The Digital Twin concept and its role in reducing uncertainty in synchromodal transport

Tomas Ambra

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MOBILITY, LOGISTICS & AUTOMOTIVE TECHNOLOGY RESEARCH CENTRE

Research Foundation Flanders
Opening new horizons

Author: Tomas Ambra. **Title:** The Digital Twin concept and its role in reducing uncertainty in synchromodal transport. Presented at IPIC 2019

Structure

1. MOBI – who we are
2. Synchromodal transport
3. The Digital Twin (DT) concept
4. Methodology – SYMBIT model
5. Experimental design (simplified)
6. Results
7. Discussion – DT for synchromodality
8. Conclusions

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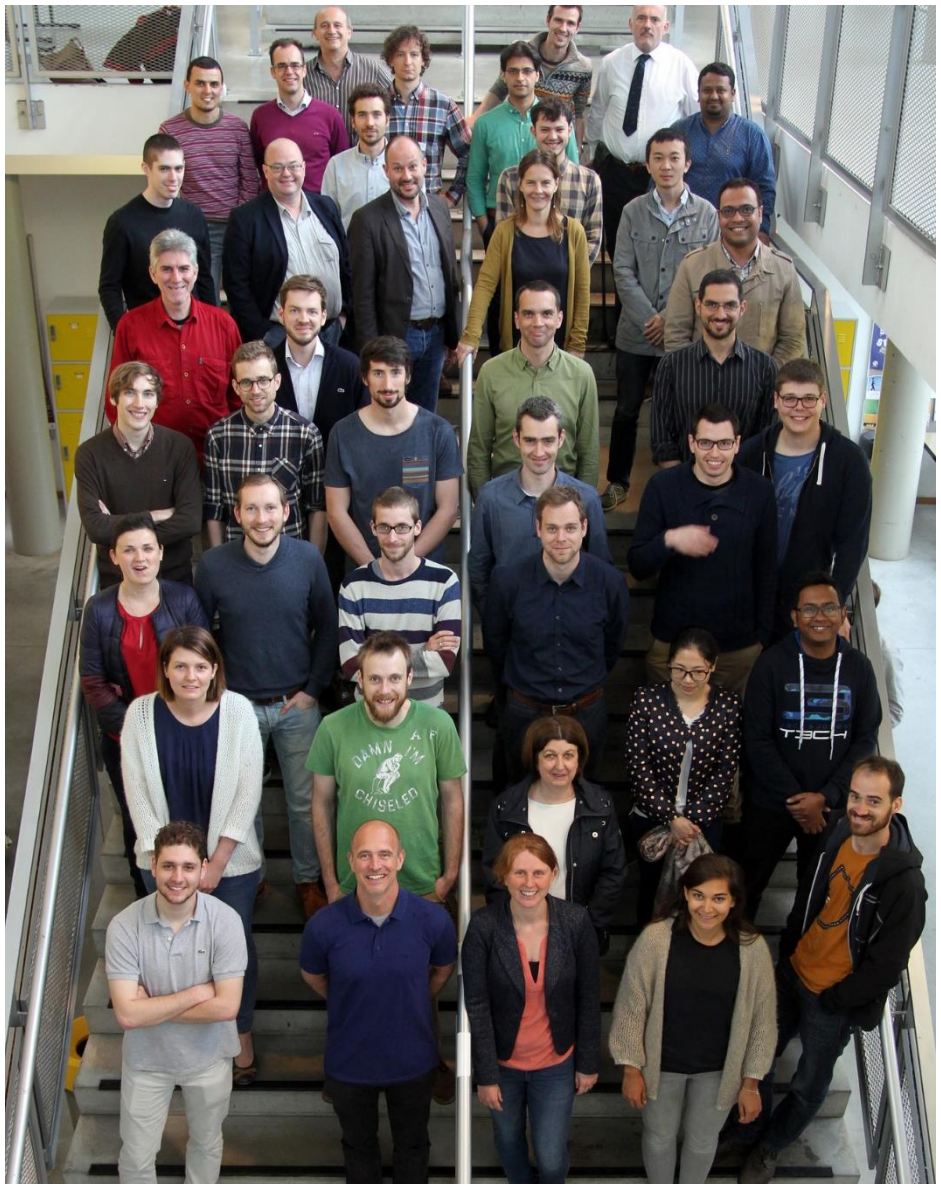

Mission statement

supporting and studying the transition towards a more sustainable mobility & logistics system

Key Assets

Sustainable logistics

Battery Innovation Centre

Electric and hybrid vehicles

Urban mobility

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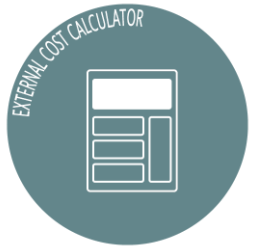
Expert tools

SUSTAINABLE IMPACT ASSESSMENT

MAMCA ©

Life Cycle Assessment



External Cost Calculator

NEW APPROACHES

Business Modelling

Consumer Behaviour

Big Data & Analytics

BATTERY & VEHICLE MODELS

Battery Models

Power Electronics

Vehicle Simulation Programme

TRANSPORTMODELS

- Intermodal Transport Model: Location Analysis Model for Belgian Intermodal Terminals (LAMBIT)
- Transport Agent-Based Model (TRABAM)
- **Synchromodal Transport Model (SYMBIT**)

Key Data

40
years of expertise

165 projects
over last 5 years

27
current EU Projects

>5.9 M€
turnover 2018

+100
team members

20
nationalities

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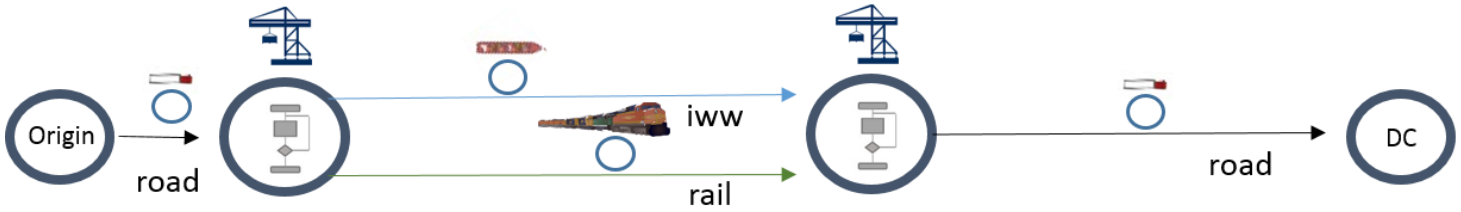
2) Synchromodal transport

2) Synchromodal transport

1) Extension of intermodal transport



2) Flexibility and transparency to facilitate **dynamic re-routing** and **modal switching** in **near to real-time**

3) Reacts to events and contextual information:
   - newly incoming orders
   - transport delays
   - cancellations
   - collaborative bundling opportunities
   - accidents
   - water levels
   - strikes etc.

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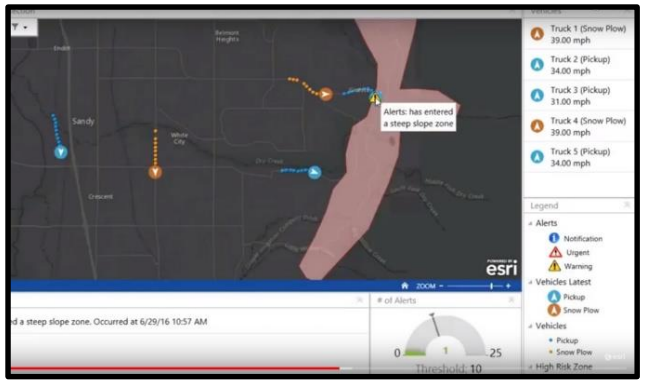
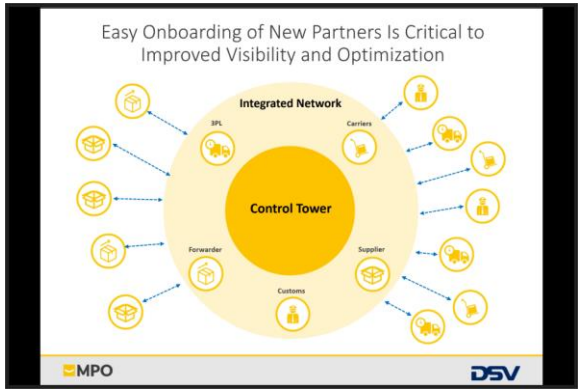
2) Synchromodal transport

