Raskaan sähkökaluston suorituskyvyn mallinnus ja digitaaliset kaksoset käytön optimoinnissa

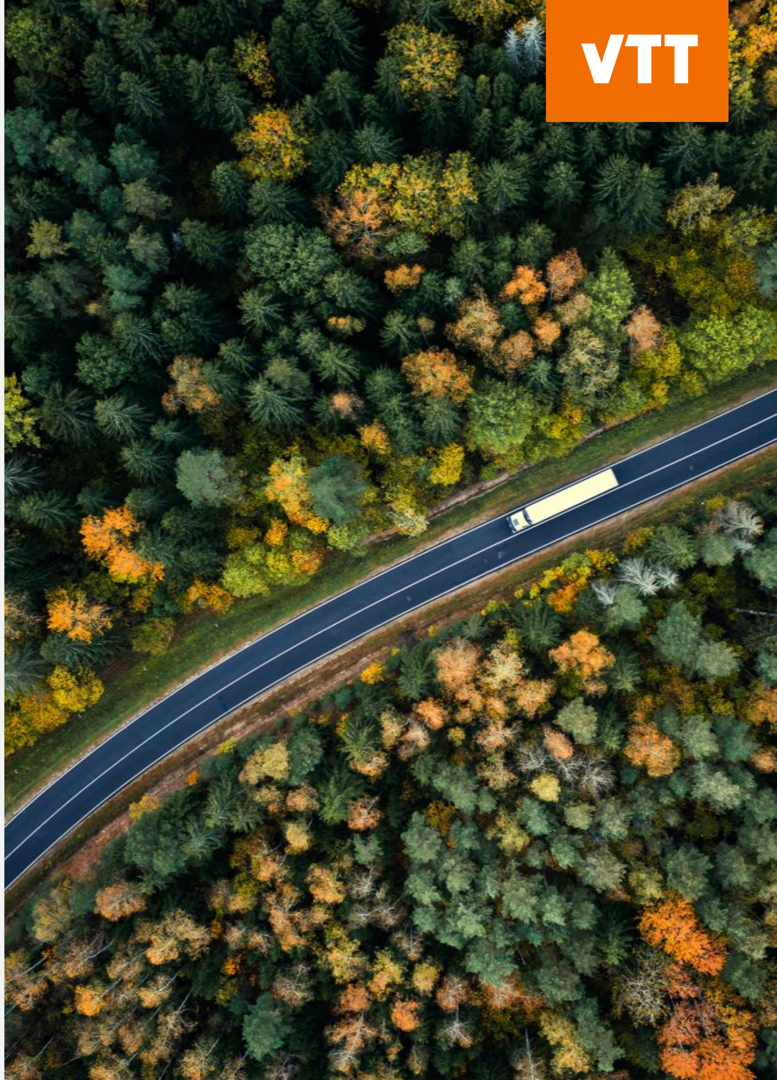
RASKAIDEN KULJETUSTEN SÄHKÖISTYMISEN SEMINAARI, Lahti

Joel Anttila, VTT

1.4.2025 VTT – beyond the obvious

Contents

- Background
- Tools for modelling
- Digital twin use cases
- Challenges and next steps



About ESCALATE EU Project

5 Truck Manufacturers
3 Infrastructure Supplier
5 OEMs
4 Shippers
10 Research Institutes
5 NGO

Duration: 42 Months
01/2023 – 06/2026

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101096598

VTT

About ESCALATE EU Project

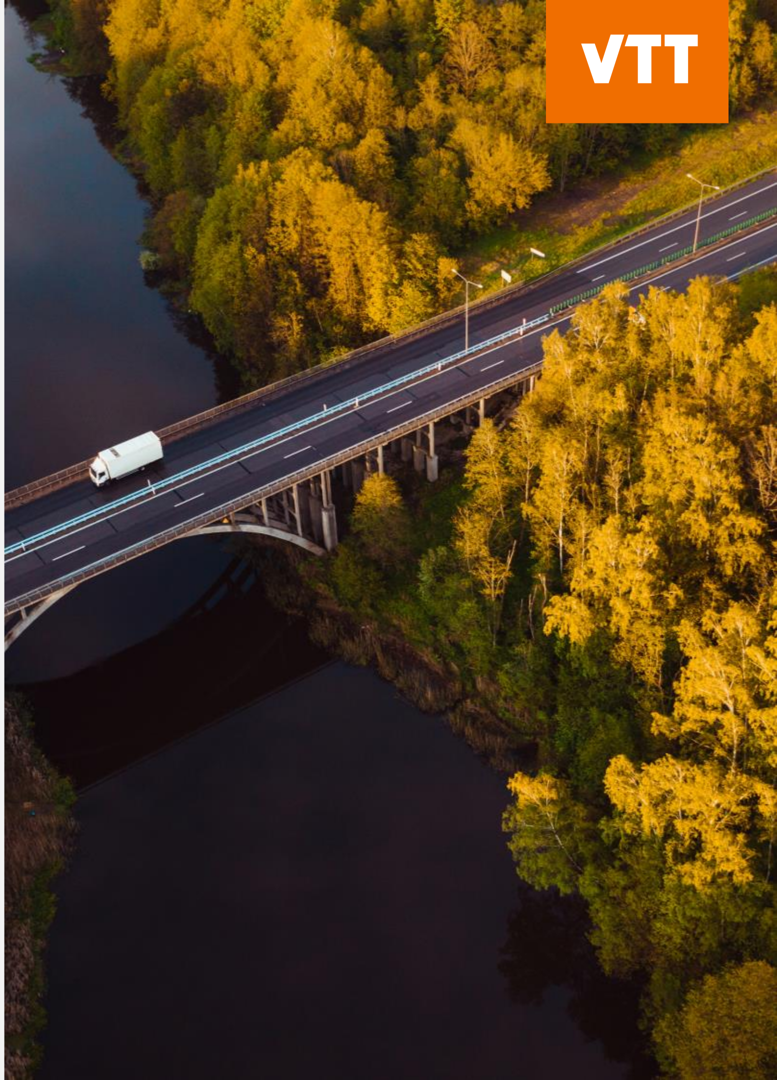
- Topic on zero emission long-haul logistics
  - Battery electric trucks
  - Fuel cell trucks
- Product development and innovations
  - Truck prototypes and system integration
  - Charging solutions (MCS)
  - Digital twins and data-based tools
- 5 pilots, out of which one in Finland

DLR Institute of Vehicle Concepts · BMC · O. JYLHÄ OY · DIN · SISU · TEKFEN ENGINEERING · ELECTRA · LAT · POLIS · VTT · virtual vehicle · cea · RSTER · VALMET AUTOMOTIVE · pbx · FORD OTOSAN · ErG tech · KEMPOWER · TÜBİTAK · DHL · inegi · bsa · ENGIE Solutions · Hydrogen Europe · RAUANHEIMO · ORTEM · Coventry University · Advanced Electric Machines · PrimaFrio · FEV · University of Surrey · Mercedes-Benz · BRING · AI4SEC

