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Dear Readers

In the first article of this issue, Wiktor Rybus focuses on the construction of the Randselva Bridge in Norway which is being built without drawings. He provides some details and specifics on BIM issues that the teams have encountered on site.

The article about a geometric update of the digital twin of a viaduct was written by David Herrero Mediavilla. He discusses some issues that may arise during the creation of a digital twin and provides an overview of methods used in the bridge industry.

Professor Chang-Su Shim from Chung-Ang University in South Korea provides an introduction into his research program on smart construction technology in South Korea.

In the interview with Professor Rade Hajdin we talked about the utilization of BIM in the bridge industry, his role in IABSE (he is a Chair of IABSE Commission 5), his career and plans for the future. We also include his CV.

The last article of this issue was prepared by Marek Salamak; it is a report about infraBIM Conference which was held online in December 2021.

I would like to thank all people and companies that have been cooperating on this issue and helping me to put it together; big thanks to members of the Editorial Board for reviewing the articles and their cooperation, to Richard Cooke who is always very helpful with e-mosty and also with this Edition of e-BrIM. I would also like to thank Sandra Komar (WSP USA) who has done the final language check of the articles.

I am very happy that this newly established magazine already has three partners – Rúbrica Engineering, Nplus and Pipenbaher Consulting Engineers. Thank you very much for your support.

We are already working on the next issues of e-BrIM which will be released on 20 May and 20 October.

March Issue of e-mosty will feature two bridges: The Pelješac Bridge in Croatia and McKinley Avenue Overpass in the USA, and June e-mosty is planned to be a special edition about 1915 Çanakkale Bridge in Turkey.

Magdaléna Sobotková

Chief Editor

1/2022
The magazine e-BrIM is an international, interactive, peer-reviewed magazine about bridge information modelling.

It is published at www.e-brim.com and can be read free of charge (open access) with the possibility to subscribe.

It is typically published three times a year: 20 February, 20 May and 20 October. The magazines stay available online on our website as pdf.

The magazine brings original articles about bridge digital technology from early planning till operation and maintenance, theoretical and practical innovations, Case Studies and much more from around the world. Its electronic form enables the publishing of high-quality photos, videos, drawings, 3D models, links, etc.

We aim to include all important and technical information, to share theory and practice, knowledge and experience and at the same time, to show the grace and beauty of the structures.

We are happy to provide media support for important BIM and bridge conferences, educational activities, charitable projects, books, etc.

Our Editorial Board comprises BIM and bridge experts and engineers from academic, research and business environments and the bridge industry.

The readers are mainly bridge leaders, project owners, bridge managers and inspectors, bridge engineers and designers, contractors, BIM experts and managers, university lecturers and students, or people who just love bridges.
In August 2021 we established a new magazine, e-BrIM, which will focus on Bridge Information Modelling.

We would like to follow the concept of the e-mosty magazine and create an international, peer-reviewed magazine with open access and the possibility to subscribe.

Our plan is to publish it three times a year; its first regular issue will be released on 20 February 2022. The September 2021 edition of e-mosty was also a “zero” edition of e-BrIM.

We believe that with the current development of BIM, there will be plenty of interesting and useful content to share.

Let us introduce and welcome our Editorial Board Members. Thank you all for accepting our invitation.

We all will do our best to prepare technical, educational and informative content for our readers.

We would also like to invite you to contribute with your articles to this newly established magazine e-BrIM:

CALL FOR PAPERS

20 May 2022 Edition:
Deadline for first drafts: 20 March 2022
Deadline for review: 20 April 2022
Deadline for final check: 5 May 2022

20 October 2022 Edition:
Deadline for first drafts: 20 May 2022
Deadline for review: 20 August 2022
Deadline for final check: 5 October 2022

The text shall be in MS Word, 3 – 5 pages plus relevant images, drawings, 3D models, links and videos and shall be sent to our email address.

You may also send an abstract before starting work on the article or contact us to discuss other options.

