Lehrstuhl für Flughafenwesen und Luftverkehr

RWTH AACHEN UNIVERSITY

A comparison of agent-based and discrete event simulation for assessing airport terminal resilience

INAIR 2019

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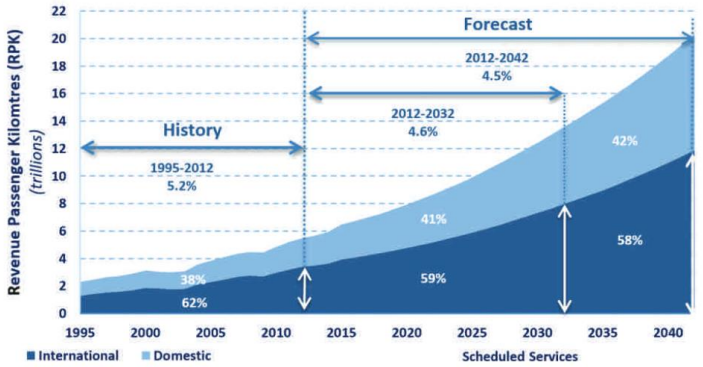
RWTH Aachen University

Introduction

- High capacity utilization
- High growth rate in aviation
- Disturbances in daily operations (weather, system outage, staff issues)



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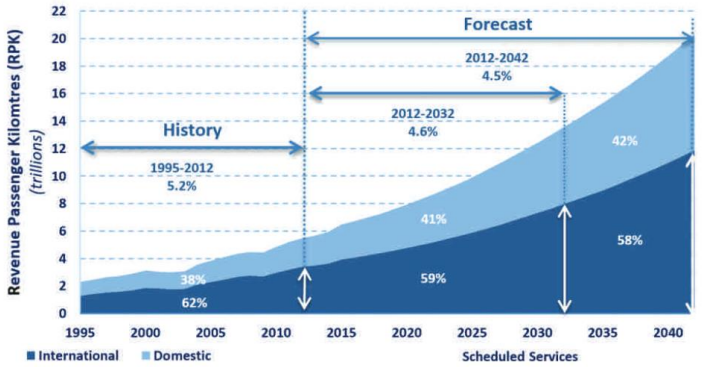
→ High **delays**



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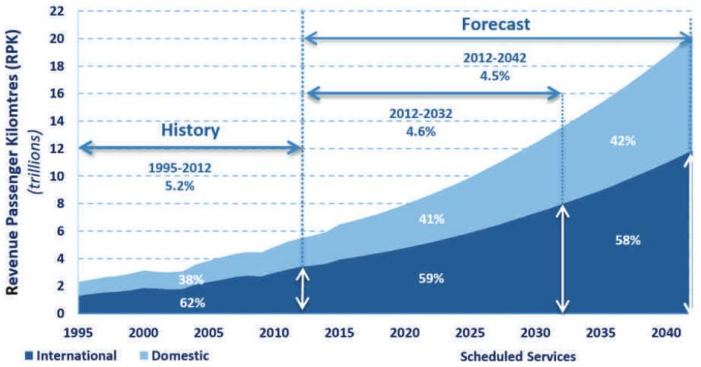
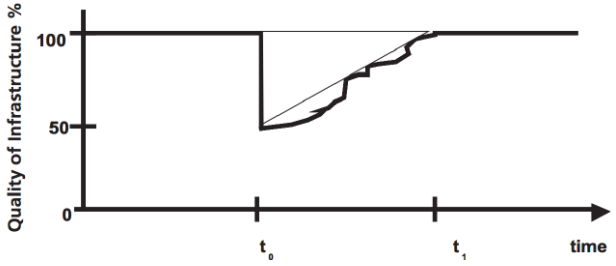


→ High **delays**

→ **Resilience** of a system as evaluation criteria to

- **Understand** system **correlations**
- **Reduce** the **impact** of disturbances



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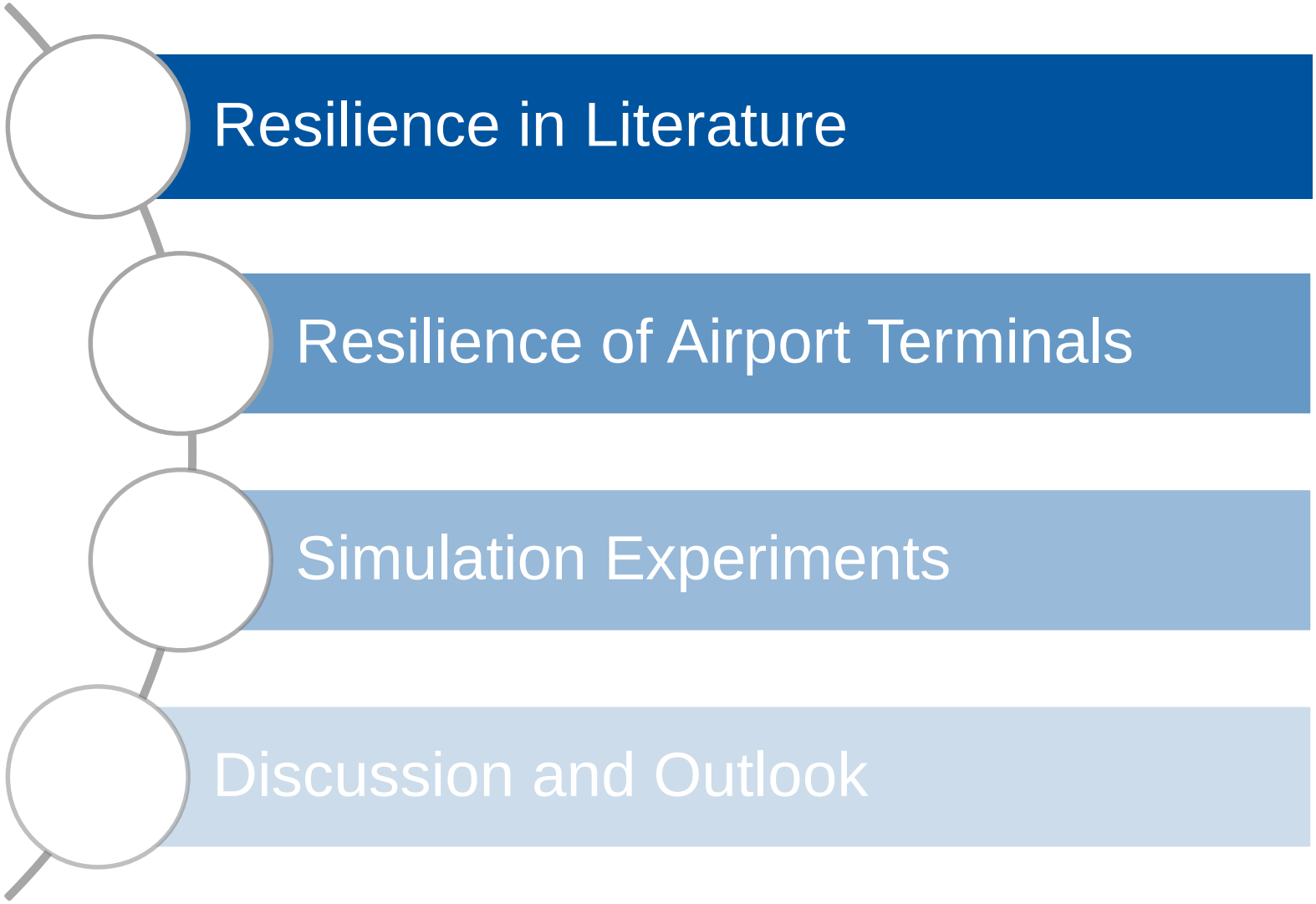
Resilience in Literature
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Resilience in Literature - Definitions

