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Modeling the European Air Transportation Network considering inter-airport coordination

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Table of Content

1. Introduction
2. European air transportation network model
3. Methodology to determining flight connections from FSNC
4. Simulation setup and results
5. Conclusion & Outlook



1. Introduction

Motivation

- Consistent growth of passenger and flight numbers
 - Delay in Europe constantly increasing with high numbers in 2018 → capacity limits reached
 - Capacity gap of 1.5 million flights in 2040 is forecasted by EUROCONTROL
- **Capacity increase essential to meet quality goals from Flightpath 2050 and ATM Masterplan**

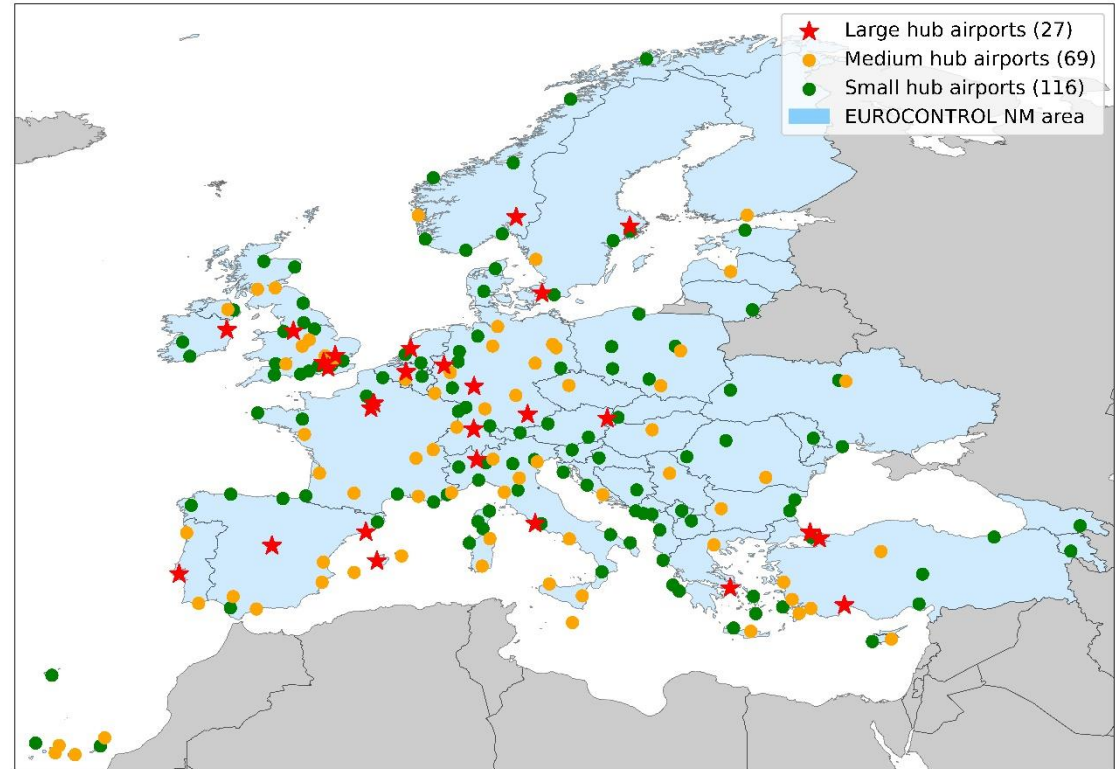
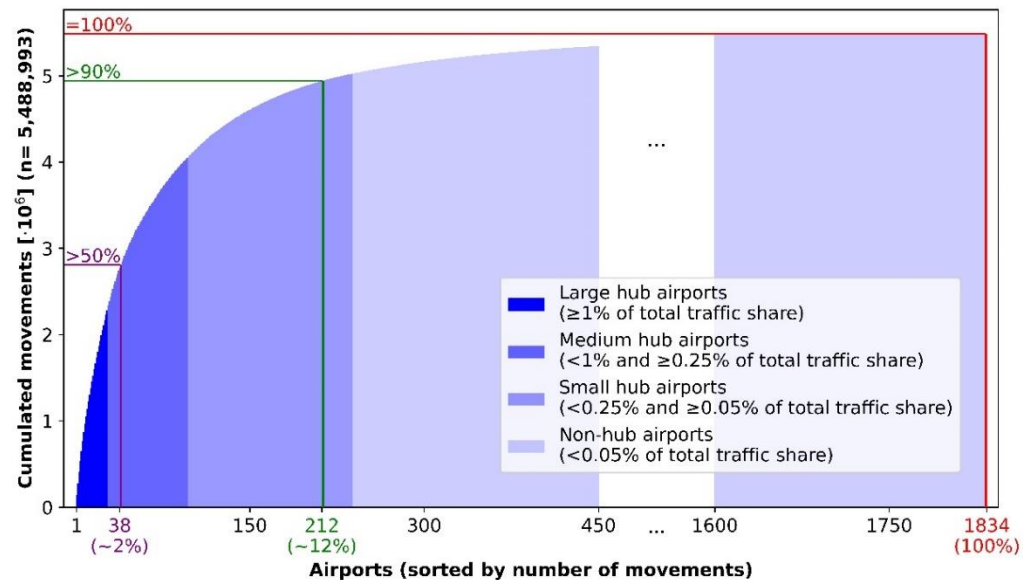
Scope of the study

