

## AMSfree

# Exchange and Exploitation of Data from Asset Management Systems using Vendor Free Format

**Project Overview • Main Results • Recommendations**

CEDR Transnational Road Research Programme / Call 2018  
Final Conference May, 24<sup>th</sup>–25<sup>th</sup> 2022, Stockholm

# Agenda

14:15	Introduction	UASKA	5 min
14:20	Main Results		
14:20	WP 2 Asset Management WP 3 Process Definition	UASKA	10 min
14:30	WP 3 Digital Condition Assessment	InGEO	10 min
14:40	WP 4 Information Delivery Manual (IDM) / ICDD & Ontologies	IMC	10 min
14:50	WP 5 / WP 6 / ICDD and Prototype	RUB	15 min
15:05	Summary and Conclusions	UASKA	5–10 min
15:15	Interactive Session		10 min
15:25	Q&A Session		15 min

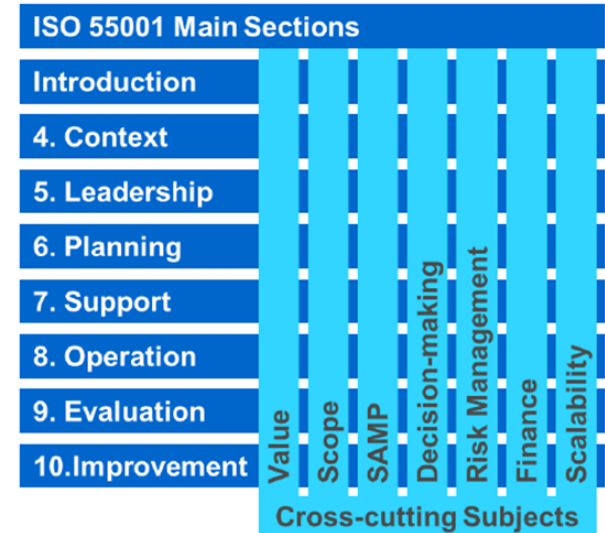
# Team



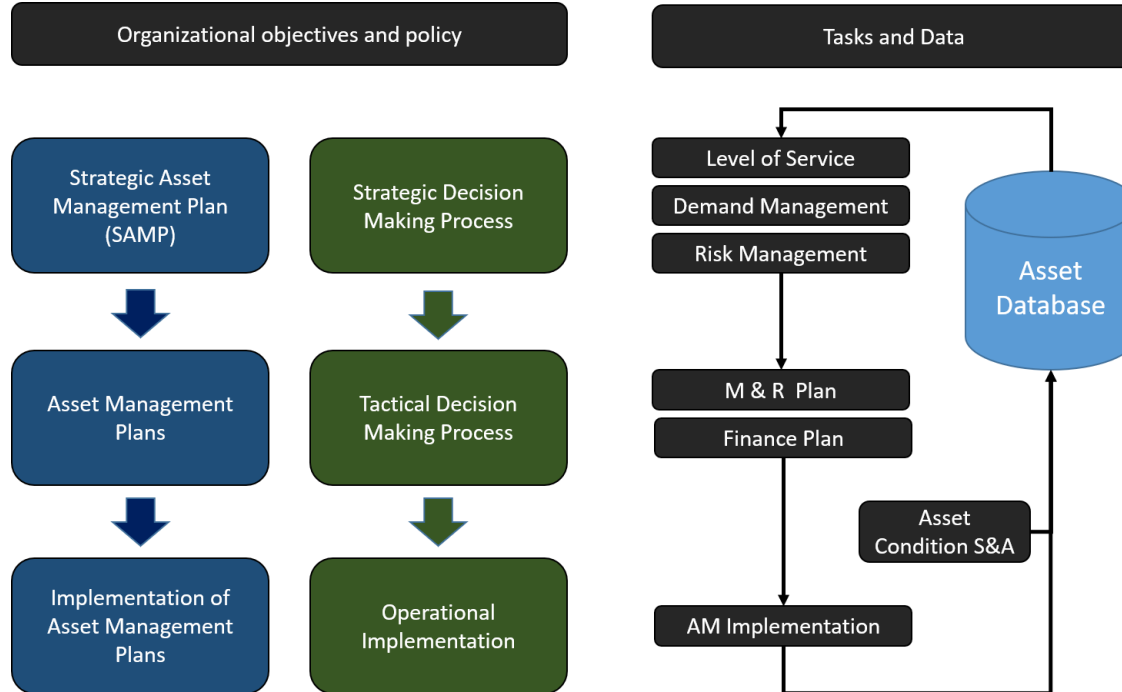
- Prof. Dr. Markus Stöckner, Ian Brow M.Sc., Philip Zwernemann M.Sc., Marcel Helbich, B.Eng.
- Prof. Dr. Rade Hajdin, Dr. sc. Frank Schiffmann, Dr.-Ing. Tim Blumenfeld, Dr. Dušan Isailović
- Prof. Dr. Ken Gavin
- Prof. Dr. Markus König, Liu Liu M.Sc., Philipp Hagedorn M.Sc.

# Introduction

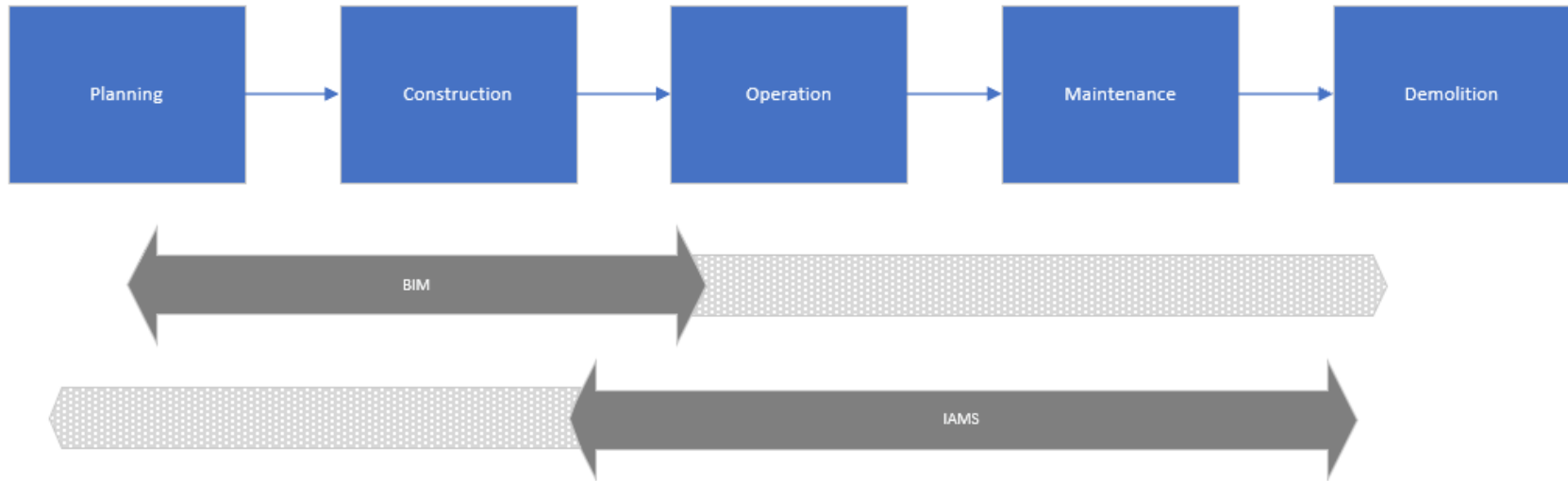
- Rational and transparent decision-making process with regard to road infrastructure for more resilient road networks
- Adhering to ISO 55000ff i.e., information driven risk-based decision making
- High quality information is a key to adequate decision making
- The basis for high quality information is a “digital twin” of road infrastructure, which already exist in most AMS
- The versatility of “digital twins” can be decisively increased using BIM technologies



# Introduction



# Introduction



# Introduction

## Data Management Challenges

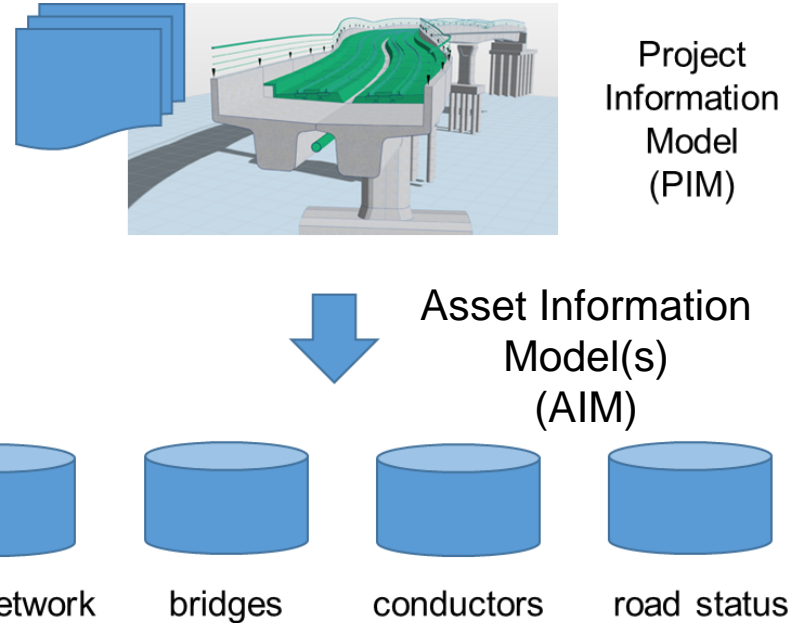
- Insufficient data transfer from the construction phase
- Different responsibilities for the management of information
- Decentralized storage and acquisition of information
- Consistency very difficult to maintain because data is stored redundantly
- Uniform access difficult because different vocabularies are used



# Introduction

## Handover Asset Management

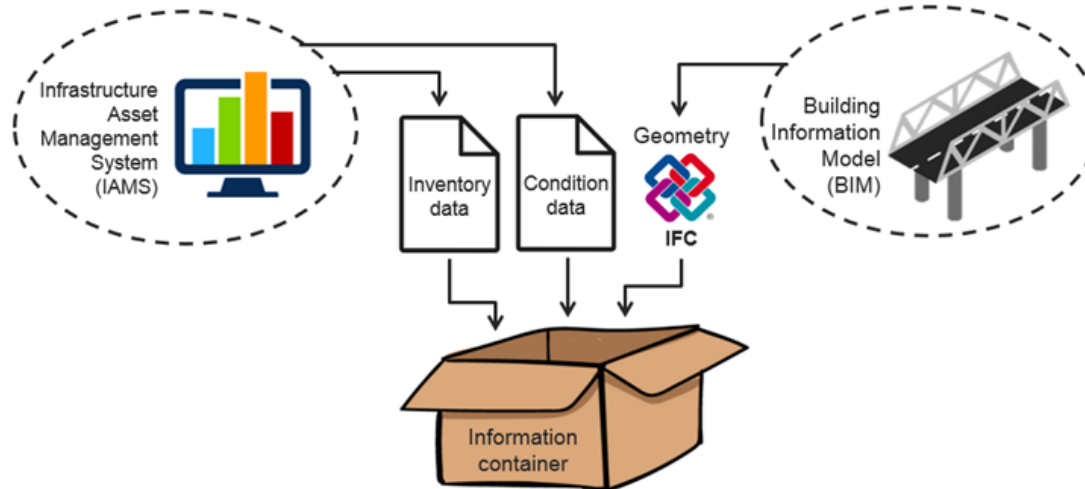
- Different information systems need to be updated with data from construction projects
- Each system has its own data models and exchange formats





# Introduction

## Solution concept



# Introduction

## Overview Work Packages

WP 1 Project Management

WP 2 Comparative Analysis of IAMS and Common BIM in Europe

WP 3 Digital Condition Assessment

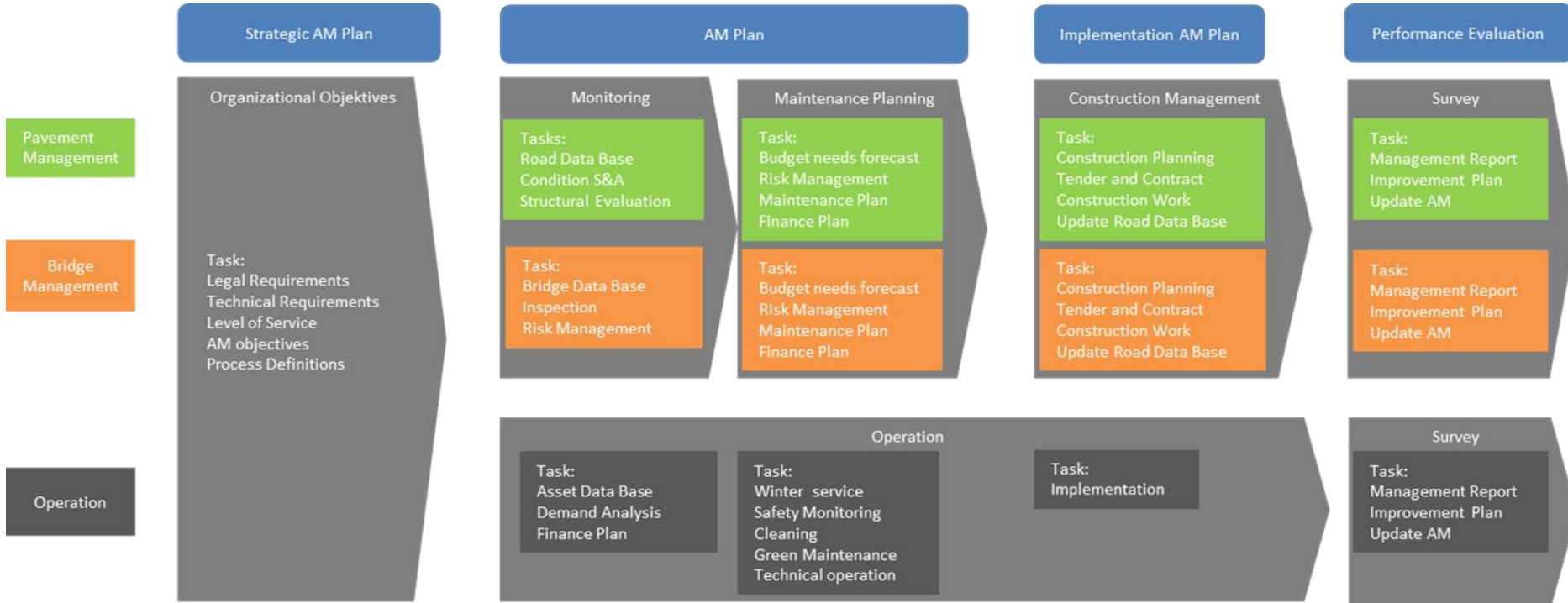
WP 4 Data Fusion and Semantic Transformations

