Requirement Analysis Report

InfraRoom

Project: IFC Road
Work Package: WP2

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Date: 2018.12.14
Version: V2.1
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1 METHODOLOGY

This report presents the Phase 1 results, focusing on identification and investigation of requirements for the upcoming extension of IFC into the domain of roads. The work on Work Package 2 (WP2) Requirement analysis started in January 2018 and finalized in October 2018, as the report was presented at the buildingSMART International summit in Tokyo. The report has been created by the joint efforts of the project partners: Korea Institute of Civil Engineering and Building Technology (KICT – Korea), APLITOP (Spain), APOGEA (Spain), China Railway BIM Alliance (CRBIM - China), BMVI (Germany), The Finnish Transport Agency (FTA - Finland), The Swedish Transport Administration (TRV - Sweden), Autodesk (world-wide), and the MINnD project (France).

1.1 PROJECT AIM

The project aim is to extend the IFC schema into the domain of roads. The extension of the IFC schema is aimed at describing road semantics and geometry to be exchanged in the context of a project (a “project” could be any undertaking during the road life-cycle, such as planning, construction or maintenance operations on a specific part of a road or road network). Phase 1 of the project focuses on capturing requirements for the IFC Road extension and in cooperation with the Common Schema project (for more information see the Project Execution Plan1). The Common schema project is responsible for identifying and developing common concepts across the various domains, such as spatial structure, earthworks or geotechnical concepts. By transferring certain concepts for development to the Common Schema project, the IFC Road Project Team also aims at refining the initial scope set out in the Project Proposal2.

1.2 METHODOLOGY

The extension projects within the InfraRoom are based on IFC4 and continued work delivered in the IFC4.1 Standard.3 IFC4.1 includes various basic infrastructure concepts, such as alignment, and is the basis for future extensions for infrastructure. Overall Architecture, part of the IFC4.1 delivery, also provides Guidelines4 for future extensions and the IFC Road Project Team have based their work on these guidelines.

The IFC Road Project Team have also based their Use cases on the identified Use Cases in Overall Architecture. The Overall Architecture had performed an extensive survey among infrastructure experts on the required use cases for the extension of IFC into the domain of infrastructure. These Use Cases have been supplemented with road specific use cases and have been put through an international consensus process. Through Expert Panels, Road experts were asked to provide their views on the importance of the use cases for this development, based on a proposal set forward by the Project Team. This was done through polling during the panel.5 In addition to the importance of Use Cases, road experts were requested to provide requirements and input for the listed Use Cases

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1 Project Execution Plan available through this link: https://buildingsmart.sharefile.com/d/semi674ecf324715a
2 Project Proposal available through this link: https://buildingsmart.sharefile.com/d/3857bc047edc4b6d8
3 IFC4.1 International Standard available through this link: https://www.buildingsmart.org/standards/standards-tools-services/
5 For the outcome of the Polls, please refer to: https://buildingsmart.sharefile.com/d/3a84b3a561d24c4ba
Example of these requirements are type of models being exchanged and information found on plans.

As Use cases also describe the required exchanges, Chapter 3 follows out of the IFC Road Process Map. The IFC Road Process Map focuses on the involved actors and processes a road object goes through during its life cycle (par.2.3.1). It is a consolidated process map, in which input from various countries has been incorporated to create an international Process Map. Please refer to Chapter 2.3 for a list of the regional Process Maps. Experts were requested to review the international IFC Road Process Map and provide input through the Expert Panels.

In Phase 1 the IFC Road Project Team also started work on the IFC Road Taxonomy. Although the entire IFC Road Taxonomy is not part of this report, Experts were requested to provide their needs regarding necessary entities and concepts. Their needs have been collected in a Questionnaire after the presentation of the Taxonomy at an Expert Panel. The Questionnaire has provided input for Chapter 2 in and out of scope decisions. The IFC Road Taxonomy has been captured in a database and is input for the IFC schema extension to be created in Phase 2.

The required geometric representations and placement chapter 4 is similarly to previous chapters based on the Overall Architecture guidelines, but input has also been formed during three project team workshops where valuable input from experts at Expert Panels were taken into consideration. A concern regarding geodetic coordinate reference systems was addressed by the experts and this has been clarified in the last paragraph of chapter 4.

An essential part of the IFC Road Project output is a set of Model View Definitions (MVDs). These are explained and presented in chapter 5. The team has based the definition of these on experience and decisions from the IFC Bridge project and the Overall Architecture guidelines. The IFC Road project is aiming to limit the number of MVDs to four and match them to the in scope Use Cases.

1.3 NEXT STEPS

The Requirement analysis report is the end deliverable for Phase 1. It defines the in and out of scope decisions on which the IFC schema extension for Roads will be developed. The next steps for Phase 2 include:

- Continued identification and description of required geometric and semantic information;
- Continuation of the work on IFC Road Taxonomy;
- Continued participation and requirement delivery for Common Schema project;
- Creation of the conceptual model, UML diagram and report;
- Identification of IFC Road properties to be included in the documentation and bSDD;
- Creation of the Candidate Standard (IFC schema extension for roads);
- Definition of Model View Definitions;
- Early testing and deployment of the Candidate standard by software vendors;
- Creation of documentation.

Chapter 2 describes the in and out of scope decisions on which the current IFC Road schema extension will be based. Not all identified Use cases can be covered at this time, due to restricted

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6 Please refer to the Project Proposal for more information: https://buildingsmart.sharefile.com/d/s857bcb47edc4b6d8
resources or complexity of the use case. It is, therefore, expected that further extension might be needed and, depending on the needs from stakeholders, the bSI InfraRoom is open to starting a new project in the future.
2 SCOPE STATEMENT

This Chapter describes the IFC Road scope, by first focusing on requirements such as Spatial requirements, the requirements of various networks e.g. road, drainage etc, asset management and early planning. These requirements are input for the scope decisions (par.2.6).

2.1 SPATIAL REQUIREMENTS

In construction and engineering a building is often spatially decomposed, i.e. a building is decomposed into storeys and spaces. Exchanging information of a building model using IFC during the construction and engineering phase has a similar spatial decomposition (source: Common Schema, 2018):

- Site;
- Building;
- Storey;
- Spaces.

This paragraph focuses on the requirements coming from Road projects for spatial decomposition in IFC. It summarizes the input delivered to the Common Schema project as part of the Spatial Structure Questionnaire (Common Schema project, 2018). As explained in the questionnaire, the spatial structure referred to in this paragraph is the breakdown of a site into facilities and its parts (in blue in Figure 1).

Requirements from IFC Road regarding the spatial breakdown are based on the hierarchy already present in Road design and projects and is similar to the spatial breakdown in buildings:
- Site: a road project or contract can be broken down into multiple sites (see Figure 2);
- Road: e.g. representation of the road under improvement.

A concept that is specific to roads (and railroads for that matter) and differs from buildings is the alignment. All elements along as well as the road itself usually reference the alignment as the central object for positioning and orientation (similar to a local coordinate system and axes in buildings). Therefore, the alignment has to be put in context that it is assigned to a specific Site. In the example illustrated in Figure 2, the main alignment of the road would be assigned to the Site complex (covering the whole Project); the complex is broken down to Site elements (A...E), each of which may contain other alignments for specific parts such as exit ramps). One Site can thus have many alignments.
Spatial as well as physical elements can be positioned along alignments. Also, the geometry of an alignment (its axis) should be reusable for sweep geometry. With spatial elements we are referring to spaces reserved for a specific function such as Road, Carriage way, kinetic envelopes etc. Physical elements are elements that interact with the environment and are assigned to spatial elements in the project (i.e. spatial) structure.

As described above, the alignment of a road is used to locate objects, including spatial elements. In addition to being positioned using coordinates, spatial elements should be relatable to each other as well as to physical elements. An example to illustrate this need: in the design phase it would be helpful if the road clearance (space) is relatable to a certain part of the road (structural) for clash detection purposes.