- „resilire“ = „bounce back“ (Latin)
  - → Ability of a system to return to the original state after a disruption

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- Application areas:
  - Ecology
  - Psychology
  - Material science
  - Economy
  - Infrastructure systems

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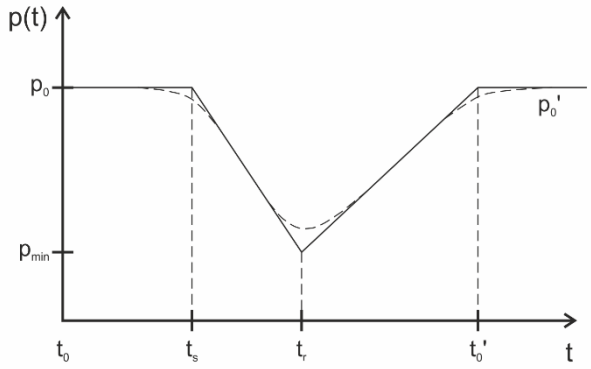
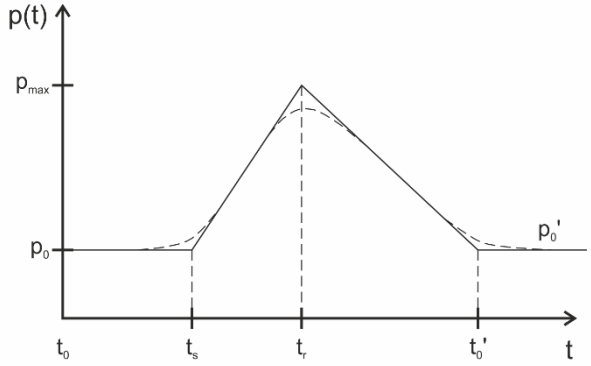
- Absorptive, adaptive and restorative capacity of a system
  - → Robustness
  - → Self-organisation
  - → Rapidity

Resilience in Literature - Quantification

- Robustness:
  - $Robustness = p_{min}$
  - $Relative\ Robustness = \frac{p_{min}}{p_0}$



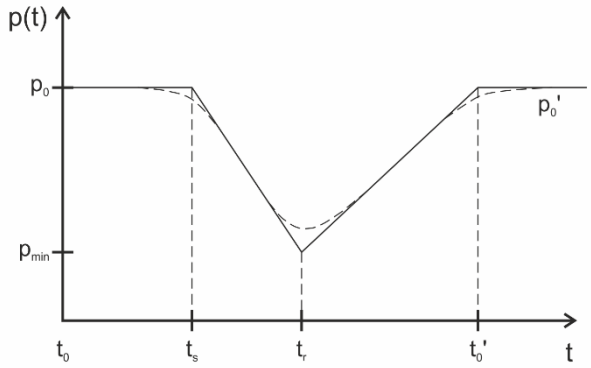
System performance over time, performance function



System performance over time, delay function

Resilience in Literature - Quantification

- Rapidity:
  - $Rapidity^{(drop)} = \frac{p(t_s) - p(t_r)}{t_r - t_s}$
  - $Rapidity^{(recover)} = \frac{p(t_0') - p(t_r)}{t_0' - t_r}$
  - $R^{(1)} = t_0' - t_s$
  - $R^{(2)} = \frac{t_r - t_s}{t_0' - t_r}$



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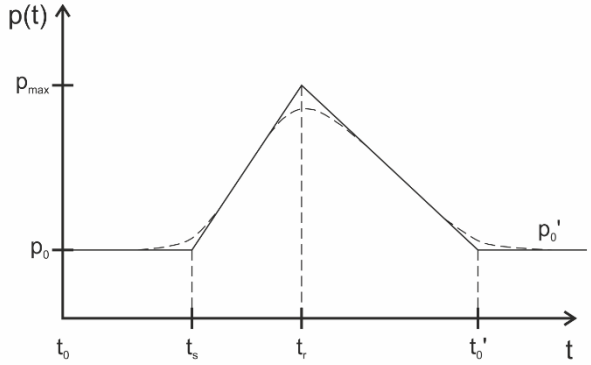
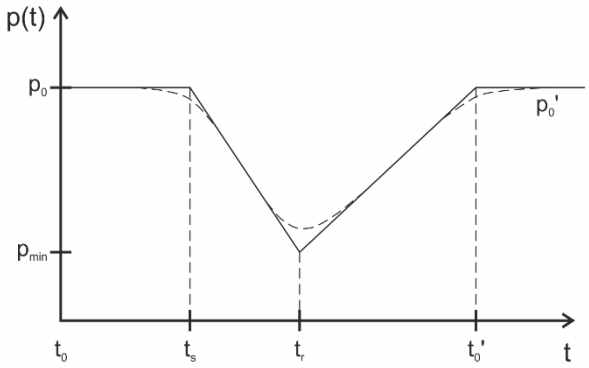


