IfcBridge Model Generation using Visual Programming

Sebastian Esser[1] and Korbinian Aicher[1]

[1]Chair of Computational Modeling and Simulation · Technical University of Munich · Arcisstraße 21 · 80333 Munich · E-Mail: sebastian.esser@tum.de

Methods and concepts of Building Information Modeling (BIM) are increasingly used in infrastructure projects. However, suitable data structures are still missing to store and exchange model data in an appropriate spatial and asset-specific context. With the IfcBridge schema extension, the vendor-neutral data format Industry Foundation Classes (IFC) now includes classes for bridge structures. This paper presents approaches to export IfcBridge models using existing authoring tools. To overcome the lack of the required spatial context for bridges, a visual programming language is chosen to extract and assign additional knowledge to a bridge model. The data gained from visual programming provides the base for the export into the new IFC 4x2 standard.

Keywords: BIM, Infrastructure, IFC4x2, IfcBridge

1 Exchange of Digital Bridge Models

1.1 Problem Statement

The use of modern digital methods can be recognized across all domains in the Architecture, Engineering, and Construction (AEC) industry. Although concepts of Building Information Modeling (BIM) are already in use for projects of different size, developments for traffic related domains and their assets are not as advanced yet. Civil infrastructure assets like roads, railways, bridges and tunnels require new concepts for geometric representations, procedural methods to describe object positions, and additional object types and assemblies.

To improve data exchange scenarios for infrastructural assets, the non-profit organization buildingSMART International (bSI) is working on extending its data format Industry Foundation Classes (IFC). IFC is a standardized product model that had been highly adopted by several vendors to exchange digital models of buildings and civil infrastructure. Until version IFC 4, the data structure was primarily focused on the needs of building constructions. With IFC 4x1, essential concepts for linear construction sites were introduced which now build the basis for asset-specific extensions like IfcBridge, IfcRoad, IfcRail and IfcTunnel (Borrmann et al., 2017). The latest published version IFC 4x2 now includes additional classes for modeling and exchanging bridges, and has currently the status of a candidate standard.

One of the general challenges in BIM is the objective to improve data exchange scenarios and to deploy already gained knowledge to other involved parties. Thus, standardized data models are essential to serve the requirements of both, domain-specific as well as cross-domain use cases. However, there is always an assessment between standardization and flexibility. On the one hand, such models must have fixed concepts to make sure, every application interprets the delivered data in the same manner. On the other hand, engineers and architects in the AEC industry mostly design unique items, which causes the need of an appropriate flexibility inside a data model for individual exchange scenarios.

The integration of novel concepts always takes a while until software vendors provide native export and import interfaces and get certifications for them. However, it is essential to test such schema extensions and their compliance to existing (proprietary) data models as early as possible. In this paper, a case study proves the capabilities of an existing tool chain to create and deploy bridge models. It shows the interaction with the new spatial structure introduced by the latest IFC version 4x2 and discusses optimization potential in the applications used in the case study.

1.2 Objectives

This paper presents and analyses an existing workflow to design bridge models using a proprietary tool chain. These bridge models are then tested if they comply with the IfcBridge data model. Since each step in a life cycle of a bridge requires individual data, an enormous amount of applications exist, which are suitable for individual requirements, phases and use cases. Therefore, the IFC interface developed in case study is sufficient for various design stages and can be reached by several data sources.

In the case study, we have used several applications from the software vendor Autodesk. With InfraWorks, an engineer can evaluate different conceptual designs of roads and bridges, and perform impact simulations in large-scale environments. The BIM-authoring tool Revit was initially tailored for modeling buildings, and, therefore, has powerful functions for load-bearing structures and related details (e.g., reinforcement design, connection between components, etc.). With the visual programming environment Dynamo, engineers can extend and automate recurring tasks in Revit. During the case study, Dynamo is used prepare bridge models from InfraWorks. Neither InfraWorks nor Revit have a native IfcBridge interface yet. Thus, we developed an innovative Dynamo library containing nodes to interact and export bridge models into the new IFC 4x2 standard. Besides this, Dynamo can be used to extend the data quality of the bridge models (e.g., setting additional material properties). Although a proprietary tool chain is used, our developed services are flexible enough to interact with third-party models as well.

