Proceedings of the 6th International Conference siBIM:
Structured Data are New Gold
Online, 3-4 November2020

DEVELOPMENT OF IFC SCHEMA FOR INFRASTRUCTURE

Full paper

Štefan, JAUD[1], Sebastian, ESSER[1], Sergej, MUHIČ[2], André, BORRMANN[1]

[1] Chair for Computational Modelling and Simulation, Technical University of Munich, Arcisstraße 21, 80333 Munich, Germany, {stefan.jaud}{sebastian.esser}{andre.borrmann}@tum.de;

[2] Model Support Group, buildingSMART International Ltd., Kings House, Station Road, Kings Langley, Hertfordshire, WD4 8LZ, United Kingdom, sergej.muhic@gmail.com;

ABSTRACT

Industry Foundation Classes (IFC) is a data schema available as ISO 16739 which enables the exchange of high-quality geometric and sematic data of civil engineering structures. Current official version IFC4.0 was first published in 2013 and updated in 2018. In the recent years, buildingSMART International (bSI) started multiple projects with the intent to expand IFC to support infrastructure workflows. This included introducing the linear referencing concept from ISO 19148 together with the basis for any linear infrastructure asset – the alignment.

This contribution focuses on the additions to the IFC standard that enable a high-quality exchange of digital models of infrastructure assets. First, the process of standardization followed by bSI is briefly described. Second, the projects expanding the IFC in the recent years are introduced. Major changes and additions to the standard as introduced by candidate standards IFC4.1, IFC4.2 and IFC4.3 are presented. We conclude with a short outlook on the currently running IFC Infrastructure Extension Deployment and IFC Rail Phase 2 projects and include their first results in this publication.

KEYWORDS: BIM, IFC, infrastructure, standards development

1 BACKGROUND

Industry Foundation Classes (IFC) is a data scheme enabling the exchange of high-quality geometric and sematic data of civil engineering structures published as ISO 16739 (ISO 2018). Its development started in the 90s and has seen multiple published versions as presented in Figure 2 (Laakso and Kiviniemi, 2012). Version IFC2x3 represents the *useful minimum* as noted by Laakso and Kiviniemi (2012) and has indeed seen vast adoption throughout the industry, both by software vendors in their products as well as by stakeholders in their workflows. The current official version IFC4 was first published by buildingSMART International (bSI) in 2012 and released in the following year as ISO 16739:2013. It is steadily gaining interest among the community, especially with first software products completing their certification process (bSI 2019a).

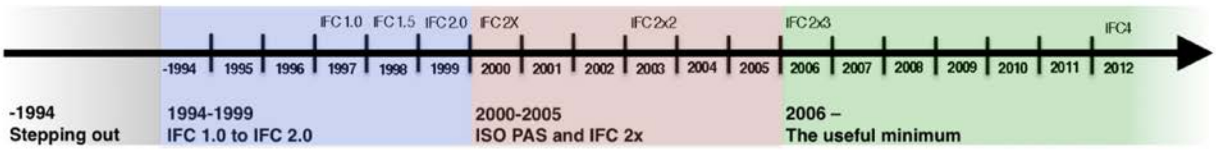

Figure 2: Timeline of IFC versions until 2013 (Laakso and Kiviniemi, 2012)

However, all IFC versions mentioned above focused on exchange of building models and neglected the infrastructure sector completely. In the recent decade, increased interest to expand IFC to support infrastructure workflows has emerged (e.g. Drogemuller 2009; Ji et al. 2013). Responding to the industry's wishes, infrastructure stakeholders started multiple projects with the intent to address these needs. This paper describes the common methodology adopted by these projects, reports their main outcomes, and provides a general overview for those experts not deeply involved with this topic.

The paper is structured as follows. This section briefly summarizes the historical development of IFC data schema and the motivation for introducing IFC to the infrastructure sector. The next section presents the methodology of IFC development followed by a list of the infrastructure projects extending the IFC in Section 3. Thereafter, the most important added concepts are described in Section 4. Section 5 concludes the paper together with a short outlook of the forthcoming projects.

2 METHODOLOGY

bSI has agreed upon and adopted a standards development process as shown in

Figure 3 (Petrie and Kelly 2019). The process foresees three phases: initiation, development, and approval, and a brief summary is provided below. Detailed descriptions of individual steps together with necessary criteria, responsible actors and governance processes can be obtained from Petrie and Kelly (2019).

