bSI UML Model Report – Part 1

Harmonised UML Report – Introduction and Background

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Foreword

The purpose of this report is to describe the process followed in order to arrive at a harmonised IFC schema extension for infrastructure, building on previous work on Alignment, Overall Architecture and IFC Bridge (published by bSI as a Candidate Standard and known as IFC 4.2). The proposed extension schema is documented using UML language and diagrams and incorporates the development work completed over 2018-2019 for Rail (and its sub-domains), Road, Ports & Waterways (collectively referred to as the domain projects in this document) and Common Schema. The full report is in 5 Parts, the first being this present document that provides the background introduction to the full harmonisation process and separate parts for each of the three project domains plus a part covering all the shared infrastructure elements.

Note that the Common Schema project responded to the identified needs of the domain projects to develop proposed extensions for specific common areas (such as spatial structure, geotechnics, earthworks, etc.), but during the harmonisation process, many other shared elements were identified and collected together into the common schema package. For the purposes of this report, all those are collectively treated as shared infrastructure elements.

The complete 5-Part Report is submitted to the bSI Standards Committee Executive as documentation in support of the adoption of the of the harmonised IFC infrastructure schema extension as a Candidate Standard.

Report Structure

This document forms Part 1 of the Report and is intended to explain the background, context and overall process followed to deliver the harmonised schema. The other four Parts are auto-generated directly from the harmonised UML conceptual model that has been created collaboratively between the separate domain project teams (in a process that will be explained further in this document). Those Parts document all proposed new entities, predefined types, modified entities (from the IFC 4.2 base line) and any entities proposed to be deprecated as part of this harmonisation work.

Part 2 reports the UML conceptual model that deals with all those concepts and specifications that are shared across the separate project domains (referred to collectively as shared infrastructure elements).

Parts 3-5 report the UML conceptual models that deal with the separate project domains of Road, Rail and Ports & Waterways: it is important to understand that these are self-contained and complete reports for each of those domain projects and therefore may include common schema concepts that are relevant to that separate domain; that leads to a lot of duplication and repetition in those Parts. It was deemed appropriate to allow that duplication in order to maintain the integrity of those Parts, which stand as important deliverables for the Stakeholders for those domain projects.

Executive Summary

Throughout 2018/19 buildingSMART ran a suite of parallel projects to deliver proposals for IFC extensions for infrastructure each with a focus on a specific project domain. There was general recognition of the need for a formal collaborative harmonisation process following a Workshop convened by the Common Schema Project on 14-15 January 2019 in Helsinki. That Workshop included representatives from all the domain projects and marked a significant move in the establishment of a strong collaboration between the Railway Room and the Infrastructure Room. A Delivery Plan was developed and refined in conjunction with Harmonisation Workshops held in June, September, October and November 2019. A robust harmonisation process was agreed in the leadup to the Beijing Summit and implemented over the period between October 2019 to January 2020.

The harmonisation process was based on a centralised (cloud) environment that hosted a structured UML conceptual model based on a UML encoding of IFC 4.2, therefore including the alignment specification and the Bridge candidate standard. The software tool used was Enterprise Architect, which allowed the harmonised model to be organised into a hierarchy of packages representing each of the separate project domains (plus the baseline IFC 4.2 encoding and the Common Schema) at the top level, with sub-packages established to suit the needs of each project domain. Since all the conceptual models were held in a single place, inconsistencies and conflicts could be identified and resolved in a collaborative process.

The final unified UML conceptual model is documented in this report (generated directly from Enterprise Architect), but it also forms the basis for the delivery of the formal specification using ifcDoc. The complete harmonised UML conceptual model can be exported from Enterprise Architect and imported (with some minor tweaks) into ifcDoc and merged with the entire IFC specification.

A critical part of this process was the development of UML Modelling Guidelines (see Appendix A) that describe the way the UML model has been built, with the general rules and patterns that have been followed. This ensures consistency, facilitates the publication process and clarity of the UML diagrams presented in this report, and smooths the transfer process from the UML model (exported in XMI format) to the ifcDoc repository. It is important to note that while 95% of the guidelines are appropriate to UML as a general-purpose conceptual modelling language, there are parts that make use of constructs supported specifically by Enterprise Architect, employed here to facilitate the harmonisation process and conversion to an IFC specification held in the ifcDoc repository.