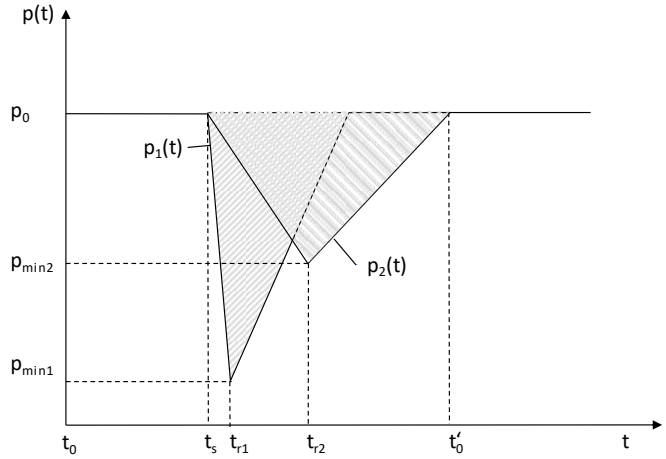
System performance over time, delay function

Resilience in Literature - Quantification

- Combination of robustness and rapidity

  - $R^{(3)}(t_{end}) = \int_{t_0}^{t_{end}} \left(1 - \frac{p(t)}{p_0}\right) dt$





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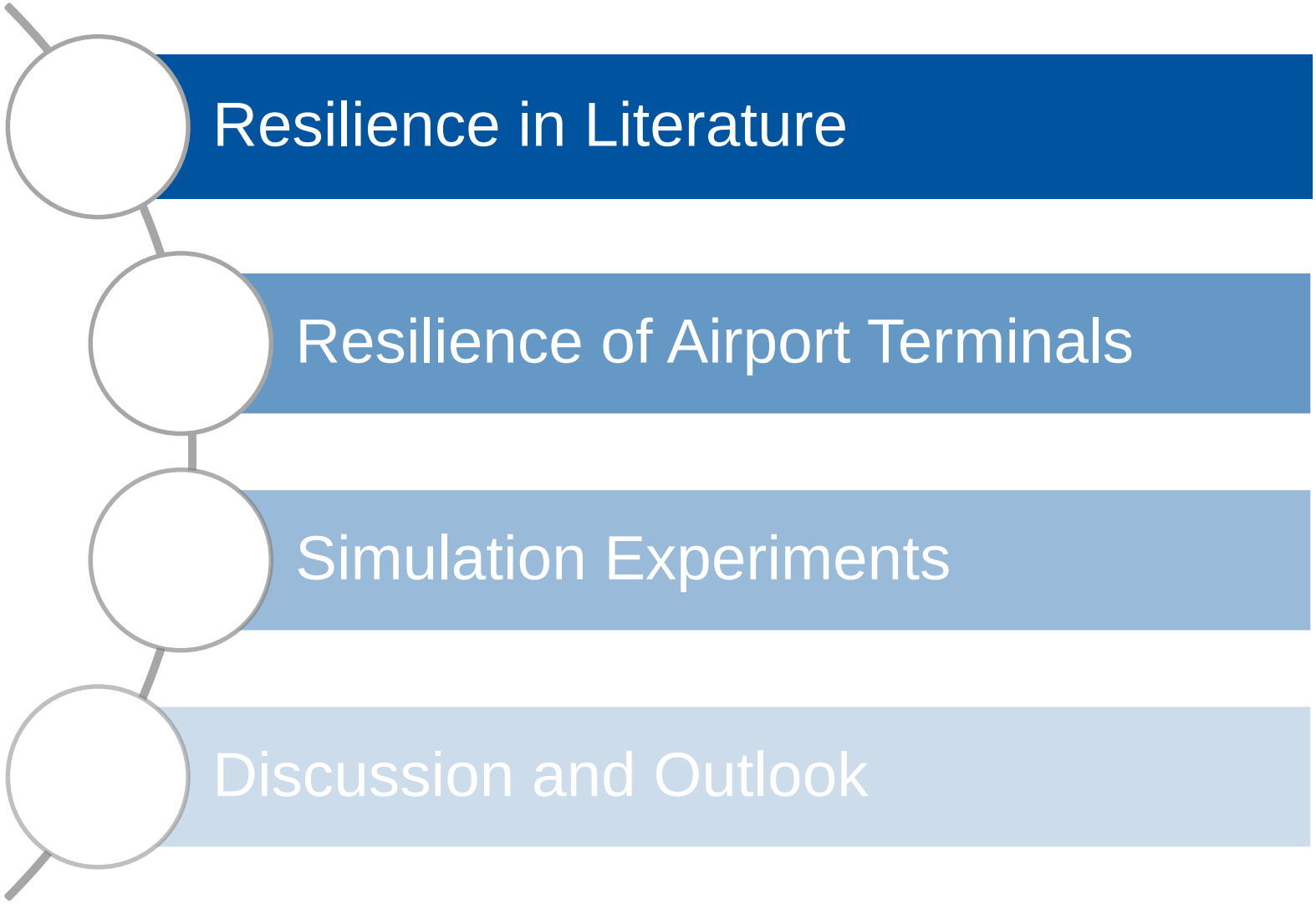
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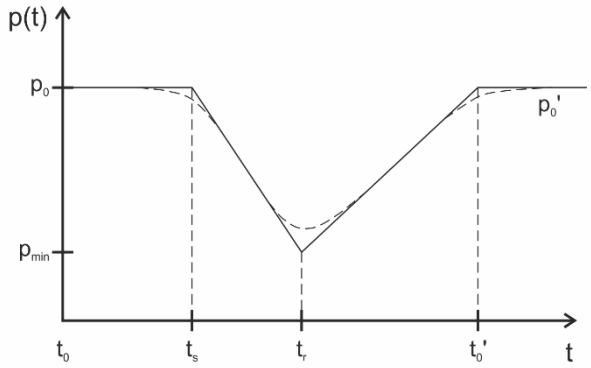
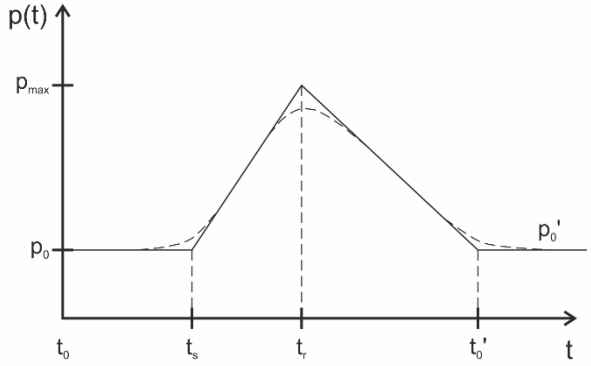
Resilience of Airport Terminals

- Definition:

  „An airport terminal is resilient, if it shows absorptive and restorative capabilities, which means that it is robust against disturbances and recovers quickly from them.“