- How does the improvement in local capacity affect the overall performance of hub airports?
- How does the local capacity increase affect the connection rate of local FSNC?
- Does the improvement have network effects on other FSNC?
- The research **does not** answer the question of how the capacity increase is achieved!



2. European air transportation network model

- Data covers reported flights to EUROCONTROL between July and September 2019
- Contains planned and actual information



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2. European air transportation network model

General principle

- Simulation is implemented based on a Node-Edge network in combination with various input information

Airports (Nodes)

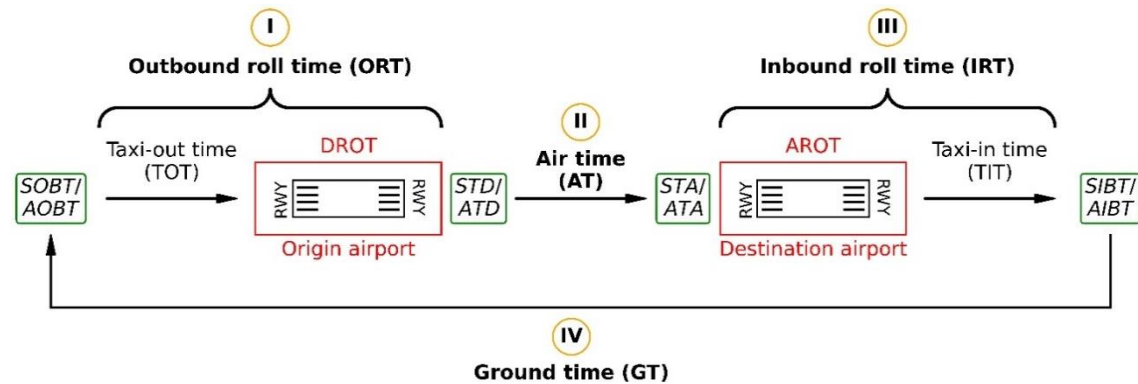
- Characterized by number of runways → server for take-off and landing operations
- Process time for runway procedure depends on Runway Occupancy Time (ROT) and Wake turbulence separation → limits runway capacity
- Runways equals a queue system
- No local operation procedures are considered



2. European air transportation network model

Flights (Edges)

- Flights consists of four **phases**, which are defined by four **timestamps**
- The same aircraft can be used for multiple flight cycles during the operation day



