Digital Twin Design

Ioannis Brilakis, Graham Starkey, Vivi Michalaki
Ran Wei,
Mengitan Yin, Linjun Lu, Judith Fauth, Junxiang Zhu, Xiaofang Wen

Research Objectives

The design of Digital Twin is crucial to the Digital Roads project (and to any other projects that aim to leverage DT technologies). The DT platform is essentially a Software as a Service (SaaS). The research objectives for the Digital Twin design encapsulates:

- Requirement engineering of the DT platform: eliciting user requirements, system requirements (which include functional and non-functional requirements), data requirements and more.
- The design of the Domain Specific Languages (DSLs): based on the requirements, the DSLs capture the concepts (e.g. assets, attributes of assets, relationships among assets) within the DT platform. The DSLs are further broken down into: i) Foundation Data Model (FDM), a general purpose DSL to hold fundamental interoperable information for the DT; ii) Reference Data Library (RDL), an extension of FDM to model the DT for the Roads. The DSLs shall also be able to fuse information from other heterogeneous models (e.g. geometric models, building information models, imageries) for data curation.
- The design of the integration cloud: the design primarily focus on how the DT product and DT process models shall be stored so that the CRUD (Create, Read, Update, Delete) operations can be performed efficiently.

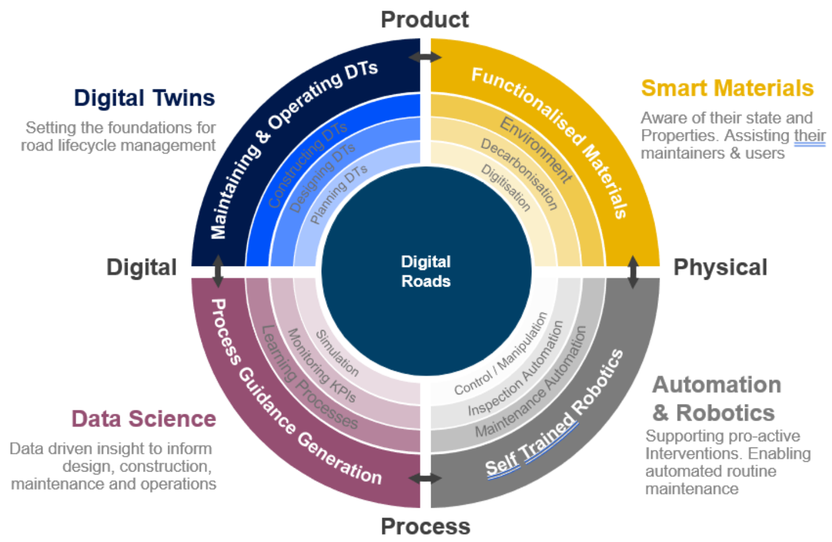

Fig. 1 Digital Roads' vision

Research methodology: The DT platform should act as an information hub and the centre for decision making for the maintenance of the roads. In this regard, the sources of information are diverse. In this regard, Model Based Systems Engineering (MBSE) methodologies are followed. In particular, technology independent DSLs are created to pull information from diverse sources; model management and indexing frameworks are being researched to facilitate automated validation and scalable indexing.

Engineering methodology: Since the DT platform is a SaaS, a typical software engineering methodology, combined with MBSE is followed. This is reflected in the revised technical annex of the Digital Roads project. In particular, a spiral software development methodology is adopted, which involves:

- Requirement Engineering: to elicit the user requirement/system requirement and organise them in the form of models;
- System design: to design the DT platform by creating DSLs for the DT platform;
- System implementation: with the help of MBSE, source code and documentation can be automatically generated, efforts are spent on developing tools to support the DT platform;
- System testing: automated test case generation
- System maintenance: requirement change impact analysis