2.1.1 SPATIAL STRUCTURE ELEMENTS VS ZONES

The main distinction between spatial structure elements and zones is the ability for their instances to overlap. Whereas the zones can overlap spatial structure elements should not and should produce an error in clash detection procedures. Taking the building as an example, it is typically broken down into stories, spaces and particular areas of spaces that might overlap. This breakdown can be translated into a road in a similar way: a road can be broken down into spatial elements that are not allowed to overlap such as carriage ways and green areas and those that have to allow crossing such as lanes.

A good example of where zones might be applicable is an intersection (Figure 3). Wherever lanes merge or overlap, for example in roundabouts and crossings, zones can be used for representing such an overlap and possible usage of same space by cars and pedestrians.
However, IFC Road does recognize that there are situations where laterally overlapping areas should not be allowed, e.g. a median strip cannot overlap a road lane. Regardless, we deem zones as the appropriate way of modelling roads laterally. Firstly, it is not always the case that overlapping is not allowed (see above for the example of lanes in junctions) and secondly the lanes are not part of the strict acyclic project breakdown structure. In conclusion, IFC Road would at least require a longitudinal breakdown into road segments (see Figure 2 and Figure 5) and a lateral breakdown of the road in for instance lanes (see Figure 4).

Example of the lateral breakdown would then for instance be: road, median strip, and lanes. While the longitudinal breakdown would refer to a road being broken down into segments along an alignment (Figure 5).
2.1.2 LIFE CYCLE STAGES
The spatial breakdown of a road can change along the life cycle stages of a road, e.g. during the design and construct phase the spatial breakdown can be different from the breakdown required for asset management. However, an information exchange takes place in one project for one of the stages of a road’s life cycle. IFC Road, therefore, assumes that the required spatial breakdown should be consistent within that exchange.

2.2 REPRESENTATION OF SYSTEMS

2.2.1 ROAD NETWORKS
Road Authorities often have entire road networks saved in their Asset management repositories. IFC Road does not per-se require the entire network of a country to be represented in one IFC file. As an information exchange often encompasses only a certain stage of the design and construction phase. Which in turn often only refers to part of the road being improved, not the entire network. However, IFC Road would like to emphasize, that for the hand-over to asset management, representation of the entire network should not be excluded in future extensions.

Moving on to geometric representation, spaces in buildings have a geometric representation. IFC Road would require a similar approach, where spaces on a road are represented using simplified geometry. An example of these types of simplified geometry are kinetic envelopes of vehicles and clearances of...
roads. IFC Road does not expect to develop full 3D geometric representation of spaces or spatial elements.

### 2.2.2 OTHER NETWORKS

As part of an information exchange in a typical road project, it is necessary to be able to use other network systems. These other networks co-exist and integrate in various ways with the road network.

- A drainage system is more or less a fully integrated part of the road system.
- Utility systems, such as water supply, wastewater, gas and oil supply often share space with a road. However, beyond shared space there is no direct connection between the systems neither from a technically point of view nor its function to support transportation flow.
- Utility systems, as electricity and telecommunications can be a fully integrated part of the road system as street lighting or traffic signalling or separate systems completely independent of the road system.

The IFC Road project assumes that other ongoing InfraRoom projects will identify similar needs and that the Common Schema project will develop a common solution for this.

### 2.3 PROCESS MAP AND EXCHANGE SCENARIOS

The international IFC Road Process Map can be found in a separate PDF for readability purposes, available through this link: [https://buildingsmart.sharefile.com/d/sb92d174a2154b678](https://buildingsmart.sharefile.com/d/sb92d174a2154b678).

The process map depicts the processes and actors participating during the entire life-cycle of a road object. The IFC Road Process Map was based on the developments in Overall Architecture and IFC Bridge (WP1). Based on these Process Maps, the international IFC Road Process Map was created by consolidating these with Process Maps from the following regions:

- Korea (provided by KICT);
- Sweden (provided by TRV);
- Spain (provided by APOGEA);
- United States of America (provided by Federal Highway Agency- FHWA);
- United States of America (provided by WisDOT);
- France (provided by the MINnD Project).

#### 2.3.1 ACTORS & PHASES

The actors and the phases have been compiled from different sources and an in-depth description can be found in [ANNEX 1: PROCESS MAP](#).

From the compiled data of the different process maps, the common denominators have been determined. Following **actors** have been identified:

- Land surveyor;
- Asset manager;
- Environmental engineer;
- Transportation engineer;
- Road designer;
- Project manager / Public authority;
- Geotechnician;
- Other domain engineers;
- Estimator;
- Asset owner;
- Contractor;
- Inspector;
- Maintenance manager.

The lifecycle of a road object can be chronologically divided into the following phases:
- Briefing;
- Preliminary Design;
- Detailed Design;
- Final Design;
- Bidding;
- Construction;
- Asset management and maintenance.

### 2.3.2 EXCHANGE SCENARIOS

The international IFC Road Process Map can be found in a separate PDF for readability purposes, available through this link: [https://buildingsmart.sharefile.com/d/sb92d174a2154b678](https://buildingsmart.sharefile.com/d/sb92d174a2154b678).

The actors communicate and exchange information for the duration of a road project. Some exchange scenarios are a mere textual communication (denoted with a brief), while others include a digital model (depicted with a file). The former are not of interest in this project, while the latter have been identified throughout the road’s lifecycle and used as indicators for use cases occurring in a road project.

Table 1 lists the identified IFC Road exchange scenarios. They are grouped according to the underlying model definition. The models are numbered and refer to the IFC Road Use cases from Chapter 3.

<table>
<thead>
<tr>
<th>Model ID</th>
<th>Description</th>
<th>Exchange Scenario(s)</th>
<th>IFC Road ID</th>
<th>Use Case(s)</th>
<th>MVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Initial state model</td>
<td>Road designer</td>
<td>Land surveyor</td>
<td>R14</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asset manager</td>
<td>R01, R14</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Environmental engineer</td>
<td>R09</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Transportation engineer</td>
<td>R09</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Geotechnician</td>
<td>R05, R09, R14, R25, R26, R27</td>
<td>TBD</td>
</tr>
<tr>
<td>2</td>
<td>Survey model</td>
<td>Land surveyor</td>
<td>Road designer</td>
<td>R15</td>
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</tr>
<tr>
<td>3</td>
<td>Corridor model</td>
<td>Asset manager</td>
<td>Road designer</td>
<td>R02, R09, R15, R29</td>
<td>TBD</td>
</tr>
<tr>
<td>4</td>
<td>Environmental model</td>
<td>Environmental engineer</td>
<td>Road designer</td>
<td>R01, R02, R07, R09, R15, R18, R19</td>
<td>TBD</td>
</tr>
<tr>
<td>5</td>
<td>Traffic model</td>
<td>Transportation engineer</td>
<td>Road designer</td>
<td>R02, R07, R09, R15, R19, R21, R24, R30</td>
<td>TBD</td>
</tr>
<tr>
<td>Model</td>
<td>Exchange Scenario(s)</td>
<td>IFC Road</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Description</td>
<td>From</td>
<td>To</td>
<td>Use Case(s)</td>
<td>MVD</td>
</tr>
<tr>
<td>6</td>
<td>Road design model</td>
<td>Road designer</td>
<td>Project manager / public authority</td>
<td>R01, R02, R06, R07</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other domain engineers</td>
<td>R02, R03, R05, R08, R09, R29</td>
<td>TBD</td>
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<td></td>
<td></td>
<td></td>
<td>Estimator</td>
<td>R03, R04, R09</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Constructor</td>
<td>R03, R04, R08, R09, R10, R17, R25, R29, R30</td>
<td>TBD</td>
</tr>
<tr>
<td>7</td>
<td>Geotechnical model</td>
<td>Geotechnician</td>
<td>Road designer</td>
<td>R02, R09, R26, R27, R28</td>
<td>TBD</td>
</tr>
<tr>
<td>8</td>
<td>Other domain model (drainage, lighting, bridge, tunnel)</td>
<td>Other domain engineers</td>
<td>Road designer</td>
<td>R02, R08, R09, R29</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Project manager / public authority</td>
<td>R01, R06, R07</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Constructor</td>
<td>R08, R09, R10, R17, R29</td>
<td>TBD</td>
</tr>
<tr>
<td>9</td>
<td>Model for construction</td>
<td>Contractor</td>
<td>Project manager / public authority</td>
<td>R01, R06, R07, R29</td>
<td>TBD</td>
</tr>
<tr>
<td>10</td>
<td>As-built model</td>
<td>Surveyor</td>
<td>Contractor</td>
<td>R11, R12</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Project manager / public authority</td>
<td>R01, R06, R07, R12</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asset manager</td>
<td>R01</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maintenance manager</td>
<td>R11, R12, R13</td>
<td>TBD</td>
</tr>
<tr>
<td>11</td>
<td>Asset management model</td>
<td>Maintenance manager</td>
<td>Project manager / public authority</td>
<td>R01, R06, R07</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asset manager</td>
<td>R13, R16</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Table 1 IFC Road Exchange scenarios