Flightplan

- Considers 35,098 flights and is defined by eight parameters

ADEP	ADES	SOBT	STA	aircraft_type	registration	WTC	airline
EDDF	LFBO	05:25:00	06:55:00	A320	DAIQH	M	LH
LFBO	EDDF	07:45:00	09:30:00	A320	DAIQH	M	LH
EDDF	LKPR	10:30:00	11:20:00	A320	DAIQH	M	LH
LKPR	EDDF	12:10:00	13:20:00	A320	DAIQH	M	LH
EDDF	EHAM	14:10:00	15:15:00	A320	DAIQH	M	LH
EHAM	EDDF	16:30:00	17:30:00	A320	DAIQH	M	LH
EDDF	EVRA	18:40:00	20:30:00	A320	DAIQH	M	LH

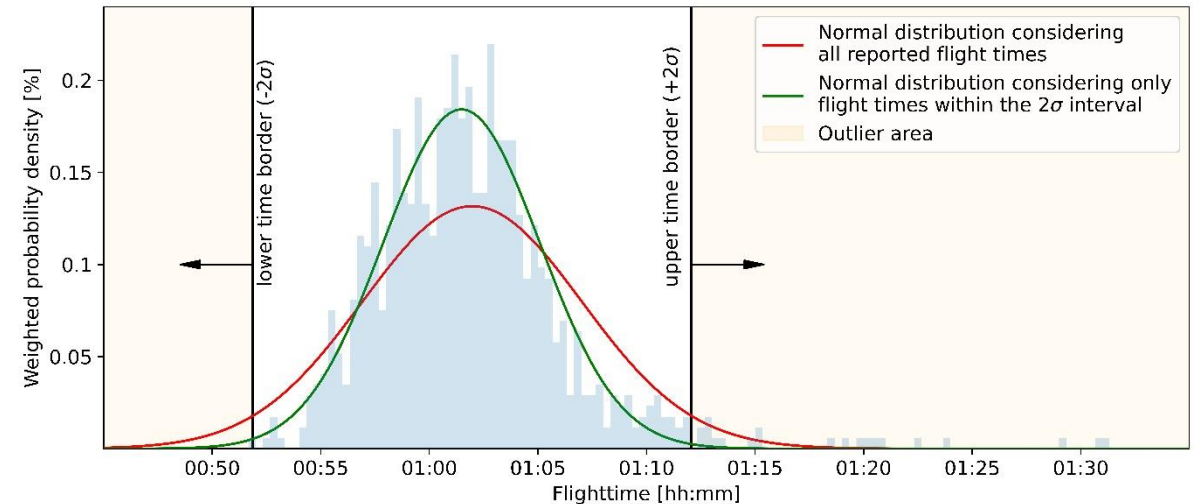
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2. European air transportation network model

Flight time

- Based on actual flight times reported in the dataset
- Normal distribution evaluated based on Origin, Destination and used aircraft type
- Only flight times within the 2σ interval are considered



Turnaround time

- Based on WTC type of used aircraft → for each category, a reference aircraft is defined (E.g., A320neo for Medium category)
- Published turnaround time by the manufacturer is used as an assumption basis