Logistics in a turning point

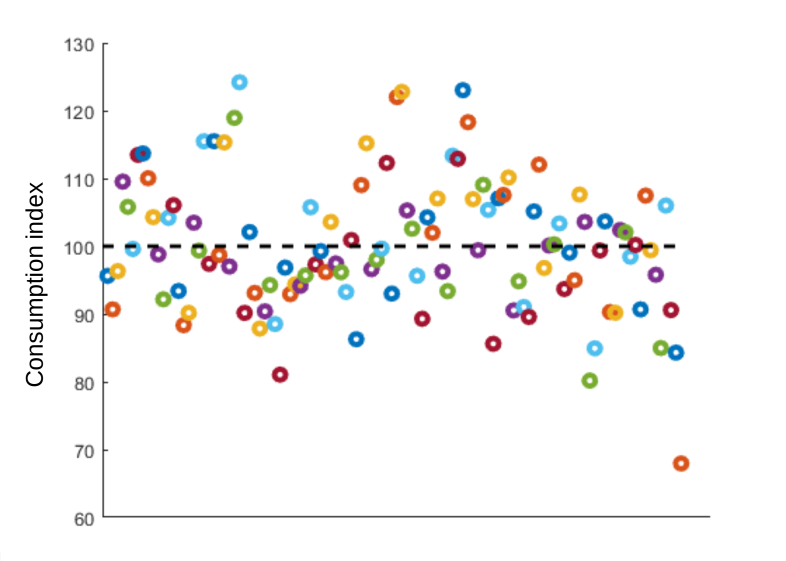
- Battery electric vehicles (BEVs) challenge the conventions in logistics sector
  - BEVs have limited operational range and require charging (unproductive dead time)
  - Ambient conditions have elevated effect on vehicle performance
  - Lower operational costs, utilisation rate ever more important for economic viability
- How to ensure successful operation, considering the limitations?
- How to react to suddenly changing conditions?
  - Changes in ambient temperature, surface conditions, traffic, congestions

“What was previously done with pen and paper now requires sophisticated tools.”



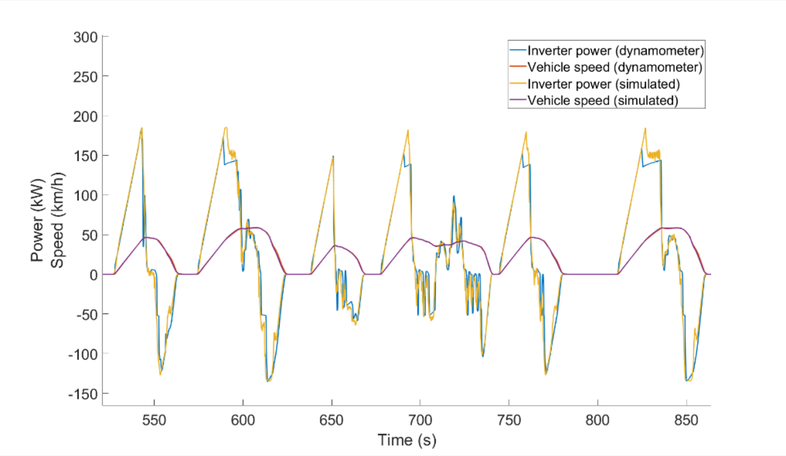
Why modelling?

- Energy consumption varies a lot based on:
  - Route
  - Driving style
  - Payload
  - Ambient conditions and traffic
- Case example:
  - One vehicle model, 120 routes
  - Up to 80% difference in kWh/km consumption
- Data-based analysis requires immense amount of data!

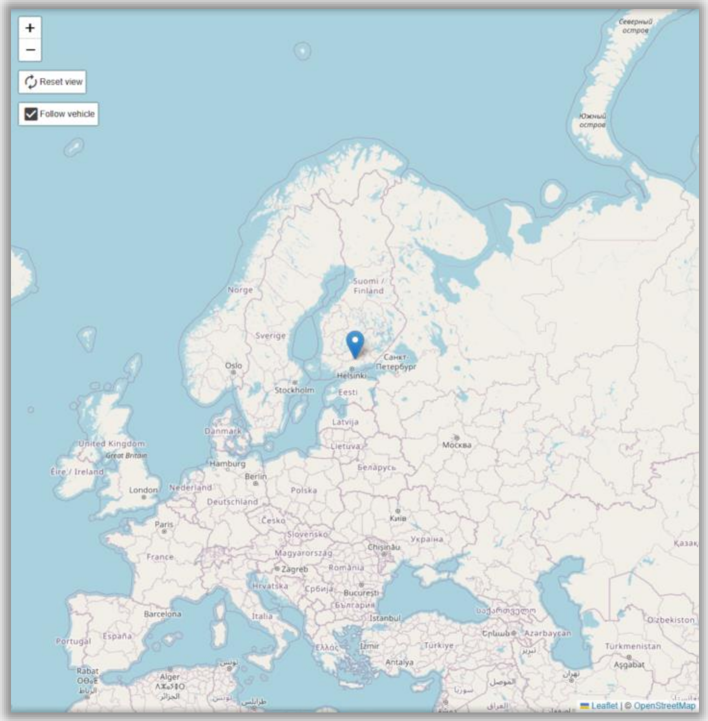


SEF simulation tool

- Smart eFleet (SEF) is a map-based vehicle fleet simulation tool developed by VTT
- VTT's research equipment and vast project catalog has been utilised in the development
- SEF energy flow modelling demonstrated 99.6% accuracy
  - Reference: IEEE VPPC 2019 "*System-Level Validation of an Electric Bus Fleet Simulator*" [10.1109/VPPC46532.2019.8952293](https://doi.org/10.1109/VPPC46532.2019.8952293)