The harmonisation process has focussed on the proposed IFC entities (new and modified existing) and associated predefined types. Some domain Property Sets have been specified as part of the domain projects, but much of that remains as a work in progress. An important next step in harmonisation (deliberately postponed until 2020) is to identify and resolve conflicts and duplication of terms in those property sets.

The ifcDoc repository will be important as we move to the next stage in this work, taking the harmonised schema and validating it through a rigorous deployment and software implementation process based on identified test cases. That work is planned for 2020 and is the subject of a separate project proposal.

1 Background and Context

Throughout 2018/19 buildingSMART ran a suite of parallel projects to deliver proposals for IFC extensions for infrastructure. These were generally concerned with linear infrastructure and have been operating across differing time frames (Figure 2). It was recognised that these domain projects would be addressing several concepts that are common, so an overarching project was established called Common Schema, responsible to track those separate domain projects to identify and define common concepts (such as spatial structure, geotechnics and earthworks, utility networks, etc.) and to ensure a level of harmonisation and consistency in the development of the separate domain extensions.

Two of those projects (Road and Ports & Waterways), having completed a "requirements definition" stage, were developing conceptual models and draft schema of their proposed extensions during much of 2019. The Rail project prepared three major reports (Requirement Analysis, Conceptual Model and Data Requirements) as part of the Candidate Standard package delivered ahead of the Beijing Summit (28-31 October 2019). The Common Schema project delivered extension proposals for key areas including geotechnics, earthworks, spatial structure and kinematic envelopes. By the middle of 2019, it was recognised that there was an urgent need to harmonise the work across those domains, taking into consideration the work previously completed ahead of the IFC Bridge Candidate Standard.

There was unanimous agreement across all the infrastructure project domains that our collaborative goal would be to deliver a single harmonised IFC schema extension proposal that incorporated all the proposed extensions (road, rail, ports & waterways and common schema). It was agreed that this would be built upon the baseline defined by IFC 4.2 incorporating the alignment specification, the Bridge candidate standard and the schema extensions that came out of the work of the Overall Architecture project completed in 2017.

The context of this harmonisation work is the bSI standards development process shown in Figure 1. The proposed harmonised extensions have completed the development phase and, subject to a Standards Committee (SC) vote, will move to the approval phase as a unified candidate standard.