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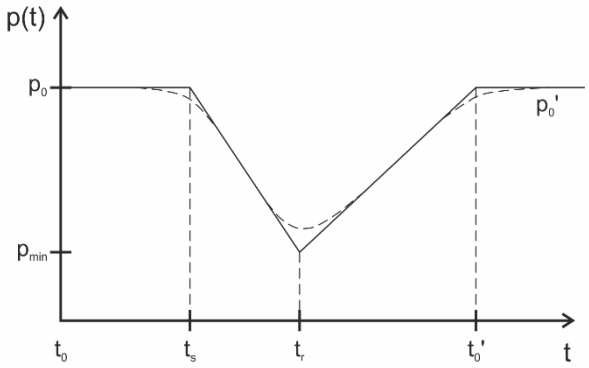
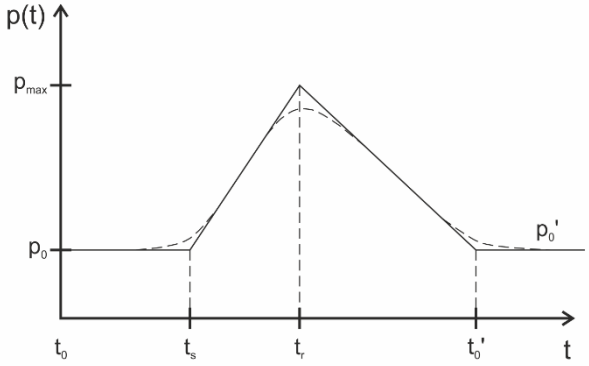


- Resilience indicators:
  - Robustness indicator
  - Rapidity indicator
  - Combination of both (depending on area)
  - Integral indicator



Resilience of Airport Terminals

- Resilience indicators:

Robustness indicator

$$R^{t1} = \frac{p_{min}}{p_0}$$

Rapidity indicator

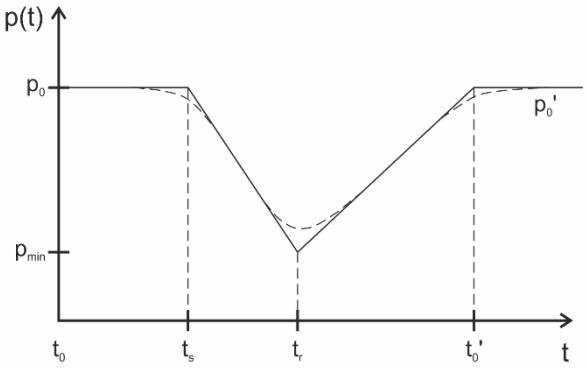
$$R^{t2} = \frac{t_{s,end} - t_{s,start}}{t_0' - t_{s,start}}$$

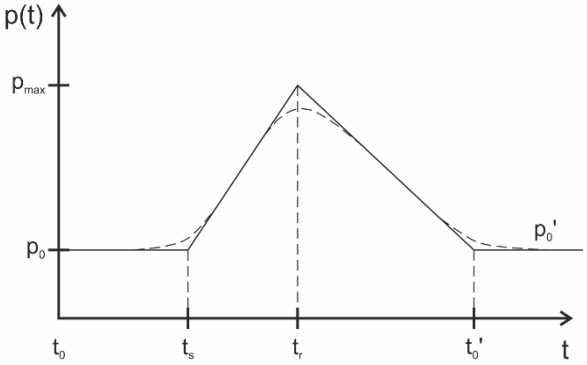
Combination of both

$$R^{t3} = \frac{\int_{t_0}^{t_{end}} p(t)\, dt}{\int_{t_0}^{t_{end}} p_0\, dt}$$

Integral indicator

$$R^{t} = R^{t1} \cdot R^{t2} \cdot R^{t3}$$





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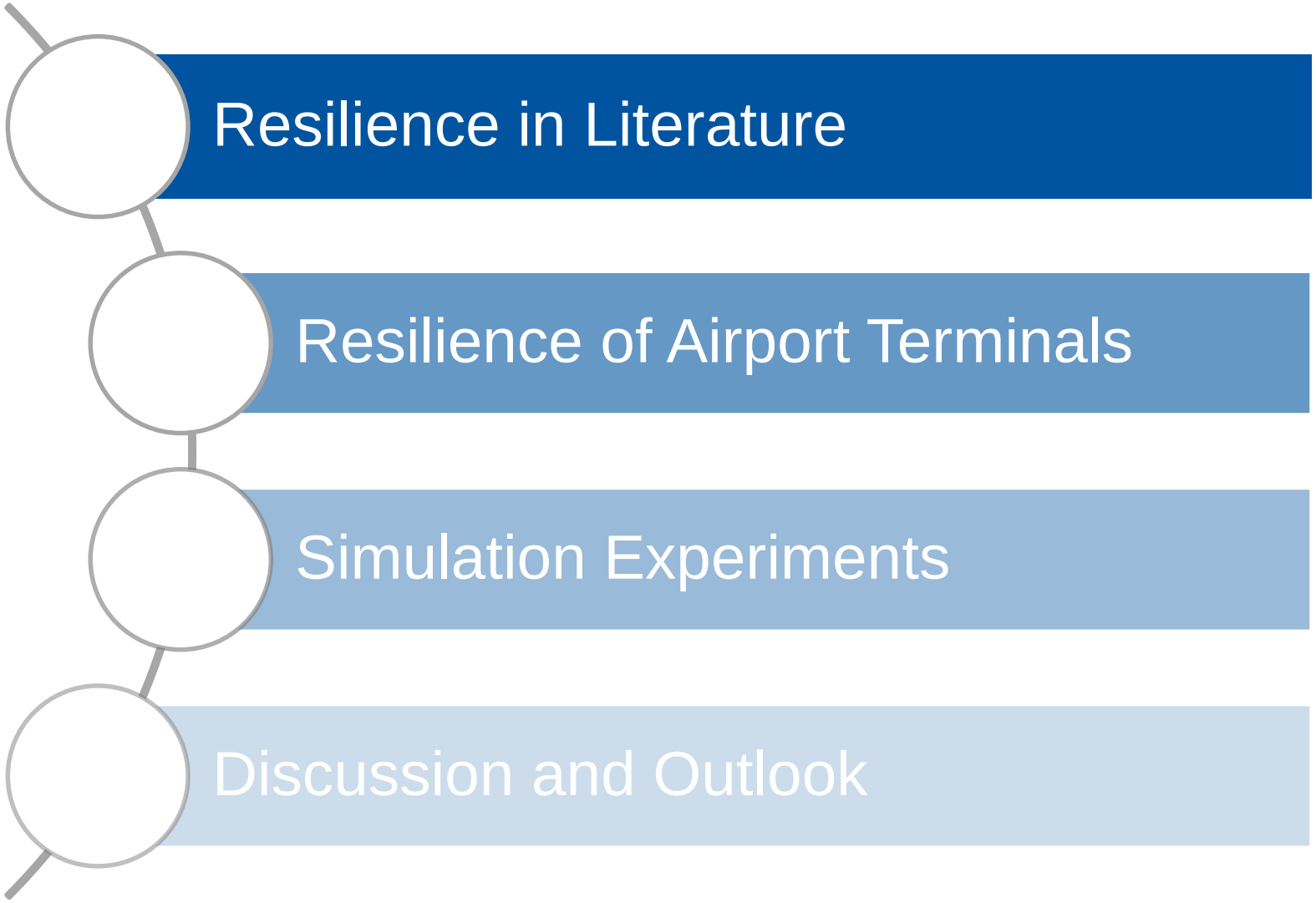
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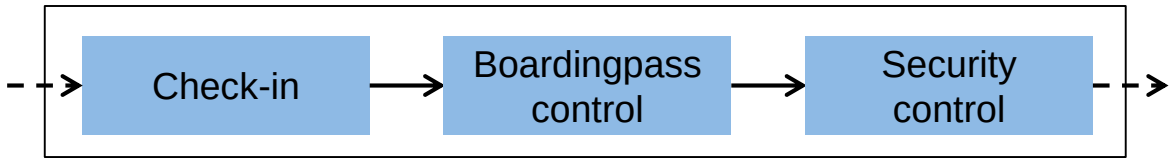
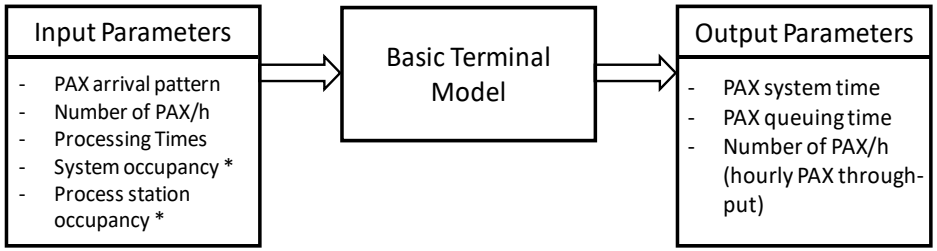
Simulation Experiments – Model setup