2.4 ASSET MANAGEMENT REQUIREMENTS

A large proportion of road asset manager’s projects and programs is maintenance of the road body and surface, this could for example be changing the wearing coarse (resurfacing), repairing damages such as pot holes (restoration) and improving the road by altering for example the cross fall to make the road safer at higher velocities (rehabilitation). These concepts require further investigation and, given that these requirements are delivered by experts and stakeholders, the IFC Road Project Team proposes to investigate these concepts in Phase 2.

The buildingSMART International Infra Room has conducted a project on Infrastructure Asset Managers BIM Requirements. The results have been published in report TR1010 available on the bSi website through this link: [https://buildingsmart-1xbd3ajdayi.netdna-ssl.com/wp-content/uploads/2018/01/18-01-09-AM-TR1010.pdf](https://buildingsmart-1xbd3ajdayi.netdna-ssl.com/wp-content/uploads/2018/01/18-01-09-AM-TR1010.pdf).
The IFC Road project team took the outcomes into consideration when defining the requirements for the IFC Road extension. The following table lists the individual requirements and how the IFC Road extension should be able to meet them.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique identification</td>
<td>Each IFC model of a road should be able to carry a unique identifier represented by an attribute of the road entity. It should include the possibility to identify both specified/designed and realised objects.</td>
</tr>
<tr>
<td>Network, geospatial, linear location</td>
<td>The model should support network, geospatial and linear placement.</td>
</tr>
<tr>
<td>Functional and physical requirements</td>
<td>The model should provide attributes and properties for capturing functional requirements, physical requirements and the realised individuals’ properties.</td>
</tr>
<tr>
<td>Dimensions</td>
<td>The model should explicitly describe dimensions in terms such as height, width etc. explained in relation to respective object type.</td>
</tr>
<tr>
<td>Spatial breakdown</td>
<td>The model should provide a flexible spatial breakdown structure.</td>
</tr>
<tr>
<td>Zone breakdown</td>
<td>The model should provide a flexible zone breakdown structure.</td>
</tr>
<tr>
<td>System breakdown</td>
<td>The model should provide a flexible system breakdown structure.</td>
</tr>
<tr>
<td>Element breakdown</td>
<td>The model should provide a flexible element breakdown structure.</td>
</tr>
<tr>
<td>Support of local/national/regional classification schemes</td>
<td>The IFC data model should allow individual elements of a BIM model to be associated with any given classification (see Overall Architecture Report).</td>
</tr>
<tr>
<td>Support of local/national/regional Object Type Libraries</td>
<td>The IFC data model should allow to connect any given Object Type Libraries with individual elements of a BIM model. To this end Linked Data approaches can be applied (see Overall Architecture Report).</td>
</tr>
<tr>
<td>Support of local/national/regional or project-specific property sets</td>
<td>The IFC data model should allow to add user-defined property sets in a flexible manner.</td>
</tr>
<tr>
<td>Simple 3D geometry for Road Asset Management</td>
<td>The Road Asset Management Handover MVD will demand explicit geometry (excluding NURBS) allowing primarily visualization and management.</td>
</tr>
<tr>
<td>Support of linking data</td>
<td>The IFC Road extension should support linking arbitrary data to individual components of an IFC model. Example of arbitrary data: sensor data linked to external data sets, photographs from inspections.</td>
</tr>
</tbody>
</table>

Table 2 Asset Management requirements (adapted from P. Jackson, 2017, Infra Asset Management report)

### 2.5 EARLY PLANNING REQUIREMENTS

For the early planning stage and project approvals process (Highways act) certain spatial elements (non-physical, see chapter 2.1) and concepts need to be considered and identified. The elements might
not be 3D modelled at an early stage and anything affecting the total land required for construction of the road (Right-of-way) should be represented in the model. The identification of these elements and their representation and properties are in scope of this IFC Road project.

**Objectives**
- High-quality modelling data transfer throughout the entire planning process that enables reuse of data in all planning phases, through construction to maintenance. Data generated in the previous phases is present during the data transfers and data can be effectively exploited.
- Modelling data can be effectively exploited in specified use of every planning phase:
  - preliminary planning: focused on the approval decision and preliminary area reservation;
  - final engineering planning: focused on the approval decision and acquisition of land;
  - construction planning: focused on construction.

### 2.6 SCOPE DECISIONS
This paragraph focuses on the in and out of scope decisions for the project and includes decisions on road types, a summary of the in scope Use cases, and lists the Use cases transferred to the Common Schema project.

#### 2.6.1 ROAD TYPES AND ROAD SPACES
The in scope road types and related spaces have been identified as the most common and widespread ones across the world. The developed IFC Road extension will be validated using examples of these road types.

**In-scope linear road types:**
- Controlled access highway;
- Dual carriageway;
- Single carriageway;
- Street;
- Bicycle path;
- Footpath.

**In-scope junction types:**
- Interchange:
  - overpass;
  - underpass;
  - ramp.
- Intersection:
  - Intersecting roads (3, 4, ..., 7 way);
  - roundabout or traffic circle;
  - pedestrian crossing;
  - bicycle crossing.

**In-scope 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.
For more details on these concepts and their definitions, please see the IFC Road Taxonomy presentation presented during Expert panel in June 2018.

- Road structure
- Road guard elements
- Road sign elements
- Road paving components
- Utilities
  - Lighting, telecom 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.

2.6.2 USE CASES
This paragraph summarizes the in and out of scope Use Cases, for more information please refer to Chapter 3.

In scope:

With validation testing:
- Visualization;
- Coordination / Collision detection;
- Quantity Take-Off;
- Design to Design (reference model);
- Machine control and machine guidance;
- Handover to asset management;
- Handover to GIS for spatial analysis;
- Initial State modelling.

Not subject to validation testing:
- 4D Construction Sequence Modelling;
- Code Compliance Checking;
- Progress Monitoring;
- As-built vs. As-planned comparison;
- Structural Analysis;
- Operation and maintenance;
- Design-to- Construction;
- Temporary works design;
- Vehicle swept path analysis.

Out of scope:
- Drawing generation and exchange;
- Design-to-Design (full model logic);
- Environmental impact assessment (EIA);
- Noise pollution simulation;
- Traffic capacity simulation;
- Traffic management;
- Dimensioning of Pavement and sub-grade.

2.6.3 COMMON SCHEMA
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.
3 USE CASES

As stated in Chapter 1, IFC Road has based its work on the “Overall Architecture guidelines” and the IFC Bridge Use Cases (WP1). In addition, a number of road infrastructure specific use cases have been identified by creating an international IFC Road Process Map (par. 2.3). This process covers the various lifecycle phases and stakeholders found in road infrastructure.

