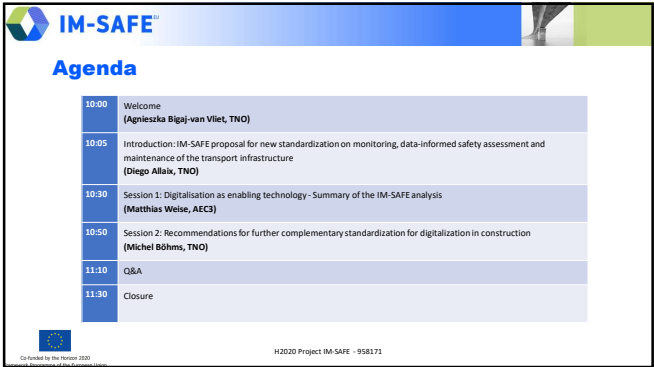




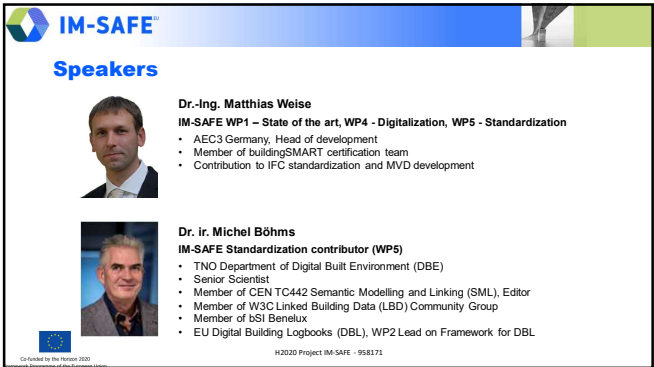
1



2



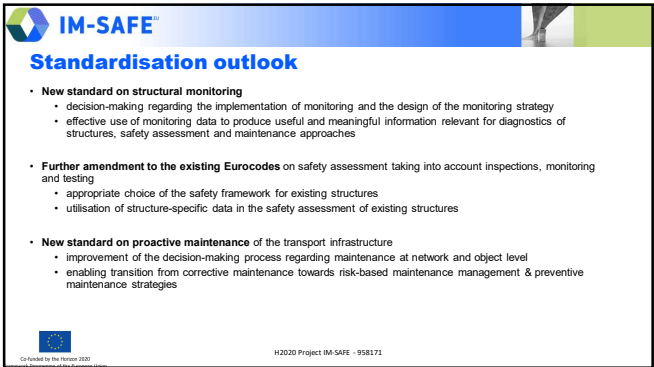
3




4



5




6



New standard on structural monitoring


Topics for standardization:

- framework for **decision making** regarding the implementation of monitoring and the design monitoring strategy
- recommendations for **installation and operation of the monitoring system** aiming to guarantee reliable data
- recommendations for **analysis of the monitoring data for extracting useful information** for the safety assessment and risk management of structures (updating of structural models, identification of damage and deterioration processes)

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

7




New standard on structural monitoring

Framework for decision making regarding the implementation of monitoring and the monitoring strategy


Two questions:

- 1) should monitoring be implemented?
- 2) if yes, which monitoring strategy should be implemented?

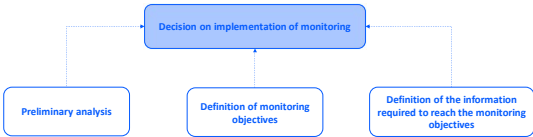
Co-funded by the Horizon 2020
Research and Innovation Programme


H2020 Project IM-SAFE - 958171

8




New standard on structural monitoring



Co-funded by the Horizon 2020
Research and Innovation Programme

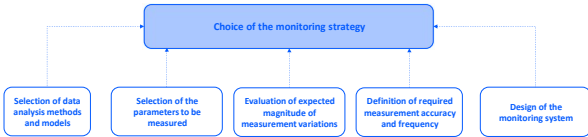
H2020 Project IM-SAFE - 958171


9



New standard on structural monitoring


Question 2: if yes, which monitoring strategy should be implemented?