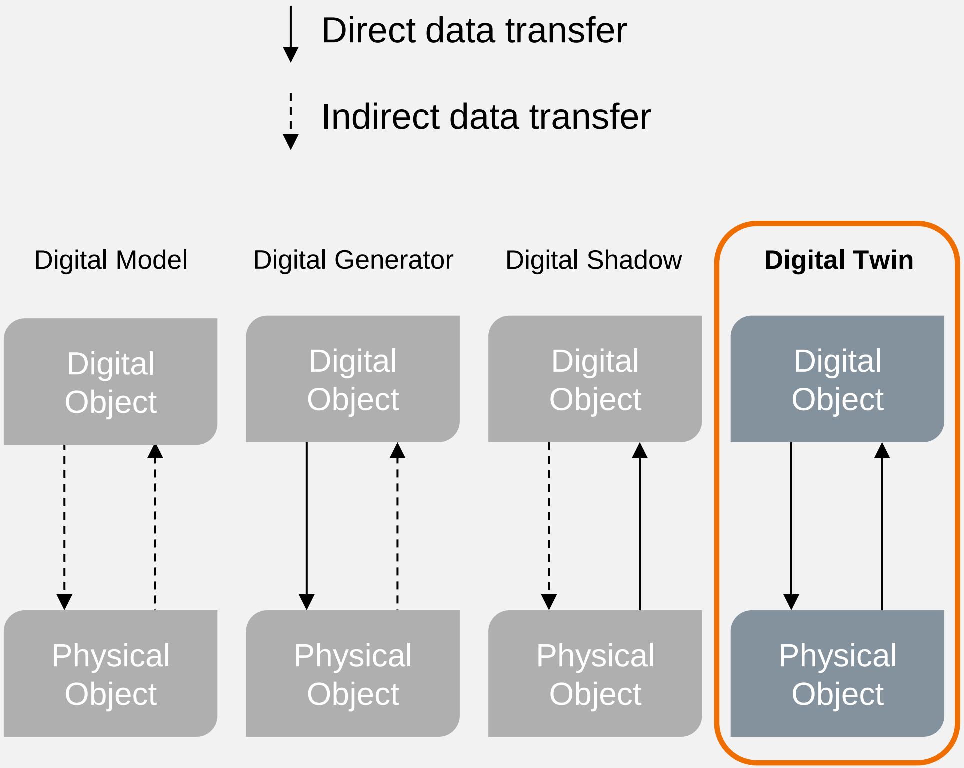


SEF simulation tool



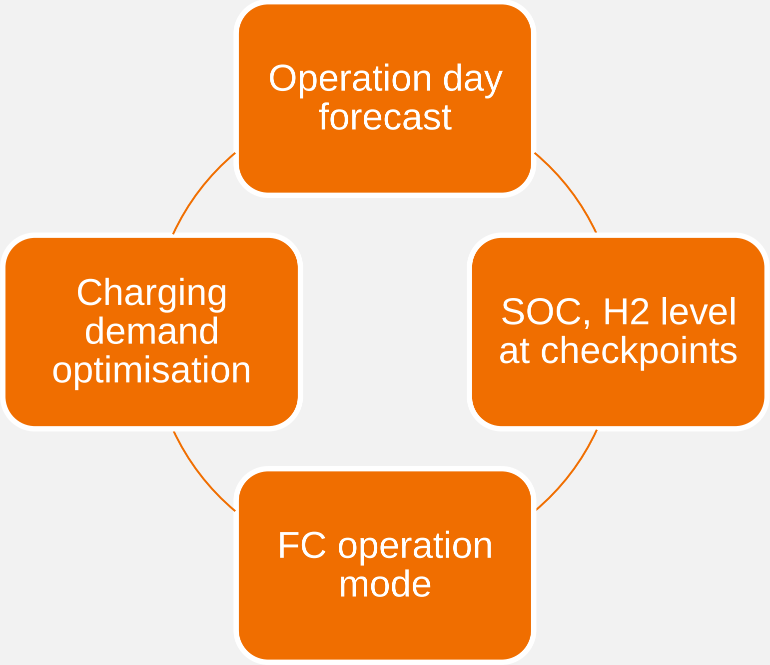
Digital Twin Definition

- Digital twin requires **direct bi-directional information exchange** between digital and physical objects
- Information exchange is a broad concept
  - It can be, e.g., guidance, notifications, control parameters and so on



ESCALATE Digital Twin Objectives

- Forecast daily operation in real-time, with focus on
  - Driving time and energy consumption
- Ambient conditions and traffic are taken into account
  - Weather and road condition
  - Congestion
  - Charging station availability
- Forecasts used to optimise operation
  - Energy cost savings (optimising fuel cell consumption)
  - Operational reliability (target SOC)
  - Charging demand optimisation (optimal charge window, charger reservation)



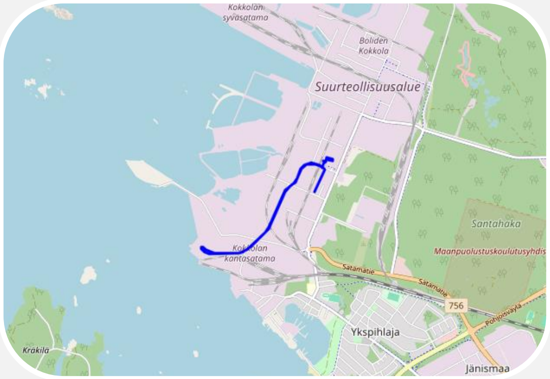
ESCALATE Pilot 1 Vehicle Specifications

- Manufacturer: Oy Sisu Auto Ab
- Type: Fuel cell electric vehicle (FCEV)
- Powertrain:
  - Motor power: 300 kW (nominal)
  - Fuel cell (FC) power: 120 kW
  - Traction 6x4
  - 12-gear transmission
- Energy storage: 664 kWh NMC
- H2 tank: 58 kg (700 bar)
- Range: >800 km
- Gross vehicle weight: 76t

ESCALATE Pilot 1 Routes

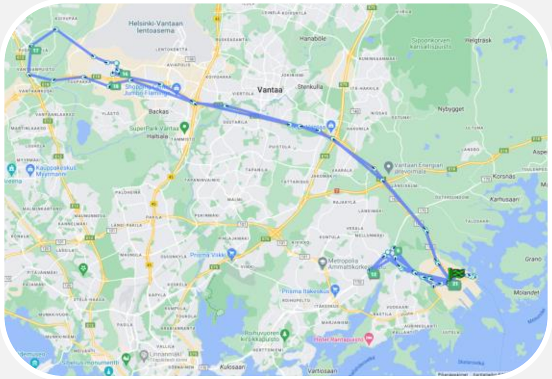
Phase 1
Q2/2025

Phase 2
Q3/2025



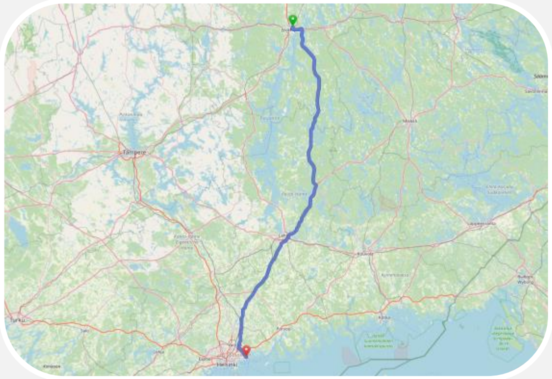
Kokkola harbour

- Closed industrial zone
- 5 km route, about 80 km per day
- GVW 60t
- Fully electric operation