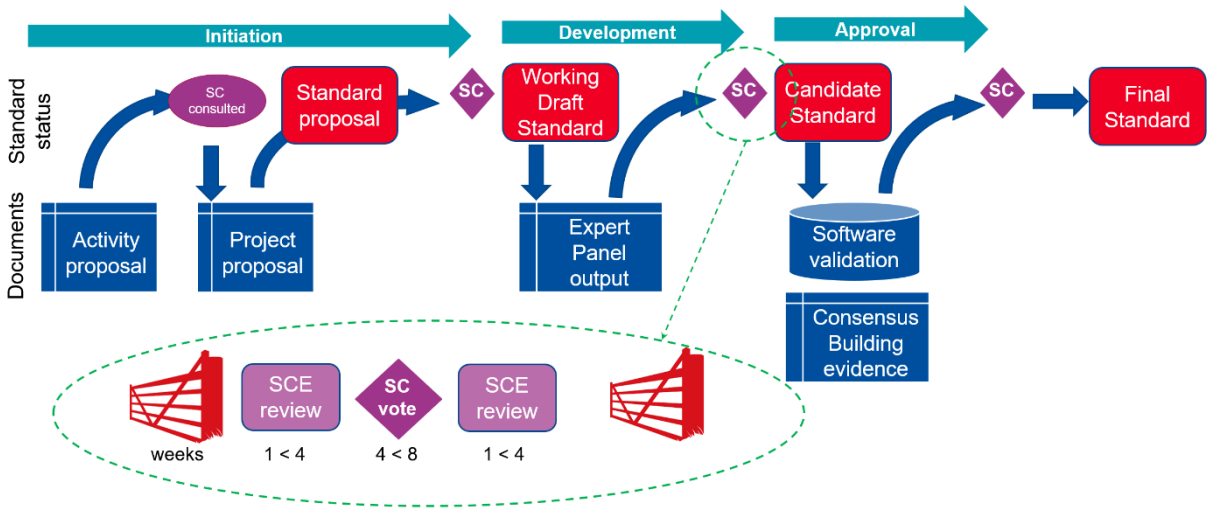

Figure 1 – bSI Standards development process

1.1 International Consensus

Evidence of international consultation through the participation Expert Panels is a critical part of the Development Phase of the process (Figure 1). Two of the domain projects involved in the harmonisation process (Bridge and Rail) have already been adopted as Candidate Standards. For the purpose of this document, it is necessary to report briefly on the Expert Panels held for Road, Ports & Waterways and Common Schema work.

1.1.1 IFC Road Project

The Road Project held a comprehensive set of Webinar-based Expert Panels to report progress to the international community and seek feedback.

Phase 1 - Requirements Analysis

EP1, 2018.05.15 Use Cases and Road process diagram
(Registered 15; Attended 14)

EP2, 2018.06.29 Taxonomy
(Registered 55; Attended 36)

EP3, 2018.09.14 Draft IFC Road Requirement analysis Report
(Registered 67; Attended 42)

EP4, 2018.11.15 Requirement Analysis report and Phase 2 Draft execution plan
(Registered 35; Attended 21)

Phase 2 – IFC Schema Extension and Deployment

EP5, 2019.05.31 DRAFT Conceptual model
(64 comments received, + 10 input documents from Experts, Registered 308)

EP6, 2019.08.29 DRAFT Schema extension
(36 comments received, Registered 248; Attended 125)

EP7, 2019.10.24 DRAFT IFC Property definitions
(40 comments received+ 7 input documents, Registered 155)

EP8, 2019.12.11 Implementation support and dissemination
(5 comments received, Registered 224)

Summits:

The project has been reporting the results and ongoing work at the summits in 2018, Paris and Tokyo and 2019, Dusseldorf and Beijing, and the final result including the harmonisation work was presented at the summit in Oslo March 2020.

Over 250 comments received and documents giving feedback from organisations worldwide. Feedback questionnaires were sent out following the webinars, these also gave an opportunity from the international community to comment on the work and to ensure it was relevant and in line with the needs of the industry.

All webinars have been documented and recorded, anyone who registered has had access to the recording in case they were not able to attend the webinar itself.

1.1.3 IFC Ports & Waterways Project

The Ports & Waterways project held a mixture of Webinars and Summit presentations.

2018-03-27	buildingSMART Standards Summit Paris Ports and waterways session in the Infrastructure Room
2018-10-18	buildingSMART Standards Summit Tokyo Ports and waterways session in the Infrastructure Room
2018-12-12	“Ports and waterways requirements analysis” Online Webinar
2019-03-27	buildingSMART Standards Summit Dusseldorf Ports and waterways session in the Infrastructure Room
2019-11-26	(rescheduled from 2019-11-19) “Review of the draft IFC based conceptual model” Online Webinar

1.1.4 IFC Common Schema Project

The extension works packages delivered by the Common Schema Project held some dedicated Expert Panel Webinars, were reported at each of the bSI Summits in 2018 and 2019 and were also subject to review as part of the domain project Expert Panels. Specific Expert Panels were:

2018-09-13	Geotechnics Expert Panel (Webinar)
2018-09-27	IDBE Discussion on Geotechnics in Singapore (Inc BRGM, France)
2018-10-19	Tokyo Summit – IDBE Meeting
2018-12-05	Earthworks Expert Panel (Webinar)
2019-01: 22-24	3-day F2F Workshop on Geotechnics (hosted by BRGM, Paris)
2019-03-29	1-day F2F Workshop on Geotechnics (following Dusseldorf Summit)
2019-09-17	Earthworks, Geotechnics & Spatial Structure (on-line discussion), part of the Stockholm Harmonisation Workshop.
2019-10-21	Cross-Domain Telecon discussion on Spatial Structure

2 Harmonisation Process

Figure 2 shows the timeline and progress of the current work program including the anticipated work going forward, subject to project approval and funding. The key part of the diagram for this Report is the left part. The right part of the diagram shows the scope of work to be undertaken in 2020 and beyond and is included only to show the on-going context of the work.

