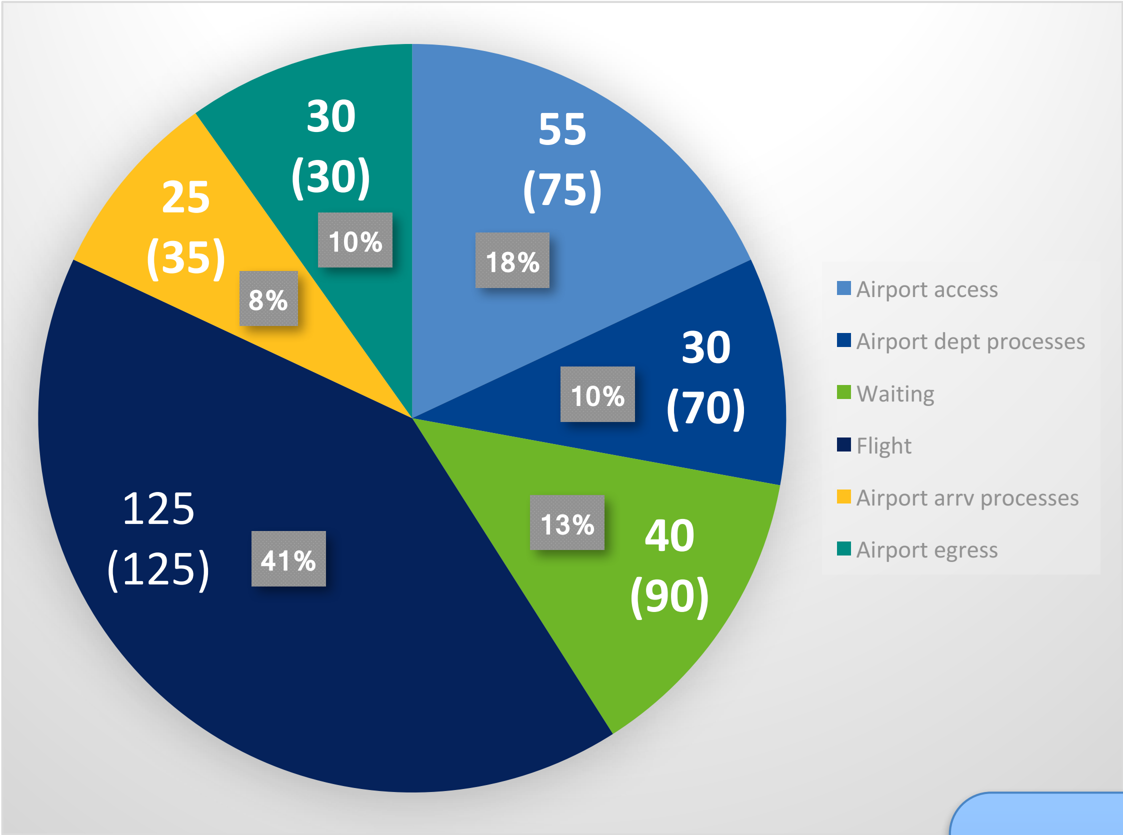
- London – Castelldefels (via Gatwick)



From 2h05 to 6h27!

From gate-to-gate to total travel

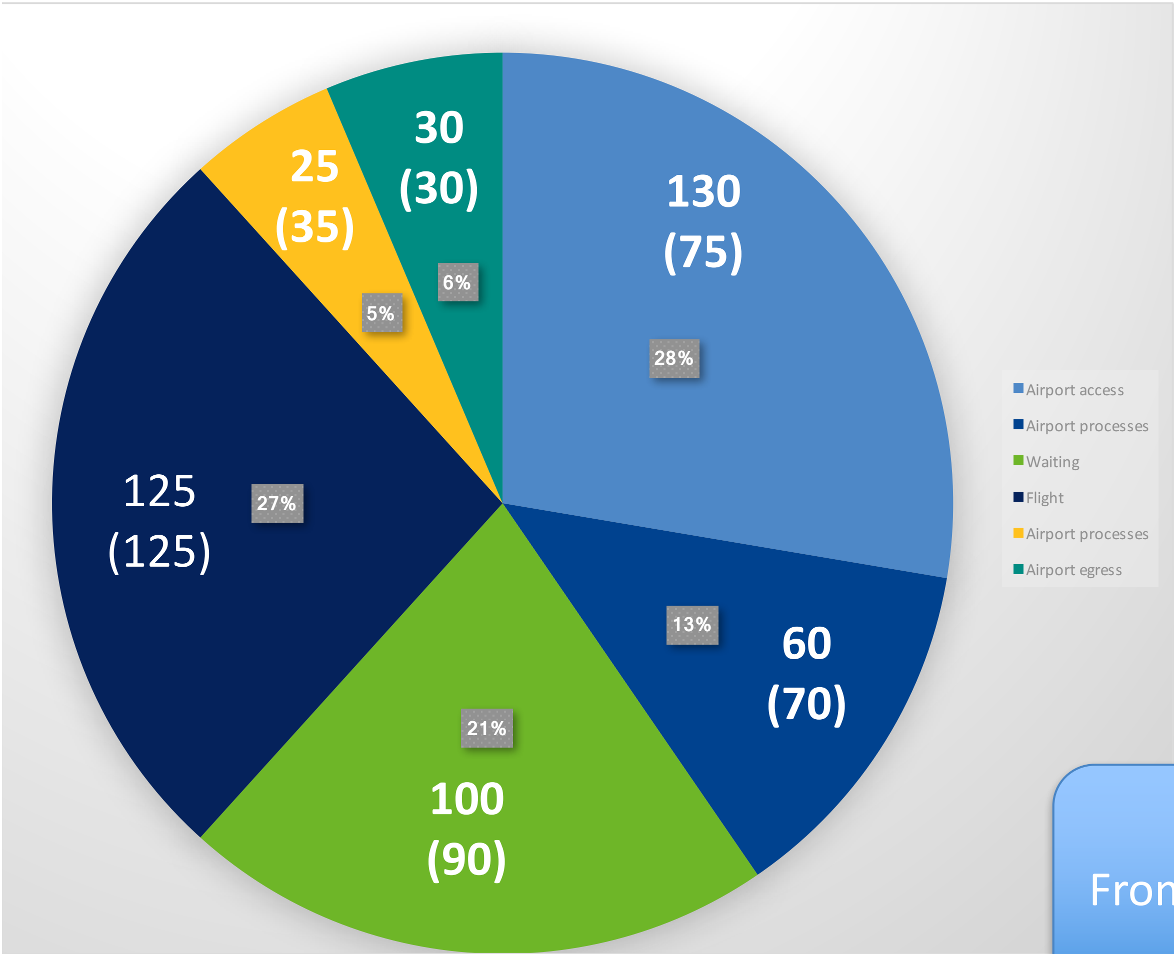
- London – Castelldefels (via Gatwick)



From 2h05 to 6h27 to 5h35

From gate-to-gate to total travel

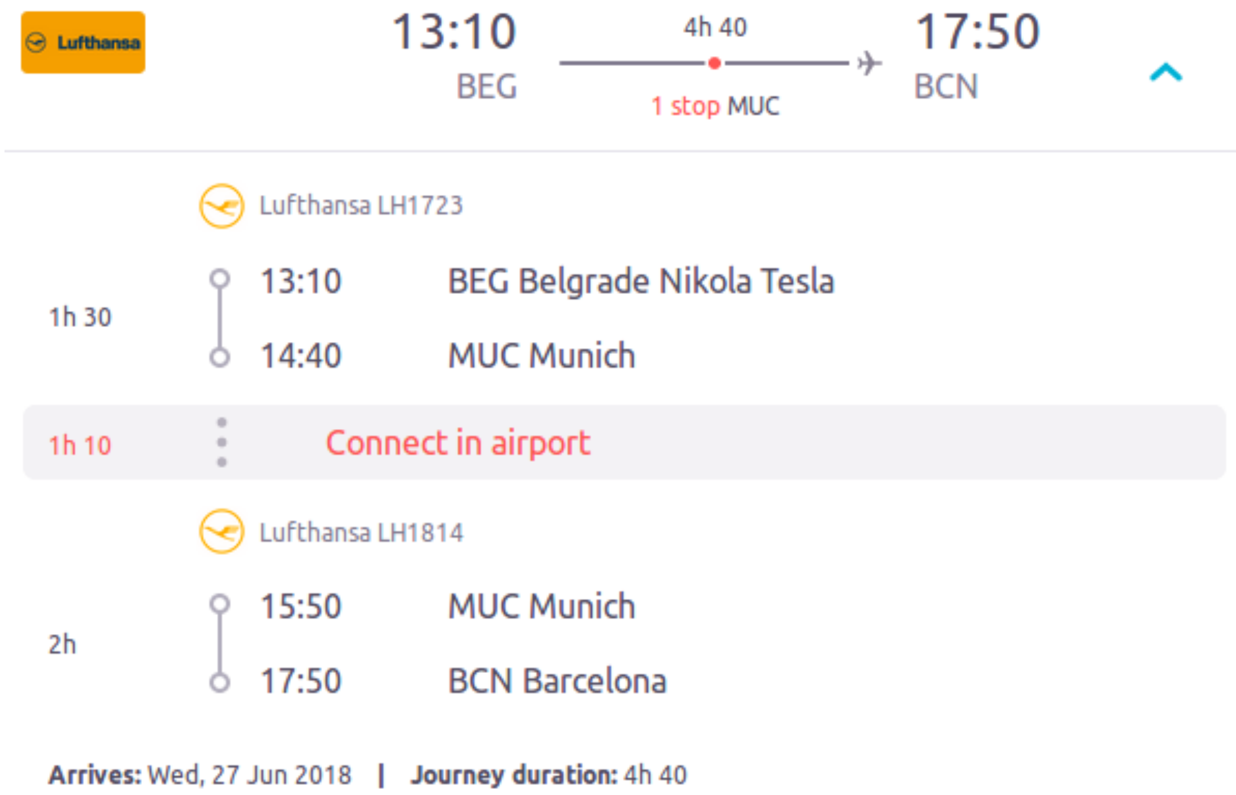
- London – Castelldefels (via Heathrow)



From 2h05 to 7h50

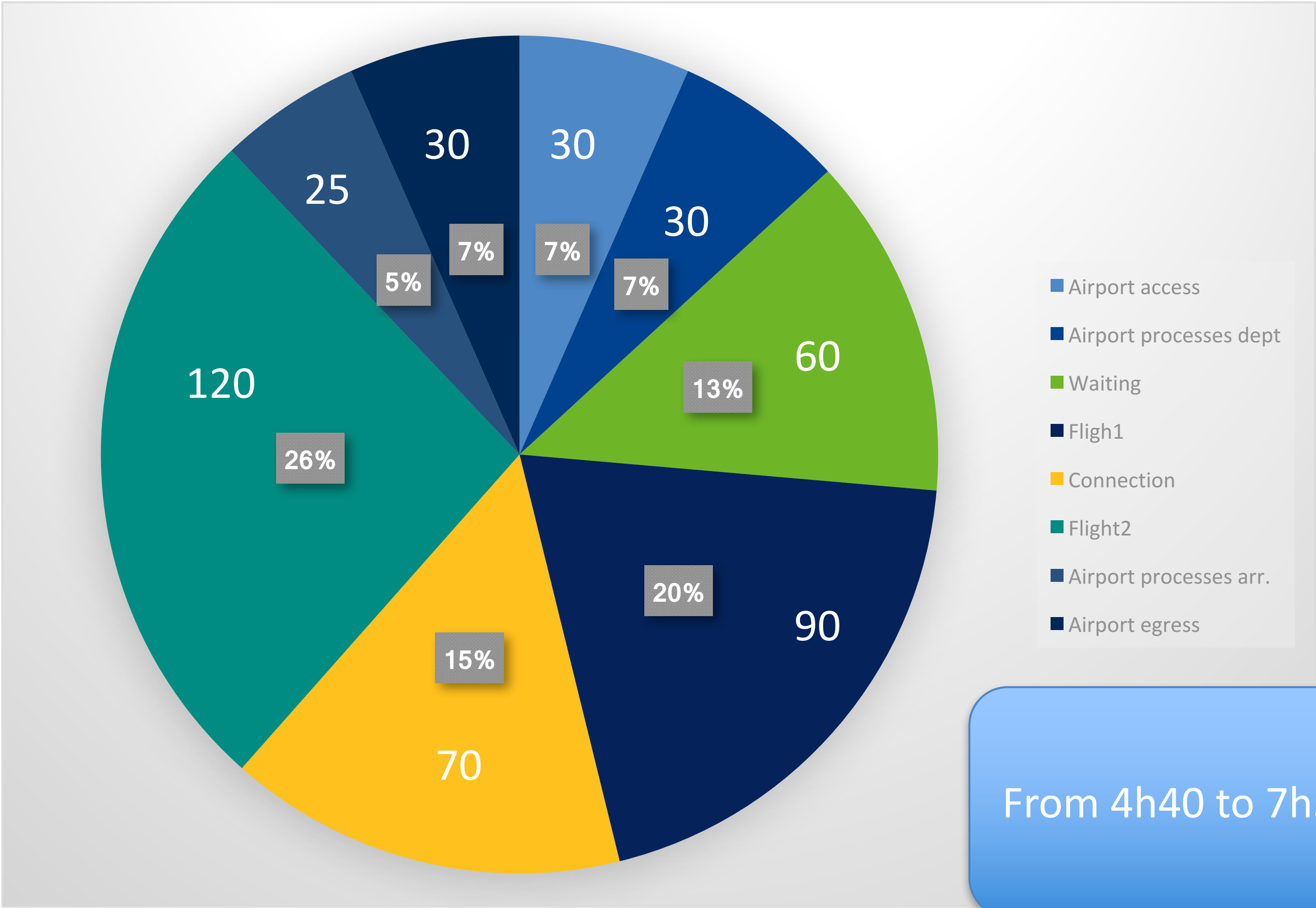
From gate-to-gate to total travel

- Belgrade – Castelldefels (via Munich)



