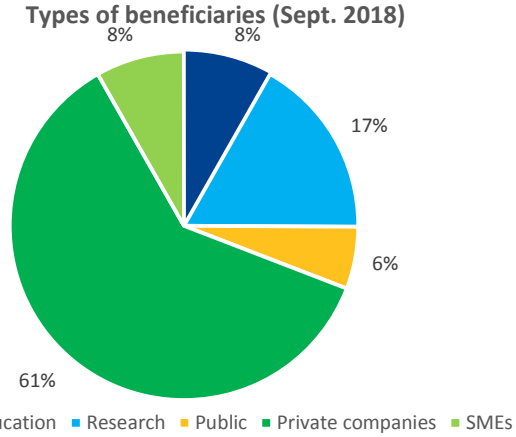
Innovations in airport operations

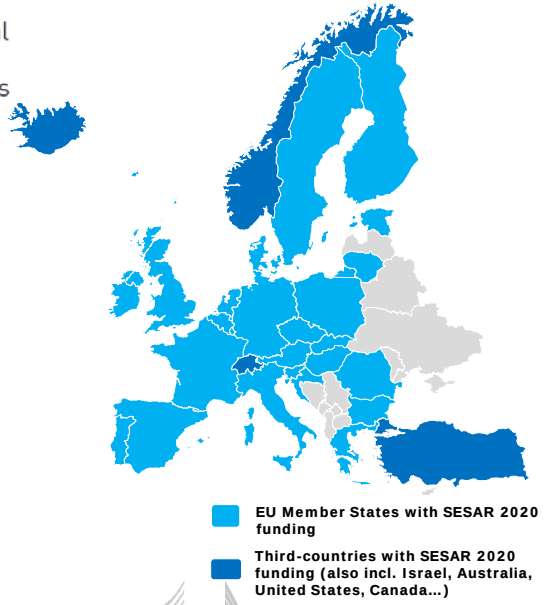
Session introduction
Olivier Mongénie
SESAR Joint Undertaking

SESAR: Technological pillar of Single European Sky and key enabler for the Aviation Strategy

SESAR 2020 projects: blended academic & industrial expertise



26 EU Member States participating



2019 2020 aerodays TANDEM

Bucharest, 27-30 May 2019

European Commission

SESAR Innovation Pipeline: integrated approach

EXPLORATORY RESEARCH

Explores new concepts beyond those identified in the European ATM Master Plan or emerging technologies and methods. The knowledge acquired can be transferred into the SESAR industrial and demonstration activities.

INDUSTRIAL RESEARCH & VALIDATION

Assesses and validates technical and operational concepts in simulated and real operational environments according to a set of key performance areas. This process transforms concepts into SESAR Solutions.

VERY LARGE SCALE DEMONSTRATIONS

Tests SESAR Solutions on a much larger scale and in real operations to prove their applicability and encourage the early take-up of solutions.

DELIVERING TIMELY SOLUTIONS

- **63 SESAR Solutions** and **candidate solutions** in the pipeline
- **40+ already under deployment** across Europe
- Disseminated through **EU aviation standards**
- Clear associated benefits: **safety, efficiency, capacity and the environment**
- **Globally applicable**

The digital airport in SESAR 2020

- Automated runway and surface operations
- Data-driven airport operations management
- Digital or remote tower
- Enhanced vision technologies
- Satellite based technologies

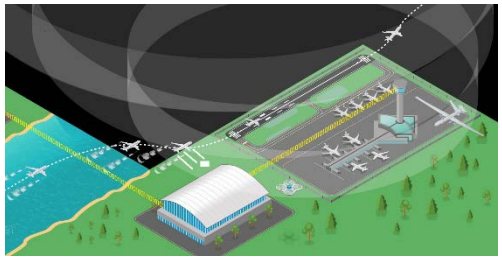
SESAR 2020: improving safety of airport operations

PJ03b-06 – Safety support tools for avoiding runway excursions

- Mitigating the risk of runway excursion
  - Pilots: better runway condition information, runway excursion risk detection tools, alerts
  - Airport operators: improved sensors, better assessment and prediction of runway condition
  - Air traffic controllers: improved runway condition assessment
- Expected safety and resilience benefits
- Target date ‘ready for deployment’: 2022

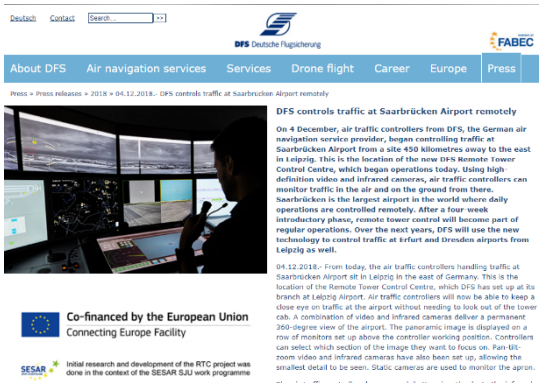
SESAR 2020: increasing runway and airport throughput

- SESAR 2020 PJ02 - Increased Runway and Airport Throughput
  - Wake turbulence and radar separation optimization
  - Satellite based & performance based navigation and new airborne capabilities enabling enhanced arrival procedures and improving access to secondary airports
  - Independent rotorcraft operations
- PJ02-08 – Traffic optimisation on single and multiple runway airports
  - *Optimising arrivals and departures flows on and around the runway(s)*
  - **Reducing runway occupancy time for arrival aircraft** by improving runway occupancy time prediction and informing air traffic controllers and pilots about the optimal runway exit
  - Target date 'ready for deployment': 2020



SESAR 2020: delivering cost efficient remote tower solutions

- Remote towers is a reality thanks to SESAR 1!



- SESAR 2020 PJ05 – Remote Tower: R&D continues to deliver cost efficient solutions applicable to more airports
  - *PJ05-05 – Advanced automated met system*
  - **PJ05-02 – Remote tower module**
    - Focus on the controller working position
    - Target date 'ready for deployment': 2019
  - **PJ05-03 – Remote tower centre with flexible allocation of aerodromes to multiple remote tower modules**
    - Similar to en-route control centres
    - Target date 'ready for deployment': 2022

Innovation in airport operations session – speakers & topics

- **Runway Condition Code Prediction with Gradient Boosted Trees**
  - Related to SESAR solution PJ03b-06 – *Safety support tools for avoiding runway excursions*
  - Wojciech Rosinski, University of Warsaw, ICM

- **Runway capacity increase using machine learning models**
  - Related to SESAR solution PJ02-08 – *Traffic optimisation on single and multiple runway airports*
  - Krzysztof Rutkowski, University of Warsaw, ICM

- **Assessment of human performance in multiple remote tower operations**
  - Related to SESAR solution PJ05-02 – *Remote tower module*
  - Anneke Hamann, German Aerospace Centre (DLR)

Thank you !

Bucharest, 27-30 May 2019

Runway Condition Code Prediction with Gradient Boosted Trees

PJ03b SAFE
Wojciech Rosinski
ICM, University of Warsaw

Problem Statement

PJ03b-06 – Safety support tools for avoiding runway excursions

[B3A]

[B3A] https://www.baaa-acro.com/crash/crash-airbus-a300b4-203f-bratislava

Problem Statement

Why is the research needed?

- Runway excursion is the most frequent runway safety accident – 22% of all runway accidents[IATA]
- Risk of excursion can be mitigated with creation of a system for improved runway condition assessment

Stakeholders Expectations

- *Airport Operator & Airline* – minimize number of runway excursions
- *ANSP & Flight Crew* – enhance level of awareness about runway safety
- *Aircraft Manufacturer* – minimize runway excursion rate and severity

[IATA] Runway Safety – Accident Analysis Report 2010-2014 – 1st edition – IATA – 2015.

Scientific & technical goals

Scientific:

- Development of a system for *RWYCC estimation*
- Achieving improvement over the *Reference Scenario*
- Ability to estimate:
  - ***Current RWYCC***: current point in time
  - ***Predicted RWYCC***: forecasting up to 60min

Technical:

- Integration of *various data types* to improve final model accuracy
- Achieving consistent improvement among *different data distributions* (different airports)

Main achieved & expected results

[BRU]

[RUB]

[BRU] https://commons.wikimedia.org/wiki/File:Brussels_Airport_Runway_25_R.jpg
[RUB] http://www.airfieldrunwayrubberremoval.com/

Main achieved and expected results

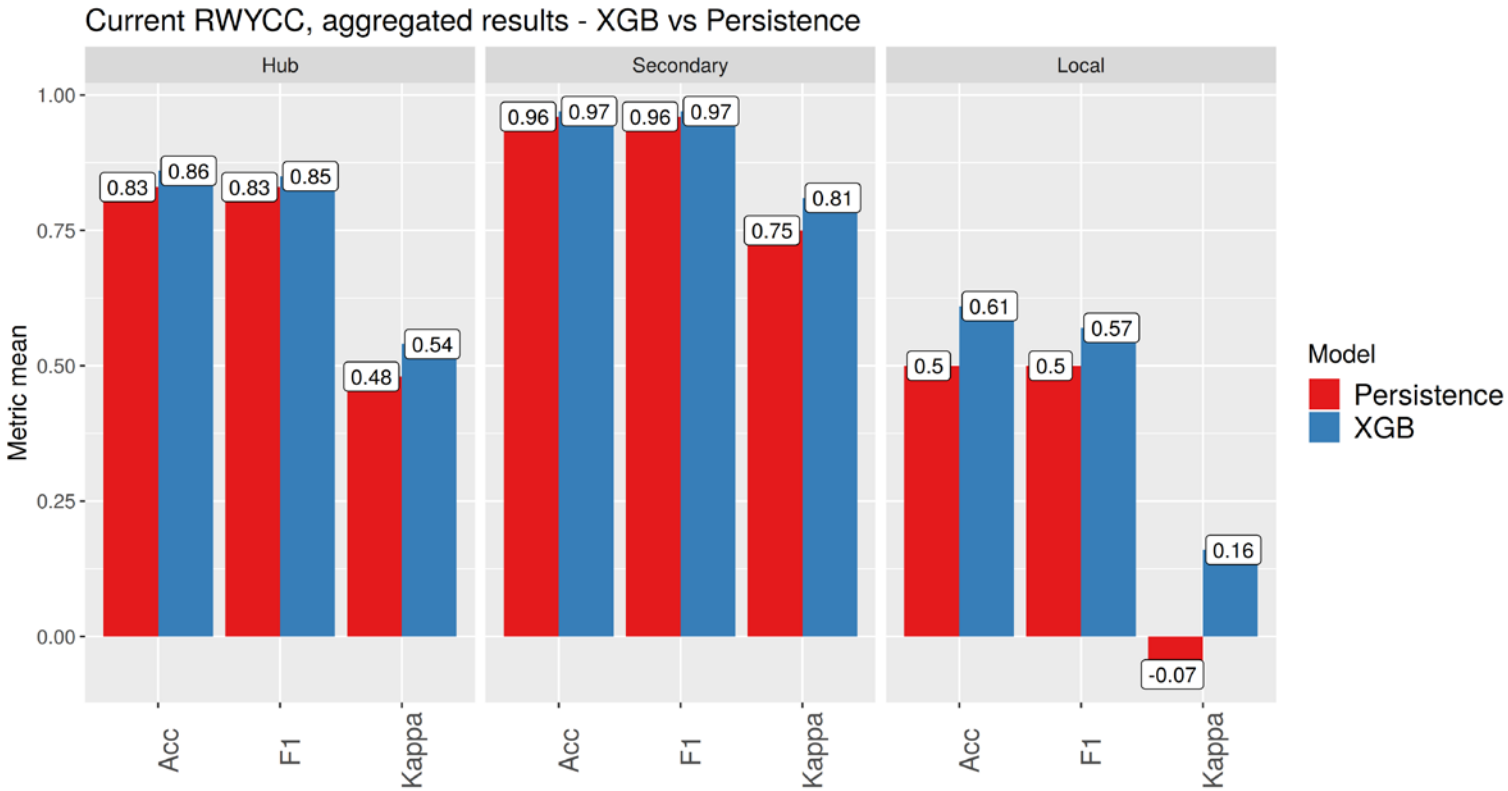
Achieved:

1. Consistent improvement over *Reference Scenario* among three validated airports
2. Predicted RWYCC accuracy close to Current RWYCC accuracy among all considered time horizons
3. Integration of high-quality surveillance data significantly improves model accuracy

Expected:

- More data should lead to improved accuracy and ability to better predict bad conditions