Helsinki region

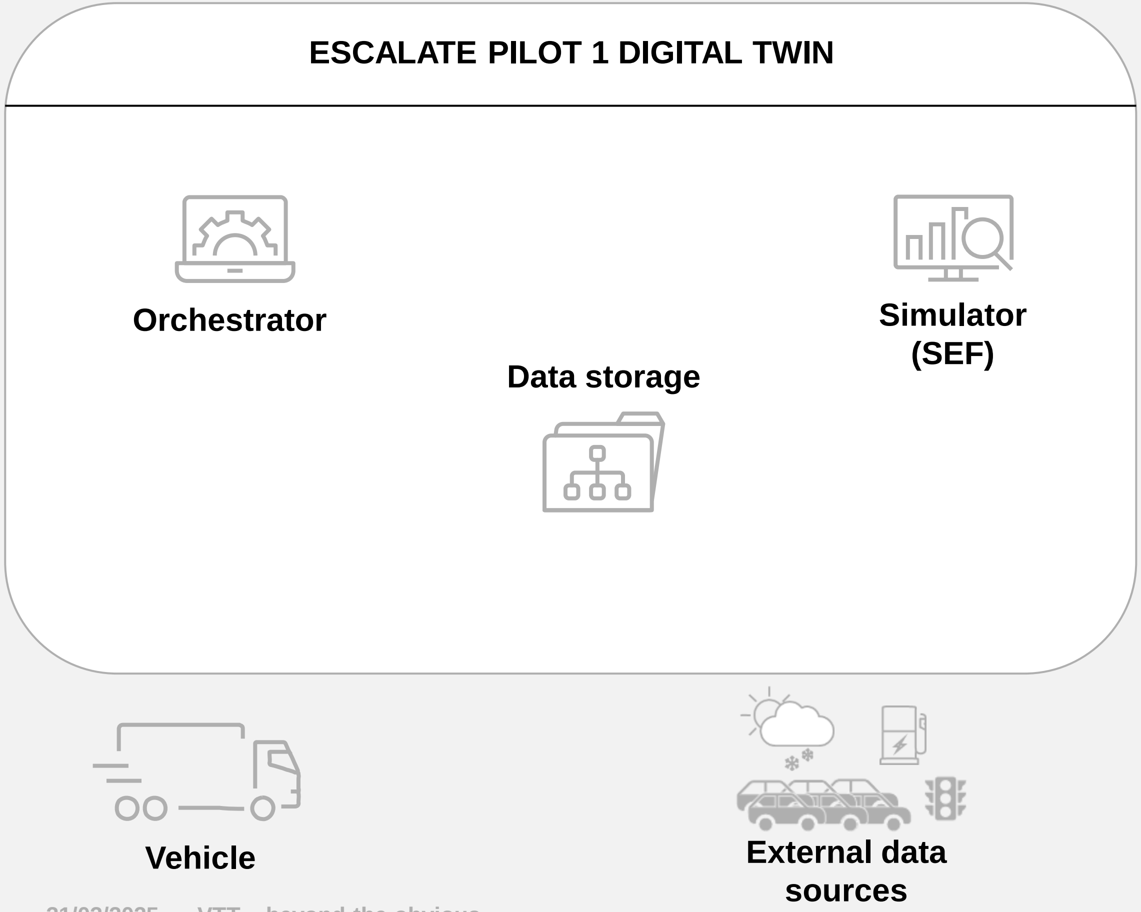
- Regional transports from Vuosaari harbour
- 30 km routes, about 150 km per day
- GVW 44t
- FCEV operation