The use cases have been prioritised and several parameters are taken in to account:
- Complexity of the exchange requirements;
- Whether or not the use of BIM tools is relevant during the identified exchange;
- Whether or not the use of IFC is relevant during the identified exchange;
- Benefits and usability of a specific use case;
- Stakeholder and expert rating of Use Case importance and necessity.

As stated in Chapter 1.3, Use cases currently identified as out of scope might be covered by future extensions of the IFC schema, given that experts and stakeholders provide their needs to the InfraRoom.

Required geometric representation and semantic information is still under development and will be part of Phase 2. All Use Cases include those road objects and parameters that are deemed in scope and these are listed in the columns “Required geometry” and “Semantic information”.

Legend |
MoScow adapted to IFC Road |
--- |
MUST HAVE |
Use Cases labelled as “Must have” have been identified by experts as necessary for the current delivery of the IFC Road project in order for it to be a success. |
SHOULD HAVE |
Use Cases labelled as “Should have” have been identified by experts as important, but not critical for the current delivery of IFC Road. |
COULD HAVE |
Use Cases labelled as “Could have” have been identified by experts as desirable, but not necessary. Although these Use cases might improve user experience, time and resources in the IFC Road project restrict the development. |
WON’T HAVE |
Use Cases labelled as “Won’t have” have been agreed by stakeholders as the least-critical, lowest-payback items, or not appropriate for the current delivery of IFC Road project. |

Table 3 Legend in and out of scope Use cases, based on the MoScow-method (adapted from Clegg, 2004).
<table>
<thead>
<tr>
<th>No</th>
<th>Use case name</th>
<th>Description</th>
<th>Purpose</th>
<th>IFC exchange scenario</th>
<th>Required geometry representation</th>
<th>Required semantic information</th>
<th>Priority</th>
<th>Complexity</th>
<th>MoSCoW</th>
</tr>
</thead>
<tbody>
<tr>
<td>R01</td>
<td>Visualization</td>
<td>3D technical visualization and presentation of the road project</td>
<td>Communication of design solutions between project partners and to third parties, including the public. Visualisation of how drivers perceive the road.</td>
<td>Design application to Visualization application</td>
<td>TIN, BRep, Sweep geometry where suitable</td>
<td>Road breakdown structure, Object Types, Material (opt), Colours (opt)</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R02</td>
<td>Coordination / Collision detection</td>
<td>Coordination of domain-specific sub-models</td>
<td>Transfer and combine models to detect interferences (clashes)</td>
<td>Design application to Design/Checking application</td>
<td>TIN, BRep, Sweep geometry where suitable</td>
<td>Component types, Classification, Relationships between entities (IfcRelConnects...)</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R03</td>
<td>4D Construction Sequence Modelling</td>
<td>4D technical visualization of the construction phases</td>
<td>Organization of construction site and construction activities</td>
<td>Design application to 4D scheduling application</td>
<td>TIN, BRep, Sweep geometry where suitable</td>
<td>Road breakdown structure, Object Types, Temporal information</td>
<td>medium</td>
<td>low</td>
<td>SHOULD HAVE</td>
</tr>
<tr>
<td>R04</td>
<td>Quantity Take-Off</td>
<td>Determine quantities (volumes and surfaces) from the model</td>
<td>Basis for cost estimation and cost calculation</td>
<td>Design application to QTO application</td>
<td>TIN, BRep, Sweep geometry where suitable</td>
<td>Material, Classifications</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R05</td>
<td>Structural Analysis</td>
<td>Structural analysis of pavement and sub-grade</td>
<td>Ensure stability of the structures</td>
<td>Design application to Structural analysis application</td>
<td>Analytical Model</td>
<td>Analytical Model</td>
<td>medium</td>
<td>medium</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>No</td>
<td>Use case name</td>
<td>Description</td>
<td>Purpose</td>
<td>IFC exchange scenario</td>
<td>Required geometry representation</td>
<td>Required semantic information</td>
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<td>Complexity</td>
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<tr>
<td>R06</td>
<td>Drawing generation and exchange</td>
<td>Exchange technical drawings derived from the model</td>
<td>Submission to owner / regulation authorities</td>
<td>Design application to Submission</td>
<td>2D representation</td>
<td>All information relevant for drawing representation (line styles, symbolic representations)</td>
<td>low</td>
<td>high</td>
<td>WON'T HAVE</td>
</tr>
<tr>
<td>R07</td>
<td>Code Compliance Checking</td>
<td>Checking the road geometry for compliance with local codes and regulations (comes back to geometry and safety, accommodate varying rules, public obligations)</td>
<td>Compliance checking conducted by regulation authorities</td>
<td>Design application to Checking application</td>
<td>Alignment and superelevations</td>
<td>Design parameters (Maximum speeds, Loads)</td>
<td>high</td>
<td>low-high</td>
<td>SHOULD HAVE</td>
</tr>
<tr>
<td>R08</td>
<td>Design-to-Design (full model logic)</td>
<td>Exchange of fully parametric description of road between two distinct design applications</td>
<td>Within the same design phase, design models are exchanged between different design applications, model remains fully modifiable, all model logic is transferred</td>
<td>Design application to Design application</td>
<td>Advanced BRep (NURBS), Fully parametric model information containing model logic, constraints and dependencies</td>
<td>All information entered in the design application</td>
<td>medium</td>
<td>high</td>
<td>WON'T HAVE</td>
</tr>
<tr>
<td>No</td>
<td>Use case name</td>
<td>Description</td>
<td>Purpose</td>
<td>IFC exchange scenario</td>
<td>Required geometry representation</td>
<td>Required semantic information</td>
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<tr>
<td>R09</td>
<td>Design to Design (reference model)</td>
<td>Use model from early design phase as a reference for creating a more detailed model in the detailed design phase, limited modifiability required</td>
<td>Models are exchanged across different design phases, model from earlier phase is used as background / reference model for next phase</td>
<td>Design application to Design application</td>
<td>TIN, Faceted BRep, Sweep geometry where suitable, some parameters may be required as geometry representation</td>
<td>Classification, Material, Component types, Relationships between entities (IfcRelConnects...), Parametric information (superelevation cross sections type and construction layers)</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R10</td>
<td>Machine control and machine guidance (during construction)</td>
<td>Usage of model information for control / steering of machines such as pavers, graders, trimmers</td>
<td>Partially automated construction of the roadway</td>
<td>Design application to Machine</td>
<td>TIN, Implicit description based on alignment and Profiles, String lines (specific)</td>
<td></td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R11</td>
<td>Progress Monitoring</td>
<td>Transfer information about the progress of the construction project</td>
<td>Track and document the progress of the construction project</td>
<td>Surveying application to Visualization application</td>
<td>TIN, BRep, Sweep geometry where suitable</td>
<td>Road breakdown structure, Object types, Temporal information</td>
<td>medium</td>
<td>low</td>
<td>SHOULD HAVE</td>
</tr>
<tr>
<td>R12</td>
<td>As-built vs. As-planned comparison</td>
<td>Compare the built structure against the as-planned model</td>
<td>Check the quality of the construction (on site)</td>
<td>Design application to Field application</td>
<td>TIN, BRep</td>
<td>Classification, Tolerance values</td>
<td>high</td>
<td>medium</td>
<td>SHOULD HAVE</td>
</tr>
<tr>
<td>No</td>
<td>Use case name</td>
<td>Description</td>
<td>Purpose</td>
<td>IFC exchange scenario</td>
<td>Required geometry representation</td>
<td>Required semantic information</td>
<td>Priority</td>
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<tr>
<td>R13</td>
<td>Handover to asset management</td>
<td>Enable the model to support the use in operation and maintenance</td>
<td>Use the model for inspection, damage detection, condition rating, condition prediction, maintenance planning</td>
<td>Design application to Asset management system</td>
<td>TIN, BRep, Sweep geometry where suitable</td>
<td>Identification, Classification, Materials, Maintenance information</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R14</td>
<td>Handover to GIS for spatial analysis</td>
<td>Handover the design to GIS for environmental analysis and/or asset management</td>
<td>GIS systems provide functionality for environmental analysis and can be used for asset management</td>
<td>Design application to GIS system</td>
<td>Alignment and superelevations/cross-sections, TIN (according to GIS requirements)</td>
<td>Major design attributes</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R15</td>
<td>Initial State modelling</td>
<td>Initial data (terrain, soil, existing structures etc.) from various GIS (and other sources) are brought into BIM space and can then be exchanged using IFC</td>
<td>GIS (and other) data provides the basis for the design task</td>
<td>GIS &amp; other sources to Design application</td>
<td>TIN (Terrain, Subsoil), Sweep geometry where suitable (existing structures, utilities)</td>
<td>Major design parameters, Material (soil classification), Accuracy and reliability of initial data</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>No</td>
<td>Use case name</td>
<td>Description</td>
<td>Purpose</td>
<td>IFC exchange scenario</td>
<td>Required geometry representation</td>
<td>Required semantic information</td>
<td>Priority</td>
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<tr>
<td>R16</td>
<td>Operation and maintenance</td>
<td>Use and update the model to support operation and maintenance</td>
<td>Use the model for inspection, damage detection, condition rating, condition prediction, maintenance planning</td>
<td>Asset management system to Asset management and/or monitoring systems / Field applications</td>
<td></td>
<td></td>
<td>medium</td>
<td>low - high (depending on case)</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>R17</td>
<td>Design-to-Construction</td>
<td>Handover from design phase to construction phase</td>
<td>Road model is handed over from Designer to Contractor for bidding and for actual construction</td>
<td>Design application to Tendering application and/or Review application</td>
<td>Faceted BRep, Sweep geometry where suitable, potentially based on alignment</td>
<td>Material information, Product information</td>
<td>medium</td>
<td>low - high (depending on case)</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>R18</td>
<td>Environmental impact assessment (EIA)</td>
<td>Used to simulate the environmental impact the road has on the surroundings.</td>
<td>To assess what measures need to be taken and what materials should be used to limit the impact of the road on environment, groundwater etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WIN'T HAVE</td>
</tr>
<tr>
<td>R19</td>
<td>Noise pollution simulation</td>
<td>Used to simulate the noise originating from the planned traffic on the road and to limit the impact on the surrounding.</td>
<td>To limit the impact of the noise originated from the road and to define the appropriate protection.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WIN'T HAVE</td>
</tr>
<tr>
<td>No</td>
<td>Use case name</td>
<td>Description</td>
<td>Purpose</td>
<td>IFC exchange scenario</td>
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<tr>
<td>R21</td>
<td>Traffic capacity simulation</td>
<td>Used to simulate traffic patterns and to dimension the infrastructure. The simulations display all road users and their interactions in one model.</td>
<td>To reassure the road has enough capacity for planned and future traffic flows</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WON'T HAVE</td>
</tr>
<tr>
<td>R24</td>
<td>Traffic management</td>
<td>Used to transfer data to application for traffic management.</td>
<td>Road design model is used in traffic management system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WON'T HAVE</td>
</tr>
<tr>
<td>R25</td>
<td>Earthworks cut and fill design</td>
<td>Used to incorporate the designed infrastructure in the existing ground</td>
<td>To enable earthworks construction planning</td>
<td></td>
<td>Geotechnical software to Road design software, Road design software to Mass haul balance, Road design software to Tendering software</td>
<td>Materials, Classifications</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R26</td>
<td>Geotechnical investigations</td>
<td>Used for dimensioning the road with regards to the existing ground conditions</td>
<td>To limit the deformation and to ensure the stability of the road</td>
<td></td>
<td>Geotechnical software to Road design software</td>
<td>TIN, BRep, Materials, Classifications</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>R27</td>
<td>Geotechnical constructions</td>
<td>ground reinforcement, sheet piling, preloading, piling</td>
<td>Use the model for temporary and permanent design to facilitate construction</td>
<td></td>
<td>Roadway design software to Geotechnical analysis software</td>
<td>TIN, BRep</td>
<td>high</td>
<td>low</td>
<td>MUST HAVE</td>
</tr>
<tr>
<td>No</td>
<td>Use case name</td>
<td>Description</td>
<td>Purpose</td>
<td>IFC exchange scenario</td>
<td>Required geometry representation</td>
<td>Required semantic information</td>
<td>Priority</td>
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<tr>
<td>R28</td>
<td>Dimensioning of Pavement and sub-grade</td>
<td>Used to determine the thickness of the road’s structural layers. Input: traffic load, speed limitation, AAdt, quota heavy vehicles, traffic growth per year, average axle load, Existing ground materials</td>
<td>To limit the deformation and to ensure the stability of the road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WON’T HAVE</td>
</tr>
<tr>
<td>R29</td>
<td>Temporary works design</td>
<td>use the model for temporary works design such as temporary road diversions and other where there is a time limit for the design</td>
<td>Modelling objects and information with temporary and other, not permanent status’</td>
<td>Design application</td>
<td>Same as permanent constructions</td>
<td>Temporal information</td>
<td>low</td>
<td>low</td>
<td>COULD HAVE</td>
</tr>
<tr>
<td>R30</td>
<td>Vehicle swept path analysis</td>
<td>Tracking of a vehicle's simulated movements in relation to geometry, based upon vehicle dimensions, chassis and steering specification.</td>
<td>Ensuring the physical area of the road is dimensioned for the appropriate vehicles</td>
<td>Design application</td>
<td>TIN, BRep, Sweep geometry where suitable, Kinetic envelope</td>
<td>Component types, Classification, Relationships between entities (IfcRelConnects...)</td>
<td>low</td>
<td>low</td>
<td>COULD HAVE</td>
</tr>
</tbody>
</table>