The elaboration is structured as follows: Section 2 gives an overview of basic conventions for schema extensions. In Section 3, we show a possible tool chain to generate bridge models and export them into IfcBridge models. Section 4 explains the implementation framework. Section 5 presents the outcomes and possible shortcomings in the chosen tool chain to generate IFC models that are compliant to the IfcBridge schema. Section 6 discusses additional requirements to improve the resulting IFC models in geometric and semantic aspects.

1.3 Related Work

Modeling concepts for bridges or other structural assets for infrastructural purposes were already an important topic before the IfcBridge project. Singer (2014) presented approaches to model bridges based on existing knowledge. At the same time, bSI started with first projects to develop basic concepts for civil infrastructure, which resulted in the schema version IFC 4x1 (Amann et al., 2014). Often called "IfcAlignment", this extension defines fundamentals for all upcoming civil infrastructure extensions.

Markič (2017) summarized several proposals for IfcBridge extensions, which were taken into account during the international standardization project. Borrmann et al. (2019) gave an overview about the toolchain and project management during the IfcBridge project.

2 Fundamentals for new IFC Extensions

The ongoing projects IfcBridge, IfcRoad, and IfcRail pose a significant challenge since a common standard is to be developed at the end. For different asset types, similar concepts should be used for modeling and exchanging related objects. At the same time, domain-specific demands must be also taken into account. Thus, the Common Schema Committee is working on issues, which are related to multiple projects (e.g., geotechnical structures and earthworks, cross section representations, level crossings between several traffic assets). A set of fundamental rules define concepts, which every asset-specific extension should follow. The overall goal is to reach a harmonized data model, which will most likely result in the next major version IFC 5.

Prototypical test implementations can help to verify whether data structures of existing applications are able to support novel concepts in data models that are tailored for cross-vendor data exchange scenarios.

3 Prototypical IfcBridge Export-Interface

In the following study, the authors discuss a prototypical implementation of an IfcBridge export module in established BIM authoring applications. The aim is to test the capacity of existing data sources to setup and edit bridge models. Besides that, the developed framework should help users to get a better understanding of IFC concepts using a visual programming language for user interactions (Preidel et al., 2017).

3.1 Workflow and Methodology

There is currently no application that provides an engineer with all the tools for a BIM-based process. Instead, there is typically a set of applications used along with a project execution. Each of those has individual functions helping the engineer to fulfill the required task like designing and checking models or perform simulations on them.

The individual content of a data exchange scenario is dependent on the subsequent use of the resulting model. For this reason, IFC provides the concept of Model View Definitions (MVDs). An MVD defines a subset of the complete IFC data schema and prepares a model for a defined use case. Well-known MVDs from previous versions are the Reference View (RV) and the Design Transfer View (DTV) (See et al., 2012). RV exchange scenarios use explicit boundary representations, whereas DTV models aim to contain procedural geometric representations for subsequent modeling and editing (Trzeciak and Borrmann, 2018).

For IfcBridge, an additional MVD "Alignment-based Bridge Reference View (Bridge-ARV)" defines the placement of components along a given alignment curve and requires new procedural geometry types describing extrusions with varying cross sections (Borrmann et al., 2019).

3.2 Application for Conceptual Design and Model Refinements

Our case study considers two main design phases: the conceptual design and variant analysis in a large-scale rendering tool and design refinements in conceptual models during a detailed design phase. Data handover scenarios can be requested by several parties during both phases using a vendor-neutral data model. Figure 1 shows several model states during such a workflow.

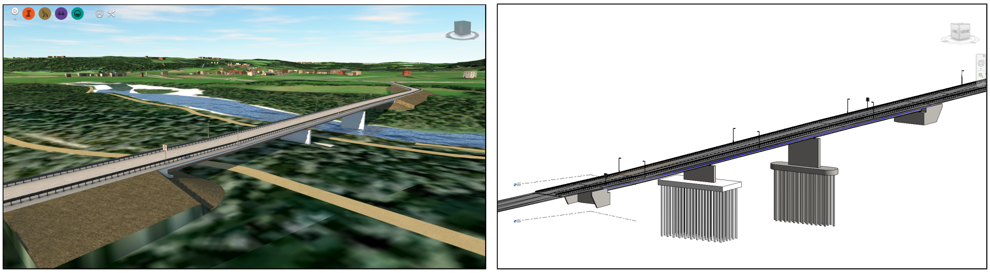

Figure 1: Conceptual Road Design in InfraWorks (left) and exported Bridge in Revit (right)

3.3 Conceptual Design

The conceptual design of infrastructure assets can be carried out in large scale rendering tools to directly receive a scenic impression of the desired design. Autodesk InfraWorks 2020 provides various tools for this phase. Such applications allow users to make quick changes on the models and directly see the results within the virtual environment. (Autodesk, 2019)

InfraWorks provides a proprietary interface to the well-established BIM authoring tool Autodesk Revit. It is used to transfer the conceptual design of a bridge into a Revit project.