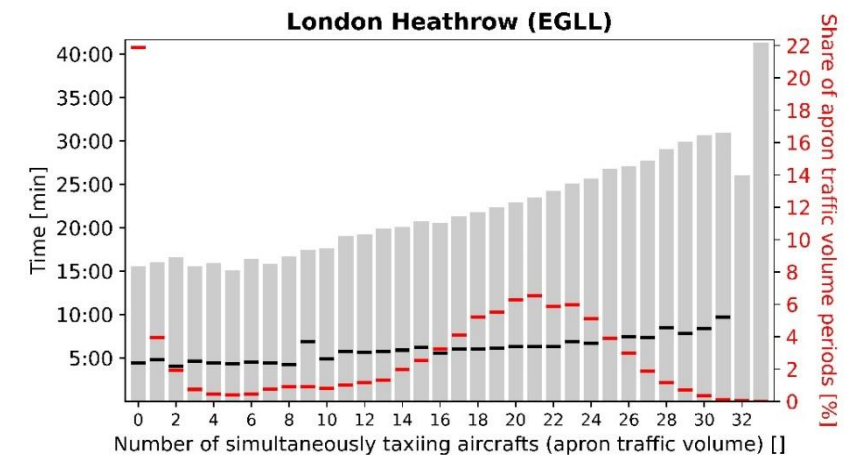
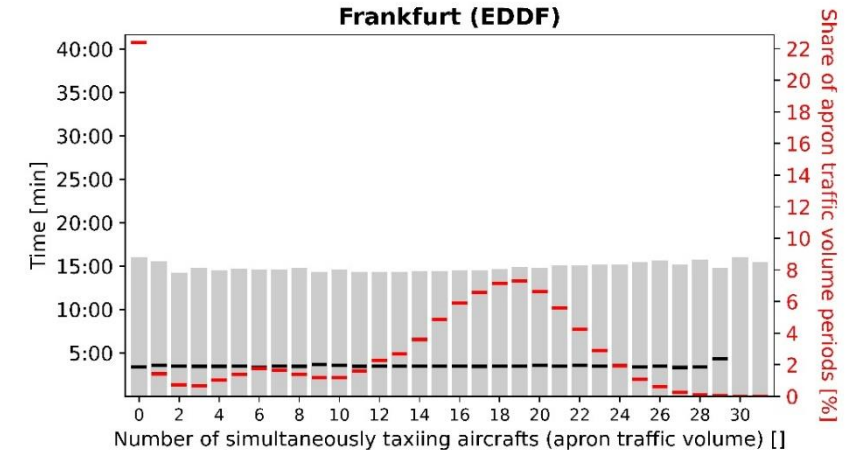
2. European air transportation network model

Taxi-out time

- Based on actual taxi-out times reported in the dataset
- Mean and standard deviation evaluated depending on apron traffic volume
- Unimpeded taxi-out time occurs when 5 or fewer aircraft are taxiing on the apron

Taxi-in time

- Differs between the network airports but remain the same for one airport
- Less traffic dependent than taxi-out time



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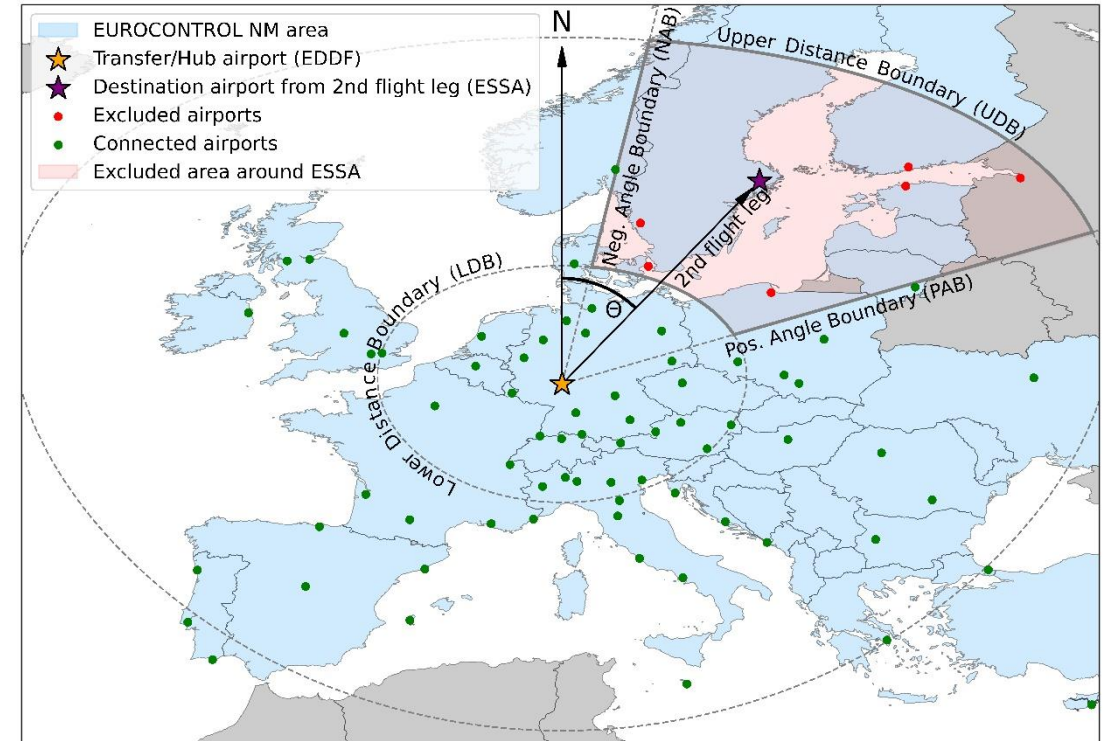


