Automatized Parametric Modeling to Enhance a data-based Maintenance Process for Infrastructure Buildings

Robert Hartung[a], Robin Schönbach[a], Dominic Liepe[a] and Katharina Klemt-Albert[a]

[a]Institute of Construction Management and Digital Engineering, Leibniz Universität Hannover, Germany
E-mail: hartung@icom.uni-hannover.de, info@icom.uni-hannover.de

Abstract –

New innovative and digital approaches, in particular digital methods like Building Information Modeling (BIM), are being used more and more in the Architecture, Engineering and Construction (AEC) Sector. However, most of building operation and maintenance processes still follow conventional processes and are hardly supported by digital databases. Within the widespread field of different infrastructure systems, the railway sector specifically brings a lot of rather old structures and components, which need intense service across their entire lifecycle. Research at Leibniz Universität Hannover explores a fundamental concept for digitally supported maintenance of railway infrastructure to enhance availability, reliability and provide a structured database for the involved stakeholders. Therefore, required methods and processes need to be defined and harmonized for different perspectives like infrastructure operators, monitoring service providers and supervising authorities. Based on digital models, a new approach for a holistic infrastructure management will be introduced and furthermore validated by using a reference project as demonstrator. The paper focuses on the organization, structure and needed level of information within digital models. Further ways of automatization in creation of such models are examined. In conclusion, the risk of damage or breakdown will be reduced and maintenance processes can be initiated on a data-driven basis. By means of this approach, it is possible to change the way from a reactive maintenance processes to efficient repair works in an early stage of damage.

Keywords –

Building Information Modeling; Structural Health Monitoring; shBIM; Digital Maintenance

1 Introduction and Motivation

The German railway and road infrastructure are taking a key role for Germany's economy and public transport, as well as for the European market. Providing a resilient infrastructure is a challenging task with multidimensional complexity [1]. With Germany being in the centre of Europe, six out of nine corridors of the Trans-European Transport Networks (TEN-T) will run across Germany by the estimated completion in 2030. The overall goal is strongly to support the Trans European Internal Market [2]. As shown in Figure 1, Germanys railway network is with more than 33,000 km one of the largest in the European context. This leads on the one hand in high efforts for development and maintenance of the network and its building structures and on the other hand it gives an indication into the complexity of inner-Germanys railway infrastructure.

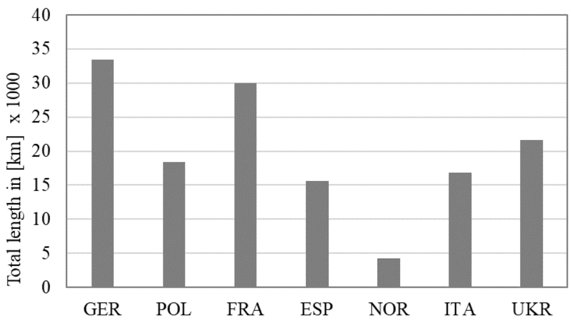

Figure 1. Total length of railway infrastructure in selected European countries, 2016 [3]

With regard to rail, not only the development of new tracks will play an important role in the future. Indeed, retrofitting and especially the maintenance of existing tracks and civil engineering structures like bridges, tunnels or retaining walls will become an enormous challenge for engineering services.

The German railway network operator DB Netz AG is responsible for track maintenance and improvement including civil engineering structures within the infrastructure network in Germany. This covers the responsibilities for the above mentioned 33,000 km tracks, 25,000 bridges and 700 tunnels [4]. The average age of Germany's railway bridges has an age of 73 years with a rising trend.

Bridges are of enormous importance since they are bottlenecks in the infrastructure system. With special regard to railway infrastructure, restrictions or failure in bridge structures have high consequences for the overall track availability and the efficiency of rail-bound traffic. Closed or malfunctioning bridges lead to redirecting trains on non-optimal routes, which leads to a significant loss in the efficiency during operation and high delays.