WP 5 Development of a Referenced Vendor-free IFC-based Data Structure

WP 6 Semantic Transformations to Legacy Systems

WP 7 Development of a Prototype

# Task of an AMS



# Overview of Regarded National AMS

Country	Overview Analysis	Detailed Analysis
Netherlands	Yes	Yes
Sweden	Yes	No
Belgium	Yes	No
Austria	Yes	No
Finland	Yes	No
Denmark	Yes	Yes
Germany	Yes	Yes

# IAMS Summary

<b>IAMS Process</b>	<b>Planning</b>	<b>Construction</b>	<b>Operation</b>	<b>Maintenance</b>	<b>Demolition</b>
<b>Documents</b>	<ul style="list-style-type: none"> <li>- Construction plans</li> <li>- Relevant information established planned and collected</li> </ul>	<ul style="list-style-type: none"> <li>- Verification of built-as-planned</li> </ul>	<ul style="list-style-type: none"> <li>- Monitoring reports</li> <li>- KPI development</li> </ul>	<ul style="list-style-type: none"> <li>- Maintenance reports</li> </ul>	<ul style="list-style-type: none"> <li>- Destruction reports</li> <li>- Samples for monitoring</li> </ul>
<b>Stakeholder needs</b>	<p>Owner</p> <ul style="list-style-type: none"> <li>- Prepare for construction</li> <li>- Ensure asset is built according to standards</li> </ul> <p>User</p> <ul style="list-style-type: none"> <li>- High standard</li> </ul>	<p>Owner</p> <ul style="list-style-type: none"> <li>- Proper construction</li> </ul> <p>Contractor</p> <ul style="list-style-type: none"> <li>- Resource planning</li> </ul>	<p>Owner</p> <ul style="list-style-type: none"> <li>- Regular monitoring providing performance</li> </ul> <p>User</p> <ul style="list-style-type: none"> <li>- Regular monitoring providing performance</li> </ul>	<p>Owner</p> <ul style="list-style-type: none"> <li>- Effective maintenance maximising longevity at minimal cost</li> </ul> <p>Asset Manager</p> <ul style="list-style-type: none"> <li>- Resource planning</li> </ul>	<p>Owner</p> <ul style="list-style-type: none"> <li>- Cost effective demolition</li> </ul> <p>Asset manager</p> <ul style="list-style-type: none"> <li>- Last inspection, material experiments</li> </ul> <p>Society</p> <ul style="list-style-type: none"> <li>- Demolition according to standards</li> </ul>
<b>BIM benefit</b>	<p>Owner</p> <ul style="list-style-type: none"> <li>- Budget planning</li> </ul> <p>Contractor</p> <ul style="list-style-type: none"> <li>- Visualisation of complex construction</li> </ul> <p>User</p> <ul style="list-style-type: none"> <li>- Participative planning processes</li> </ul>	<p>Contractor</p> <ul style="list-style-type: none"> <li>- Automatised resource planning</li> <li>- Visualisation of complex construction</li> </ul>	<p>User</p> <ul style="list-style-type: none"> <li>- Dynamic performance monitoring</li> </ul>	<p>Asset manager</p> <ul style="list-style-type: none"> <li>- Damage localisation</li> <li>- Improved prediction mechanics</li> </ul>	<p>Contractor</p> <ul style="list-style-type: none"> <li>- Notification of potential hazards</li> <li>- Clearer cost estimation</li> </ul>
<b>What information is needed by IAMS</b>		<ul style="list-style-type: none"> <li>- Geometry</li> <li>- Material properties</li> </ul>	<ul style="list-style-type: none"> <li>- Geometry</li> <li>- Monitoring/inspection results</li> <li>- Material properties</li> <li>- Definition of treatments and prioritisation</li> <li>- Deterioration models</li> <li>- Storage of high resolution data, drawings, sketches and images</li> </ul>	<ul style="list-style-type: none"> <li>- Geometry</li> <li>- Maintenance results / alterations</li> </ul>	<ul style="list-style-type: none"> <li>- Geometry</li> <li>- Material properties</li> </ul>
<b>Additional external data</b>		<ul style="list-style-type: none"> <li>- Weather at construction (asphalt)</li> </ul>	<ul style="list-style-type: none"> <li>- Natural hazard events, traffic load development</li> </ul>		

# Generic Process for Asset Management

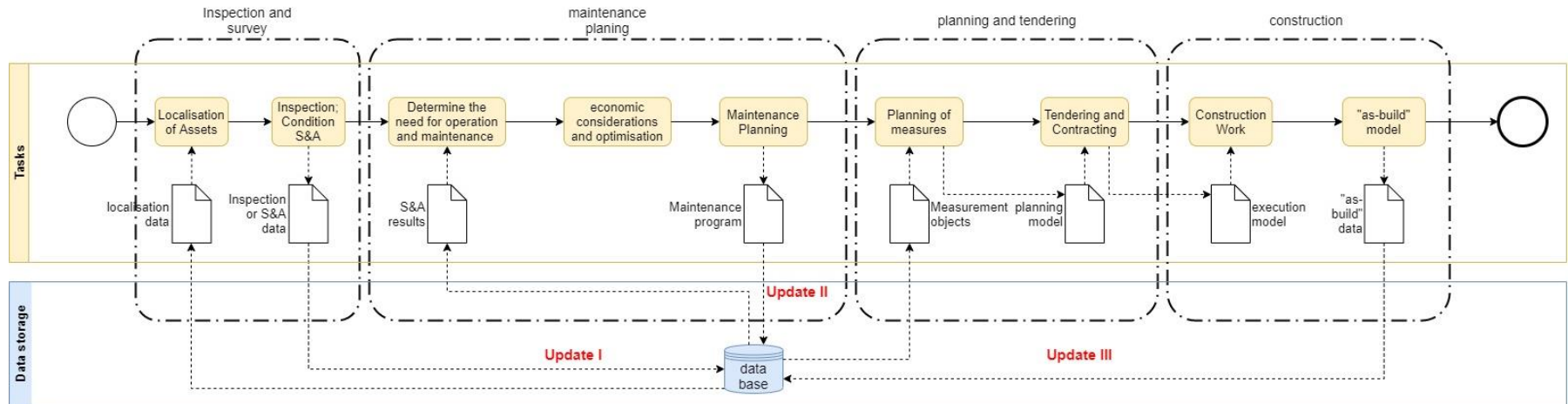
## Detailed Reference Process Model for IAMS:

### Definition of an AM Reference Process Model

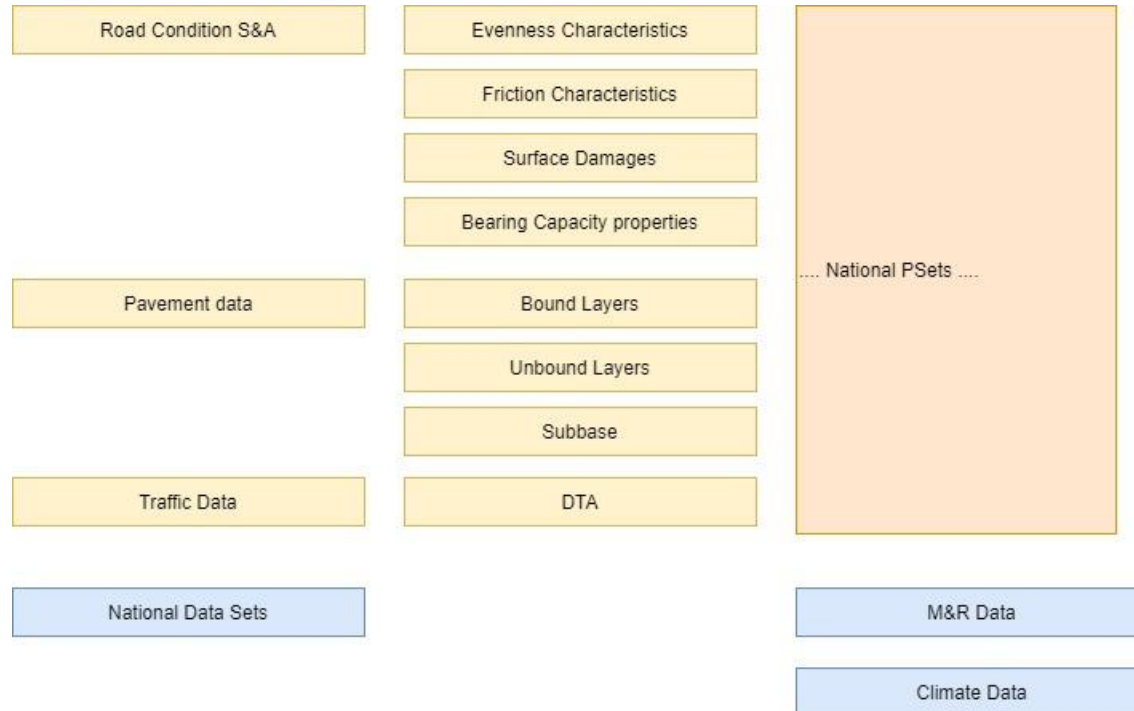
- General approach
- Process model
- AMSfree generic process model

### Required Data Overview

- Data flow requirements
- Required data
- Data classification

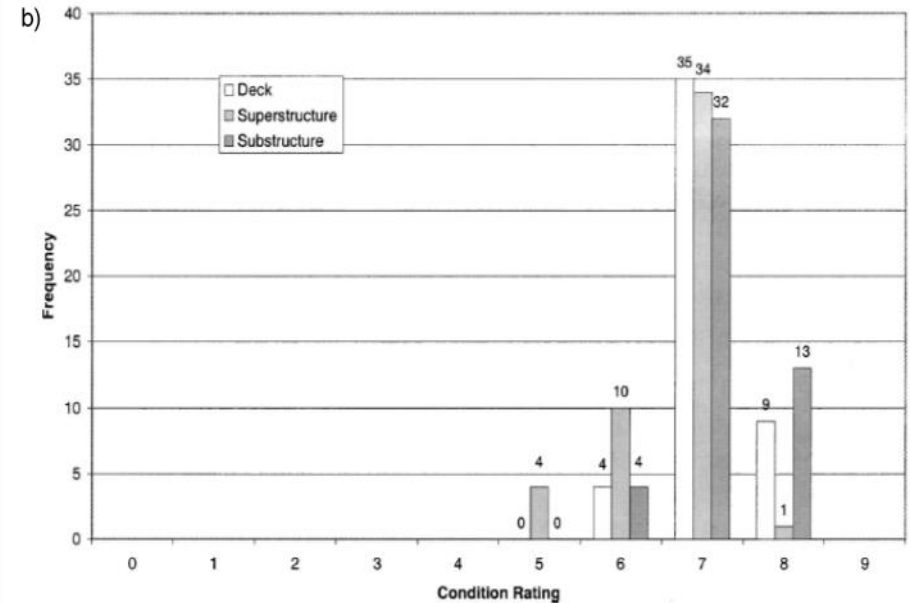
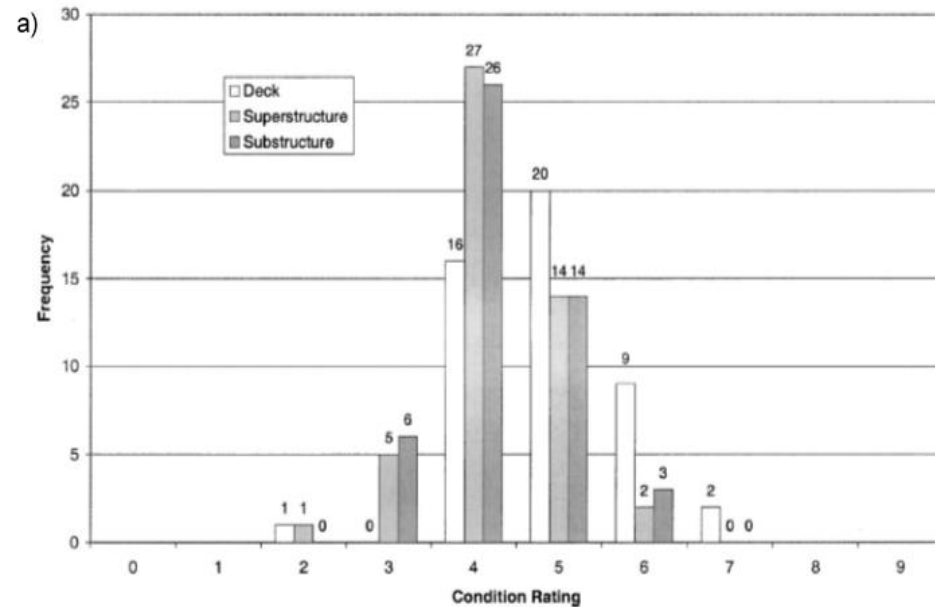