Simplified terminal model

- Agent-based vs. discrete event simulation
- Stochastic vs. deterministic
- Model design:



- Model input and output parameters:



* calculated depending on other input parameters

Simulation Experiments – Parameter variation

Simplified terminal model

- Input parameter variation

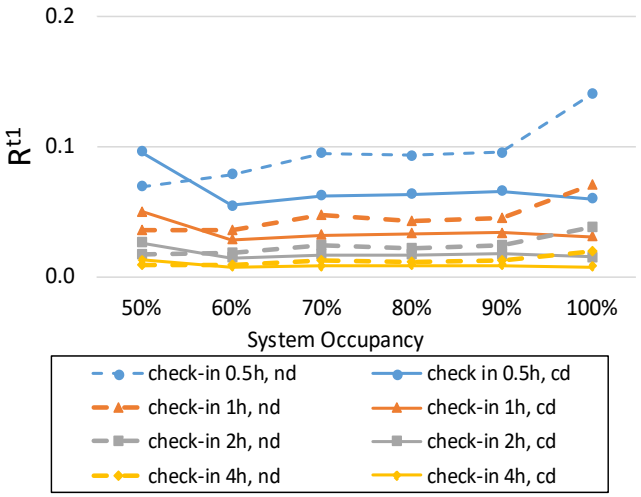
Parameter	*Range*
Occupancy at process station/terminal system [%]	{50; 60; 70; 80; 90; 100}
Passenger arrival rate [PAX/h]	{30; 36; 42; 48; 54; 60}
Duration of disturbance [h]	{0.5; 1; 2; 4}
Affected process station	check-in; security
Processing times at check-in, boarding pass control, security control [sec]	120; 6; 35
Passenger arrival pattern	constant rate; normal distribution

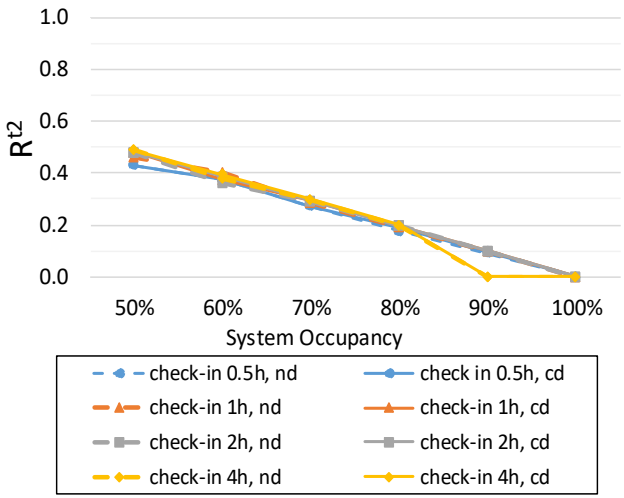
→ Simulation of 1 day of operations with disturbance event