In order to minimize and prevent the risk of failure, DB Netz carries out a periodic bridge inspection to evaluate the bridge conditions. This binds a high amount of material as well as human resources.

2 Status Quo processes of maintenance

In Germany, the maintenance of civil engineering structures is regulated in a national standard (DIN 1076). Furthermore, there are specific regulations with respect to the infrastructure operator (e. g. Deutsche Bahn, RIL 804 [5]) for Germany's railway network. Due to the later introduced reference project, the aim of the following description of maintenance processes focuses on railway infrastructure in Germany, since the process is highly standardized and regulated by the government.

The established maintenance concepts do not envisage continuous bridge monitoring or condition assessment. The maintenance is usually reactive-oriented and leads to expensive repair works to ensure the system reliability. As can be seen in Figure 2 following the conventional maintenance process results in a periodic assessment of the bridge condition.

The periodic assessment starts with a first obligatory assessment of the bridge structure before start of operation.

The second assessment will be before the end of the warranty period in case of new construction, but in maximum six years after the last assessment. After the end of warranty period the supervision and the assessment will be alternatingly done in a three-year rhythm. The documentation of damages and the information exchange during the process is based on protocols and reports, primarily in paper form or non-object-oriented data bases.

In case of serious damages, solutions for limiting or remedying the damage is approved at a decision conference where all relevant stakeholders are involved. It should be noted, that in all categories the safety of the bridge structure for operation is guaranteed. Otherwise, immediate action would be taken to close the bridge.

Even if small inspections are carried out in the meantime, the periodic condition assessment can lead to a serious lack of information during the inspections. Using Structural Health Monitoring (SHM) in addition to the conventional maintenance process provides a continual assessment in real time (see also Figure 2) [5]. Knowing the real-time-status of the civil engineering structure and evaluating the development in a small-scale, predictive maintenance concepts can be implemented and applied [6]. Appropriate data processing and efficient evaluation mechanisms are required to develop target-orientated treatments.

Data linking between Building Information Modeling (BIM) and Structural Health Monitoring (SHM) to create a holistic data platform with intelligent data organization and data analysis can be a key for a performant status assessment. This new approach is defined as structural health BIM (shBIM) and includes data processing from different sources and different perspectives.

3 Concept shBIM

The key to an innovative digitally supported maintenance approach is a sensor-supported continuous monitoring system, which supports and supplements the traditional manual inspection techniques and leads to a completely new quality of maintenance approaches [7], [8], [9].

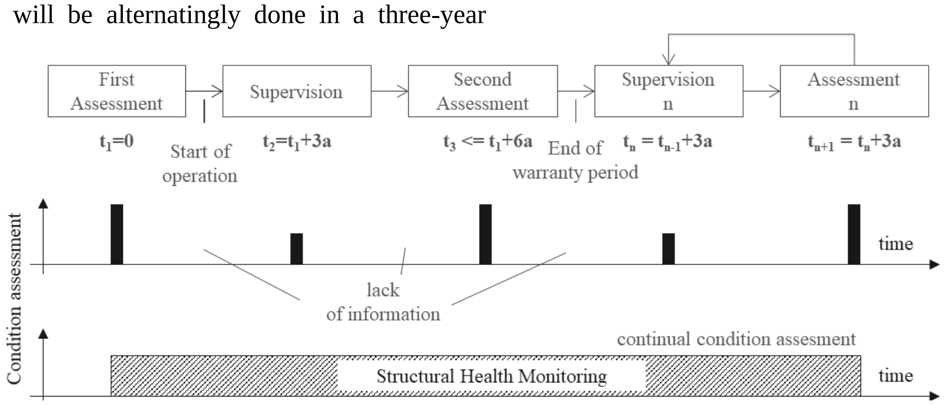

Figure 2. Qualitative degree of condition assessment in the conventional maintenance process (top) compared to a continuous structural health monitoring (bottom)