From gate-to-gate to total travel

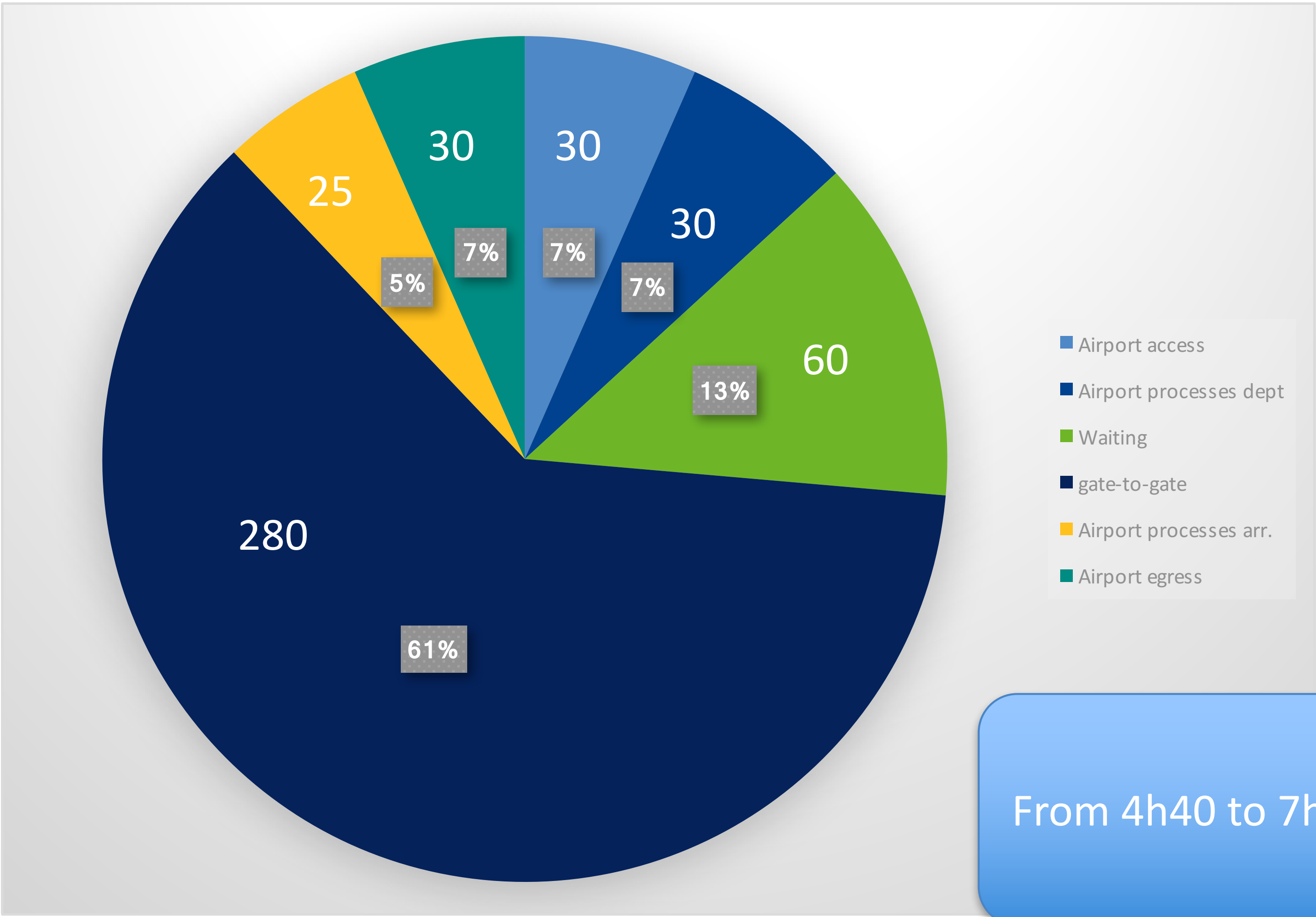
- Belgrade – Castelldefels (via Munich)



From 4h40 to 7h30

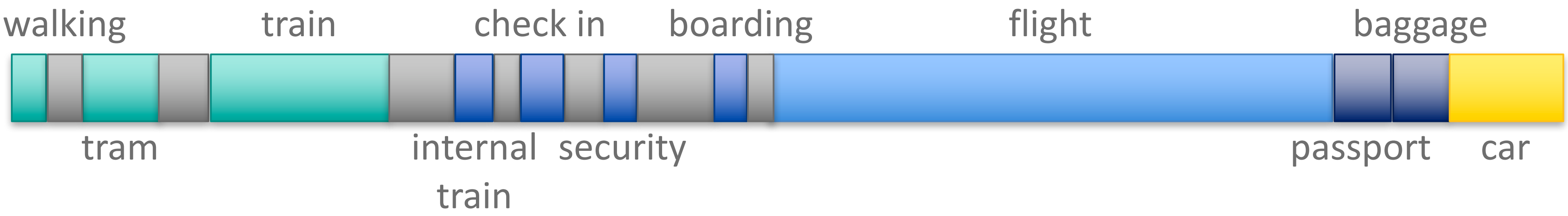
From gate-to-gate to total travel

- Belgrade – Castelldefels (via Munich)

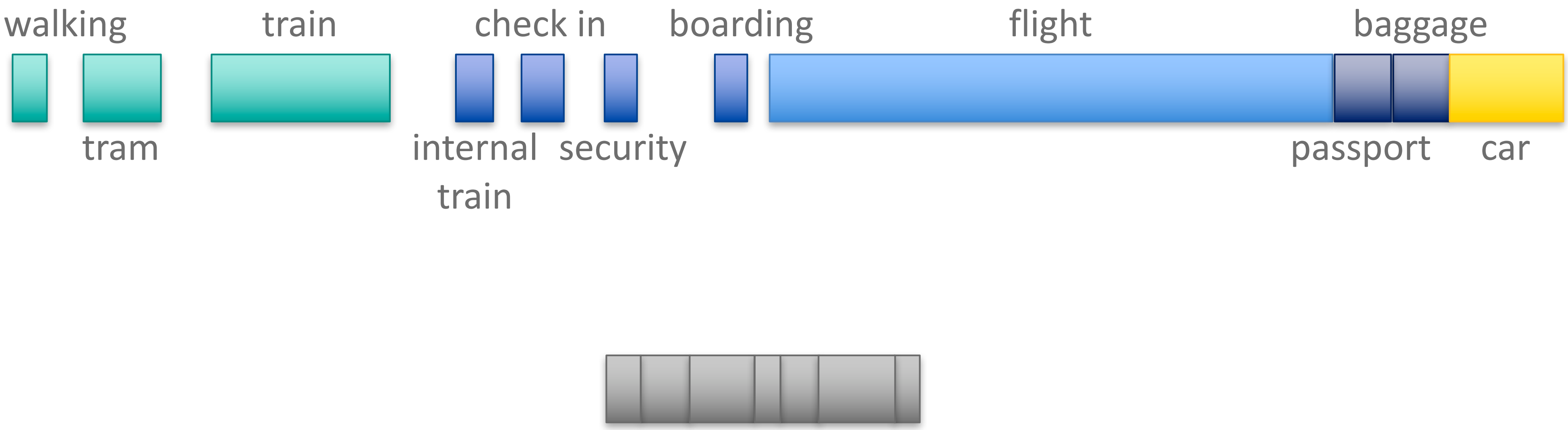


From 4h40 to 7h30

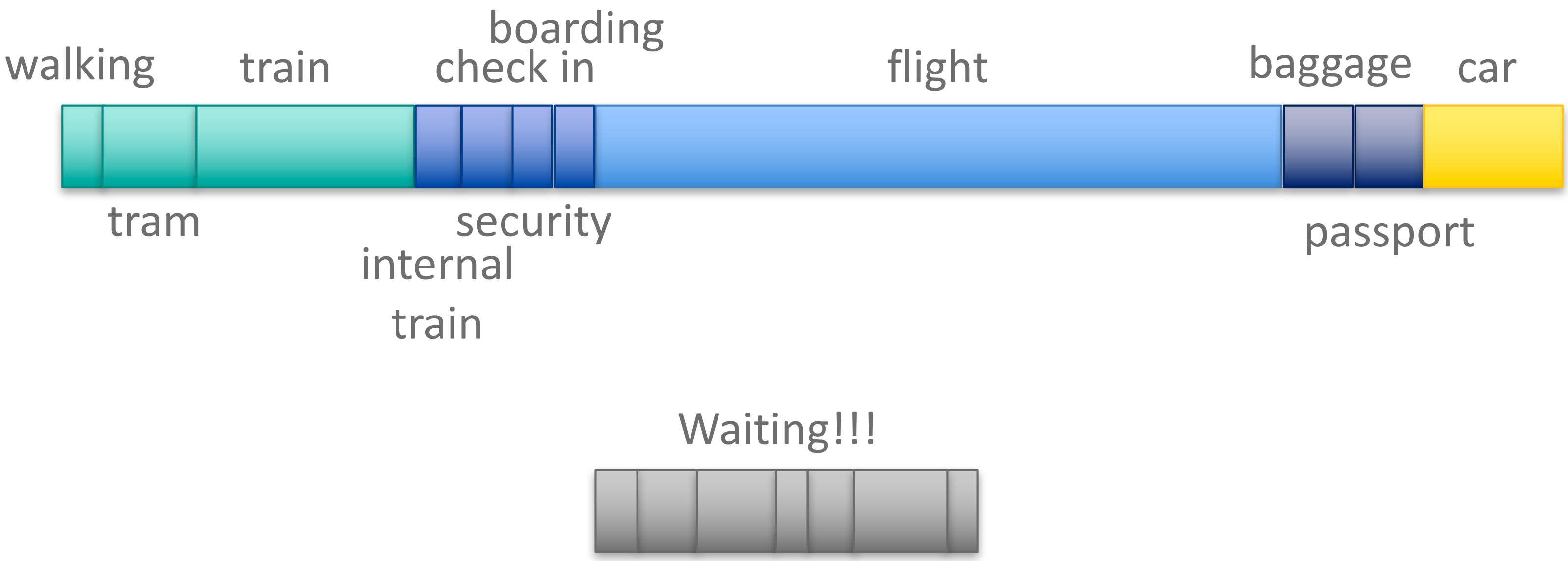
From gate-to-gate to total travel



From gate-to-gate to total travel

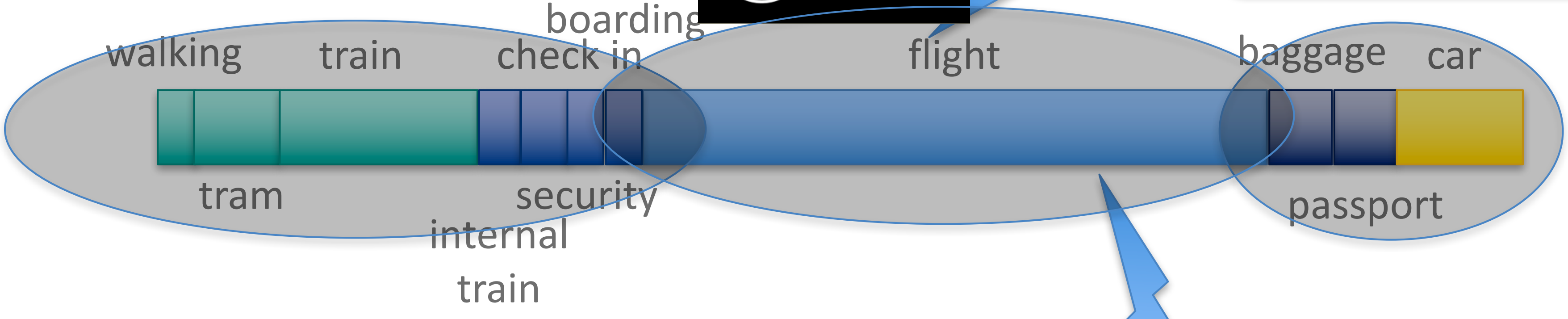


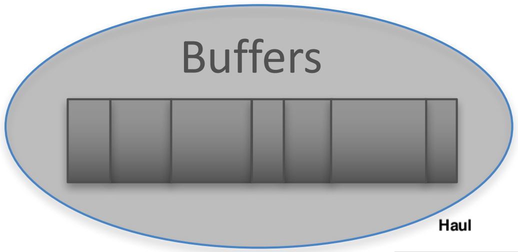
From gate-to-gate to total travel



From gate-to-gate to total travel

New technological solution (e.g. new arrival manager)





New regulatory change

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

black: 2005
blue: 2009
red: 2016-17(est.)