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171


10



New standard on structural monitoring


Installation and operation of the monitoring system

- a large variety of surveying technologies → recommendations
- aspects to be considered:
 - installation
 - calibration
 - management including maintenance
 - documentation

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171


11



New standard on structural monitoring

Data pre-processing

- identification of outliers
- removal of the environmental effects
- evaluation criteria for **data quality assurance**
 - completeness
 - accuracy
 - precision
 - consistency

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

12

New standard on structural monitoring

Diagnostics based on data analysis and predictive modelling

- updating of structural performance model
- identification of damage
- quantification of actions and action effects

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

13

Further amendment to the existing Eurocodes on safety assessment taking into account inspections, monitoring and testing

Topics for standardization:

- data-informed assessment framework for including information from diagnostics of structures based on data from inspection, monitoring and testing
- minimum reliability requirements (and corresponding reference period) considering differentiation of reliability requirements between the assessment of the fitness-for-use of an existing structure during operation and the design of structural interventions
- use of structure-specific indirect information in the safety assessment

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

14

Performance assessment of existing structures

EXISTING STRUCTURES

SUBSTANTIAL COSTS OF INTERVENTIONS on existing structures in order to increase performance levels

DETERIORATION MECHANISMS are to be taken into account

REMAINING WORKING LIFE and REFERENCE PERIOD often smaller than design life of 50 years

TESTING, INSPECTION AND MONITORING is to be done in order to increase KNOWLEDGE LEVEL

ADJUSTED B-TARGET PERFORMANCE LEVELS in assessment to be considered

Assessment assisted by adequate models (e.g. NETA) and reliability-based & semi-probabilistic verification methods

ADJUSTED REFERENCE PERIOD in assessment to be considered

ADJUSTED TREATMENT OF UNCERTAINTIES, BASIC VARIABLES DISTRIBUTION and UPDATED MODELS to be considered

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

15

Data-informed performance assessment flow

DATA-INFORMED PERFORMANCE ASSESSMENT

STRUCTURAL PERFORMANCE ASSESSMENT

STRUCTURAL SAFETY ASSESSMENT

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

16

Data-informed performance assessment flow

DATA-INFORMED PERFORMANCE ASSESSMENT

STRUCTURAL PERFORMANCE ASSESSMENT

STRUCTURAL SAFETY ASSESSMENT

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

17

New standard on proactive maintenance of the transport infrastructure

Topics for standardization:

- risk-based decision-making process regarding maintenance management
- decision-making process regarding the maintenance strategies
- through-life information management

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

18

New standard on proactive maintenance

Risk-based framework for maintenance management

Co-funded by the Horizon 2020

IM-SAFE Project IM-SAFE - 958171

19

New standard on proactive maintenance

Framework for selecting the maintenance strategies

Co-funded by the Horizon 2020

IM-SAFE Project IM-SAFE - 958171

20

New standard on proactive maintenance

Through-life information management

Why collecting information about the assets?

- to support prioritisation of the assets in need of maintenance
- to define maintenance strategies
- to help planning and budgeting
- to support the evaluation of lifecycle costs
- to support decision making regarding inspection, testing, condition and performance monitoring
- to manage and review risks

Co-funded by the Horizon 2020

IM-SAFE Project IM-SAFE - 958171

21

New standard on proactive maintenance

Through-life information management

Which information about the assets should be collected?

- inventory data
- legal data
- inspection data
- structural assessment data

Co-funded by the Horizon 2020

IM-SAFE Project IM-SAFE - 958171

22

New standard on proactive maintenance

Through-life information management

What about the information quality?

- information acquisition phase:
 - accuracy
 - precision
 - consistency
- information processing and sharing phase:
 - accessibility
 - interoperability
 - security
- decision-making phase:
 - traceability
 - timeliness
 - completeness
 - relevancy

Co-funded by the Horizon 2020

IM-SAFE Project IM-SAFE - 958171

23

Digitalisation as enabling technology


Summary of IM-SAFE analysis

Matthias Weise (AEC3)

Co-funded by the Horizon 2020

IM-SAFE Project IM-SAFE - 958171


24



IM-SAFE[®]

Main Topics of Digitalisation


- **Data requirements**
General requirements for data acquisition, transmission, storage and processing for asset management, monitoring and analytics workloads for civil infrastructure
- **Standards for interoperability**
Address interoperability between future and current IT standards in IoT, BIM, GIS and Semantic Linked Data
- **IT platform design**
Recommendations for the common design of an IT platforms for monitoring data of transport infrastructure
- **Data analytics case studies**
Identify data analytics technologies, and provide best practices and case studies illustrating their added value



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171


25



IM-SAFE[®]

Main Topics of Digitalisation


- Data requirements
How to get correct measurements about the asset?
- Standards for interoperability
What common data language do we need to support collaboration?
- IT platform design
How to provide access to distributed data?
- Data analytics case studies
How to efficiently and effectively use the data to support decision making?