# Required Data Sets



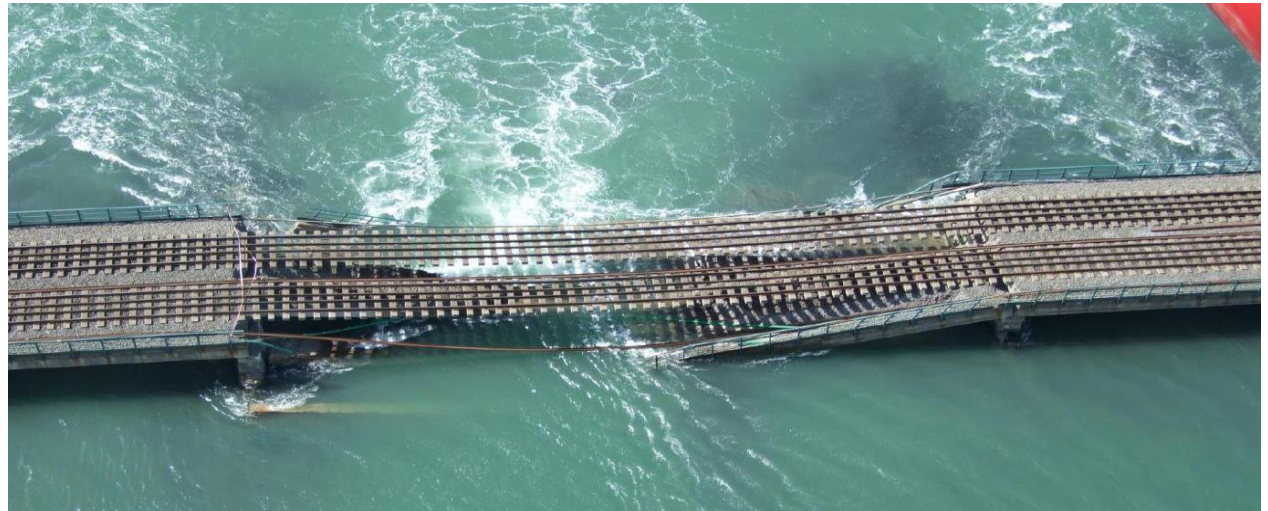
# Visual Survey Results of Bridge

in (a) good and (b) poor condition

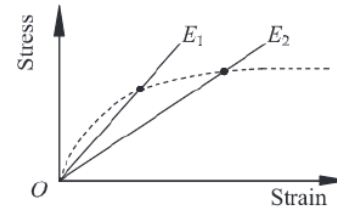
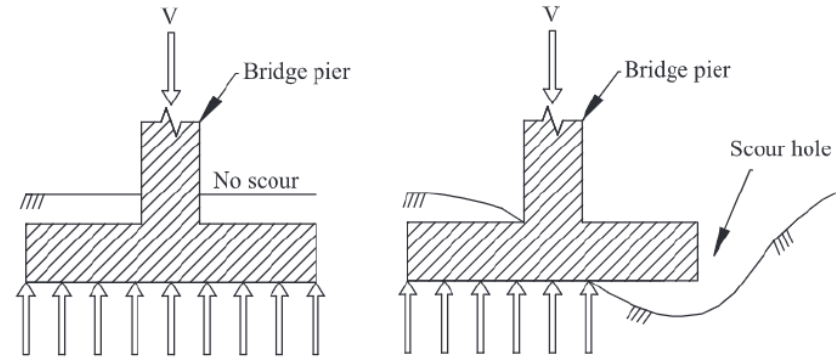
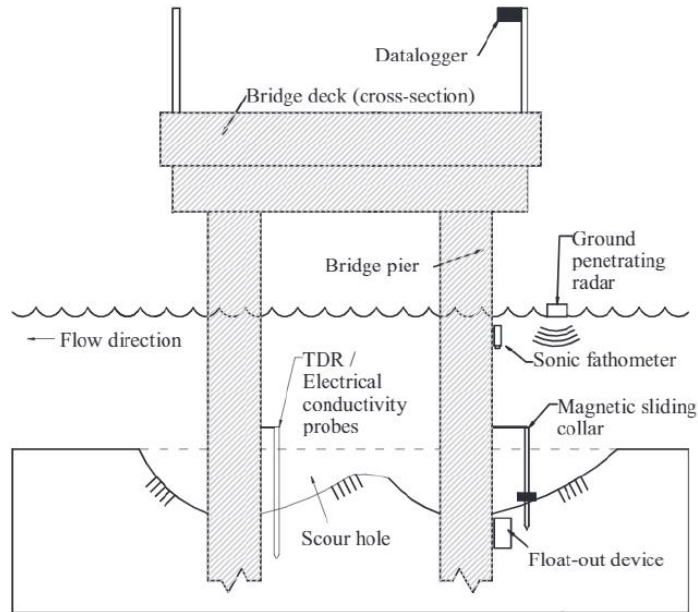




# Scour driven Collapse in May 2009



# Scour Monitoring Techniques



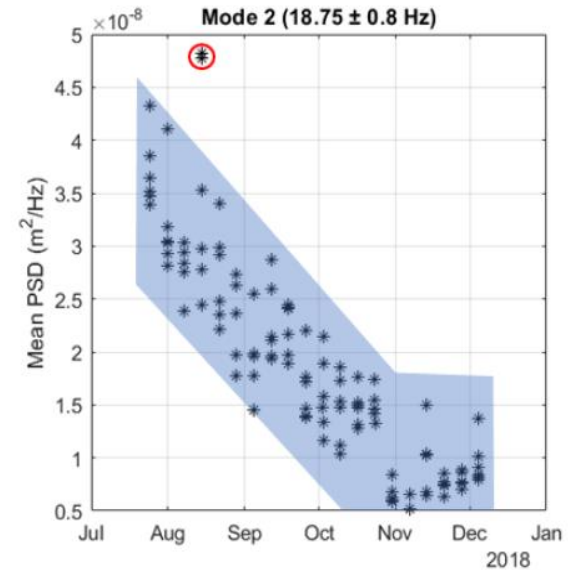
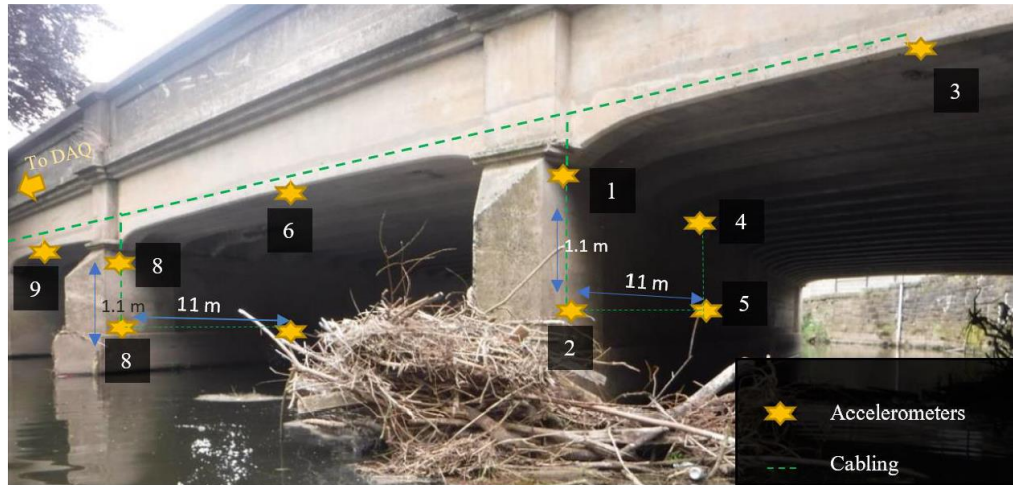
$E_1$  = Stiffness before scour

$E_2$  = Stiffness after scour

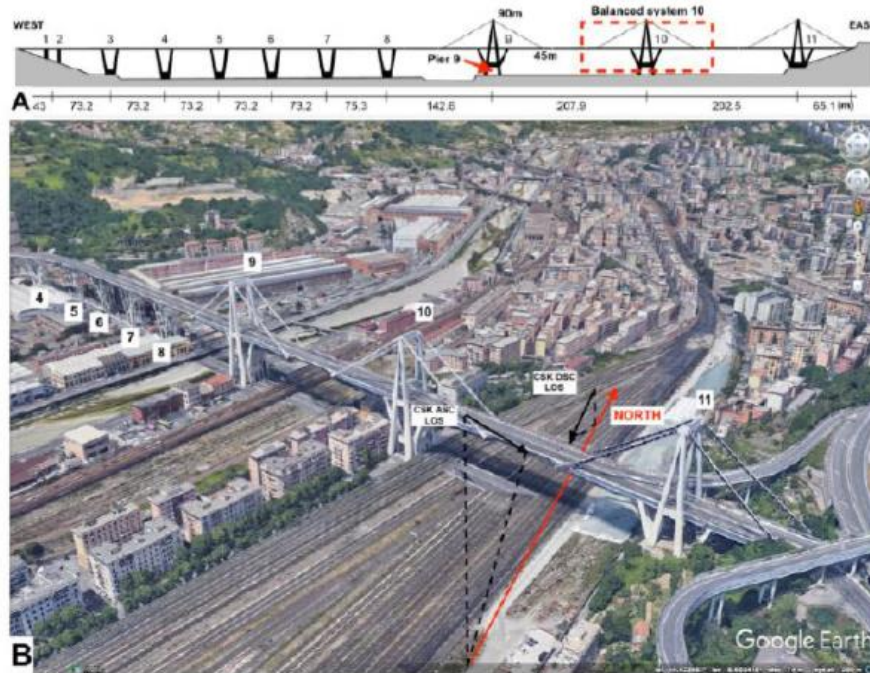
$E_2 < E_1$

# Field Trial Baildon Road Bridge UK

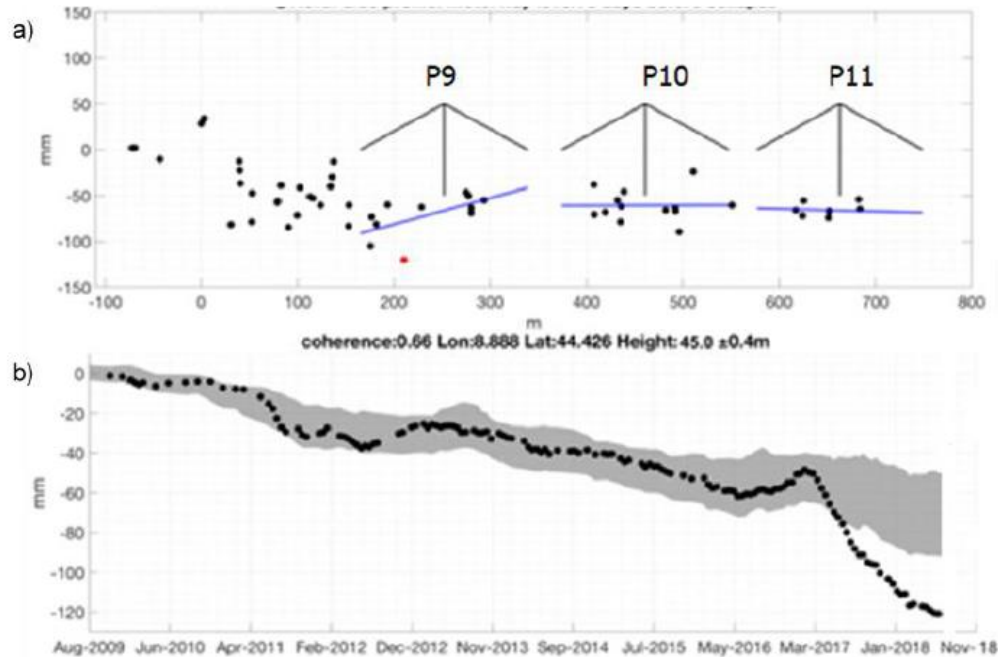
Kariyawasam et al. 2019



# Satellite Monitoring of Bridge Condition

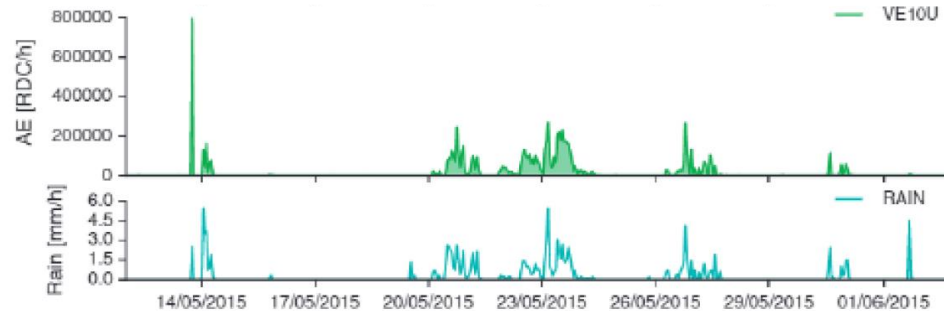
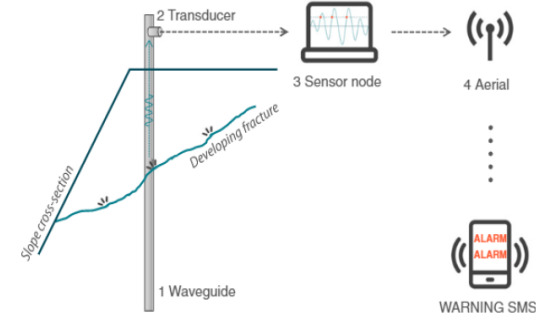