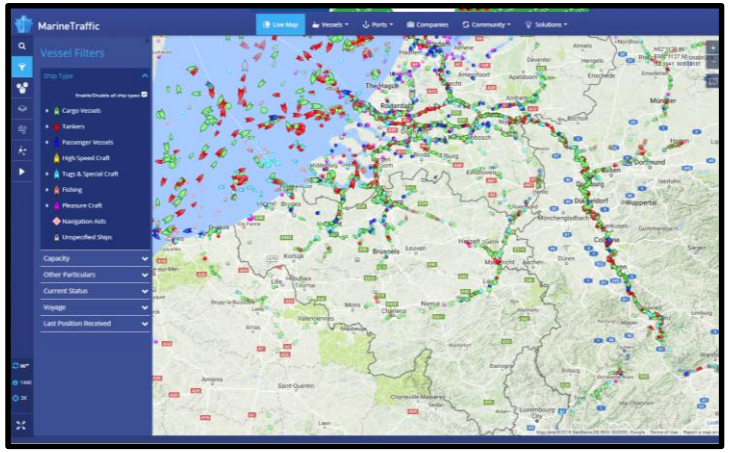
Examples of control towers



Source: ESRI



Source: MPO



Source: marinetraffic.com

Provide past and present positions of assets and trends

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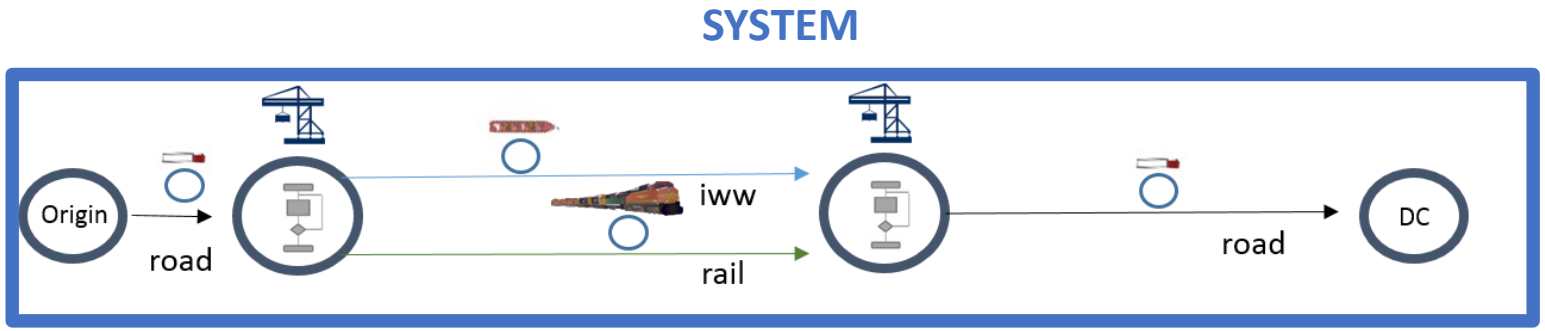
2) Synchromodal transport

- Situational awareness of the current system state and projections:

  how will the system evolve once different actors take different actions?



t+ 1
t+ 2
t+ 3
…

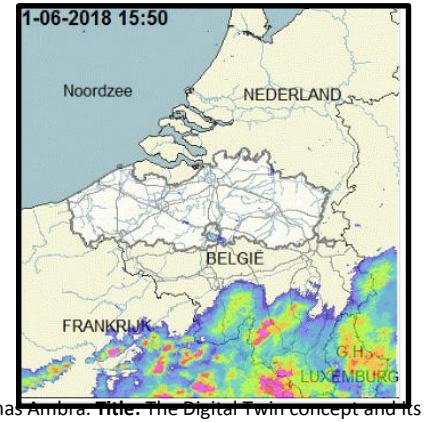
?

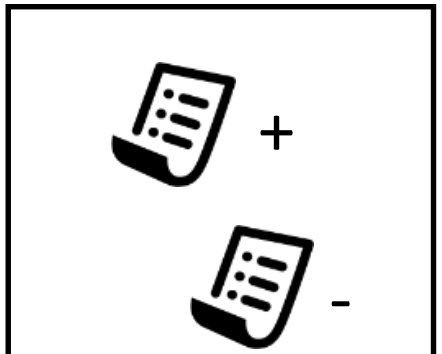
Congestion

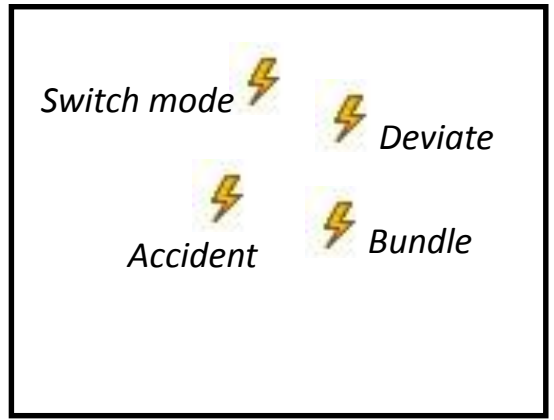
Weather

Orders

Events







2) Synchromodal transport

t+ 1
t+ 2
t+ 3
…

?

- which mode to use, where to switch, what terminals are located enroute
- what other assets are in their radius, what is their capacity, how far the handling points are
- will the assets make it before closing hours given the assets' current geo-location? etc.)

The solution?

Legends of Tomorrow - time machine

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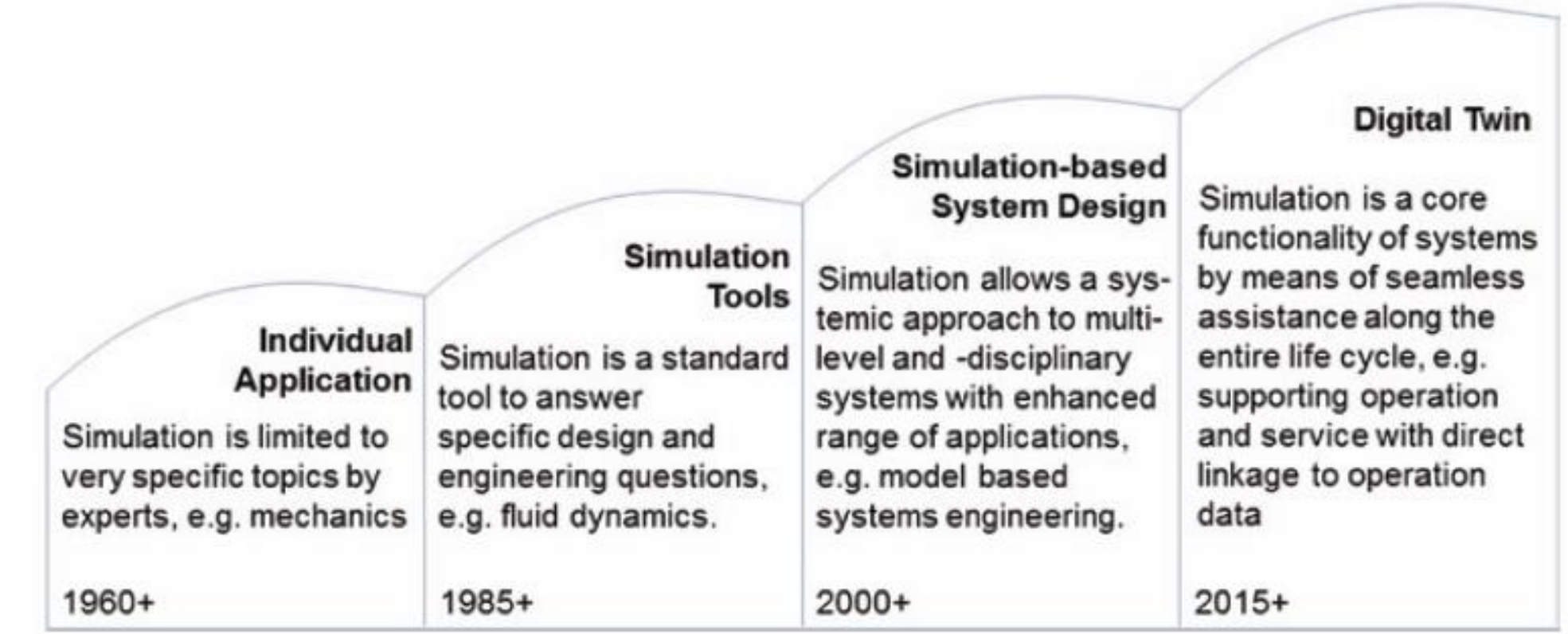
3) The Digital Twin concept

Stages of simulation technology



Digital Twins as the next wave in simulation technology.
Source Boschert & Rosen (2016)

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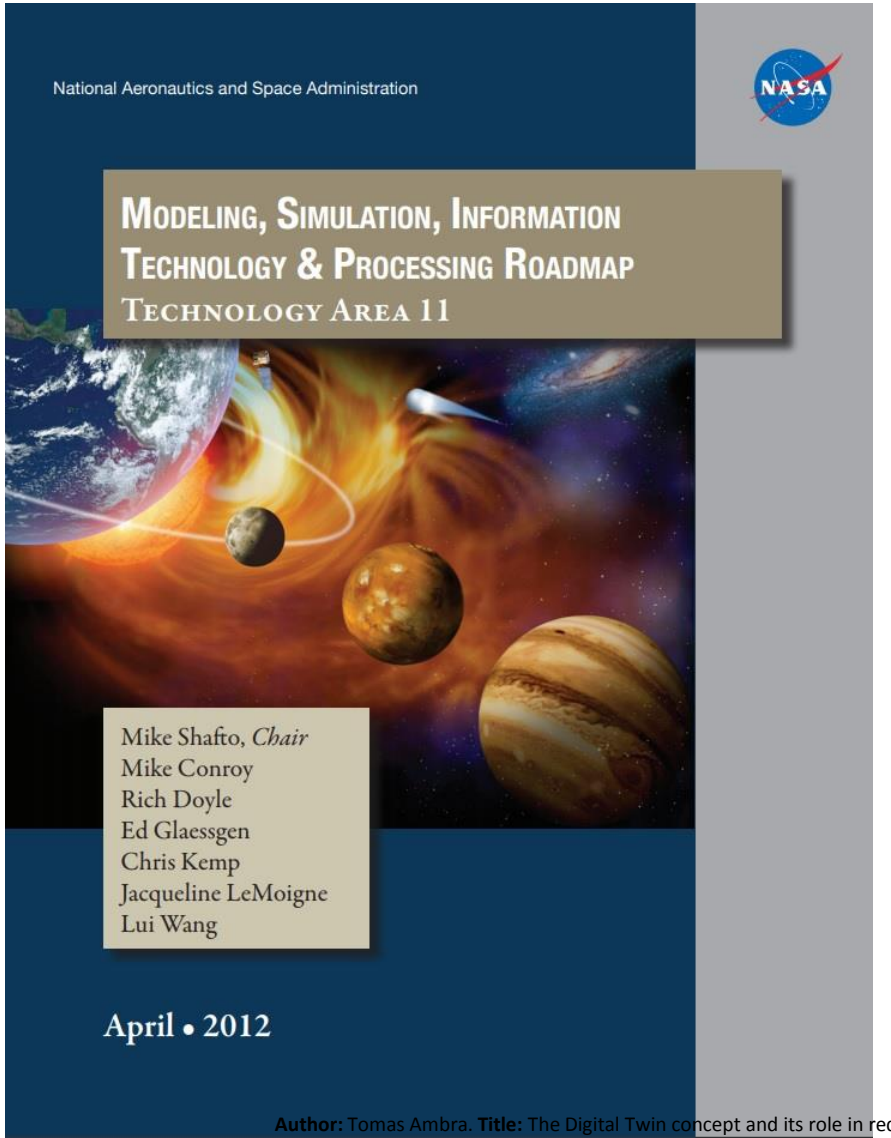
Digital Twin origins