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

26




IM-SAFE[®]

Current status and conclusions for standardization

MAIN QUESTIONS


- What is the state-of-the art in mentioned areas?
- What is the situation in terms of standardization?



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

27




IM-SAFE[®]

Data Acquisition and Quality Assurance

SCOPE


- Data collection
- Data pre-processing (quality assurance)
- Data storage and management
- Data security



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

28

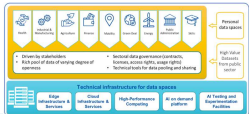


IM-SAFE[®]

Data Acquisition and Quality Assurance

SCOPE


- Data collection
- Data pre-processing (quality assurance)
- Data storage and management
- Data security



Common European data spaces

RESULTS


- 19 different surveying technologies, incl. unified approach to describe them by 6 categories
- quality assurance depends heavily on surveying technology, purpose of use and monitoring environment
- frameworks and reference architecture are emerging (DigiPlace, Gaia-X, Fiware/IDS, SOLID approach + base technologies), but not yet available
- data security topics can use universal base layer of data management frameworks, but need proper configuration (RBAC)



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

29




IM-SAFE[®]

Data Acquisition and Quality Assurance

CONCLUSIONS

- storage, processing and management of measurement data is still highly proprietary
- "common ground" data format and structure for monitoring data recommended:
 - key characteristics about used surveying technologies (see used categories)
 - meta-data about the measurements, monitoring system and data processing; mainly for documentation purposes

Basic product data + domain knowledge to be agreed in ontologies/dictionaries



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

30

BIM, GIS and IoT data interoperability

SCOPE

- Open standards for interoperability – Model
- Data integration workflows – Modelling
- Data interoperability framework – Management

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

31

BIM, GIS and IoT data interoperability

SCOPE

- Open standards for interoperability – Model
- Data integration workflows – Modelling
- Data interoperability framework – Management

RESULTS

- Existing standards mainly from BIM and GIS provide a sound basis for IM-SAFE use cases, they can be reused, combined and extended (IFC, CityGML)
- Extension of standards are recommended, but can follow a roadmap with most urgent use cases
- Use of linked data technology following the FAIR principle are recommended

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

32

BIM, GIS and IoT data interoperability

GAPS IN EXISTING STANDARDS

- Documentation of the condition and degradation of the asset and its parts (BIM, GIS)
- Documentation of monitoring systems and measurement set-ups (BIM, GIS)
- Product specifications for sensors and other monitoring equipment (IoT, BIM)
- Documentation of maintenance activities (BIM)

Priority for further extensions should be based on importance of (collaborative) use cases

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

33

Design of IT data platforms for transport Infrastructure

SCOPE

- Compare functionality of existing asset management systems (9)
- Design of software platforms for the construction sector

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

34

Design of IT data platforms for transport Infrastructure

SCOPE

- Compare functionality of existing asset management systems (9)
- Design of software platforms for the construction sector

RESULTS

- Lack of features in all tested environments
- Asset management systems should follow modern software design
 - User-centric design
 - Abstraction layers to automated resource allocation
 - Modular and extensible platform
 - Reliance to standard data security and data governance best practiced, and open standards

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

35

Design of IT data platforms for transport Infrastructure

RECOMMENDATION

- Focus on modular and extensible platform design with use of open standards

A common standardized platform for

Domain experts (civil engineer)

Machine Learning researcher


Specialized workflows for different user personas

Move to standardized frameworks, APIs, data structures, security layers etc. as they become available and focus on domain specific setups

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171


36

**IM-SAFE**

Big Data analytics and Artificial Intelligence

SCOPE


- Overview of the Data Analytics and Artificial Intelligence technologies
- Example from current practice



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

37

**IM-SAFE**


Big Data analytics and Artificial Intelligence

SCOPE

- Overview of the Data Analytics and Artificial Intelligence technologies
- Example from current practice

RESULTS


- Artificial Intelligence (AI) and Machine Learning (ML) are emerging technologies with use cases in data monitoring and evaluation
- While there is a typical workflow for data preparation, model building and deployment, further standardization does not seem to be feasible yet



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

38


**IM-SAFE**

Big Data analytics and Artificial Intelligence

CONCLUSIONS

- Applying AI and ML technologies is a continuous iterative process – even more today
- Guidelines on how to select and apply this technology are needed
- Provide criteria and metrics for selection, such as: quality of data, performance, explainability/trustworthiness, training time and cost, complexity etc.