The suite of domain projects that ran throughout 2019 are shown as bands in the diagram running up to the end of 2019, noting that Ports & Waterways will actually continue as a funded project up to May 2020, though the core schema development work was completed in step with the other projects. The Bridge project completed in early 2019.

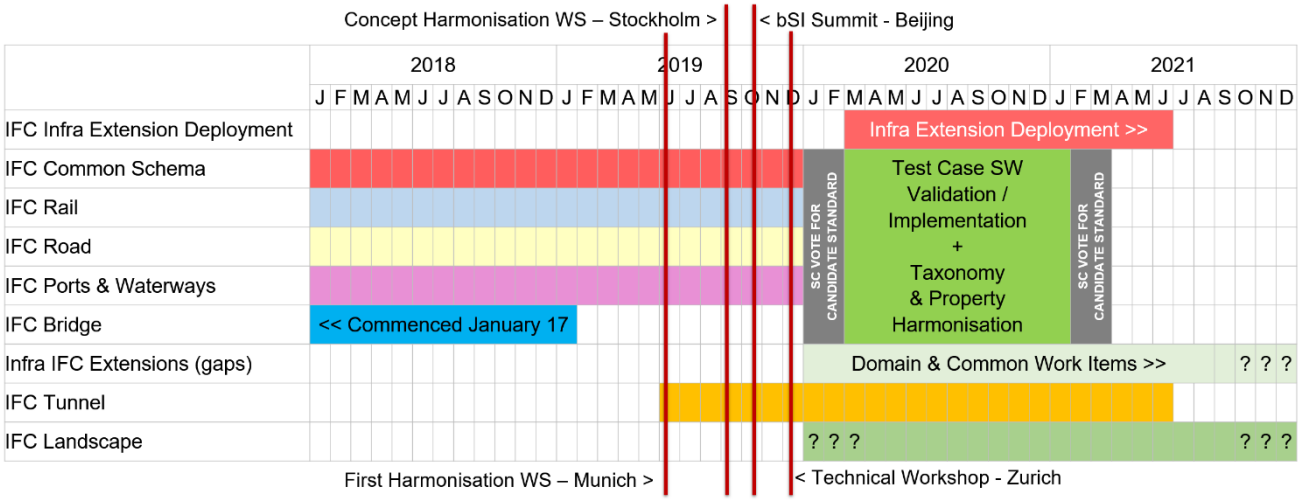

Figure 2 – Expected progress and completion of the current suite of projects

Throughout 2019, the Common Schema project hosted a series of workshops that sought to create a dialogue across all the parallel domain extension projects. The first, held on 13-14 January in Helsinki, brought together representatives from Road, Rail, Ports & Waterways and Bridge with the explicit goal to identify "user requirements for common concepts across those domains". During the months following that workshop, there was a growing recognition that we needed a clear delivery plan that brought the separate domain project work together, particularly around the need to harmonise the IFC schema extension proposals. A formal Delivery Plan document was prepared and refined in parallel with a series of Harmonisation Workshops: 26-28 June in Munich, 16-17 September in Stockholm, 31 October in Beijing and a final Technical Harmonisation Workshop on 10-11 December in Zurich.

A significant outcome from this harmonisation effort has been an absolute commitment from the leaders of each of the current projects (Rail, Road, Bridge, Ports & Waterways and Common Schema) to work towards a single unified infrastructure schema extension proposal by the end of 2019. This is significant because it means that the three domain extension proposals (which have been developed as separate projects) and the Common Schema proposals are now fully harmonised at the schema level to support effective implementation in software and a consistent use of shared concepts. Since most infrastructure projects are inter-modal (having elements from across all the infrastructure domains as well as buildings), it is essential that the schemas be consistent at the conceptual level.