Table 4 Use Case table.
GEOMETRIC REPRESENTATIONS AND PLACEMENT

In general, we can distinguish between the following two geometric representations:

- Explicit geometry - boundary representation
- Procedural geometry – parametric representation

Both have their own uses and advantages. Whereas boundary representations are necessary for quantity take off, visualizations etc., parametric representations are crucial in design to design exchange. It also has to be noted that when comparing the road domain to the building domain the road domain relies on surface representations more than body representations.

Essentially, we could identify two main surface representations that are required for exchanging geometric data in the road domain. The first one are triangular irregular networks (TIN) for the representation of terrain surfaces. The second one is a parametric surface description of the road body and the layers making up the “road prism”. Focusing on TIN, there are no special requirements we could narrow down, other than the typical TIN definitions available in various standards such as InfraGML, LandXML or IFC.

Going forward to the parametric surface definition of a road body we can see some specific requirements that are not available on typical surface definitions. These requirements include the following conditions:

- The definition has to be an extruded profile along an alignment, where the alignment represents the axis of extrusion
- The profile being extruded is an open profile represented by a series of segments defined with a width or radius and a superelevation. The first segment starting point is at the location of the alignment. The starting points of the rest of the segments are defined by the ending point of the previous segment which is uniquely defined by the width and the superelevation values.
- The layers comprising the road body require a surface definition as described in the previous point.
- Unless a change to the values of width, radius or superelevation occur along the alignment it shall be assumed that the initial profile definition of segments has not changed.
- Changes to the values of width, radius and superelevation shall be documented in the geometric representation of the surface as a location along the alignment (linear reference) and the corresponding value of the segment in question that has changed.

Such a parametric definition would allow a more efficient storage of long road stretches saving valuable memory space when exchanging data. Additionally, being a parametric definition such a geometric representation allows changes on the receiving software that can be communicated back to the sending software due to the nature of procedural geometric definitions. By using such a parametric surface definition, TIN surfaces can be generated which would allow for quantity take off scenarios being covered. It has to be noted that by using different triangulation algorithms differences in quantity take off values should be expected. Therefore, it is advised to use the appropriate TIN surface definitions in quantity take-off use cases.

