IFC-Bridge Fast Track Project

Report WP1: Requirements analysis

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1 Overview and methodology

The IFC-Bridge project aims at extending the IFC data model in order to allow the precise description of the semantics and geometry of bridges. It was initiated by the bSI Infra Room as a fast track project with a project duration of two years.

WP1 was intended to define the scope of the project and the requirements of the IFC-Bridge extension. Given the restricted project duration, it was necessary to focus on common and widespread bridge types and to include only those use cases that provide a high value to the end users and require reasonable efforts for defining and validating the necessary IFC extensions.

As a basis for defining the IFC-Bridge extensions, the international project team identified the most important uses cases of the data exchange processes in infrastructure projects. The point of departure for this process had been provided by the outcomes of the IFC-Infra overall architecture process.

The defined list of use cases is not intended to be exhaustive. Instead, the most important use cases have been selected from interviews with experts having practical experience in bridge projects. In addition, the input from several national initiatives was taken into account:

- China: CRBIM project
- France: MiND project
- Germany: IFC-Bridge Expert Group
- Nordic Chapter: IFC-Bridge Expert Group
- USA: FHWA project

From the identified use cases, the basic requirements for the IFC-Bridge have been derived focusing on geometry representations and semantical descriptions. They have been distilled into three proposed Model View Definitions (MVDs) which are going to be developed throughout the project.

2 Bridge types covered

The following bridge types (structural system) have been identified as the most common and widespread ones across the world. They are thus considered to be in-scope of this project. The developed IFC-Bridge extensions will be validated using examples of theses bridge types.

- Slab Bridge
- Girder Bridge
    - Slab-Girder Bridge
    - Box-girder bridge
- Frame Bridge
- Rigid Frame Bridge
- Culvert

The following bridges types are expected to be covered by IFC and the IFC-Bridge extension as well, however, they will not be subject to validation tests:

- Truss bridge
- Arch bridge
- Cantilever bridge
- Cable-stayed bridge
- Suspension bridge

From a material viewpoint, the following bridge types are covered:

- Reinforced Concrete bridges
- Prestressed Concrete bridges
- Steel/Concrete Composite bridges
- Steel girder bridges
- Steel bridges

Particular emphasis will be placed on realizing the necessary data structures for modeling pre-stressing systems.

3 Use cases

The following IFC-Bridge use cases have been identified by the project team by analyzing the outcomes of the national bridge projects and by discussions with the international expert panel. The table shows the priority of each use case and the complexity involved with defining the necessary data structures. This analysis formed the basis for the subsequent decisions regarding the scope of the projects whose result is indicated by the color of the first column.

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
1	Initial State Modeling	initial data (terrain, soil, existing structures etc.) from various sources (including GIS) are brought into BIM space and exchanged using IFC	GIS (and other) data provides the basis for the design task	GIS & other sources to design application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc),	Major design parameters, Material (soil classification), accuracy and reliability of initial data	high	low	Bridge Reference View
2	Import of alignment and major road / railway parameters	alignment information is imported from roadway/railway design tool into bridge modeler	Alignment provides the basis for bridge design	From roadway / railway design system into bridge modeling system	Alignment and cross-sections	Maximum Speeds, Loads etc.	high	low	Alignment-based Bridge Reference View
3	Technical Visualization	3D technical visualization of the bridge project	Communication of design solutions to third parties, including the public	Design application to Visualization app.	Triangulated Face Sets	Bridge Breakdown Structure Object Types Material (opt) Colors (opt) Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
4	Coordination / Collision detection	Coordination of domain-specific sub-models	Transfer and combine models to detect interferences (clashes)	Design application to Design application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Component types Classification Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View
5	4D Construction Sequence Modeling	4D technical visualization of the construction phases	Organization of construction site and construction activities	Design application to 4D scheduling application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Temporal information	high	low	Bridge Reference View
6	Quantity Take-Off	Determine quantities (volumes and surfaces) from the model	Basis for cost estimation and cost calculation	Design application to QTO application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Material, Classifications Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View
7	Progress Monitoring	Transfer information about the progress of the construction project	Track and document the progress of the construction project	Surveying application to visualization application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Temporal information	high	low	Bridge Reference View
8	As-built vs. as-planned comparison	Compare the built structure against the as-planned model (Geometric Control)	Check the quality of the construction (on site)	Design application to field application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Classification Tolerance values Relationships between entities (IfcRelConnects...)	high	low	Bridge Reference View