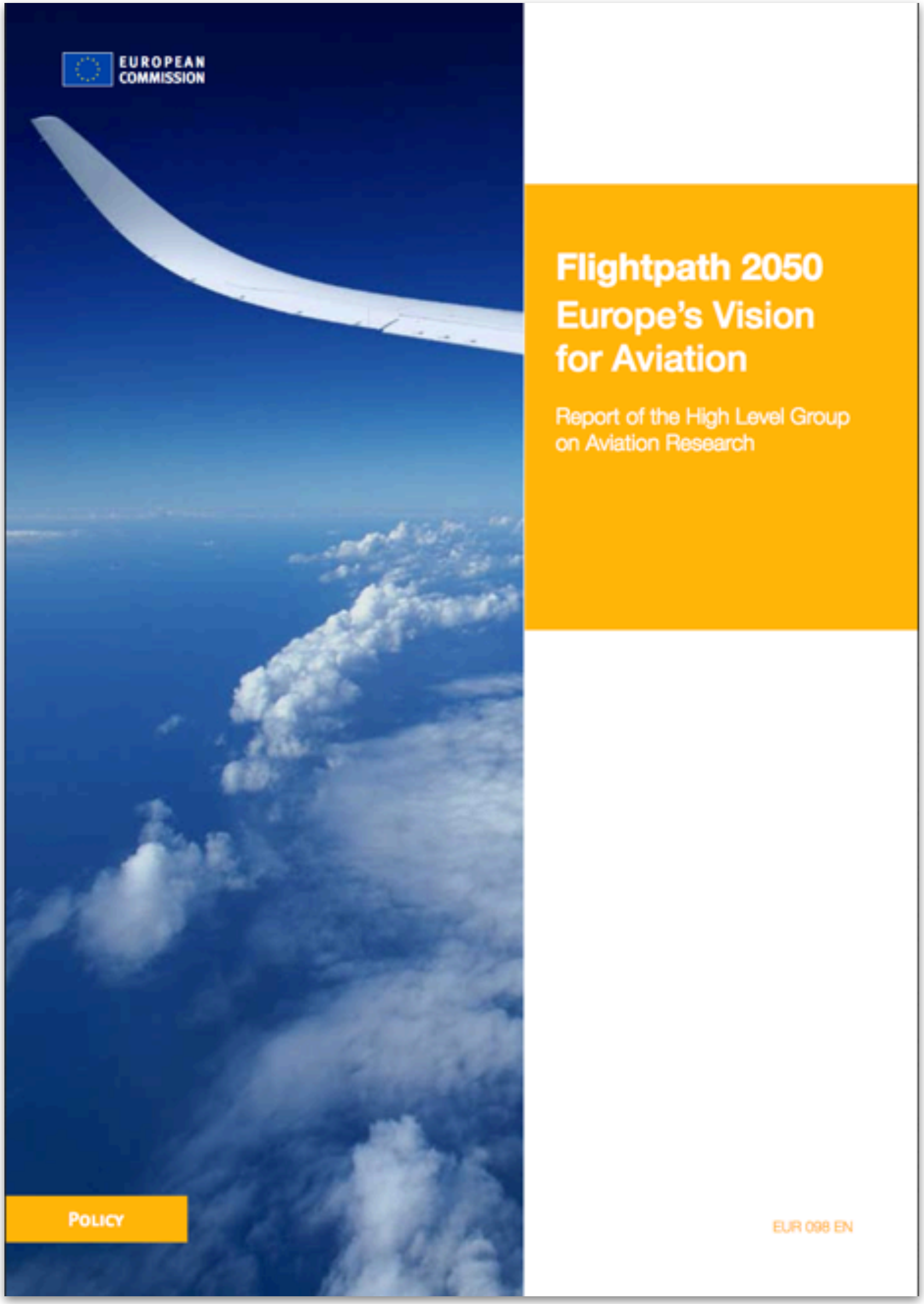
Need of platform to test changes on these phases that are not gate-to-gate

DATASET2050

Goal 2. 90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours. Passengers and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on-time.

2050

TODAY ?



How can we assess door-to-door times?

Analyzing Door to Door Travel Times Through Mobile Phone Data.
Pedro García-Alb
Oliva G. Cantú R
Ricardo Herr

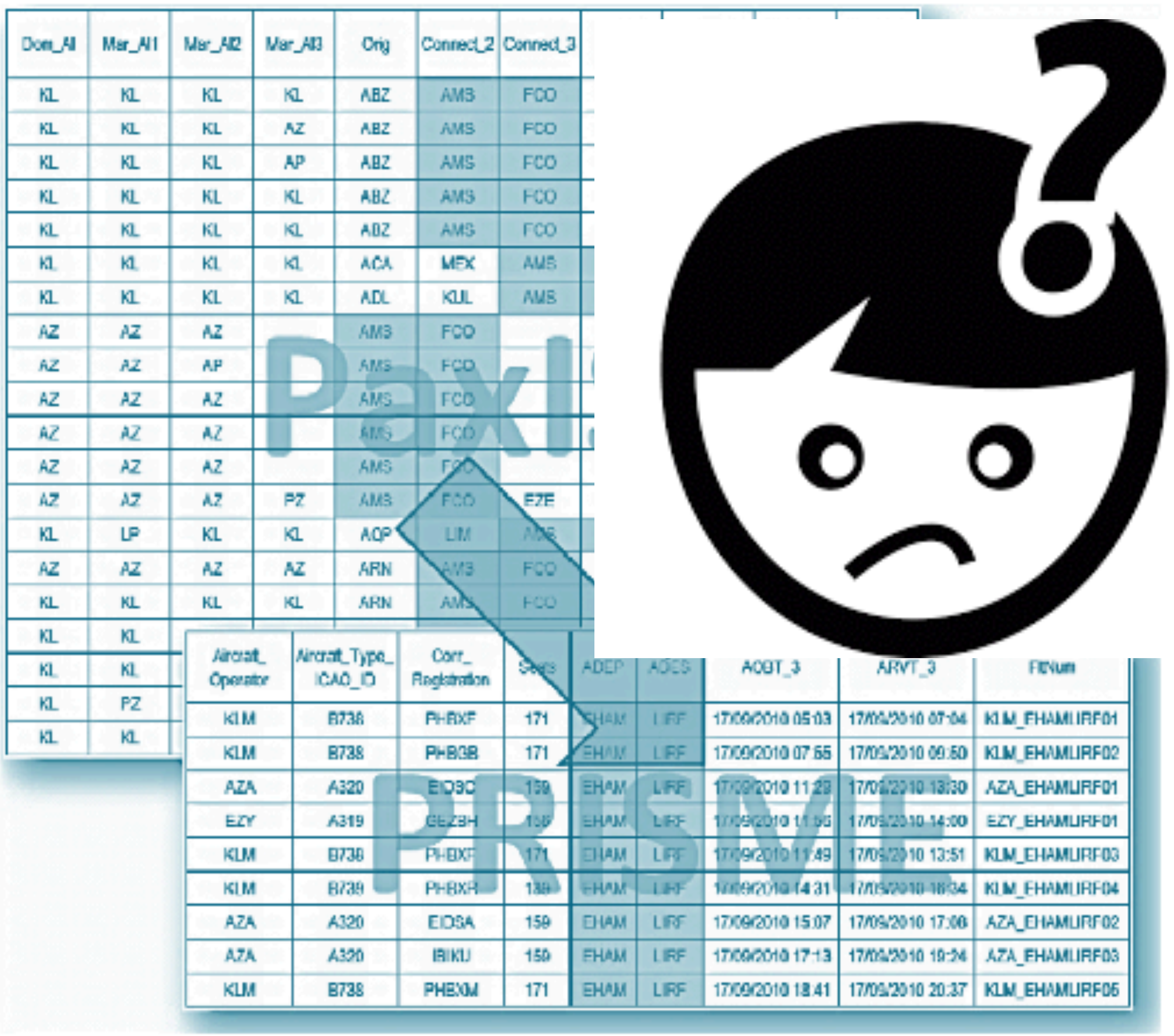
Fri.
2:40 pm
026V

S: Schengen Agreement countries
EFTA: European Free Trade Association countries

DATASET2050

DATASET2050

How many passengers?



PaxIS (IATA ticket) pax data

\+

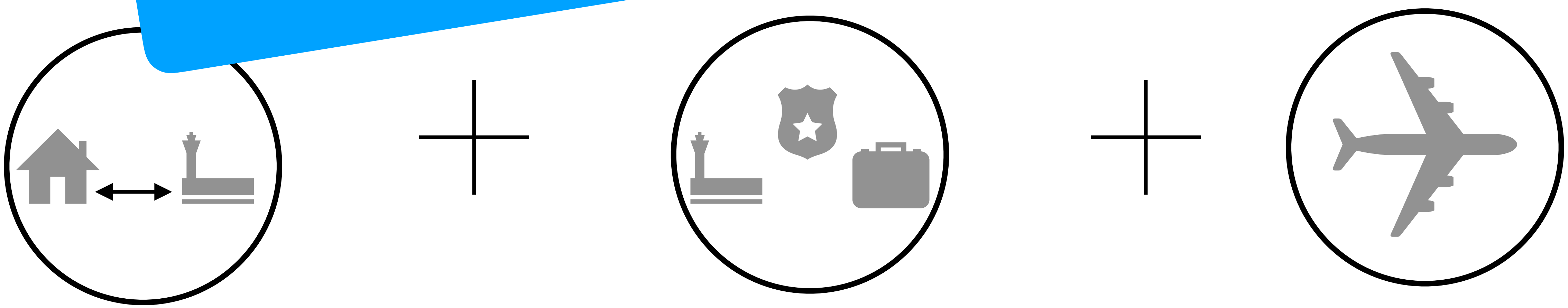
ndividual flights (PRISME traffic data)

200 airports
30.000 flights
2.5 million pax

DATASET2050

On wh… …ols?