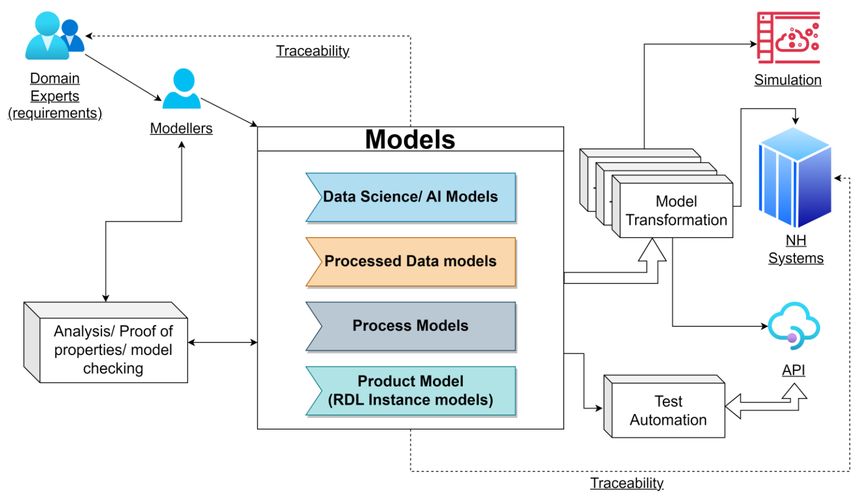

Fig. 2 MBSE and models of the DT platform

Requirement Engineering: Requirements are captured using FDM for user and system requirements, the requirements come from IDM as well as interviews from industrial partners. The contents of the IDM can be extracted and requirement models can be created in an automated manner, as shown in Fig. 3. Traceability from DT model to requirement can be established, in case of requirement change, automated impact analysis can inform the validity of the DT model.

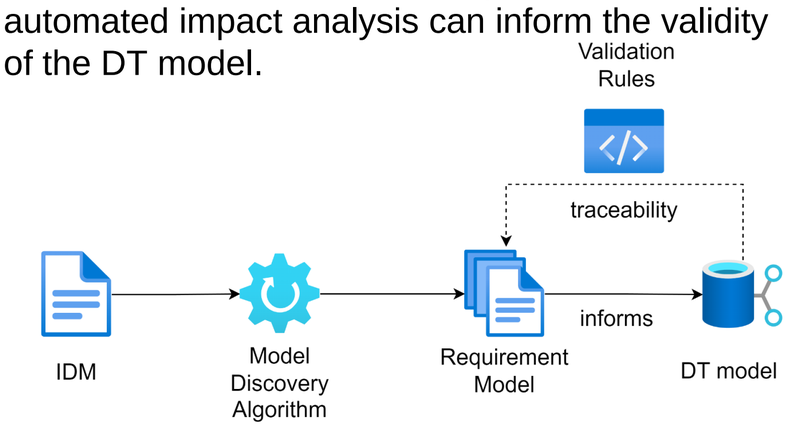

Fig. 3 Requirement engineering

DT modelling: The DT model (RDL instance model) is created using Eclipse Modelling Framework (EMF), a widely used modelling tool used for MBSE. EMF's metamodeling language stems from Essential Meta Object Facility (EMOF), a specification from the Object Management Group (OMG). DT models are able to refer to any data model, and can also be used in conjunction with business models, as shown in Fig. 4. A preliminary RDL instance model is created to test out the facilities modelled in the FDM and RDL to integrate heterogeneous models, as shown in Fig. 5.