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
9	Handover to asset management	use the model to support operation and maintenance of the bridge,	use the model for inspection, damage detection, condition rating, condition prediction, maintenance planning	Design application to asset management system	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc)	Classification Material Maintenance information	high	medium	Bridge Asset Management View
10	Handover to GIS for spatial analysis	Handover the bridge design to GIS for environmental analysis and/or asset mgmt.	GIS systems provide functionality for environmental analysis and can be used for asset management	Design application to GIS system	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc), potentially based on alignment	Major design attributes	high	low	Alignment-based Bridge Reference View
11	Design to Design (reference model)	Use bridge model from early design phase as a reference for creating a more detailed bridge model in the detailed design ohase, limited modifiability required	Models are exchanged across different design phases, model from earlier phase is used us background / reference model for next phase	Design application to design application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc), potentially based on alignment	Classification Material Component types Relationships between entities (IfcRelConnects...)	high	medium	Alignment-based Bridge Reference View
12	Design-to-Design (full model logic)	Exchange of fully parametric description of bridge between	within the same design phase, design models are exchanged	Design application to	Advanced BRep (NURBS), Fully parametric model information containing	All information entered in the design application	medium	high	Bridge Design

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
		two distinct design applications	between different design applications, model remains fully modifiable, all model logic is transferred	design application	model logic, constraints and dependencies				Transfer View
13	Design-to-Construction	Handover from Design Phase to Construction Phase	Bridge Model is handed over from designer to Contractor for bidding and for actual construction	Design application to Tendering application and/or Review application	Faceted BRep, Sweep Geometry where suitable (Deck, Rebar, Boring Piles etc), potentially based on alignment	Material information Product information etc.	high	medium	Alignment-based Bridge Reference View
14	Structural Analysis incl. Structural Dynamics, Fluid-Structure Interaction, etc.	Structural analysis of bridges, tunnels, retaining walls	Ensure stability of the structures	Design application to structural analysis application	Procedural Description (Sweep and CSG) and/or Analytical Model	Loads, Material properties	medium	medium - high	Bridge Structural View
15	Code Compliance Checking	Check design of bridge for compliance with local codes and regulations	Compliance checking conducted by regulation authorities	Design application to checking application	Procedural description (Alignment, Sweep Geometry, CSG, BRep)	Information regarding the applying regulations (dimensions, distances, materials, etc.)	medium	high	?

No	Use case	Description	Purpose	IFC exchange scenario	Required geometry representation	Required semantic information	Priority	Complexity	MVD
16	Drawing generation and exchange	Exchange technical drawings derived from the model	Submission to owner / regulation authorities	Design application to Submission	2D representation	All information relevant for drawing representation (line styles, symbolic representations, etc.)	low	high	?
17	Prefabrication and manufacturing	Usage of model information for control / steering of prefabrication machines.	Partially automated construction of bridge components	Design application to machine	Procedural description (Alignment, Sweep Geometry, CSG, Advanced BRep)	(specific)	low	medium	?

4 In-scope / Out-of-scope decisions

Based on a careful analysis of the benefits of the individual uses cases and the complexity and effort involved with defining the necessary data structures, the project team decided to prioritize the following use cases for explicit consideration when designing the IFC-Bridge extension:

- Initial State Modeling
- Import of major road / railway parameters
- Technical Visualization
- Coordination / Collison Detection
- 4D Construction Sequence Modeling
- Quantity Take-Off
- Progress Monitoring
- As-built vs. as-planned comparison
- Handover to asset management
- Hanover to GIS for spatial analysis
- Design to design (reference model)

Due to overly high complexity, the following use cases are out of scope of this fast-track project:

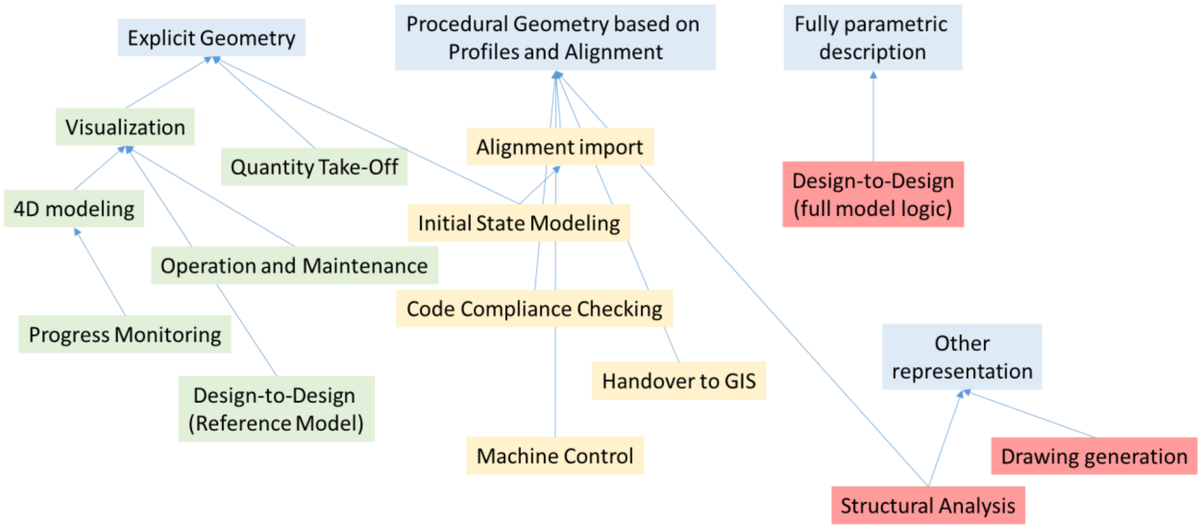
- Design to Design (Full model logic)
- Structural analysis
- Code Compliance Checking
- Drawing generation and exchange
- Prefabrication and manufacturing

It is emphasized that the exclusion from the fast-track project does not mean that these use cases cannot be covered by future extensions of IFC-Bridge.

It has to be noted in particular, that the full design-to-design use case which incorporates the model's design logic, is excluded here as it would require a major effort from both bSI in defining the necessary data structures and from the software vendors in correctly implementing them. Currently, there is no well-defined industry need that would justify this effort.

5 Geometry

The following figure depicts the dependencies of the use cases from specific geometry representations.



The in-scope use cases require explicit BRep geometry based on tessellation and/or implicit geometry based on sweeps. This outcome allows to focus on these two geometry representations when defining the IFC-Bridge extension.

More specifically, many of the required use cases demand the usage of sweeps for representing the superstructure elements (deck, shoulder, etc.), rebar and the pre-stressing system. It has well agreed by the project team, that the usage of triangulated face sets is not appropriate for these elements in many use cases as described in the table above, due to the loss in accuracy and the excessive increase in data size. The use of sweepings is a strong demand for realizing meaningful data exchanges.

An important role plays the entity *IfcSectionedSolidHorizontal* which has been introduced with IFC 4.1 as a result of the development activities in the IfcAlignment and the IFC Infra Overall Architecture projects. The entity allows to perform sweeps along an alignment where the cross-section's y-vector is kept pointing in the global z direction, in contrary to the conventional IfcSweptAreaSolid where the cross-section is kept perpendicular to the sweeping path at any time. IfcSectionedSolidHorizontal has been introduced for correctly modeling elements of infrastructure facilities (roadway layers, bridge decks) and will be applied in this sense in the IFC-Bridge extensions. It will be included in the Bridge Model View Definitions (see below).

6 Model View Definitions

In order to reduce the complexity of the data model developments, it was decided to map the use cases to the following basic Model View Definitions.