# Satellite Monitoring of Bridge Condition





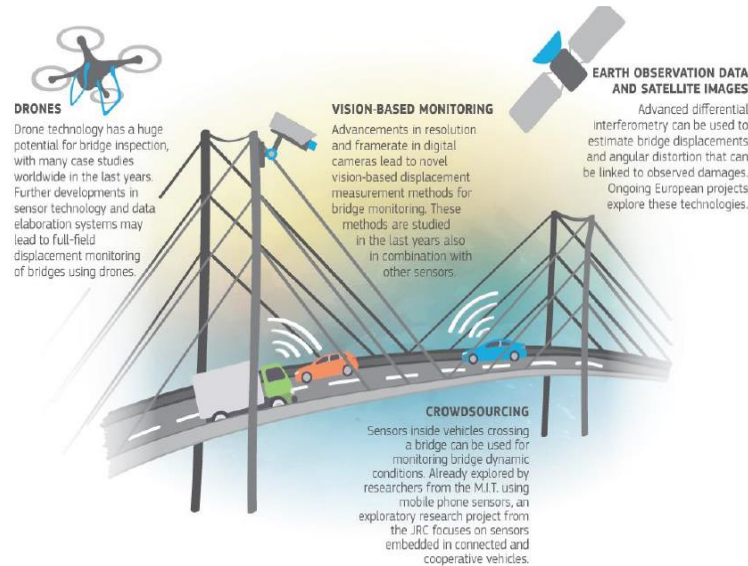
# Impact of Rainfall on Rock falls



Codeglia et al. (2017)

# Data Fusion

integrating multiple data sources to produce more consistent, accurate, and useful information

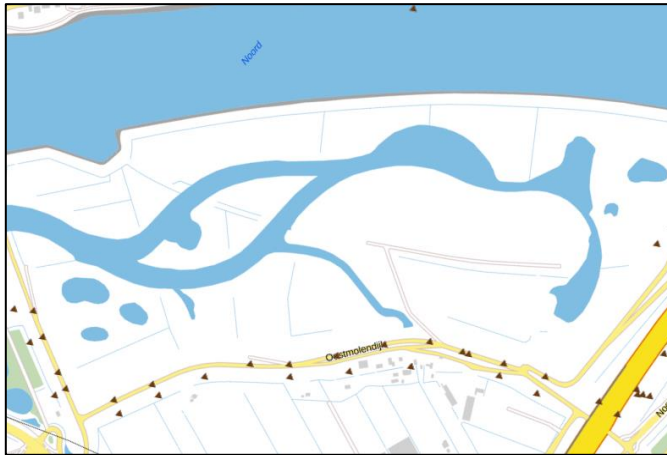


# Case Study - Oostmolendijk

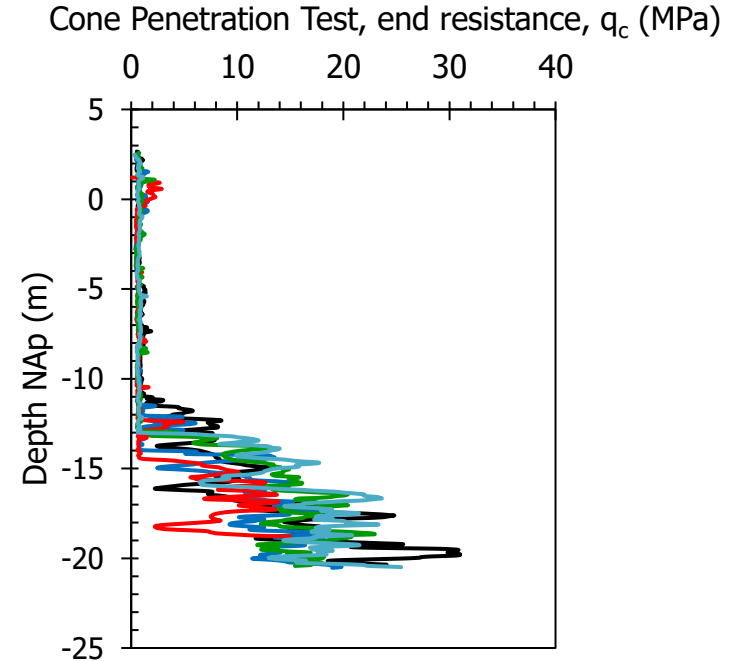
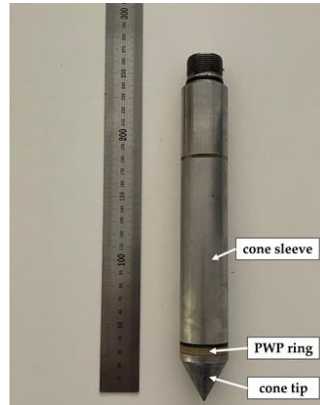




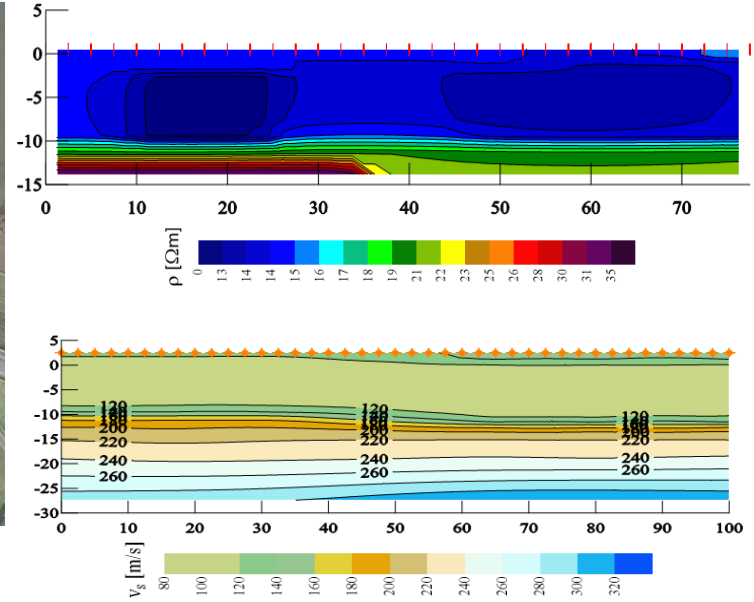
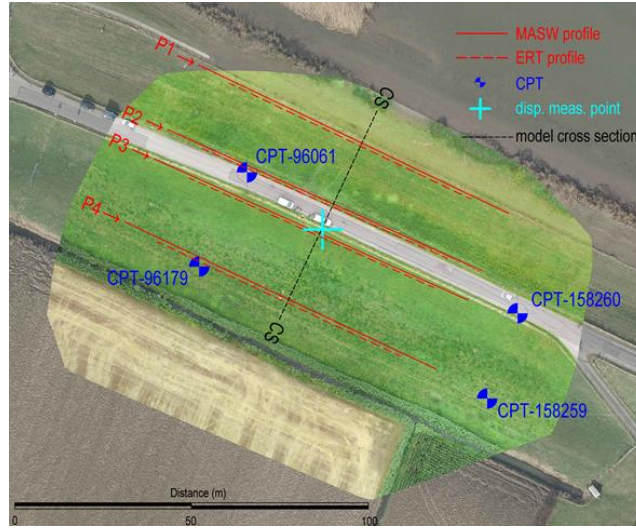
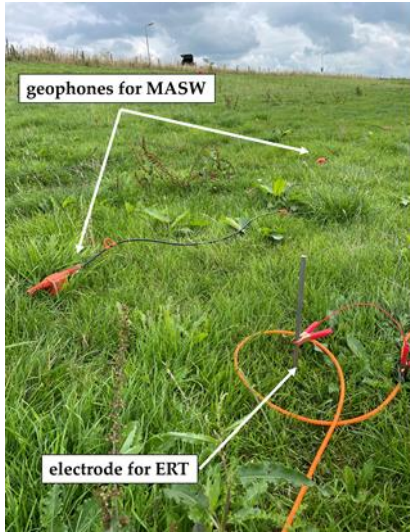
# Case Study – In-Situ Profiling



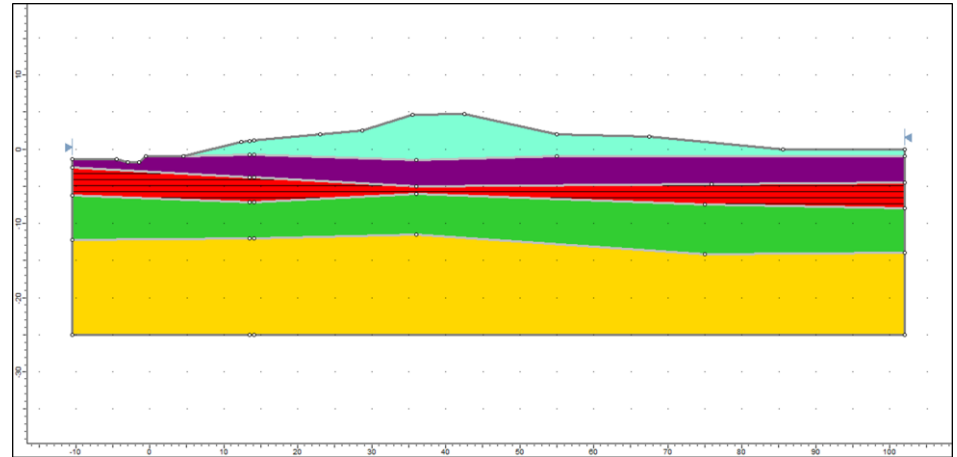
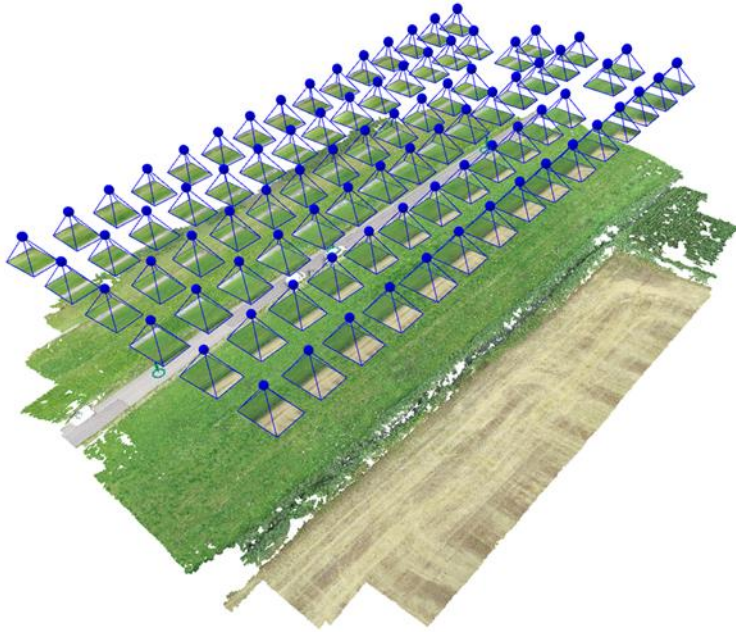
[www.dinoloket.nl](http://www.dinoloket.nl)