INDEPENDENT PROCESSES — **VALID?**



Access/Egress Times

Passengers + City

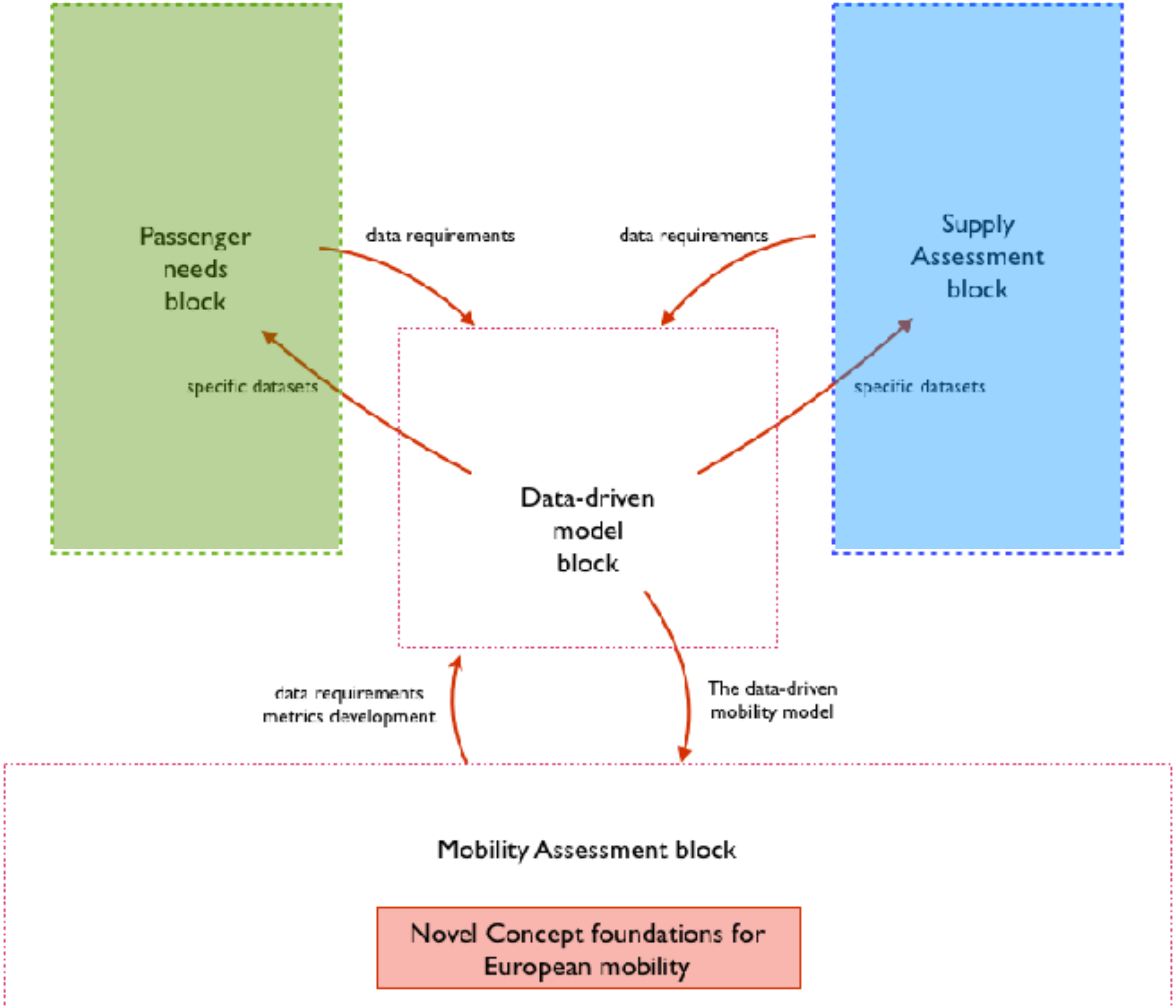
Kerb-Gate Segment

Passengers + Airport

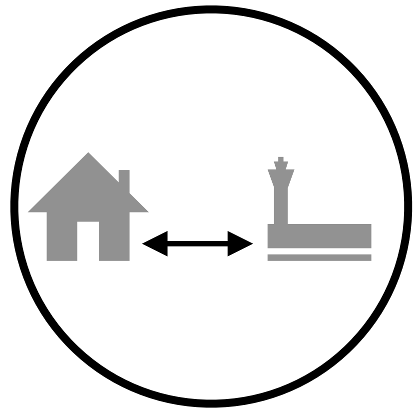
Actual Flying time

Air Transport System (delays, regulations, airline strategies, etc.)

DATASET2


Passenger
needs
block
data requirements
data requirements
Supply
Assessment
block
specific datasets
specific datasets
Data-driven
model
block
data requirements
metrics development
The data-driven
mobility model
Mobility Assessment block
Novel Concept foundations for
European mobility

DATASET2050



Access/Egress Times

What profiles for our travellers?

Economy class

Business class

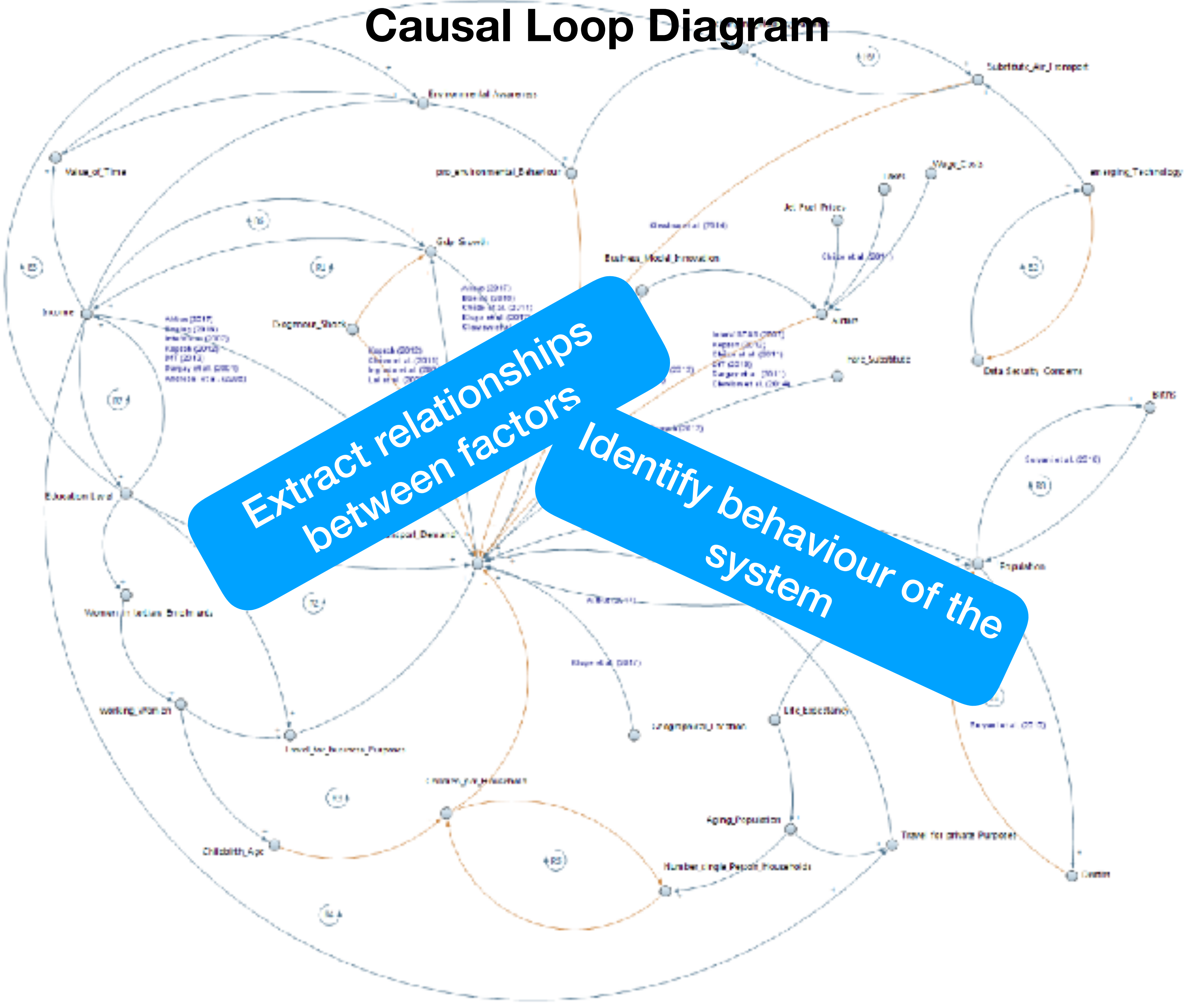
Factors influencing passenger characteristics?

Profiles are based on available European data and forecasts only

DATASET2050

Behavioural aspects
- Information and communications technology
- Environmental awareness

Causal Loop Diagram



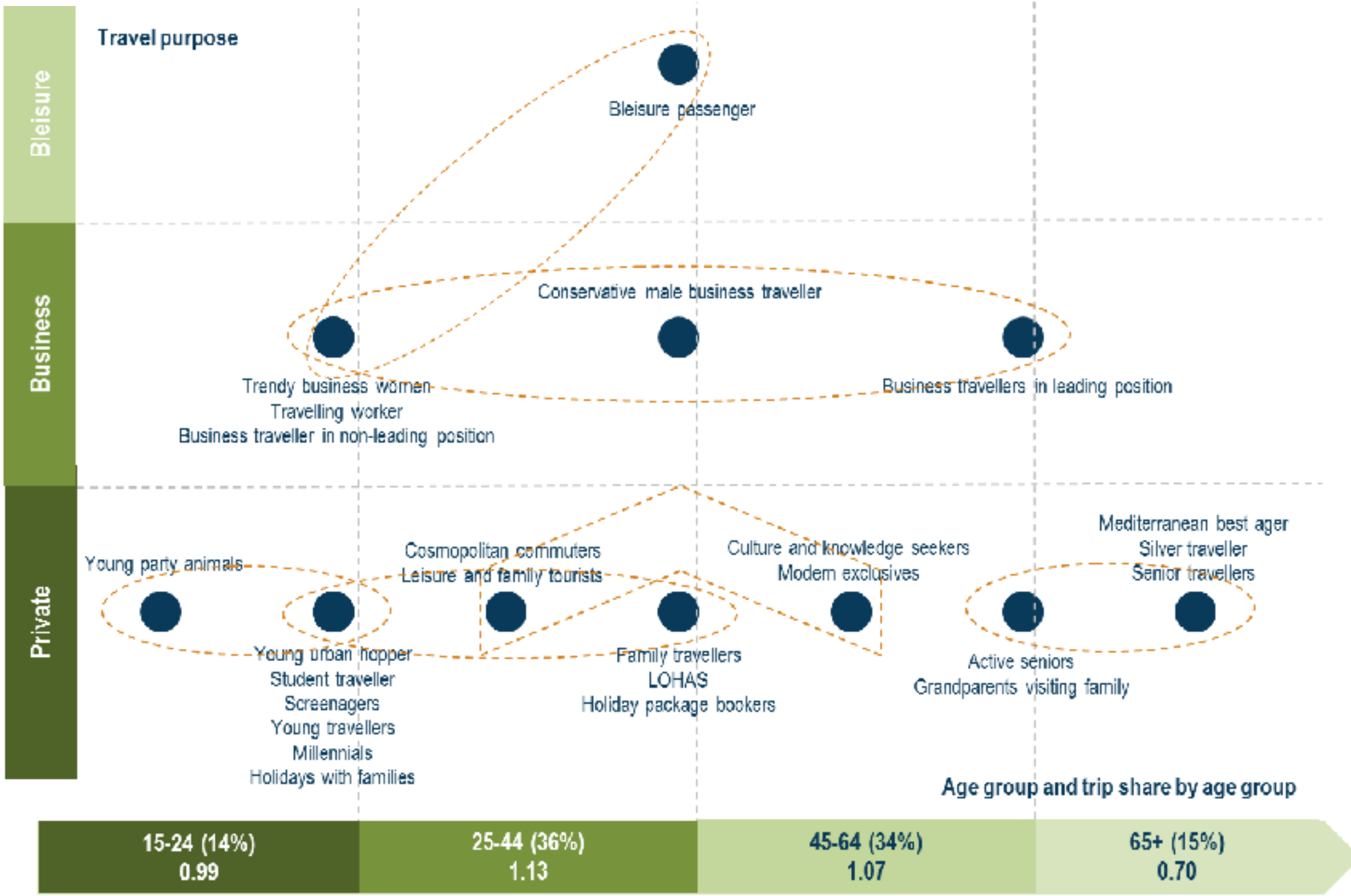
Kluge, U., Paul, A., Urban, M., Ureta, H. (2017). Assessment of Passenger Requirements along the D2D Air Travel Chain. In: Towards user-centric transport in Europe. Challenges, solutions and collaborations. Munich. Manuscript submitted and accepted.

Kluge, U., Paul, A., Ureta, H., & Ploetner, K.O. (2018). Profiling Future Air Transport Passengers in Europe. Vienna: 7th Transport Research Arena 2018.