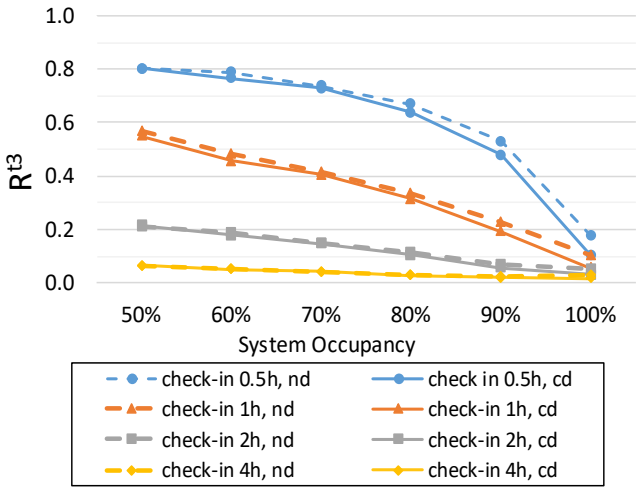
→ Calculation of resilience indicators

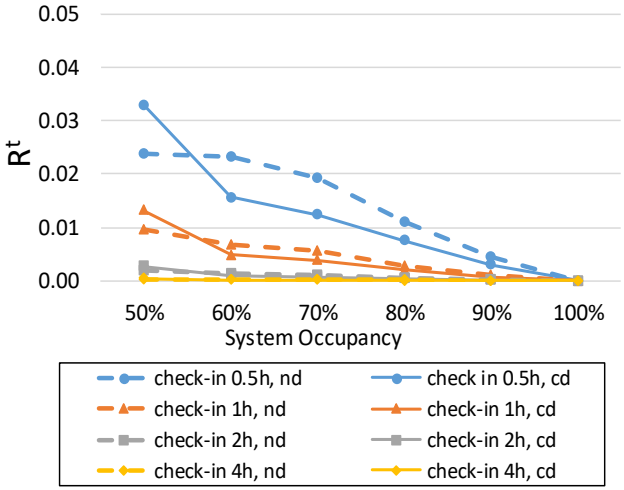
Simulation Experiments – Results

- Disturbance at check-in
- Influence of
  - Passenger arrival rate
  - System occupancy
  - Duration of disturbance



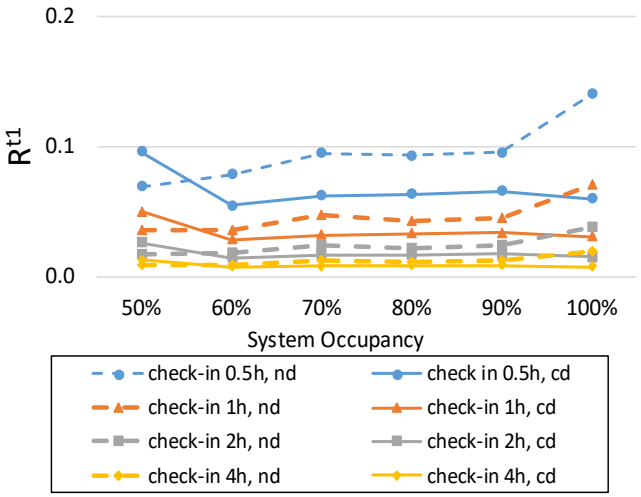


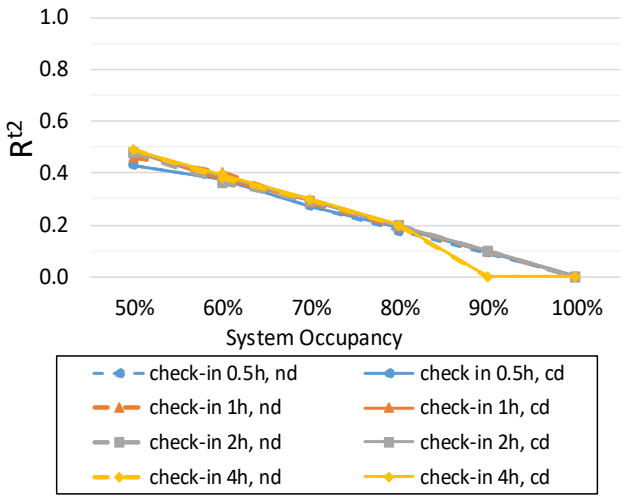


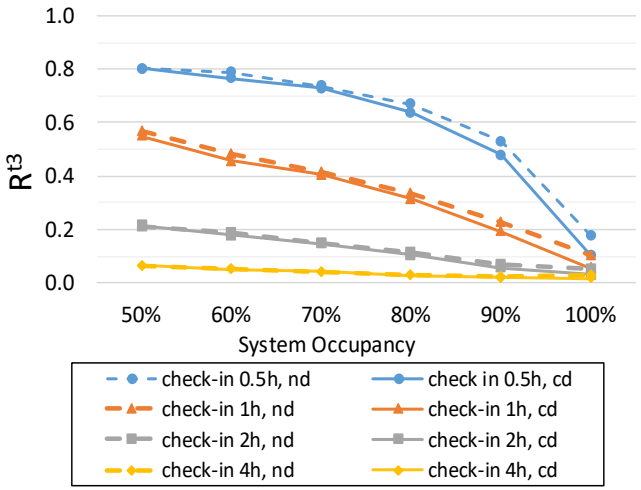


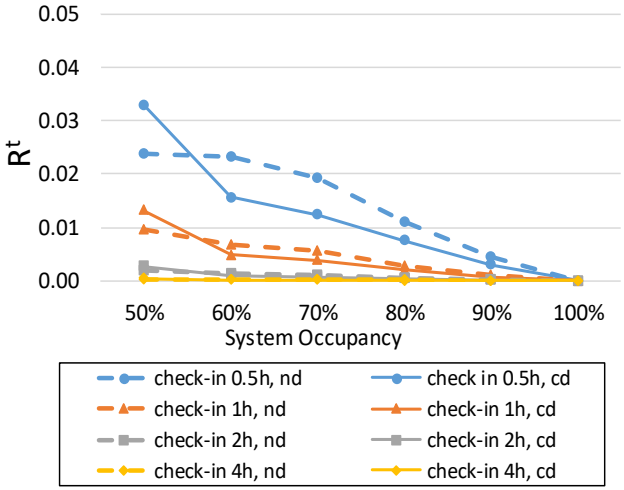
Simulation Experiments – Results

- Disturbance at check-in
- Influence of
  - Passenger arrival rate
  - System occupancy
  - Duration of disturbance
- **Robustness** does not show any trend
- **Rapidity** depends on **system occupancy**
- Influence of **arrival rate** at **high occupancies**