Initiation. First, the needs from the industry are identified and an activity is proposed. A bSI Standards Committee (SC) composed of all bSI members and chapters is consulted and, if appropriate, the activity proposal can be expanded into a full project proposal. Next, the SC initiates the project if the proposal fulfils clearly defined criteria, including funding, participant roles, milestones, and deliverables.

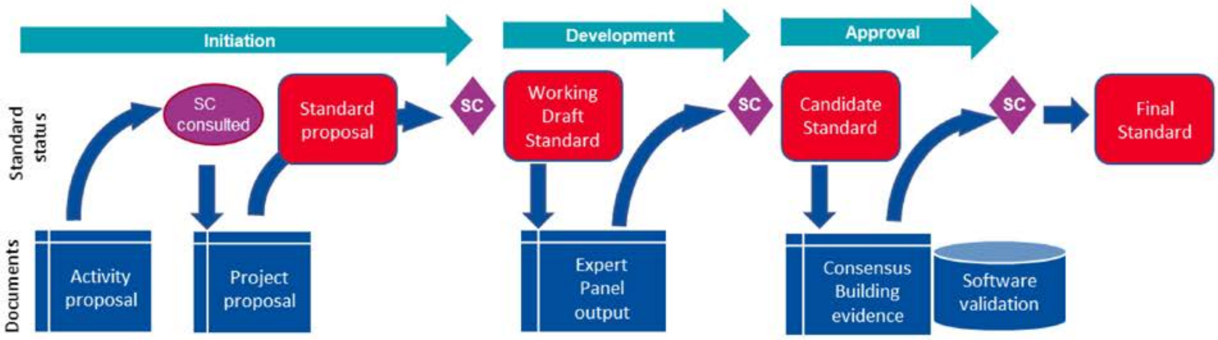

Figure 3: bSI standards development process (adapted from Petrie and Kelly, 2019)

Development. Second, the project team can commence the standard development stage as shown in more detail in

Figure 4. In the beginning, it is important to clearly define the scope and the use cases to be covered by an extension project (Laakso and Kiviniemi, 2012). For this, domain experts are consulted to capture domain requirements. Having these, the Information Delivery Manual (IDM) consisting of process map(s) and exchange requirements can be defined and a requirements analysis report produced (e.g. Castaing et al. 2018).

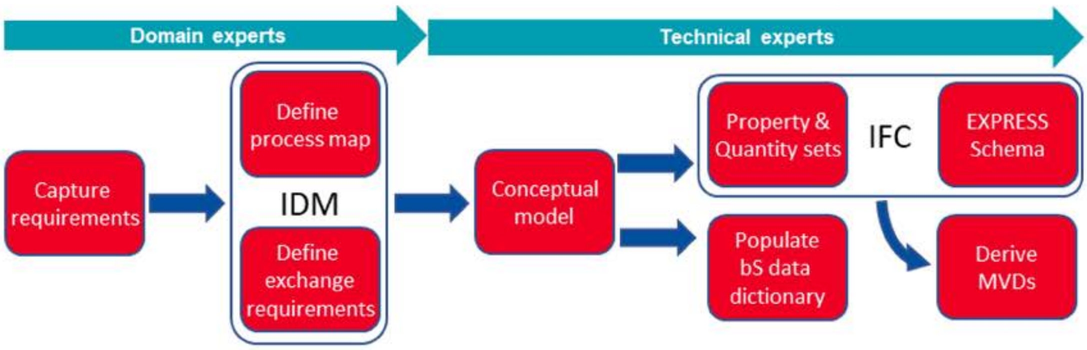

Figure 4: A detailed view of the development phase from Figure 1 as adopted by the IFC extension projects (adapted from Petrie & Kelly, 2019)

Having the IDM, the technical experts take over, identifying unique concepts, and producing a conceptual model which incorporates the needs as specified by the domain experts. The elements of the conceptual model are then mapped to IFC entities and/or property and quantity sets, whereas a reuse of already existing concepts is mandated wherever possible (Borrmann et al. 2017). If such a concept cannot be identified, there are two main possibilities: (a) the definition of an existing concept can be expanded to incorporate the missing one; or (b) a totally new concept can be introduced to the schema together with the necessary documentation. Based on the finished IFC schema, Model View Definitions (MVDs) are then specified as a subset of the schema together with concept templates and properties which can be used for software certification (bSI 2019). The buildingSMART Data Dictionary can be populated with

additional properties not covered by the official property and quantity sets within the IFC standard and optionally added to the MVDs as needed by the industry.
As shown in

Figure 3, multiple expert panels are held during the development process, where the international community can comment on the project's results and contribute their input and critique. This crucial step ensures an international consensus and serves as quality assurance.
Approval. Third, the standard is voted upon by SC at the end of the development phase which ensures the bSI standards process from

Figure 3 has been followed, and then receives the status of candidate standard. With this, the approval phase commences, where the standard is implemented by software vendors and tested in real world exchange scenarios. After enough evidence about the validity and usability is collected, the extension reaches the status of final standard following a final vote by the SC.

