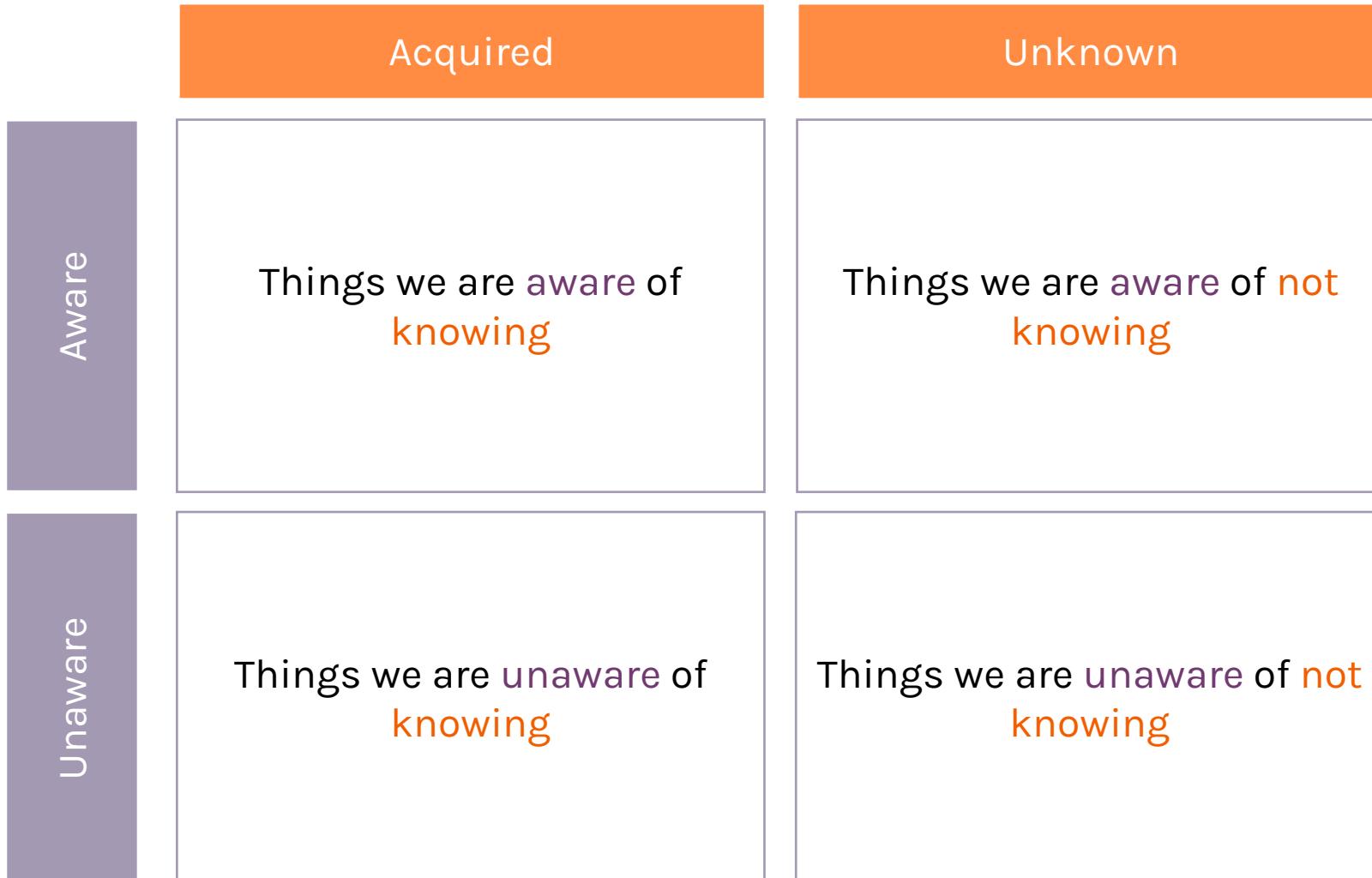


Process Mining in Aviation

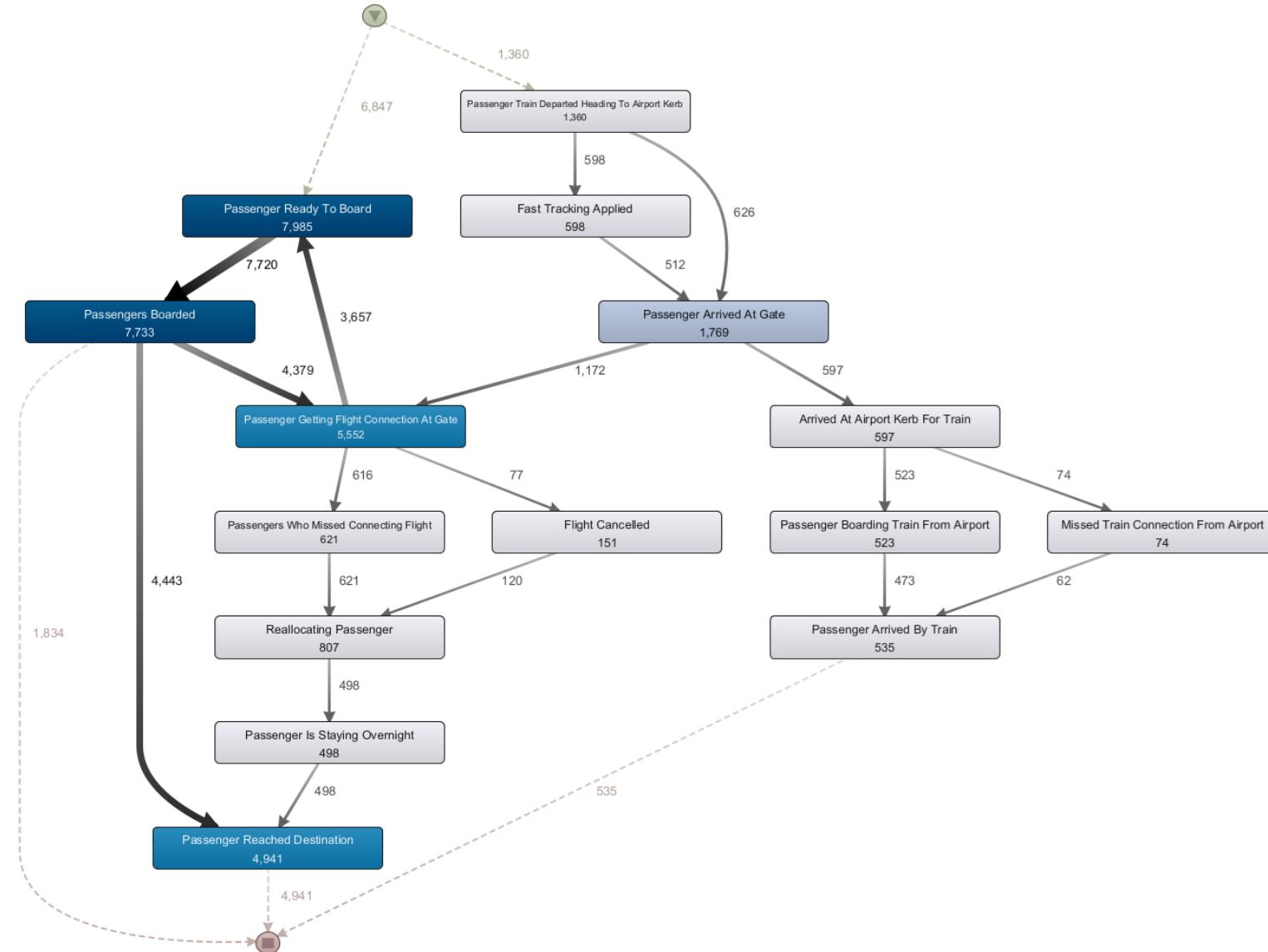
Rolf Bänziger



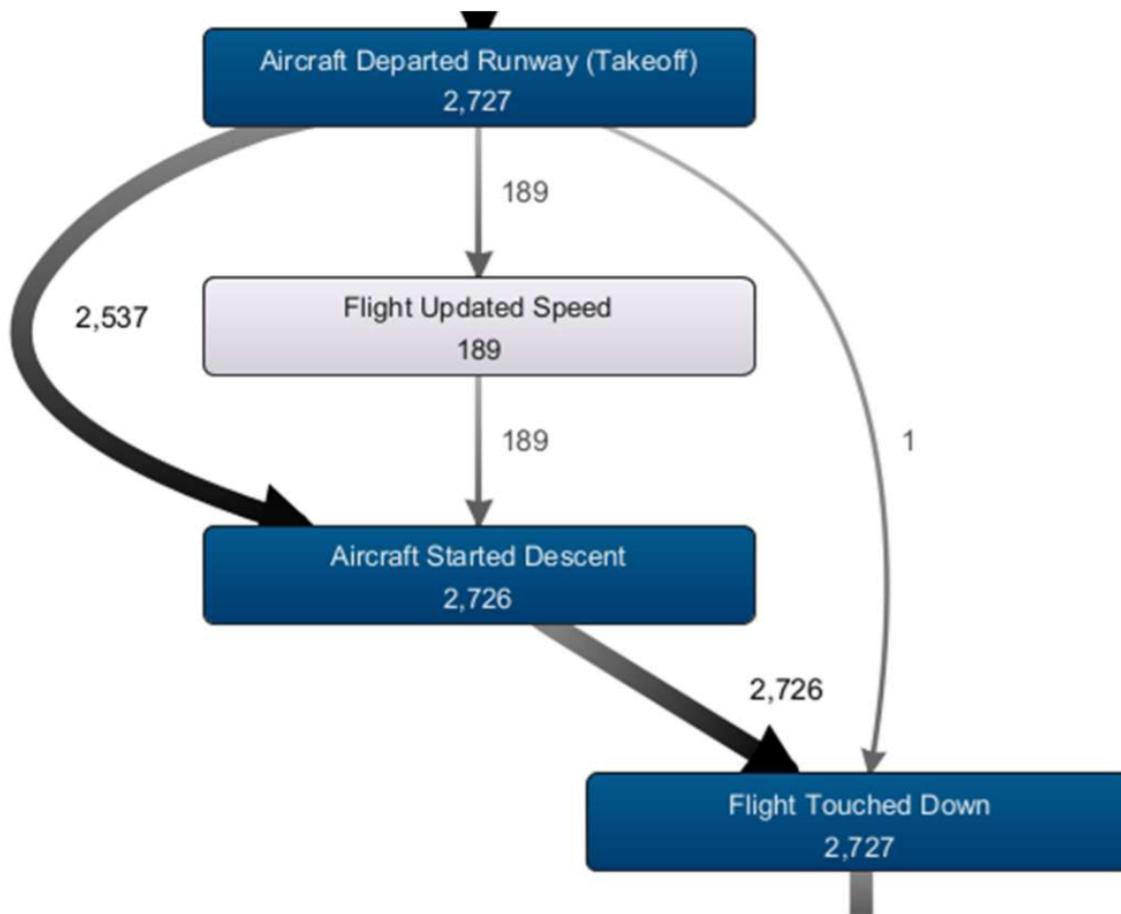
What do we know?



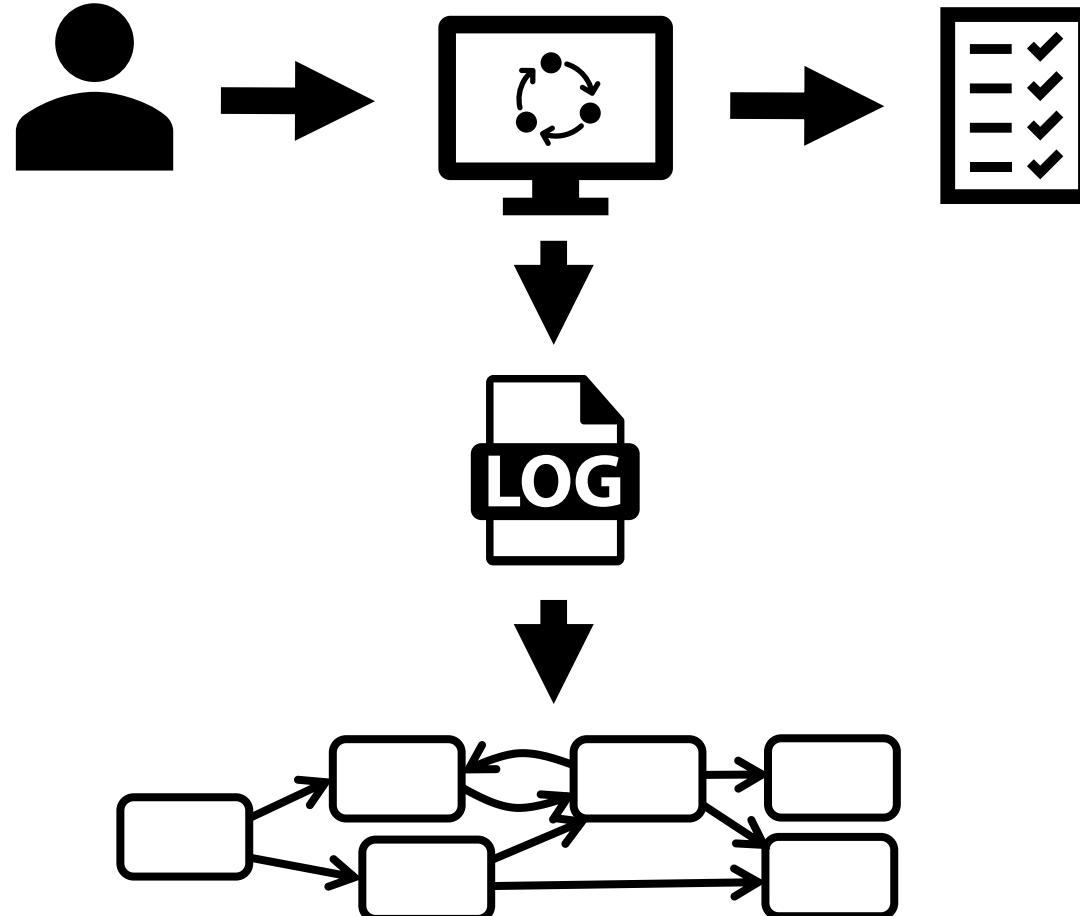
Process Intelligence can help



Find the unexpected



What is a Process Mining?



What is Process Mining?

Using event data to discover, monitor, and *improve* real processes

Three main types:

- Process discovery
- Conformance checking
- Performance analysis (enhancement)



Analyse real process (as opposed to assumed process)

Event logs: The source of truth

Case ID	Timestamp	Activity	Person
1	1 Feb 10:13 AM	Receive enquiry	Malar
	1 Feb 12:06 PM	Send offer	James
	2 Feb 3:53 PM	Receive booking	Malar
2	1 Feb 3:13 PM	Receive enquiry	Tom
	1 Feb 4:05 PM	Send offer	Sarah
	1 Feb 5:28 PM	Offer rejected	Tom
3	1 Feb 4:02 PM	Receive enquiry	Natalia
	1 Feb 4:59 PM	Send offer	James
	2 Feb 9:58 AM	Discount requested	Natalia
	2 Feb 11:02 AM	Approve discount	James
	2 Feb 2:48 PM	Send offer	Sarah
	2 Feb 4:59 PM	Receive booking	Natalia

Components

Case and Activity identifiers

Order (usually timestamp)

Additional info

Anatomy of an event log

Case Id: What is object we're tracking?