Main achieved and expected results



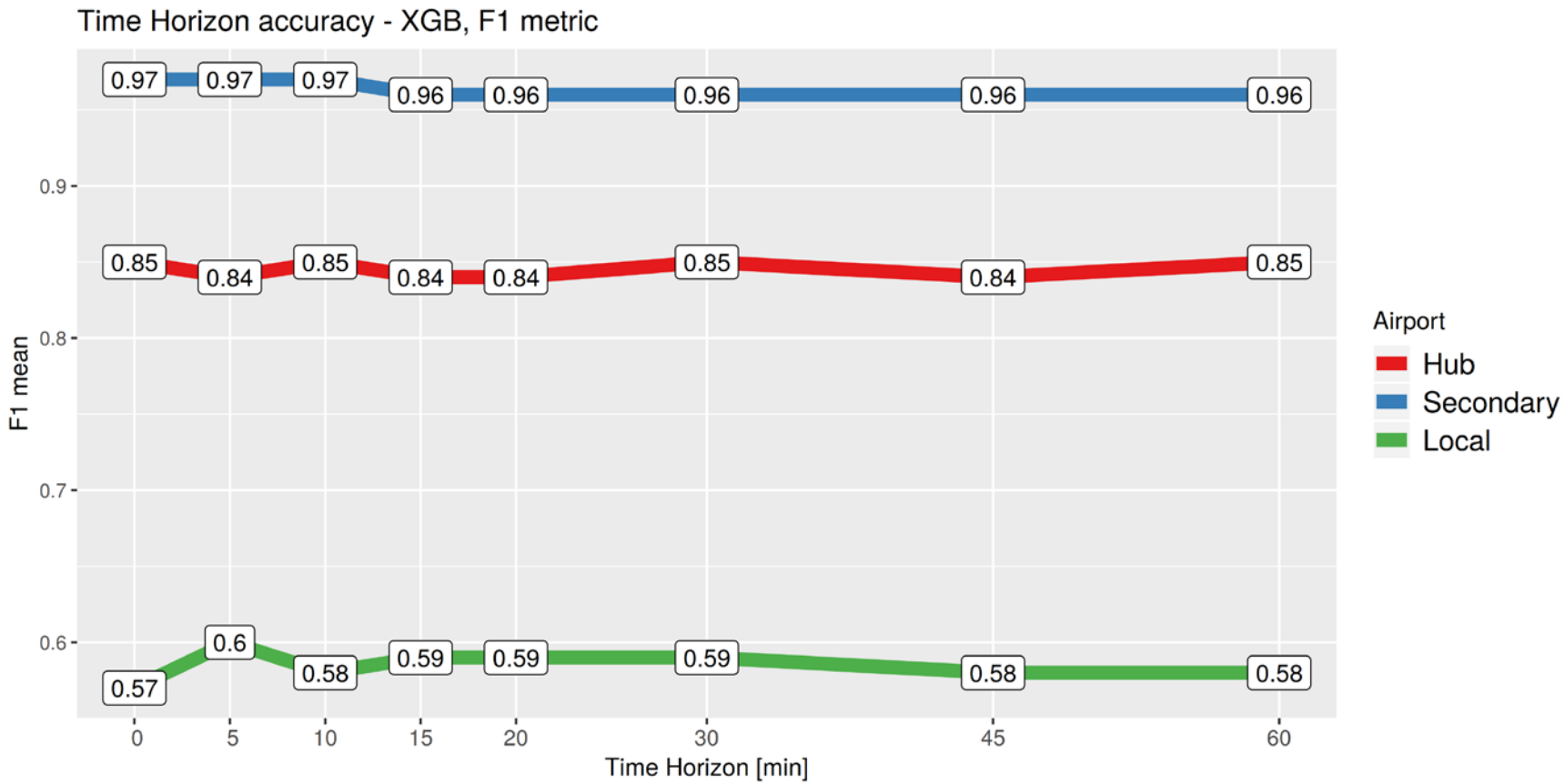
1. Consistent improvement among three validated airports; developed model performs better as measured by **all chosen metrics**

Main achieved and expected results

2. Predicted & Current RWYCC accuracy close to each other

- Consistent results for current prediction and forecasting
- Almost constant accuracy between time horizons → due to irregular observations and moderate number of changes

Main achieved and expected results



2. Predicted & Current RWYCC accuracy close to each other

Main achieved and expected results

3. Integration of surveillance data

1. **Hub airport**: high quality surveillance data significantly improves model performance,
   - F1 0.71 -> **0.84**
   - Kappa 0.18 -> **0.52**
2. **Secondary airport:** slight improvement for Secondary airport, surveillance data quality was worse and data already contained rich set of variables
   - F1 0.96 -> 0.96
   - Kappa 0.76 -> **0.79**

Potential gaps and challenges

[ETI]

[ETI] https://www.flickr.com/photos/faisal_akram/8042318288/

Potential gaps and challenges

1. Low number of variables for Hub and Local airports
2. Low number of samples for Hub and Local airports
3. Difficult prediction of bad conditions RWYCC due to their very limited representation
4. Access to all types of data may be a challenge in real-time system deployment

Potential gaps and challenges

1. Low number of variables (**7**) for Hub and Local airports -> impact on model accuracy

- *Ground & Air Temperature*
- *Dew Point*
- *Runway freezing Point*
- *Relative Humidity*
- *Contamination type and depth based on ground sensors*

No information about visibility, wind, current weather conditions!

This information was available for Secondary airport.

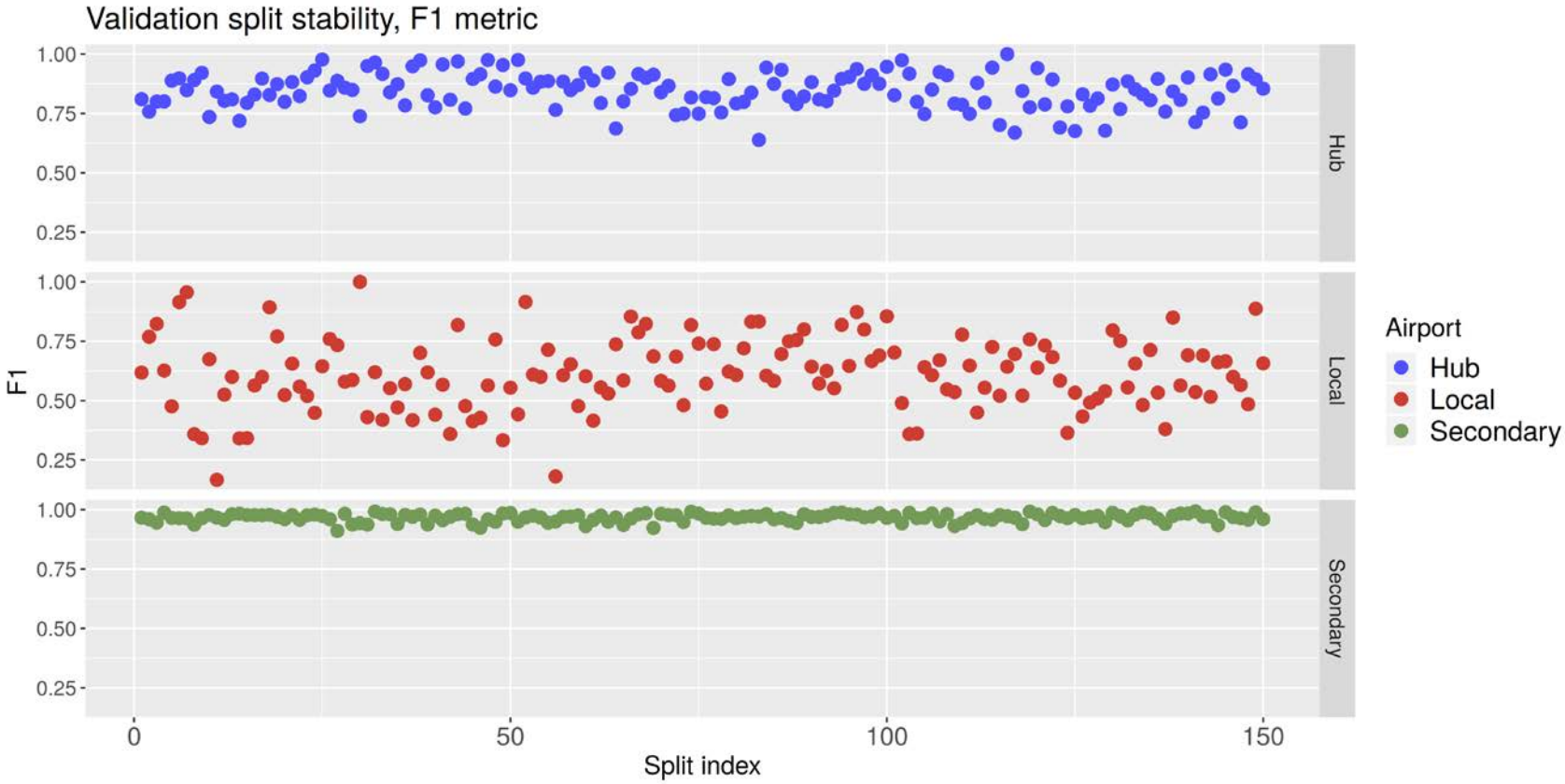
Potential gaps and challenges

2. Low number of samples for Hub and Local airports → more difficult validation and robustness assessment

- **Secondary** airport (>3000 samples): stable results
- **Hub** airport (210 samples): medium results stability
- **Local** airport (63 samples): low results stability

On Hub and Local airpots - validation score highly dependent on random split;
there are splits with perfect score – **1.0** and others with **0.2** !

Potential gaps and challenges



2. Low number of samples for Hub and Local airports leads to varying split stability

Potential gaps and challenges

3. Difficult prediction of bad conditions RWYCC due to small number of examples in the training datasets.

- **RWYCC 5** & **6**: majority of examples on all airports
- **RWYCC 3**: 6 samples on Local, 1 on Hub
- **RWYCC 4**: 1 sample on Hub
- **RWYCC 1**: 1 sample on Local
- Lack of other classes

Cross-cutting issues

Accurate RWYCC prediction may serve as feature for models making use of information about Runway Condition (used in SESAR PJ02 Earth)

Potential model improvement

Cross-cutting issues (other)

- Predicted RWYCC procedures (who?, when?, why?)
- Use of current/predicted RWYCC in wider airport operations – APOC, management
- Standardization of runway sensors

- Ingestion of live on-board generated data – downlinked OBACS with braking action information (SESAR wave 2)

Impacts

*Improved **safety** and **resilience** to adverse conditions*

→ minimizing runway excursion risk via more accurate prediction of runway conditions

*Increase of **situational awareness***

→ better decision-making tools lead to less need to use anti-ice substances and positive *environmental impact*

*Improved **runway capacity***

→ fewer diversions (inspections) due to constant monitoring of runway conditions leading to *increase in punctuality*

Useful infos and acknowledgements

SESAR PJ.3B
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The research presented here was conducted in cooperation with Polish Air Navigation Agency (PANSA). We would like to acknowledge Jarosław Niewiński and Mateusz Sokołowski for their support.

We would like to acknowledge IMGW-PIB for providing the data used for parts of this research. We would like to especially thank Tomasz Siejek and Janusz Cichocki for their assistance.

The data used in this research was also provided by Aeroports de Paris and Microstep-MIS.

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www.pansa.pl

Thank you !

Additional content

Surveillance data influence

Airport	Radar Merge	XGB F1	XGB Kappa	XGB Accuracy
Hub	False	0.71	0.18	0.73
	True	0.84	0.52	0.86
Secondary	False	0.96	0.76	0.96
	True	0.96	0.79	0.96

Table 9: Integration of Surveillance Data

Datasets overview

Airport	Data type	Number of observations	Date range
Hub Airport	SNOWTAM	210	2017-12-01 - 2018-03-22
Secondary Airport	METAR	3273	2017-10-17 - 2018-07-30
Local Airport	SNOWTAM	63	2018-02-16 - 2018-04-02

Table 1: Datasets Overview

Datasets labels distribution

RWYCC	1st runway part	2nd runway part	3rd runway part
6	165	164	163
5	45	46	45
4	0	0	1
3	0	0	1

Table 3: Hub Airport RWYCC Distribution

RWYCC	1st runway part	2nd runway part	3rd runway part
6	18	17	18
5	38	39	38
3	6	6	4
1	1	1	1

Table 4: Local Airport RWYCC Distribution

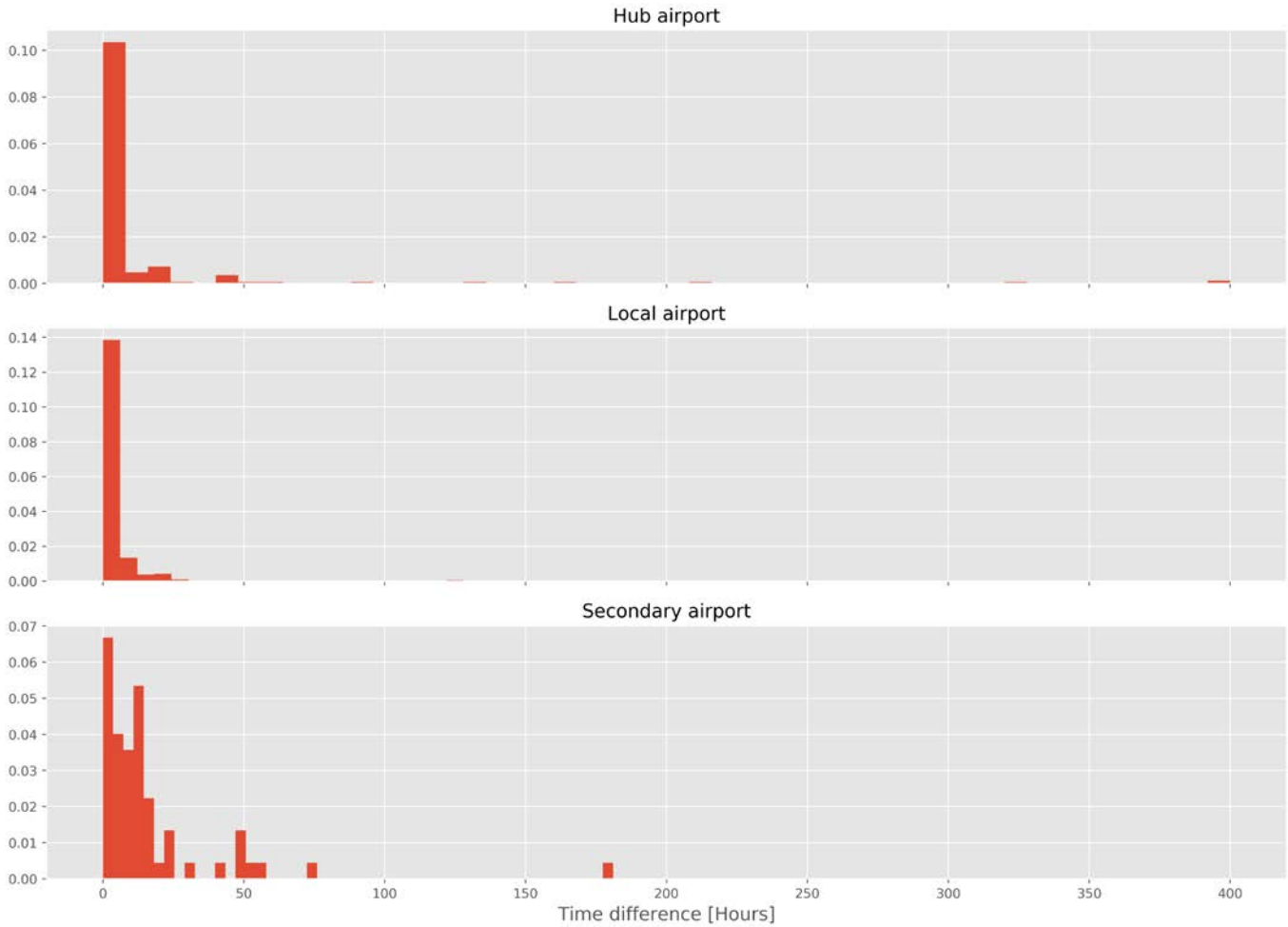
RWYCC	Runway
6	2949
5	324

Table 5: Secondary Airport RWYCC Distribution

Potential gaps and challenges

3. Number of runway operations influences labels distribution

- Frequent operations lead to better runway state → less time for contamination build up
- Effectively, frequent operations lead to smaller number of severe conditions labels



