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

#### **Tomas Ambra**

6th International Physical Internet Conference 9th July 2019, London







#### **Structure**

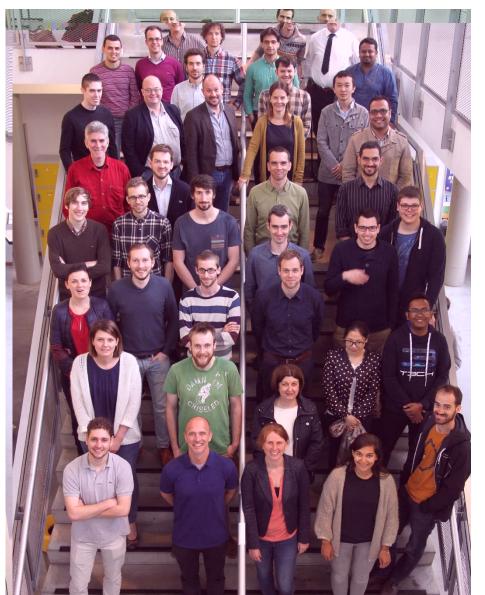
- 1. MOBI who we are
- 2. Synchromodal transport
- 3. The Digital Twin (DT) concept
- 4. Methodology SYMBIT model
- 5. Experimental design (simplified)
- 6. Results
- 7. Discussion DT for synchromodality
- 8. Conclusions

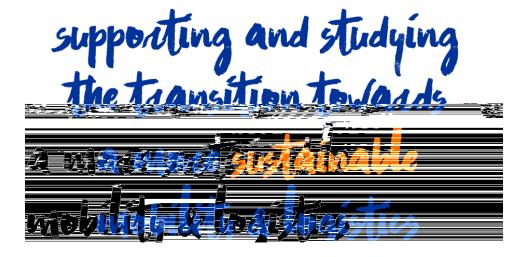




# MOBILITY, LOGISTICS & AUTOMOTIVE TECHNOLOGY RESEARCH CENTRE







**Key Assets** 

Sustainable logistics









#### **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

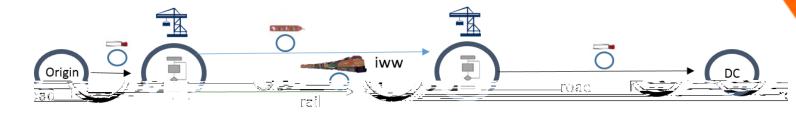
27 current EU Projects

>5.9 M€ turnover 2018

+100 team members

20 nationalities

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.