Digital Twin

An integrated multi-physics, multi-scale probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin

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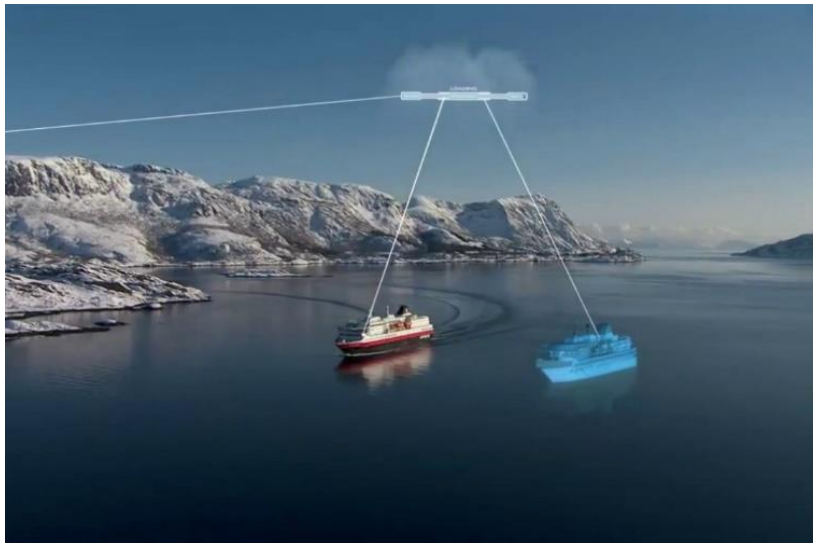
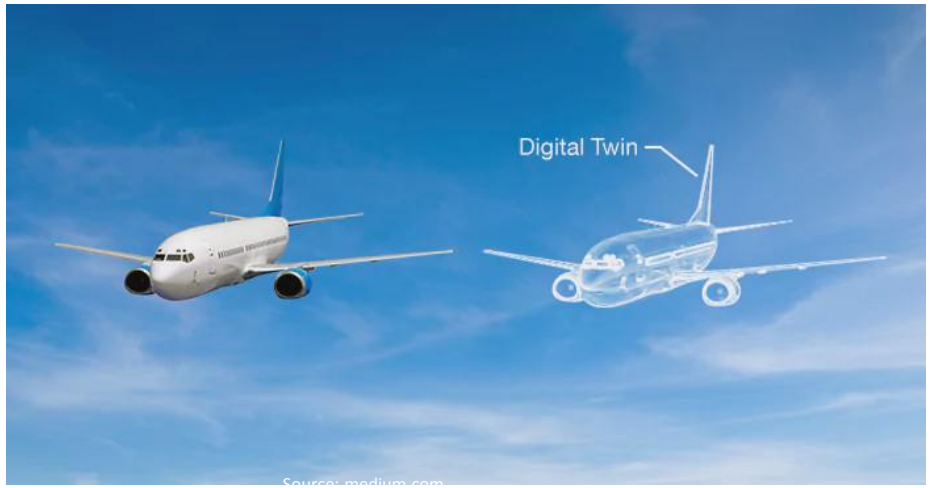
Digital Twin origins



Source: Mfame



- **A living digital simulation model**

- **Learns and updates itself to represent real-time positions, working conditions etc**

- **Updates via sensor data**

- **The twin shifts with the context (and proceeds reality)**

Update/change as their physical counterparts change

Current use:

applied to manufacturing, shop floor management, product and engineering designs

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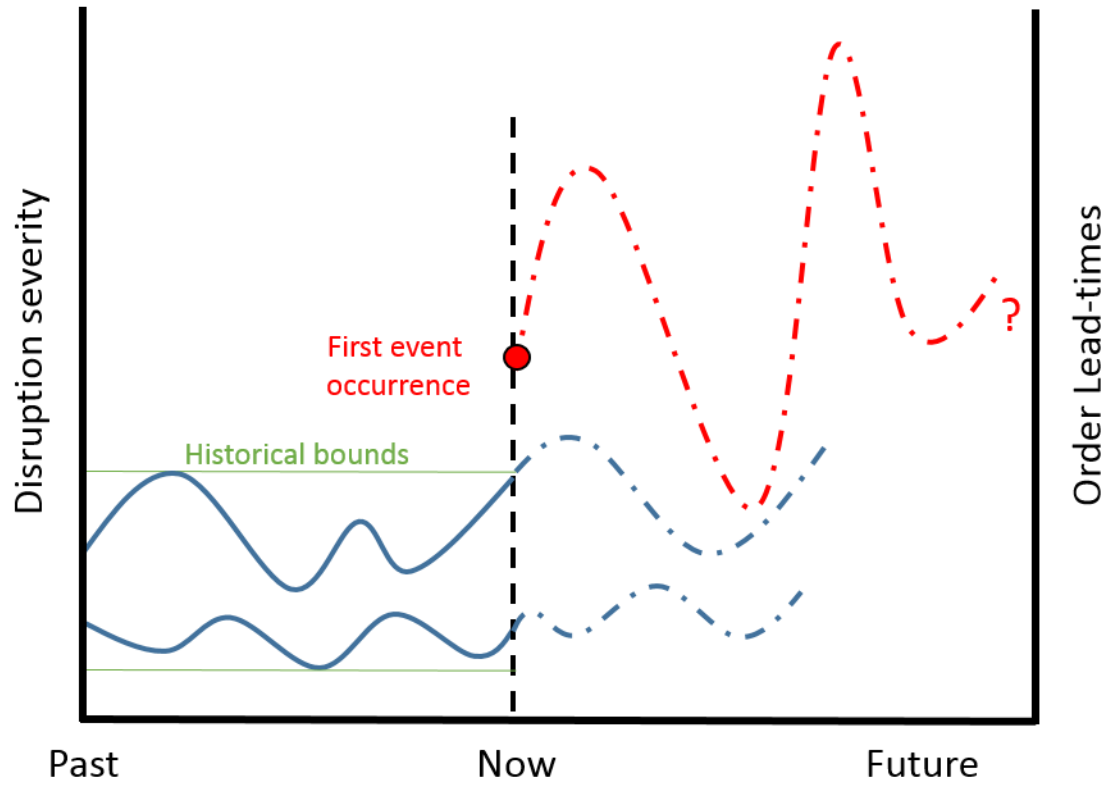
4) Methodology – SYMBIT model

Research questions:
(1) Is synchromodal dynamic switching and re-routing always a better solution?
(2) How can the digital twin concept/technology reduce uncertainties?

Objective: deepen the understanding of digital twins and their potential use in synchromodal transport.