3. Methodology to determining flight connections from FSNC

O&D = Origin $\xrightarrow{\text{Leg 1 flight}}$ Hub $\xrightarrow{\text{Leg 2 flight}}$ Destination

3-step approach

- 1) Time-based assumption
 - Planned arrival time from leg 1 flight is 3h before leg 2 flight
 - Minimum transfer time between both flights is defined by the Minimum Connecting Time (MCT)
- 2) Spatial approach I – Excluded area
 - Distance-based (+/- 600 km) and angle-based (+/- 20°) boundary around destination airport defines the excluded area



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3. Methodology to determining flight connections from FSNC

3) Spatial approach II – Detour factor (DF)

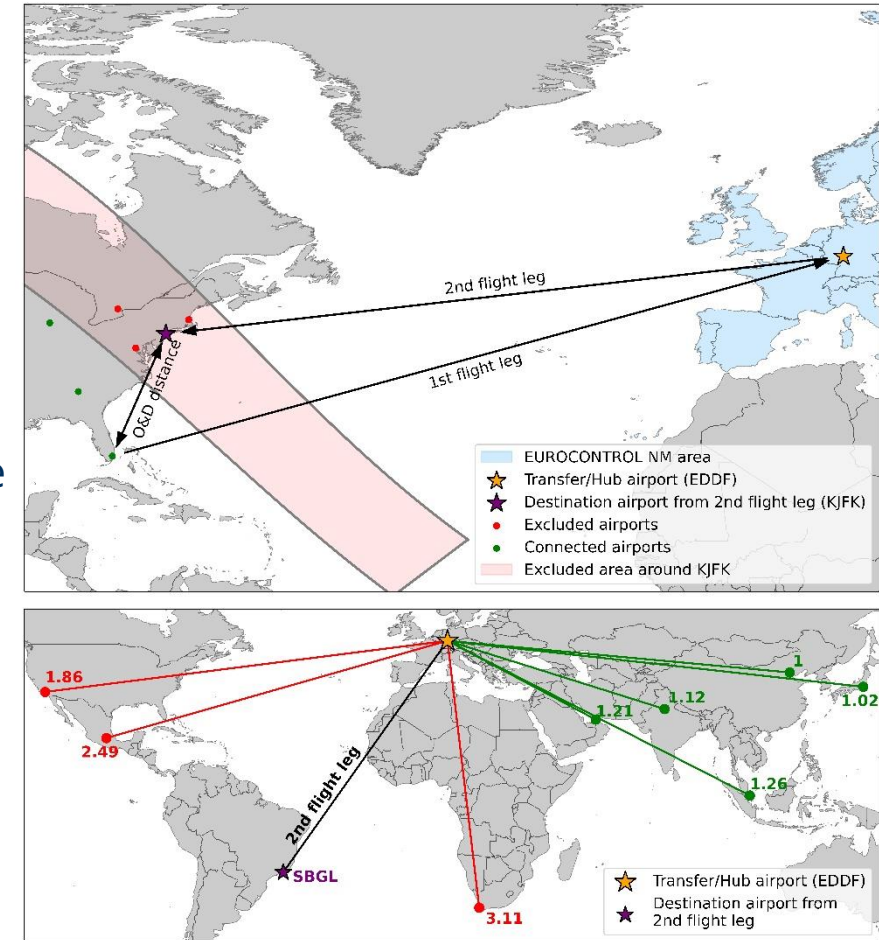
- Excluded area approach doesn't work for long-range O&Ds → Detour factor is calculated:

$$DF_{O\&D} = \frac{d_{Origin \rightarrow Hub} + d_{Hub \rightarrow Destination}}{d_{Origin \rightarrow Destination}}$$