All abstracts and articles will be peer-reviewed and also subject to approval by the Editorial Board.
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RANDSELVA BRIDGE: CONSTRUCTION WITHOUT DRAWINGS

Wiktor Rybus, BIM Developer, Sweco Norway (until 01/2022 PORR/PNC)

INTRODUCTION

The Randselva Bridge is a 634m long cantilever concrete box girder bridge over the River Randselva in Norway, near the city of Hønefoss which is around 50km northwest of the Norwegian capital Oslo.

The bridge will carry the E16 highway which originates in Sweden.

The Randselva Bridge is the world’s longest bridge being built without drawings to date; it is based solely on BIM models. The models consist of more than 50 IFC files regarding the bridge construction and other file formats of the models for roads and earthworks.

Project Owner: Statens Vegvesen (Norwegian Public Roads Administration)

Design & Calculations: Armando Rito Engenharia

Design, Calculations & BIM-models: Sweco Norway

Construction (Contractor): PNC Norway (Group Porr)

BIM Software: TEKLA
BUILDING A BRIDGE WITHOUT A SINGLE DRAWING

What does this mean for the Contractor and the other stakeholders?

Since transferring the data through IFC files is the main source of technical input to proceed with the installation on-site, it is the most critical aspect for all to succeed. This method has not yet been developed on such a scale and does not yet include all the solutions needed to be implemented and described before the work started. Drawingless BIM design sets the framework for Information Management in the digital environment to be followed in each project phase.

The Contractor, especially, has an integral part for project success. Their responsibilities include:

- To deliver Model information to all stakeholders by managing the CDE platform, leading the process under the Model quality control by close coordination with the design team to decrease errors, missing data, or clashes in the Model.

- To be a source of input for Model object properties such as supplies of material/equipment design, duration of tasks, activity distribution to have the Model built to cover their internal processes during the execution to deliver construction within time, quality and under sufficient control of costs.

- To manage the output of Model data for the installation work on a site. This is new for everyone as the workers must be delivered all the information needed without the traditional 2D drawings.

- To create a solution to store and make the Model able to track changes to capture the history of as many activities as possible that occur while building the Model on the construction site. Creating a digital diary of the project best connected to the Model can be very useful for further handover, as-built documentation, or possible claims in regards to change orders or delays on site.

- To produce on-site according to the latest BIM models that have been released and approved. If the real construction deviates, then the Models have to be updated accordingly.

The as-built model is created according to the progress and changes during the construction phase. It is not only about deviation but also about the internal design that has ensued related to equipment installation and other supplies of material/solutions.

If it is possible to use and analyse data from the digital interpretation of the structure during any construction phase, the general contractor has made successful implementations of the BIM process.

The information takeoff tool inside the software allows the generation of any classification of information needed. For this purpose, the general contractor, supplier, and designer have discussed the form of data included in the 3D reinforcement model.

The measures are taken according to the specification and the shape-code is assigned to each bar so that the supplier knows exactly how to produce them.
The possibility to generate the rebar bending list (bending list is a bending schedule list of reinforcement to be ordered/produced and installed) by the general contractor is very helpful. Not being dependent on designer delivery is beneficial because of this additional factor that may contribute to the delay of production.

The model enables to generate, in very quick time, the bending list needed for particular rebars and enables to have control over them. To help avoid a lot of manual work at the fabrication site with preparing the orders for production, the supplier can load their own template of excel data which the system can read to create the production bending list data.

Such excel data include all the reinforcement position attributes necessary to produce them: dimension, name, measurements, shape-codes, dates, bending radius, amount, weight, etc.

Prior to this phase, the shape codes need to first be predefined manually to let the system recognize the bending process. This avoids a lot of mistakes during the construction phase and delays in the material delivery.

Having over 200,000 rebars in the Model, it is important for the contractor to have access to data that can be controlled in a much earlier phase than before.

It is fully traceable to see which materials have been installed in each part of the project. Updates are made to the BIM viewer inside Solibri with actual data and that data can be filtered and shared through each BIM model in CDE.