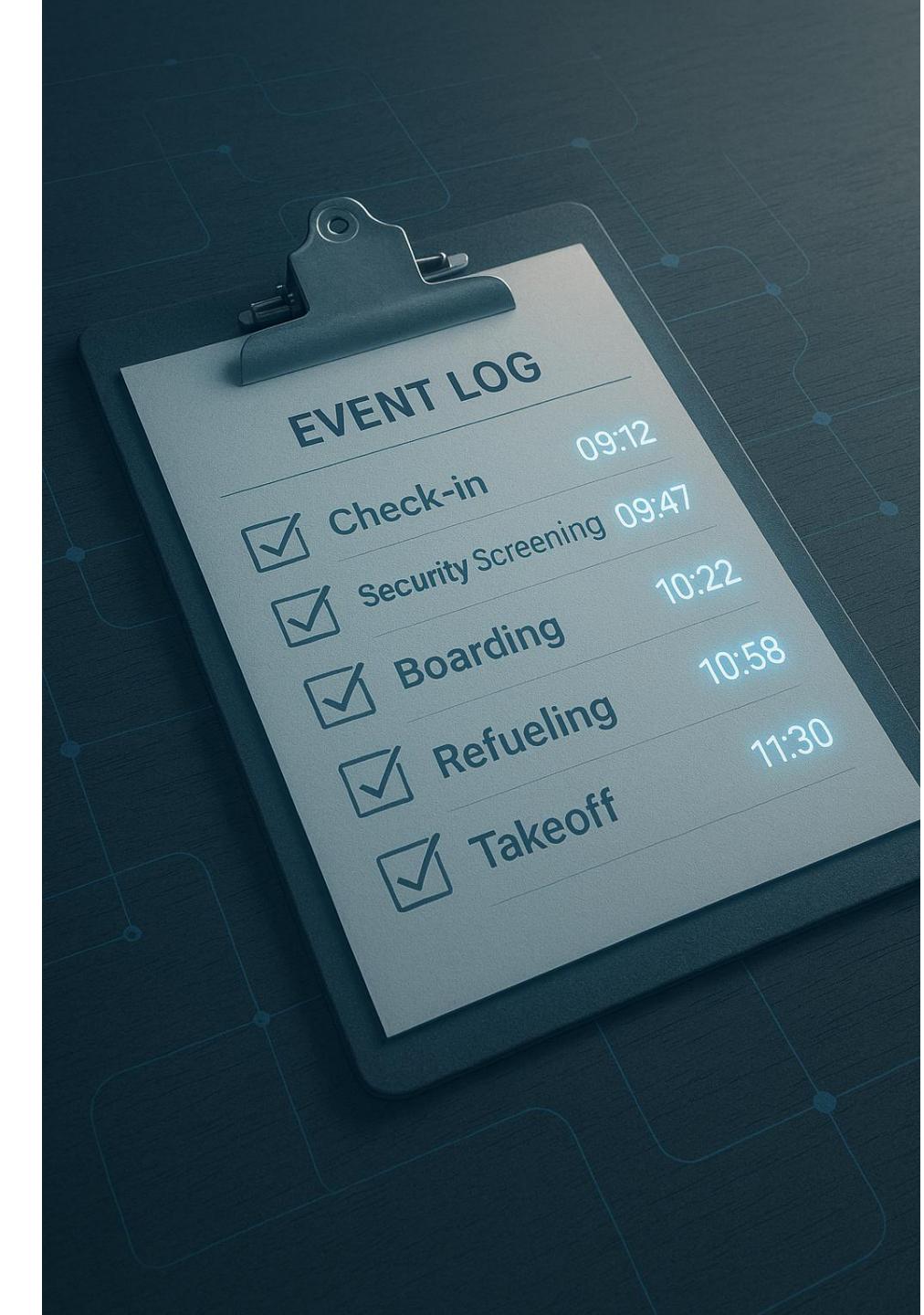
e.g. Flight number + date, Tail number (specific aircraft), passenger, baggage item, etc...

Activities: Type/class of event in the process

e.g. "Aircraft on stand", "Fuel complete", "Boarding started", "Pushback", etc.

Timestamp: when each event happens

Additional attributes: gate, crew Id, weather, etc.



Challenges

Noise

- Incomplete or incorrect timestamps
- Out-of-order events
- Missing activities

Parallelism

- Concurrent activities (e.g., fueling and cleaning)
- Hard to distinguish from sequential behavior

Complexity

- Large number of variants
- Long traces with many activities

Data Quality

- Inconsistent case identifiers
- Ambiguous activity labels



An aviation example

Turnaround process

Planes earn money only when flying

Several tasks need to happen before the aircraft can depart again

Some can happen in parallel, others cannot

Based on a case study at the Airport Munich by Rott et al. 2023



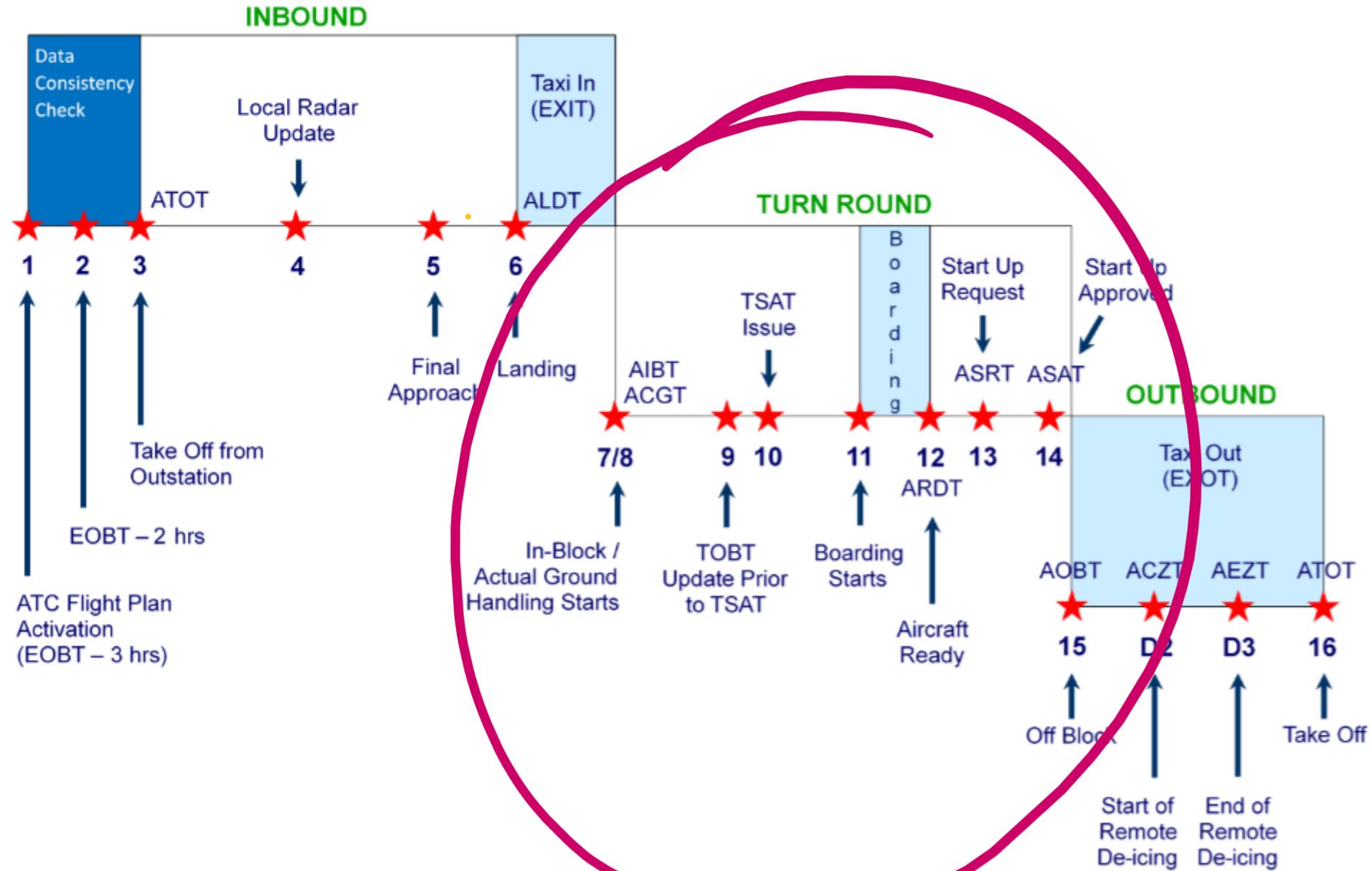
*“What insights can PM,
building upon Λ CDM
timestamps, provide for the
turnaround process at
airports?”*