### Examples of control towers







Source: ESRI Source: MPO

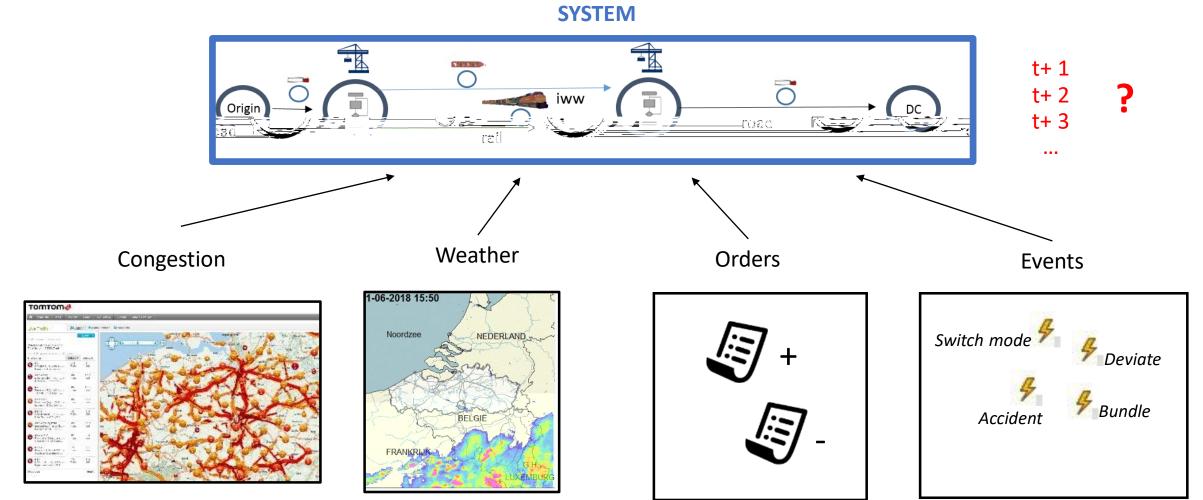
Source: marinetraffic.com

Provide past and present positions of assets and trends



Situational awareness of the current system state and projections:

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



#### The solution?



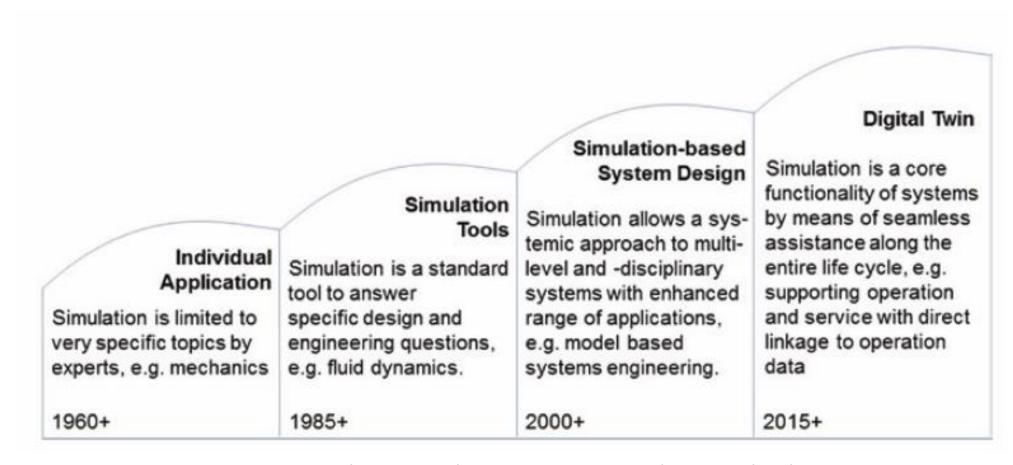
Legends of Tomorrow - time machine



### 3) The Digital Twin concept



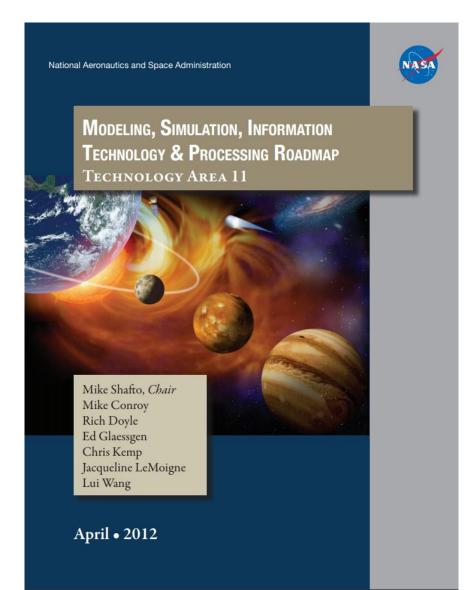
#### **Stages of simulation technology**