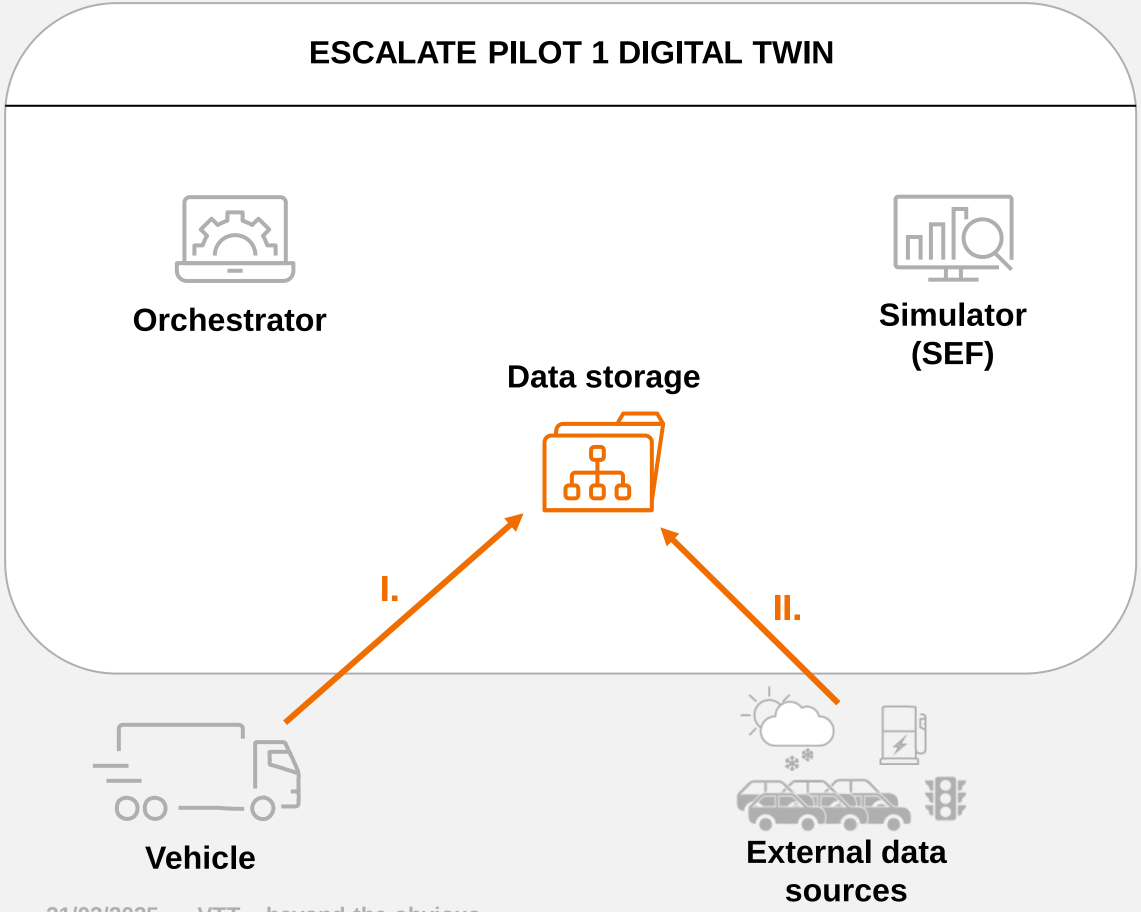
Jyväskylä-Helsinki-Jyväskylä

- Long-haul operation
- 530 km route
- GVW 44t and 76t
- FCEV operation

ESCALATE Digital Twin Architecture



ESCALATE Digital Twin Architecture

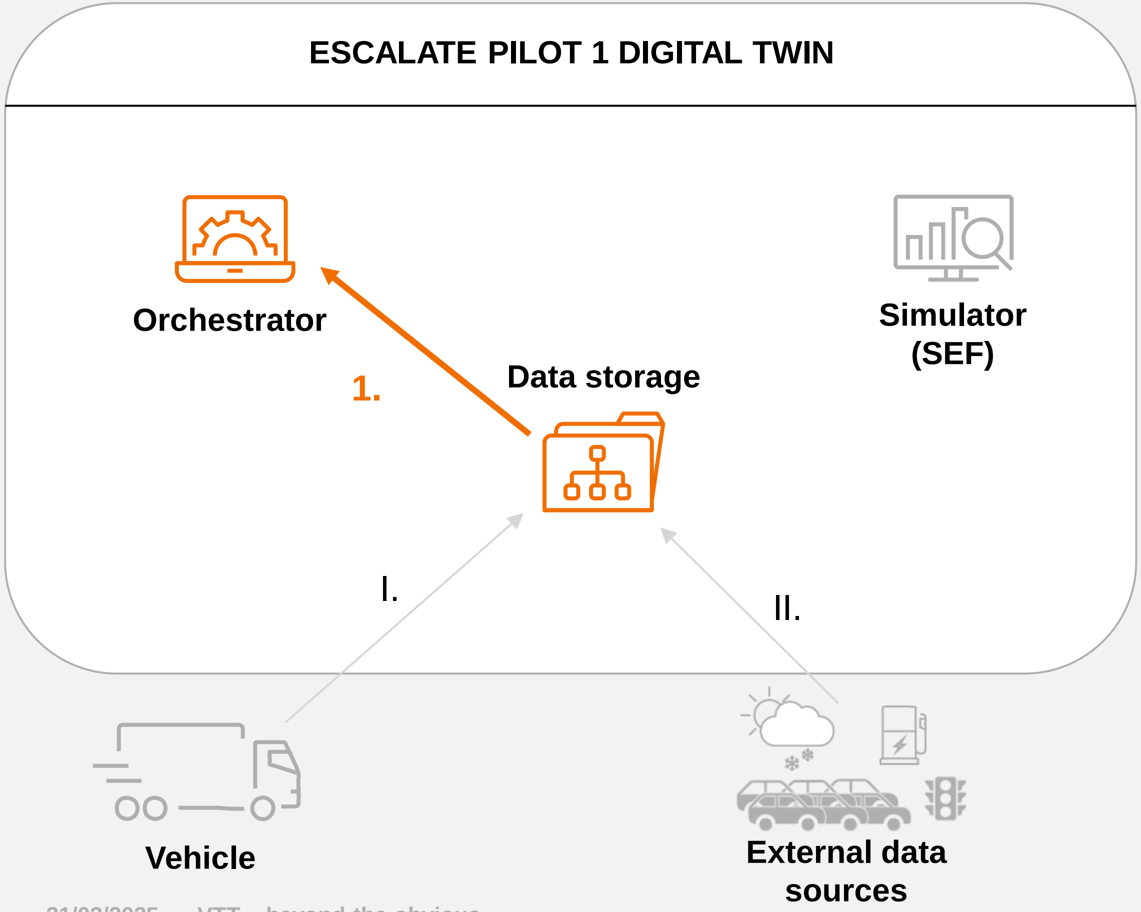


Data about operational conditions are stored in **Data storage**:

I. **Vehicle** real-time data
II. **External data sources** include data from
    - Ambient conditions, charging stations, traffic