To achieve this harmonisation, a shared (cloud) modelling platform was set up and, following the Beijing Summit, a UML modelling team was established with (generally) 2 representatives from each domain charged with the responsibility to enter their own domain models and work with the other team members to resolve conflicts and identify/address commonalities. A combination of regular on-line meetings, a technical face-to-face meeting in Zurich in December 2019 and discussion threads on the BSI Forum were used to identify and resolve issues that arose.

The software tool used was Enterprise Architect, which allowed the harmonised model to be organised into a hierarchy of packages representing each of the separate project domains (plus the baseline IFC 4.2

encoding and the Common Schema) at the top level, with sub-packages established to suit the needs of each project domain.

Figure 3 summarises the essential deliverables from this process. All the outputs of the work are brought together, first into a harmonised UML Report and then into a harmonised IFC schema that incorporates the infrastructure extensions.

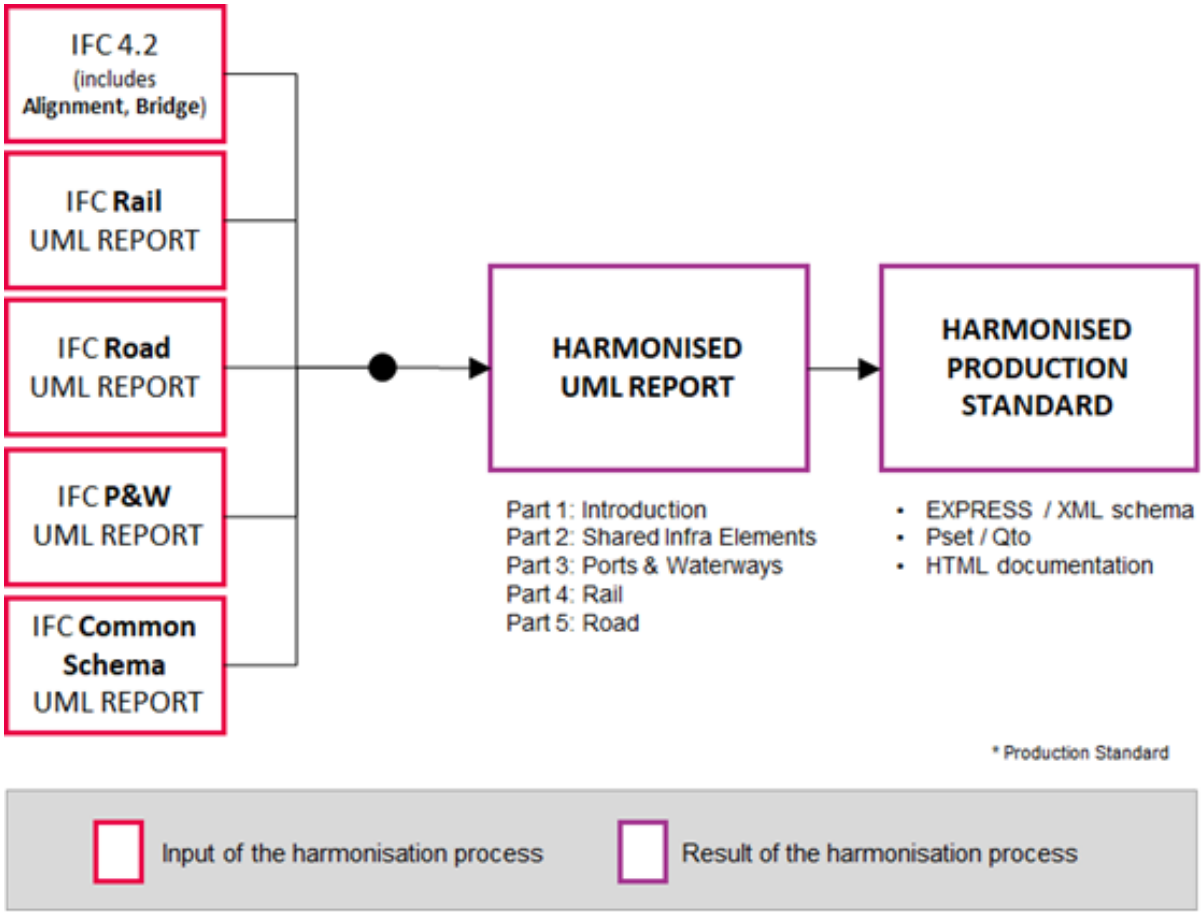

Figure 3 Outcomes of the Harmonisation Process

The deliverables shown in Figure 3 have been produced in a semi-automatic fashion from the harmonised schema held in the shared cloud environment: the four technical reports (Parts 2-5) are based on a common template; the fully-harmonised schema has been exported in XMI format and pushed into the ifcDoc repository.