3 PROJECTS EXTENDING IFC FOR INFRASTRUCTURE

Figure 5 presents the projects initiated in the recent years that expanded IFC data schema for infrastructure objects (bSI 2020a). All developments are based on the current official version IFC4, shown in blue at the bottom.
The first two projects IFC Alignment and IFC Overall Architecture (shown in green in Figure 5) focused on foundamental concepts found across the infrastructure domains, like alignment, linear placement, and terrain model. Additionally, a general guideline was developed for other planned activities in the infrastructure sector, e.g. to reuse existing IFC entities wherever possible to diminish the effort needed by software vendors already supporting IFC standard to support the new developments (Borrmann et al. 2017, Liebich et al. 2017). The extension was dubbed IFC4.1 and has reached the status of final standard after the completion of the IFC Alignment Deployment project (e.g. Malmkvist et al. 2017).

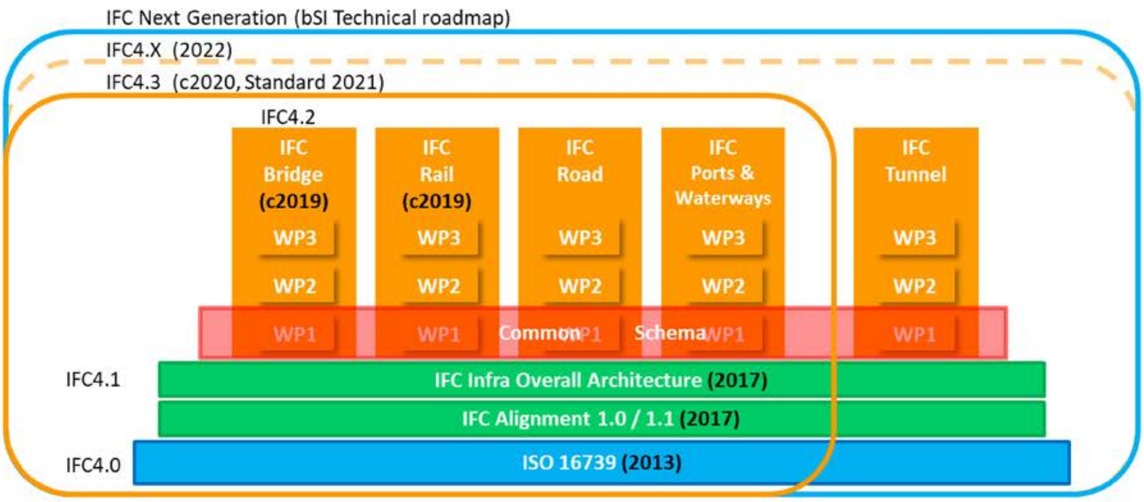

Figure 5: An overview of the bSI projects expanding IFC for infrastructure. The year denotes project's completion date, with the letter "c" denoting candidate standard status (adapted from bSI, 2020a)

Following this, domain specific projects were started (shown in red and orange in Figure 5). First to secure the funding and establish a project team was the IFC Bridge Fast track project, which focused on a schema extension to support the semantically rich modelling of bridge structures. The final extension IFC4.2 reached the candidate standard status in early 2019 and all reports are made available on the official bSI website (bSI 2020a).

Parallel to the developments for bridges, four projects commenced in 2018: IFC Common Schema, IFC Road, IFC Ports & Waterways, and IFC Rail. The former focused on common topics like geotechnics and earthworks, while the latter three on their respective infrastructure sectors: roads, ports & waterways, and railway assets. The IFC Common Schema project also oversaw the harmonization across the domain projects. The conceptual model of IFC Rail project reached candidate status in late 2019 (bSI 2019b). A harmonization process based on a unified UML model brought all conceptual models together in the recent IFC4.3 candidate standard extension. The reports generated from the UML model are made available at bSI official webpages together with other supporting material (bSI 2020a, 2020b, 2020c, 2020d).