The role of simulation in data-centric and process-centric realms

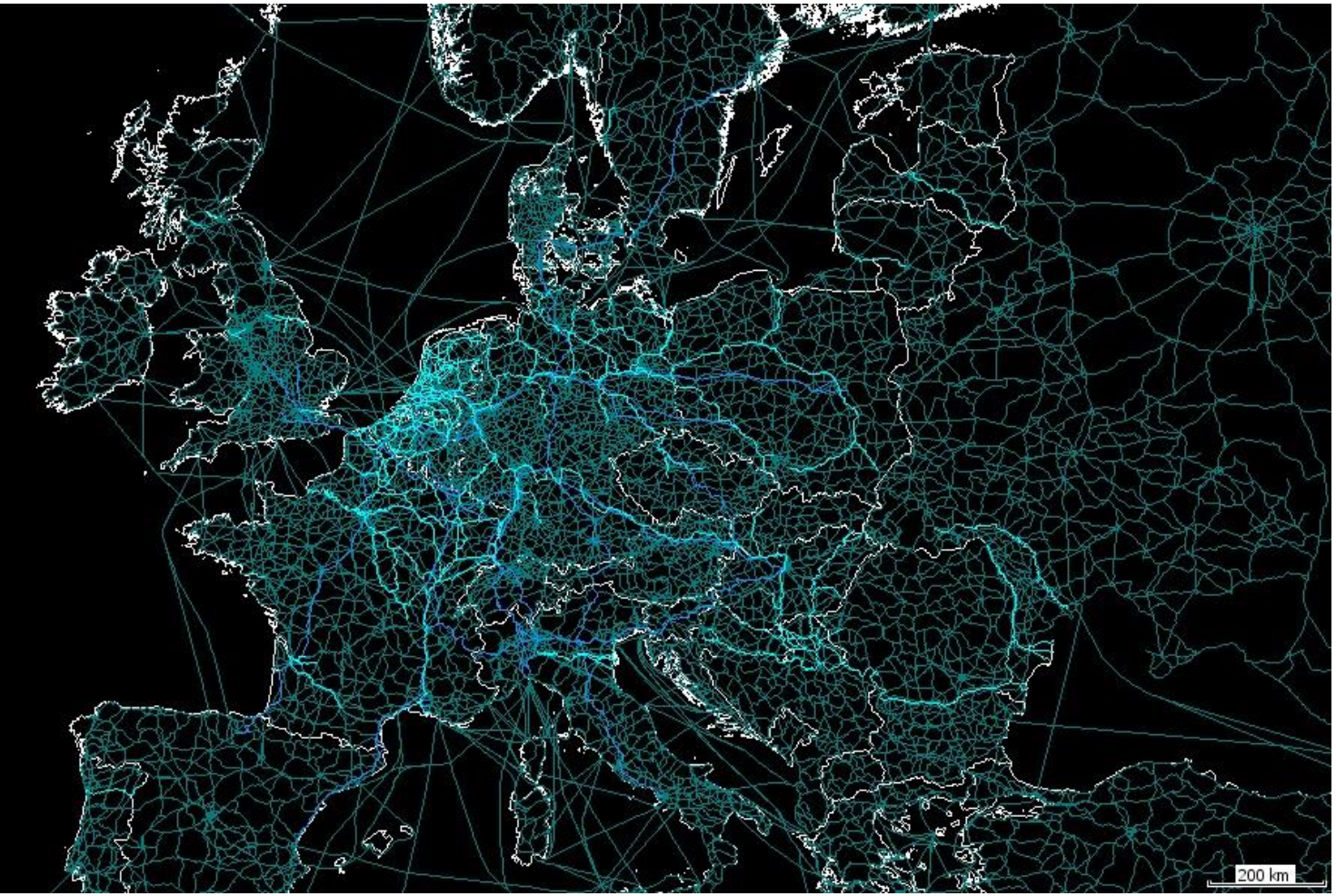
In an event for which there is no data, or the phenomena under study do not exist, simulation can generate a vast amount of data and execute model runs outside of historical bounds



Replicate and simulate:

- Fidelity of physics
- Business rules
- Constraints etc.

SYMBIT – MOBI's synchromodal model



Key characteristics:

- Real-time synchromodal simulations
- Scalable and transferable
- Decentralized routing strategies
- Ability to evaluate asset movement based on firing rules and triggering events

A wide array of applications

- Modal shift
- Disruption management, SC resilience
- Bundling of fragmented flows
- Increasing fill rates
- Evaluate effects of sensor technologies (IoT)

Case 1
Case 2

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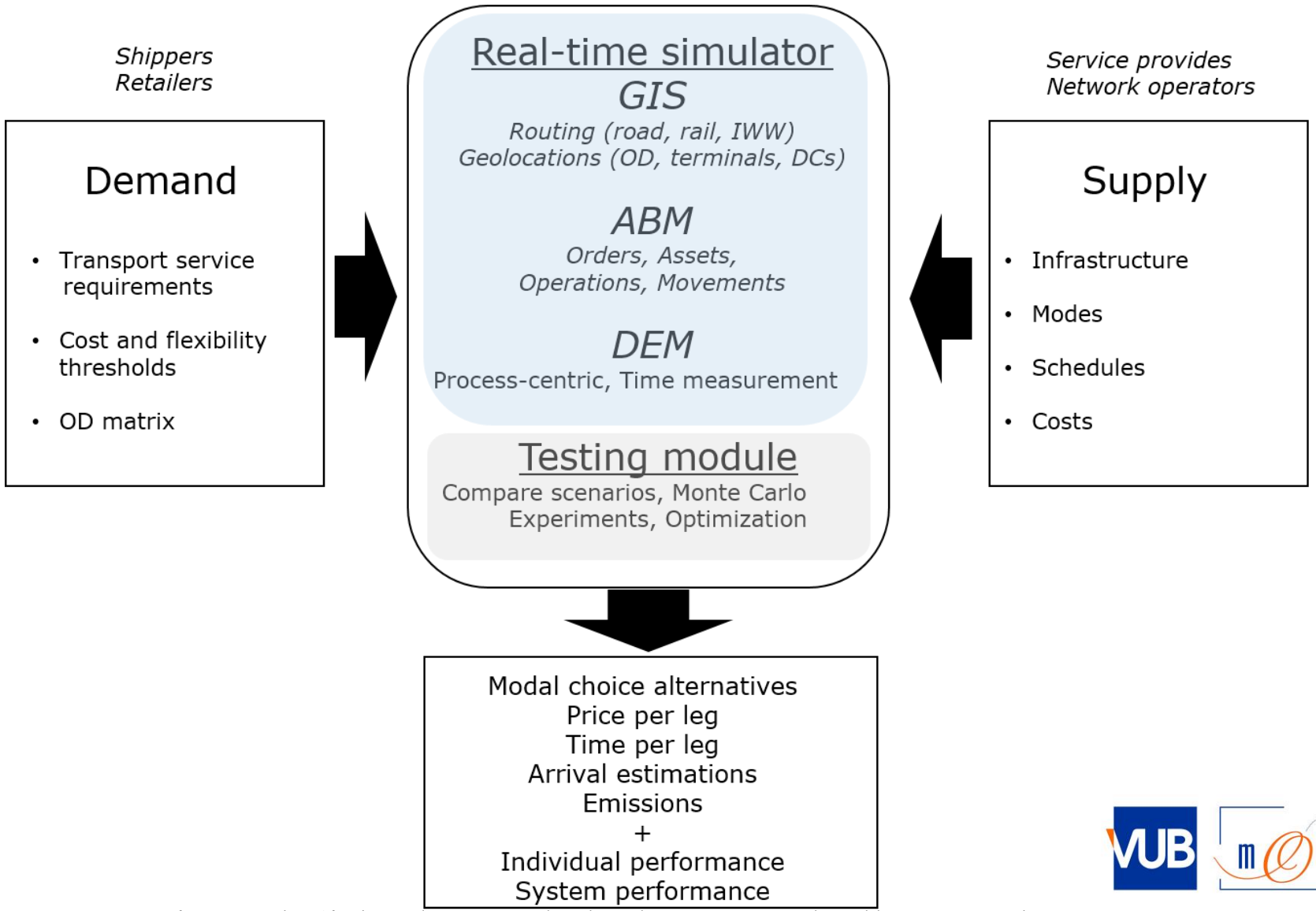
SYMBIT composition