ESCALATE Digital Twin Architecture

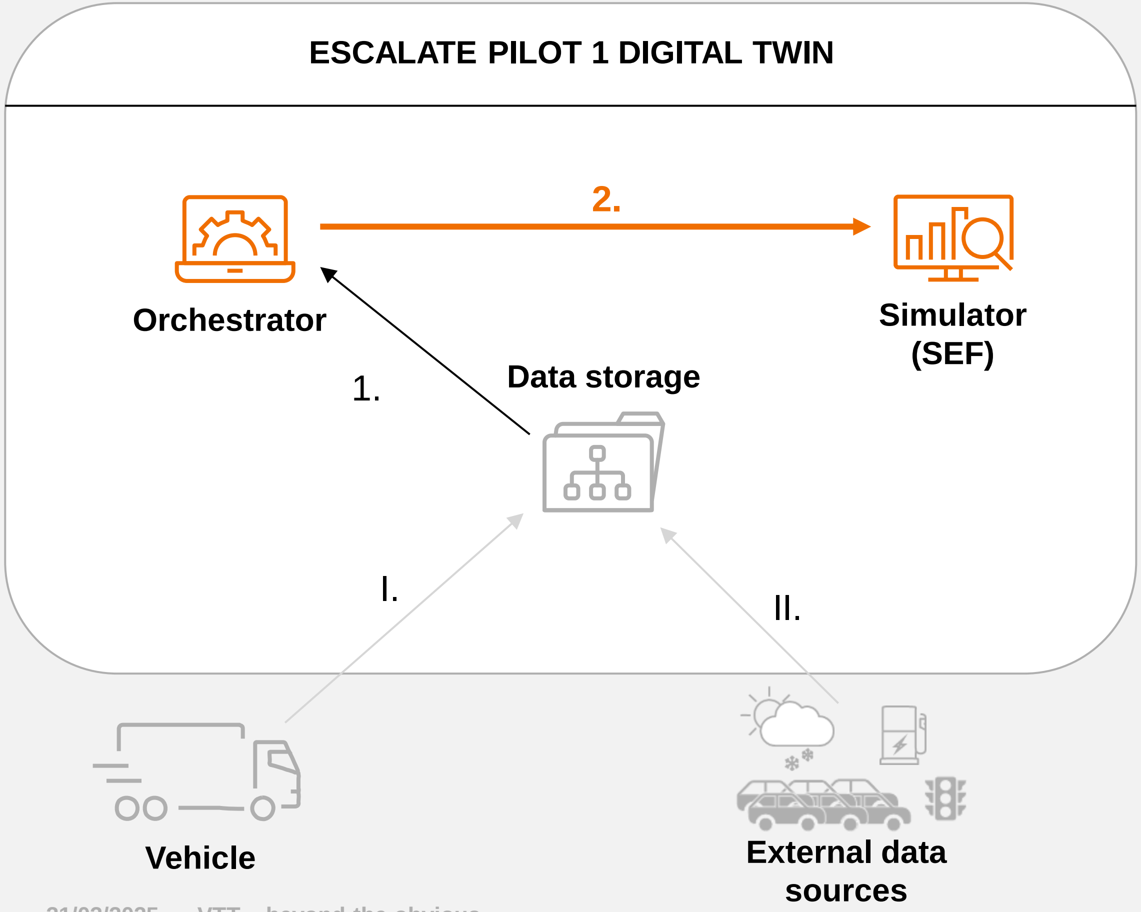
VTT



Creating an operation forecast

1. **Orchestrator fetches current operation data**

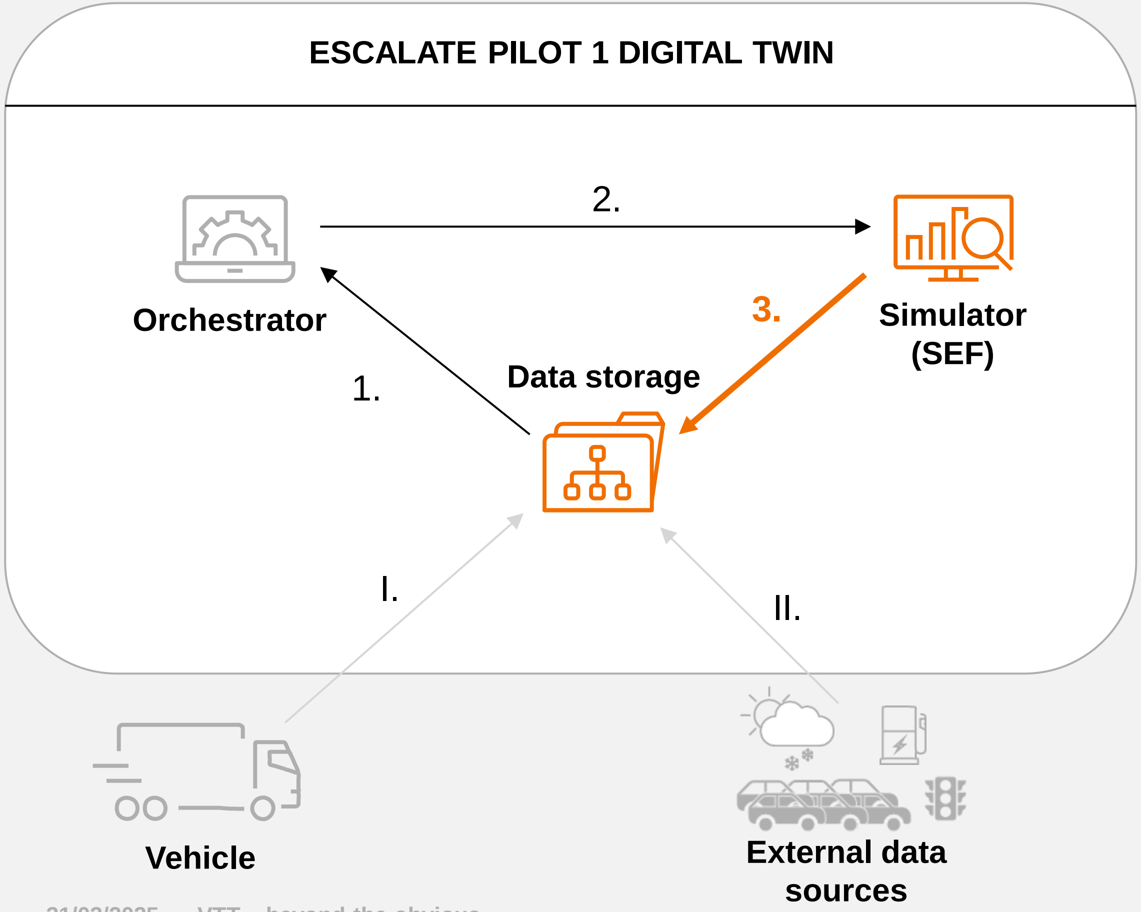
ESCALATE Digital Twin Architecture



Creating an operation forecast

1. **Orchestrator** fetches current operation data
2. **Orchestrator forms input parameters for SEF and starts simulation**