To make all the data available and traceable, it needs to be properly assigned into the 3D objects. This has been developed so far in terms of ordering material, such as reinforcement, and controlling the deliveries. Installation might be more controlled in the future with, for example, QR scanning components.

The delivery of IFC files that contains geometry and metadata can be a great preview of the planning.

Figures 3 and 4: Construction of the bridge
phase regarding the equipment and material design/order.

It is very important to have a common format of data both for structure components and equipment or any other objects that can be modelled and compared to each other through the 3D viewer (mainly CDE is used for that purpose).

It is only possible to get the best benefits of BIM implementation when it is possible to implement all subjects covered in a three-dimensional world full of properties and attributes.

This should be set according to project specifications and stakeholders’ process requirements.

A general BIM station is set up at the construction site so that everyone can have access to the live Model.

Not only workers who execute the installation have access, but also the client or any suppliers or guests that are on-site are able to see and understand what the bridge or elements look like.
The challenge comes when one has to build the bridge according to the model. Even though all measurements, cross-sections and all the properties of an element can be checked on the computer, there are always questions about how to install the rebars without the drawings.

Solibri software has been in use since the beginning. BIM stations have all up-to-date IFC files read by Solibri via Dropbox as this software does not work on its own cloud solution. People have gotten used to working with that and simply taking screenshots and including the description manually.

The next step of development is an ongoing process via cloud server Trimble Connect where one can create many different views with assigned information that is then shared with all people that work on the project (including BIM station etc).

This can also be taken outside and, once prepared, can be used on iPads directly. This solution ensures that the drawing is not lost and that the data is always up to date.

In addition, once it is created, it is easily editable.

The Contractor has been testing the right model for the AR tool called Trimble Site Vision.
This is connected with the Trimble Connect server where the IFC files are stored so the live Model is easily accessible.

Trimble Connect made the application available to export the views to a native file that can be loaded into the site vision AR tool. This is significant since previously only the entire IFC files were able to be downloaded.

This tool can be useful for client quality control on-site as it enables to make the relevant checklist before construction proceeds.

During the construction, the Contractor develops the Model for final documentation as it is always possible to go back in time and check the details.

This can be done in various ways or solutions so that the construction workflow can be implemented and improved.

This allows people at the site to check very quickly what should be in the delivery notes of the materials ordered. The deliveries consist also of some additional information like the confirmation and date of truck arrival.

BIM coordination, in this case, is not only the quality control coordination but also the Model utilization allowing one to transfer as much data in the most transparent way possible.

Using the Common Data Environment (CDE), all relevant parties of the project can contribute to
task coordination and communication with one another to solve issues or just to inform one another about changes or any other important information that should be accessible to everyone involved.

As changes to the project or documentation are possible via the BIM model, it is very important that all parties are notified about any changes and have access to them through, for example, the website. Those changes can also be generated into BCF files in order to proceed with the acceptance process if necessary.

Whatever one can create within Trimble Connect - e.g.: the different kinds of views that can comprise the drawings for workers, the progress of the construction phase, some inputs for claims, or the manufacture information or even pictures from iPads - can be sent immediately to, for example, the HSE manager or to the Site Managers and inform them about the case.

Collaboration between internal design control has been held also by using the BCF (BIM Collaboration Format) file format made for issue tracking with a building information model.
Below is an example of how some clashes can be generated and visualized by relevant software and exported into BFC format.

Objects and their quantities might be used for linking the activities with other properties or data to have a better overview of the different processes the contractor cares about.

This way, it is possible to build a smart model to present necessary data of the construction progress, productivity, performance and many more related to the schedule and the budget. Better and detailed data collection generates a more accurate and up-to-date general overview.

It is a very useful tool for tracking the data for possible delays, forecast results, as-built schedule or any claim-related issues.