AI/ML are young technologies and we are still learning how to use them.
Documentation of experiences for evaluation and reuse in other projects should be in focus.



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171


39

**IM-SAFE**

Digitalisation as enabling technology

SUMMARY

Topic	Ready for use	Ready for standardization
Data requirements	X	(x)
Interoperability	X	X
IT Platform Design	(x)	
Data analytics (AI/ML)	(x)	



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

40

**IM-SAFE**

Recommendations for further complementary standardization for digitalization in construction


Dr.ir. Michel Böhms (TNO)



Co-funded by the Horizon 2020
Research and Innovation Programme


H2020 Project IM-SAFE - 958171

41

**IM-SAFE**

Standardization scope

- On real things (**assets**, products, materials, **sensors/actuators**)
- On abstract things
 - Processes, methodologies, methods
 - Data (about real things or coming from real things)
 - Software
 - Digital Twins (data + software + sensors/actuators)
- Our focus here
 - Infra assets & sensors
 - Data about/coming from them (→ static & dynamic data)



Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

42

Data standardization issue

- First there was data chaos
- Standards can help out
- Now there is data standardization chaos

TYPES OF CABLES AND USB

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

43

What data aspects do we have?

Extended ISO 8000 Data Architecture

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

44

Again, now simplified ...

- Data formats
- Data access methods
- Data languages

}

Technologies

- Data specifications
- Data dictionaries
- Identification schemes

}

Specifications
(using those technologies)

“Semantics”

- All being prime candidate topics for “data standardization”

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

45

Intermezzo 1, there is more

- WHY? Pragmatics, Purpose, Use Case
- WHAT? Specifications (‘semantics’)
- HOW? Technologies (syntax, language)
- WHERE? The medium: ‘federated data spaces’

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

46

Who do we have?

- International Standardization Organization (ISO)
- International Electrotechnical Commission (IEC)
- The European Committee for Standardization (CEN)
- European Committee for Electrotechnical Standardization (CENELEC)
- National formal standardization bodies (NEN, DIN, AFNOR, SN, ...)
- buildingSmart International (bsi)
- Open Geospatial Consortium (OGC)
- Object Management Group (OMG)
- World Wide Web Consortium (W3C)
- Internet Engineering Task Force (IETF)
- ECMA International industry association for ICT
- GraphQL Foundation (under Linux Foundation)
- Open API Initiative (under Linux Foundation)
- gRPC (incl. Google Protocol Buffers)
- GNAI.V / International Data Spaces Association (IDSA)
- National organizations/initiatives
 - Like in NL: buildingSmart Benelux (BSB), Geonovum, Platform Linked Data Nederland (PLDN), DigGOBIM Loket, CROW, CE23, iSHAPE

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171

47

Who do we have?


- All having many technical committees, task groups, working groups, community groups, joint technical committees
- Producing many formal/industry standards/guidelines for the various data aspects: both standard technologies & standard specifications
- All trying to make data “FAIR”

- Sometimes complementary, often overlapping or competing
- We highlight a selection of data standards we think is most important

Co-funded by the Horizon 2020
Research and Innovation Programme

H2020 Project IM-SAFE - 958171


48



Intermezzo 2, coverage

- In the end you want “world-wide” coverage
- From user-side (international users/usage)
- From support-side (international software providers)
- Both need focus and critical mass, not fragmentation, to invest


- Example
 - NEN-2660 >>> CEN-SML >>> ISO-SML?
- Note: luckily, many already world-wide (bSI, OGC, W3C)



Co-funded by the Horizon 2020

H2020 Project IM-SAFE - 958171

49



What technology standards do we have?