For this purpose, all information of the inventory, the manual inspection processes as well as from the structure monitoring need to be linked intelligently, edited and provided customized and on demand for the various process stakeholders to enhance the reliability of the rail infrastructure system. The digital method Building Information Modeling provides an ideal conceptual and methodological basis for this collection, linkage and evaluation of multiple data sources and will be extended by the integration of structural health data (monitoring data, inspection data). The overall concept of shBIM is shown in the following Figure 3. The shBIM platform operates as a data hub which is fed by different sources. For generalization, these sources can be defined as three main sources:

First, monitoring data, which includes all data from the SHM systems and dynamic data of the operation phase are linked to an object-oriented building model. The extensive data sets from different monitoring elements like acceleration sensors, strain sensors or temperature sensors will be pre-processed and appropriated for integration in the platform using suitable interfaces (A).

Second, the digital BIM model itself needs to be developed, which includes the information of the infrastructure building and the installed monitoring systems. It contains the object information, geometric information as well as static semantic information and is the central module for the user interface, data visualization and user-oriented data preparation (B).

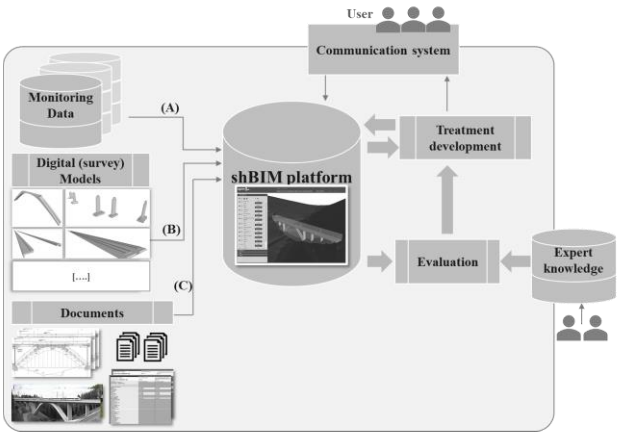

Figure 3. System architecture of the shBIM platform integrating expert knowledge and evaluation processes based on [9]

Third, documents and further data bases, which provide a more detailed description of the construction object, like conventional drawings, photo documentations, reports or maintenance instructions as well as the building documentation of past years, are integrated. They are linked to individual objects or object groups within the shBIM platform (C).

It can be seen that the structuring of the different data sources is strongly dependent on the data sources themselves. Especially for automatization in data analysis and in providing a user-friendly platform, different requirements need to be fulfilled to make evaluations by means of artificial intelligence possible. Merging the information of different sources in an automized way, an evaluation on the health of the examined civil engineering structure can be drawn. The results can be provided for the involved stakeholders to support the maintenance servicing processes. Therefore, also expert know-how can be included in terms of a knowledge-based system. The automated and continuous analysis of the data is used for prediction of probability of occurrence of damage cases as well as for the development of appropriate measures, which are also communicated platform-based. Finally, the information gathered during the service tasks will be recirculated and is used for the assessment of the maintenance measures.

The shBIM approach leads to a comprehensive and user-oriented monitoring data integration. All relevant information is fully integrated into the BIM model and linked to the digital representation objects. To ensure practicability, the question of a convenient level of detail regarding the bridge model needs to be answered. There is a large need for automatization in generating object-oriented models to provide the model as the central data hub to guarantee efficient implementation processes of the existing bridges.

4 Use cases for digital model and needed Information

The use cases for the digital maintenance of bridge structures are diverse. Pursuing different use cases in a digital environment, e.g. manual bridge inspection according to the regulations in RIL 804 [6], supportive monitoring by an SHM system or recalculation to verify the load-bearing capacity of the structure lead to different applications and information densities. However, geometric and semantic requirements of the BIM model need to be formulated for each use case separately.