Additional Impacts

Short-term RWYCC ***forecasting***

→ enables earlier applying of *countermeasures*

Conditions ***change prediction***

→ notable improvement over Reference Scenario

RUNWAY CAPACITY INCREASING USING MACHINE LEARNING MODELS

SESAR PJ02 EARTH

Krzysztof Rutkowski
ICM, University of Warsaw

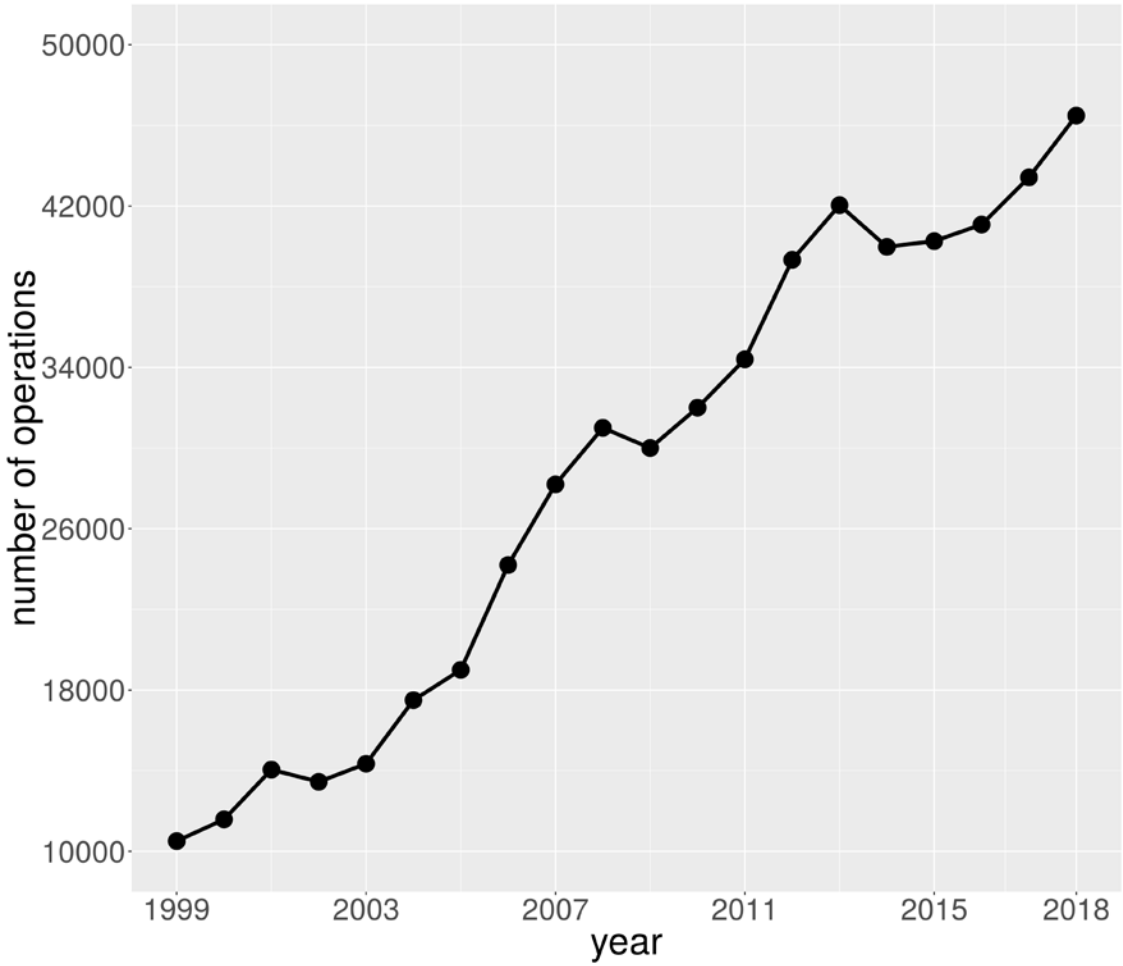
Problem statement

Solution PJ.02-08 - *Traffic optimisation on single and multiple runway airports*

Our research: more optimal use of runway

Problem statement

Number of operations at Gdańsk Lech Wałęsa Airport



Problem statement

Gdańsk Airport layout and exits distribution

C	D	E	G	F
11.9%	28.4%	37.2%	21%	1%

Scientific & technical goals

- Scientific goals:
  - **recommendation of exit taxiway using machine learning on medium regional airport - Gdańsk Lech Wałęsa Airport**
  - **Prediction of Runway Occupancy Time (ROT)**
  - **influence of recommended exit on runway capacity**

- Technical goals:
  - **possible delivery of recommendation from Tower to flight crew**

Scientific & technical goals

- **Hypothesis 1**: our recommendations result in overall ROT reducing
- **Hypothesis 2**: reducing ROT by our model imply decreasing radar separation minima and in effect runway capacity increasing

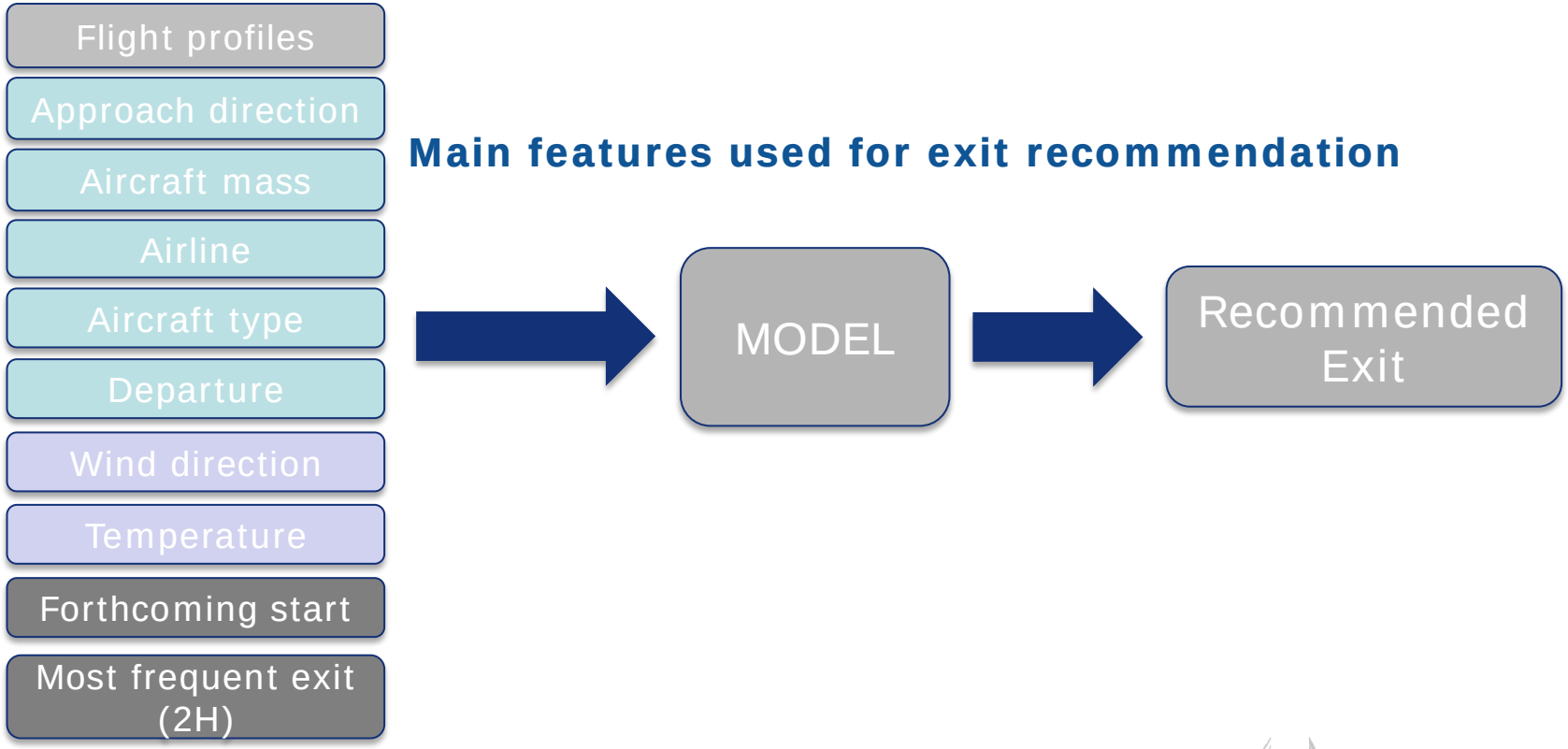
Methodology

- Simulations - segregated and mixed mode based on real Gdańsk airport traffic
- **Segregated mode simulation scenario (arrivals only)**:
  - For each direction random sample of 30 days was chosen
  - For each pair of subsequent flights only last approach phase was chosen
  - Tested 9 levels of radar separation on approach phase: **from 2 miles to 4 miles**
- **Mixed mode simulation scenario**:
  - For each direction random sample of 30 days was chosen
  - For each pair of subsequent arrivals only last approach phase was chosen
  - Tested 13 levels of radar separation on final approach phase: **from 2 miles to 5 miles**
  - For each radar separation testing how many departures possible between arrivals

Main achieved and expected results

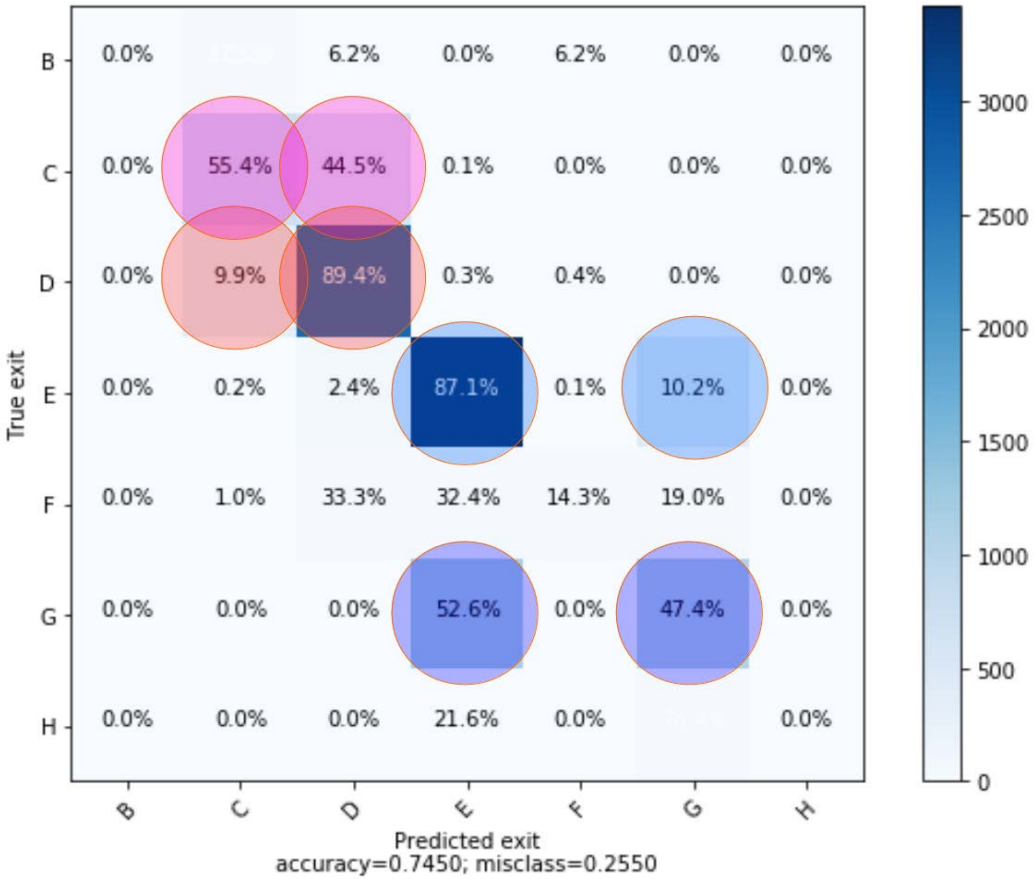
- In total **105** different features used for model training from different sources: ***Meteo, Surveillance, Aircraft data, Runway frictions, Runway Condtion Code predictions, previous exits statistics***