Airport Collaborative Decision Making

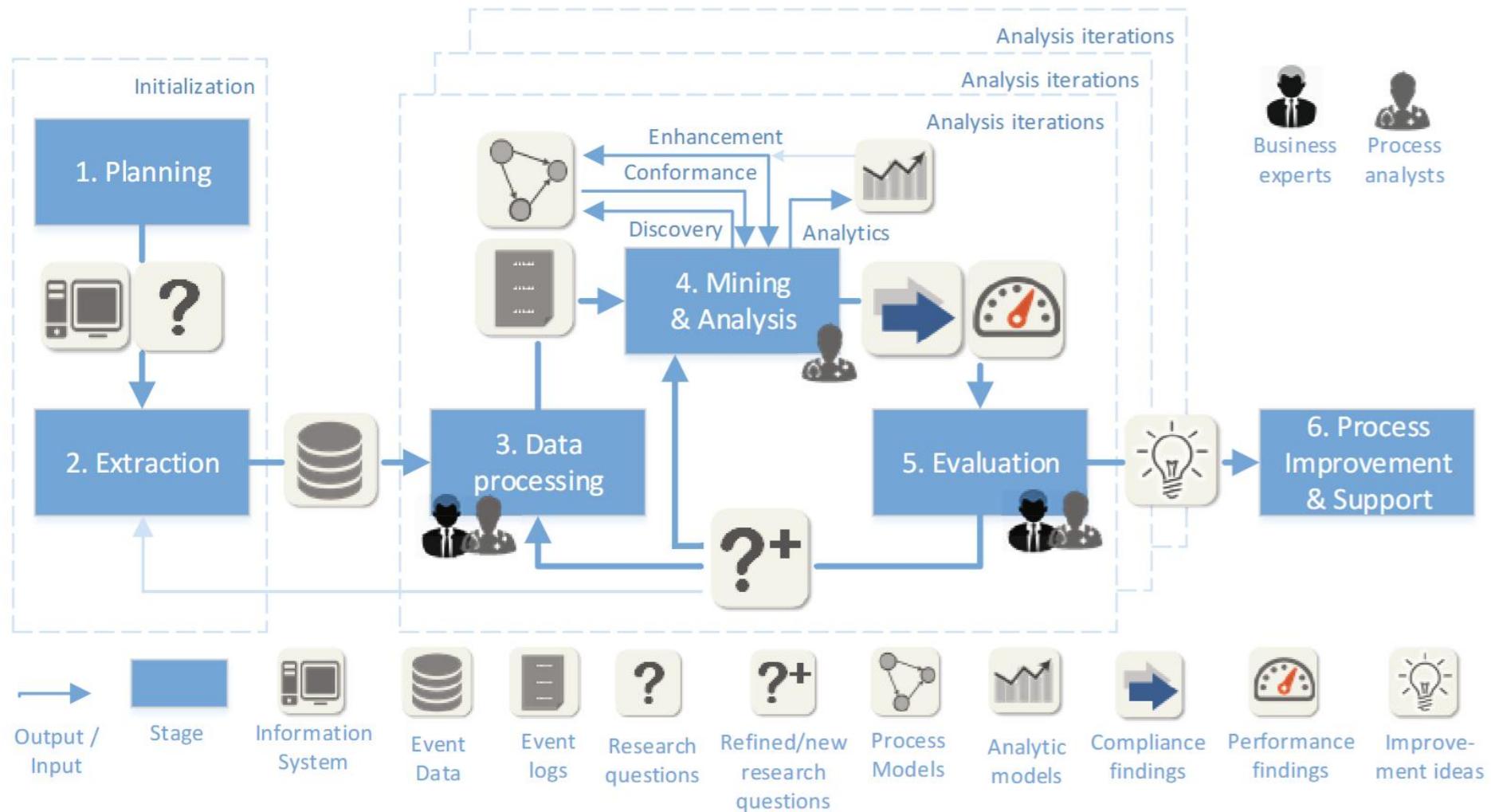
Joint operational concept designed to improve airport efficiency
by enhancing the sharing and use of accurate, timely information
between all airport partners (Eurocontrol 2027)

Airport Operator, Ground Handlers, ATC, Maintenance, etc.

Everyone works from a single version of the truth – real-time, data-
driven decisions based on shared event milestones.



PM² Methodology



Analysis questions

- What does the actual process look like (Process discovery)?
- What are the discrepancies and commonalities between the observed and modeled process behaviors (Conformance checking)?
- How is the process performance concerning off-block delay and TOBT quality (KPI performance)?



Extraction

26'198 turnarounds (cases)

495'754 events

September 2019 and

September 2021

Included events and their corresponding ACDM timestamp.

Own ID	ACDM number (EUROCONTROL, 2017)	Milestone (event) description
2	2	2 h before the expected off-block time (EOBT)
3	3	Take off from outstation
5	5	Final approach
6	6	Landing
6.1	-	Hand-Over inbound
7	7	In-block
7.1	-	Scheduled in-block time (SIBT)
9	9	Target off-block time (TOBT) issue
10	10	Target start-up approval time (TSAT) issue
11	11	Boarding starts
11.1	-	Boarding ends
12	12	Aircraft ready
12.1	-	TOBT timestamp
12.2	-	TSAT timestamp
13	13	Start-up request
14	14	Start-up given
14.1	-	Pushback request
14.2	-	Pushback given
15	15	Off-block
15.1	-	Taxi request
15.2	-	Taxi given
15.3	-	Hand over outbound
15.4	-	Scheduled off-block time (SOBT)
16	16	Take off
Legend:		Mandatory timestamp
		Nonmandatory timestamp