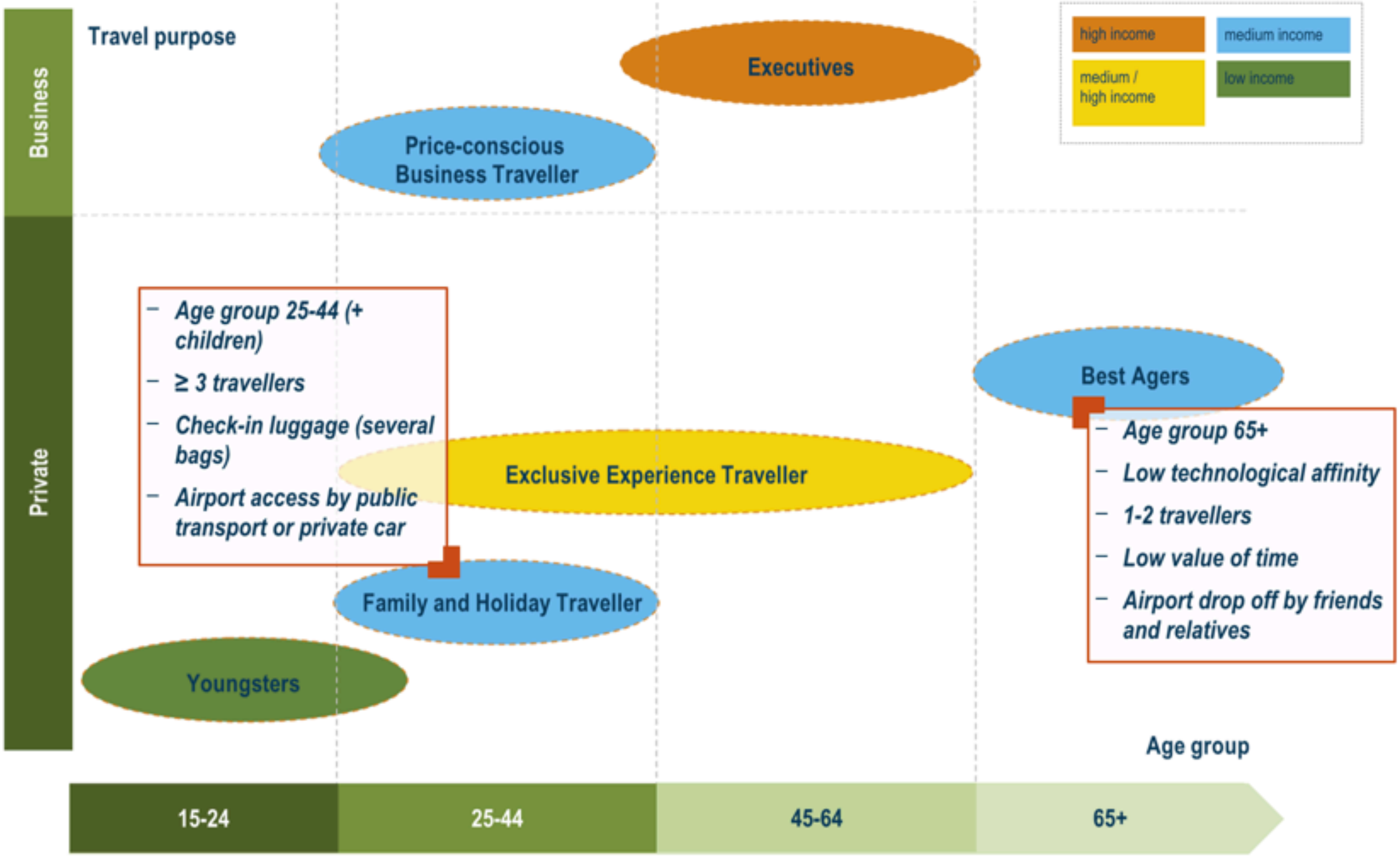
Kluge, U., Paul, A., Cook, A., & Cristóbal, S. (2017). Factors influencing European passenger demand for air transport. Antwerpen: 21st Air Transport Research Society World Conference.

Bauhaus Luftfahrt
Neue Wege.

DATASET2050



DATASET2050



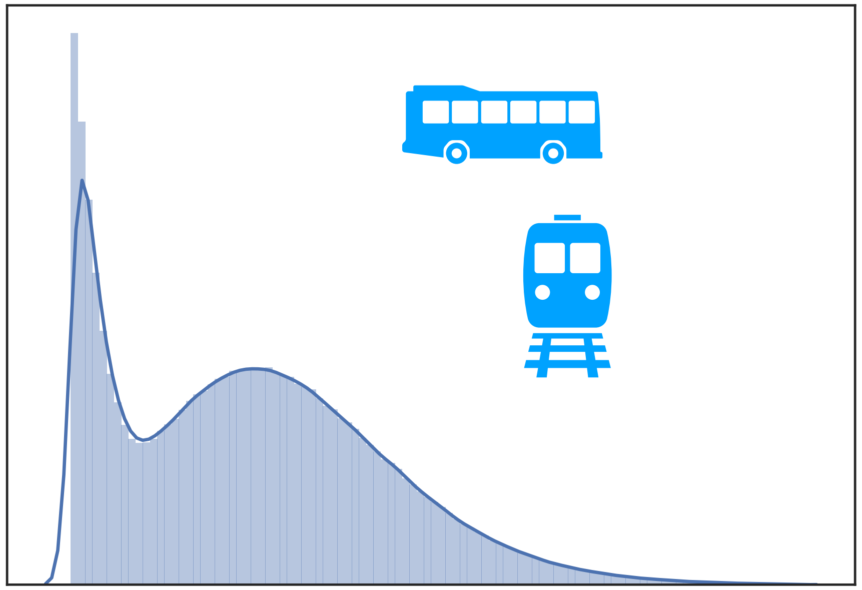
DATASET2050

	1) Cultural Seeker	2) Family & Holiday Traveller	3) Single Traveller	4) Best Agers (Next Generation)	5) Environmental Traveller	6) Digital Native Business Traveller
Main travel purpose	Private	Private	Private	Private	Bleisure	Business
Predominant age group	15 – 65	30 – 50 + children below 15	44+	65+	30 – 44	24 – 64
Luggage requirements of passenger	Hand luggage only (short trips) Check-in luggage	Check-in luggage	Hand luggage only (short trips) Check-in luggage	Check-in luggage	Hand luggage only (short trips) Check-in luggage (if necessary)	Hand luggage only (short trips) Check-in luggage
Access mode choice	Public transport Taxi Car Sharing	Public transport Private car (park and travel)	Public transport Kiss & fly	Private car (park and travel) Kiss & fly	Public transport Car Sharing Cycling (if possible)	Public transport Taxi Car Sharing

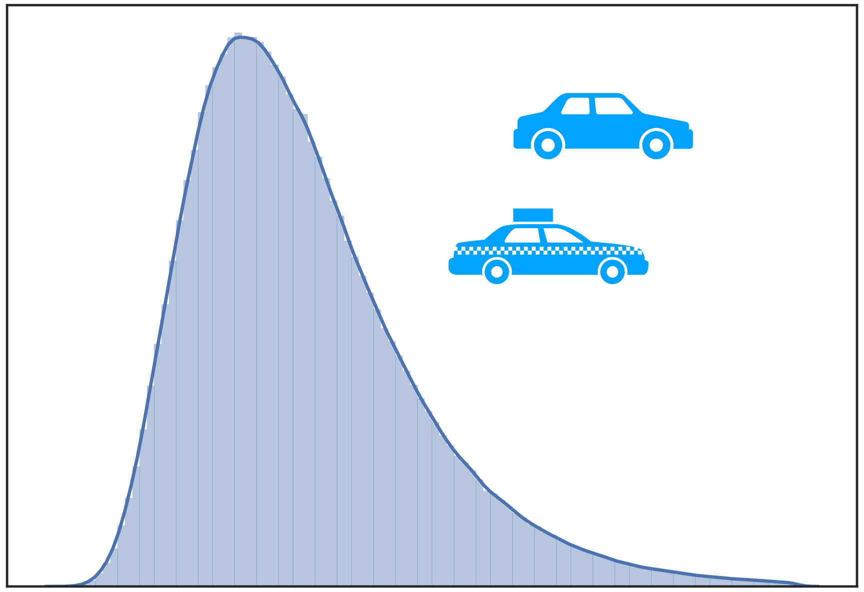
DATASET2050

$$D2K_k = \boxed{T_{m_k}} + B^1_{k,m_k}$$

$m_k \sim$ **Generalized Bernoulli Distribution with** $p(m_i) = p_i$



$$T_m \sim \sum_{i=1}^{2} LogN(\mu, \sigma^2)$$



$$T_m \sim LogN(\mu, \sigma^2)$$

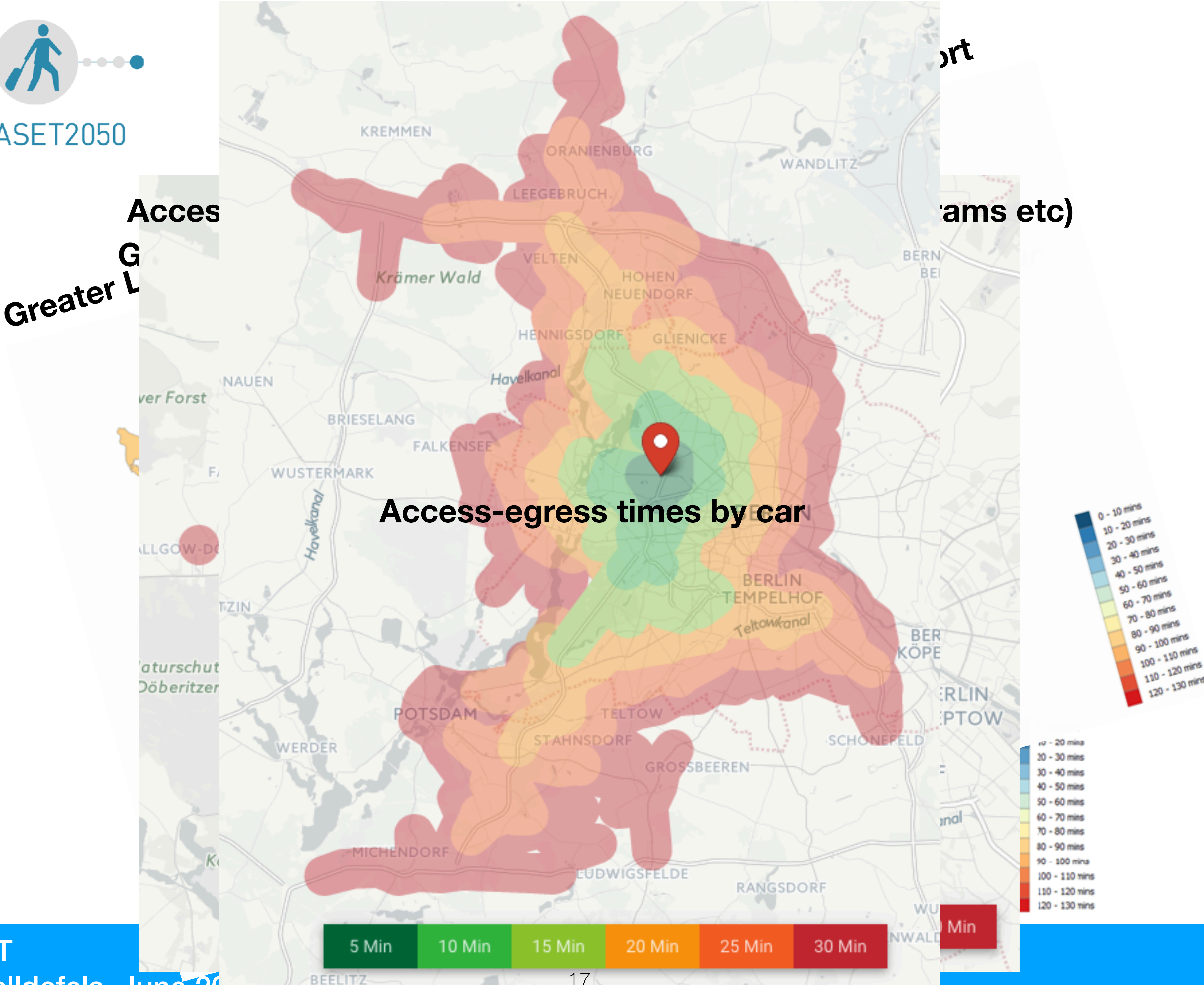
DATASET2050

$\mu?\sigma?$

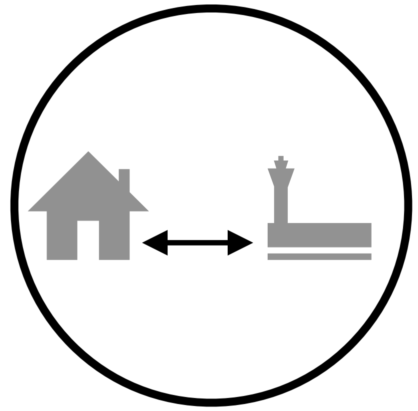
AIRPORT/CITY DEPENDANT

16

DATASET2050



DATASET2050



Access/Egress Times

$$D2K_k = T_{m_k} + B^1_{k,m_k}$$

Unavailable information!