A critical part of this process was the development of UML Modelling Guidelines (see Appendix A) that describe the way the UML model has been built, with the general rules and patterns that have been followed. This ensures consistency, facilitates the publication process and clarity of the UML diagrams presented in this report, and smooths the transfer process from the UML model (exported in XMI format) to the ifcDoc repository. It is important to note that while 95% of the guidelines are appropriate to UML as a general-purpose conceptual modelling language, there are parts that make use of constructs supported

specifically by Enterprise Architect, employed here to facilitate the harmonisation process and conversion to an IFC specification held in the ifcDoc repository.

The ifcDoc repository allows the schema (with infrastructure extensions) to be specified in EXPRESS and XML format and the normal HTML documentation published to the Web (including the change log that identifies all the extensions and proposed changes to the IFC schema). There will still need to be some refinements to the documentation to include information not held in the UML models, but the entity descriptions and relationships will be defined automatically. As a final step in the process, the ifcDoc web documentation will be checked by the domain teams to ensure the integrity of the harmonisation process and add that extra information (formal propositions, diagrams, etc.). The Property and Quantity Take-Off sets are held separately and will become part of the final documentation on ifcDoc as they are delivered by the separate domain projects.

Table 1 summarises the size of the proposed infrastructure extensions in terms of new entities, predefined types (PDTs), Enumeration Types, SELECT types, new type entities, modified entities and deprecated concepts. This is broken down into project domains but should not be interpreted as a measure of the impact of those domain projects on the IFC schema since many domain concepts were shifted to the Shared Elements during the harmonisation process.

Table 1 Extension Schema Statistics

	Total	Shared	P&W	Rail	Road
New Occurrence Entities	**44**	20	5	13	6
New Predefined Types	**286**	68	58	121	39
New Type Entities	**14**	5	4	5	0
New Select Types	**5**	5	0	0	0
New Enumeration Types	**25**				
Deprecated Entities	**24**				
Modified Entities	**34**				

3 Next Steps

The harmonisation process has focussed on the proposed IFC entities (new and modified existing) and associated predefined types. Some domain Property Sets have been specified as part of the domain projects, but much of that remains as a work in progress. An important next step in harmonisation (deliberately postponed until 2020) is to identify and resolve conflicts and duplication of terms in those property sets.

The ifcDoc repository will be important as we move to the next stage in this work, taking the harmonised schema and validating it through a rigorous deployment and software implementation process based on identified test cases. That work is planned for 2020 and is the subject of a separate project proposal.

4 Scope of the Harmonised Schema

The following sections provide a general indication based on initial scope statement of each domain project, showing also what is out-of-scope at this stage.

4.1 Rail Project

Domain Track

In-scope

- Panels (Track, Turnout, Dilatation)
- Objects of Track (Rail, Sleeper, Fastening)
- Ballast
- Slab track
- Rack Railway
- Elements of turnouts
- Track covering (for level crossing, light rails, tramways)
- Track alignment stops like buffers
- Track bench
- Lubrication
- Special equipment for shunting yards
- Track spatial structures
- Survey element
- Alignment

Out of scope

- Subsoil (should be treated by ifcRoad)
- Underground (should be treated by ifc Earthworks)
- Drainage of track
- Temporary objects
- Functional views and conditions
- Special equipment for depots (turntable etc.)