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5) Experimental design

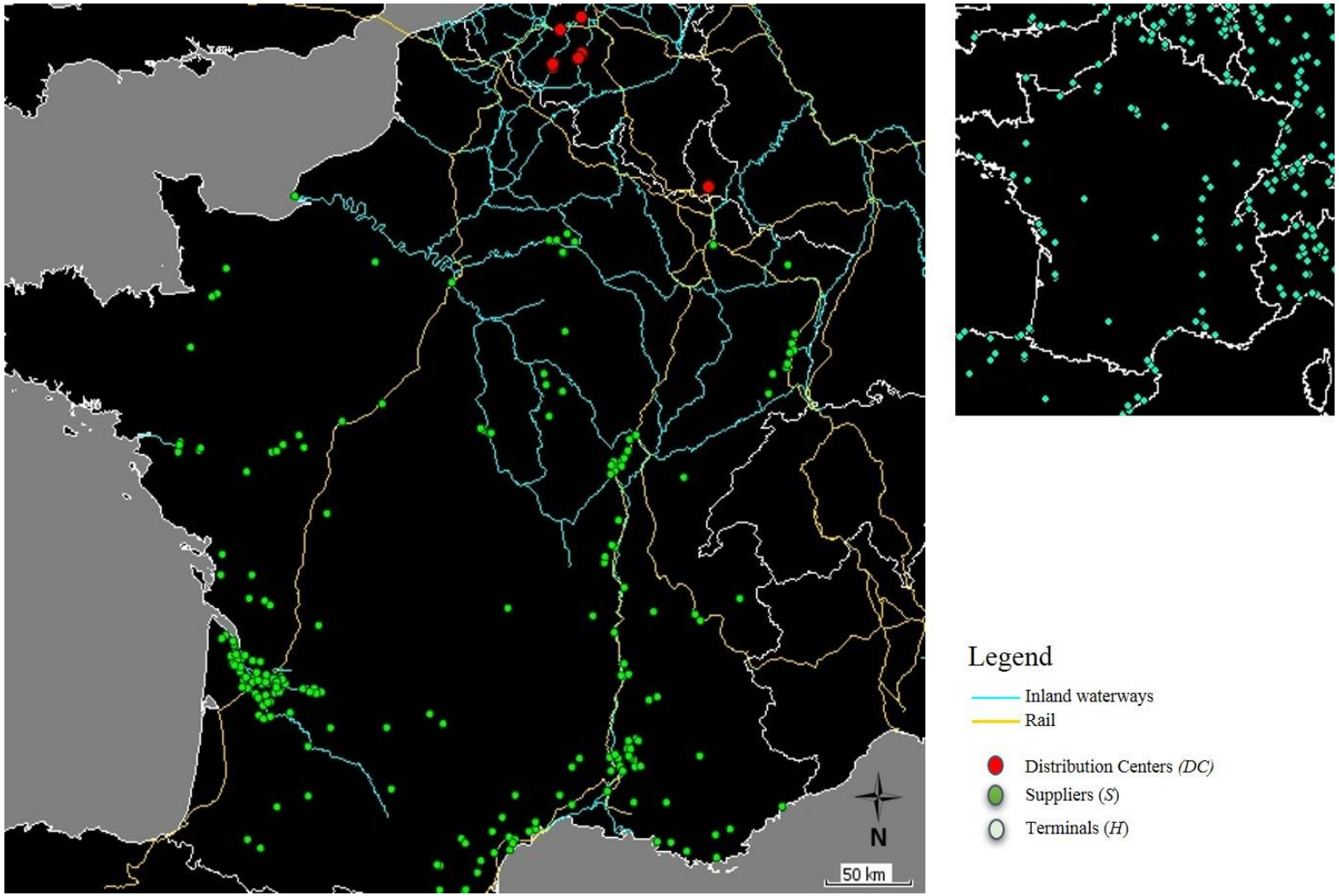
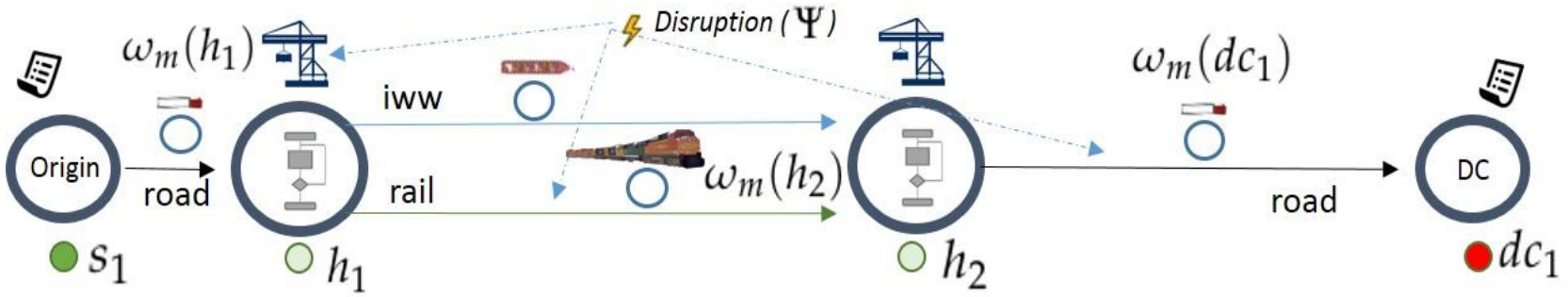


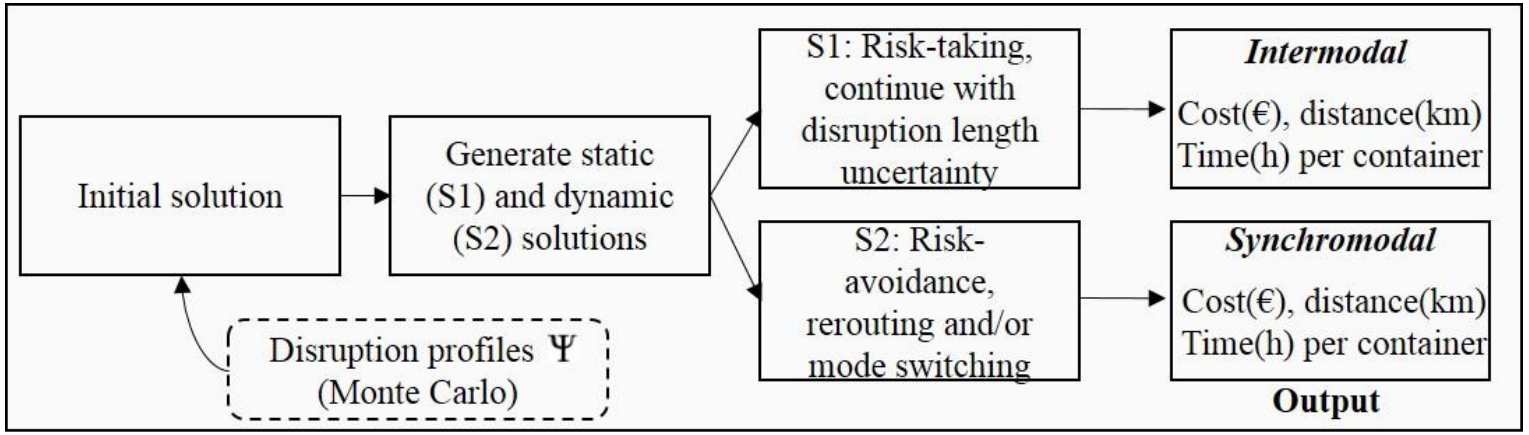
Figure 2: The left image illustrates our study area depicting 220 origins (S), six destinations (DC) and 325 terminals (H). Road shapefiles were excluded for visual clarity. The right image represents all European terminals

5) Experimental design



Ψ	Description (Example)	Probability of occurrence per year	Duration
1	Frequent and short (Delays caused by detours, blockages, light accidents, road works,etc.)	30% - 40%	Uniform (1, 3) h
2	Less frequent and short (Breakdowns, maintenance, moderate weather conditions, trees on rails etc.)	6% - 9%	Uniform (3, 6) h
3	Less frequent and mid-long (Strikes, severe weather conditions, floods, train collision, derailment etc.)	6% - 9%	Uniform (1, 3) d

5) Experimental design



Explicit version can be found in:

Ambra, T., Caris, A., & Macharis, C. (2019). **Should I Stay or Should I Go? Assessing Intermodal and Synchromodal Resilience from a Decentralized Perspective**. *Sustainability*, *11*(6), 1765.

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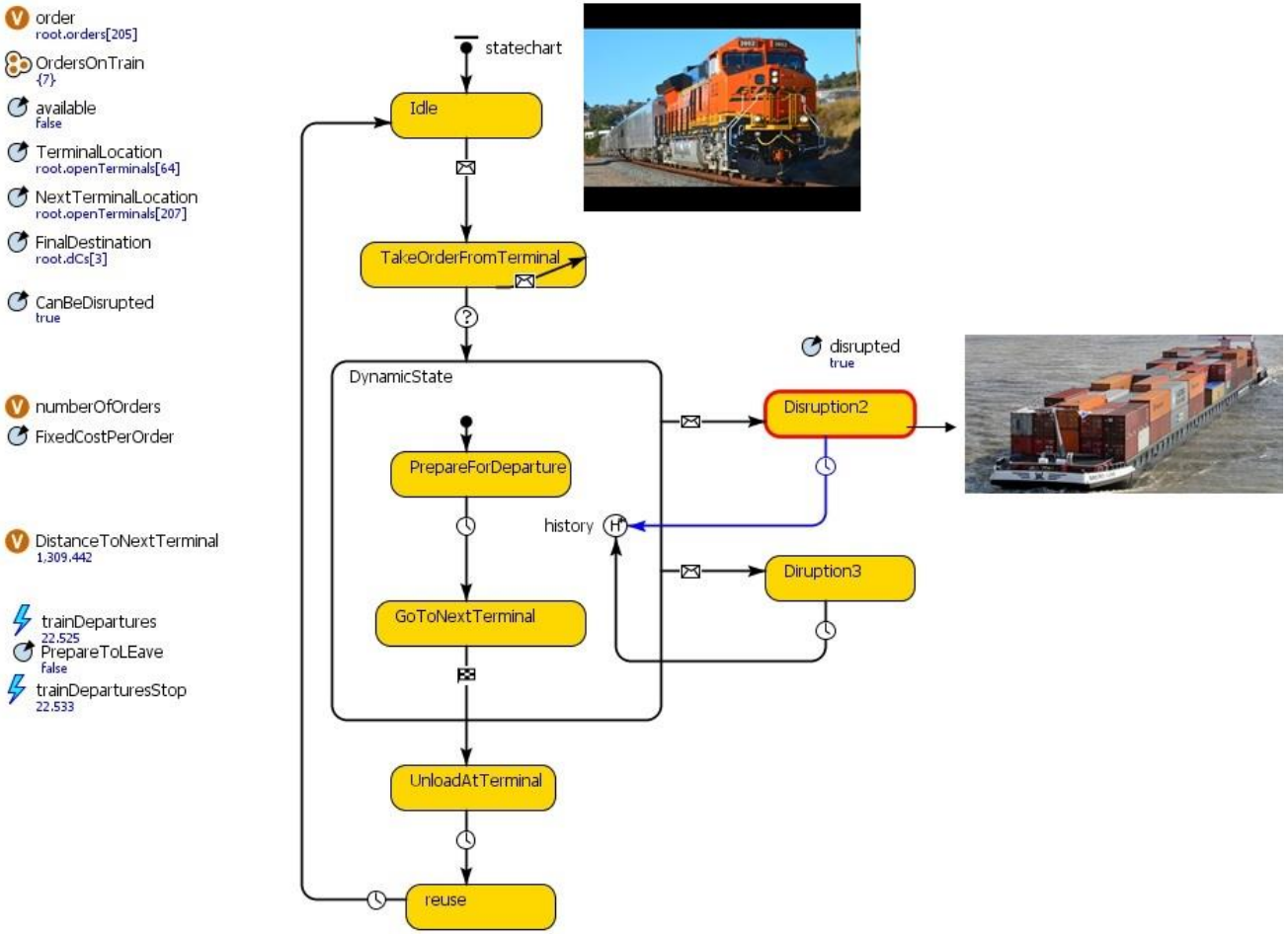