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



### **Digital Twin origins**

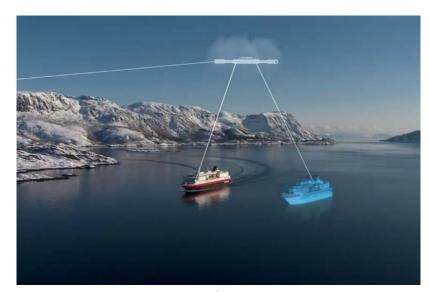


#### **Digital Twin**

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



### **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

## 4) Methodology – SYMBIT model

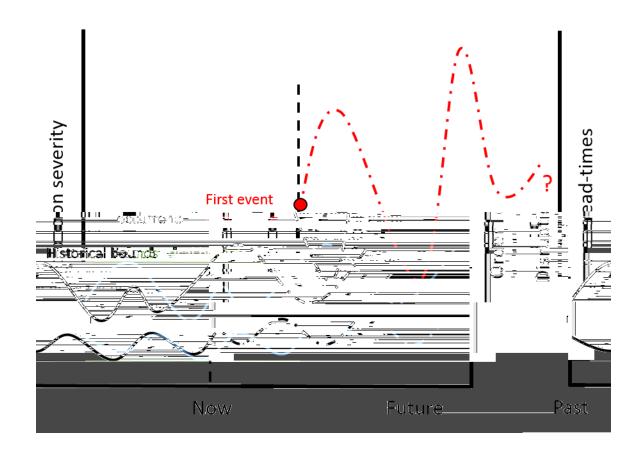
### **Research questions:**

- (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.

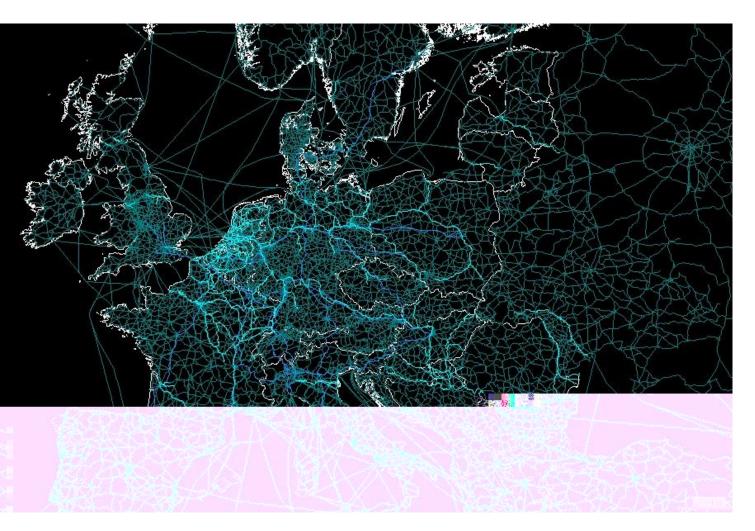
### The role of simulation in data-centric and process-centric realms

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:**

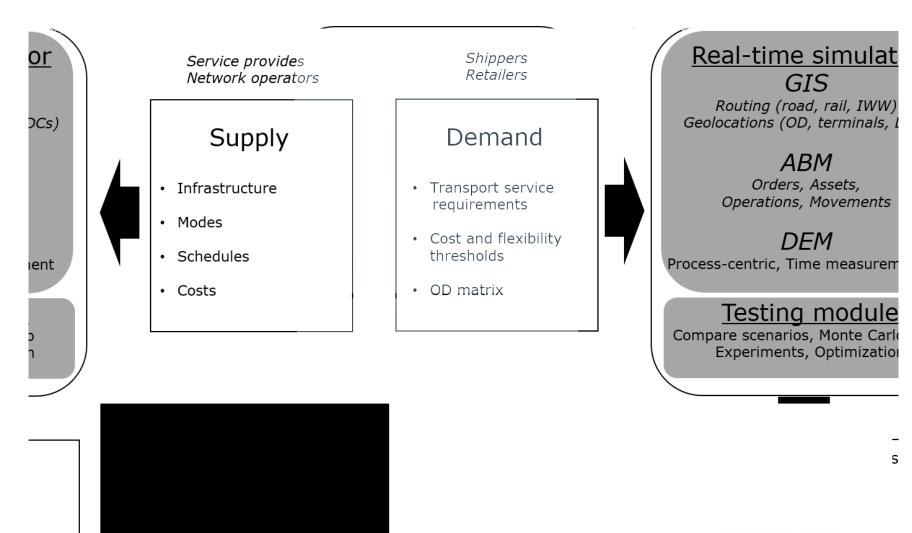
Real-time synchromodal simulations
Scalable and transferable
Decentralized routing strategies
Ability to evaluate asset movement
based on firing rules and triggering events

