DEVELOPING A STANDARDIZED APPROACH OF ASSET LIFECYCLE INFORMATION MODELLING FOR SEMANTIC DIGITAL TWIN IN THE BUILT ENVIRONMENT

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CONTENT

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1. RESEARCH OBJECTIVE

› Main objective:

To propose **Asset Lifecycle Information Modelling (ALIM)** approach within the vision of **Semantic Digital Twin (SDT)**

› Sub objectives:

› To clarify the concept and identify the research challenges of SDT and ALIM from a scientific perspective

› To reflect on the preliminary findings from exploratory case study and to provide a direction for follow-up research
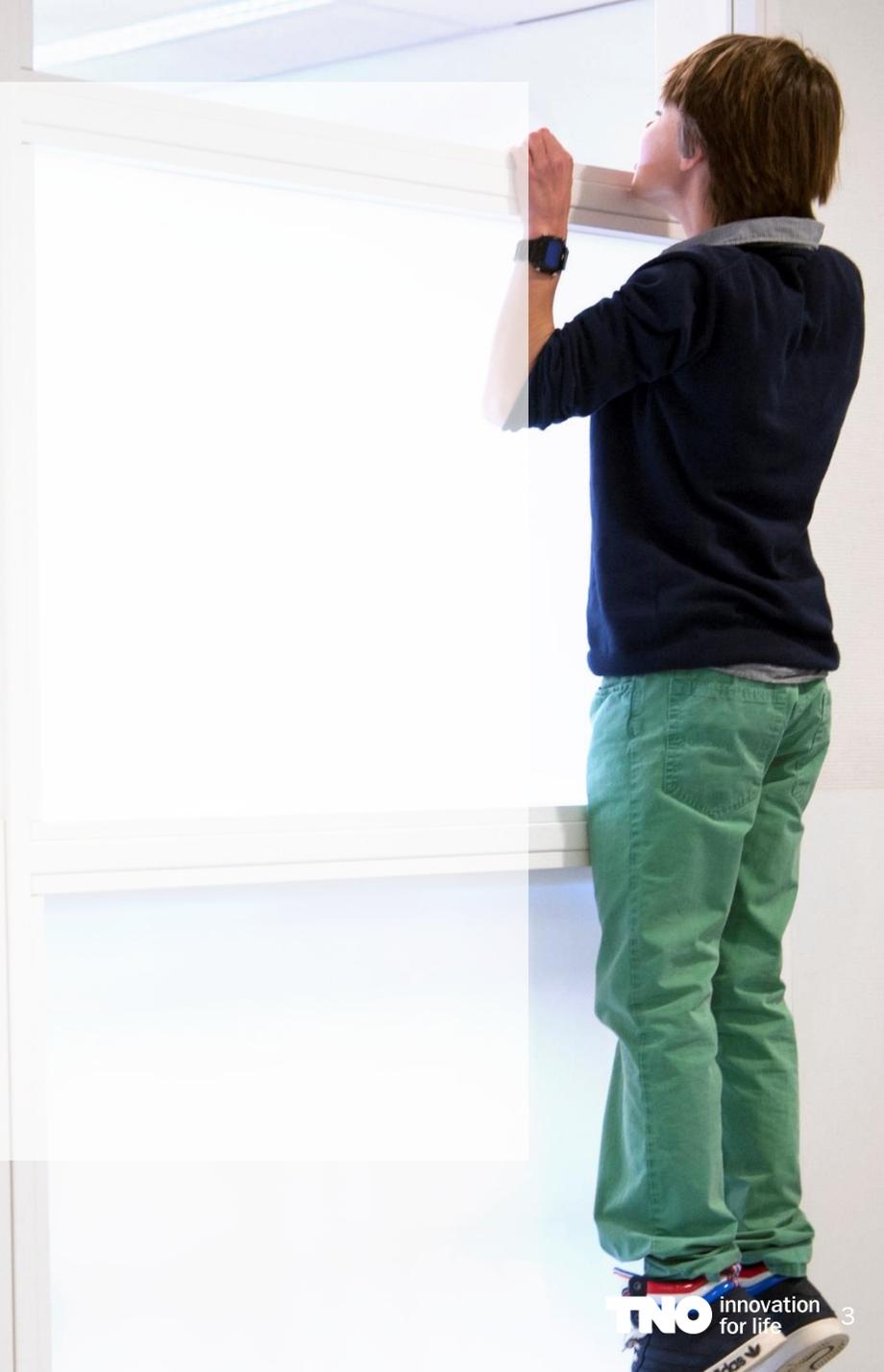
2. RESEARCH CHALLENGES FOR DIGITAL TWINS IN THE BUILT ENVIRONMENT