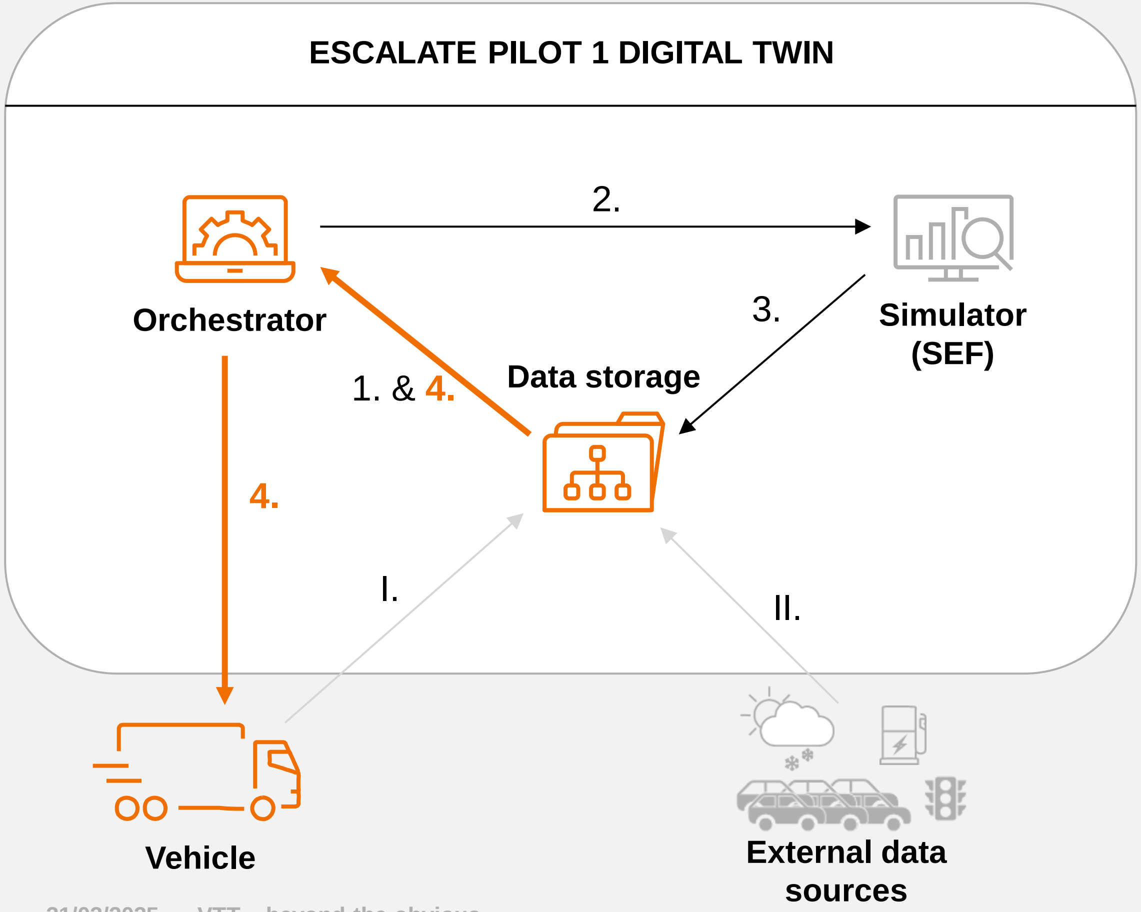
ESCALATE Digital Twin Architecture



Creating an operation forecast

1. **Orchestrator** fetches current operation data
2. **Orchestrator** forms input parameters for **SEF** and starts simulation
3. **SEF stores simulation results to Data storage**