Domain Energy

In-scope

- Substations
- Earthing and current return
- Overhead constructions and supporting structures
- Overhead lines
- Switching post
- Suffix post
- Fundation and Fundaments
- AC and DC Installations
- Protection devices (Birds, touch protection)
- Lineside signs and signals

Out of scope

- High voltage lines (Distribution network)
- Power plants
- Rigid catenary
- Catenary for Tramways and light rails
- Trolley bus overhead lines
- Induction lines (non-contact system)
- Third rail (mounted trackside / on track panel)
- Equipment for diesel powered trains
- Equipment for steam powered trains
- Equipment for gas powered trains
- Installations for consumption measurements

Domain Signalling

In-scope

- Lineside installations
- Main signals (as standalone objects, simplified modelled)
- Shunting signals
- Relays
- All types of trackside signals and signs as information for train driver (no specific function yet)
- ETCS/CTCS lineside equipment (Balises, signs etc)
- Barriers for level crossing
- Warning signals at level crossings for road and pedestrian traffic (lights and bell)
- Level cross protection signs for rail traffic
- Operation and Surveillance equipment (Computer, Cabinets, Video cameras)
- Turnout machines and mounting installation, incl. manual switch lever
- Turnout heating (only electrical)
- Signalling cables (incl. trench, cable canal)
- Trackside sensors (Hotbox, etc.)
- Axle counter

Out of scope

- Signal components (like aspect lampes etc.)
- Logical and functional detailed aspects
- Small electronical components (fuses, etc.)
- ETCS/CTCS on board equipment
- Mechanical signalling equipment (bares, steel cables)
- Rods / turnout lock
- Gas turnout heating
- Signals for tramways and light rails
- Natural hazards sensors/surveillance
- Dynamic axle weight device

Domain Telecom

In-scope

- Mainly trackside equipment
- Terminals
- Cabinets and shelters
- Cabling (cables and connectors)
- Cable Routing (Laying installations)
- Sensors (snow, wind etc.)
- Antennas
- Towers and Poles
- Active Networks
- Base Transceiver Stations (BTS)
- E-Utran Node B for LTE (4G)
- Lineside telephones
- Vending and ticket machines
- Tetra Networks (limited mobile network)

Out of scope

- Centrals (inside equipment)
- Servers, terminals, computers, consoles (inside equipment)
- Radio inside devices
- Operation and surveillance installations
- CCTV
- Security systems (Access controls, batch readers etc.)
- Customer information systems (screens, loudspeakers)
- Functional modelling

4.2 IFC Road

In-scope:

- Linear road types:
  - Controlled access highway;
  - Dual carriageway;
  - Single carriageway;
  - Street;
  - Bicycle path;
  - Footpath.
- Junction types:
  - Interchange (grade separated):
    - overpass;
    - underpass;
    - ramp.
  - Intersection (at grade):
    - Intersecting roads (3, 4, …, 7 way);
    - roundabout or traffic circle;
    - pedestrian crossing;
    - bicycle crossing.
- Road components, elements and equipment: Some of these concepts may be identified as being common and handed over to the common schema project and some may be developed by the IFC Road project team for the Common Schema project.
  - Road structure (road prism (road body)
  - Road guard elements
  - Road sign elements
  - Road paving components
  - Utilities
  - Lighting, telecommunications and power
  - Storm-, surface- water and drainage systems
  - Other underground facilities located in the road body.

Expected to be covered (but not subject to validation tests):

- paved surfaces of:
  - parking lots;
  - service areas;
  - toll plazas;
  - parking buildings;
  - ferry ports;
  - airports.

Out of scope:

- Equipment and buildings of the above listed paved surfaces;
- railway crossings;
- tramways;
- city scape / urban planning.

The following developments are out of scope for IFC Road because they are delivered through the Common Schema project:

- Earthworks cut and fill design;
- Geotechnical investigations;
- Geotechnical constructions.

4.3 Ports & Waterways Project

In-scope:

- **Complex types**
  - Cargo ports (Container, dry bulk, liquid bulk, roll-on roll-off)
  - Passenger terminals (cruise, ferry & foot traffic)
  - Marinas & leisure terminals
  - Ship & boat building yards
  - Marine & water maintenance
  - Offshore support/construction base
  - Canal complexes/networks
  - Channel regulation & water control
  - Ship lock complexes
- **Facility types**
  - Breakwaters
  - Revetments
  - Sluices, spillways &control gates
  - Ship-lifts
  - Hydraulic lift docks
  - Slipways
  - Dry docks
  - Floating docks
  - Wharf/Quays & Piers/Jetties
  - Ship locks
  - Anchorages
  - Navigational channels/areas
  - Storage/working areas
  - Intermodal yards/areas
- **Marine Products & Components**
  - Cargo & Vehicles
  - Cranes
  - Marine dock/lock gates
  - Aids to navigation (buoys, lights, markers etc.)
  - Fenders & bollards
  - Mooring systems & devices
  - Rock armour systems