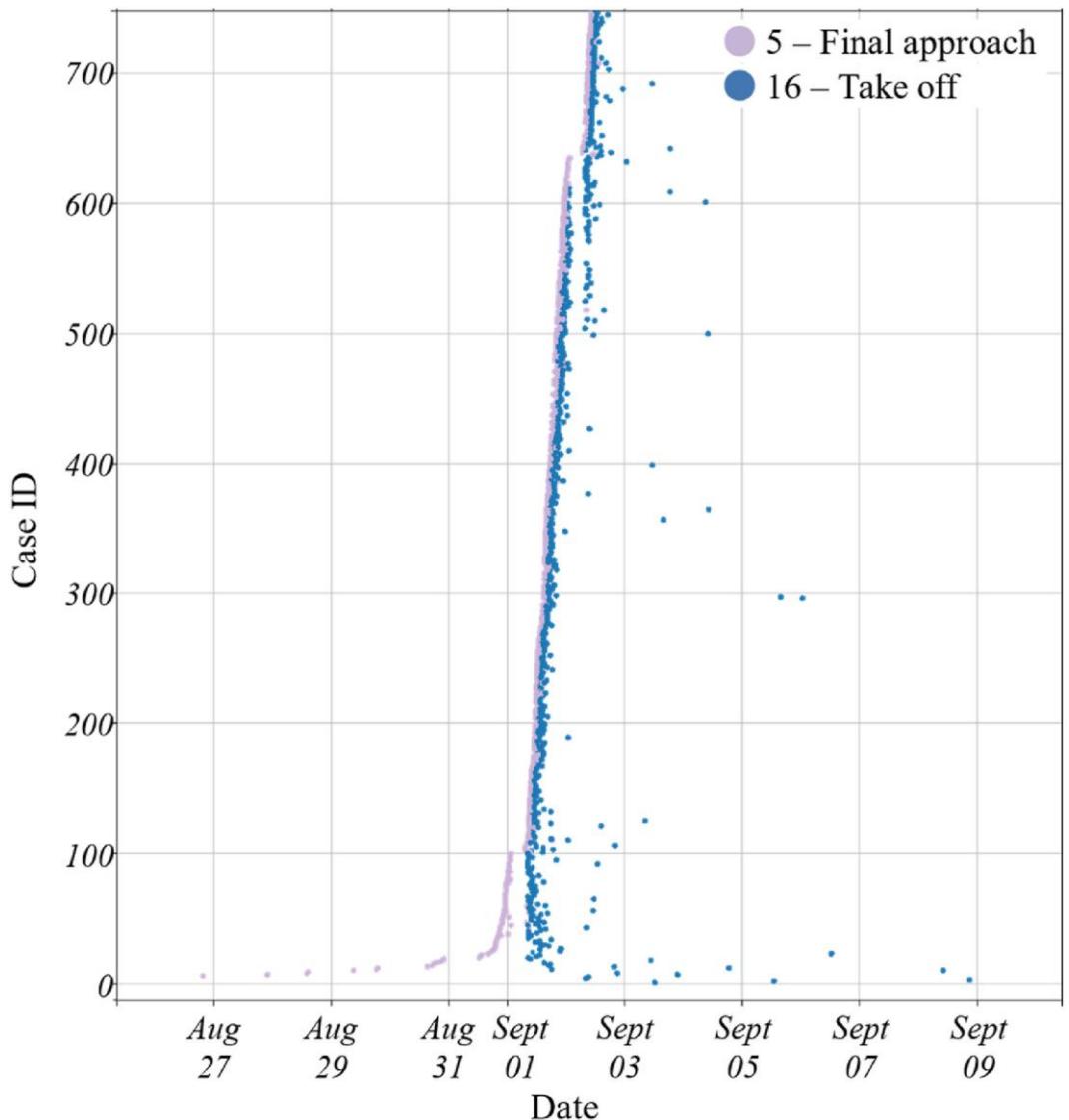
Rott et al. 2023

Analysis

Dotted chart

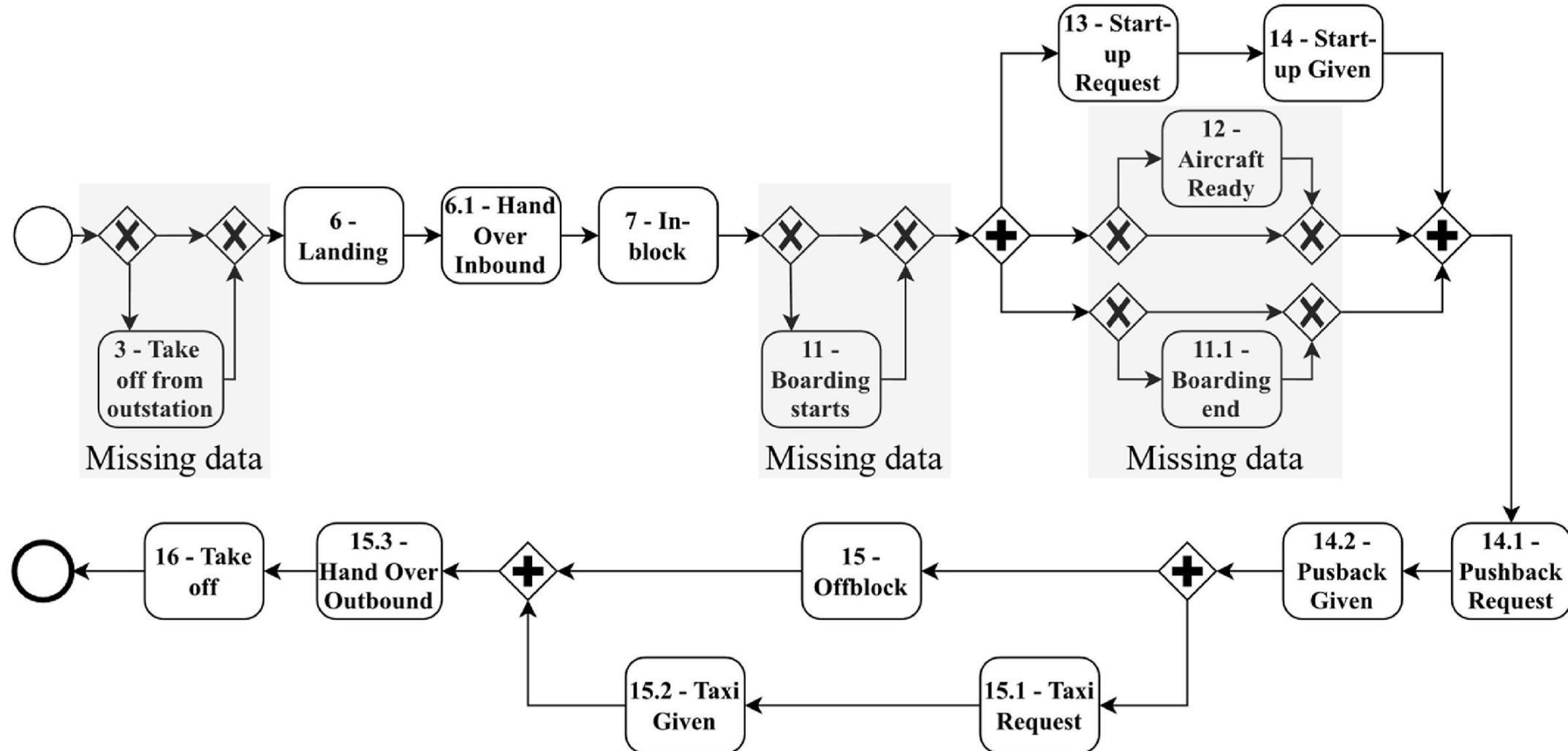
Shows all events of certain activities on timeline

Able to see unusual events (duration of several days)



Rott et al. 2023

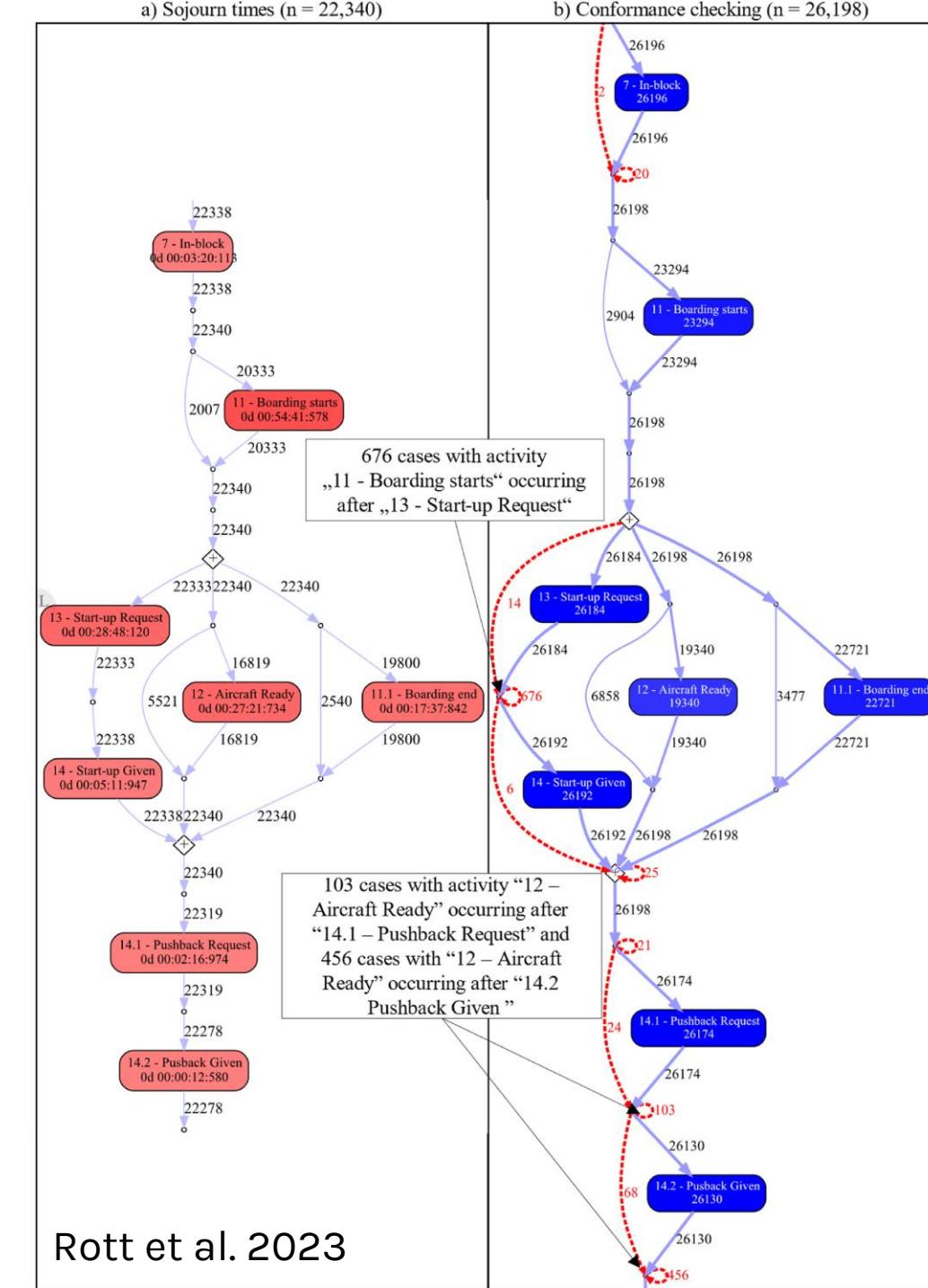
Process flow



Analysis

Long Dwell times between “7 - In-Block” and “11 - Boarding starts” (54 minutes) → Area for improvement