#### A wide array of applications

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



### **SYMBIT** composition



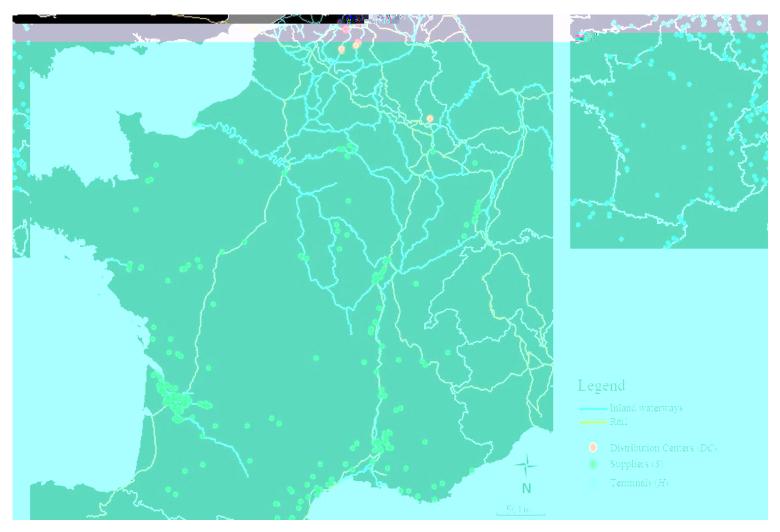
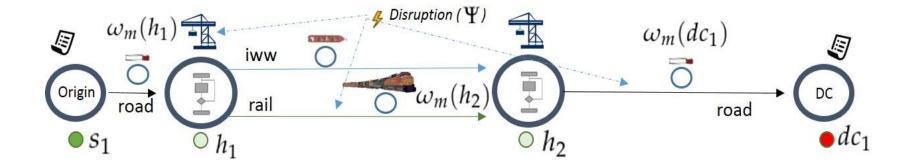
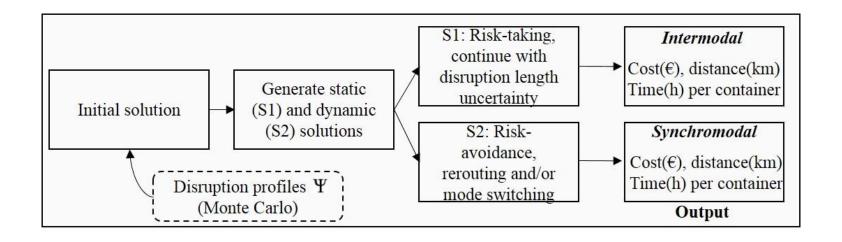


Figure 2: The left image illustrates our study area depicting 220 origins (S), six destinations (DC) and 325 terminals (H). Road shapefiles were excluded for visual clarity. The right image represents all European terminals



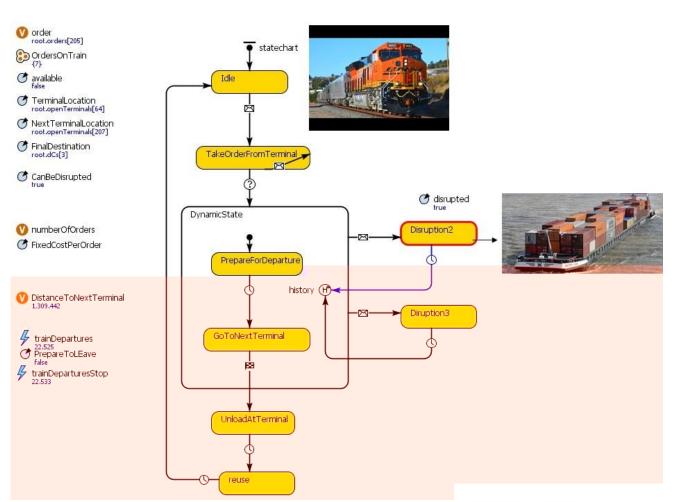
Ψ	Description (Example)	Probability of occurrence per year	Duration
1	Frequent and short (Delays caused by detours, blockages, light accidents, road works,etc.)	30% - 40%	Uniform (1, 3) h
2	Less frequent and short (Breakdowns, maintenance, moderate weather conditions, trees on rails etc.)	6% - 9%	Uniform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