Important use cases focusing maintenance processes can already be implemented with an abstract information model. An abstract model is defined as a model which consists predominantly of geometric objects without a high demand for geometric detailing, but in accordance to the classification system of Deutsche Bahn. Therefore, the focus is on the semantic description of the objects. It is assumed for use of digital models in maintenance, that the geometry of the components is pushed into the background compared to the specific semantic description [10]. Consequently, the approach is pursued that abstract geometric objects are sufficient to satisfy the information management in maintenance processes with regard to the introduced structural health monitoring concept. By reducing the geometric detailing, the bridge components can be represented by parameterized objects and thus lead to an enormous time saving in the digital transformation of the documentation of existing bridge buildings. The developed digital models can be integrated as the central data hub for the shBIM platform. Generating the BIM model in an automatized way will reduce errors in manual model creation and enhance efficiency.

- The formulation of the geometric and semantic requirements for each particular use case depends on the internal systems, processes and standardization of the operator. Those are critical input parameters for the automatization process, which will be introduced in the following chapters. The purpose of the abstracted models can be summarized to correspond to the existing standardization of civil engineering structure
- include inventory data for civil engineering structure description
- provide a visual 3D model to improve perception and information management
- allow integration in shBIM-platform for communication and collaboration processes

As already mentioned, this paper focuses on railway infrastructure. However, the developed approach is transferable to any kind of comparable classification system.

5 Concept for parametric modelling

In the following chapter the overall process for an automized abstracted model will be introduced (see Figure 4). In addition, the demonstrated process will be validated on a real reference project within the railway sector in Germany.

5.1 Overall process description

The development of a feasible process for automated model generation is an essential part of the research on digital maintenance of bridge structures. To generate the abstracted models, the approach of parametric modelling with the software Autodesk Revit is used in combination with Dynamo, a visual programming interface. It should be mentioned that the method of visual programming allows an intuitive way of programming, since pre-assembled code blocks are available and can be linked together in a logical way. Instead of having a textual script, the coding follows the logic of the arrangement of the coding blocks (see Figure 5).

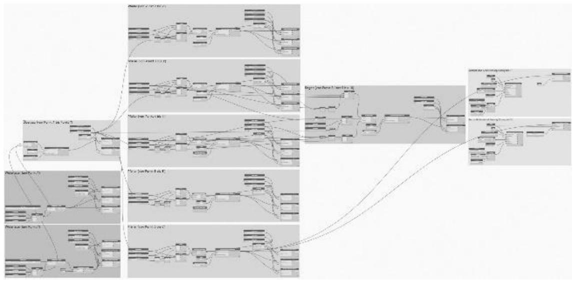

Figure 5. Overview of a part of the script to generate abstracted models using visual programming

This software combination enables the implementation of model generation based on defined geometric and semantic parameters. However, the approach is transferable to alternative software solutions that enable export in open data exchange formats.

At the beginning of the process, the use cases for digital maintenance are defined to obtain the relevant semantic information. In dependence on the semantic description, the possible maximum abstraction level of the building elements is defined, which describe the input parameters for automatization in the modeling process. The abstraction is based on company related specifications, which define structuring and also could include derivations for standard cross sections.