3.4 Design Refinement

Revit is intended for design improvements and to add additional parameters to components. It is a powerful tool for the detailed design of load-bearing structures, especially concrete and steel constructions. In the case study, Revit is used in version 2020.0.

Most of the BIM authoring tools currently available on the market were not developed to model infrastructural assets like bridges or tunnels. Thus, many vendors provide plugin solutions for bridge structures in the context of a BIM-based workflow (SOFiSTiK, 2018) (Allplan, 2019).

The authoring tool Revit organizes all components in families. Categories aggregate several families, whereas a family itself can have specific family types. Although InfraWorks provides a proprietary interface to Revit, all received bridge components are only received as 'DirectShape' geometries and are mapped into a generic component type. For some components, the type cannot be identified. To overcome this issue, the common classification system *UniClass* is used. This work-around requires the engineer's knowledge since he has to add the classification codes manually. However, it makes the approach more flexible and adaptable. By using an independent classification systems, bridge models from various authoring sources can be processed. In the last years, lots of developers and researchers have actively worked on design work-flows in environments of various scales (Obergriesser, 2016).

4 Data Extraction and IFC-Export

Existing BIM authoring tools typically arrange building components in grids, levels, and spaces. This approach stays in contrast to the spatial structure of IfcBridge splitting the whole bridge in bridge parts. Additionally, components of civil infrastructure assets are often positioned along an alignment curve. To overcome the lack of these essential concepts in Revit, the visual programming language Dynamo is used to extract and prepare data for the desired IfcBridge export.

4.1 User Interaction

In a first step, Dynamo is used to group elements of similar types. These results are passed into our *IfcBridgeToolKit* library, which contains nodes to setup an IFC model and insert elements into it. Figure 2 demonstrates the use of our nodes by an example of bridge girders.

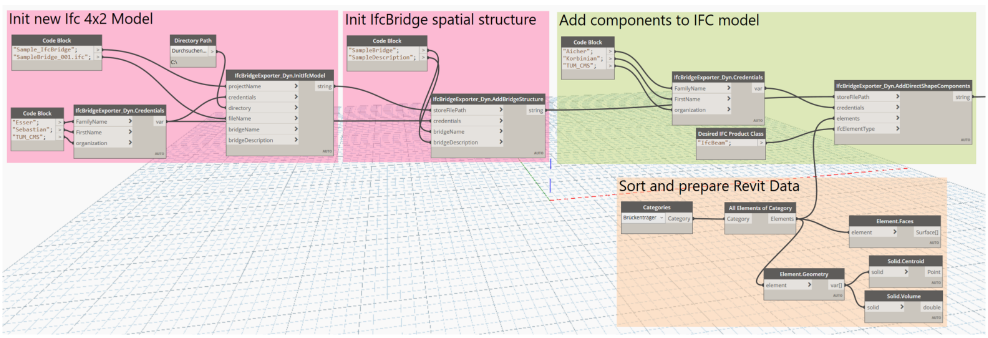

Figure 2: User Interaction between Dynamo and the IFC Model

Each interaction with the IFC model might be triggered by a new responsible designer belonging to an individual domain. IFC is capable of such scenarios providing an owner history concept. Therefore, each node with transactions on the IFC model requires credential data as an input.

4.2 Implementation Architecture

The implementation follows object-oriented principles and has a modular structure. Figure 3 presents an extract of our architecture.