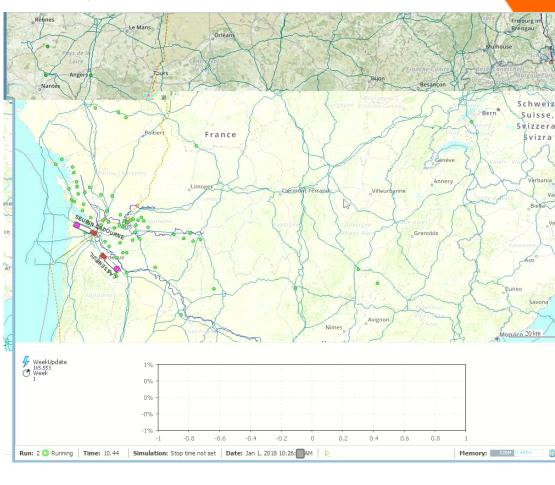


Explicit version can be found in:

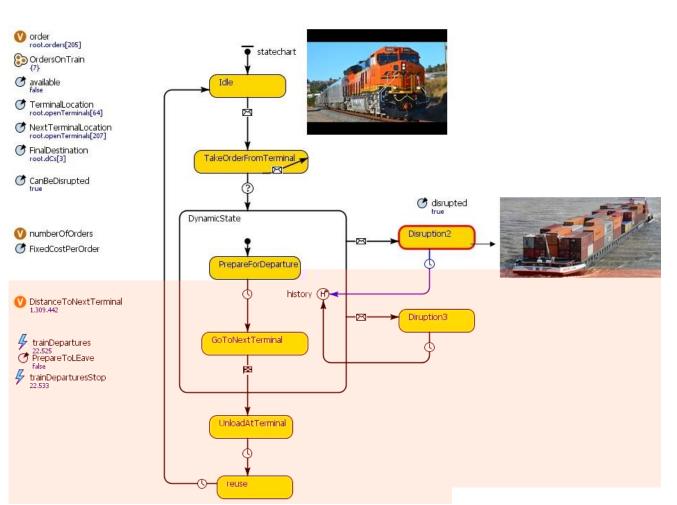
Ambra, T., Caris, A., & Macharis, C. (2019). Should I Stay or Should I Go? Assessing Intermodal and Synchromodal Resilience from a Decentralized Perspective. Sustainability, 11(6), 1765.