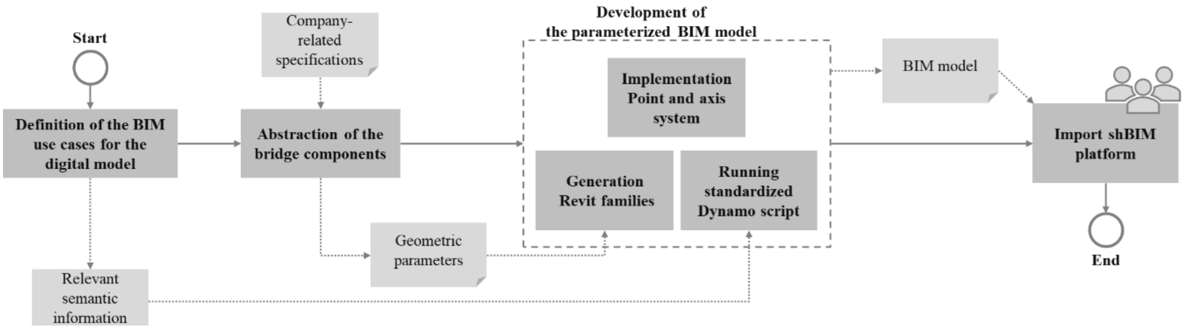

Figure 4. Development process of the abstracted parametrized BIM model

The result of the abstraction is the derivation of geometric input parameters. The development of the parameterized BIM model itself is based on three essential steps. First, the creation of a point-axis-system for the positioning and extrusion of the bridge components need to be set up. The system describes the positioning and the relationships between each abstract component. Components like the abutments can be abstracted as a cube, which follow user-specific input parameters and are placed using a single identification point. Supplementary components like the superstructure, piers and arch are characterized by a start point and an end point, which are represented by the point-axis-system. Between start and end the cross section will be extruded.

The positioning and relationship to other components is realized by the placement of specific points. The arcs are represented in a circle section shaped three-point definition. The extrusion of the rectangle cross section is realized along the curved axis.

Second, the parameterized Revit families based on the identified geometric input parameters from the abstraction process are developed. For cuboid components, the cross section of the element is defined by width and depth. The length of the component is defined due to the length of the corresponding axis.

Third, the creation of a dynamo script that connects the parametric Revit families and the point-axis-system and implements the semantic information from the use cases, has been carried out.

The algorithm goes through the placed families and adds standardized attributes to the components. Then the blank attributes are filled with the values of the specific building. After execution of the script, a geometrically abstracted BIM model is finally generated in an authoring software environment.

An export of the native model to the open standard Industry Foundation Classes (IFC) allows the implementation in the shBIM platform and can be combined with other information such as geodata. This enables the integration of further model data from different disciplines, companies and authoring tools.

In order to be able to practically comprehend the process of geometric abstraction and to demonstrate that a defined information content can be implemented, the development is explained step by step in the following chapter, based on a reference rail infrastructure project.

5.2 Reference project

The *Grubentalbrücke (Railway Bridge Grubental)* is a railway crossing of the "Verkehrsprojekt Deutsche Einheit Nr. 8" (VDE 8), which was completed in 2013. The VDE 8 project is part of an infrastructure program decided by the German government in 1991, to establish the import north-south axis between the cities of Berlin and Munich. The infrastructure is part of the project's subproject 8.1. The Railway Bridge Grubental is one of 24 railway bridges located on the rail route between Nuremberg and Erfurt (see Figure 6), which also interlinks major German cities like Hamburg, Frankfurt and Munich and is of great importance.

The Railway Bridge Grubental is chosen as the reference project since the bridge is characterized by a good data basis and by the existence of an implemented structural health monitoring system. The automated modelling will focus on the geometries of the abutments, piers, superstructure and arch to develop the abstraction process. The implementation of the structural health monitoring components is not part of the automatic process.

Figure 6. Railway Bridge Grubental (left) and the local placement within the high-speed rail network in Germany (right)

5.3 Abstraction of relevant building parts

To start the abstraction process of the Railway Bridge Grubental, two use cases are defined. The exemplary use cases use the semantic information that will be added after the geometric model generation.

Use case A comprises the implementation of a component-specific coding based on the component hierarchy of Deutsche Bahn AG. With the coding it is possible to uniquely identify the individual objects later. This information is model-inherent, directly attached to the component by a corresponding parameter. In addition, almost 450 attributes are taken into account in order to address the maintenance requirements of the existing system with the BIM model. Those parameters can be clustered in different categories. For this use case the cluster results out of the building structure (e.g. abutments, piers, superstructure, etc.), where attributes describe the individual building component in terms of structure, material and environmental conditions. The numerous attributes can be static or be developed dynamically over time. This allows the identification and semantic description of each individual object as well as the structural health assessment on the level of the component.

Use case B pursues the linking of an as-built drawing in PDF format with the BIM model. Therefore, a unique identification parameter is integrated to the semantic. The linked document can be located on a different location. By mapping the unique object parameter with a document link, a clear allocation is realized.

These use cases have no direct influence on the geometric abstraction, but are intended to show what is possible within linking maintenance information to the model and managing it in the shBIM platform. These use cases present an exemplary method and can be adapted to more detailed considerations.