The latest project to commence its work is the IFC Tunnel project, shown on far right on Figure 5. The project focuses on extending the IFC4.3 specification to support the peculiarities of tunnel facilities. The team is currently finalizing the Requirements Analysis Report which is to be published on the official bSI webpage (bSI 2020d).

Currently, two projects entrusted with software validation activity (but not limited to) are running in parallel: IFC Rail Phase 2 and IFC Infrastructure Extensions Deployment (bSI 2020b, 2020c). The deployment process as adopted by both projects is shown in Figure 6. Here, domain experts (top lane), software vendors (bottom two lanes), and facilitators (between the two) cooperate in producing storylines and unit tests to thoroughly verify the applicability of the developed IFC4.3 schema extensions as well as validate them against the IDMs specified in the requirement reports. Both projects have gained much attention from the industry, with participants from big and small software companies alike.

The process envisions export-import pairs of software vendors exchanging IFC files as defined by the storylines or unit tests. There are three feedback loops incorporated in the process that allow to update the standard as well as the examples. (a) If the storyline datasets are erroneous, the domain experts should correct them. (b) If the produced IFC files are erroneous or there are implementation issues, the software vendors should correct their interfaces. (c) If the developed extension is proving difficult to implement, or the model does not cover requirements, or there is documentation issue, the standard needs updating.

At the end, on the one hand, the software vendors will have verified the standard, i.e. the standard allows implementers to do *things right*. On the other hand, the domain experts will have checked the standard to be valid, i.e. that it supports the exchange of *right things*.