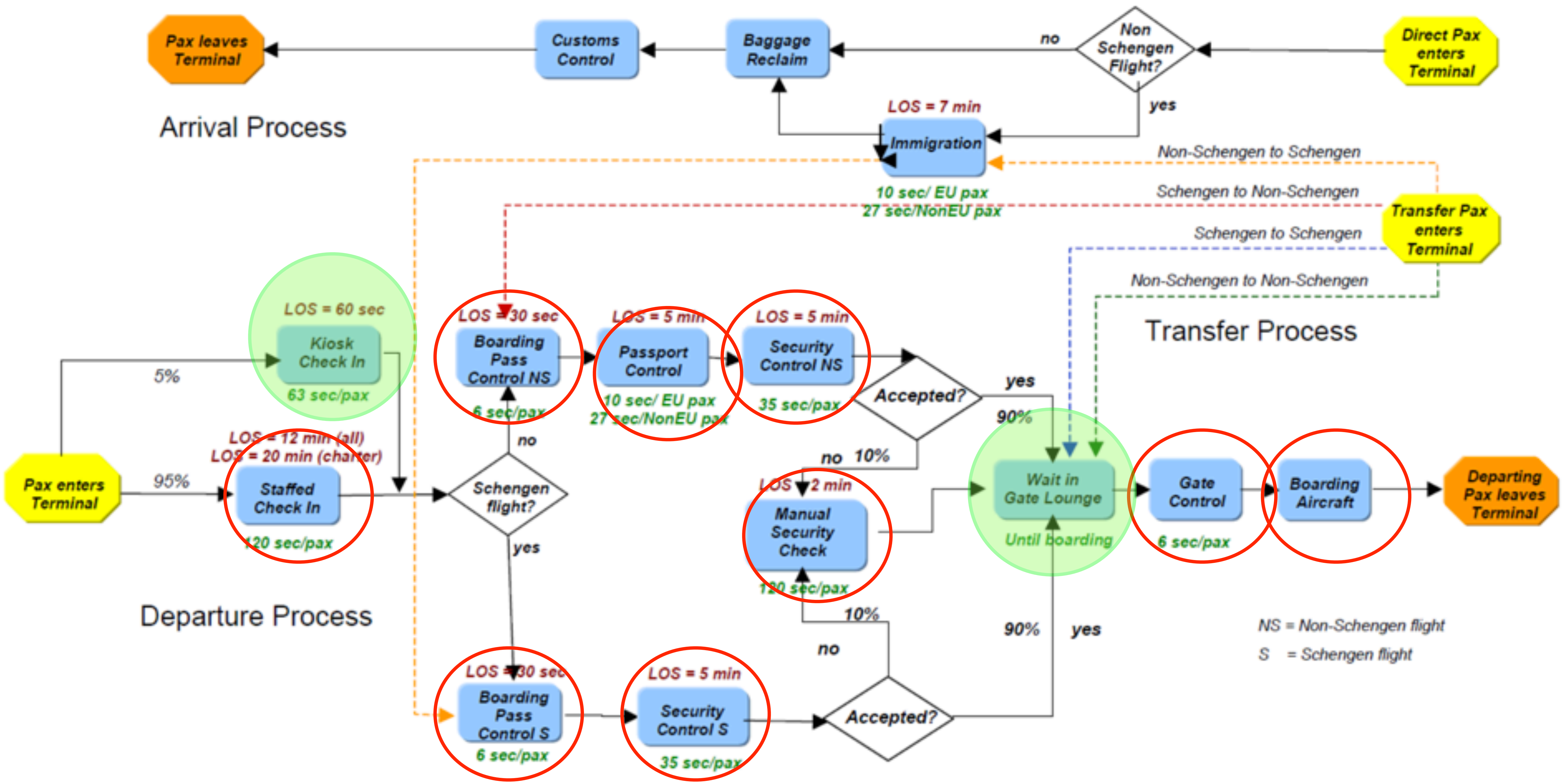
18

Kerb-Gate Segment

DATASET2050

PROCESS

BUFFER



DATASET2050

Airport	Total pax/year (million)	Avera… securi… queue… (minu…
Heathrow	72.3	7.27

Facility	Process time (secs)
Check-in counter	120
Check-in terminal	63
Bag-drop	45 +25/bag
Boarding-Pass Control	6

Walking time (google maps)

Airport	Terminal	Minimum walk (m)	Maximum walk (m)	Average walk (m)	Internal shuttle (mins)	Shuttle frequency (mins)	Minimum time (min)	Maximum time (min)	Average time (min)
Munich	T1	100	200	150	0	0	1.2	2.4	1.8
	T1S	300	450	375	0	0	3.6	5.4	4.5
	T2	200	680	440	0	0	2.4	8.1	5.2
	T2S	280	710	440	1	1	4.3	10.5	6.7
Frankfurt	T1	150	800	400	0	0	1.8	9.5	4.8
	T2	150	1350	320	0	0	1.8	16.1	3.8

DATASET2050

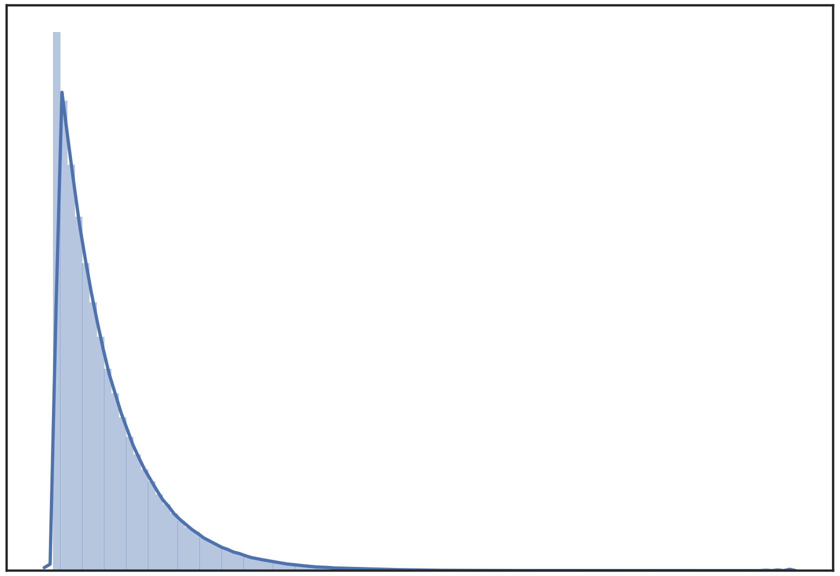
PROCESSING TIMES

$$K2G_{k,a} = \sum_{i} (\delta_k^i \,.\, P_a^i) + B_{k,a}^2$$

$$G2K_{k,a} = \sum_{i} (\delta_k^i \,.\, P_a^i)$$

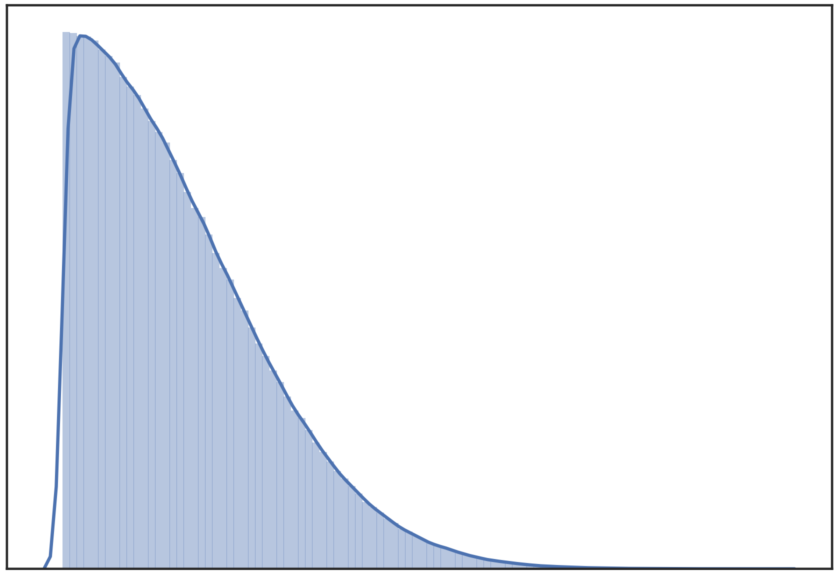
PROCESSING TIMES

Queuing processes



$$\sim \lambda e^{\lambda . x}$$

Other processes



$$\sim \frac{\phi(\frac{x-\mu}{\sigma})}{\sigma(\phi(\frac{b-\mu}{\sigma}) - \phi(\frac{a-\mu}{\sigma}))}$$

DATASET2050

PROCESSING TIMES

$$K2G_{k,a} = \sum_i (\delta_k^i \cdot P_a^i) + B_{k,a}^2$$

$$G2K_{k,a} = \sum_i (\delta_k^i \cdot P_a^i)$$

DATASET2050

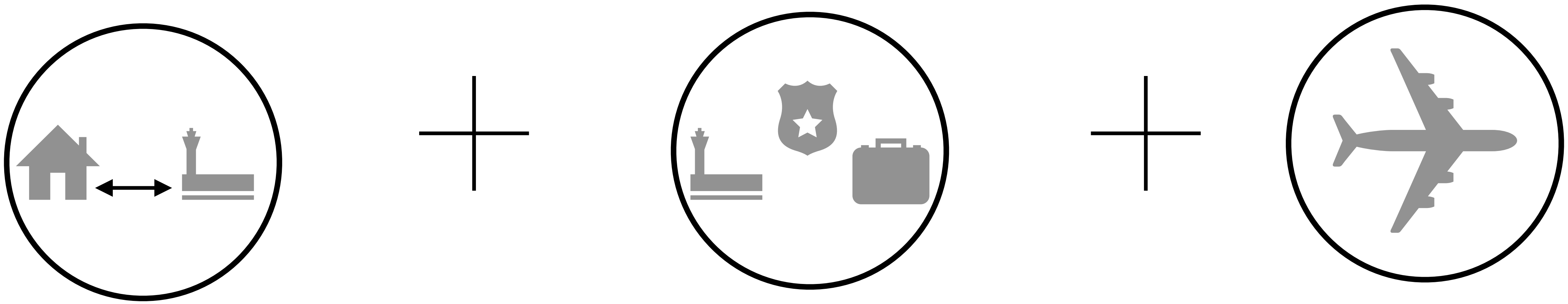
BUFFER TIMES

$$B^{2}_{k,a} = B^{process}_{a,k} + B^{travel}_{a,k}$$

$$= B^{1}_{k,m_k}$$

Actual Flying time

BLOCK STRUCTURE



Access/Egress Times + **Kerb-Gate Segment** + **Actual Flying time**

DATASET2050

```python
            self.extractD2K(np.random.choice(np.arange(len(weights)),
                                                        int(count), p=weights_temp),Options)

        #self.price_list = np.array(self.price_list,dtype=float) + np.array(self.price_D2K,dtype=float)

    def extractD2K(self,Val,Options):

        time_options = Options.time_airp_dist.loc[self.origin_type]
        lo = []
        priceD2K = []
        for v in Val:
            lo.append(time_options[v](np.random.randint(0,len(time_options[v]))))
            priceD2K.append(Options.price_airp.loc[self.origin_type][v])
        self.D2K_list.extend(lo)
        self.price_D2K.extend(priceD2K)

    def get_list_K2D(self, Options):
        """Return actual D2K travel time of all passenger for a concrete origin/business."""
        type_destination = Options.type_airp[self.arr_airp]
        if type_destination == 1:
            self.destination_type = self.arr_airp
        elif type_destination == 2:
            self.destination_type = '100MD'
        elif type_destination == 3:
            self.destination_type = '100seas'
        elif type_destination == 4:
            self.destination_type = '200MD'
        elif type_destination == 5:
            self.destination_type = '200seas'

        weights = np.array(Options.weight_airp.loc[self.destination_type].fillna(0))/100

        l = np.unique(self.pax_cat_list,return_counts=True, return_index=True)
        for element, count in zip(l[0][np.argsort(l[1])],l[2][np.argsort(l[1])]):

            weights_temp = np.nan_to_num( weights * np.array(Options.type_pax.loc[element,:]) )
            weights_temp = weights_temp / np.sum(weights_temp)

            self.extractK2D(np.random.choice(np.arange(len(weights)),
                                                        int(count), p=weights_temp), Options)

        #self.price_list = np.array(self.price_list,dtype=float) + np.array(self.price_K2D,dtype=float)

    def extractK2D(self,Val,Options):
```