Main features used for exit recommendation



Main achieved and expected results

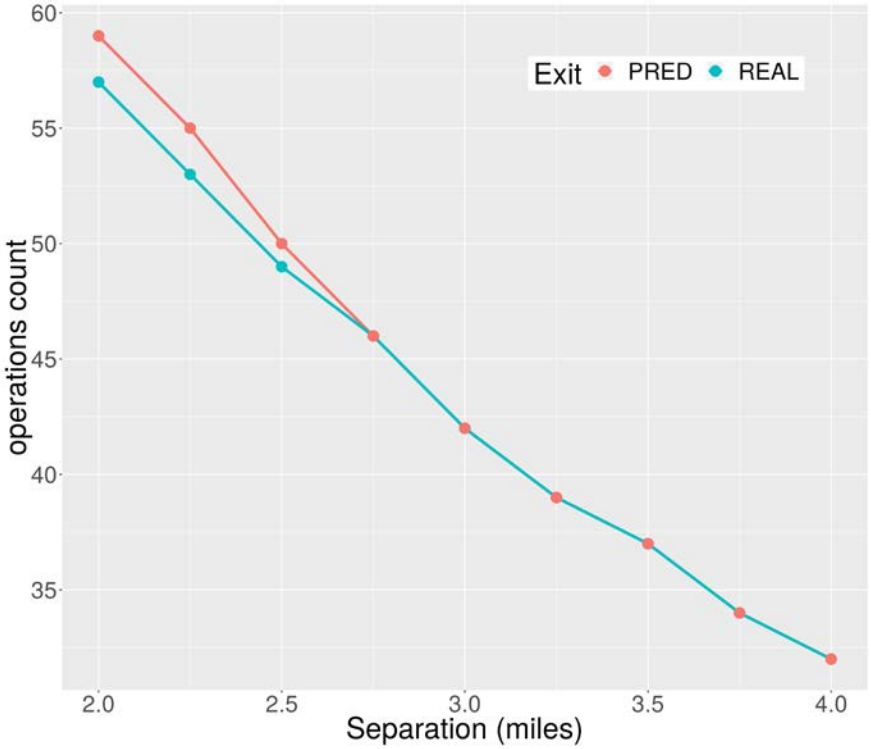
- Exit taxiway recommendation confusion matrix
- Gradient Boosting model
- Each row indicates each real exit, in matrix percent distribution of recommendations per exit is presented



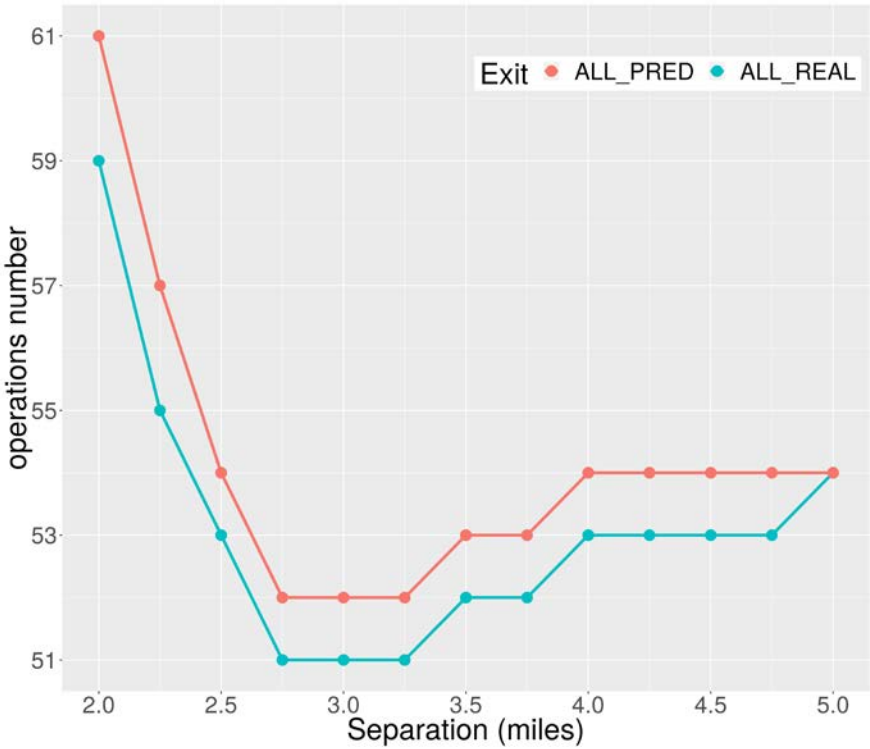
Main achieved and expected results

Number of operations per hour:

Segregated mode

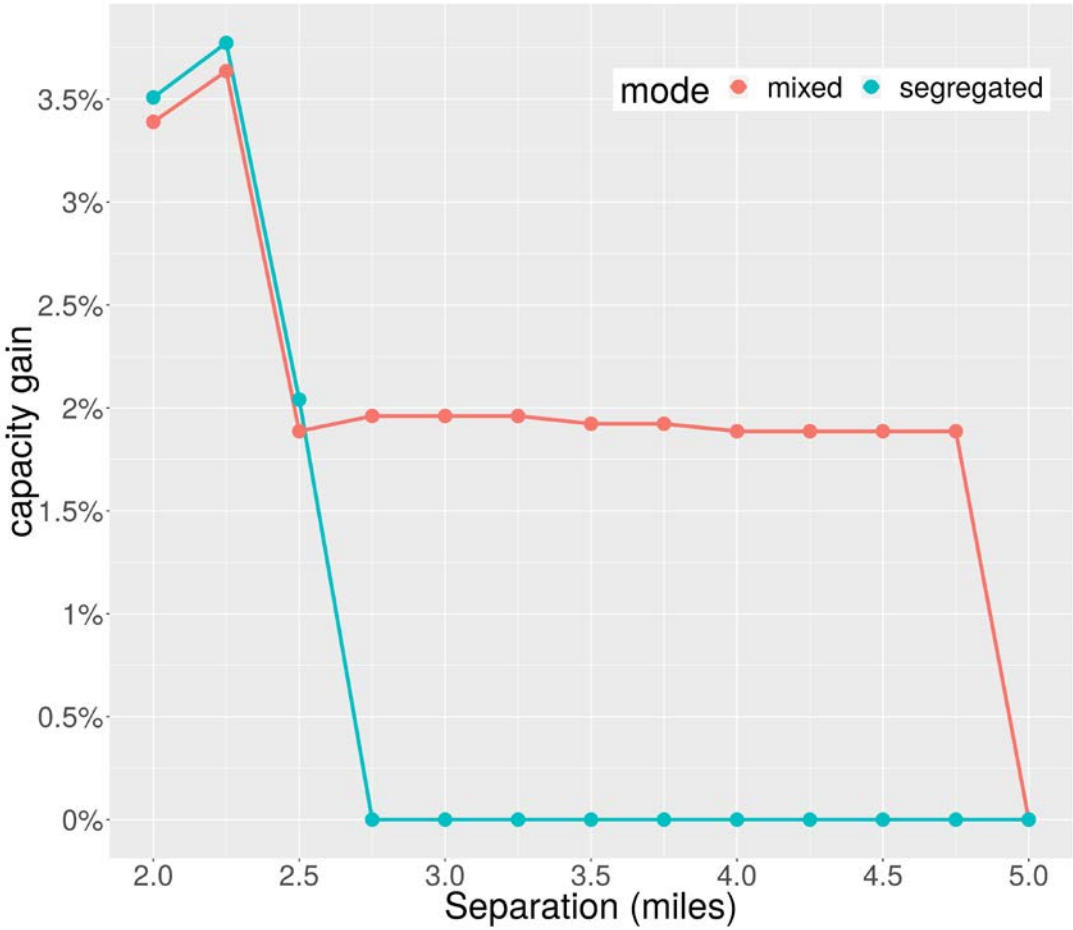


Mixed mode



Main achieved and expected results

Capacity gain for mixed and segregated mode



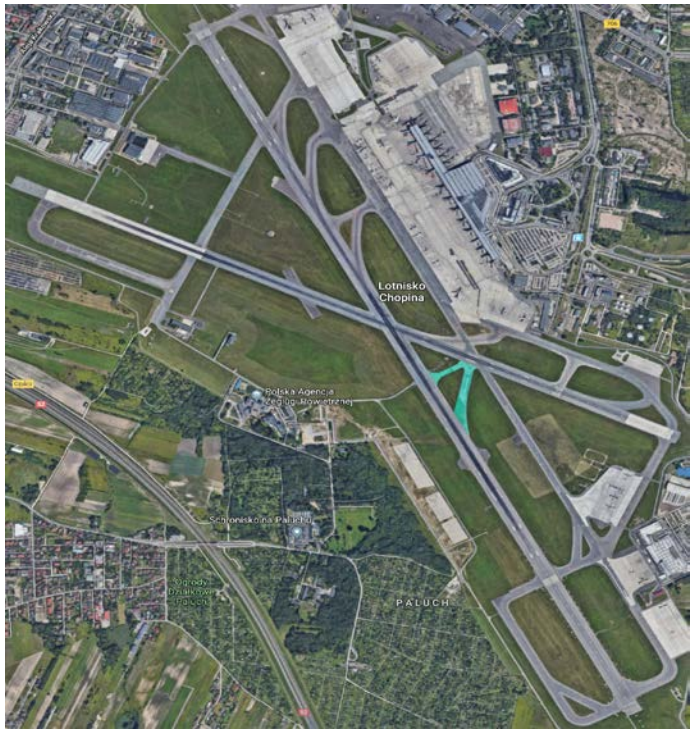
Main achieved and expected results

- **Segregated mode** (arrivals) simulation results:
  - For very small separation (2, 2.25 miles) significant increasing of capacity is possible - 3.5%, gain vanishes with increasing of separation

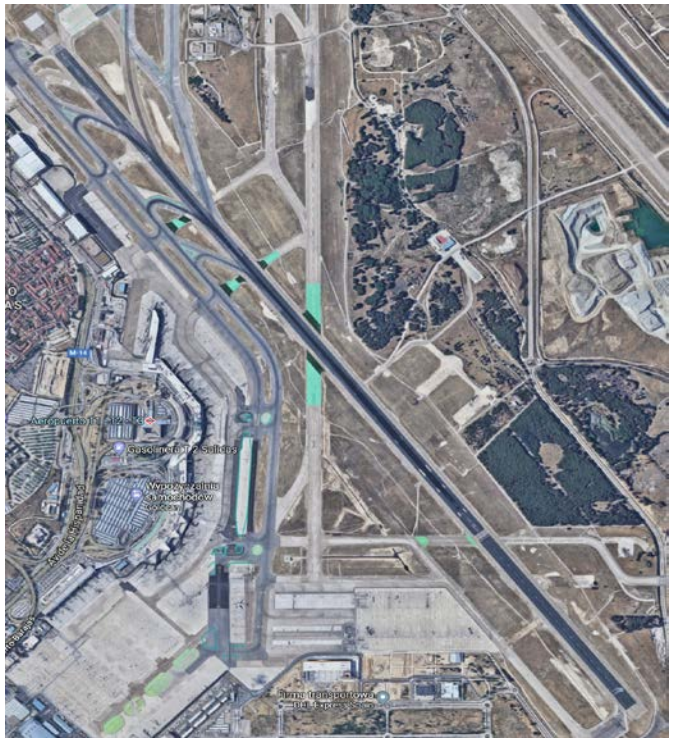
- **Mixed mode** simulation results:
  - For very small separation similar results as in segregated mode – there is no possibility of inserting departures between arrivals
  - For 4 miles separation satisfactory amount of departures (40% of operations) is possible and 1.9% increasing of runway capacity is achieved

Potential gaps and challenges

- Gdańsk is a **medium airport** (slightly over 45k ops/y), system not evaluated in big+ aerodromes
  - When operations are dependent between runways (example: Warsaw Chopin)
  - When there is a lot of exits in one direction (example: Madrid Barajas)



Warsaw Chopin layout



Madrid Barajas layout

Potential gaps and challenges

- System recommendation rigorously investigated but **lack of reference data** = lack of 100% confidence in result
  - Model sometimes **recommends further exit than actually was chosen**,

- **Ground traffic beyond runway was not taken into account** – in case of series of the same subsequent recommendations it may lead to congestion on the apron

- We have no influence on the moment of touchdown, recommended exit may be not possible **in case of too late touchdown**

- System is **not sensitive on sudden runway conditions changes** or unexpected accidents

Potential gaps and challenges

Cross-cutting issues (tech & non-tech.)

- Runway Occupancy Time prediction might be used as **input to the AMAN/DMAN (or combined system) - system managing arrivals/departures queues.** Both for segregated and mixed mode

- Runway Occupancy Time prediction might be used as additional input in **planning runway inspections/maintenance** by airport services

Impacts

- **Capacity**: Implementation of our model may contribute to increasing number of operations on medium, regional airports at low cost

To further research:

- **Environment:** Implementation of our model may reduce time on taxiway what may contribute to decrease amount of ground emissions, further assessment of this KPI (Key Performance Indicators) required (will be completed within SESAR wave 1)

- **Safety:** Model may have potential to detect runway overrun potential in advance, this needs to be investigated separately using different dataset (not planned within SESAR wave 1)