A geometric abstraction of the Railway Bridge Grubental has been implemented in accordance to the bridge specification regarding the building structure of Deutsche Bahn (see Figure 7). Therefore, it is not important that the exact geometry of the component is created, but their existence is, in order to be identifiable in the classification. The relevant components for the reference project consist of abutments, piers, superstructure and the arch.

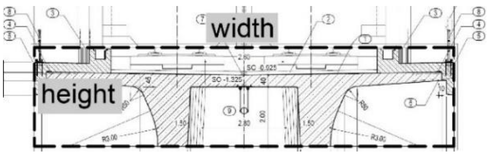

Figure 7. Enveloping rectangle shape to abstract superstructure cross-section

According to the introduced process model, the first step is the description of a point-axis-system for positioning and description of the relationships between the objects (see Figure 8).

A total of 15 points is required to describe the components of the reference railway bridge. For example, the line from point 1 to point 7 is the representation of the superstructure-axis, which is function as extrusion line of the superstructure. The point-axis-system is generated by a standardized dynamo script in accordance to the number and position of the bridge piers. The script acts further as the interface between the developed parameterized Revit families and the point-axis-system. The families are also standardized for cuboid geometries, which have individual compulsion points. The component families are designed in a way that the component is either positioned directly by a pre-defined point in the geometry (abutment) or needs a start and end point to create a corresponding extrusion along the defined axis (piers, superstructure, arch). For the extrusion, an abstracted rectangle cross section as well as the axis itself is parametrized. Focusing on the individual components, they are abstracted in a rectangle shape, so that they take on a simple enveloping shape, here shown using the example of the superstructure.

The superstructure of the reference bridge is a double-webbed slab beam, as continuous beam. The shape is abstracted by stretching a rectangle as a surrounding boundary at the maximum vertical and horizontal shape of the superstructure. The geometric parameters "height" and "width" are created, which define the dimensions of the reduced rectangular cross-section. These parameters are the geometric input for the parameterized Revit families, which can be indicated bridge specific. Using the same method, the other components can also be simplified as cuboid objects, which is the first step to a digital object with a low degree in geometric detailing. The dynamo script has a modular structure and can be supplemented by further components if required or reduced if some components are not needed.

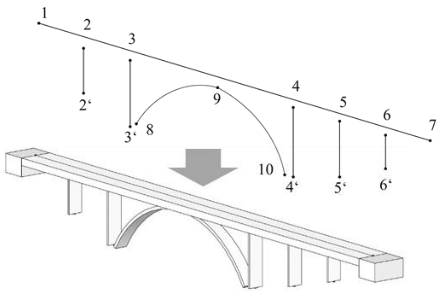

Figure 8. Point and axis system of the abstracted Railway Bridge Grubental and abstract geometric with automated model generation

After the geometry has been created by the script, the semantic information can be added in the next step. For this purpose, an attribute editor forms the end of the algorithm. The attribute editor adds standard attributes from the today's maintenance system and add the bridge specific values based on a csv-file (use case A). The csv-file is generated as a bridge specific export and is imported as an array to the dynamo procedure afterwards. The last step in accordance to the introduced process is the export of the model for integration to the shBIM platform.

5.4 Evaluation of different Level of Detail

To evaluate the level of detail, a second digital model of the reference railway bridge was modelled in another software tool and has been exported in the open, international standard IFC. This model is characterized by a high level of detail corresponding to the detailed design (see Figure 9). It is used as a reference structure to validate the quality of the abstraction.

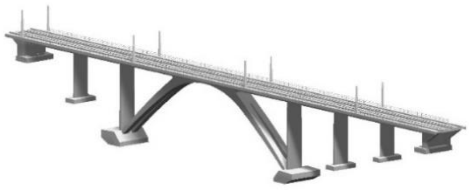

Figure 9. Precisely modelled Railway Bridge Grubental on the basis of the detailed design

The validation of the model quality is divided into the criteria of geometric and semantic parameterization and interoperability. During the validation it was checked whether the implemented geometric input parameters like "width_abutment", "height_ superstructure" or "thickness_pier" were generated and transferred correctly.