PARALLEL SPEED-UP ∼ 15 min

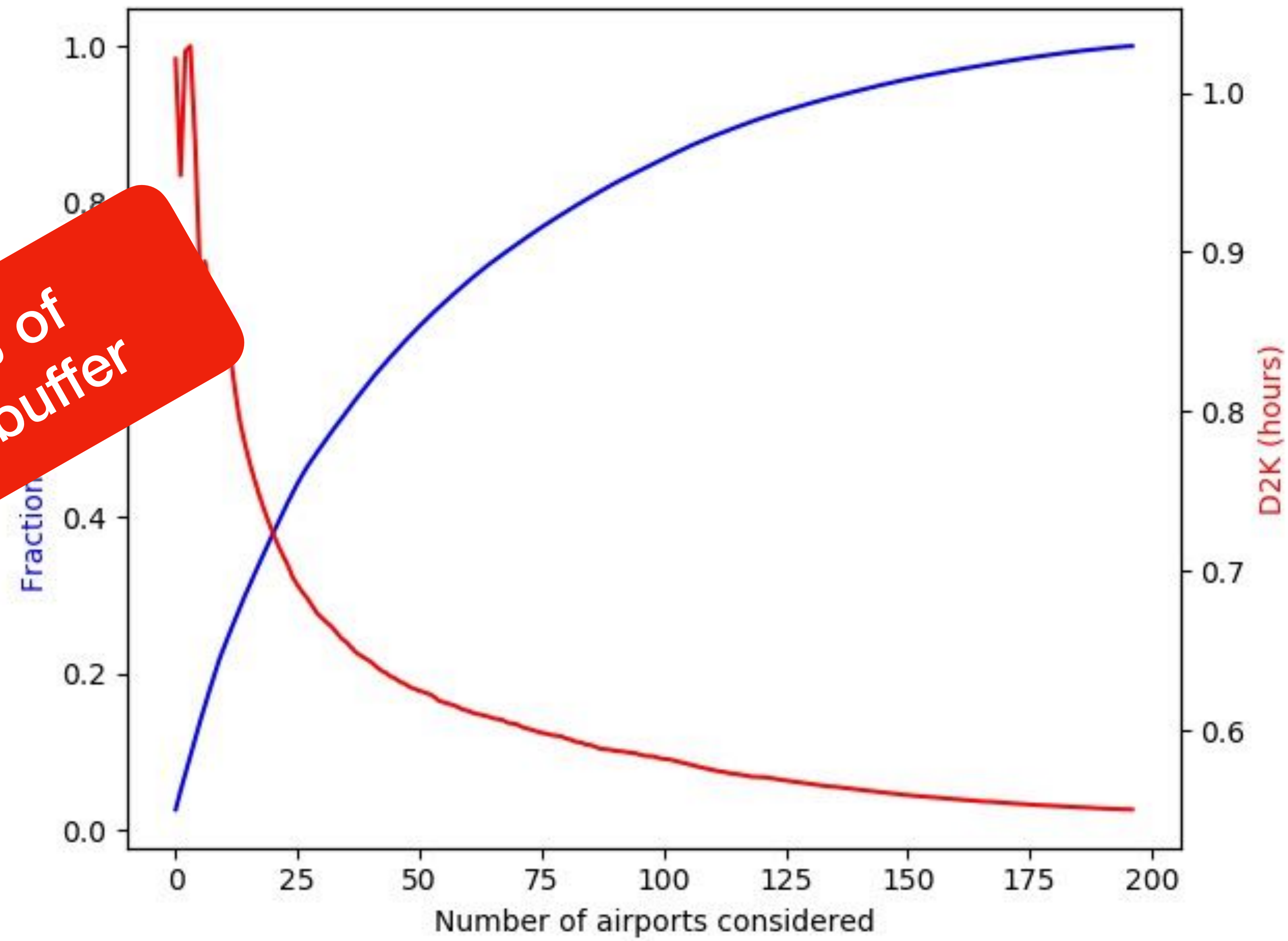
∼ 2 Millions Passengers simulated

DATASET2050

DATASET2050

Segment	Avg. times
D2K	33 minutes
K2G	1 hour 54 minute
G2G	2 hours 3
G2K	31 m
K2D	28 mi
D2D	6 hours

70-80% of K2G is buffer



Interactive results - for fun only?

http://visual.innaxis.org/dataset2050/d2d-time-distribution

http://visual.innaxis.org/dataset2050/d2d-time-map

DATASET2050

PROFILE	MEAN	90TH PERCENTILE	% IN LESS THAN 4 HOURS
EXECUTIVE	5 hours 20 minutes	7 hours 10 minutes	30%
EXCLUSIVE	5 hours 45 minutes	8 hours 5 minutes	14%
FAMILY	6 hours 20 minutes	8 hours	2%
PRICE-CONSCIOUS	5 hours 25 minutes	7 hours	17%
BEST AGERS	6 hours	7 hours 40 minutes	4%
YOUNGSTERS	5 hours 35 minutes	7 hours 15 minutes	13%

DATASET2050

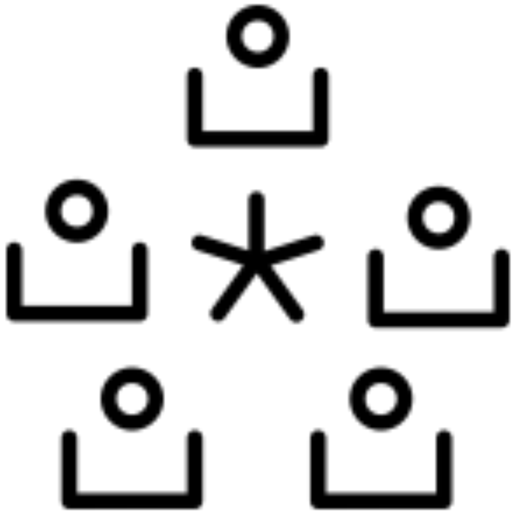
what gets measured gets managed –
even when it's pointless to measure and manage it, and even if it harms the purpose of the organisation to do so

Peter Drucker
1909 – 2005

KPIs

1. Time of Travel
2. Passenger confo
3. Affordability: http:// maxis.org/dataset2050/d2d-price-map

Other important KPIs
pax-oriented?



Validation?

Validations done

EUROCONTROL or CODA's statistics

Sensitive internal statistics from a top-10 airport against which the results of our simulator matched with a 5% error

Other possible validations

Internal airport/airline pax-data statistics

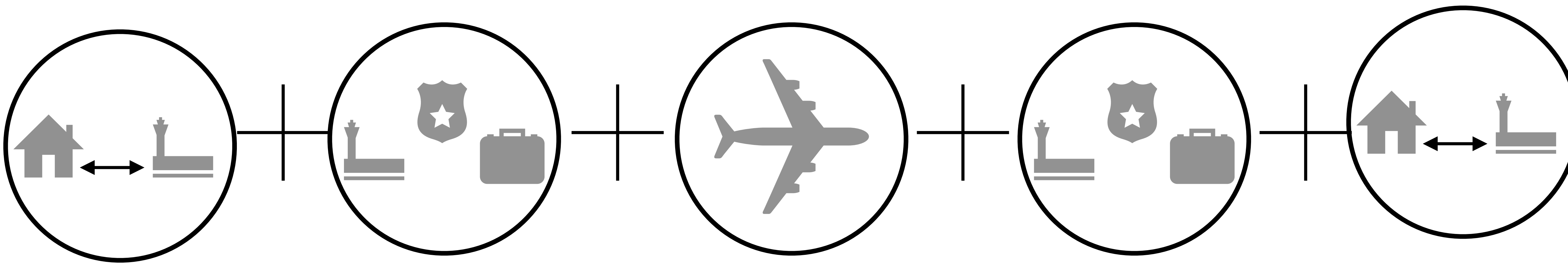
Cross-reference with other projects:

1. BigData4ATM
2. DORA (Bayesian Approach)


2050?

DATASET2050

What would you do to reduce D2D times?



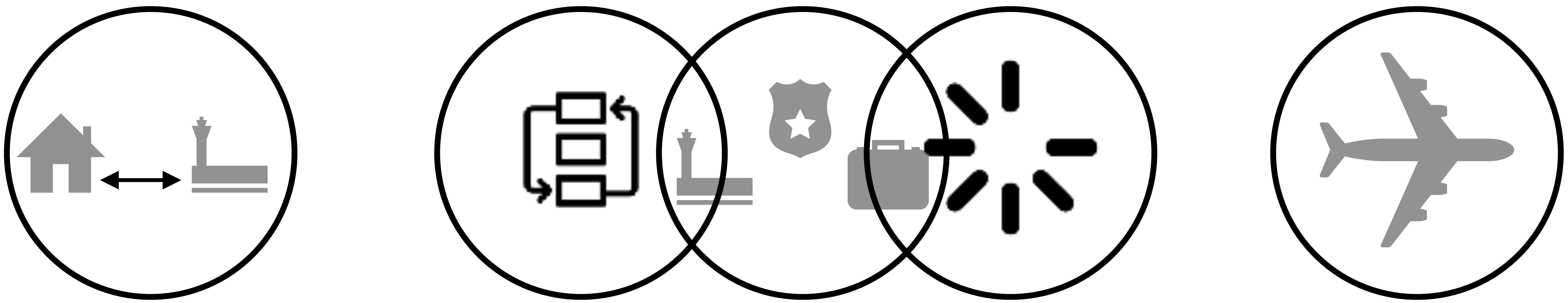
Access Times | **Kerb-Gate Segment** | **Actual Flying time** | **Gate-Kerb Segment** | **Egress Times**

DATASET2050

AREAS OF INTEREST

4 GROUPS

~~3~~ ps of brainstorming



Access/Egress Times

Kerb-Gate Process

Kerb-Gate Segment

Buffer/Waiting times

Actual Flying time

DATASET2050

AREAS OF INTEREST

How do we reduce the access/egress time to airport?
e.g. smart airports? Unique travel ticket? Insurance?

GROUP C

Are process in airports efficient?
e.g. over all airports? Necessity of all steps? Queue management?

GROUP B

Can we reduce G2G duration?
e.g. speed of aircraft? Higher traffic = higher delays?

GROUP D

What about buffers?
e.g. conservative vs. risky behaviours/persons, shopping willingness, sp… rk?

GROUP A

How to assess the validity/effects of our ideas?