On the linear infrastructure project, there is a very helpful tool used by the survey team to scan the terrain in 3D for progress reporting of the earthworks.
However, when it is used for the roadway portion of the project, it is beneficial to use it as Trimble Connect point clouds to have the boundaries of the rigging area for any planning activity around the bridge such as cranes, deliveries of material, casting with pumps, concrete trucks or disassembly operations. Pix4D cloud service enables one to compare drone scanning from different dates that could be easily presented for any purpose during the construction or post-construction phase.

**CHALLENGES FOR THE FUTURE**

There are still some elements of a BIM approach that would require improvement.

I would recommend implementing BIM workflow already in the tender phase as the results showed that the schedule and productivity of the manpower hours on critical activities were underrated.

BIM can definitely help save money for better planning and forecasting.

There is still a “BIM on-site” workflow to be improved, mainly the way to generate 2D/3D...
annotations with the geometry of the objects purely from IFC files.

This is the most important lesson from this project to have in mind. There are BIM viewers to generate the views, but there is still no tool to include in the view data from attributes and assign them into geometry through simple annotations.

Implementing 4D could be developed and improved by setting a strong foundation. The reinforcement design basis should also be improved.

The Clash system and the limitation from the factory production as well as the transport need to be considered.

It may be beneficial to have a lower amount of shape codes, simplifying the rebars naming positions and their geometry.

To make the BIM design more useable during the construction stage, it should enable modelling additional files for surveyors including points, lines, road alignment profiles, etc.

BIM objects consist usually of geometry and data such as material, but more can be added dependently based on the construction process needs.
There is room for creating the way for transforming that data for planners, surveyors, project managers, cost controllers and others during the construction phase.

BIM approach would generally also require a change of the qualifications of the workers on site.

On the Randselva Bridge Project, the transformation to using mobile devices and software by workers has, in general, been very smooth.

However, it would be good to motivate and assist some people with their adaptation to this method. Without proper qualification and usage, there may be a risk of using wrong data which leads to bad quality of work performed on-site.

**CONCLUSION**

As BIM is becoming more widespread, it also has found its way into designing and constructing bridges.

Experience with a drawingless project such as the Randselva Bridge shows that it is possible and it can be expected that this method will become more preferred in the future even for more complex and larger-scale projects.

It has brought many challenges and requirements for improvement which will be resolved in future projects.

Read about the design of the Randselva Bridge in the September Edition of the magazine e-mosty which is also a “zero” edition of e-BIM magazine:
GEOMETRIC UPDATE OF THE DIGITAL TWIN OF A VIADUCT

David Herrero Mediavilla
Head of Technical Office / Survey Manager / BIM and Civil Engineering

The implementation of the Model Building Information (BIM) methodology in the framework of bridge projects requires the modelling of the structures.

The objective of this modelling is to obtain a digital twin\(^1\) that accompanies the project during all its phases: from the first stage of design engineering, through the construction of the structure, the maintenance and conservation, until the end of the useful life of the bridge.

A digital twin of a bridge in Figure 1 is a virtual model of the bridge, Figure 2, with a greater or lower degree of detail Level of Development (LOD) according to the defined objective.

The LOD should be defined within the BIM Execution Plan (BEP).

The lifespan of a bridge depends on many factors, but in general terms, it will be around 60-70 years.

The years of design and construction phase must be added to this average lifetime, which implies a long period of time during which the designed structure will undergo variations in its geometry and the condition of its structural materials.

All these changes should be recorded and integrated into the digital twin in order to know exactly at any moment the status of the structure. This will make it possible to predict future problems through simulations before they happen.

---

\(^1\) Geometric update of the digital twin of a viaduct.
DEGREES OF DIFFICULTY ACCORDING TO PROJECT STAGE

Depending on the phase of the bridge project, there will be different degrees of difficulty to generate the digital twin.

In the first phase, the structural design, there would be no major difficulties in modelling the bridge since the geometric shapes are perfect, Figures 3 and 4, formed by straight and curved lines without deformations.

The classification of the different materials that constitute the bridge does not present any problems.