- DF threshold equals 1.45 determined using different example O&Ds using EDDF as the hub airport

→ DF logic avoid O&Ds located in the same region of the world

O&D definition methodology is applied for all outbound flights of a FSNC at the corresponding hub airport



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4. Simulation setup and results

Simulation Setup

- Flightplan covers a whole operation day from a busy weekday in the summer flight plan period
→ 35,098 flights with 58,478 movements at the network airports are considered
- Capacity enhancement via reduction of WTC separation minima and ROT times at an airport

Scenarios: Baseline → Doesn't consider any capacity improvement

Scenario 1 → Capacity at EDDF is enhanced by 5% up to 30% (in 5% steps)

Scenario 2 → Capacity at EGLL is enhanced by 5% up to 30% (in 5% steps)

Investigated KPIs:

KPI	Calculation method	KPI area
Inbound delay	ATA – STA	Airport performance
Outbound delay	AOBT – SOBT	Airport performance
Additional taxi-out time	Queue time at runway (departure)	Airport performance
ASMA additional time	Queue time at runway (arrival)	Airport performance
Connection rate	Fulfilled flight connections / Planned flight connections	FSNC performance

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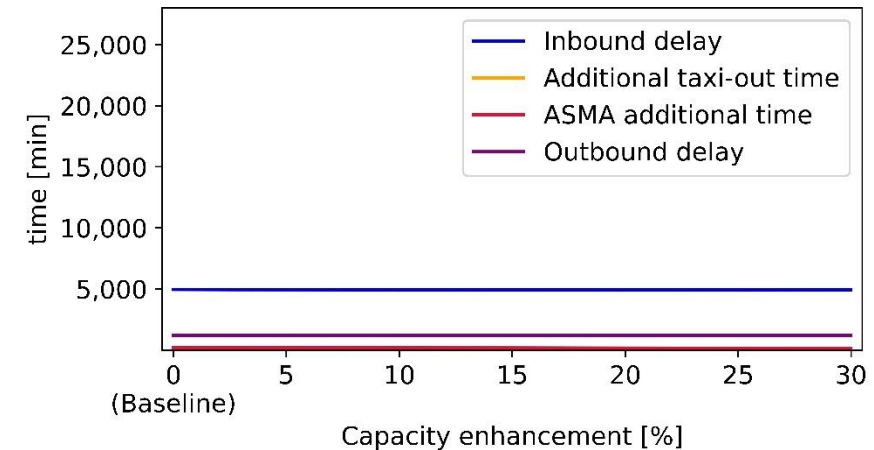


4. Simulation setup and results

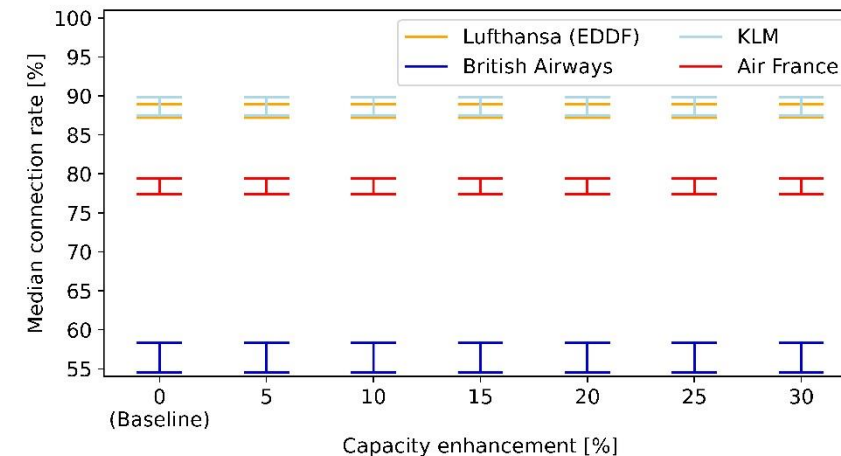
Scenario 1 – EDDF improved

- Airport is not congested in the baseline scenario
- Inbound delay can be recovered at the airport
- No additional waiting times at the runway
- Capacity improvement doesn't show any effect → Delay is formed at other network airports or is a result of a tight flight schedule
- Median Lufthansa connection rate between 87%-90% → No improvements for capacity enhancement scenarios
- Other FSNC performances are also not affected