The model abstraction of the selected bridge components resulted in a reduction of the geometric objects from 4936 of the precise modelling to 9 using the abstract approach. When the two models are overlaid, it becomes clear that the two models differ only in points of geometric detailing of the individual objects and missing equipment components, which are not considered in the abstraction e.g. railings, track, etc. Where in the detailed model the abutments consist out of several components such as swing and chamber walls and the support bench, the abstraction consists of one abutment representation-object. However, bridge specific dimensions such as bridge length, spans, pier heights and the width of the superstructure do not differ from the model based on the detailed design.

The validation of the abstract model with regard to interoperability is of crucial importance. The generated BIM model based on the defined use cases for digital maintenance serves as the data hub in the shBIM platform. Therefore, after integration in the shBIM platform the quality of the abstract BIM model is also validated.

5.5 Integration in shBIM platform

Due to many stakeholders involved in design, construction and operation, this specific platform must guarantee a manufacturer-independent data exchange format, such as the internationally accepted IFC format for open BIM data exchange. The model quality and usability are primarily dependent on the data transfer quality of the interface.

The basis for the development of the shBIM platform is the Common Data Environment (CDE) "Squirrel". To make the abstract model available for maintenance purposes, the last process step is the import of the abstract bridge model into the CDE (see Figure 10) via the open BIM format IFC.

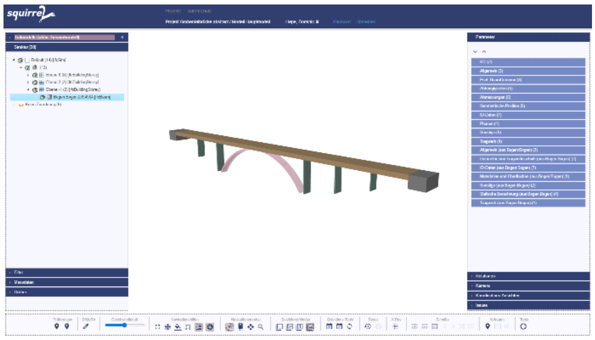

Figure 10. View of the imported BIM model within the CDE-based shBIM platform

On the left side of the user interface, the model structure of the partial model for revisions as well as the partial model management with different functionalities is shown. On the right side, it is possible for each individual user of the CDE to look at the semantics of the bridge elements. Individual elements of the digital bridge model can be selected and therefore their individual properties can be viewed (use case A). Other geometric objects, such as the sensor technology of the SHM system, could also be imported as a separate partial model within the CDE. Specific data, related to the structure or the sensor technology, can be linked to the CDE using a linked data approach (use case B), which means an allocation of each document in the platform to a unique identifier at the building component it belongs to. The overarching objective is to organise and manage all prepared information and processed data within the shBIM concept via the CDE platform. The platform is supposed to support the whole structural health monitoring process of the railway bridge with data and information management throughout the whole life cycle of the railway bridge. Moreover, the shBIM platform will ensure the traceability of edited information and data as well as the documentation of performed maintenance services within the digital BIM model. The access of the shBIM platform is defined via an individual and project-specific authorisation concept.

5.6 Discussion

Deutsche Bahn AG maintains more than 25,000 bridge structures. Detailed 3D modelling for digital maintenance approaches on the basis of the detailed design or even more precisely the actual condition (as built) is economically questionable. The presented approach of abstracted geometric modelling of the bridge using automated generation algorithms shows a method to reduce the effort. It was explained that the semantic information of the digital use cases is in many cases more important for the maintenance processes than the geometric detail depth. In addition, simple geometric bodies are easier to check during creation and processing. Regarding the interoperability of the models, simple geometry also has advantages. The IFC format has established itself as an international and manufacturer-neutral data exchange format. However, development is ongoing and will continue to be subject to constant changes over the next few years, especially with regard to new infrastructure specifications, which are expected in the next years. Simple geometric shapes guarantee significantly fewer data exchange errors.