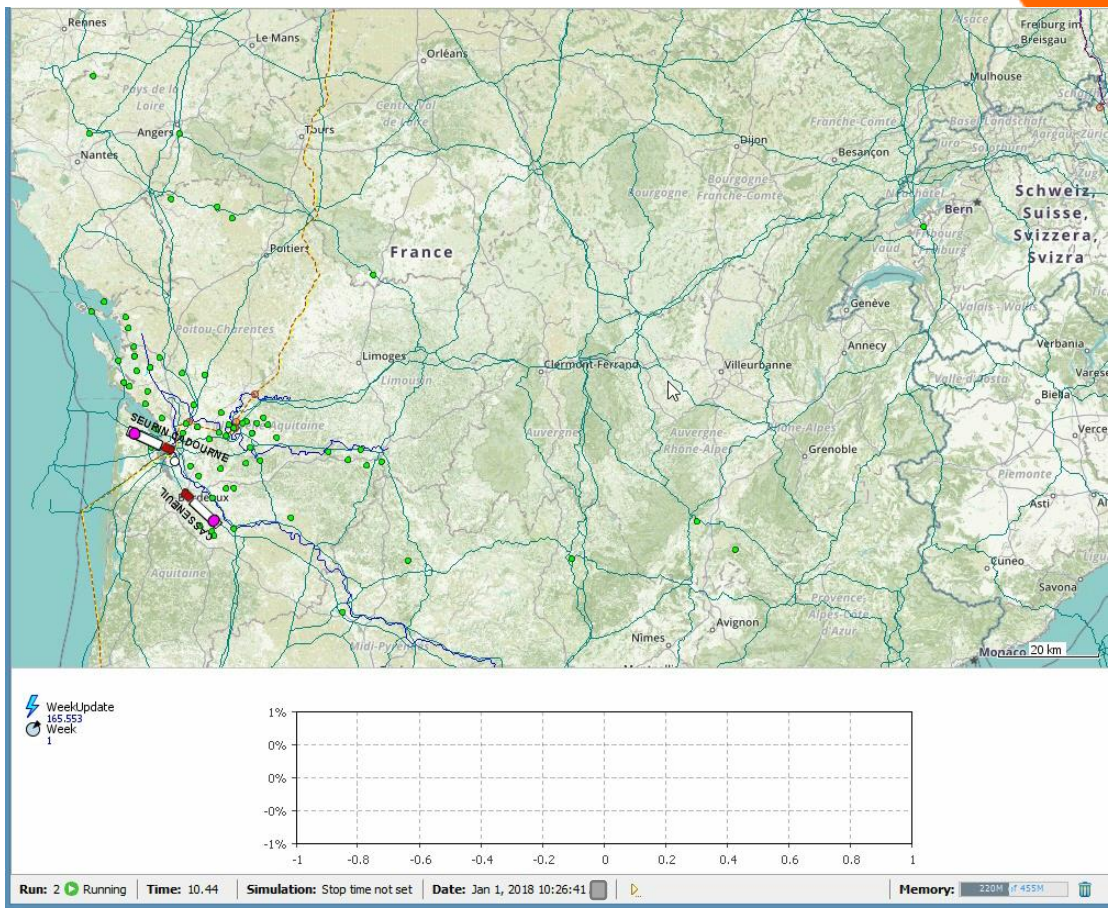

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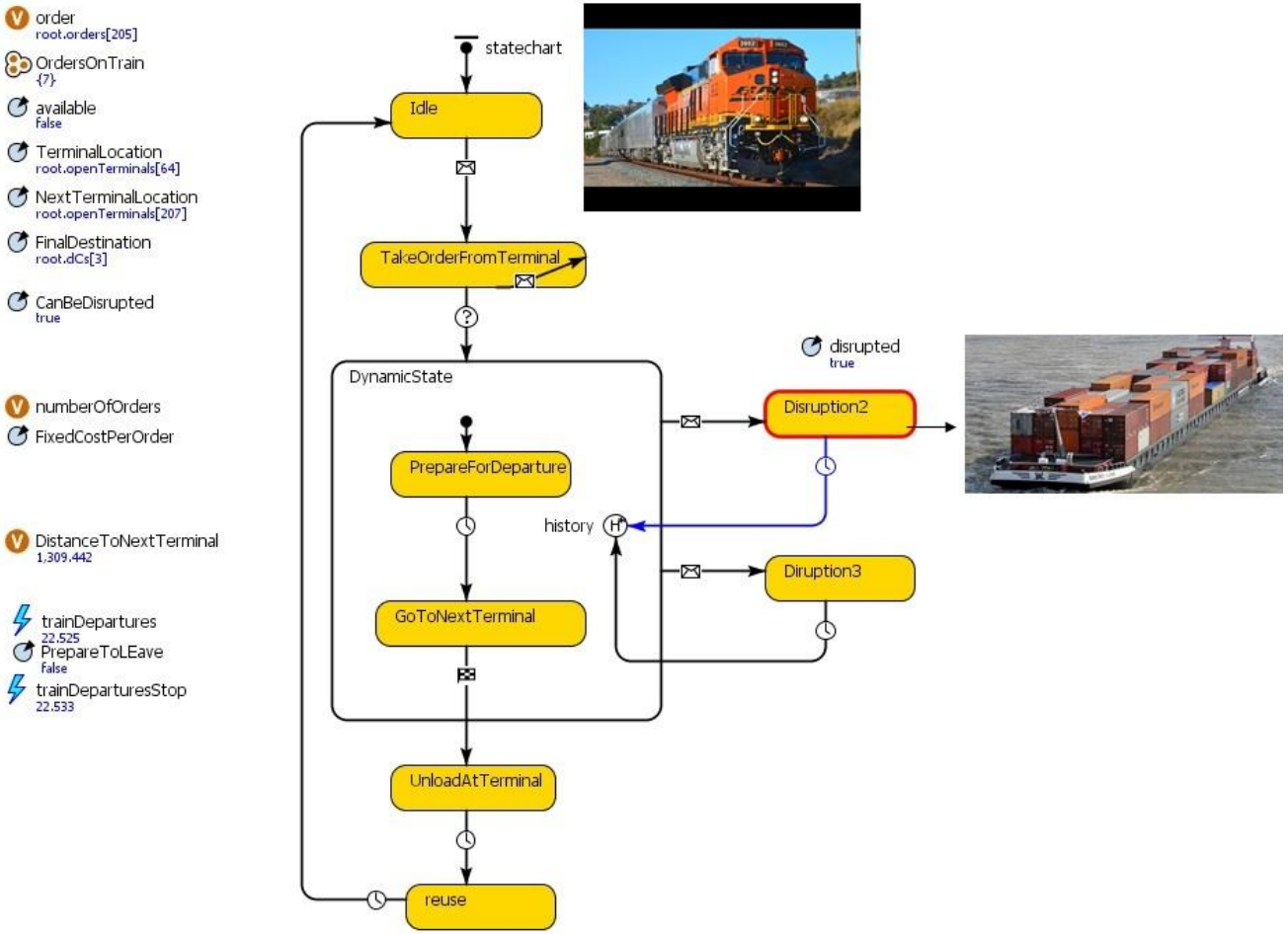
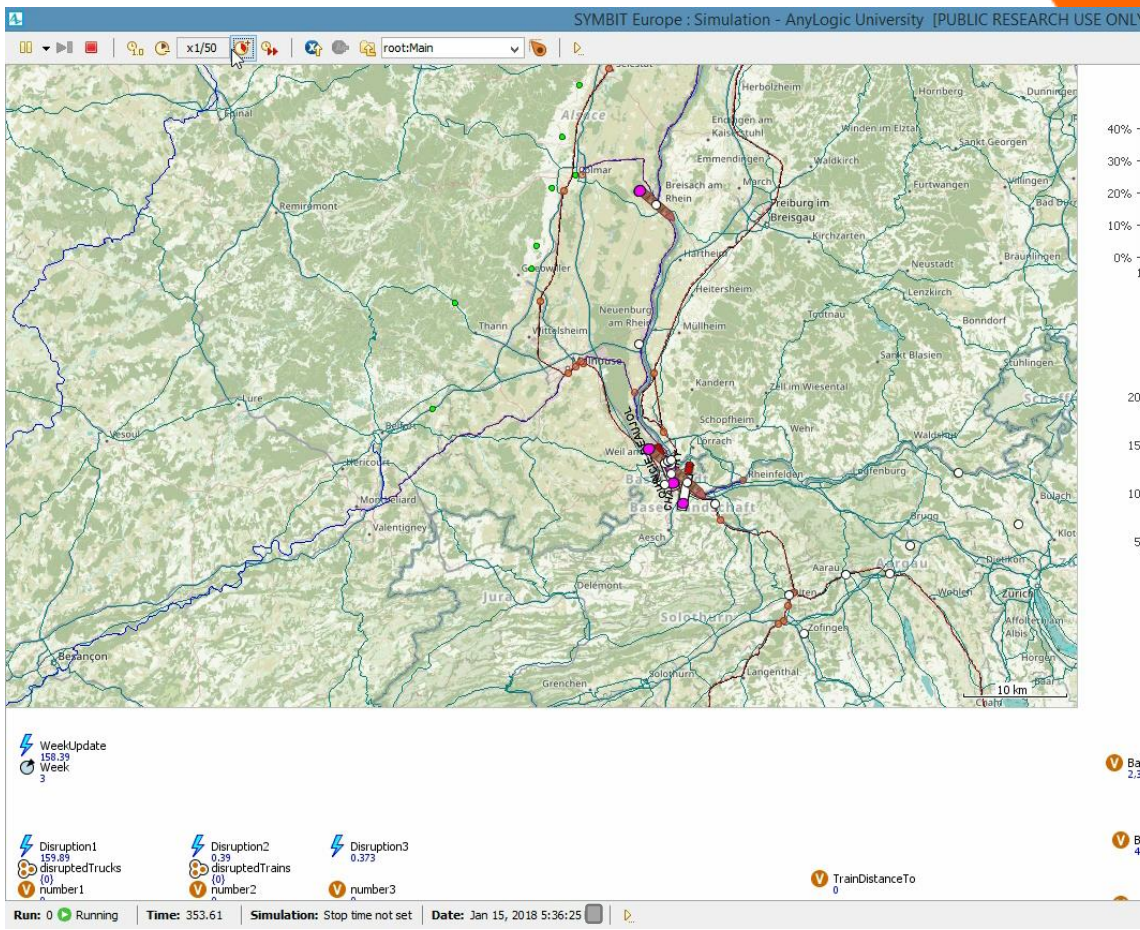
5) Experimental design