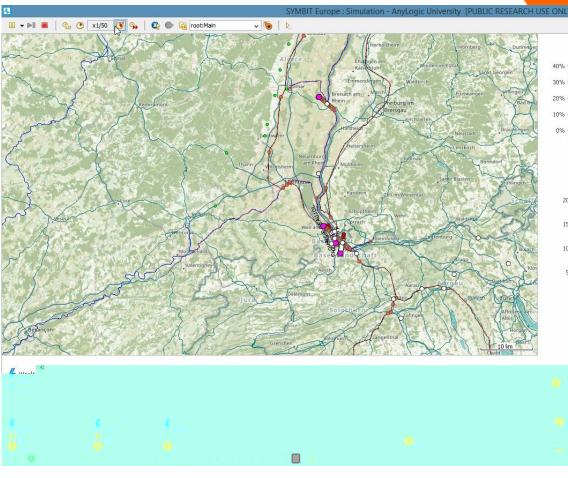












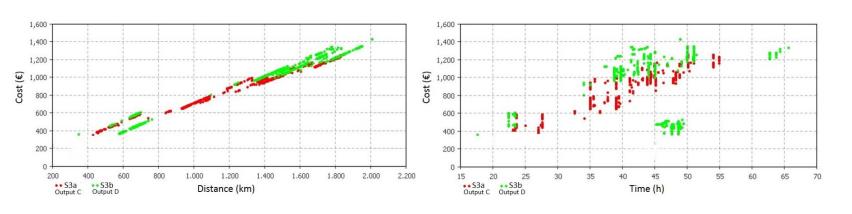


### 6) Results

Intermodality (Risk taking)
Static, continue with disruption length uncertainty

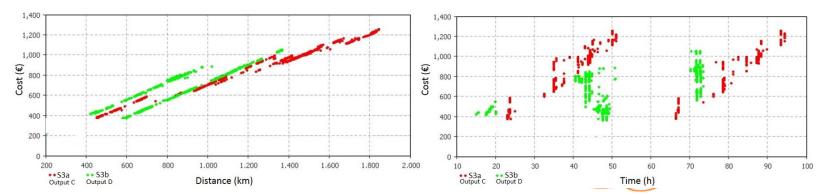
Synchromodality (Risk avoiding) dynamic and proactive re-routing and mode switching

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
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#### Disruption profile 2

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

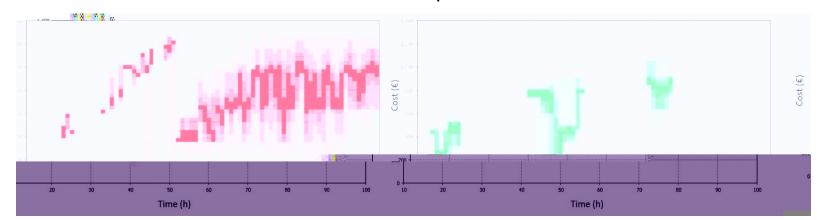


#### Disruption profile 3

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



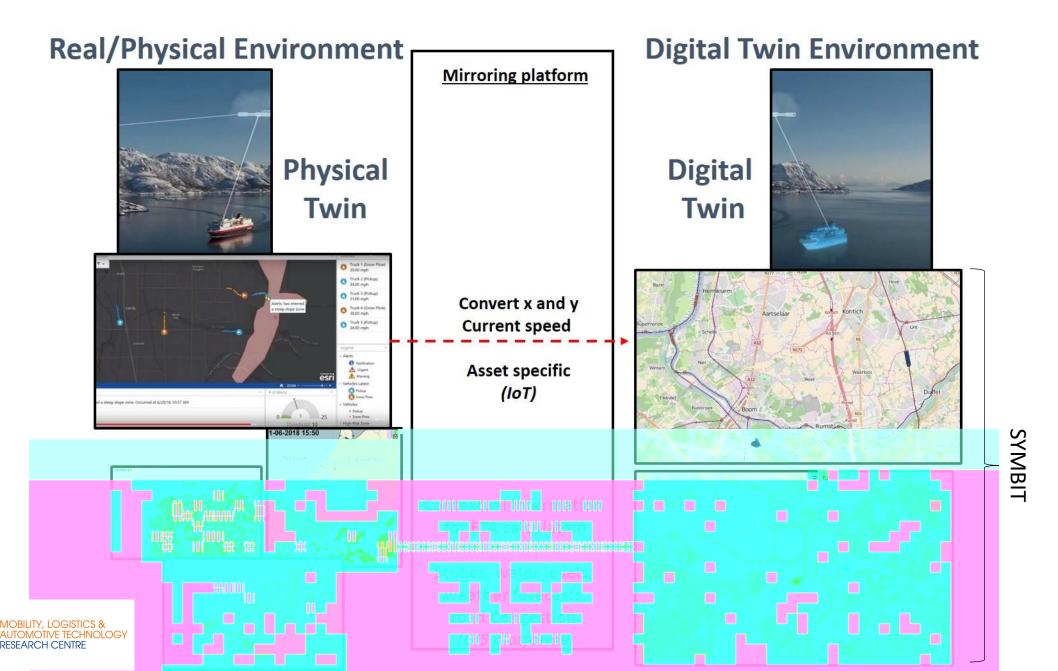
RQ2: How can the digital twin concept/technology reduce uncertainties?