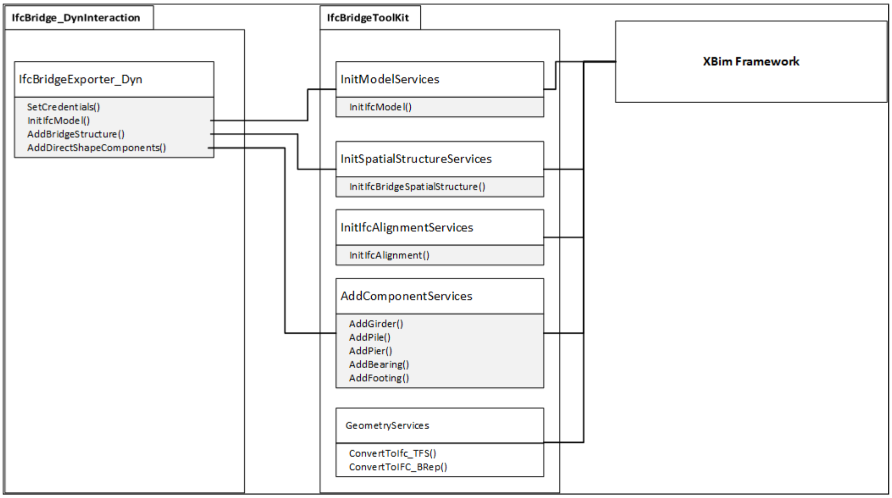

Figure 3: Implementation Architecture

The package *IfcBridge DynInteraction* manages the user interaction with Dynamo processes. Besides public accessible methods, additional private methods and classes prepare Revit-related data to interact with our toolkit framework. In consequence, the library *IfcBridgeToolKit* is decoupled from any Autodesk related references or data types. The toolkit itself provides methods to insert groups of IFC instances into an IFC model. Any interactions with the IFC model are realized using the early-binding framework *xBIM* (*xBIM Toolkit*, 2019).

5 Results

With the presented tool chain, we are now able to deliver IfcBridge models in the context of a Cartesian Coordinates based Reference View. The existing tools provide suitable functions for the conceptual design and refining components in later project phases. Figure 4 shows the resulting IFC model in the FZK viewer (Karlsruher Institut für Technologie, 2019).

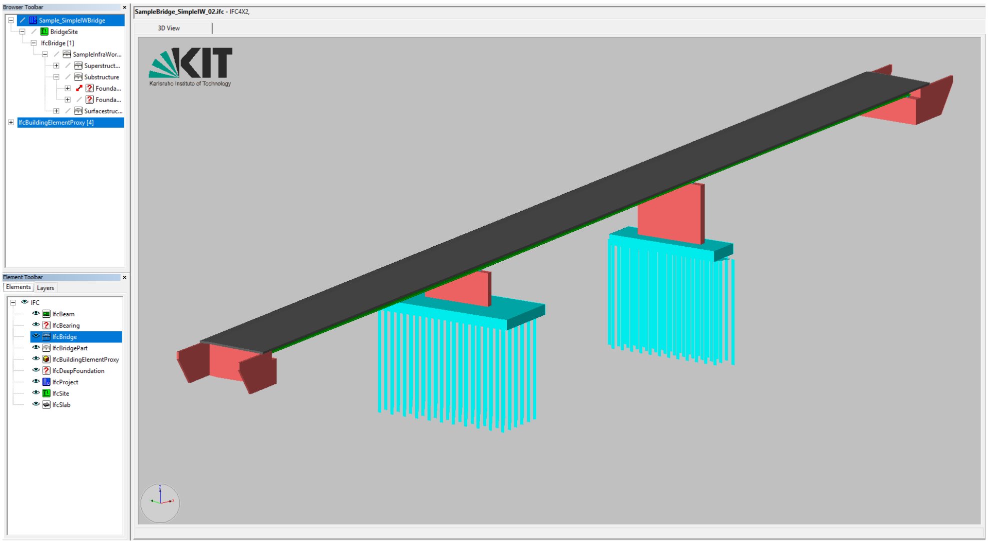

Figure 4: Resulting IFC Model in the FZK-Viewer

6 Discussion

The case study has successfully shown the tested tool chain to provide proprietary bridge models in a vendor-neutral representation. The use of a visual programming language enables a broad range of users to get a deeper understanding of the technical behavior of and to quickly change the resulting IFC content. However, improvements and less flexibility is required to implement and provide legally binding interfaces. Although it was possible to export models in a coordinate-based RV, the implementation of alignment-based models is not realized yet since no alignment curve was present in the models. However, the chosen implementation architecture can be extended for such requirements.

7 Conclusion and Outlook

In this paper, we presented an innovative approach to generate IfcBridge models. As shown in the case study, established tools build a robust base for future import and export interfaces. In the next steps, the resulting models should be tested against the official MVD definitions using MVDXML. Additionally, many engineering and consulting companies have developed own Dynamo codes for bridge design tasks. Thus, a connection between the IfcBridge-nodes and their custom codes can gain many benefits. Finally, cross-domain interfaces are of high importance to reach the overall goal: to improve the quality of collaboration.

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