An important note regarding the described parametric geometric definition would have to be added. The requirements listed in this chapter are not seen as demands for such a development. The issue of parametric exchange is very complex and the IFC Road Project Team due to limited resources cannot...
promise such a development to be incorporated in the IFC schema extension. To summarize, a full parametric representation is not in scope of the IFC Road project. On a side note, in case such a definition does reach publishing status and thus finds its way into the official IFC release it will definitely not be a requirement in every MVD. Further explanations can be found in Chapter 5.

Another geometric representation that has to be considered and cannot be assigned to either a boundary or a parametric representation and has found its place as an alternative for representing road geometry is the string line representation. Similarly to the parametric representation it allows the receiving software to interpret the string lines and generate a boundary representation body geometry. Essentially, the string line representation is a list of longitudinal lines each representing a position in the road construction such as the edge of pavement. Each individual string line shall have its geometry defined as a bounded curve that can be as simple as a polyline (list of points with three coordinates and linear interpolation between the points) or more type of representation, such as an alignment curve with horizontal and vertical component. The string lines shall have the option of grouping them into sets for a particular reason, e.g. to make up a surface representation. When using string line representation or surface representation (i.e. not parametric), there should also be a data structure that allows exchanging design parameters such as superelevation changes, widths etc. as events placed on the alignment.

For the purpose of geo-referencing the road project an EPSG code shall be used. This means that the “world coordinate system” (WCS) of the project shall be an engineering coordinate system that by means of a context in which it resides shall carry the information about the conversion of the WCS coordinates into the appropriate map coordinates.
5 MODEL VIEW DEFINITIONS

New Extension developments will need to be tested by software and implemented. Certification of this software and the implemented extension is based on MVDs.

An MVD is a subset of the IFC EXPRESS schema as well as a set of implementation instructions and validation rules that serve specific exchange requirements put forward by the industry. Following from that, the Model View Definitions (MVDs) that will be put forward by the IFC Road project will take into account the exchange scenarios from the official process map (see 2.3) and the use cases extracted from it (see 3). Also, the guidelines put forward by the Overall Architecture project and the developments and decisions of the bSI IFC Bridge project will be taken into consideration. This means that the number of MVDs will be limited and will not correspond to the number of listed use cases from Chapter 3. The reasoning for that is two-fold. Firstly, limited resources do not allow to take into consideration local requirements and thus the MVDs cannot go into detailed semantics. Secondly, also as a consequence of the previous statement requirements of various use cases can be combined into one exchange model. Looking at use cases R01 and R02 which focus on geometry we can realize that one exchange model could easily cover both of them.

Based on that, a prediction can be made that limiting the number of MVDs to four is a good estimate. We would distinguish between the following MVDs:

1. Road Reference View
2. Alignment based Road Reference View
3. Road Design Transfer View
4. Road Asset Manager View

The Road Reference View shall feature boundary representation geometry with various semantic information requirements (could be defined locally). It shall feature all the road elements that shall be put forward by the IFC Road project. Elements can be referenced but in general not modified geometrically. Positioning is limited to Cartesian coordinates with the possibility of stations being transferred as semantic information. The reasoning behind having such an MVD is that existing standard IFC viewers would be able to open IFC Road IFC files without the need to implement the full complexity of IfcAlignment and the related linear referencing concepts for the positioning of products along the alignment.

The Alignment based Road Reference View shall have all the features of the Road Reference View but shall add linear referencing along the alignment. With alignment being featured in the view, extrusion geometry along the alignment is a possibility.

The Road Design Transfer View shall feature geometric representation enabling the modification of geometry in the receiving software. The scope of these geometric definitions shall reflect the requirement set forward in Chapter 4.

The Road Asset Manager View shall focus on the requirements of asset managers. These revolve predominantly around semantic information. A common ground has to be defined internationally for property sets that shall be released with the official documentation of the IFC schema and used in this MVD.
The IFC software certification process focuses on specific MVDs. In essence this means that not every requirement, definition or concept from the IFC schema has to be implemented in order for the software to be IFC certified. In case the software is a visualization software it can apply for a Road Reference View, thus supporting the IFC Road elements but not being obliged to implement alignment or linear referencing. Same holds true for other MVDs, meaning, the complex geometric representation structures are not required for every exchange i.e. every MVD.
6 CONCLUSION

This report is presenting the final result of the IFC Road project Phase 1. In Phase 1, a detailed project execution plan was established, and the Requirement Analysis Report was completed to define the requirements for the IFC Road schema extension in phase 2. This Requirement Analysis Report details the necessity and feasibility to develop IFC Road. In particular, we discussed from a perspective of IFC Road utilization the common definition of spatial structure and geotechnics in order to derive common items from bridges, railways, and ports.

Although there may be some differences in the evaluation of priorities for some use cases, during phase 1 we have identified the most important use cases through feedback from the expert panels.

The IFC Road Process Map is composed of a common process map at an international level in terms of how IFC Road can be delivered and generated during the life cycle. This is explained in terms of roads, but is in common with road linear facilities such as bridges and tunnels.

Spatial requirements are still under discussion with the Common Schema. It is hoped that it will be able to be structured appropriately from the viewpoint of a common understanding in all ongoing bSI InfraRoom projects as well as the IFC Rail project.

Requirements on geometric representations included in this report include general level geometry requirements, and specific parameters and shape representations will be discussed and developed in phase 2 of the IFC Road Schema extension with especially representation of cross sections of roads.

In addition, we reviewed a taxonomy of road structures required for the expansion of the IFC Road Schema. This taxonomy was collected from stakeholders and registered in a database. In addition we started to identify the general properties required for each item in the taxonomy database. This will be the foundation for further work in Phase 2.

In Phase 2, we will proceed with the IFC Road Schema Extension and its deployment with detailed project execution plan based on the requirements of Phase 2 in earnest. The next actions for Phase 2 include: project execution plan for phase 2, Required geometric and semantic information, IFC Road taxonomy classification, Continued cooperation with the Common Schema project, IFC Road conceptual model with UML diagram, Property set definitions with bSDD, IFC schema extension for IFC Road, MVDs, Software deployment for IFC Road testing, and finally the creation and delivery of final version of documentation for IFC Road.

In Phase 2, the final IFC Road V1.0 will be developed according to In and Out of scope as defined in the IFC Road scope and statement. The project recognises there are requirements that will most likely not be fully covered in the delivery. The need for further development will be considered in the bSI InfraRoom.
7 REFERENCES

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IFC Road Project Execution Plan phase 1:
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Expert Panel 1 documentation Use Cases and poll result:
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bSI, Technical report TR1009, IFC Infra Overall Architecture Project Documentation and Guidelines:

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ANNEX 1: PROCESS MAP

The international IFC Road Process Map can be found in a separate PDF for readability purposes, available through this link: https://buildingsmart.sharefile.com/d/sb92d174a2154b678.

The following description of the process map is split into three main categories of elements:
- **actors** (horizontal swimming lanes) are explained first;
- **phases**, (vertical grouping) are explained next;
- **actions** of each actor (represented in boxes) are explained within each corresponding section of the phase they belong to.

1. ACTORS

In this section, the actors and stakeholders partaking on a road project are listed and described in a general matter as they appear around the world. The letter in front of the individual actors is used for identification in further text.

   A. Land Surveyor
   The land surveyor determines the terrestrial or three-dimensional positions of points and the distances and angles between them. These points are usually on the surface of the Earth, and they are often used to establish maps and for ownership or governmental purposes. To accomplish his objective, surveyor use elements of geometry, engineering, trigonometry, mathematics, physics, and law. (WIKI)
   The land surveyor sets the coordinate reference system, and the geodetic and vertical datums which in turn define the engineering coordinate system in which the asset is planned.