Expected but not validated

- **Complex types**
  - Lifeboat & coast guard stations[1]
  - Military complexes[1]
- **Facility Types**
  - Retaining walls
  - Port/Complex Roads[2]
  - Railways (for cranes & vessel transfer systems)[2]
  - Tunnels
  - Buildings[3]
- **Geology, hydrology & geotechnics[4]**
  - Geo strengthening
  - Hydrology/water elements
  - Earthworks

Out of Scope

- **Complex types**
  - Coastal protection
  - Erosion protection
  - Flood protection
  - Power generation (Hydroelectric, tidal, wave, offshore wind)
- **Facility types**
  - Seawalls
  - Groynes
  - Dams/levees
  - Weirs

1. Is considered in scope due to similarities with other complex types being addressed but will not be explicitly validated.
2. Roads, railways, bridges & tunnels are considered vital facilities within ports & waterways but are included as referenced facilities where their content will be developed by other existing projects.
3. Entrance gates and buildings form the use of existing functionality for buildings within the IFC, with an extension of the possible typing mechanism to provide identification and classification of maritime specific buildings.
4. Geology, hydrology & geotechnics features are key to the maritime domain but have been handed off to the common schema project for common development.

Appendix A – bSI UML Modelling Guidelines

Appendix B – IFC Rail Contributor List

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Trafikverket	Trafikverket	Lars Wikström, Jitka Hotovcova, Peter Axelsson
TUM	TUM	André Borrmann, Sebastian Esser

Note: names and companies are simply listed alphabetically

Appendix C – IFC Road Contributor List

Company	Name
Stakeholders, bSI InfraRoom Project Steering Committee (IRPSC)	
Apogea, *Spain*	Jesús Valderrama
APLITOP, *Spain*	Francisco Navarette
AutoDesk, *global*	Marek Suchocki
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The Danish Road Directorate, *Denmark*	Svend Kold Johansen
The Finnish Transport and Infrastructure Agency, *Finland*	Tarmo Savolainen
Korea Institute of civil engineering and building technology, **KICT**, *Korea*	Dr Hyunseok Moon
MIDAS, *Korea*	Sangyoon Kim
Modélisation des informations interopérables pour les infrastructures durable, **MINnD**, *France*	Christophe Castaing
The Norwegian Public Roads Administration, *Norway*	Hanne Hermanrud
Nye Veier, *Norway*	Per Qvalben
The Swedish Transport Administration, *Sweden*	Peter Axelsson
Trimble, *Global*	Duane Gleason

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Team members	
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AEC3	Thomas Liebich
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BMVI, *Germany*	Štefan Jaud (TUM), André Borrmann (TUM)
CRBIM, *China*	Zhao FeiFei, Dongxu Yan, Tianhua Zhu, Hanbin
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The Swedish Transport Administration, *Sweden*	Karin Anderson Lars Wikström (Triona)
Technical University of Munich, TUM, *Germany*	Štefan Jaud (TUM), André Borrmann (TUM), Sebastian Esser (TUM)
Trimble, *Global*	Johnny Jensen

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Co-project leader:	Karin Anderson
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Technical lead:	Juha Hyvärinen, Jhy OY
IFC lead:	Sergej Muhič, Siemens
Conceptual model lead:	Lars Wikström (Triona) STA
Validation lead:	Štefan Jaud (TUM) BMVI
Property lead/OGC Liaison:	Johnny Jensen, Trimble

WP5, Prototypical implementation, Participating software vendors

Aplitop, Autodesk, Bentley, KICT / Midas IT, TUM, Autodesk, TUM, Obermeyer/ProVI, 12D, Trimble, AKG, Tool, Card-1, CGS-Labs, Istram, SierraSoft, Catenda

Note: names and companies are simply listed alphabetically