In the next stage, construction, see Figure 5, the update of the digital twin is more complex. Not only for updating all the changes in the materials but also for updating the geometry.

The construction process is not perfect, and depending on the bridge typology, there may be...
significant geometrical variations with respect to the theoretical model.

For example, the calculations can determine a behaviour of the bridge deck once tensioned that differs by several cm from those obtained in its construction.

The third stage, operation, Figure 6, and maintenance, comprises the putting into operation of the structure until the end of its useful life and is the most complex stage to update in the digital model of the bridge for two reasons:

1) The structure suffers a greater number of geometric deformations that, in many cases, are complex to transfer to a digital twin.

   This is due to the fact that modelling software has most of its tools focused on creating perfect geometric shapes. The software is more oriented towards the design of the bridge and does not provide tools that facilitate the modelling of complex geometric deformations.

2) This is the longest stage and generally has fewer financial resources than the two previous stages. This means that there are fewer human resources available to measure the changes in the bridge and record them in the digital twin.
HOW TO CAPTURE THE GEOMETRIC VARIATIONS OF THE STRUCTURE?

In order to measure and record the deformations in the geometry of the bridge during the construction, operation and maintenance phases, it will be essential to have a survey engineering team analyse the condition of each structure and determine the best way to capture the reality and transfer it to the modelling team.

This can be done in two ways:

1) Conventional methods: The total station is used to capture a small number of singular points chosen by the inspection team based on their experience. This method is not very ambitious, as it leaves a significant number of deformations unrecorded.

2) Point cloud current topographic tools, both hardware and software tools, make it possible to obtain millions of georeferenced points in the project coordinate system (point cloud), which define the geometry of the bridge with great accuracy.

The maximum separation between two points in the defined cloud could be about 5 millimetres.

Obtaining the point cloud can be done by:

- Terrestrial Laser Scanning (TLS)\textsuperscript{2}, Figure 7,
- Aerial photogrammetry (drones)\textsuperscript{2},
- Combination of the two previous techniques: TLS+Photogrammetry.

**Terrestrial Laser Scanning (TLS)**

The TLS is an instrument that captures the geometry and colour of any object due to the measurement of distances and angles with a laser light beam combined with photographic cameras.

This provides the object with coordinates in the established reference system with millimetric precision\textsuperscript{3}.

The process is carried out by stationing the equipment at locations close to the bridge, see Figure 8, and without the need for physical contact.
Figure 7: Point cloud of viaduct obtained with Terrestrial Laser Scanning (TLS)
Source: Topcon Positioning Spain

Figure 8: TLS set up to capture bridge status
Source: Topcon Positioning Spain
There are several drawbacks:

- From the position of the TLS, all the elements of the structure to be measured must be clearly visualized. Otherwise, they would remain undetected.

- The working distance from the position where the TLS is located to the bridge covers a range that depends on the model and manufacturer of the equipment. Outside this range, the accuracy decreases rapidly, and its use is not desirable. The range starts at a distance of approximately 1 metre from the object and a maximum of several hundred metres (400-500 m). Some equipment may be able to reach up to 1 km with less accuracy.

- The stationing position of the TLS must be in a place without movement; therefore, it can never be located on the structure to be captured.

- The number of TLS positions (setting up) should be as few as possible; the greater the number of positions, the greater the possibility of obtaining greater errors in the coordinates of the points generated.

- The location of the structure can greatly affect the capture of the point cloud, see Figure 9, due to the impossibility of positioning the equipment within the distance range recommended by the manufacturer. In some cases, such as large bridges located in bays, it may not be possible to use it at all.

Due to the above mentioned limitations, it is very likely that there are elements of the bridge that need to be documented geometrically with other tools. In such a case, drones could be used.

**Point Clouds with Aerial Photogrammetry. Drones**

The combined use of drones and photogrammetry has undergone great development in recent years, reducing costs and increasing the accuracy of the captured point cloud⁴.