   He performs and/or oversees the activities of an engineering survey party engaged in the gathering of data used in the planning and/or design. (USA)

   B. Asset Manager
   The asset manager monitors and maintains things of value to an entity or group. This may apply to both tangible assets (such as buildings) and to intangible assets (such as human capital, intellectual property, goodwill and/or financial assets). Asset management is a systematic process of developing, operating, maintaining, upgrading, and disposing of assets cost effectively. (WIKI)

   C. Environmental Engineer
   The environmental engineer is concerned with the issues of energy preservation, protection of assets and control of waste. The work of the environmental engineer includes waste water management, air pollution control, recycling, waste disposal, radiation protection, industrial hygiene, animal agriculture, environmental sustainability, public health and environmental engineering law. It also includes studies on the environmental impact of proposed construction projects. (WIKI)

   Performs professional engineering work in the coordination of environmental documentation, agency coordination, and regulatory requirements; may direct the activities of a squad or small section of technical engineering staff. Includes management of pre-design activities. (USA)

   D. Transportation Engineer
   The transportation engineer is concerned with the planning, functional design, operation and management of facilities for any mode of transportation in order to provide for the safe, efficient, rapid, comfortable, convenient, economical, and environmentally compatible movement of people
and goods (transport). The planning aspects of transportation engineering involve technical forecasting decisions and political factors. (WIKI)

Performs professional engineering work in the planning, design, inspection, or implementation of traffic-related elements; may direct the activities of a squad or small section of technical engineering staff. (USA)

**E. Road Designer**
Planning engineers determine and develop the most suitable and economically viable construction and engineering methods for projects. They are involved throughout the development stages, and are present on site during the build to oversee procedures. It is the responsibility of the planning engineer to estimate a timescale for a project and to ensure that the outlined deadlines are met. (WIKI)

Performs professional engineering work in the planning, design, inspection, or implementation of roadway engineering elements; may direct the activities of a squad or small section of technical engineering staff. (USA)

**F. Project Manager / Public Authority**
Overall project lead in developing, managing, monitoring and controlling the project scope, schedule, budget, quality, team, communications, risks, stakeholders, and changes. (USA)

**G. Geotechnician**
The geotechnician is concerned with the engineering behaviour of earth materials and uses principles of soil mechanics and rock mechanics to investigate subsurface conditions and materials, determine the relevant physical/mechanical and chemical properties of these materials, evaluate stability of natural slopes and man-made soil deposits, assess risks posed by site conditions, design earthworks and structure foundations. (WIKI)

Performs materials functions by working on material, geotechnical, or pavement engineering elements; normally assisting higher level specialist and engineers. (USA)

**H. Other Domain Engineers**
Included are structural, drainage, electrical, bridge, and tunnel engineers. Structural engineers are trained to understand, predict, and calculate the stability, strength and rigidity of built structures for buildings and non-building structures and to supervise the construction of projects on site. Bridge engineers ensure that bridges can carry the weight of people and/or cars without breaking, buckling, or falling down. Tunnel engineers are responsible for planning, designing and managing tunnel building projects. These projects could include: rail, roads/motorways, urban and underground railways, underground water tunnels and sewers. (WIKI)

Structural engineer performs professional engineering work in the planning, design, inspection, or implementation of structure related elements; may direct the activities of a squad or small section of technical engineering staff. (USA)

**I. Estimator**
An Estimator (building or cost estimator) is an individual that quantifies the materials, labour, and equipment needed to complete a construction project. (WIKI)
J. Asset Owner
The public authority owning the asset.

K. Contractor
The contractor is an independent person/firm that agrees to furnish certain number or quantity of goods, material, equipment, personnel, and/or services that meet or exceed stated requirements or specifications, at a mutually agreed upon price and within a specified timeframe to the project owner. (WIKI)

Construction engineer performs professional engineering work in the construction of roadway engineering elements; may direct the activities of a squad or small section of technical engineering staff. (USA)

L. Inspector
The inspector is a professional engaged by the owner of a construction project, contractor, or government agencies to ensure a project's compliance with its specifications and statutory requirements. The inspection is carried out purely to give an independent view of the works either for the client or a third party, the term supervision might imply taking some responsibility for the works, when in fact contractual responsibility lies with the contractor. (WIKI)

M. Maintenance Manager
The maintenance manager is engaged to maintain the resources of the company so that production proceeds effectively and that no money is wasted on inefficiency. There are many software programs that assist with this process, and there are a few objectives that a maintenance manager should seek to accomplish. These objectives are to control costs, to schedule work properly and efficiently, and to ensure that the company complies with all regulations. (WIKI)
2. PHASES & ACTIONS

1. Strategic Briefing
This phase serves as the brainstorming hub, search for ideas and evaluation of traffic needs and/or shortcomings. The end goal of the phase is the initiation of the project.

B. Information gathering and function analysis
- Existing state of affairs SE
- Fixing of problems SE
- Needs and values in the area SE
- What works well in the current transport system SE
- Problems and values in the area SE
- Location and Identification F
- Residents briefing session F, KOR
- Information exchange KOR
- Informative study SP
- Routes Consultation of relevant agencies KOR

C. Significant environmental impact analysis SE
- Prior environmental review KOR
- Traffic Impact Assessment KOR

D. Actions and consequences analysis SE, F

E. Initial analysis briefing
- Analysis of conflict points between these and existing construction objects (Risk management) SE
- Goal achievement (Prioritization of measures) SE
- Consultation and Report SE
- Design Consulting (Kick-off Stage) KOR
- Position on continued work on the project SE
- Definition of program maintenance F
- Design policy creation KOR
- Determine the final route KOR

F. Initiation
- Approved Design Policy (Review and approve routes, total expenses, economic efficiency, etc.) KOR
- Estimate review in Scoping meeting USA
- Ordering Plan Design KOR
- Approve estimate USA

I. Initial estimate
- Start initial construction estimate and delivery budget development (scoping) USA
2. Preliminary Design

The preliminary design often bridges a gap between design initiation and detailed design, particularly in cases where the level of conceptualization achieved during the search for ideas did not suffice for full evaluation. In this task, the overall system configuration is defined, and schematics, diagrams, and layouts of the project may provide early project configuration. During detailed design and optimization, the parameters of the part being created will change, but the preliminary design focuses on creating the general framework to build the project on.

A. Preliminary roadway survey SE
- Surveying and Ground Investigation KOR

B. Preliminary roadway corridor analysis F
- Access routes SE
- Costs of consequences, proposals on road corridors SE
- Definition of geometric characteristics F

C. Preliminary environmental and ecological analysis
- Drainage Concept F
- Preliminary Environmental Review KOR

D. Preliminary analysis of traffic and accessibility SE
- Estimation of future traffic F

E.a. Initial state model for preliminary design
- Blueprint SP 1.2

E.b. Preliminary road design SE
- Delivery of final products in preliminary design KOR
- Creation of preliminary design book KOR
- Road layout SP 1.3
- Design consultation (Kick-off phase) KOR

F. Approval of preliminary design
- Validation of the hypothetic design F
- Post evaluation input KOR

G. Preliminary geotechnical analysis
- Soil tests SE

H. Preliminary design

I. Preliminary estimate
- Assessment of roadworthiness, accessibility and public transport SE
- Consultation SE
- Design consultation KOR
3. **Detailed Design**

Following the preliminary design is the detailed design phase, which may consist of procurement of materials as well. This phase further elaborates each aspect of the project/product by complete description through solid modelling, drawings, as well as specifications.