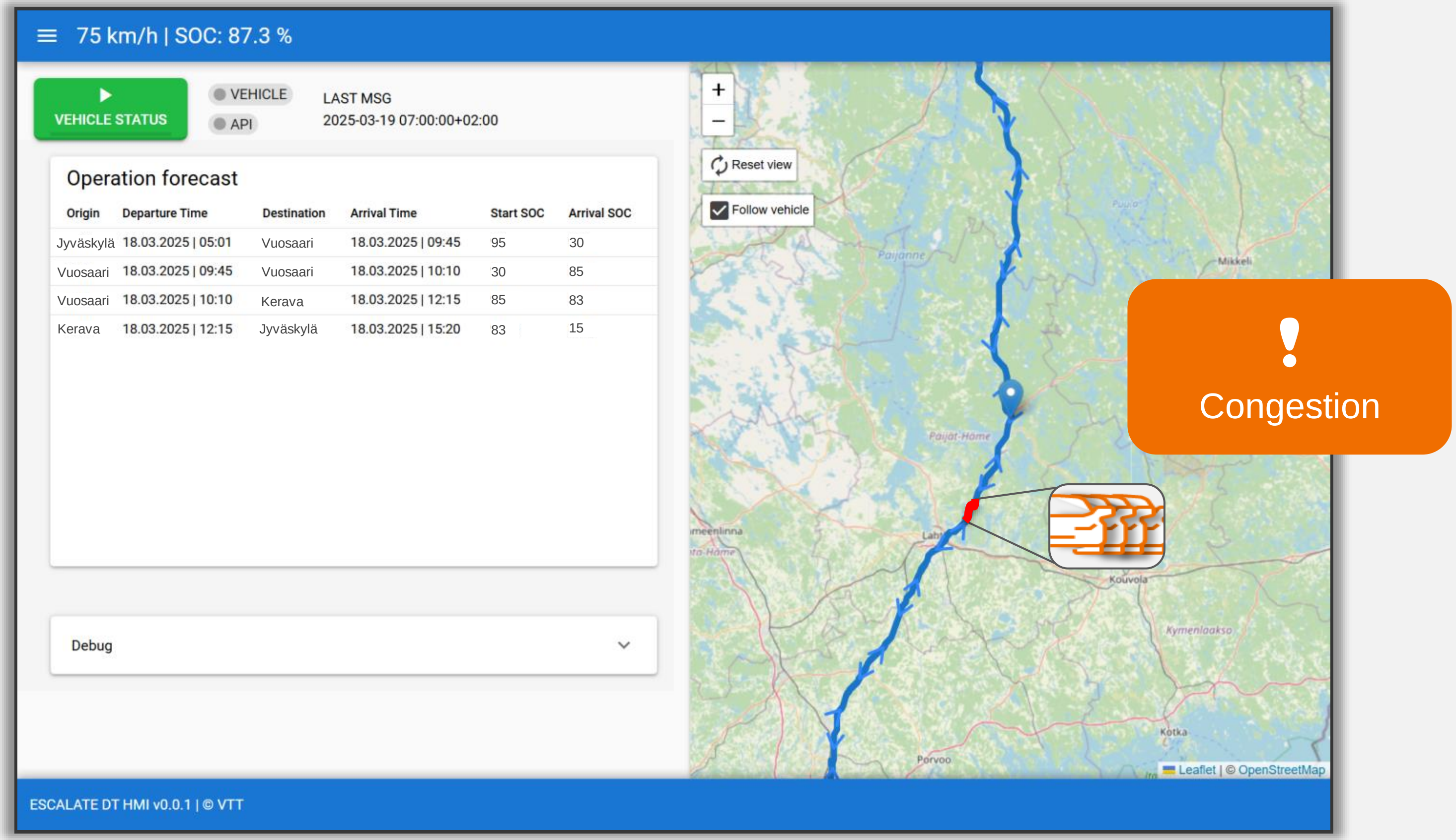
ESCALATE Digital Twin Architecture



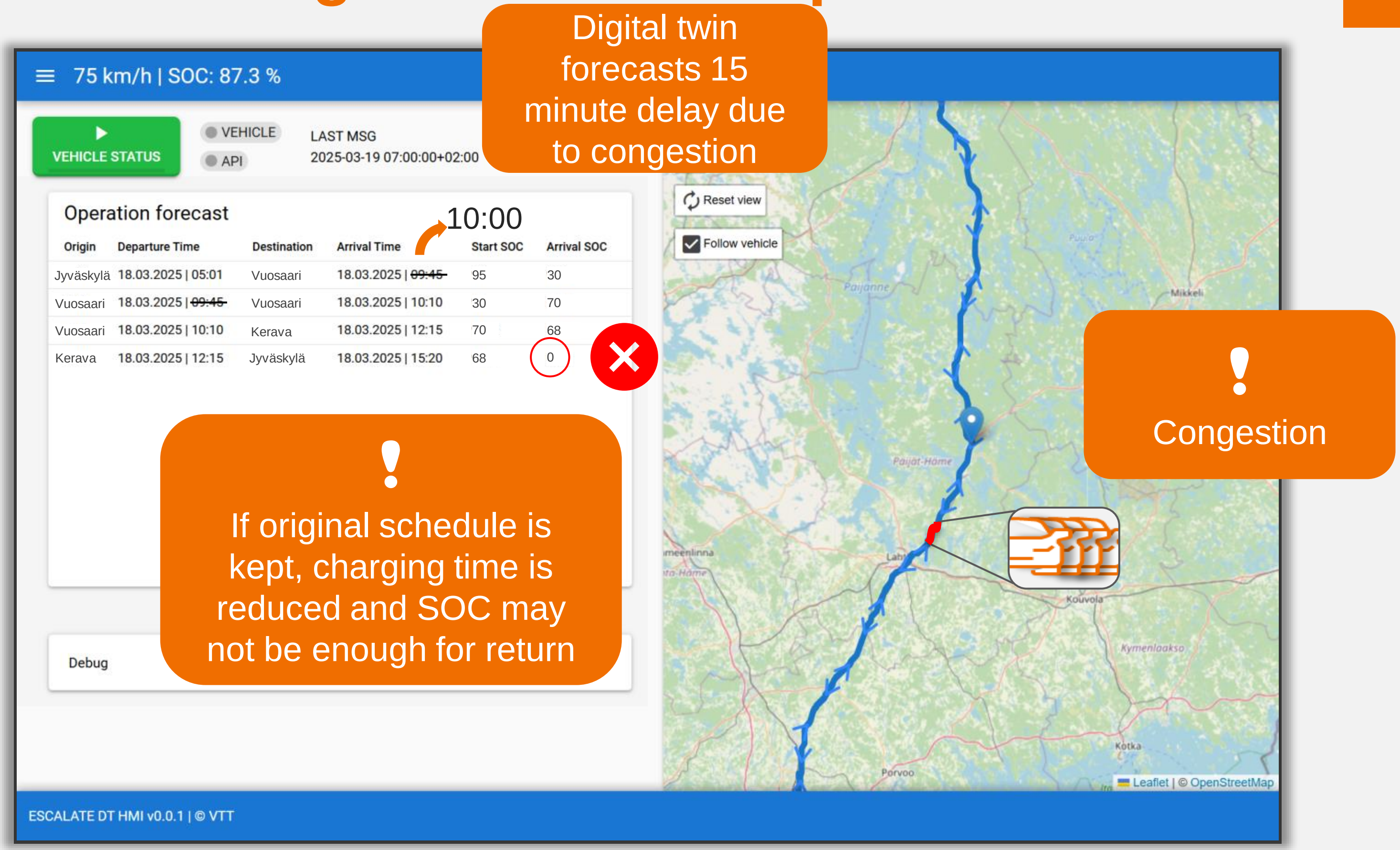
Creating an operation forecast

1. **Orchestrator** fetches current operation data
2. **Orchestrator** forms input parameters for **SEF** and starts simulation
3. **SEF** stores simulation results to **Data storage**
4. **Ochestrator fetches results, processes them and forms a forecast, then passed to the Vehicle**

ESCALATE Digital Twin Example



ESCALATE Digital Twin Example



Origin	Departure Time	Destination	Arrival Time	Start SOC	Arrival SOC
Jyväskylä	18.03.2025 | 05:01	Vuosaari	18.03.2025 | ~~09:45~~	95	30
Vuosaari	18.03.2025 | ~~09:45~~	Vuosaari	18.03.2025 | 10:10	30	70
Vuosaari	18.03.2025 | 10:10	Kerava	18.03.2025 | 12:15	70	68
Kerava	18.03.2025 | 12:15	Jyväskylä	18.03.2025 | 15:20	68	0

ESCALATE Digital Twin Example

VTT

75 km/h | SOC: 87.3 %

VEHICLE STATUS

VEHICLE

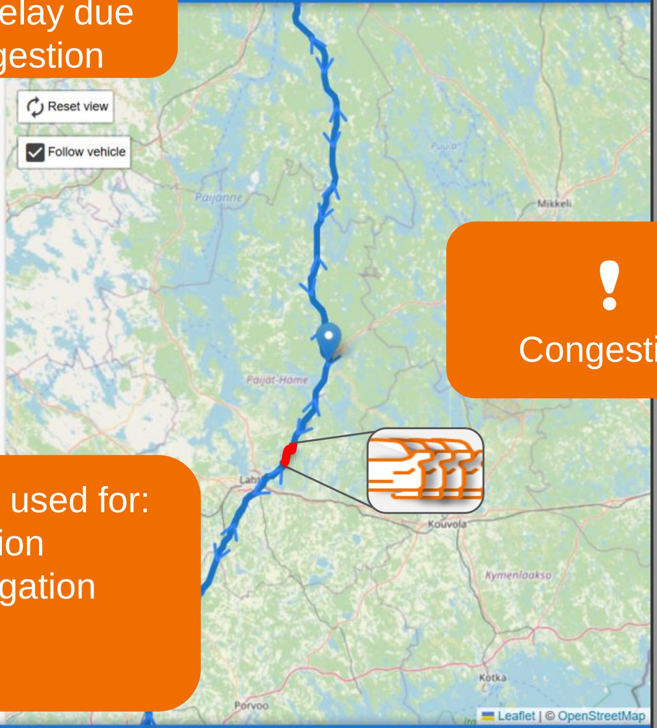
API

LAST MSG
2025-03-19 07:00:00+02:00

Digital twin forecasts 15 minute delay due to congestion

Operation forecast

Origin	Departure Time	Destination	Arrival Time	Start SOC	Arrival SOC
Jyväskylä	18.03.2025 | 05:01	Vuosaari	18.03.2025 | ~~09:45~~ 10:00	95	30
Vuosaari	18.03.2025 | ~~09:45~~	Vuosaari	18.03.2025 | ~~10:10~~	30	85
Vuosaari	18.03.2025 | ~~10:10~~	Kerava	18.03.2025 | ~~12:15~~	85	83
Kerava	18.03.2025 | ~~12:15~~ 12:30	Jyväskylä	18.03.2025 | ~~15:20~~ 15:35	83	15



! Congestion

Test different options with Digital Twin, e.g.:
Extend charging time at Vuosaari for 15 minutes

OR

Drive part of the route little slower

Forecasts can be used for:

1. Delay detection
2. Creating mitigation strategies

Known Challenges

- Model accuracy
  - How to ensure prediction accuracy
- Driving does not match forecast
  - How to adjust to different drivers and driving styles?
  - What happens if the driver doesn't follow expected route?
- Shortages in operational data
  - Traffic data (e.g. traffic flow speed, roadworks, accidents)
  - Road condition, especially in winter
- Communication issues
  - Interruptions in communications
  - Data security
- Conclusions
  - Repeat analysis often
  - Start with a testing period (commercial level operation shouldn't expect at first)
  - Gather as much operational data as possible

Future developments

- Digital twin based fleet management
  - Optimise charger utilisation at fleet level
- Dynamic duty cycles and scheduling
  - Adapt to new driving missions during the day
  - Useful e.g. for taxi and on-demand delivery services
- Autonomous decision making
- High-level control system for autonomous vehicle systems

beyond the obvious

Thank you!

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