- ISO STEP Technology
 - STEP Physical File Format (SPFF)
 - EXPRESS, EXPRESS-G
- W3C XML technology
 - Extensible Markup Language (XML)
 - XML Schema Definition (XSD)
- CMG model-driven technology
 - Business Process Modeling Notation (BPMN)
 - Unified Modeling Language (UML)
 - Systems Modeling Language (SysML)
- ISO/IEC 28002-2/IEC 61937 for Software engineering and interfaces
 - JavaForge Object Notation (JSON), RFC-8259, <https://www.rfc-editor.org/rfc/rfc8259>
- GraphQL Foundation
 - GraphQL Schema Definition Language (SDL)
 - GraphQL
- W3C Linked Data/Semantic Web technology
 - RDF, RDFa, Turtle, JSON-LD
 - Resource Description Framework (RDF), RDF Schema (RDFS), Ontology Web Language (OWL), Shapes Constraint Language (SHACL)
 - SPARQL Protocol and RDF Query Language (SPARQL)
- Microsoft
 - Excel

- Data Format
- Data Access Method
- Data Language



Co-funded by the Horizon 2020

H2020 Project IM-SAFE - 958171

50



What specification standards do we have?

- ISO 15926
 - In paper (1)
- ISO Information Container for Interact Data Delivery (ICDD)
 - In XML
- ISO 15926-3 International Framework for Datacenter (IFD)
 - In EXPRESS/ISO 15926-3-G, XML, ISO, CD-XML
- ISO/IEC Industry Foundation Classes (IFC, ISO 15926)
 - In EXPRESS/ISO 15926/IFC/JSON Schema
- ISO BuildingSmart Data Dictionary (ISDD)
 - In ISO 15926-3 (Formal), in JSON data template (actual)
- OGC INSPIRE Geospatial Markup Language (GML), CityGML, CityJSON
 - In ISO, JSON Schema
- W3C/OGC GeoPARC
 - In RDFS
- W3C Time, Programme Location Core Vocabulary (LOCV), Semantic Sensor Network/Service, Observation, Sample, and Actuator (SSN/SSOS), Data Catalog (DCAT)
 - In RDFS/JSON
- CEN TC442 (BIM) Data Template standards: EN ISO 23386, EN ISO 23387, EN 17022 (SIA)
 - In native (natively XSD, LD/SIF languages)
- EC INSPIRE specifications
 - In XML/JSON (see Article 7: Encoding)
- Structural Analysis Format (SAF)
 - In XML/JSON (see Article 7: Encoding)
- National agreements: Ben Belin-USA and ILS Ontology & Engineering (OCE) how to define your Open BIM (IFC)
 - Supported by ILS Configuration Setting



Co-funded by the Horizon 2020

H2020 Project IM-SAFE - 958171

51



What standardization do we still need?

- No more new data standards!
- Instead, we have to select, delete, ignore
- And to reformulate & integrate, combine or align

- Both, for technologies and specs
- Focus on complementarity, future-proofness & world-wide coverage


- Note, we cannot keep all: “Transform is Trouble”
- Better link them flexibly in standard ways



Co-funded by the Horizon 2020


H2020 Project IM-SAFE - 958171

52



What standardization do we still need?


- Align underlying technology
 - Opportunity for JSON-LD (“web devs meets semantics”)
 - Opportunity for GraphQL next to SPARQL
 - Opportunities for SHACL / GraphQL Schema (closed world assumption)
- Integrate/link BIM and GIS specifications better
 - IFC <> GML/CityGML
- Design one data language in bSI (for bSDD) and CEN TC442
 - Discussion started in TC442: IFD versus EN ISO 23387 versus SML
- Reuse semantic resources especially W3C SSN/SOSA



Co-funded by the Horizon 2020

H2020 Project IM-SAFE - 958171


53



Key choices & alignments needed (whatever the technology outcome...)

- We get compatible semantics
- Fundament for semantic data eco-system


- W3C, OGC, bSI, EC specifications, all linked
 - SML TopLevel, SSN/SOSA, FOAF, QUDT, ...
 - GML, CityGML, GeoSparql, ...
 - IFC4, bSDD
 - INSPIRE



Co-funded by the Horizon 2020


H2020 Project IM-SAFE - 958171

54



Open questions we need feedback

- What standards DO you miss?
- What key existing standards not yet addressed?
- What's your view on way forward?
- Under which governance?
 - CEN <> ISO >>> 'Vienna agreement' in place
 - ISO/CEN <>bSI <> OGC >>> 'partners'
 - Need for something new on top? Or role ISO?



Co-funded by the Horizon 2020
research and innovation programme

H2020 Project IM-SAFE - 958171

55



Q&A



Co-funded by the Horizon 2020
research and innovation programme

H2020 Project IM-SAFE - 958171

56



Thank you for your attention

www.IM-SAFE.eu
www.platformbruggen.nl



57