Further, the maintenance operator will not be in false expectations due to a reputed exact model. Rather, the stakeholders involved in maintenance are aware that this is an abstraction and that exact geometrical dimensions must be determined, if applicable use cases require a higher level of development. Since bridges along the lifecycle are subjected to modifications, it cannot be assumed, that detailed design from several decades ago and digital models which are based on those, correspond to the status quo. By classifying the bridge types and developing an abstraction standard for each type, an area-wide implementation of automated creation of BIM models for the shBIM platform can be achieved.

Continuous and further detailing of abstract models due to special tasks, such as renewal or repair measures, can be done afterwards.

6 Conclusion and Outlook

In summary the research has shown, that it is possible to highly automate the way of modeling to generate digital models for specific use cases. Abstract models are an adequate option to realize sufficient information management and visualization for various maintenance measures.

However, there is still a lack of description to grasp the manifoldness of bridges and model them in a standardized parametric way. In the next step, the automatization method should be enrolled to a higher number of relevant civil engineering structures from different years of edification and from different structural types to implement specifics in the superstructure and the overall structural system. Open formats can provide a life cycle-oriented, comprehensible and transparent information management in a common data environment, which allows different stakeholders to access. The approach should be exposed for further use cases e.g. the integration of damage assessment and repair measures.

Acknowledgement
This research is supported by the Federal Ministry of Transport and Digital Infrastructure (BMVI) in the funding program mFUND (FKZ: 19F2075A).

References

[1] Klemt-Albert, K., Hartung, R. and Bahlau, S. Enhancing Resilience of Traffic Networks with a Focus on Impacts of Neuralgic Points Like Urban Tunnels. In *Resilience Engineering for Urban Tunnels*, pages 55-70, Reston, USA, 2018.

[2] European Commission. Trans-European transport network (TENtec), https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/index_en.htm, Accessed: 26/05/2020.

[3] Weltbank, World Development Indicators. Länge der Schieneninfrastruktur in ausgewählten Ländern. Online: http://databank.worldbank.org/data/source/world-development-indicators, Accessed: 26/05/2020.

[4] Deutsche Bahn. Infrastrukturzustands- und entwicklungsbericht 2017, *Deutsche Bahn AG*, 2018.

[5] Hartung, R., Senger, L., Klemt-Albert, K. Linking Building Information Modeling and Structural Health Monitoring for reliable railway infrastructure. In *Proceedings of the 29th European Safety and Reliability Conference*, pages 596-603, Hannover, Germany, 2019.

[6] Marx, S., Krontal, L., Tamms, K. Monitoring von Brückenbauwerken als Werkzeug der Bauüberwachung. In *Bautechnik 92 (2)*, pages 123-133, Germany, 2015.

[7] Deutsche Bahn Netz AG. Eisenbahnbrücken (und sonstige Ingenieurbauwerke) planen, bauen und instandhalten – Inspektion von Ingenieurbauwerken (8001), *Deutsche Bahn AG*, 2015.

[8] Hartung, R., et. al. Evaluation of Structural Health Monitoring Systems in Bridge Engineering for Increase of Safety in Operations, in *Proceedings of the 30th European Safety and Reliability Conference and the 15th Probabilistic Safety Assessment and Management Conference*, pages 1-8, Venice, Italy, 2020.

[9] Chan, B., Guan, H., et. al. Defining a conceptual framework for the integration of modelling and advanced imaging for improving the reliability and efficiency of bridge assessments. In *Journal of Civil Structural Health Monitoring*, pages 703-714, Berlin/Heidelberg, Germany, 2016.

[10] Isailovic, D., Stojanovic, V., Trapp, M., Richter, R., Hajdin, R., Döllner, J. Bridge damage: Detection, IFC-based semantic enrichment and visualization. In *Automation in Construction*, Vol. 112, Amsterdam, Netherlands, 2020.