**A. Detailed land survey**
- Land access and land acquisition SE
- Surveying and Ground Investigation KOR

**B. Detailed roadway study**
- Final definition of geometrical characteristics F

**C. Detailed environmental and ecological analysis**
- Pre-disaster impact review KOR
- Analysis of the land issues SE
- Environmental Impact Assessment KOR
- Planning of handling construction noise and emissions SE

**D. Detailed traffic and connectivity analysis**
- Proposing the most appropriate road connection in the selected corridor SE
- Estimation of future traffic F
- Traffic Impact Assessment KOR
- Route consultation KOR
- Determine the final route KOR

**Ea. Initial state modelling for detailed design SE**
- Planning of demolition or relocation of buildings SE
- Planning of groundwater and well protection SE
- Planning of transport routes SE
- Detailed design orders KOR
- Determine structures’ locations and types KOR

**Eb. Detailed road design**
- Continued designing SE
- Production of technical descriptions SE
- Project management SE
- Presentation to public F
- Create Detailed Design Book KOR
- Design consultation (Intermediate stage) KOR
- for detailed design KOR

**F. Approval of detailed design**
- Land owner meeting (County administrative board) SE
- Approved Design Policy (Review and approve route, Project expense, economy, etc.) KOR
- Revise and verify detailed estimate (Design eng.) USA
- Preparation of a business register SE
- Residents briefing session KOR

**G. Detailed geotechnical analysis**
- Soil sampling and evaluation

**H. Detailed design**
- Bridge and tunnel design, electrical and drainage systems design

**I. Detailed estimate**
- Work plan establishment SE
- Start of the production of SMEs for work plan SE
- Design program SE
- Construction costs SE
- Costs SE
- Preparation of a settlement document with summary report SE
- Design policy creation KOR
- Prepare Detailed Estimate (design eng.) USA
- Post evaluation input KOR

### 4. Final Design

During the final design stage the final architectural and engineering models of all physical components of the project are produced. In some complex projects, such as multi-disciplinary research centres, it is necessary to prepare in addition a written final design report. This summarizes the facility as designed.

**A. Final land survey**
- Studies and measurements SE
- Complementary field measurements SE

**C. Water handling**
- Drainage study SP(1.4.12)

**D. Final traffic analysis**
- Finalize the report

**Ea. Initial state model**

**Eb. Road design**
- Delivery of final design KOR
- Design consultation (Final stage) KOR
- Construction project SP 1.4
- Drawn in plan SP(1.4.1)
- Layout in elevation SP(1.4.2)
- Section definitions SP(1.4.3)
- 3D modelling SP(1.4.4)
- ACV/ACCV (Life Cycle Analysis/Life Cycle Cost Analysis) SP(1.4.6)
- Consistency analysis SP(1.4.7)
- Construction budget SP(1.4.9)
- Documentation generation SP(1.4.10)

**F. Approval of final design**
- Code compliance analysis SP(1.4.5)
- Approve final project documentation
- Approve final detailed estimate USA

**G. Geoengineering design**

**H. Final design**
- Bridge and tunnel design
- Final drainage design F
- Pavement analysis SP 1.4.13
- Structural analysis SP 1.4.11

**I. Final estimate**
- Submit Final Detailed Estimate with no contingencies USA
- Quantity take off SP 1.4.8

**5. Bidding**
Bidding is used to determine the cost or value of the designed asset and can be performed by a "buyer" or "supplier" of a product or service based on the context of the situation.

**F. Tender evaluation, awarding SE, F**
- Submit, review and approve Plans, specifications and estimates USA
- Review proposal document USA
- Approve proposal USA
- Confirm contractor qualification USA
- Identify contractor to be awarded and select bid. USA
- Award proposal to contractor and send awarded bid items to masterworks USA
- Review and send contract to contractor for approval USA
- Approve and execute contract USA
- Send executed contract to contractor USA
- Obtain required contract start information USA
- Issue notice to proceed USA

**J. Contract documentation preparation**
- Preparation of production documents SE
- Transfer of documentation and facility SE
- Establish an execution plan KOR
- Writing a bid KOR
- PQ document review KOR
- Bid document analysis KOR
- Plans, specifications and estimates submittal forms USA
- Prepare plans, specifications and estimates documents USA
- Prepare, approve and export plans, specifications and estimates USA
- Confirm contractor qualification USA
- Create and validate proposal USA
- Create proposal document USA
- Permit for water activities SE
- Bid announcement KOR
- Field description KOR
- Defect evaluation data check KOR
- PQ examination KOR
- Bid registration KOR
- Bidding KOR
- Self-contract KOR
- Procurement contract KOR Licensing and Permit agreement KOR
- Road zone decision notice KOR
- From Construction (Post-environmental impact investigation)
- Post environmental impact investigation KOR
- Procurement contract KOR

**K. Tender preparation**
- Production of quantities SE
- Analysis of specification techniques F
- Modify estimate/pricing and assign funds SE
- Submit PQ documents KOR
- Submit bid documents KOR
- Submission of contract documents KOR

**L. Property inspections**
- Request inspection USA
- Conduct inspection/site walk-through USA
- Qualification screening KOR

6. **Construction**
The construction period is a specific period, stipulated in a contract (beginning from the date stated in the notice to proceed) during which the contractor takes control of the construction site to carry out the path-works and must complete construction, subject to the conditions of the contract.

**A. Survey of construction**
- Prepare basic survey conduct record
- Survey the progress of construction

**B. Land compensation KOR**
- Conduct property appraisal
- Compensation Appraisal Decision
- Loss compensation consultation
- Acceptance /settlement /deposit
- Compensation payment

**E. Road design SE**
- Review of filed situation report KOR
- Create design change report KOR
- design change overview, drawings, KOR

**F. Approval SE**
- Review and approval of construction

**Ka. Work plan establishment**
- Cost-cutting calculation SE
- Time and resource planning SE
- Purchase SE
- Planning of traffic change during the construction period SE
- Production of data for machine control SE
- Calculation book, bill, etc. KOR
- Field situation report KOR

**Kb. Construction**
- Completing of the working plan SE
- Covering SE
- Transport SE
- Production preparation SE
- Workspace establishment SE
- Tree falling and clearance SE
- Soil/ground blow up SE
- Ground reinforcement work SE
- Deflection management SE
- Conduct deflections SE
- Excavation SE
- The start of construction (Construction Registration) KOR

**L. Inspection and control of the construction process**
- Construction work ledger management KOR
- Start supervision KOR
- Request preliminary completion inspection KOR
- Reception and review KOR
- Inspection KOR
- Prepare preliminary completion inspection result KOR
- Receipt of inspection result KOR
- Review / check the inspection result KOR
- Submit completion inspection report KOR
- Review KOR
- Completion Supervision Record Preparation KOR
- Completion inspection conduction KOR
- Report of completion inspection result KOR
- Completion inspection result reception KOR
- Completion money request KOR;
- Receipt of completion money; Completion book production KOR
- Review and confirmation KOR
- Reception and expenditure resolution KOR
- Payment of completion money KOR
- Execution performance management KOR
- Receipt of Final products KOR
- Completion Book Review KOR
- Completion processing and notification of results KOR
- Post evaluation input KOR
- Completion result reception KOR
- Establishment of facility turnover plan KOR
- Preparation of the facility transfer receipt KOR
- Receipt KOR

7. **Asset Management and Maintenance**

Asset management and maintenance refers to any system that monitors and maintains things of value to an entity or group. Asset management is a systematic process of developing, operating, maintaining, upgrading, and disposing of assets cost-effectively.

**B. Archive management SE**

- Data storage and management

**F. Archive preparation SE**

- Preparation of the facility transfer receipt
- Receipt
- Registration of facilities
- Establish disaster countermeasures
- Disaster occurrence
- Disaster preparedness

**M. Maintenance planning**

- Winter road maintenance SE
- Repairing of defects SE
- Maintenance of road pavement, bridges and tunnels SE
- Control of procurement SE
- Procurement of operation and maintenance SE
- Statement of damage and repairs F
- Establish an inspection plan KOR
- Maintenance reinforcement decision KOR
- Conduct maintenance and reinforcement KOR
- A close inspection; Precision safety diagnosis KOR
- Regular inspection KOR
- Damage Class Cor less KOR
- Reception of report KOR
- Construction order KOR
- Completion inspection KOR
- Defective repair KOR