> Challenges related to the 3 main aspects of Digital Twins

1) Big data management

2) Integration of expert models/algorithms

3) User-friendly visualization and simulation-based decision-making

> Focusing on the first research challenge on **(1) Big data management**, especially:

> Resolving data uncertainties, assuring data quality for Digital Twins, structuring and linking data semantically, and managing big data repositories

> Interoperability and sense-making of data (ensuring 'meaningful data' to feed the expert models and simulations in digital twins)

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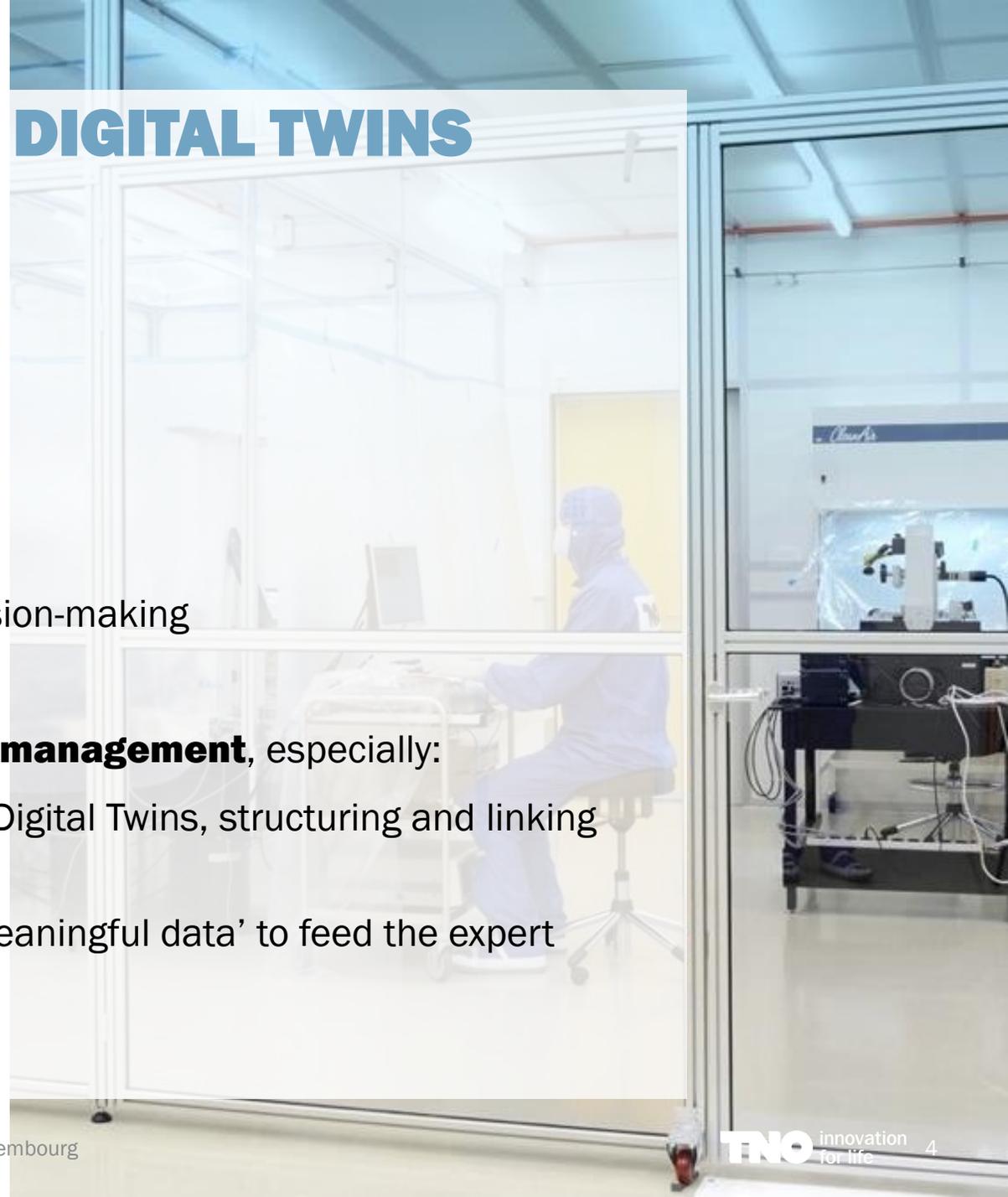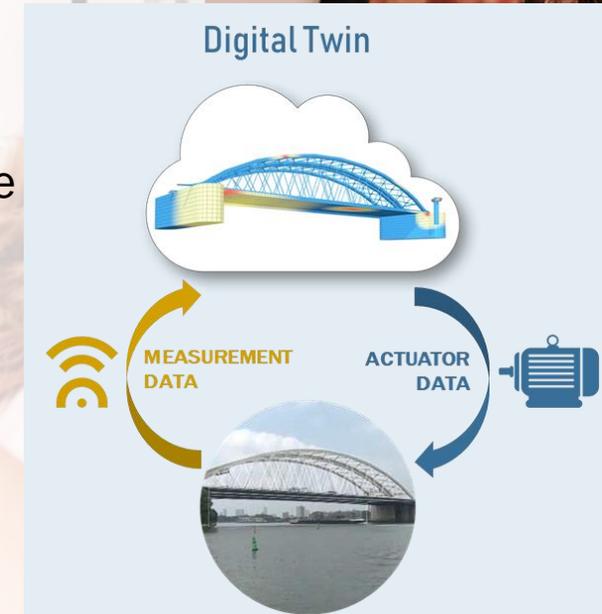
3. TOWARDS SEMANTIC DIGITAL TWIN (SDT)