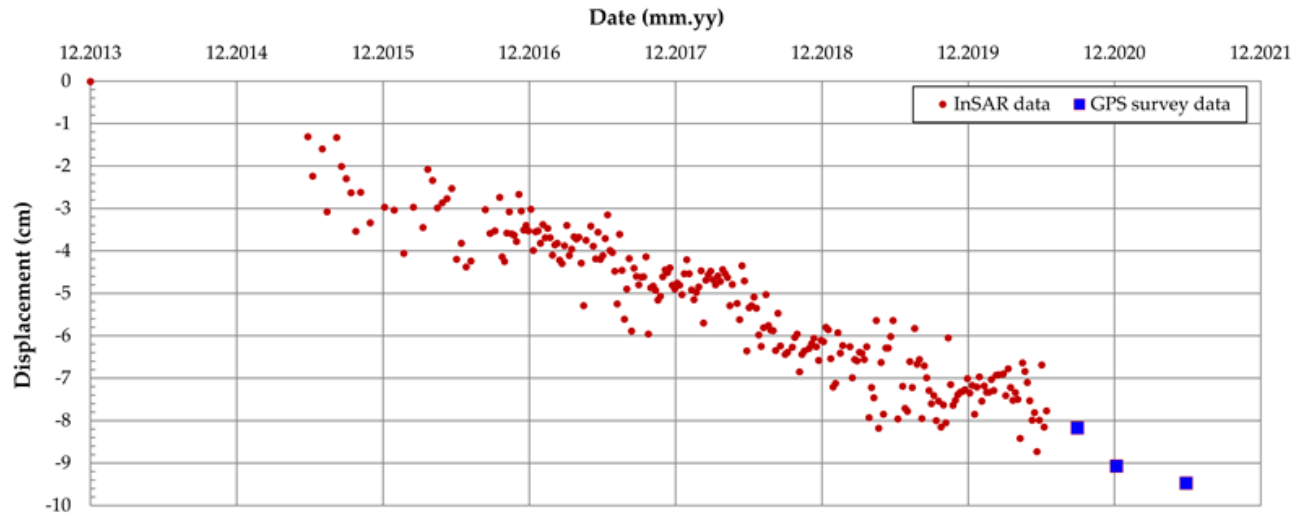
# Range of Non-intrusive Testing



# Development of Numerical Model



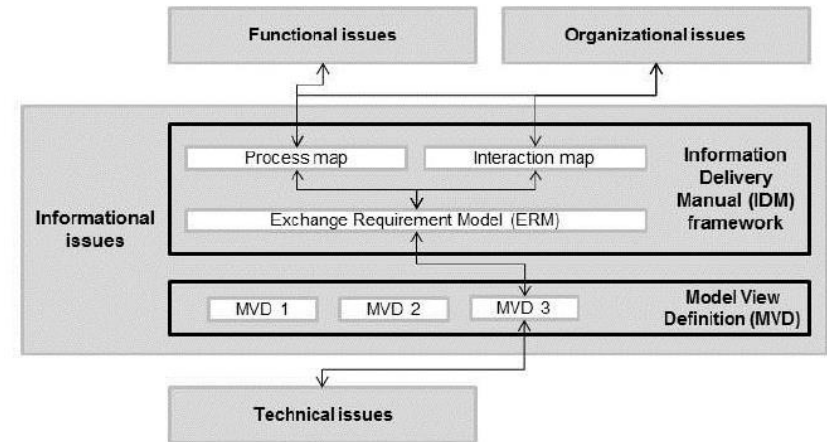
# Satellite Monitoring Data to look back over Performance



# Information Delivery Manual

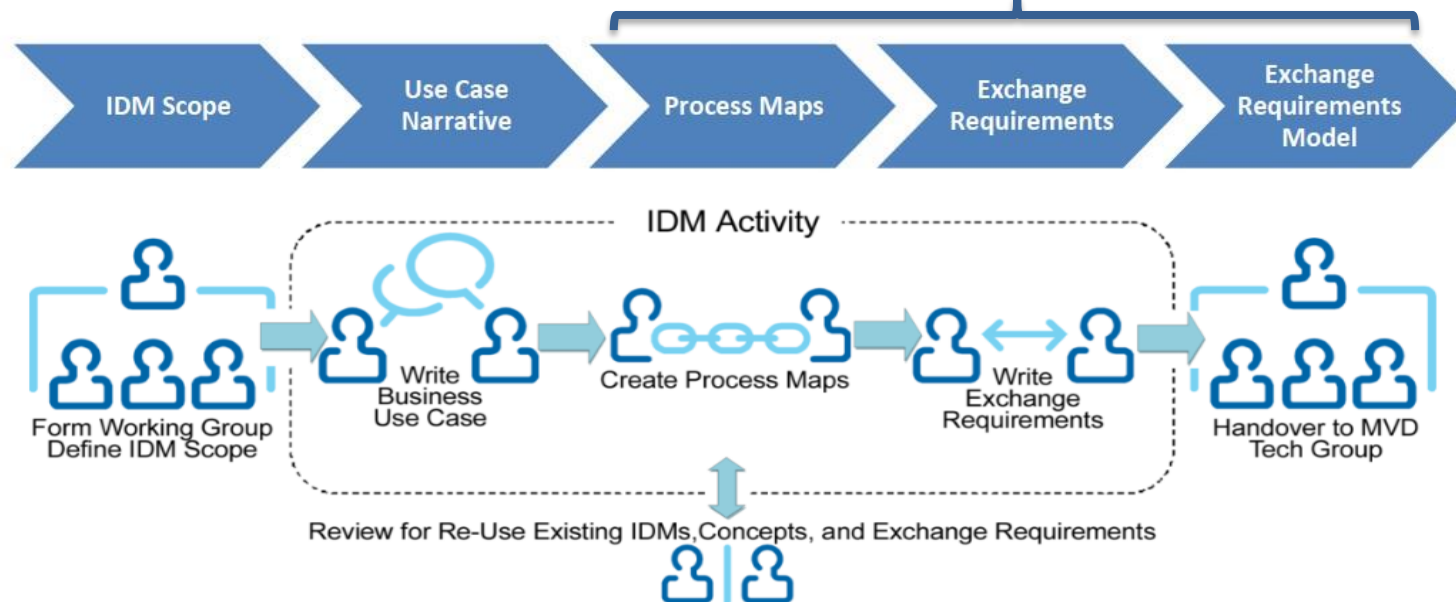
## Methodology based on EN ISO 29481

- Standardized agreements regarding the contents of the model to be exchanged
- Data transfer points are formally defined between the participants
- Open and standardized data formats should be used