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6) Results

Intermodality (Risk taking)

Static, continue with disruption length uncertainty

Synchromodality (Risk avoiding)

dynamic and proactive re-routing and mode switching

Ψ	Description (Example)	Probability of occurrence per year	Duration
1	Frequent and short (Delays caused by detours, blockages, light accidents, road works,etc.)	30% - 40%	Uniform (1, 3) h
2	Less frequent and short (Breakdowns, maintenance, moderate weather conditions, trees on rails etc.)	6% - 9%	Uniform (3, 6) h
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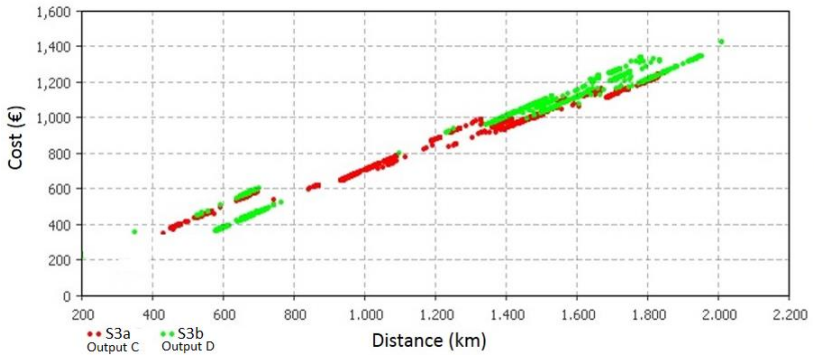
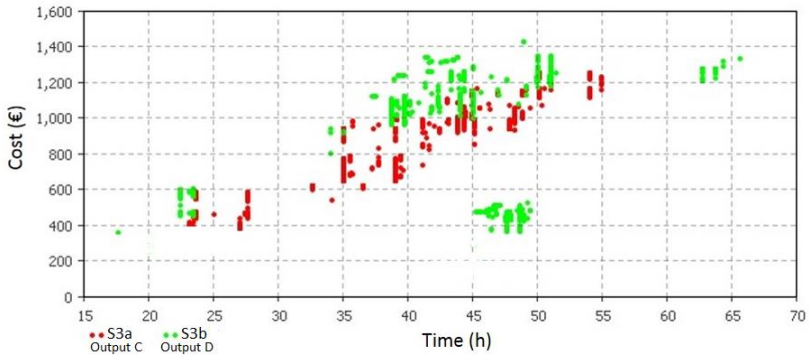
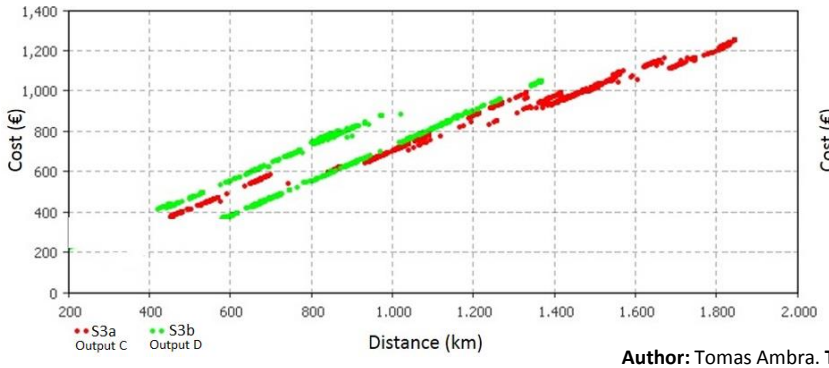
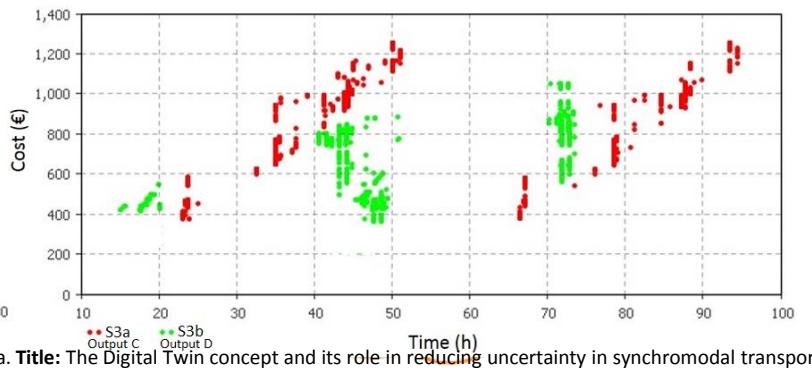




Disruption profile 2

- Dynamic re-routing **not always** better
- Unnecessary deviations



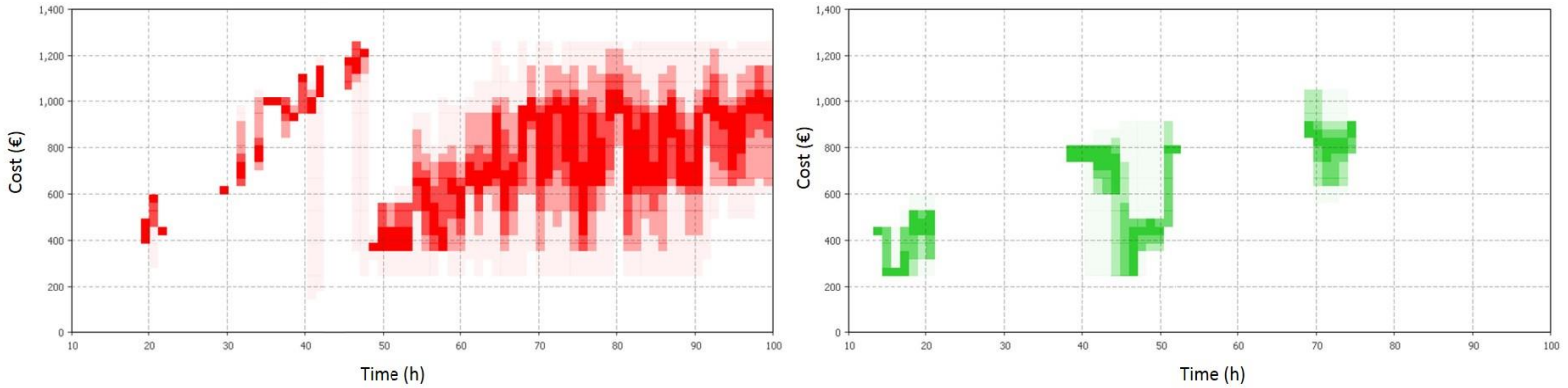


Disruption profile 3

- Dynamic re-routing and mode switching make sense

6) Results

After 100 replications



More stable/predictable bounds

+ Benefits of a transparent user network

+ Rests on info exchange and reactive behavior

- Reliance on network openness and benevolence to flexibly change modes

RQ2: How can the digital twin concept/technology reduce uncertainties?