There is a wide variety of equipment, some of which, thanks to the gimbal camera - a mechanical and electronic element that allows the stabilisation and movement of the camera on several axes, Figures 10 and 11, are capable of recording points in inaccessible areas of bridges, Figure 12, such as the underside of the deck, Figures 10 and 11.
Figure 10: A drone equipped with a basic gimbal that does not allow capturing the underside of a viaduct

Figure 11: A drone equipped with a versatile gimbal that allows capturing the lower part of a viaduct   
Source: Parrot
Its main limitation is the lower precision in the coordinates of the points obtained with respect to those generated through TLS\textsuperscript{5}.

This is the reason why the geometric capture of the structure should be carried out through TLS, and only in those areas of the structure not covered by TLS should drones be used.

In economic terms, point cloud capture by drones, Figure 13, is cheaper than the TLS method in those structures that require many TLS equipment positions (setting up) due to their complexity.

This advantage could lead to the choice of drones over TLS in those projects with large budget limitations.

The following considerations should be considered when using drones for point collection:

- High-end professional drones, equipped with professional cameras with high sensitivity sensors and a wide dynamic range, shall be used.
- The drone must have a gimbal that allows shots in a very wide angular range.
- The atmospheric conditions should be studied at the moment of planning the shots and their variations during the time of execution of the captures.
- The definition of the drone’s flight plan will be critical.
**Point Clouds with Aerial Photogrammetry + TLS**

In the case of large bridges, both in length and height, the combination of both techniques, TLS and aerial photogrammetry with drones, will be necessary to capture the complete structure, Figure 14.

Two fundamental aspects must be taken into account:

- It is essential to check and compare the areas captured by the TLS and by the drone to compare the accuracies obtained. In this way, the limitations of the different point clouds will be known at any given moment, being able to correct using software those in which the deviations are known.
The selection of the software to be used to join the point clouds obtained by the TLS and the point clouds obtained by drone deserves a reflection. Not all software has the necessary tools for the treatment of combined point clouds.

**COMMON CHARACTERISTICS TO THE USE OF AERIAL PHOTOGRAMMETRY AND/OR TLS**

Both in the use of TLS and drones, it is mandatory the use of control points georeferenced by classic topography. These points define the network of high precision control points along with the entire structure. This network will be necessary to test the TLS and drone point clouds.

The control network will be independent of the network of support points that need the images captured by the drones for model formation.

A common problem to all topographic work for control and geometric capture of the structure is the movement of the structure. The movement can be due to atmospheric conditions such as wind, Figure 15, and/or the passage of vehicles that pass over the bridge.

In order to obtain high accuracies, the best moment to perform the capture must be studied. In some cases, it could be very complex.

**CONCLUSION**

In conclusion, in order to update the geometry of the digital twin, there are many limitations in the use of topographic tools.

The location, typology and length of the bridge make each structure different, and this causes the same methodology is not valid for all cases.

The greater the height and length of the structure, Figure 16, the greater the difficulties in capturing the reality with high accuracy.

Obtaining a highly accurate point cloud implies the detailed study of all aspects without leaving any detail to chance.

The planning of the work and the *in-situ* study of the bridge location is very important. The methodology to be used should never be selected from the technical office without visiting the bridge.

In those structures that have a BEP, the LOD with which the digital twin must be modelled and generated, as well as the periodicity of the verification, must be consulted.

In the case of not having a BEP, the level of detail and the periodicity of the verification must be established according to the available economic resources, both present and future.
Structural modelling software has room for improvement in the development of tools that facilitate the transfer of the real deformations produced in the bridge and their representation in the virtual model.

Each bridge is a different case. Even if there are two identical bridges, the location of the bridge determines the methodology used to generate the point cluster.

The process of geometric capture of a bridge and its transfer to the digital twin is a long and delicate process if we want to obtain accurate models in the millimetric-centimetric environment.

But the possibilities that derive from this work will provide crucial information not only to conserve and maintain the structures in an optimal way but will also help in the design and optimisation of future structures to be projected and built.