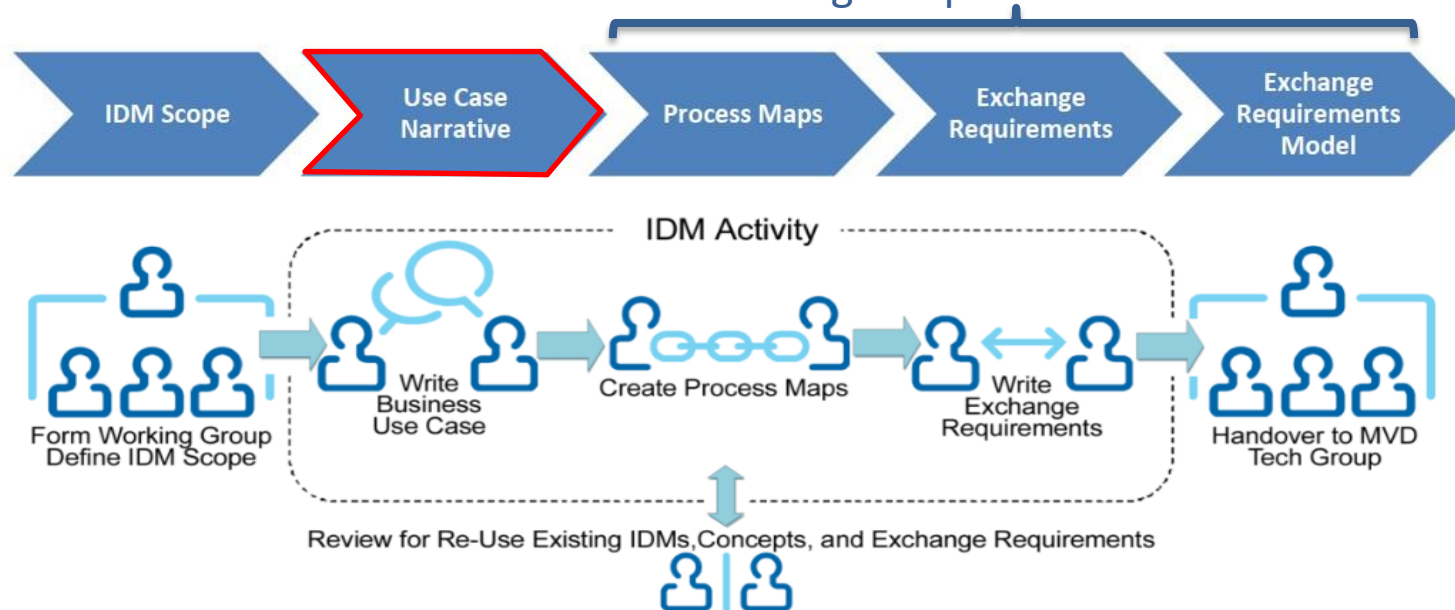
# Information Delivery Manual

Specification of the data flow and exchange requirements



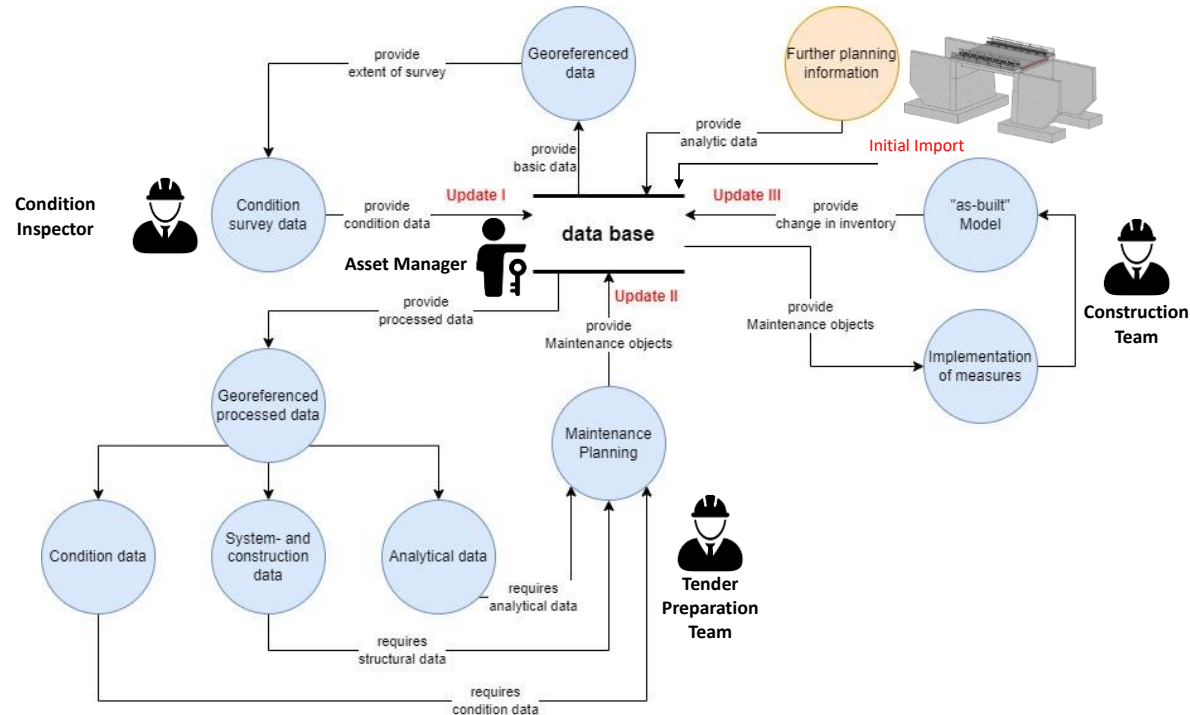
# Information Delivery Manual

Specification of the data flow and exchange requirements





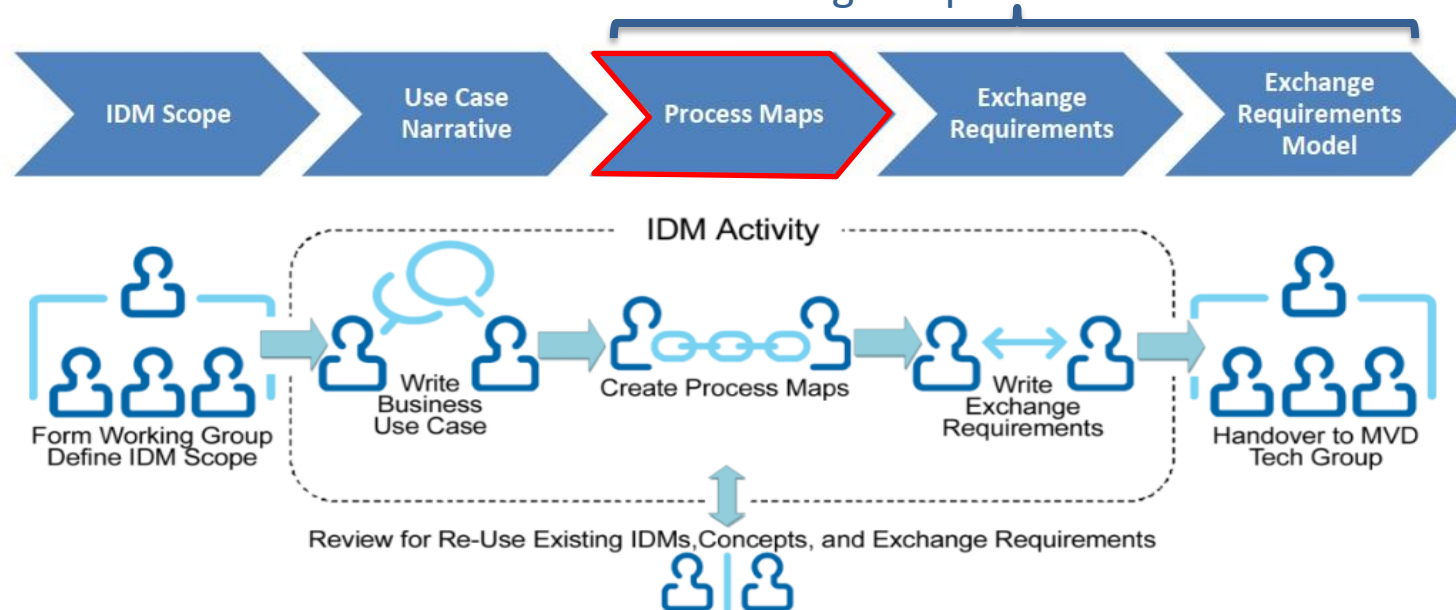
# Information Delivery Manual





# Information Delivery Manual

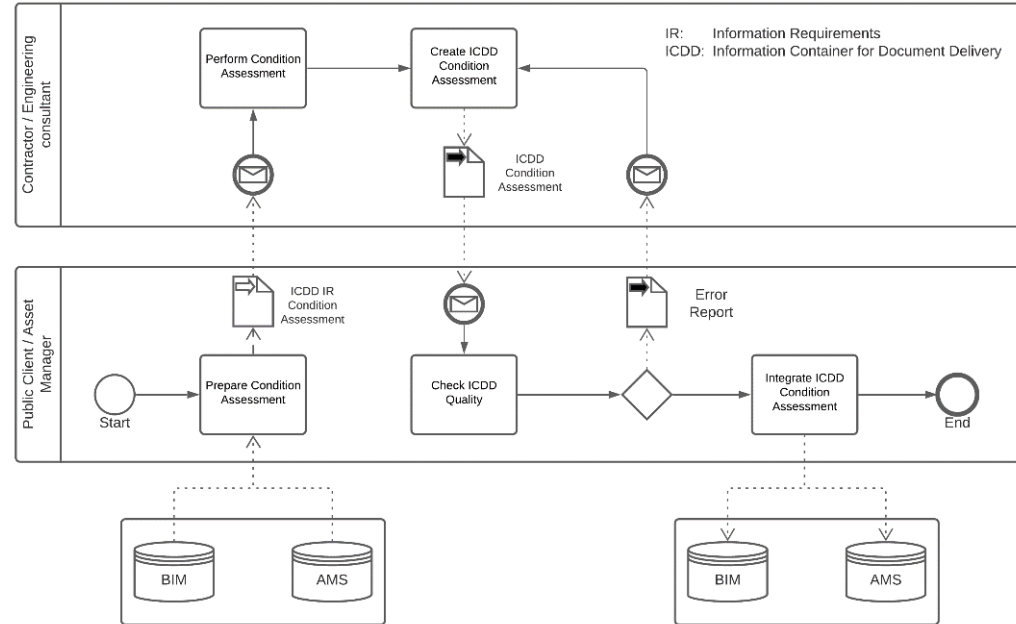
Specification of the data flow and exchange requirements



# Information Delivery Manual

## Generic Process Maps

- Actors
- Processes
- Data drops
- Exchange Requirements



# Information Delivery Manual

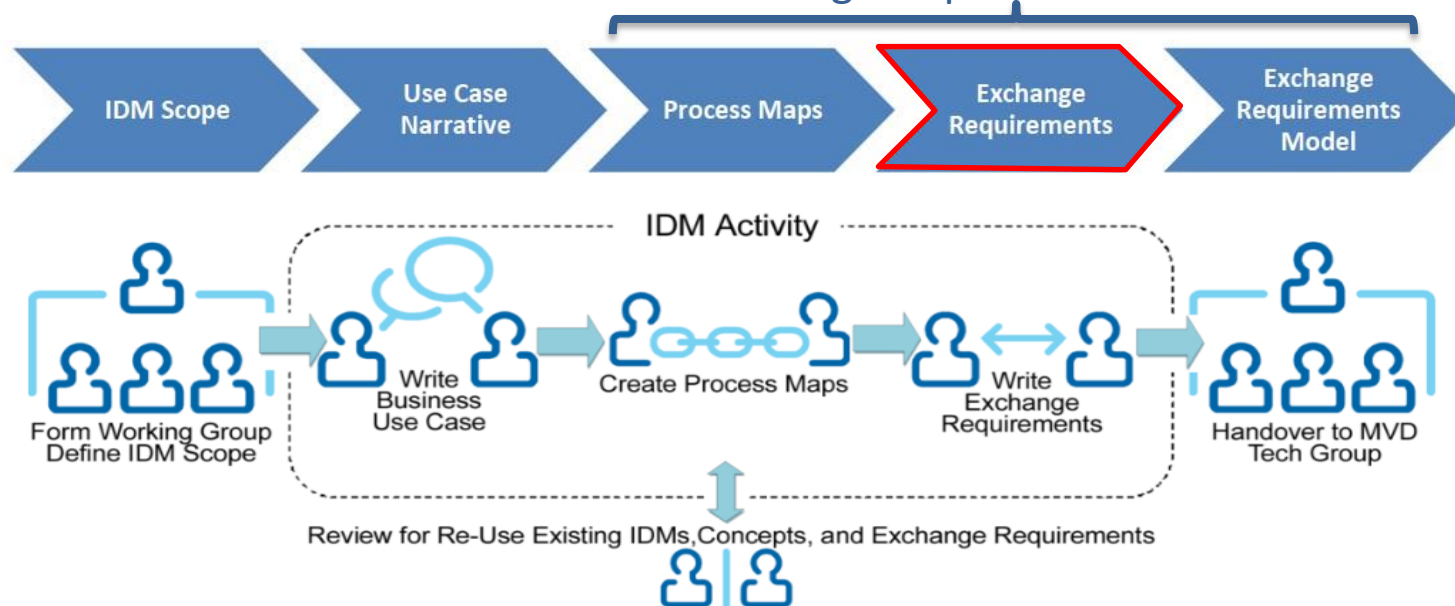
## Generic Process Maps

- Actors
- Processes
- Data drops
- Exchange Requirements

Process Model			
Name:	PM_Condition_Assessment		
Identifier:			
Autors:			
Create Date:			
Document Owner:			
Task	Name	Description of Task	
	Prepare Condition Assessment	Asset Manager requests for an inspection and prepares the ICDD: - in according to the type of inspection - extracting parts of the IFC model - using a template for the report	
	Perform Condition Assessment	The inspector receive the ICDD for condition assessment and performs the inspection - using certain technologies - compiling the results - creating a report	
	Create ICDD Condition Assessment	The inspector stores the result of condition assessment in the ICDD: - in according to the data model "ER1_ICDD_Inspection_Assignment" - linking the different information - checking the results and fulfillment of the information requirements The result of condition assessment are delivered in the form of ICDD	
	Check ICDD Quality	Asset Manager checks the ICDD against the exchange requirement - in according to the data model "ER1_ICDD_Inspection_Assignment" - creating a quality report	
	Request upgrade of ICDD Condition Assessment	If the check result of delivered ICDD is not compliant with the exchange requirement, a error report be will created and sent back to the inspector for a revision	
	Review Error Report	inspector checks the error report and revises the ICDD: - in according to the data model "ER1_ICDD_Inspection_Assignment" - linking the different information - checking the results and fulfillment of the information requirements The result of condition assessment are delivered in the form of ICDD	
	Integrate ICDD Condition Assessment	if the delivered ICDD is compliant with the exchange requirement, the data will be saved back to the BIM/AMS.	
Exchange Requirements	Name	Type	Description of Dokumentation
	ER1_ICDD_Inspection_Assignment	ICDD	Information Container for linked Document delivery with all necessary information for preparing the condition assessment. It should be specified for each typ of the condition assessment.
	ER2_ICDD_Condition_Assessment	ICDD	Information Container for linked Document delivery with all necessary results of the condition assessment
Object Data	Name	Type	Description of Object Data
	BIM	ifc	An as-built model using IFC
	AMS	-	Asset management system for storing the condition assessment results

# Information Delivery Manual

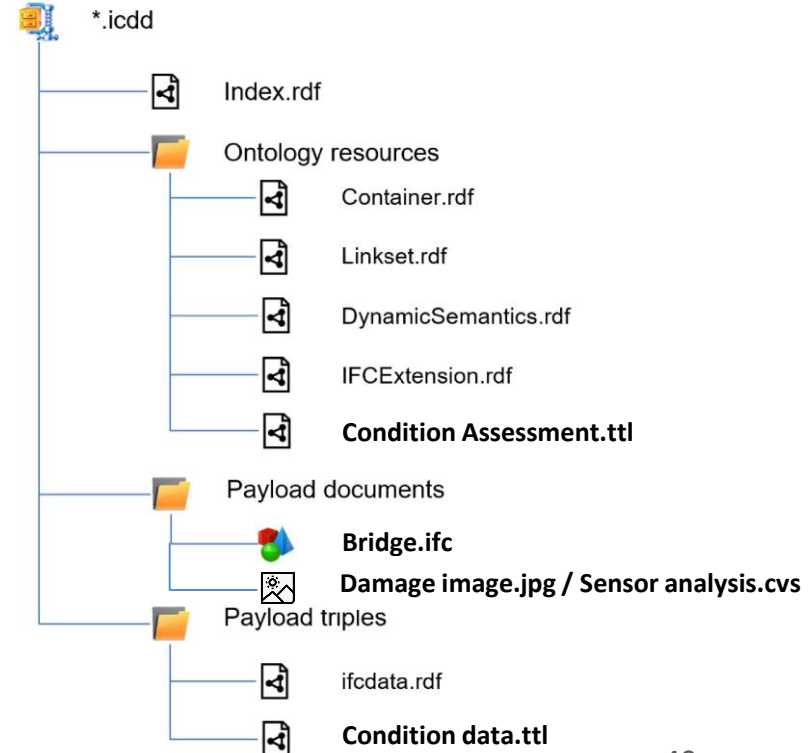
Specification of the data flow and exchange requirements



# Information Delivery Manual

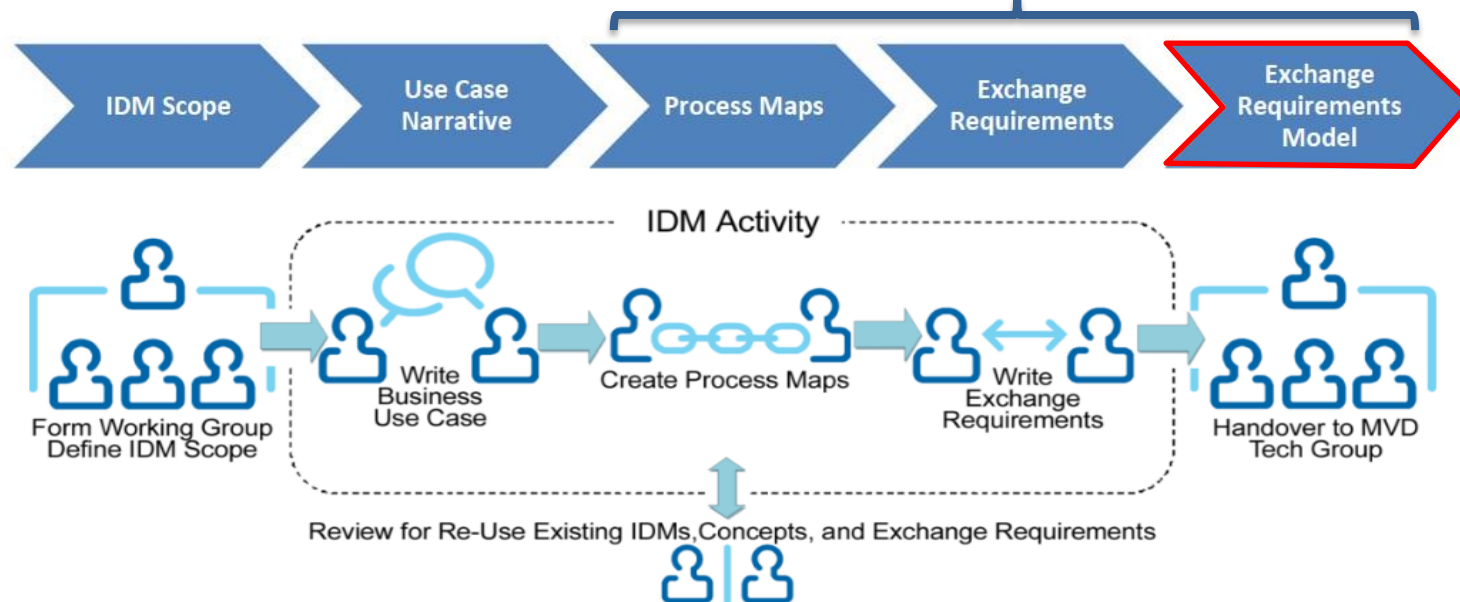
## Exchange requirements

- Exchanged data using Information Container according to ISO 21597
- Required data for the defined use case and IAMS must be considered
- Content of the container must be clarified for each exchange (BIM model, Properties, Domain ontology, Links ...)
- Results can be checked (SHApE Constraint Language SHACL)