“13 - Start-up Request” happening before 11 – “Boarding starts” → unreliable timestamps



Delays

56% of turnaround started late (Actual In-Block Time > Scheduled In-Block Time)

74% of turnarounds ended late (Actual Off-Block Time > Scheduled Off-Block Time)

Is the minimum turnaround time underestimated?

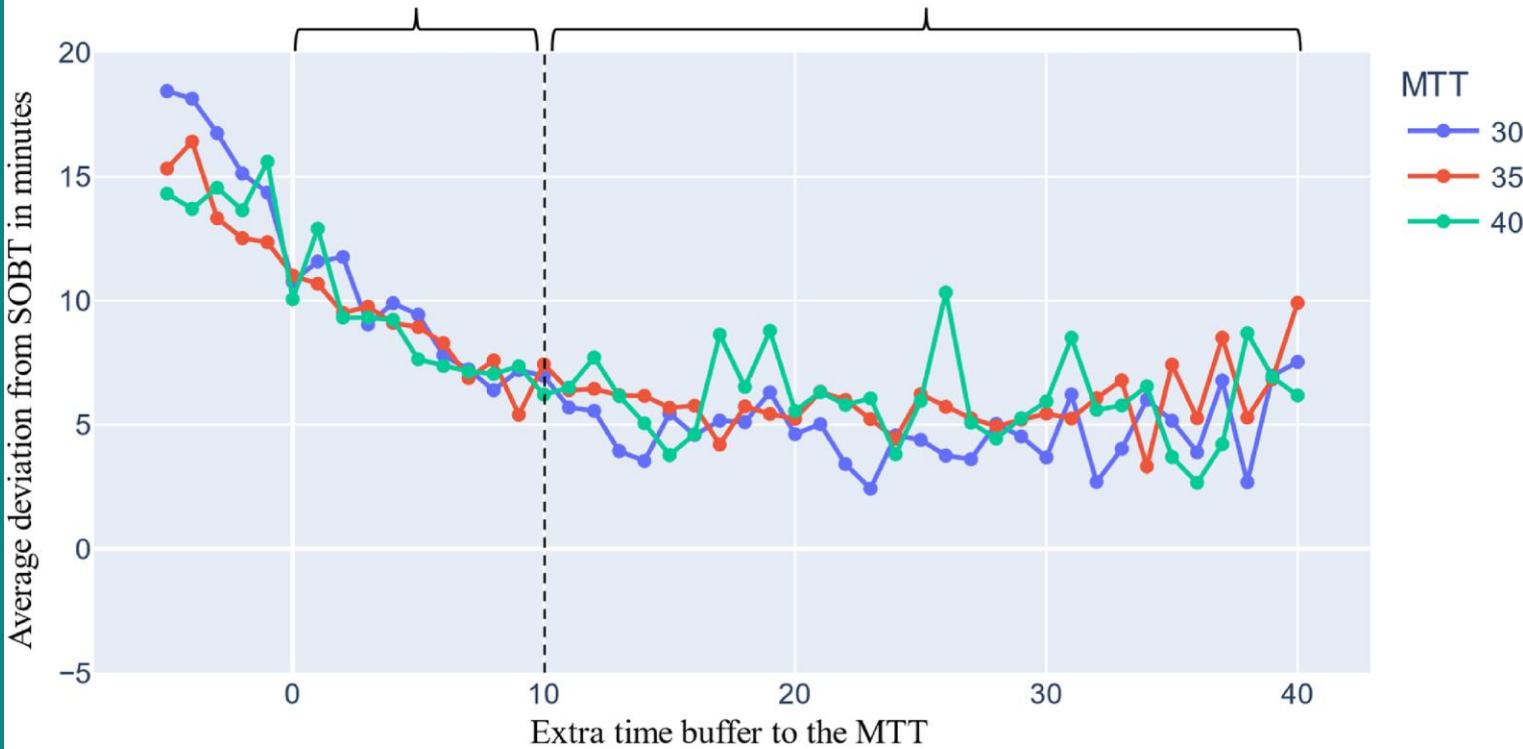


Looking at longer turnarounds

Filter log to only include cases
with MTT between 30 and 40
minutes

Adding up to 10 minutes reduces
delays

No effect for > 10 minutes



Rott et al. 2023

Tools



ProM

Standard open-source tool

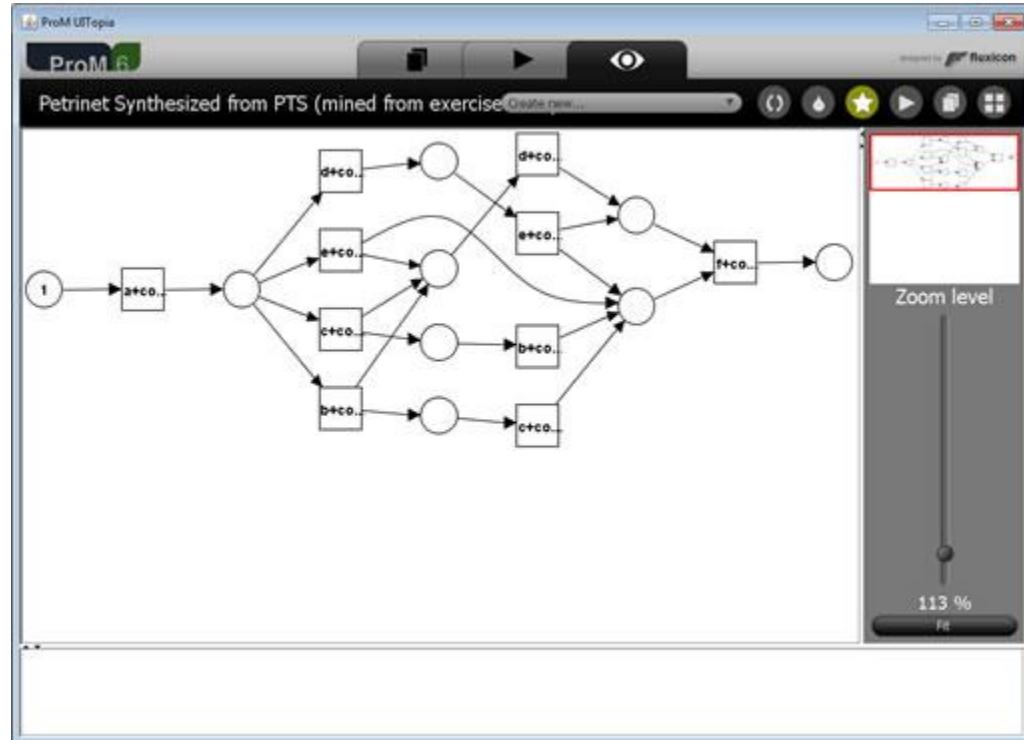
Often used in academia

Powerful, plugin-based

Can be difficult to use

<https://promtools.org/> (also contains many example event logs)