Airport performance:



FSNC performance:



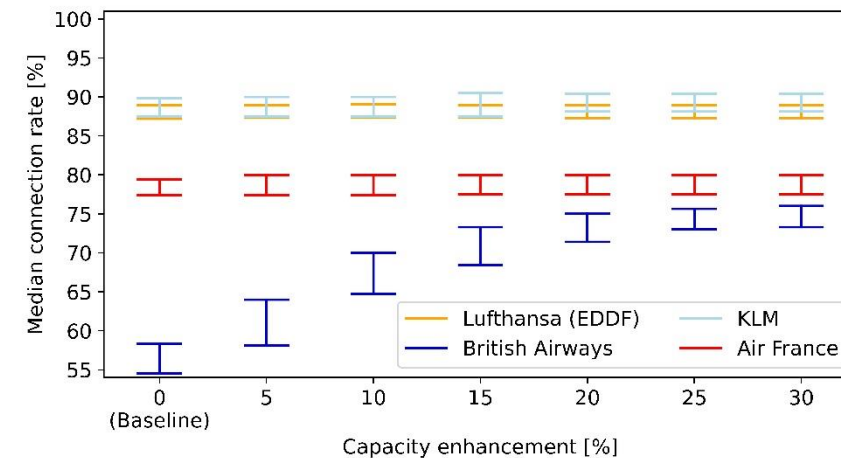
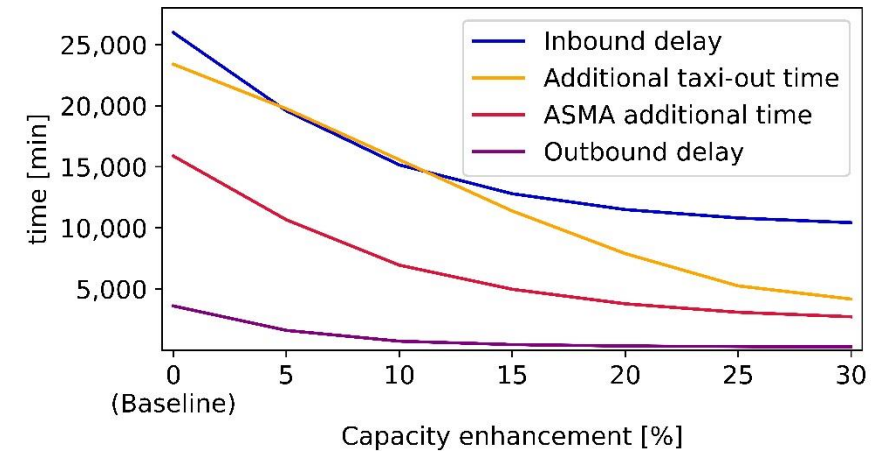
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4. Simulation setup and results

Scenario 1 – EGLL improved

- Airport is congested in the baseline scenario
- Capacity enhancement improves airport performance significantly
- 10% more capacity → Inbound delay (-42%)
Outbound delay (-80%)
Additional taxi-out time (-33%)
ASMA additional time (-56%)
- Median British Airways connection rate between 55%-58% → Improves under capacity enhancement
- Other FSNC performances are slightly improved
- Saturation effect for high capacity enhancement rates



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5. Conclusion & Outlook

Conclusion

- Capacity improvement leads to airport performance increase if the airport is congested
- Capacity improvement leads to a higher connection rate of **local** FSNC in- and outbound flights if the airport is congested
- The performance of **network** FSNC using the capacity improved airport as spoke airport are also improved slightly → The network effects are not significant

Outlook

- Include airline rules for missed flight connections
- Delay Cost analysis
- Improvement of European airport network model



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Thanks for your attention!

Q&A session

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