# Information Delivery Manual

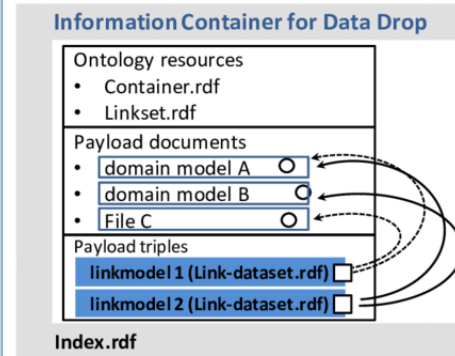
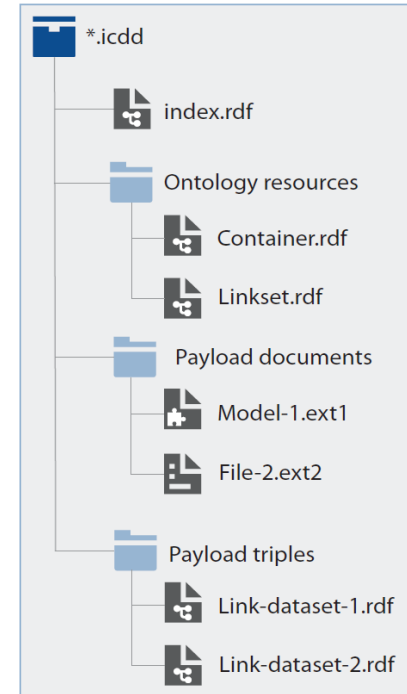
Specification of the data flow and exchange requirements



# Information Delivery Manual

## Information container for linked document delivery (EN ISO 21597)

- Generic container format for storing a linked document dataset
- Using the Resource Description Framework (RDF) to describe meta-information

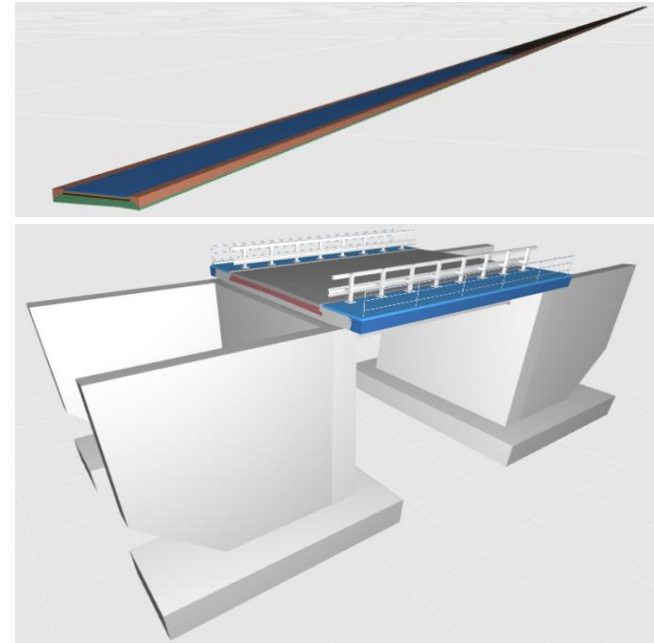


# Information Delivery Manual

## Data Exchange Model based on ICDD

- **BIM models**
  - Pavement model with a virtual layer and maintained elements in 100m and 1000m sections
  - Bridge model with damage placement and maintained elements
- Domain Ontology developed in this project
- Additional documents

### BIM models with maintained elements



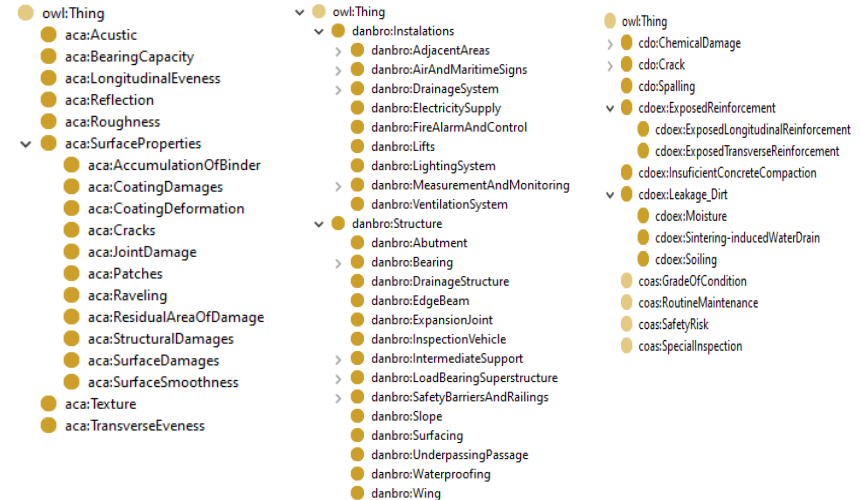


# Information Delivery Manual

## Data Exchange Model based on ICDD

- BIM models
- **Domain Ontology developed in this project**
  - Asphalt condition assessment ontology (ACA – General attributes EU country)
  - Bridge classification ontology (DANBro – Denmark guideline)
  - Condition assessment ontology (COAS – Denmark guideline for bridge)
  - Extension of Damage Classification ontology (CDOEx – General for bridge)
- Additional documents

## Overview of the defined domain ontologies

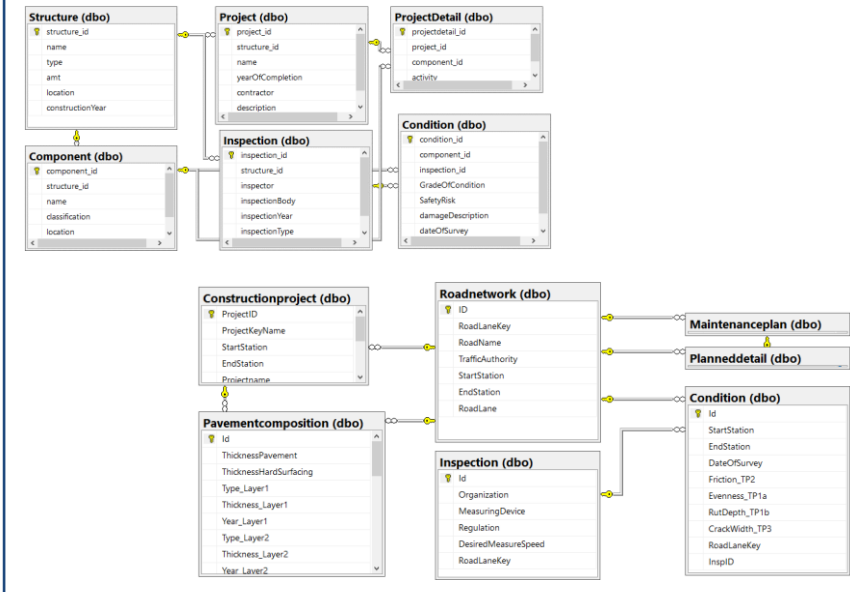


# Information Delivery Manual

## Data Exchange Model based on ICDD

- BIM models
- Domain Ontology developed in this project
- **Additional documents / Database**
  - Data schema for bridge inspection report (XSD based on Denmark guideline)
  - Demo relational database for roads (based on German IAMS)
  - Demo relational database for bridge (based on German IAMS)
  - Links between documents/data (use case-based creation and storage in ICDD)

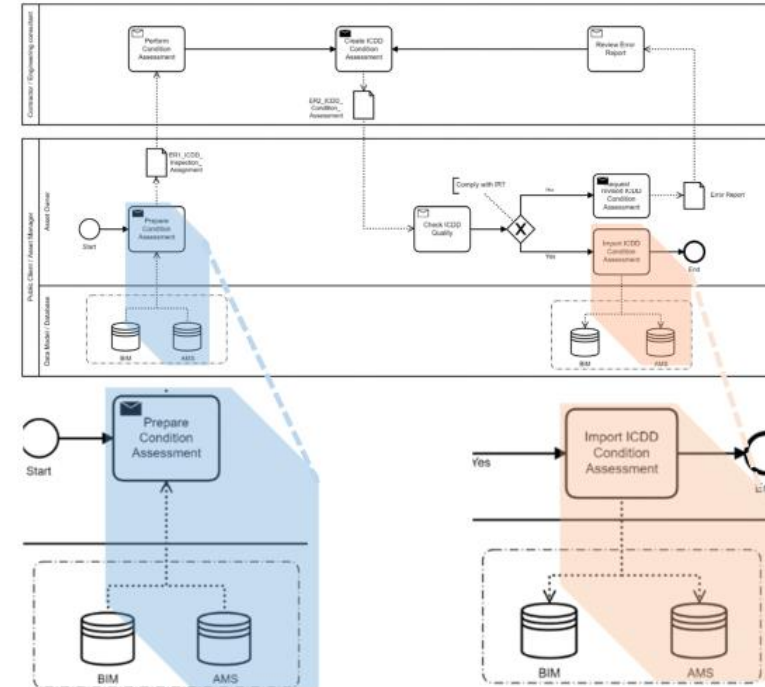
## Overview of demo relational databases Bridge and Pavement



# IAMS-Oriented Information Delivery Manual

## Existing IAMS

- IAMS are mostly established with a relational database (RDB) structure
- IAMS-Data is used and upgraded by BIM-supported Asset Management
- IAMS-Data is collected and structured with BIM via the ICDD
- IAMS-Data is converted into RDF-based Data using domain ontology

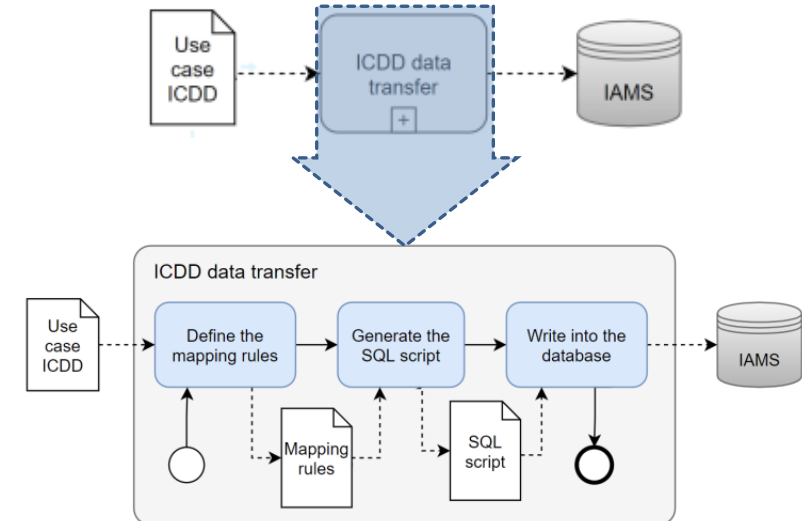


# IAMS-Oriented Information Delivery Manual

## Data flow between ICDD and IAMS

- Definition of data requirements with consideration of ICDD and IAMS
- Definition of mapping rules between RDF-based data and IAMS-data
- Generate and execute SQL commands

### General process of data import into IAMS

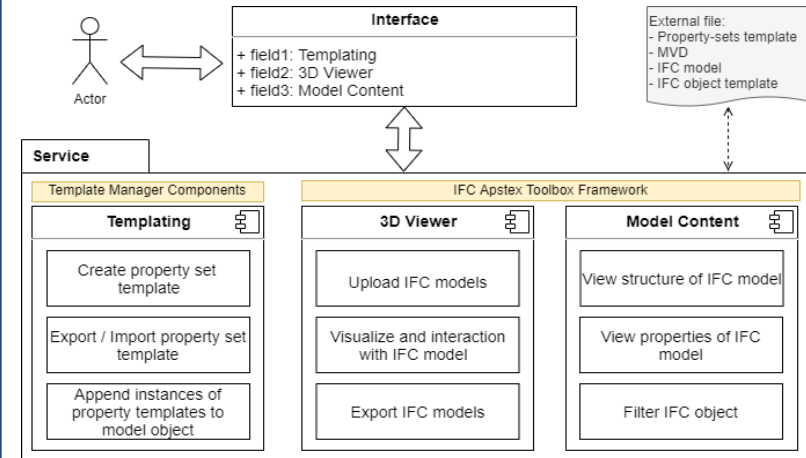


# Extension of IFC / Linking of EUROTIL

## Extension of IFC

- User-defined property sets to consider required data within BIM
- Verification of data with corresponding defined MVD
- Realization with a project-independently developed tool kit *IFC Property Template*

## System Architecture of a Mapping Tool for the IFC Property Template



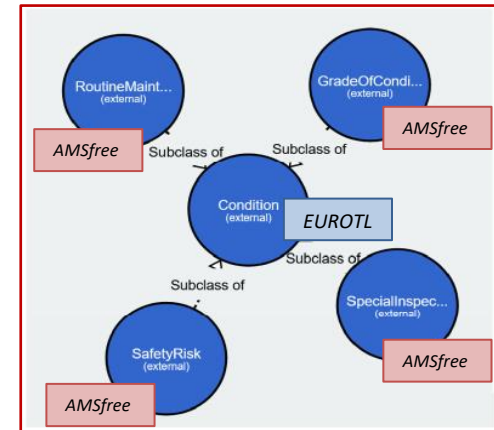
# Extension of IFC / Linking of EUOTL

## Linking of EUOTL

- on the Class-level by defining the linking ontology with the domain ontology
  - bridge damage ontology extension
  - condition assessment ontology
- on the Instance-level with a link supported by the ICDD