Useful infos and acknowledgements

SESAR PJ02
https://www.sesarju.eu/projects/earth
TandemAerodays19.20
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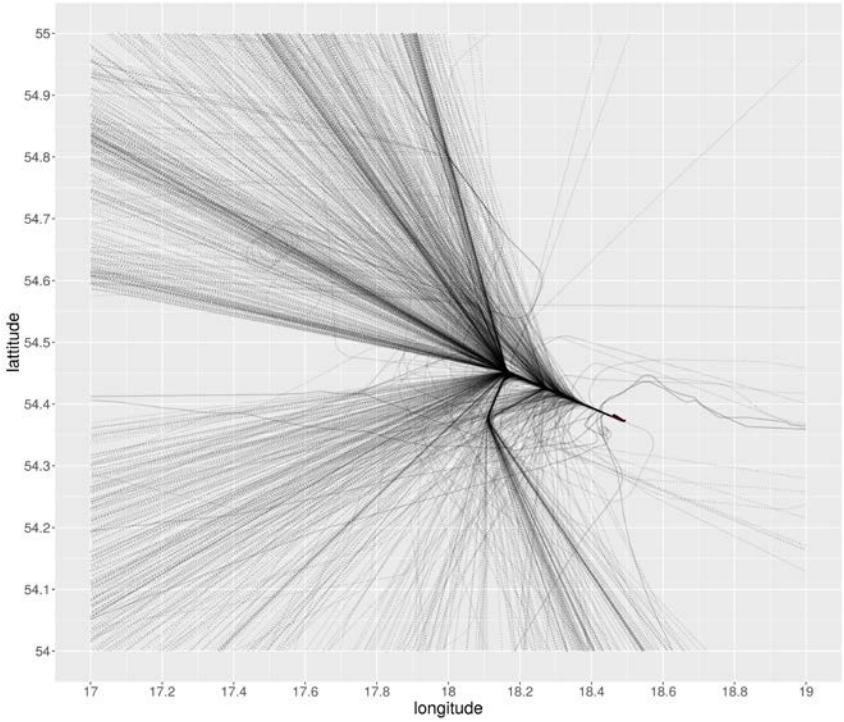
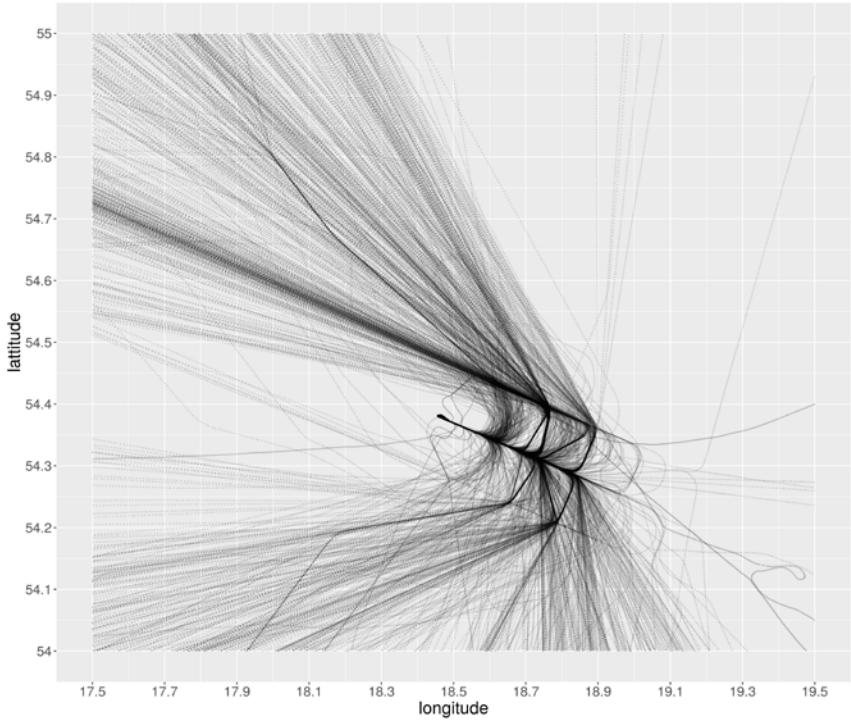
Thank you !

Problem statement

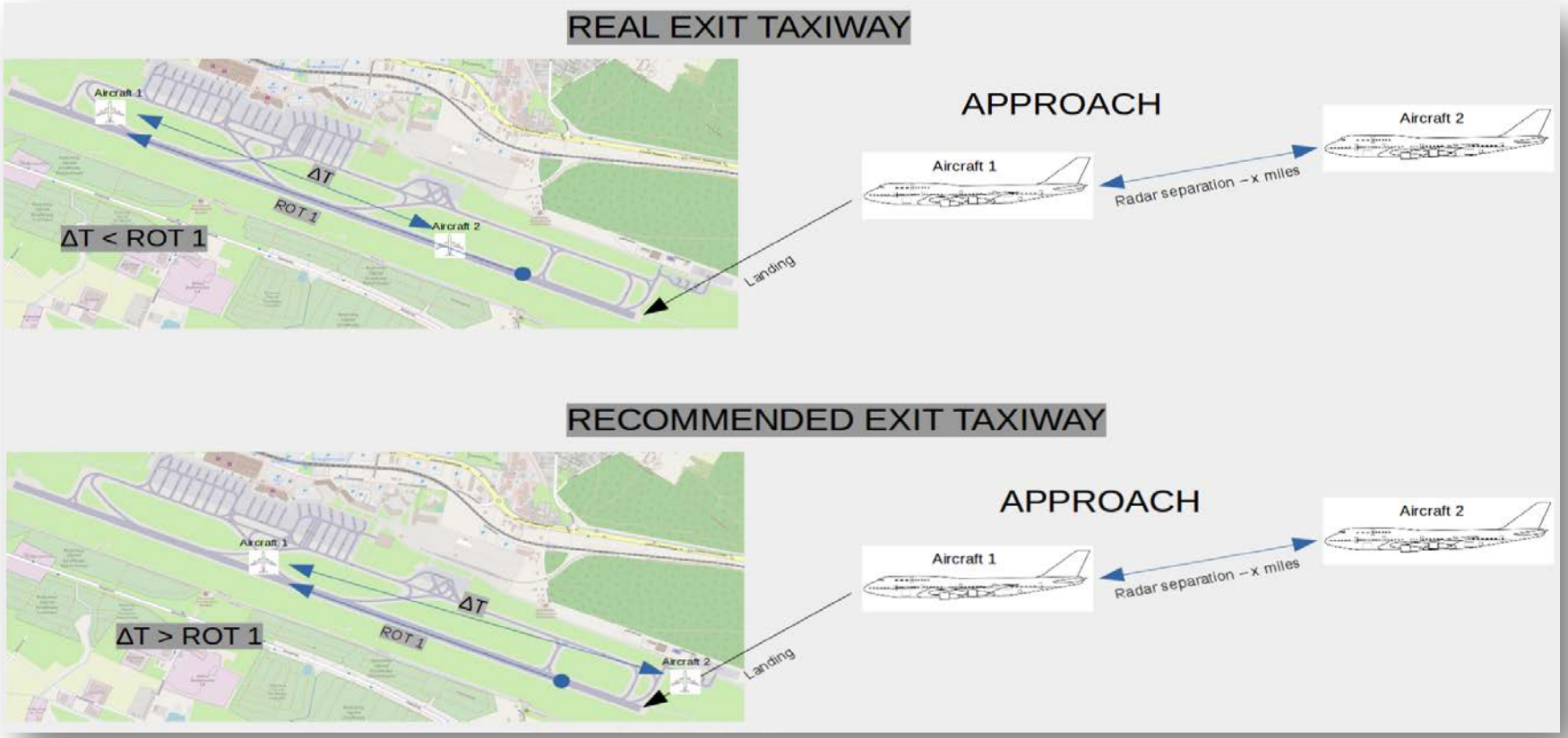
Arrivals taken to simulations in both directions:





Methodology

Reducing ROT may imply radar separation decreasing



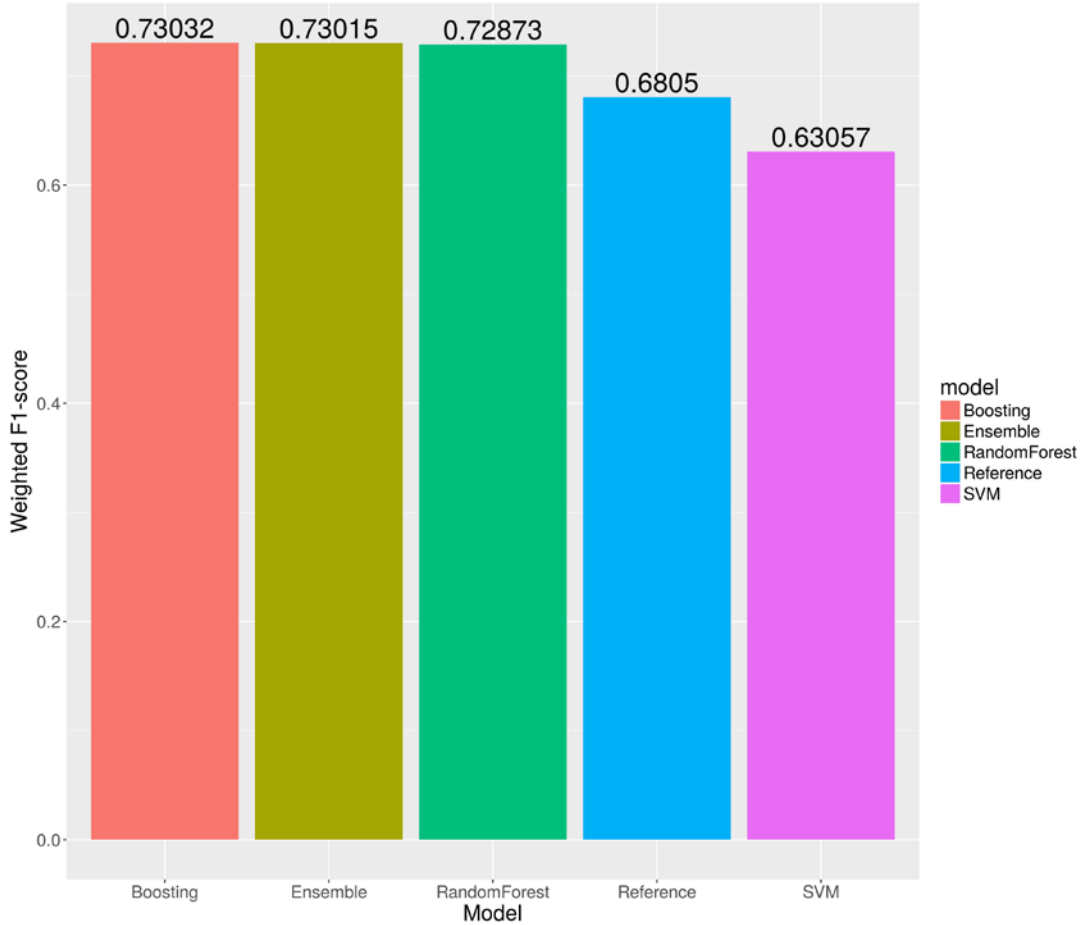
Main achieved and expected results

For exit recommendation machine learning model was developed based on historical data:

Data	Source	Period	Additional info
Surveillance	ADS-B, Tracker	1 year	26000 tracks (only passenger traffic, arrivals and departures)
Meteo	METAR, AWOS	1 year	
Frictions	Frictions estimates from sensors	1 year	
Aircraft data	Eurocontrol service	-	
Runway Condtion Code	Runway Condition Code estimation from SESAR PJ03b SAFE		