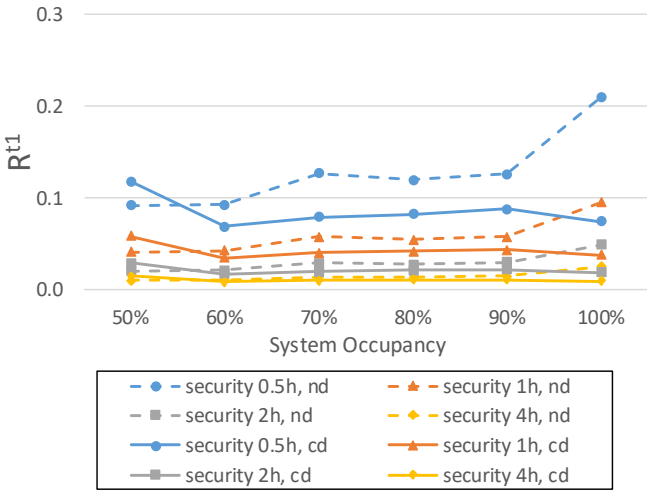


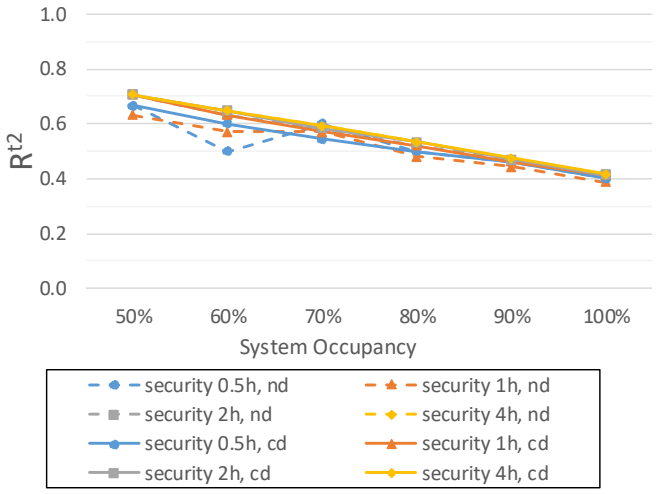


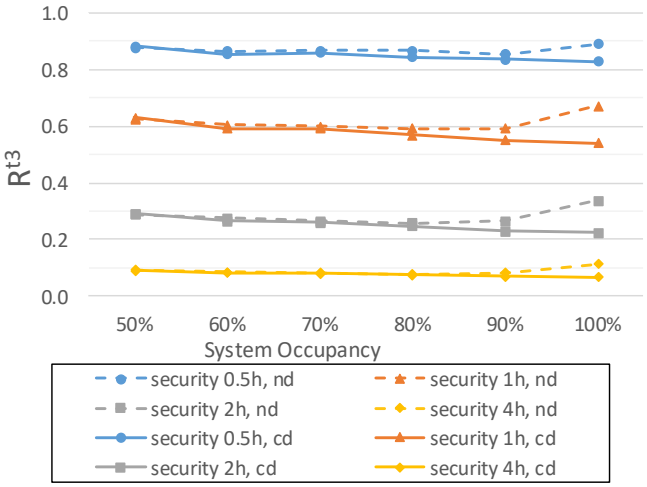


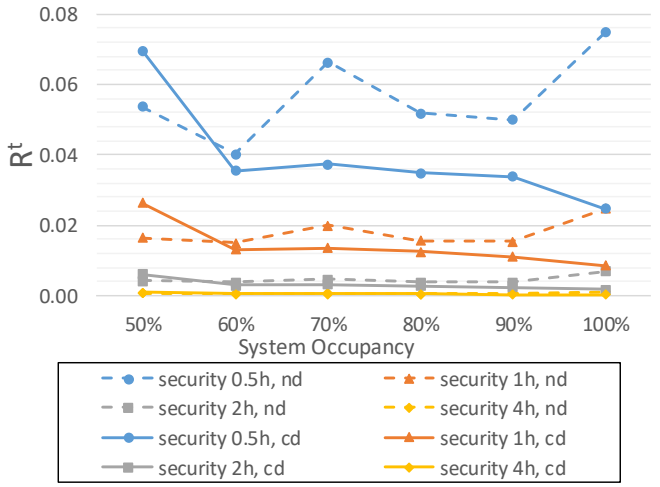
Simulation Experiments – Results

- Disturbance at security
- Influence of
  - Passenger arrival rate
  - System occupancy
  - Duration of disturbance