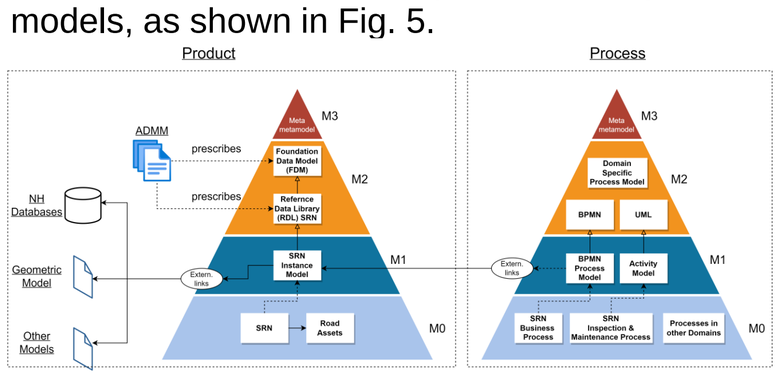

Fig. 4 DT Product and Process models

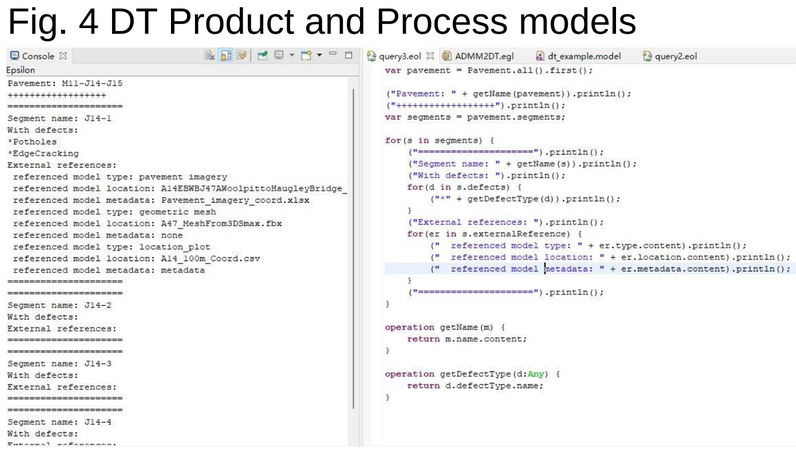

Fig. 5 Sample RDL instance model for the DT.

What next?

Over the upcoming six-months the Digital Twins design team will embark on full development campaign with the primary goal of realising and validating the proposed DT models (FDM and RDL).

- **Full Reference Data Library and its instance model:** Based on the IDM and NH's existing ontologies/systems, derive a full version of the RDL for expressways DT.

- **Digital Twin Generation & updating:** Digital Twin model generation and update mechanisms will be developed to enabled the automated DT model creation/update based on information provided by the Data Science team.

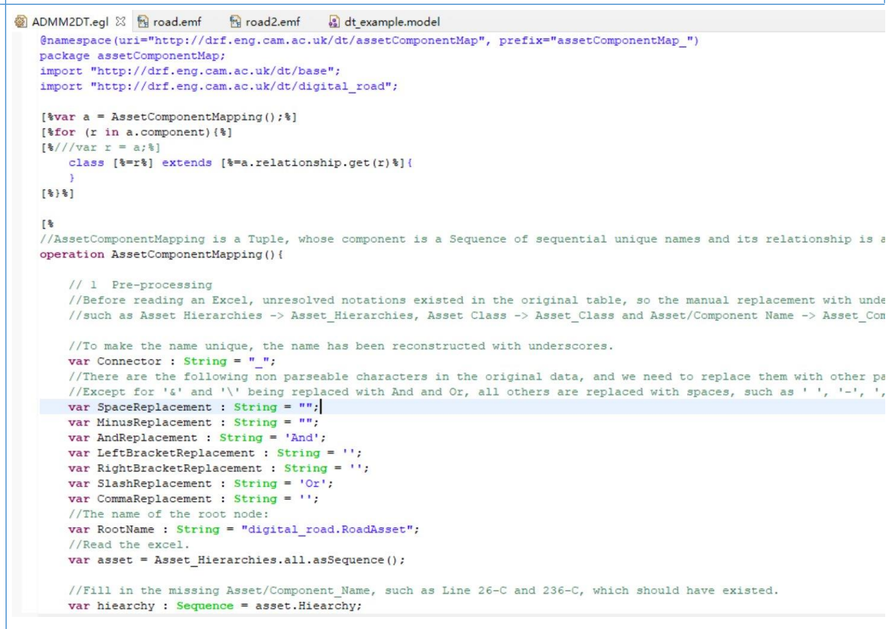

Fig. 6 RDL generation from ADMM

RDL and ADMM: To show the benefits of automation brought by MBSE, the RDL is created using a model-to-text transformation (M2T), as shown in Fig. 6. The M2T program takes the ADMM (Asset Data Management Manual) from NH as input, and produce the RDL written in EMF as output. This is a show case to illustrate how MBSE can be used to reflect changes in RDL in a very efficient manner.