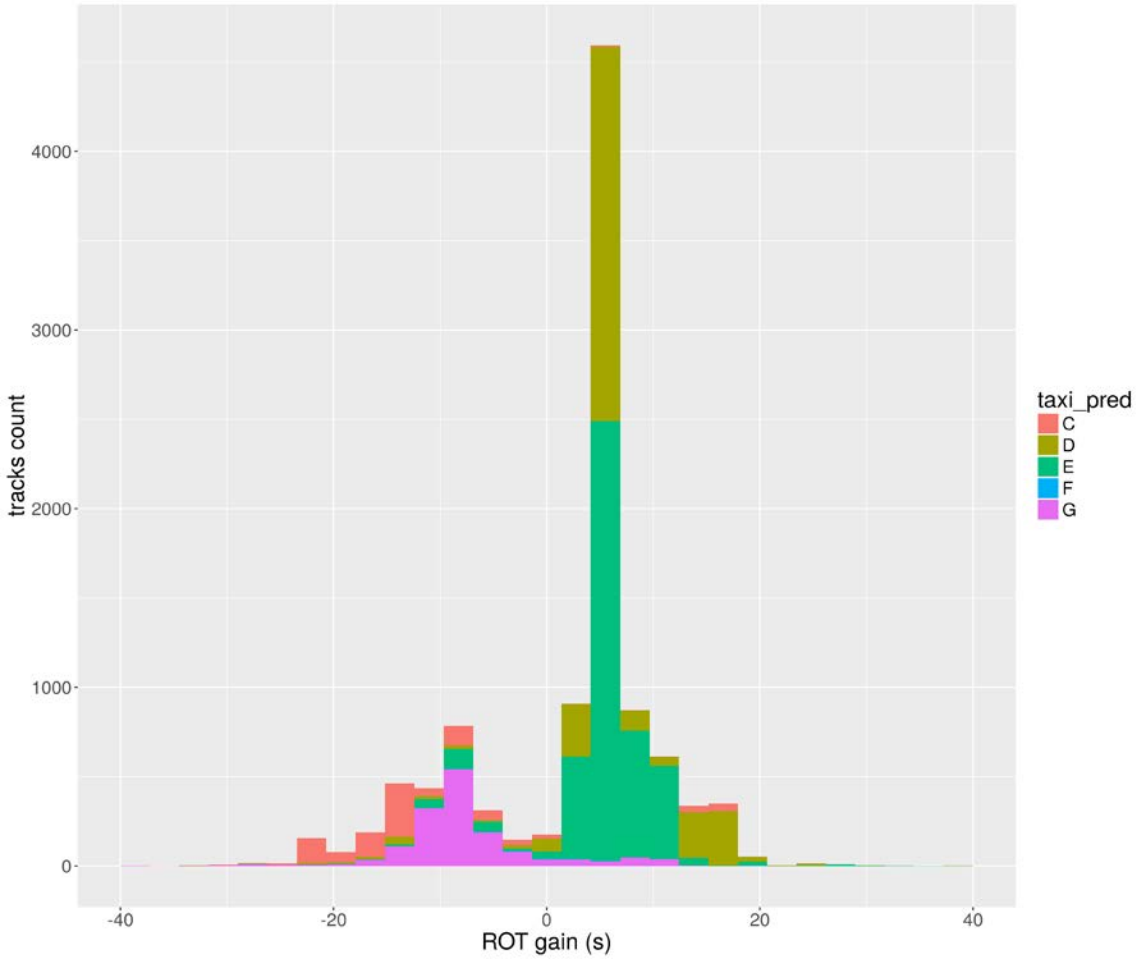
Main achieved and expected results

Exit taxiway
models performance



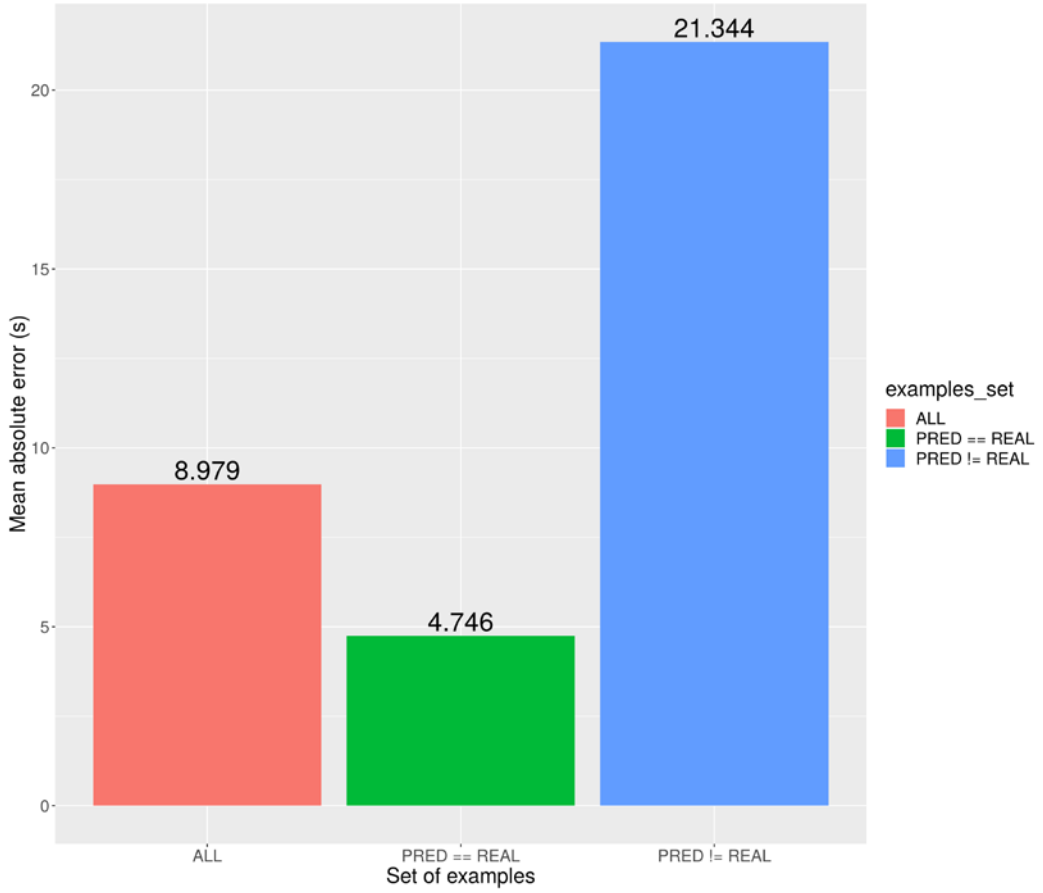
Main achieved and expected results

Runway Occupancy Time (ROT) gain distribution for recommended exits



Main achieved and expected results

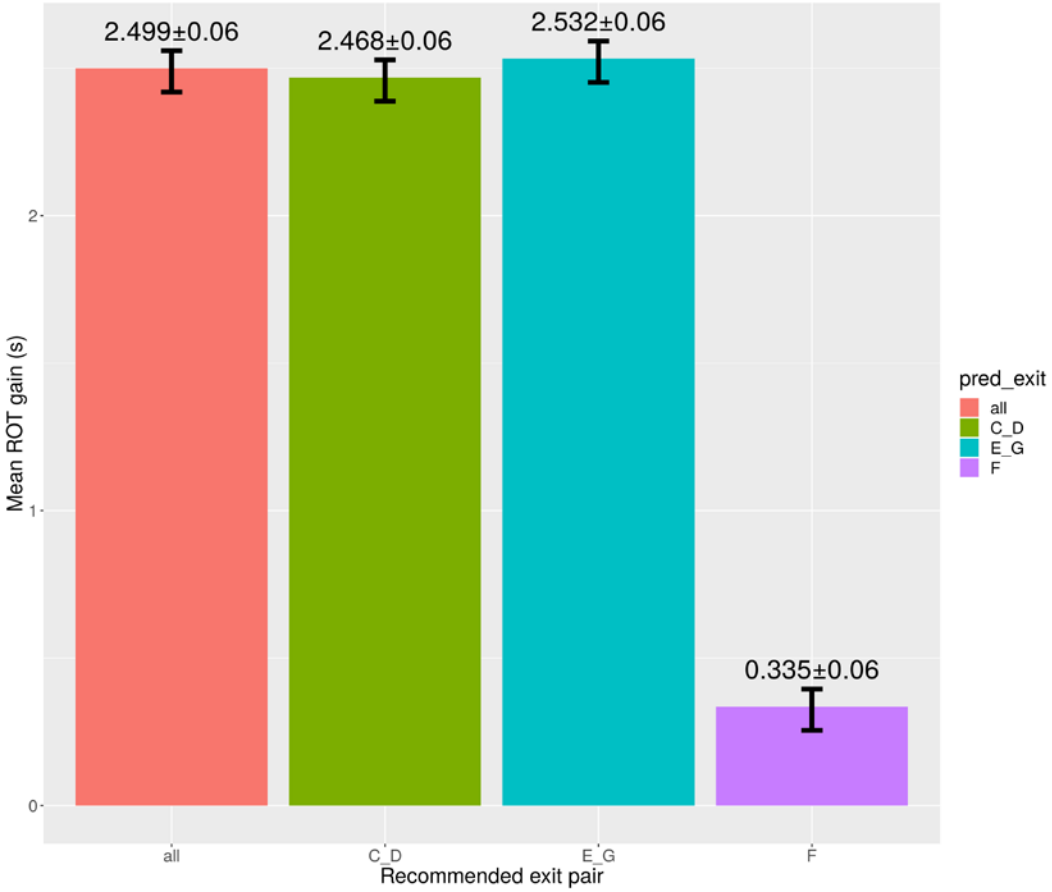
ROT mean absolute error per example set



Main achieved and expected results

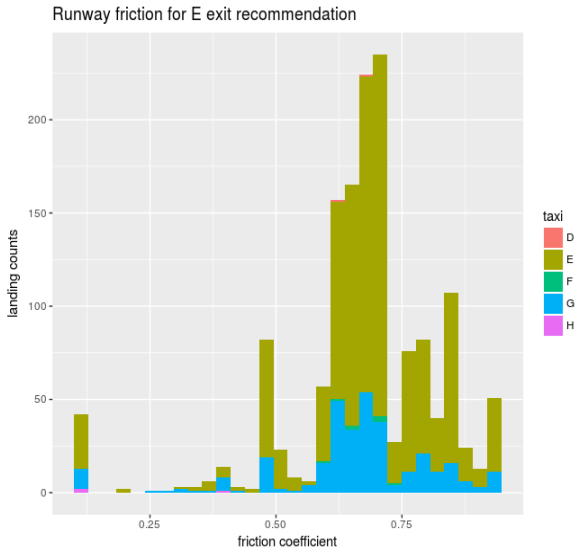
Mean ROT gain per operation different recommended exit pairs

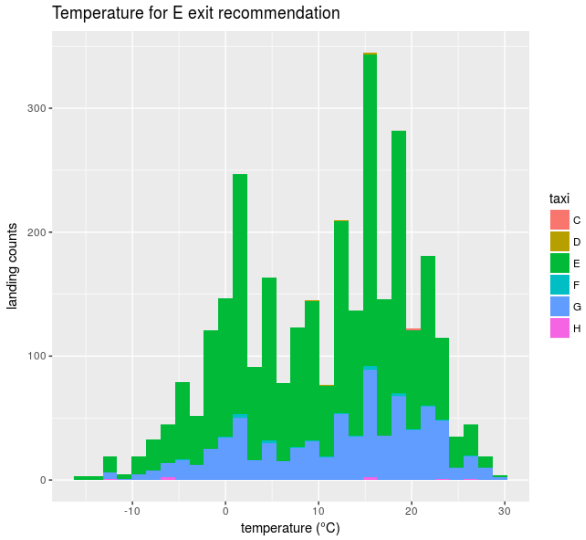
- Mean error from ADS-B ROT measure – **0.026 s**
- Mean error from ROT prediction – **0.052 s**

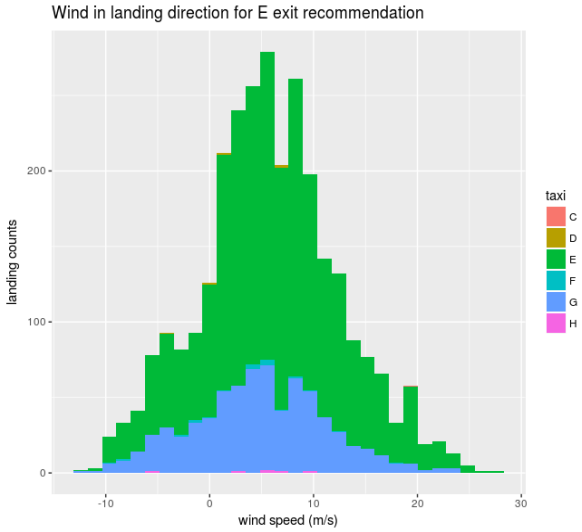


Main achieved and expected results

Recommendation justification – none of factors objectively indicating slower decelaration doesn't justify further exit



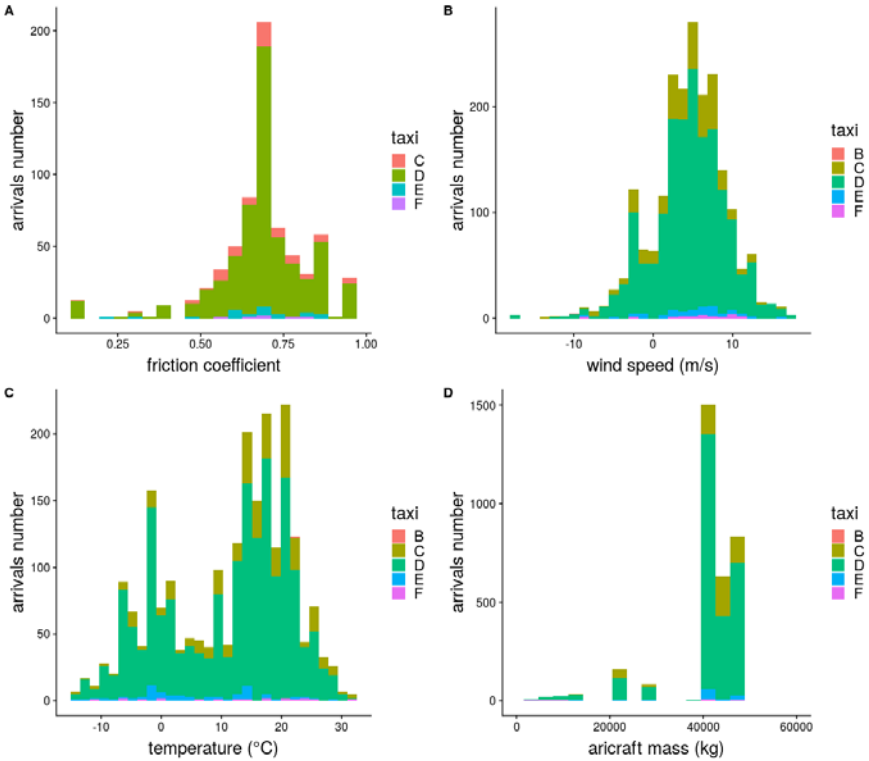




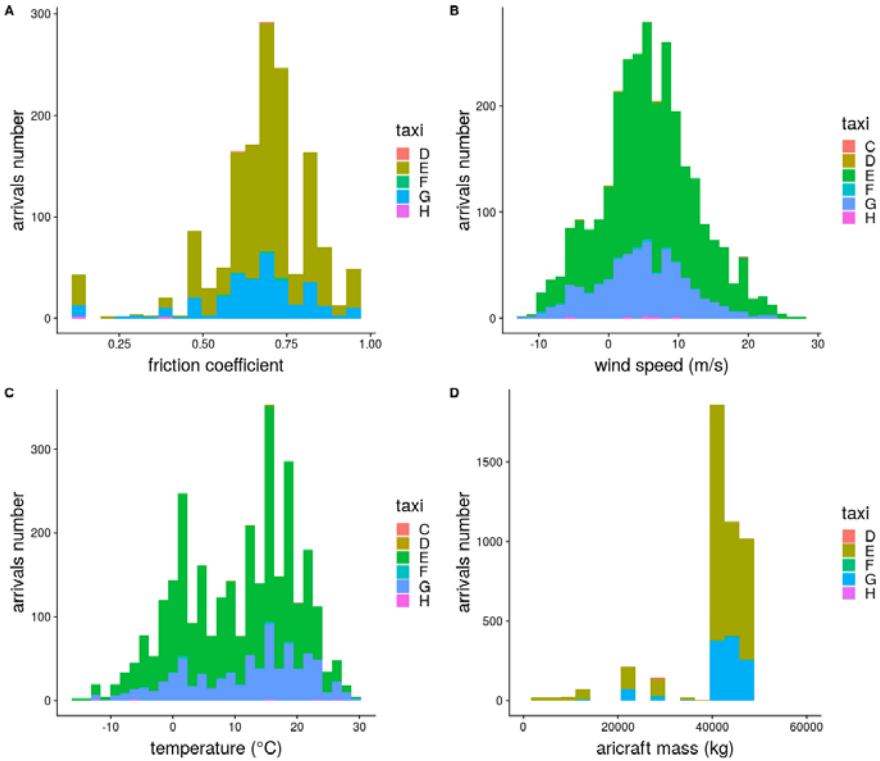
Main achieved and expected results

Recommendation justification – none of factors objectively indicating slower decelaration doesn't justify further exit