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SIMPLIFIED PROGRESS OVERVIEW

› From *Digital Modelling* to *Semantic Digital Twinning*:

> **Digital Model** : Digital representation and/or simulation without automatic update

> **Digital Shadow** : Digital model updated automatically through one-way dataflow

> **Digital Twin** : Bi-directional dataflow between digital and physical objects, enabled by Cyber-Physical Systems (CPS) known in Industry 4.0; DT might also act as a controlling agent to the physical object

> Next, **Semantic Digital Twin (SDT)**

Digital Twin

MEASUREMENT DATA   ACTUATOR DATA

3. TOWARDS SEMANTIC DIGITAL TWIN (SDT)

ENVISIONED STEPS BEYOND BIM

› Taking **BIM as starting point**

  › Accessible digital model with 3D geometry, object properties and asset information

› **Integrating dynamic data** in Digital Twins throughout the **asset's lifecycle**

  › Integration of actual data, a.o. from IoT sensors

  › Update of the digital model across lifecycle phases

› **Enabling machine-interpretable** information and AI in **Semantic Digital Twins**

  › Implementing Linked Data and Semantic Web technologies and open standards

  › Providing semantic data for AI-based expert models and simulations in SDT

4. ENHANCING SDT THROUGH ASSET LIFECYCLE INFORMATION MODELLING (ALIM)

"ALIM" IN A NUTSHELL

› **Technology**

  › Capitalizing on the power of **Linked Data and Semantic Web** technologies

  › Aligned with European **open standards** for semantic modelling and linking data

› **Applicability**

  › **Whole-lifecycle coverage** of information modelling for assets in the built environment

 › Facilitating **FAIR** (Findable, Accessible, Interoperable, Reusable) data principles

4. ENHANCING SDT THROUGH ASSET LIFECYCLE INFORMATION MODELLING (ALIM)

ALIM'S CONTRIBUTIONS TO SEMANTIC DIGITAL TWINS (SDT)

› An approach to define, tailor and manage semantic asset information of buildings or civil infrastructures, and to represent this information in **ontologies and graph databases**

› Guidance for **linking and sharing data** from BIM, GIS, Facility Management, Asset Management, environment and IoT.