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7) Discussion – DT for synchromodality

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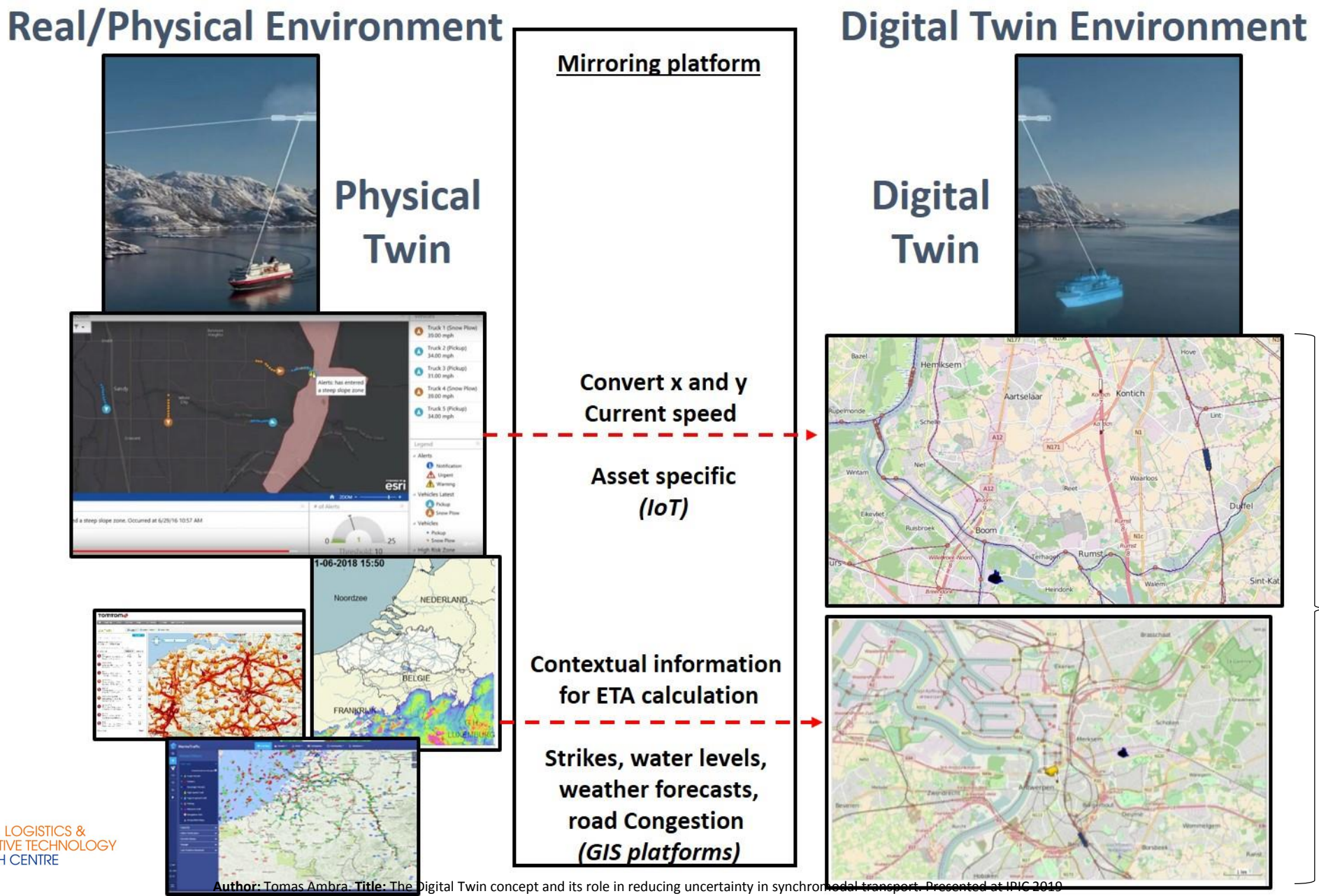
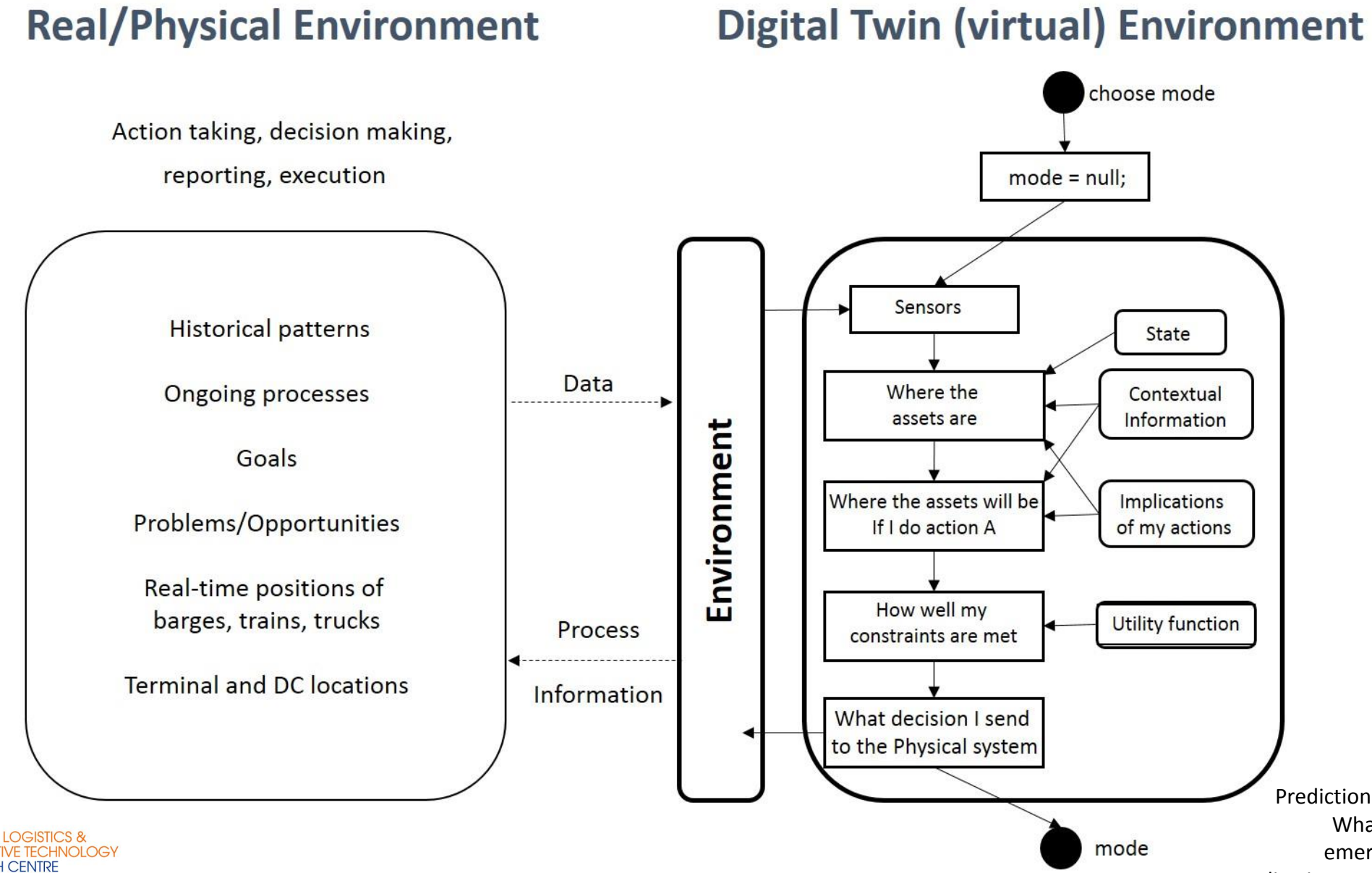


7) Discussion – DT for synchromodality



Conclusions

(1) Is synchromodal dynamic switching and re-routing always a better solution?

- Dynamic re-routing **not always** better
- Unnecessary deviations

(2) How can the digital twin concept/technology reduce uncertainties?

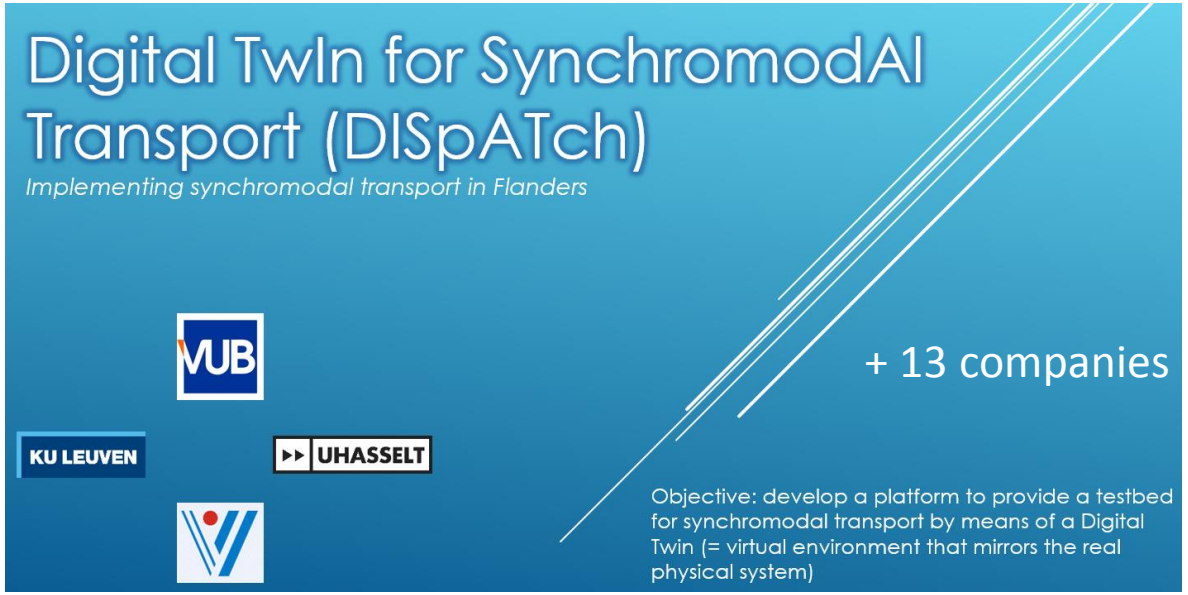
- Parallelization of solutions via simulation
- By providing most probable future outcomes

t+ 1
t+ 2 ?
t+ 3
…

- Optimization of routing and mode switching

(which mode to use, where to switch, what terminals are located enroute, what other assets are in their radius, what is their capacity, how far the handling points are, will the assets make it before closing hours given the assets' current geo-location, etc.)

Further research starts in September 2019



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Thank you for your attention!

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