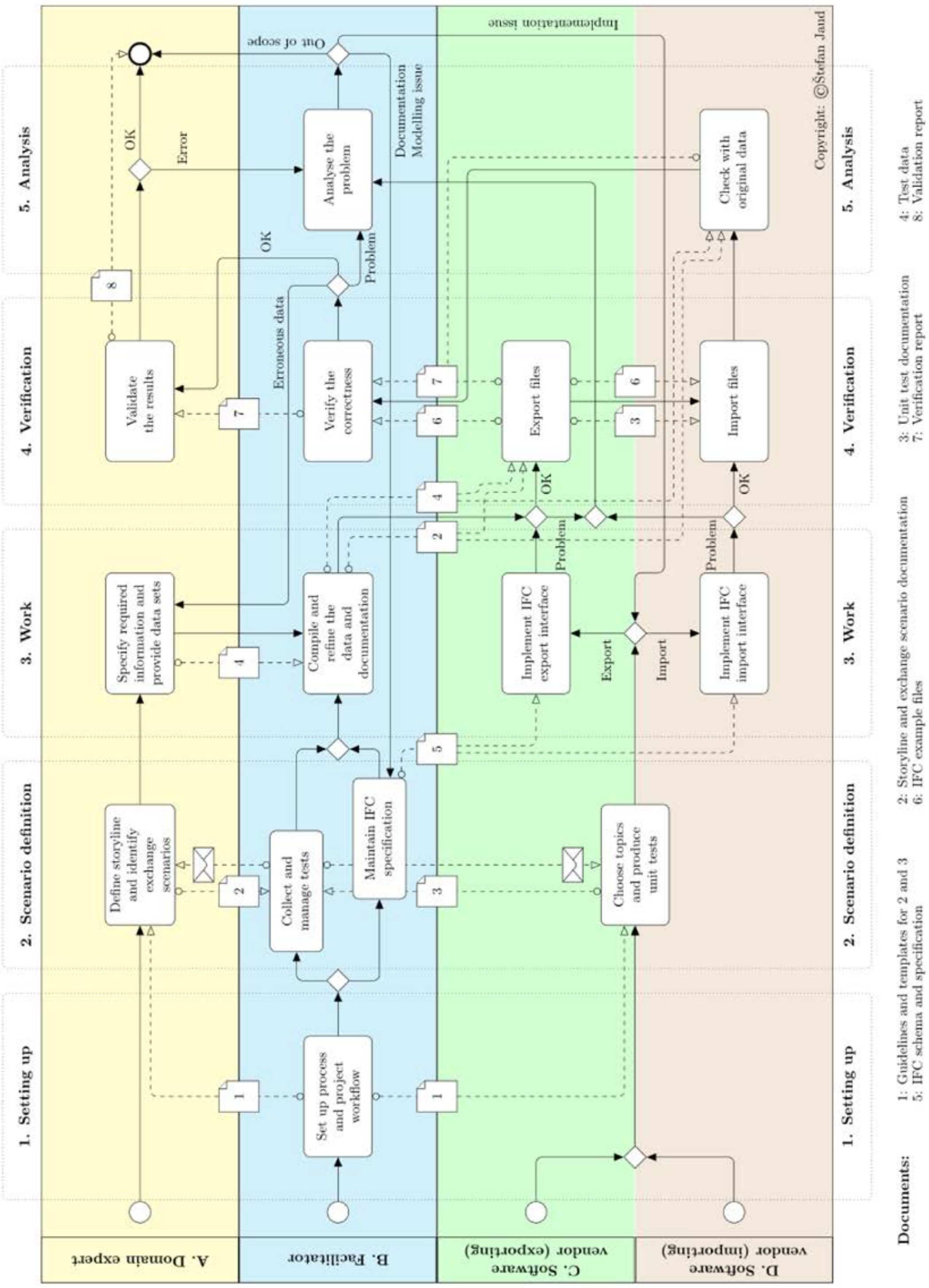

Figure 6: The deployment process adopted by currently running IFC Rail Phase 2 and IFC Infrastructure Extensions Deployment projects

4 RESULTS

This section merely provides a short overview of the results. The reader is advised to conduct their own research of the individual reports provided by bSI (2019b, 2020a, 2020b, 2020c, 2020d) and the recordings of the recent developments within the IFC Rail Phase 2 and IFC Infrastructure Extensions Deployment projects (bSI 2020e).

Following the guidelines laid down by the IFC Infra Overall Architecture project, the projects reused as much of the existing entities and concepts (Borrmann et al. 2017) as possible. An overview of the changes made to the IFC schema is presented in Table 1, where the total number of additions, updates, and deprecations for the different elements of the IFC standard are listed.

Table 1: Number of changes in the IFC4.3 extension as compared to the IFC4.0 baseline.

Element of the Standard	Addition	Update	Deprecated
Entity	120	25	6
Enum Type	40	40	3
Select Type	7	4	0
Function	2	3	0

Perhaps one of the most important extension to the standard is the concept of linear referencing based on ISO 19148:2012 (ISO 2012). For this, the entities *IfcPositioningElement, IfcLinearPositioningElement, IfcReferent,* and *IfcRelPositions* have been introduced, which supply the semantics required to position elements relative to other elements. The object's placement can now be specified with *IfcLinearPlacement*, allowing for any *IfcProduct* to be placed along a linear axis. Additionally, the geometry kernel was expanded with linearly extruded geometries such as *IfcOffsetCurveByDistances, IfcSectionedSurface,* and *IfcSectionedSolidHorizontal* that support describing assets in ways common to the infrastructure sector.

Other additions and changes include but are not limited to: (a) versatile project & spatial structure elements, e.g. *IfcFacilityPart* and *IfcFacilityPartTypeSelect*, (b) extension of the product tree for infrastructure elements with new entities and new predefined types, e.g. *IfcRail*, *IfcRailTypeEnum*, and *IfcRailType*, (c) support for earthworks and geotechnical concepts, e.g. *IfcEarthworksElement* and *IfcGeomodel*, (d) addition of property and quantity sets for these entities, e.g. *Pset_BearingCommon*, (e) customizable coordinate reference systems, *IfcWellKnownTextCRS*, and (f) other geometry definitions, e.g. *IfcOpenCrossProfileDef*, *IfcReferenceSegment* and *IfcSegmentedReferenceCurve*.

5 CONCLUSION

The projects have proven that extending the IFC standard in a limited time frame is possible (Borrmann et al. 2019). The formalized processes of bSI as described in Section 2 guided project teams to deliver a high-quality product: candidate standard IFC4.3.

The IFC Rail Phase 2 and IFC Infrastructure Extension Deployment projects are currently underway to prove its technical validity and its applicability in the target domains following the process on Figure 6. The first results as presented in the recent joint Expert Panel have been included in Section 4 (bSI 2020e).

ACKNOWLEDGEMENTS

The extension projects have been funded by many governmental agencies, research projects, private companies, and supported by in-kind contributions of bSI members; please refer to the individual reports as provided in Section 3 for complete lists. The authors gratefully acknowledge their support. The authors would also like to thank Karin Anderson, Andrew Sheil, and Jim Plume for reviewing the draft version of this manuscript.

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