› Supporting **compliance to open standards** for data (i.e. CEN/TC 442 SML), FAIR, GDPR

› Establishing the semantic data **architecture of Common Data Environment (CDE)**

5. EXPLORATORY CASE STUDY

DIGITAL TWIN PROTOTYPE
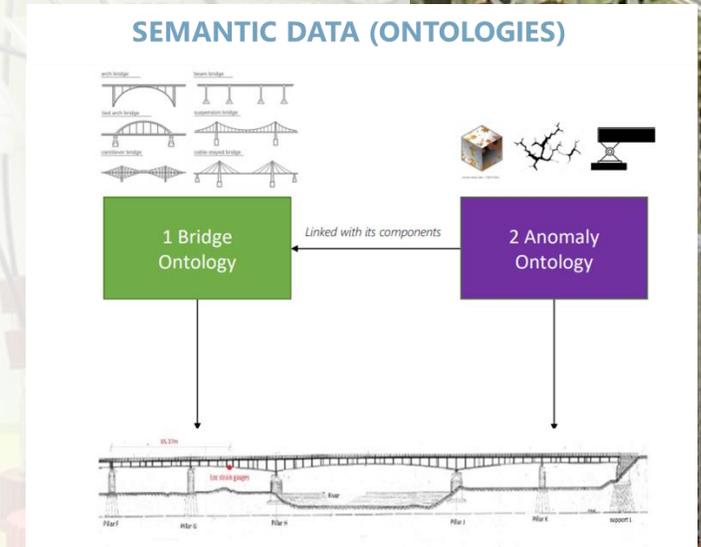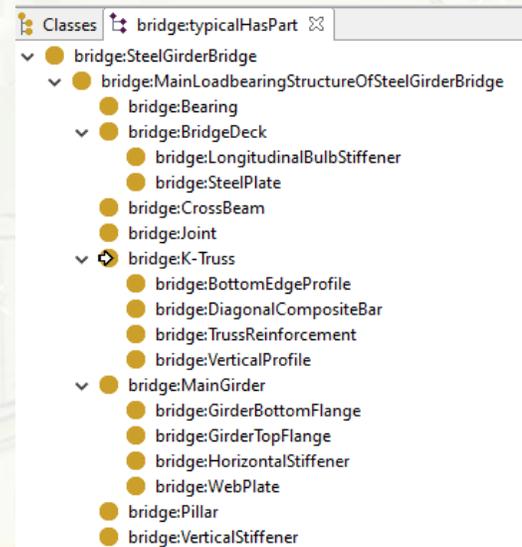
- › ALIM approach is applied in a prototype digital twin of a highway bridge in the Netherlands
- › ALIM-based 'bridge ontology' is developed for structural health monitoring, predictive maintenance simulation, and impact analysis of traffic loads and vehicle configurations

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5. EXPLORATORY CASE STUDY

ALIM-BASED DIGITAL TWIN METHODOLOGY, STEP-BY-STEP

1. Choosing the appropriate linked data language and format (a.k.a. serialisation)

2. Identifying and modelling the relevant concepts

3. Relating those concepts in a specialization hierarchy (a.k.a. assigning the taxonomy)

4. Identifying and modelling the relevant attributes

5. Identifying and modelling the relevant (inter)relations

6. Identifying and modelling the relevant constraints, especially the decomposition constraints (a.k.a. assigning the meronomy)

7. Populating the ontology for the real bridge.

Note: In this case study, Ontology Web Language (OWL) is used as linked data modelling language and Turtle as the human-friendly format.

6. CONCLUDING REMARKS

› A Digital Twin is not merely a digital copy containing the data of the physical object, but a **digital surrogate incorporating expert models / algorithms** for analyzing the conditions, behaviors and performance of the object

› There is an urgent challenge concerning **semantic data management in Digital Twins** to be resolved before encapsulation of expert models and simulation-based decision-making

› Semantic Digital Twin (SDT) based on Asset Lifecycle Information Modelling (ALIM) is the envisioned approach **to advance beyond BIM and to use Linked Data and Semantic Web technologies** in Digital Twins

› Research should progress towards 'agent-driven socio-technical platforms for SDT' in preparation of the **people-centric approach for Digital Twins in Industry 5.0**

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