<https://promtools.org/prom-6-tutorial/>



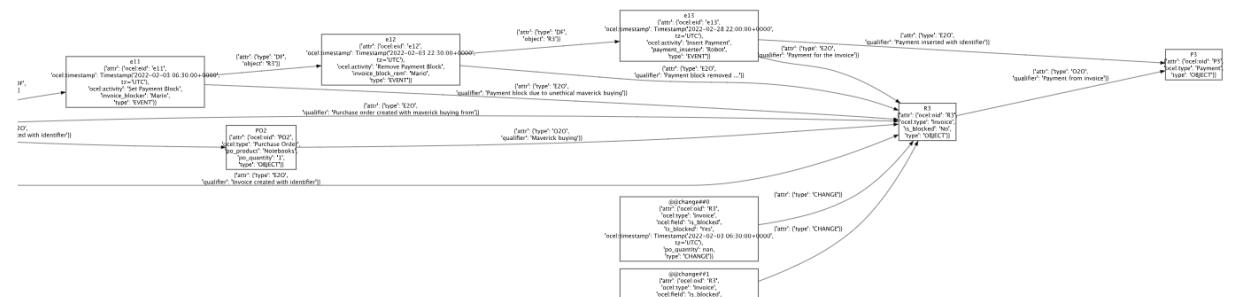
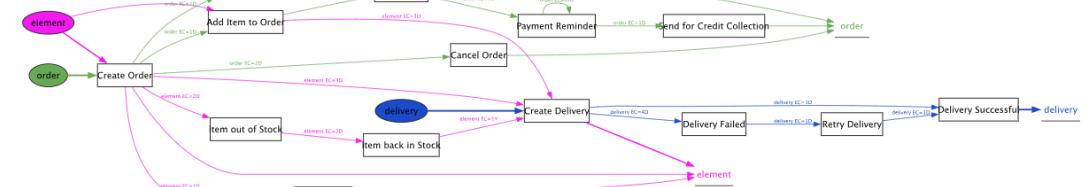
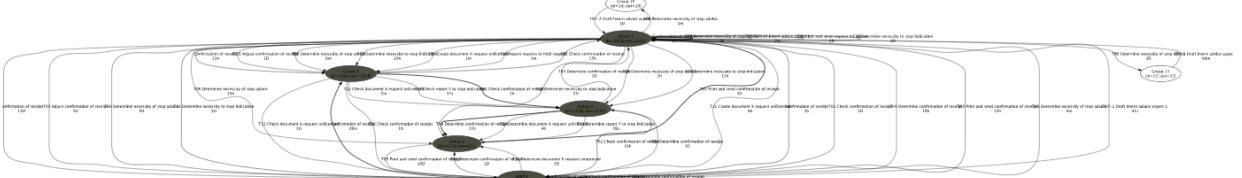
PM4Py

Leading open-source process mining library for Python

Commonly used in academia and industry

Well documented

[https://processintelligence.solutions
/pm4py](https://processintelligence.solutions/pm4py)



Fluxicon Disco

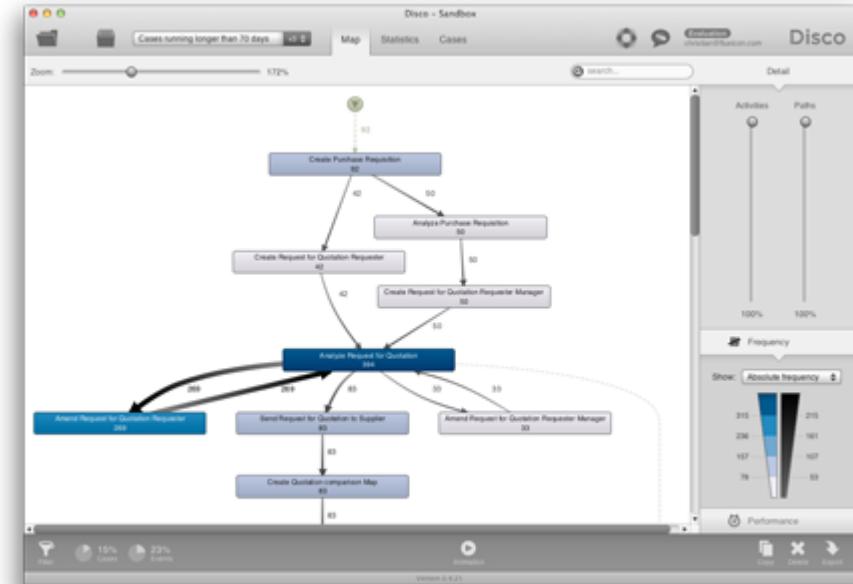
Commercial tools

Free for academic use

Very user-friendly

Limited functionality

<https://fluxicon.com/disco/>



Celonis

Commercial tool

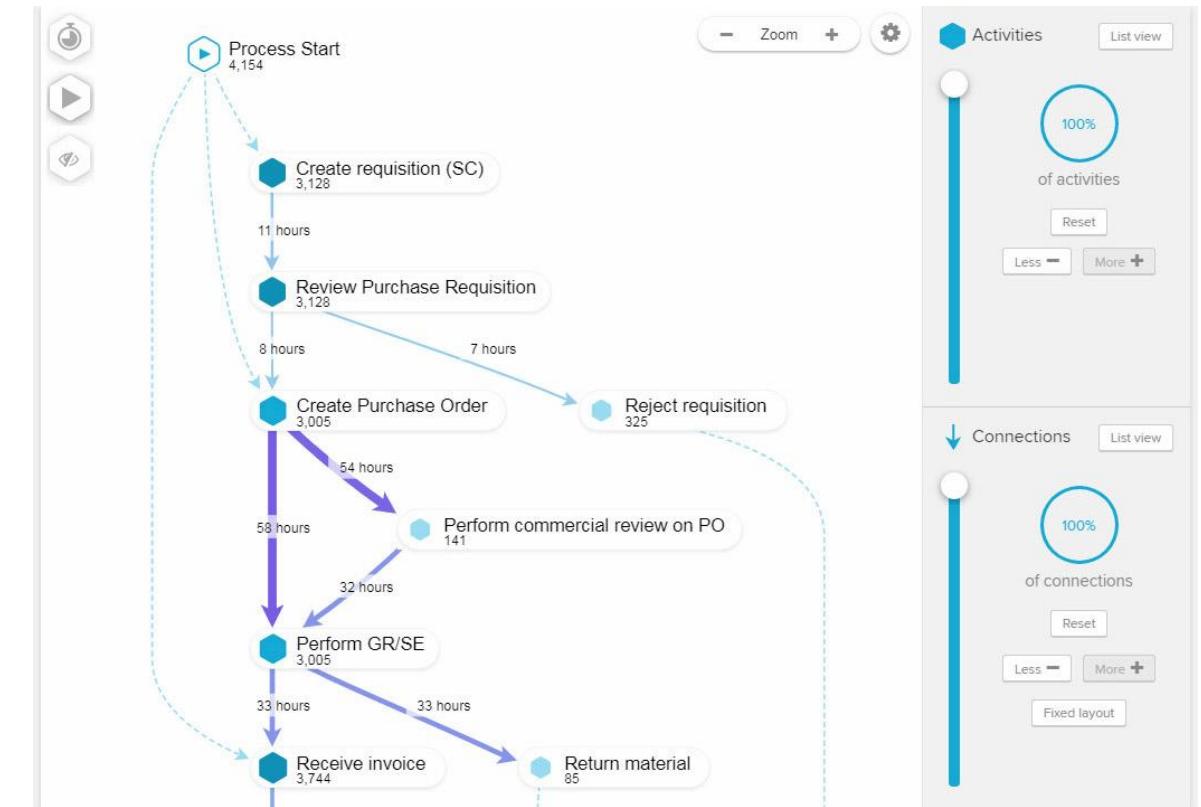
Free academic version

Market leader

Powerful

Complex

<https://www.celonis.com/>



Advanced techniques



Predictive Process Mining

Goal: Anticipate future process states and outcomes.

How it works:

- Uses historical event logs + machine learning models to predict things like:
 - Remaining time of an ongoing case
 - Probability of SLA violation
 - Risk of deviation or cancellation
- Typical methods: LSTMs, Random Forests, Gradient Boosted Trees, or Process-Aware Recurrent Neural Networks (RNNs).

Aviation example: Predicting whether a turnaround will miss its TOBT (Target Off-Block Time).



Context-Aware Process Mining

Goal: Capture external factors that affect process performance.

How it works:

- Incorporates contextual data (weather, time of day, crew roster, airport congestion).
- Allows process discovery conditional on context segments.