### linking ontologies for the predefined inspection-related ontologies

Prefix	Namespace	Description
Cdoex2E UOTL	<http://www.amsfree.eu/ontology/cdoex2eurotl>	Linking between bridge damage ontology cdo, cdoex and eurotl
COAS2 EUOTL	<http://www.amsfree.eu/ontology/coas2eurotl>	Linking between ontology condition assessment and eurotl



# Guideline Exchange of LBD Using ICDD

## Workflows with ICDD

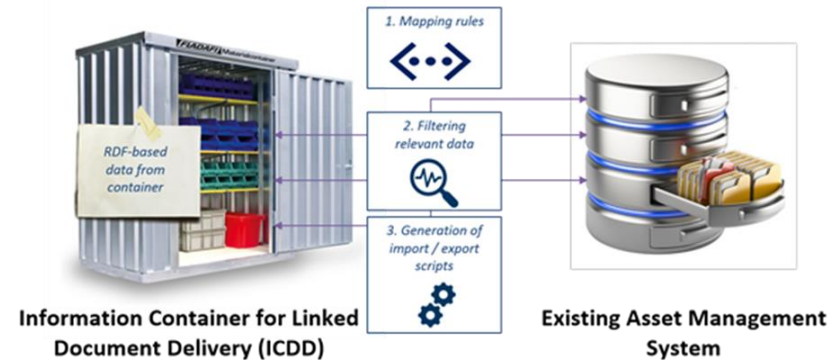
- Use case related data flow with the description of data exchange points
- Data processing
  - Creation of BIM models with consideration of LOIN
  - Creation and using of domain ontology for semantic data
  - Data collection, linking, and querying with Information container
- Data transmission between ICDD - IAMS



# Guideline Exchange of LBD Using ICDD

## Workflows with ICDD

- Use case related data flow with the description of data exchange points
- Data processing
- Data transmission between ICDD – IAMS
  - Definition of mapping rules
  - Selection of relevant data
  - Generation of import and export scripts

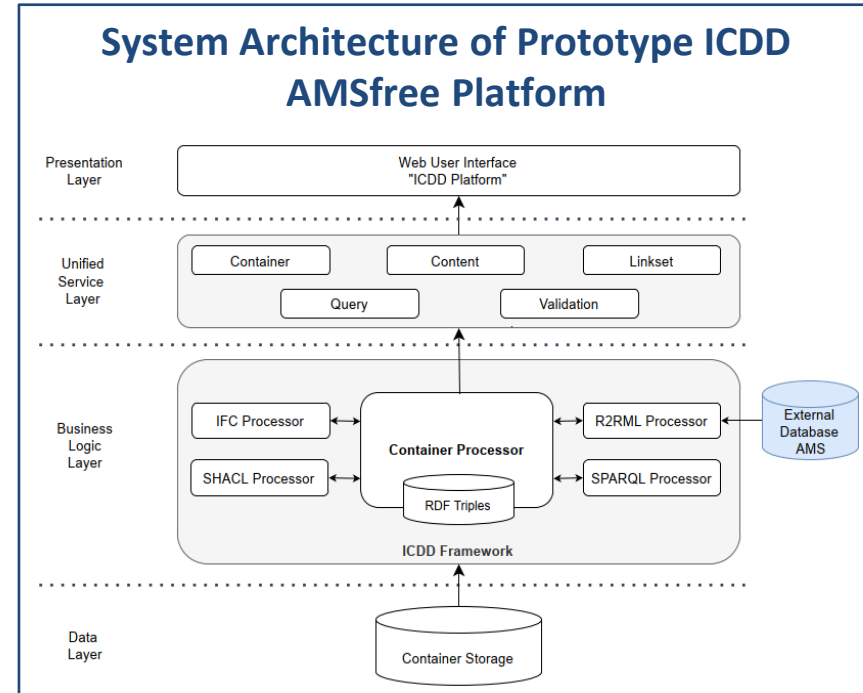




# Prototype ICDD – AMSfree Platform

## System Description

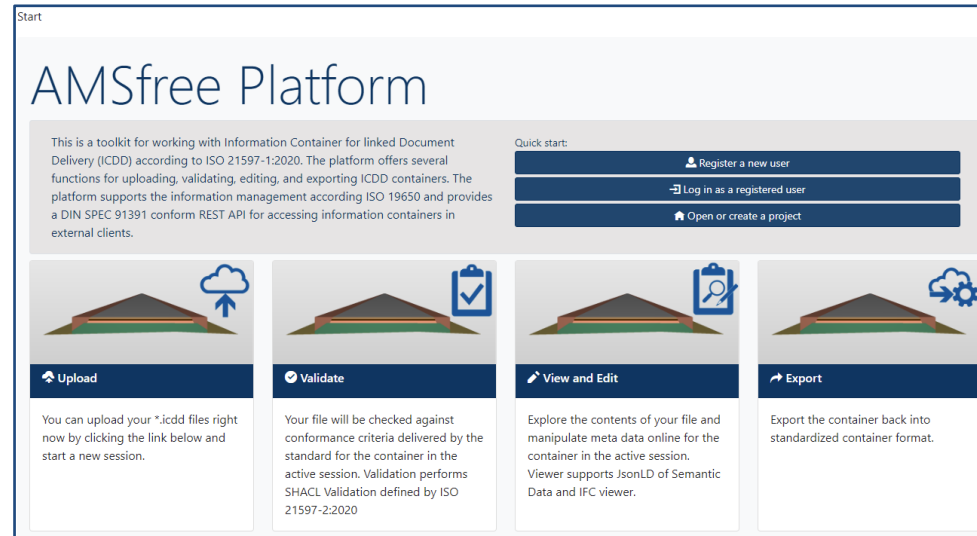
- Based on ICDD Standard ISO 21597
- ICDD as the unit for information storage
- Processing the Linked Data by container processor
- Processing BIM model by IFC Processor
- Connection with external database (IAMS) by R2RML Processor



# Prototype ICDD – AMSfree Platform

## User interface and functions

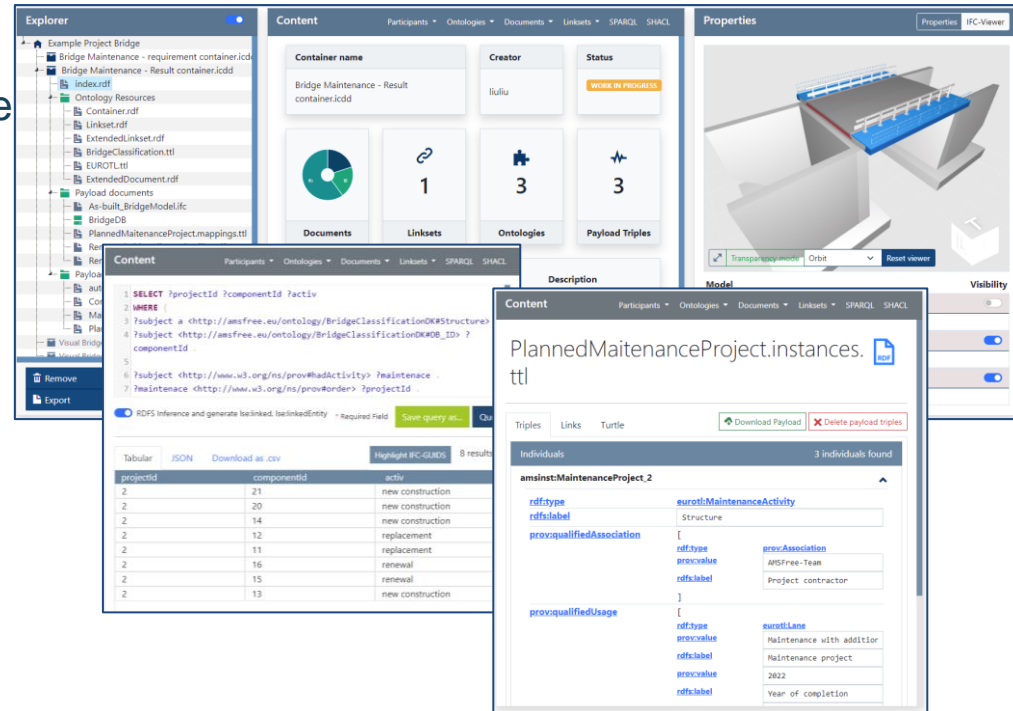
- Project-related management of the containers
  - Create
  - Inherit
  - Download and upload
  - Delete
- Edition of a container



# Prototype ICDD – AMSfree Platform

## User interface and functions

- Project-related management of the containers
- Edition of a container
  - Collection of documents
  - Creation of links
  - Querying container content
  - Transmission data between ICDD and existing database (IAMS)



The screenshot displays the AMSfree Platform interface with several panels:

- Explorer:** A tree view on the left showing a project structure with folders like 'Bridge Maintenance - requirement container.icdd' and files like 'Index.rdf', 'Ontology Resources', 'Linkset.rdf', 'ExtendedLinkset.rdf', 'BridgeClassification.ttl', 'EUROTL.ttl', 'ExtendedDocument.rdf', 'Payload documents', 'As-built\_BridgeModel.ttl', 'BridgeDB', 'PlannedMaintenanceProject.mappings.ttl', 'Ref', and 'Payload'.
- Content:** A central panel showing details for 'Bridge Maintenance - Result container.icdd'. It includes a 'Container name' field, a 'Creator' field (Iulia), a 'Status' field (WORK IN PROGRESS), and a 'Documents' section with a pie chart and a '1' count. Below this are 'Linksets' (3), 'Ontologies' (3), and 'Payload Triples' (3).
- Properties:** A panel on the right showing a 3D model of a bridge structure with a blue track and a 'Transpogameweb' label.
- Query Result:** A panel at the bottom showing a table of results for a query. The query is:
 

```
1: SELECT ?projectId ?componentId ?activ
2: WHERE
3: { ?subject a <http://amsfree.eu/ontology/BridgeClassificationDK#Structure>
4:   ?subject <http://amsfree.eu/ontology/BridgeClassificationDK#ID_ ?
5:     componentId
6:   ?subject <http://www.w3.org/ns/prov#hadActivity> ?maintenance
7:   ?maintenance <http://www.w3.org/ns/prov#order> ?projectId }
```

 The table has columns 'projectId', 'componentId', and 'activ'. It shows 8 results.
 

projectId	componentId	activ
2	21	new construction
2	20	new construction
2	14	new construction
2	12	replacement
2	11	replacement
2	16	renewal
2	15	renewal
2	13	new construction

# Summary and Conclusions

## Summary I:

The AMSfree project analyzed the architecture of Infrastructure Asset Management Systems (IAMSS) used by National Road Authorities (NRAs), as well as the asset information content in current IAMSS in order to establish detailed technical requirements for linking IAMSS and Building Information Models (BIMs) as infrastructure asset databases on a macro and micro level.

The use and maturity of BIM in Europe and the existing IFC Model were analyzed and described, which content of common IAMSS BIM can be provided by designers and contractors

# Summary and Conclusions

## Summary II:

Current and new assessment techniques were assessed to identify opportunities how to incorporate new data streams in condition assessment. The techniques firstly comprises the assessment of roads and bridges and secondly new technologies and examples of their application.

Based on this results an Information Delivery Manual (IDM) für condition assessment were developed as well as the IFC using for condition assessment were analyzed.

# Summary and Conclusions

## Summary III:

A generic reference process model was developed and characteristic data updates were defined. For this model, data demands for pavements and bridges were defined, according to the requirements of national AMS. This includes the data flow requirements.

Based in this, Information Containers for Pavements and Bridges were created, as well as the ontologies and the payload documents. This leads to the development of a referenced vendor-free based data structure.

An IAMS oriented IDM is given as well as IAMS-oriented application and extension of the IFC Standard.

# Summary and Conclusions

## Summary IV:

A prototype for the data exchange to legacy systems was developed using information containers. The web-based application was tested based on a project-related database with different use cases according to the relevant updates within the IAMS Process for bridges and pavements.

The prototype application is described in a guideline for IFC Property Mapping, in a functional memorandum and the description of different use cases.

# Summary and Conclusions

## Conclusions I:

The process, data handover from as built model to operation model and the data demand for the operation period is clearly described. Property sets and properties can be extended related to national demands.

Relevant data updates regarding needs of IAMS during the operation period are defined.

IDM for condition assessment / inspection regarding also new assessment methods are given.



# Summary and Conclusions

## Conclusions II:

A linked data concept and prototype for using legacy data bases based on information containers is given and tested with different use cases. The method and workflow is given, so that the approach is scalable.

The approach allows asset managers to keep their working routines, legacy databases (incl. valuable data), and software applications. The ICDD contains all relevant data and information referred to one geometric model.

The approach is tested as “lab-application”, the next step should be system demonstration in the real operational environment of a road authority.

# Interactive Session

# Interactive session

How do you see the future of existing databases? Is it realistic to develop them into IFC databases?

- (a) Existing databases will be kept. It is not realistic to move in near future into an IFC based data base, because the existing databases are more specified.
- (b) To establish an IFC database and keep all data in one source will be more efficient, so that a turn to IFC database will make sense

# Interactive session

The prototype delivers a method for linking legacy databases. Do you think this approach is for a wide use in road authorities applicable?

- (a) It seems a big advantage, because the engineering work will be the same and existing tolls can be kept.
- (b) The approach seems a good solution, but it takes too much IT-knowledge for civil engineering.

# Interactive Session – Live Poll



# Q&A



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THANK YOU FOR YOUR ATTENTION!