- Bridge Reference View (Bridge RV)
- Alignment-based Bridge Reference View (Bridge ARV)
- Bridge Design Transfer View (Bridge DTV)
- Bridge Asset Management Handover View (Bridge AM)

The decision was taken to align both the Bridge Reference View and the Bridge Design Transfer View with the existing views in IFC4, but extend them where necessary to capture the specifics of bridges.

lists the differences in terms of the geometry representations supported between the IFC4 Reference view (IFC4 RV), the IFC4 Design Transfer View (IFC4 DTV)., the Bridge Reference View (Bridge RV), the Bridge Alignment-based Reference View (Bridge ARV) and the Bridge Design Transfer View.

The basic differentiation between RV and DTV is also applied to the Bridge MVDs. Most importantly, IfcCSGSolid (Constructive Solid Geometry = Boolean Operations on Solids) is not supported by the Bridge RV, but by the Bridge DTV. Another important difference lies in the support of *IfcFacetedBrep* and *IfcAdvancedBrep* which is only realized in Bridge DTV. For representing BRep geometry in RV, the *IfcPolygonalFaceSet* representation must be used. Curved surfaces (NURBS) are not supported by RV.

In addition, there will be the Alignment-based Reference View (Bridge ARV) which extends the IFC4 Reference View by the support for *IfcAlignment* and *IfcSectionedSolidHorizontal* for positioning and geometry creation. The reason for introducing the additional MVD lies in the importance of alignment for linear infrastructure. As however, standard IFC viewers (which typically do not support alignment) should be able visualize bridge models, the basic Bridge RV will not demand *IfcAlignment* to be supported, but rely instead on explicit geometry and on Cartesian coordinates for positioning.

Other differences between Bridge RV, Bridge ARV and Bridge DTV may lie in further geometric and semantic aspects and will be elaborated in the next phases of the project. Also details of the Bridge Asset Management Handover View are to be decided in the upcoming phases of the project.

	IFC4 RV	Bridge RV	Bridge ARV	IFC 4 DTV	Bridge DTV
IfcSolidModel	x	x	x	x	x
IfcCsgSolid				x	x
IfcManifoldSolidBrep				x	x
IfcAdvancedBRep				x	x
IfcAdvancedBRepWithVoids					
IfcFacetedBrep				x	x
IfcFacetedBrepWithVoids					
IfcSweptAreaSolid	x	x	x	x	x
IfcExtrudedAraSolid	x	x	x	x	x
IfcExtrudedAreaSolidTapered				x	x
IfcFixedReferenceSweptAreaSolid				x	x
IfcRevolvedAreaSolid	x	x	x	x	x
IfcRevolvedAreaSolidTapered				x	x
IfcCurveSweptAreaSolid				x	x
IfcSweptDiskSolid	x	x	x	x	x
IfcSweptDiskSolidPolygonal					
IfcSectionedSolid			**x**		x
IfcSectionedSolidHorizontal			**x**		x
IfcTesselatedItem	x	x	x	x	x
IfcTesselatedFaceSet	x	x	x	x	x
IfcTriangulatedFaceSet	x	x	x	x	x
IfcPositioningElement	x	x	**x**		x
IfcAlignment			**x**		x
IfcAlignment2DHorizontal			**x**		x
IfcAlignment2DVertical			**x**		x
IfcAlignment2DSegment			**x**		x
IfcAlignment2DVerticalSegment			**x**		x
IfcAlignment2DHorizonalSegment			**x**		x

Figure 1: Comparison of the geometry supported by Ithe IFC4 Model View for Bridges and the Bridge MVDs to be developed, full list of the IFC 4 MVDs: http://www.buildingsmart-tech.org/specifications/ifc-view-definition/ifc4-reference-view/comparison-rv-dtv

7 Next Steps

In the next Work Package (WP2), the project team will identify the object types and attributes that are required for describing bridges from a semantic viewpoint in a way that is satisfying the use cases identified in WP1. To this end, a bridge taxonomy is created defining all necessary terms used in the context of bridge engineering. On the basis of the taxonomy, a mapping of the identified concepts to existing or new IFC entities is defined. This allows to specify new data structures (where necessary) as well as the Model View Definitions as discussed above.