### 7) Discussion – DT for synchromodality



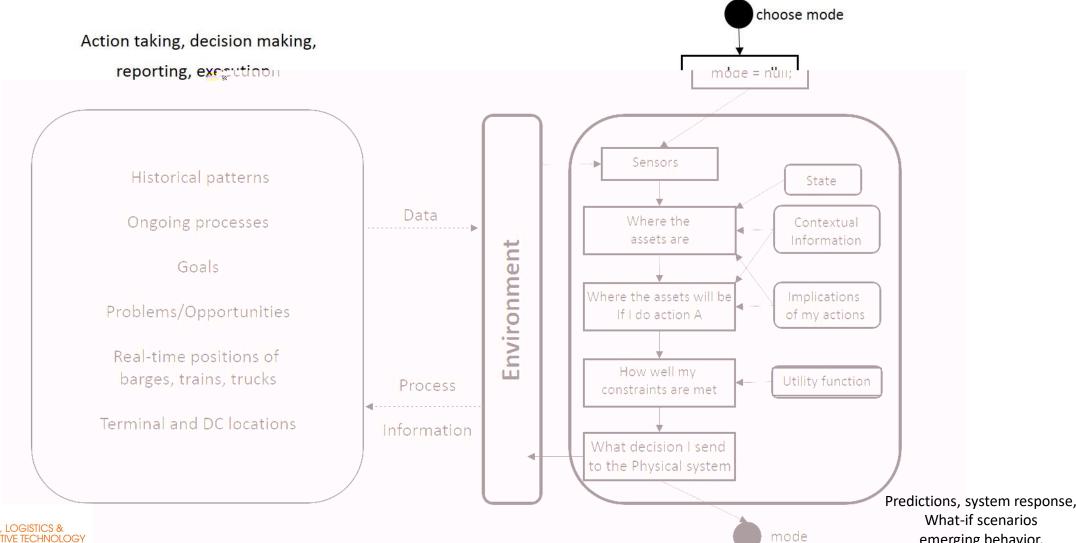
### 7) Discussion – DT for synchromodality



### 7) Discussion – DT for synchromodality

#### **Real/Physical Environment**

### **Digital Twin (virtual) Environment**









What-if scenarios emerging behavior, Replications, Monte Carlo experiments

### **Conclusions**

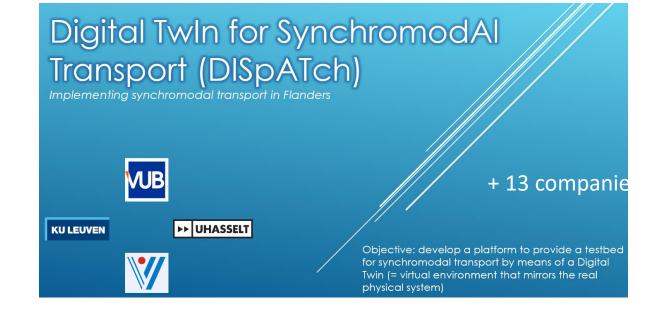
- (1) Is synchromodal dynamic switching and re-routing always a better solution?Dynamic re-routing **not always** betterUnnecessary deviations
- (2) How can the digital twin concept/technology reduce uncertainties?Parallelization of solutions via simulationBy providing most probable future outcomes



#### 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





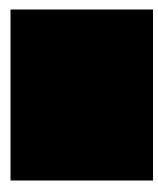
# Thank you for your attention



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