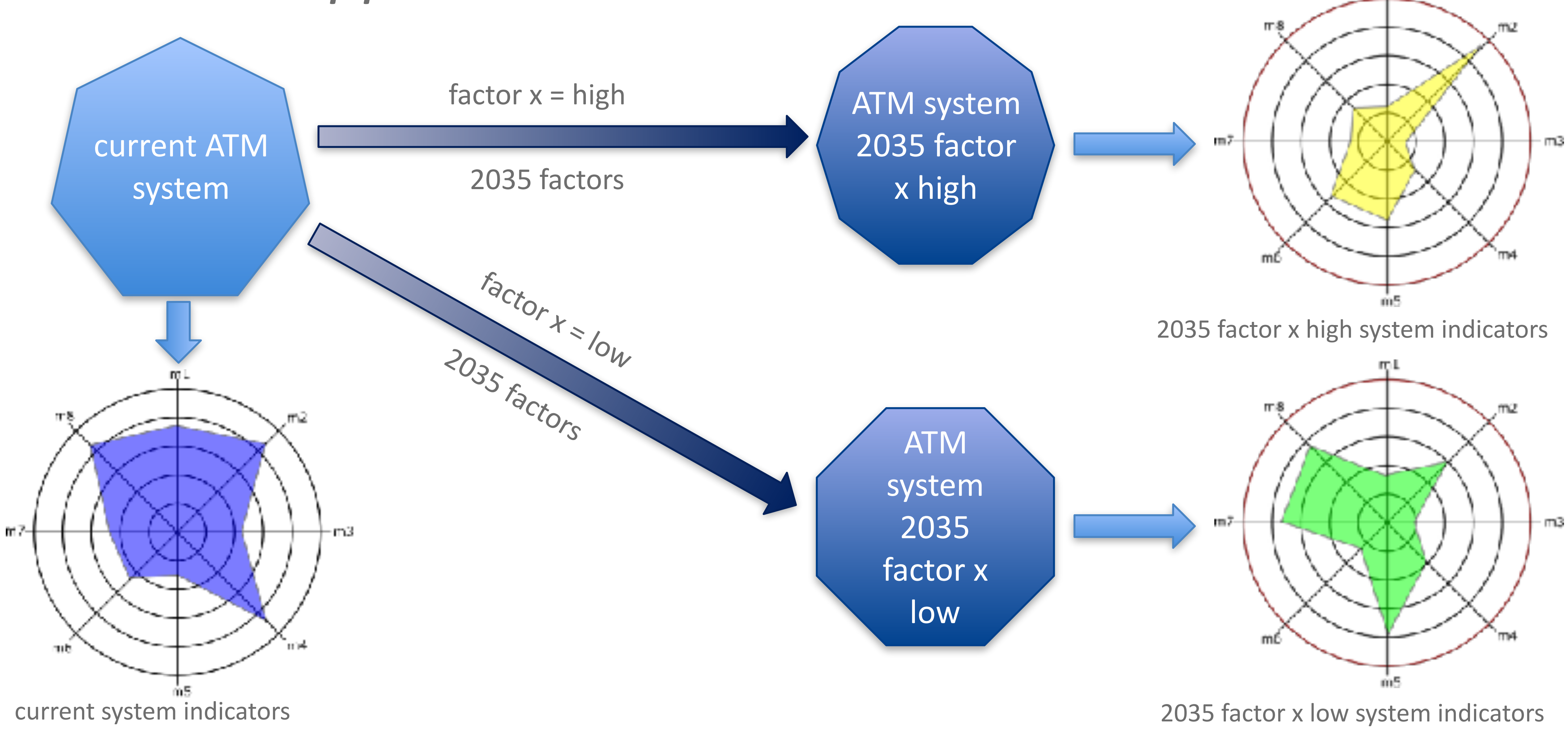
Vista model

Vista model is a ‘what-if’ simulator

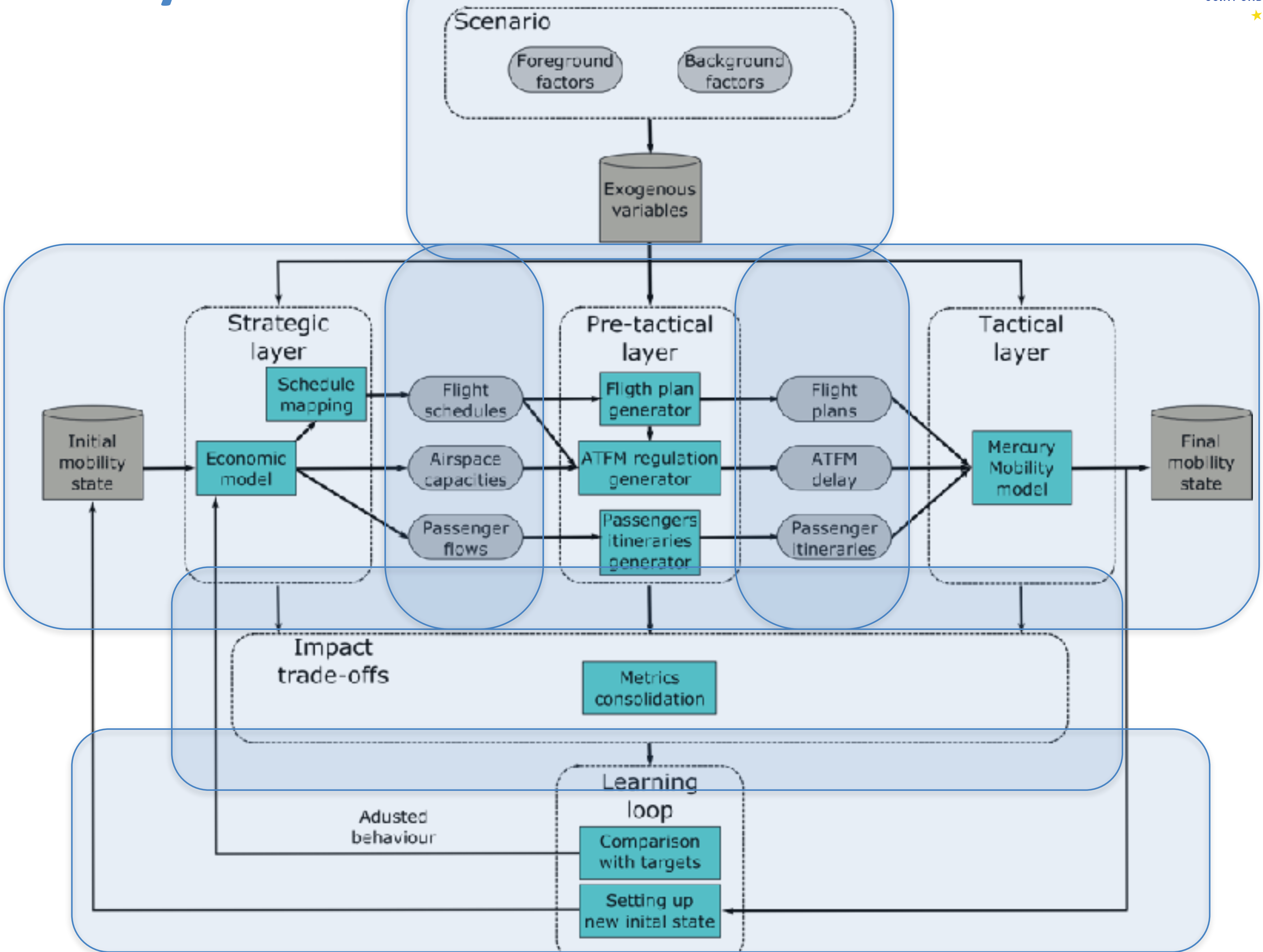
- *What happens if I do something in the system?*

And **not**:

- *What will happen in 2035 or 2050?*



Multi-layered architecture of Vista



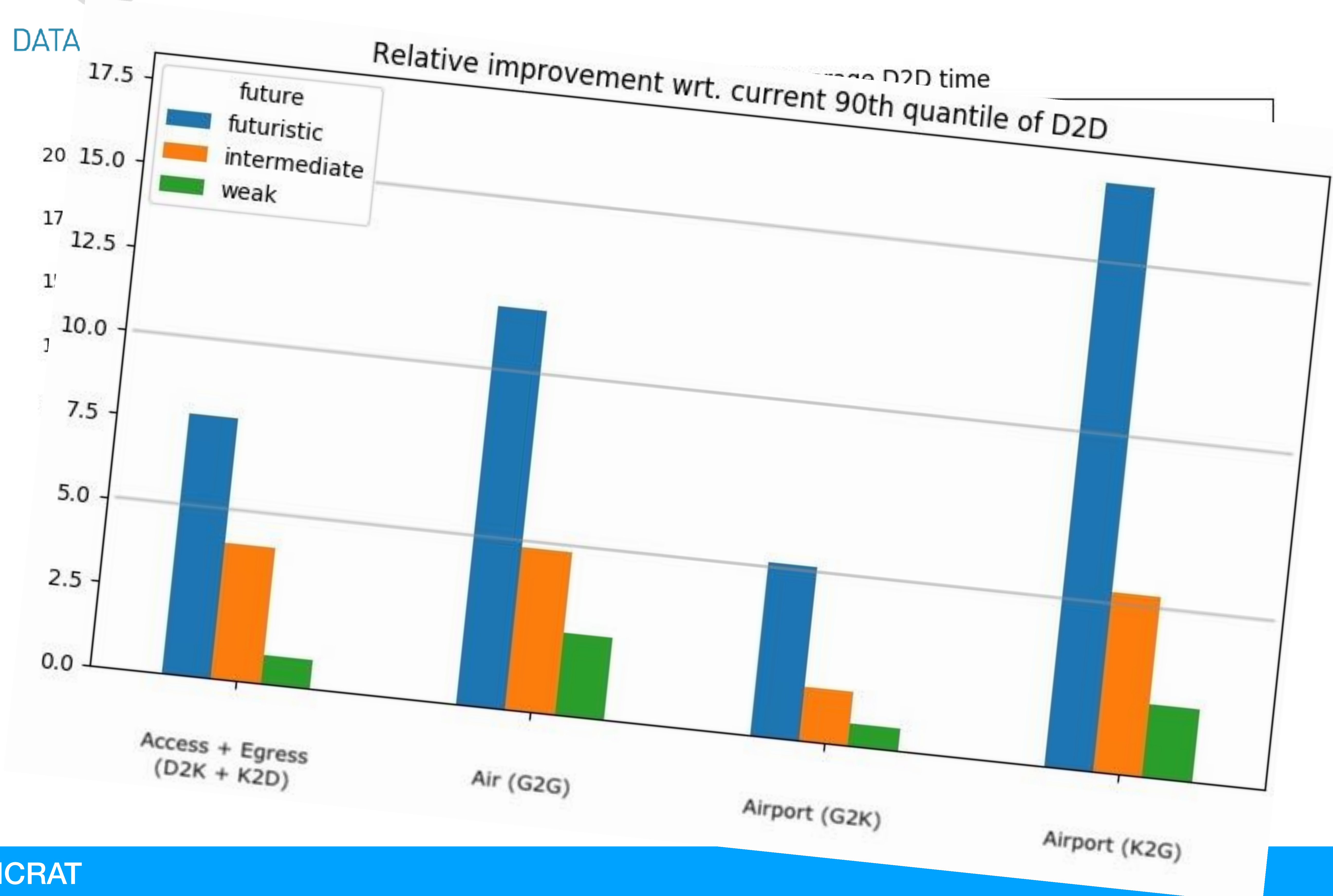
Tested solutions

Futuristic version

Average expectations

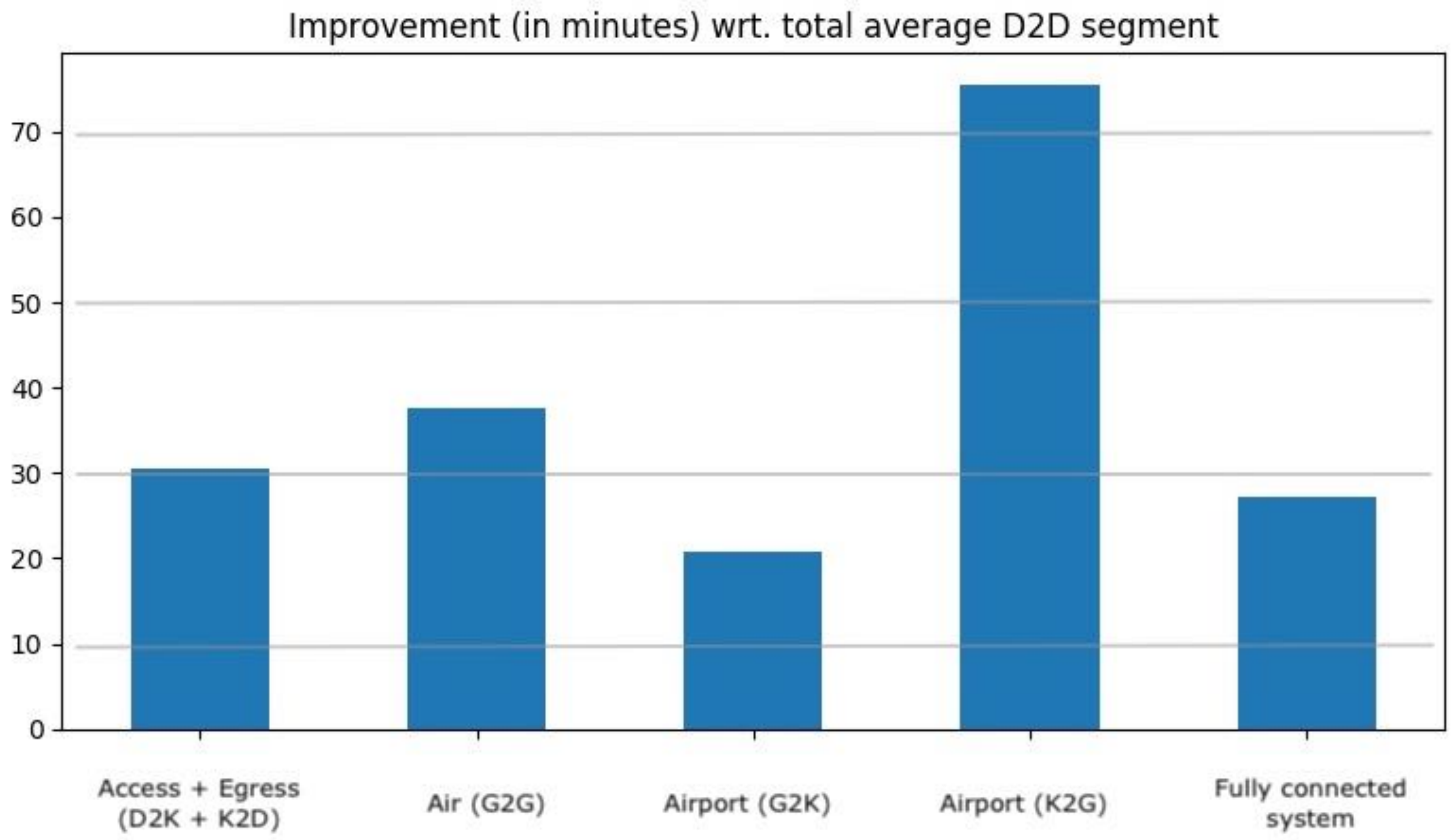
Low development

DATA



Relative improvement wrt. current 90th quantile of D2D
future
futuristic
intermediate
weak
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Access + Egress (D2K + K2D)
Air (G2G)
Airport (G2K)
Airport (K2G)

DATASET2050



Conclusions

What do we measure?
How do we measure it?

If we don’t measure something,
we don’t consider it.
Pax need to be included

Which trade-offs?
Which optimisations?

How to validate?

Q&A session

DATASET2050

Thank you

Luis Delgado & Seddik Belkoura
University of Westminster (UoW) & INNAXIS Research Institute

UNIVERSITY OF WESTMINSTER

innaxis
innovation for a complex world