Aviation example: Comparing turnaround performance under good vs poor weather conditions or peak vs off-peak hours.



Object-centric Process Mining

Remember: The case is the object we want to track, e.g. a flight

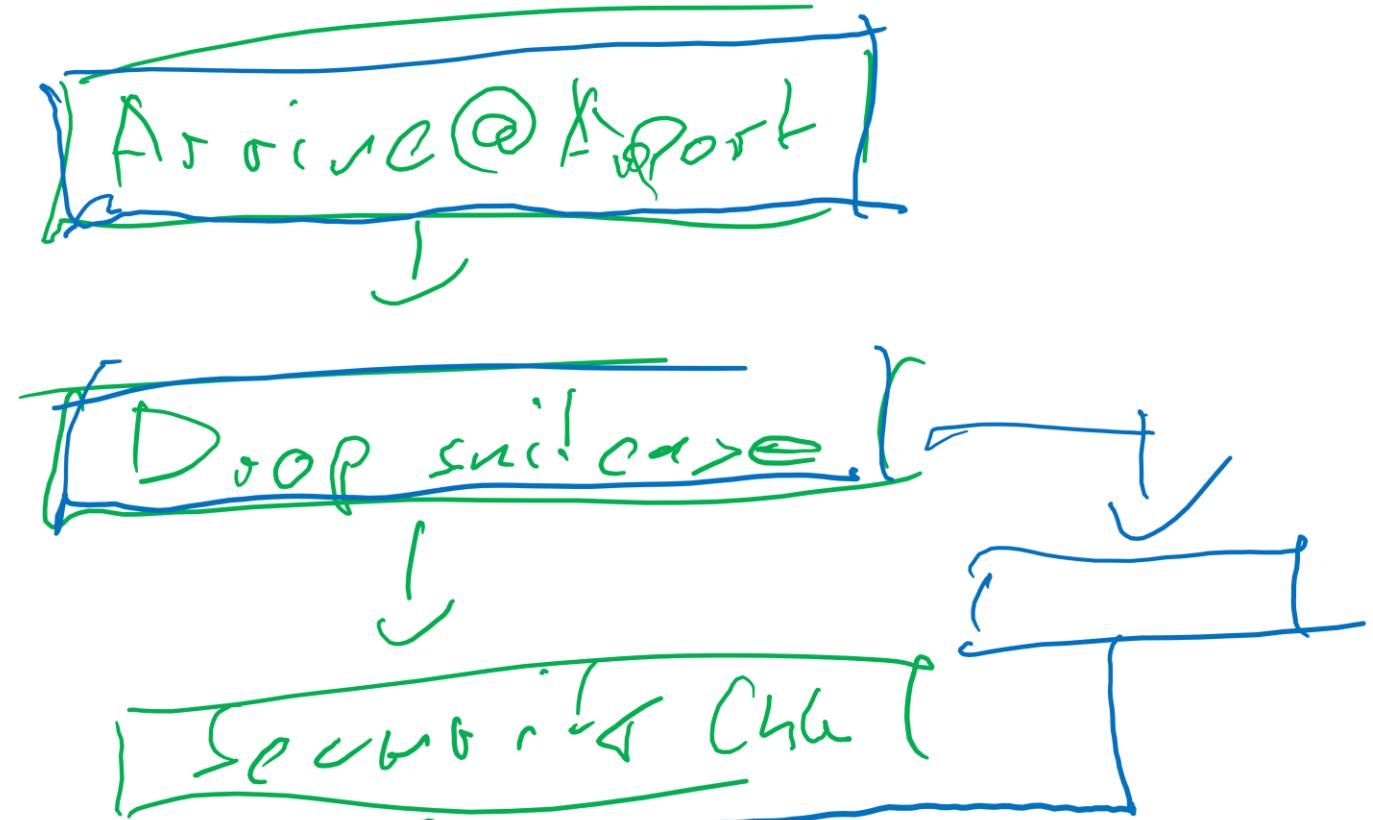
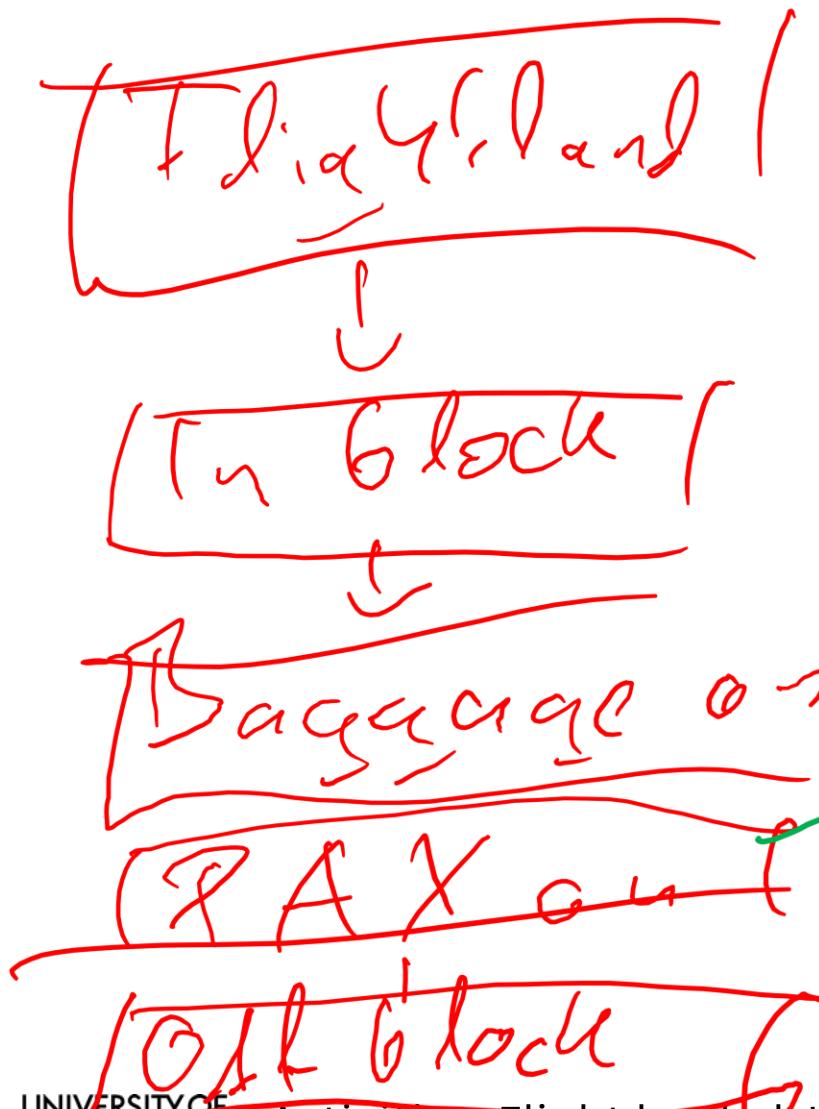
Problem: What about multiple objects?

e.g. Baggage & Passenger, Flight, Train & Passenger, etc

Traditional solution: Map each process separately

OCPM: Show interconnected processes at a glance

OCPM



Getting started...

Define activities of interest

Discover Process Model

Compare against expected model
("Conformance checking")

Beyond the basics: performance
analysis, prediction, object-centric



Eurocontrol (2017) Airport Collaborative Decision-making. Available at:
<https://www.eurocontrol.int/concept/airport-collaborative-decision-making>.

Eurocontrol (2024) “EUROCONTROL Specification for Airport Collaborative Decision Making (A-CDM).”

Rott, J. et al. (2023) “Process Mining for resilient airport operations: A case study of Munich Airport’s turnaround process,” Journal of Air Transport Management, 112, p. 102451. Available at: <https://doi.org/10.1016/j.jairtraman.2023.102451>.

van Eck, M.L. et al. (2015) “PM2: A Process Mining Project Methodology,” in J. Zdravkovic, M. Kirikova, and P. Johannesson (eds.) Advanced Information Systems Engineering. Cham: Springer International Publishing, pp. 297–313. Available at: https://doi.org/10.1007/978-3-319-19069-3_19.

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THANK YOU