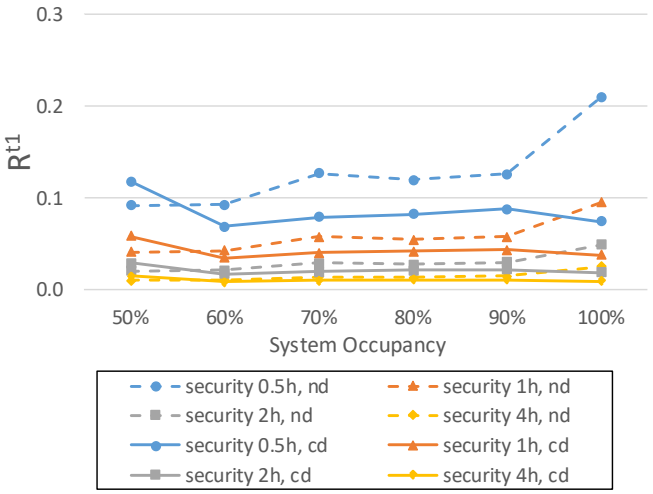


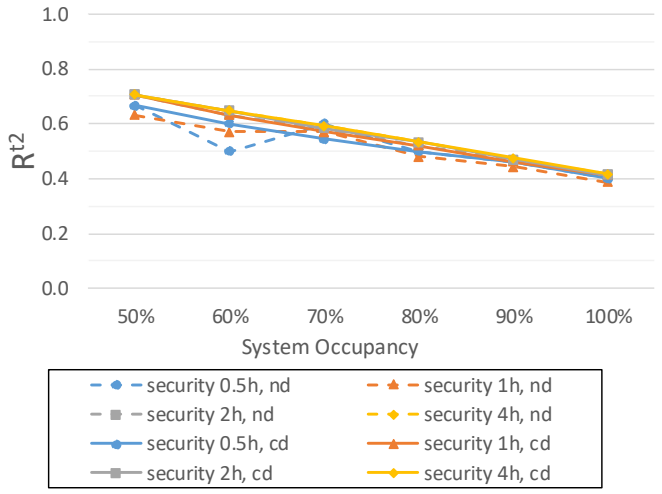


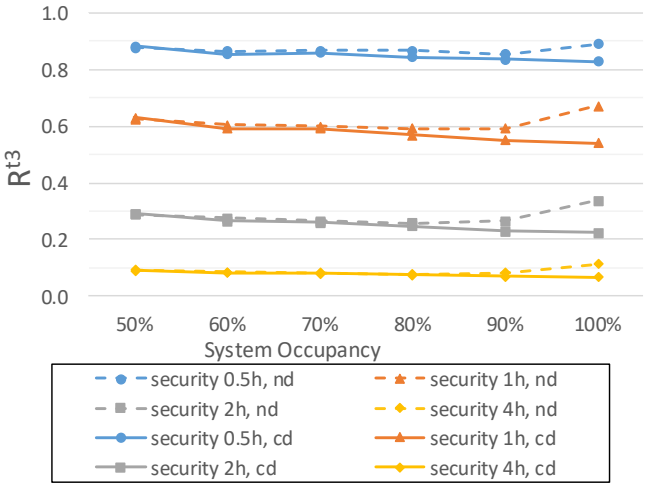


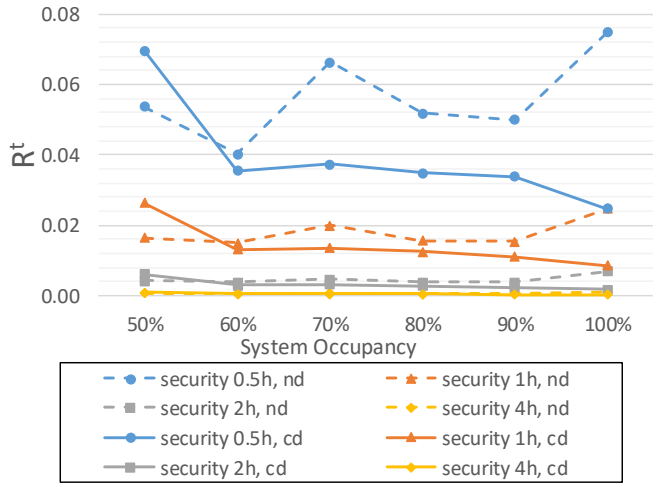
Simulation Experiments – Results

- Disturbance at security
- Influence of
  - Passenger arrival rate
  - System occupancy
  - Duration of disturbance
- **Higher level** of **rapidity**
- **Higher values** of R^{t3} especially at **high occupancies**
- Influence of **arrival rate** at **high occupancies**









Simulation Experiments – Comparison

Results in CAST Terminal	Results in AnyLogic
▪ **Robustness** does not show any trend	▪ **Robustness** independent of system occupancy
▪ **Rapidity** independent of duration of disturbance	▪ **Rapidity** independent of duration of disturbance
▪ **Combined indicators** differ for affected check-in/security station	▪ **Combined indicators** differ for affected check-in/security station
▪ **Robustness** and $\boldsymbol{R^t}$ show **irregularities**	▪ **Analytical calculations** verify simulations

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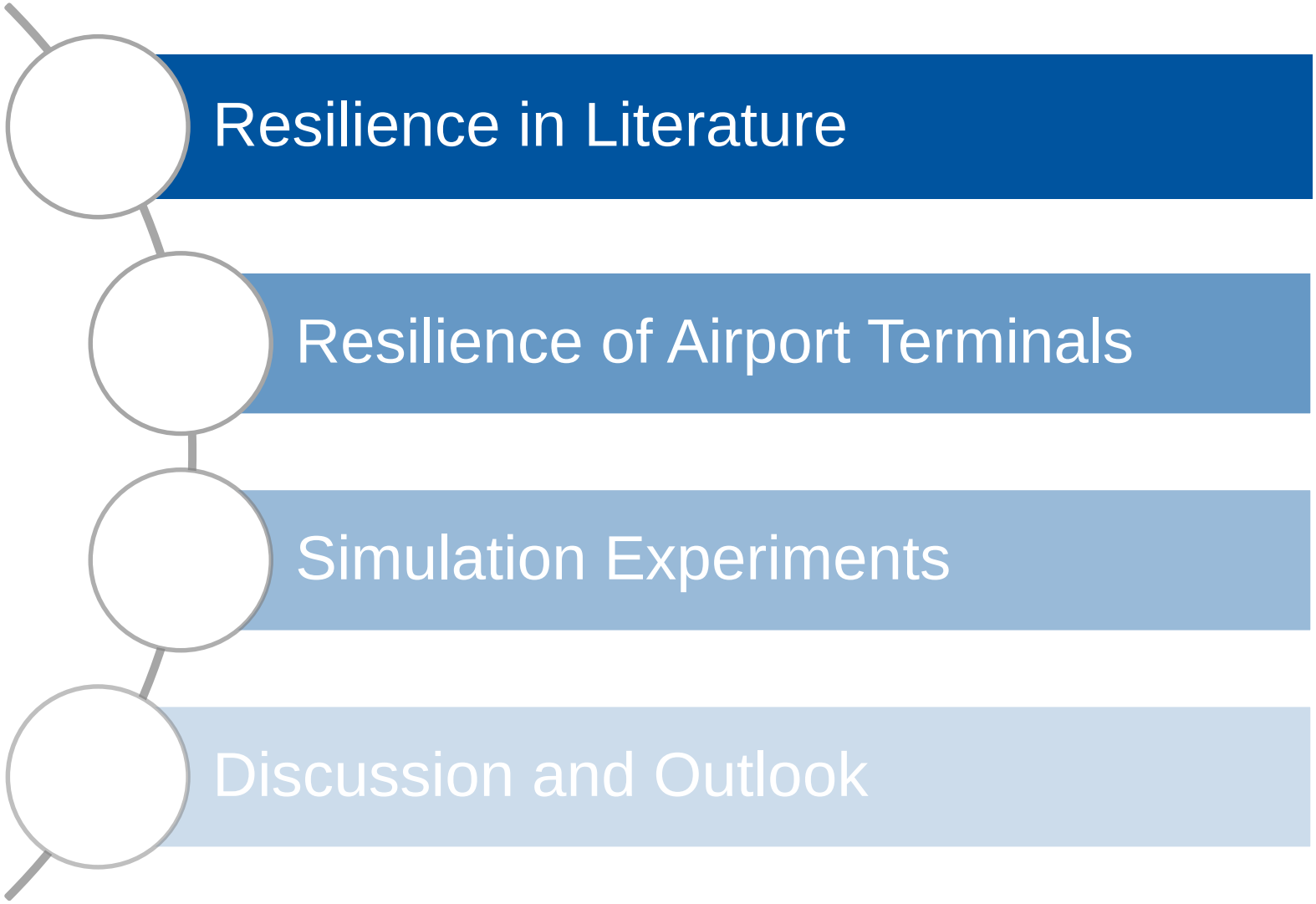
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Discussion and Outlook

- **Robustness** and **rapidity** of a system were identified as **key indicators** for resilience
- Simulation experiments showed that **robustness** depends on the **duration of the disturbance** while **rapidity** depends on the **system occupancy**
- There are more **irregularities** for **CAST Terminal** simulations
- The **applicability** of the **AnyLogic** simulation results can be shown
- The simple model should be **enlarged** to gain **more insights**

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