D exit recommendation

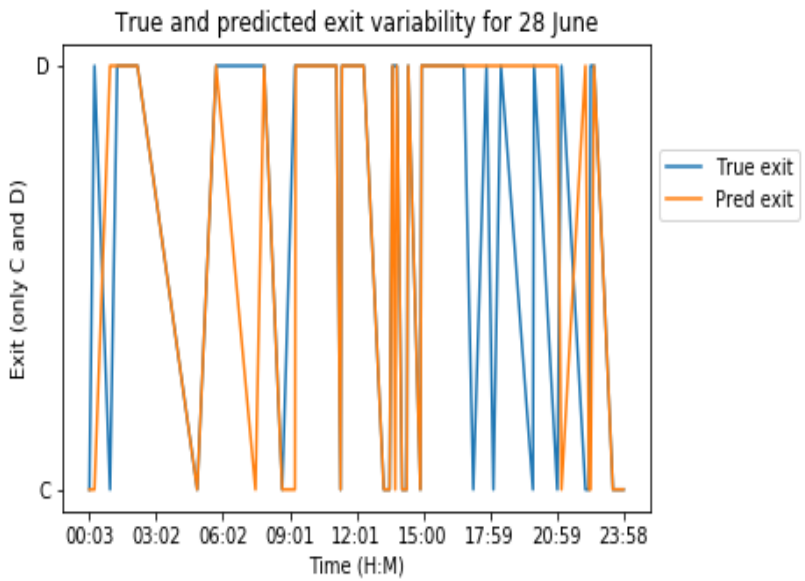


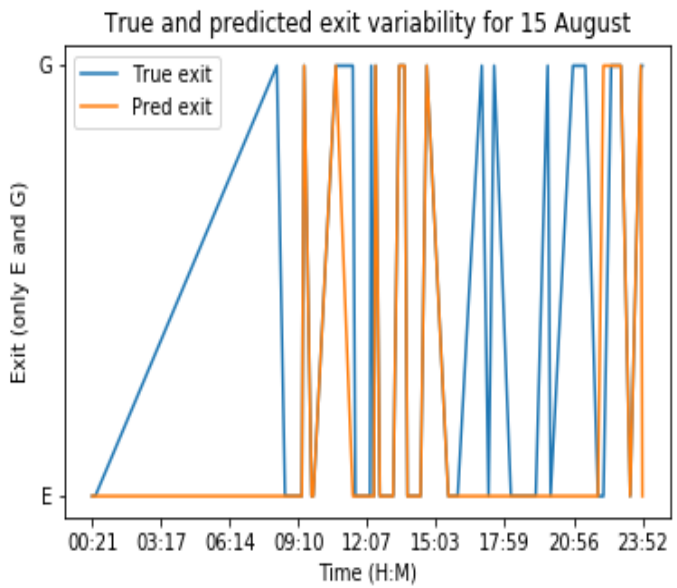
E exit recommendation



Main achieved and expected results

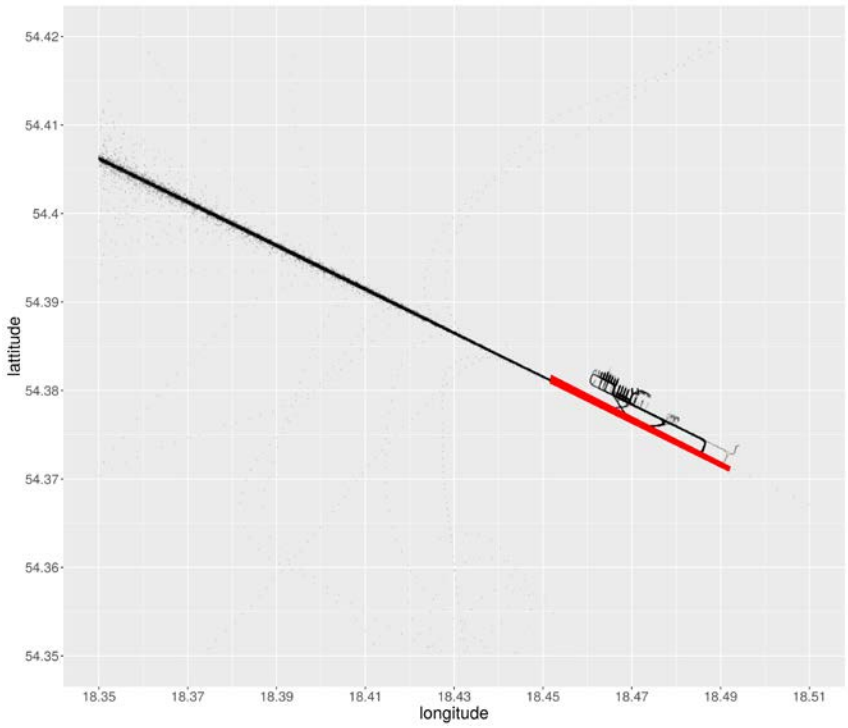
Recommendation justification – exits frequently depend on pilot decision – examples of days with good weather and huge exits variance

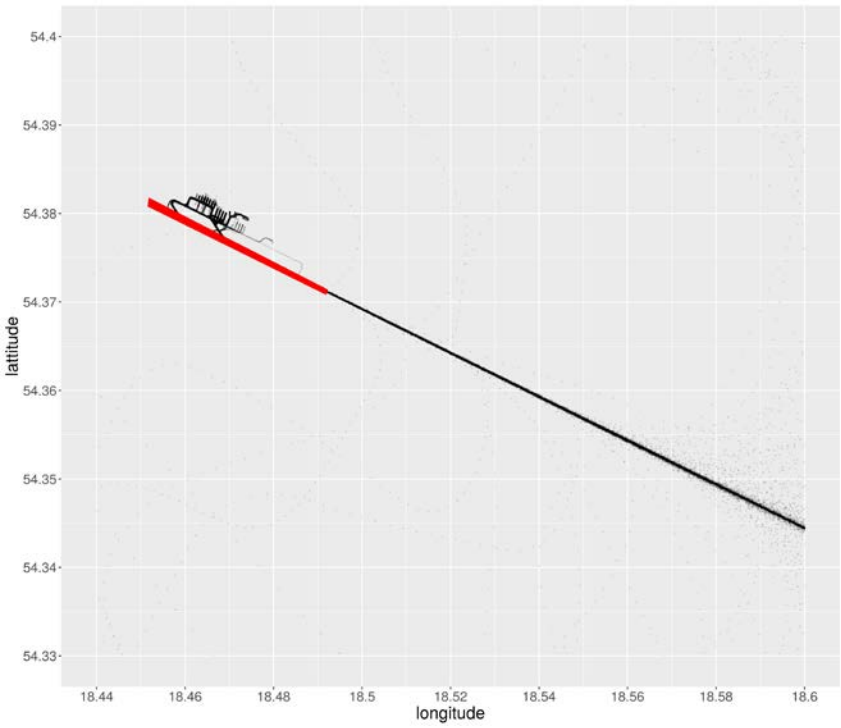




Main achieved and expected results

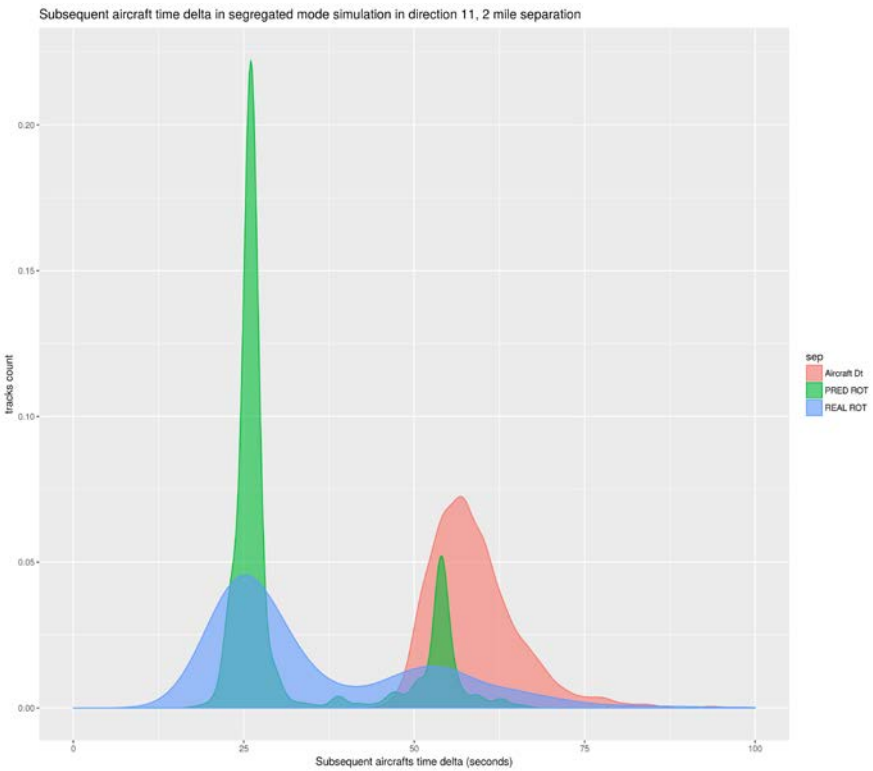
Trajectories taken to simulation in final approach phase:

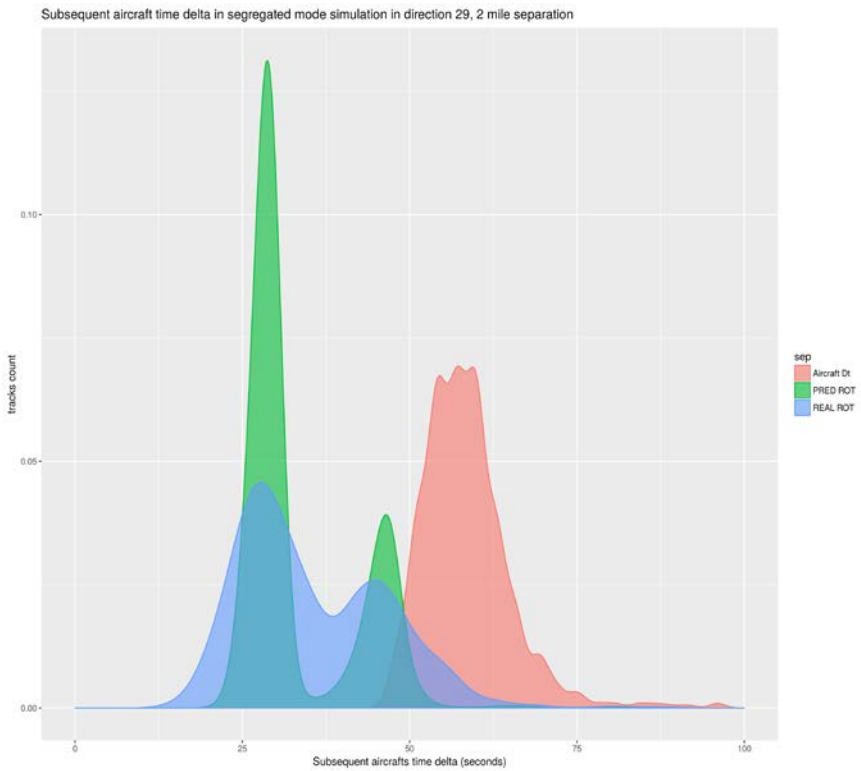




Main achieved and expected results

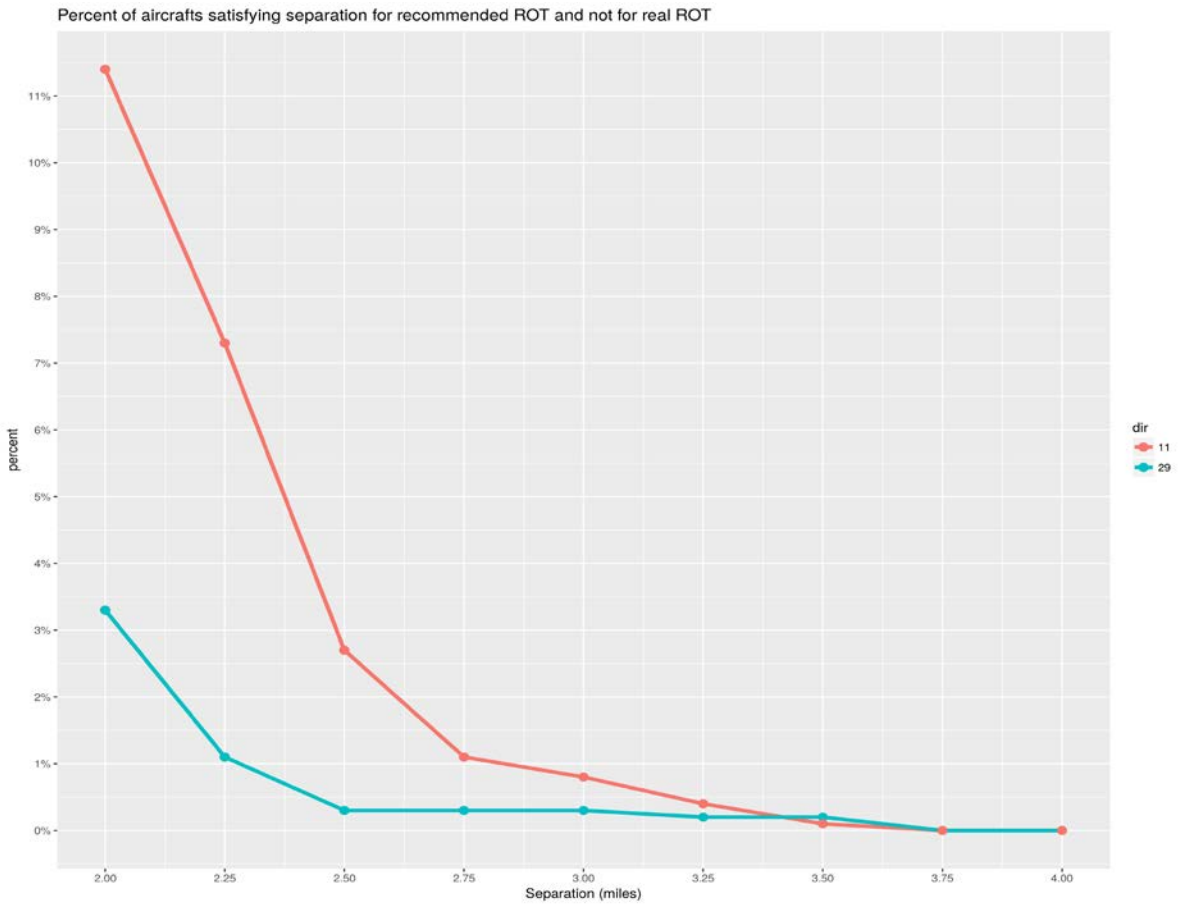
Segregated mode simulation – ROT and arrivals time difference distributions:





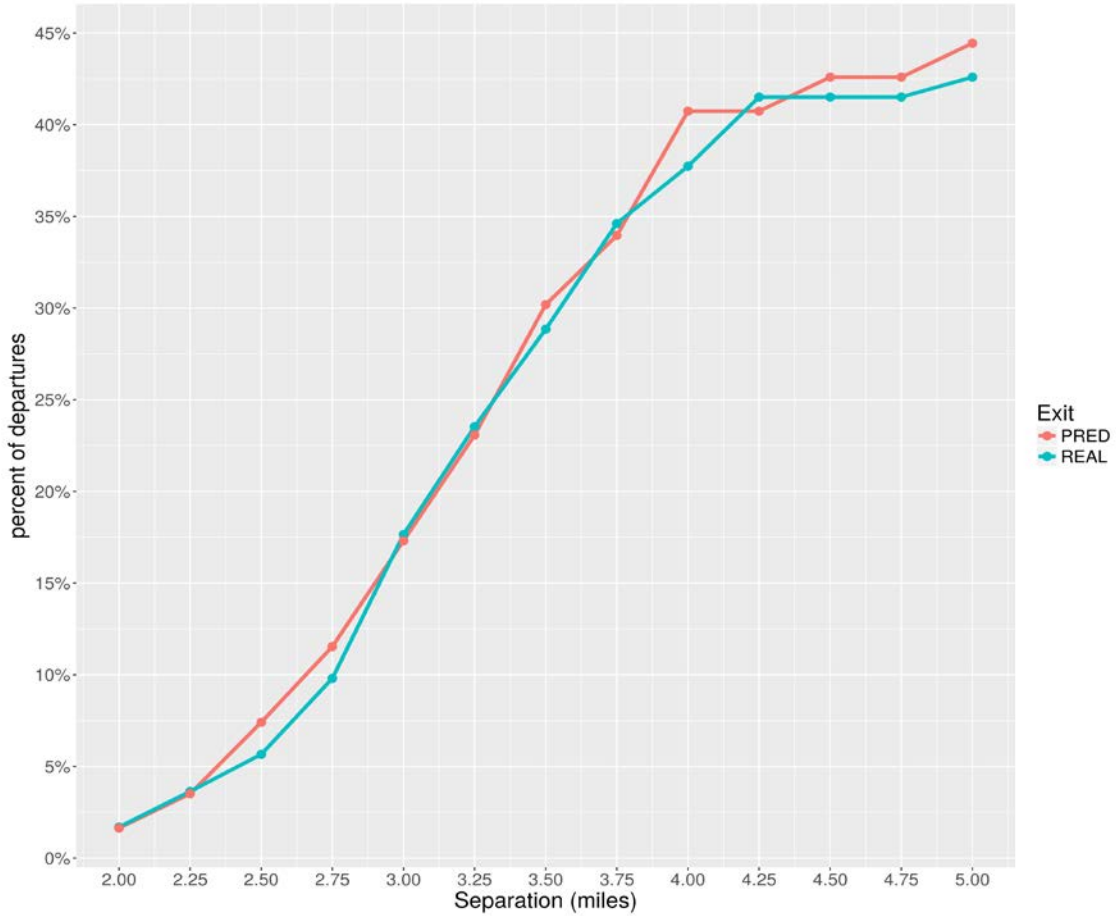
Main achieved and expected results

Segregated mode directions difference



Main achieved and expected results

Percentage of departures per hour in mixed mode simulation



Assessment of Human Performance in Multiple Remote Tower Operations

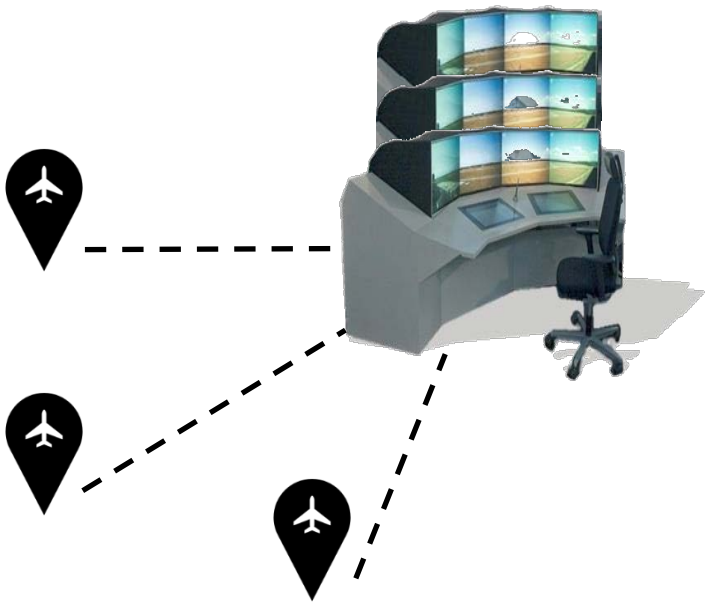
PJ05 – Multiple Remote Tower

Anneke Hamann
German Aerospace Center (DLR)

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Scientific & technical goals

- Remote Tower
  - Remote surveillance of one aerodrome
- Multiple Remote Tower
  - Remote surveillance of up to three aerodromes



→ *Is it safe, efficient and do controllers like it?*

Scientific & technical goals

- Te

Simulation Setup

- Real-Time Simulation
  - NARSIM simulation platform
  - 5 scenarios

- Participants
  - 7 controllers from HungaroControl
    - 5 male, 2 female; 5 civilian, 2 military
    - ATC experience: 7 - 36 years (*M* = 18, *SD* = 10)
- Design
  - incomplete 2 (traffic distribution) x 3 (incident type) within-subject design
    - traffic distribution: even/uneven
    - incident type: wind change/oil leakage/emergency landing

Simulation Setup

- Traffic amount: 21 mov/h (incl. ground)
- Scenarios approx. 50min

Scenario ID	Distribution	Type of Incident
Training	even	none
SCN 1	**uneven**	Unplanned RWY closure (oil leak)
SCN2	**uneven**	RWY direction change
SCN3	even	Unplanned RWY closure (oil leak)
SCN4	even	RWY direction change
SCN5	even	Emergency (engine failure, no fire)

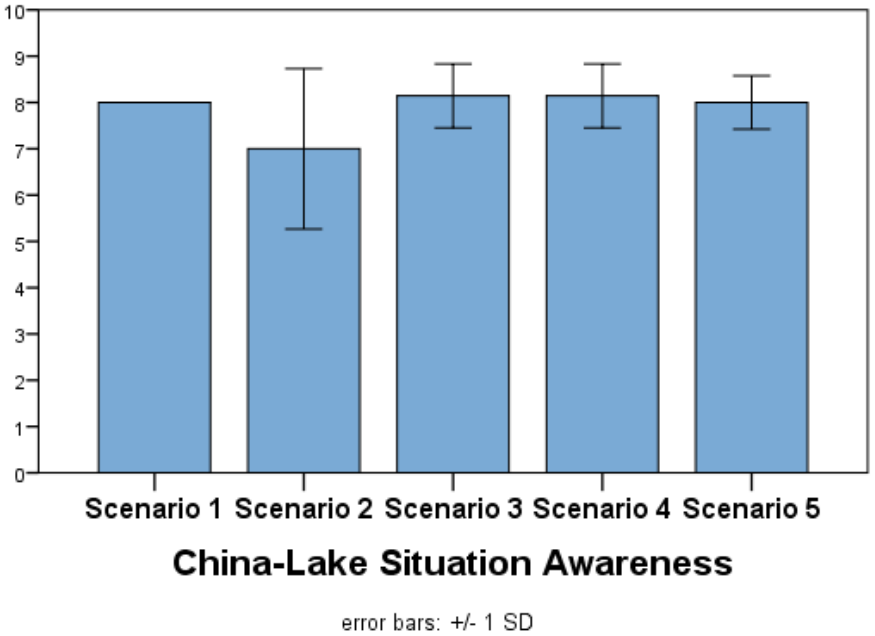
Results – Situation Awareness

8-10 (good)

5-7 (reduced)

2-4 (low)

1 (far too low)



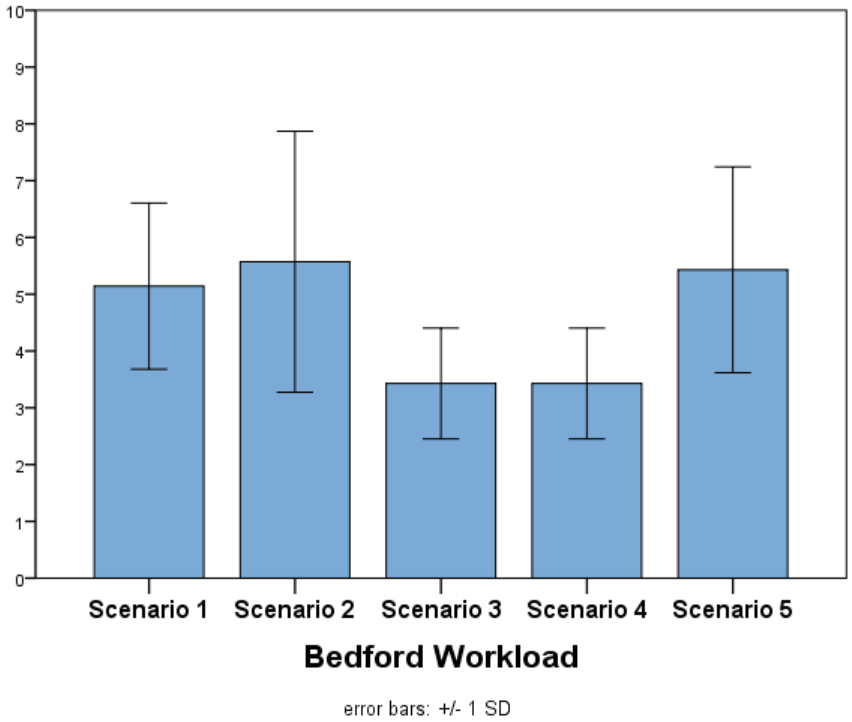
Results – Workload

1-3 (low)

4-6 (medium)

7-9 (high)

10 (extreme)



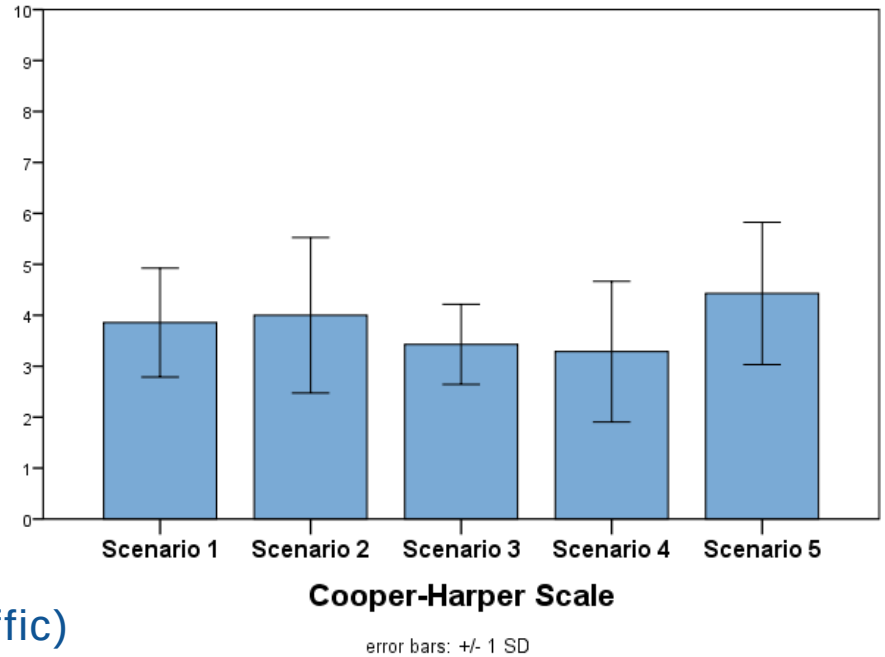
Results – Safety

1-3 (no impairment)

4-6 (reduced capacity)

7-9 (reduced safety)

10 (unable to control traffic)



Potential gaps and challenges

1 controller,
3 aerodromes

→ max. 10 mov/h &
4 simultaneous

→ Multiple Remote Tower is yet another factor contributing to complexity

- Mitigations for high WL
  - Splitting aerodromes
  - Support staff
- Technical equipment
  - Automated camera functions?
  - Radar coverage?
- Combination of aerodromes
  - Traffic amount
  - Harmonised procedures?

Impact

- ANSPs (Air Navigation Service Providers)
  - Cost efficiency
  - Surveillance of new aerodromes
- Controllers and unions
  - Change in work conditions & responsibilities
  - Endorsements
- Pilots
  - Raise awareness: changes in phraseology

Contact and Information

Remote Tower
https://www.remote-tower.eu/

SESAR Joint Undertaking
https://www.sesarju.eu/

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We would like to thank our project partners HungaroControl and Frequentis.

https://www.hungarocontrol.hu/
https://www.frequentis.com/

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Bucharest, 27-30 May 2019

Thank you !

Bucharest, 27-30 May 2019