LITERATURE


RESEARCH PROGRAM ON SMART CONSTRUCTION FOR PREFABRICATED BRIDGES IN SOUTH KOREA

ChangSu Shim, Professor at the School of Civil and Environmental Engineering
Chung-Ang University, South Korea

As the digitalization of the construction industry plays a key role in technology innovation, a government-led research & development program was initiated in South Korea.

The development of the four sectors — which are equipment automation, digital engineering model-based prefabricated structures, digitalized safety management, and data platform for construction projects — is taking place.

This article aims to introduce the research & development program to expand the OSC (Off-Site Construction) of roadway structures.

A digital engineering model is developed under the consideration of necessary information in the design, manufacture, construction and maintenance stage.

This model is utilized in DfMA (Design for Manufacturing and Assembly) technology, which is the core technology of prefabricated structure.

This research program will be conducted for six years under government support.

Despite numerous smart technologies being implemented in each industry, the process of fusing with domain knowledge is necessary to be applied to the construction industry.

Moreover, the construction industry lacks a data-based information delivery system requiring further time and effort.

Technical development of prefabricated structures is focusing on applying a certain level of standardization, digitalization of manufacturing, virtual preassembly, and robot technology based on digital models for site assembly.

I am, as the Professor at Chung-Ang University, in a role of the primary investigator of the research team of the prefabricated structures.

Figure 1 on the next page shows the overview of the research program on smart construction technology in South Korea.

When BIM technology is applied to the construction project, the digital models need to be dynamically changed with flexibility and in real-time to enhance the applicability.

The essential content that the digital model requires in engineering must be defined and its potential variation at the stage of construction and maintenance must be considered in advance.

DfMA&M is defined as the design technology that embraces the concept of DfMA (Design for Manufacturing and Assembly) and improves its performance in maintenance.

The digital engineering model is composed of the digital model that defines the geometry, and the data required.

The digital model's algorithm is designed to reflect the change in data.
The level of detail varies on the purpose of the model.

In terms of ease of manufacture and preassembly, the prefabrication structure must be standardized.

The variables determined under the assumptions in the design stage have their geometry and property altered by the measurement conducted for quality control during fabrication and assembly.

The model created by digital inspection using scanning technologies extracts the parameter values and updates the design model.

This model is used in preassembly simulation and its data is also used in the remote construction by a robot manipulator.

In each stage of the construction, the geometry of the structure changes and the measured data alter the geometry of the digital model defined in the design stage.

In the case of prefabricated bridge girders, the change by the camber and lateral deformation measured at the center-span is applied to the update of the digital model.

The completed as-built digital models are transferred to the maintenance stage as shown in Figure 2.

DfMA requires defining tolerance of fabrication and assembly error for each stage from the completed geometry of the structure.

For this, the reference points in each stage of construction must be defined and monitored.

The coordinates of bearings are typical examples of the reference points for preassembly of sub-structures.
In bridge girders, the camber and lateral deformation of the center and the connecting points of lateral beams are monitored as data.

If bridge decks are planned to be prefabricated, the location of the connectors of the girder and the shear pockets of the bridge deck is also defined as data.

Even if the suppliers of the prefabrication members differ, uploading the geometry error at each stage through the predefined data on the preassembly evaluation system will take the difference into account and the construction engineer will perform coordination.

If the error cannot be accommodated by cast-in-place concrete parts, methods to coordinate the geometry error range must be considered in advance. Digital models are used in these assembly checks before construction.

Before casting concrete, sensors are installed

Low-power sensor system (Battery for 2 years) + QR code by E paper

Figure 2: Digital Engineering Model for DfMA&M

Figure 3: Smart Sensing for Life-Cycle Monitoring of Prefabricated Bridges
Through the real implementation of the methodology for a few bridges, practitioners are trying to establish standard data templates for preassembly.

Further technical advancement to extend the service life in prefabrication member design is needed.

In order to do that, the performance records in the maintenance stage must be accumulated at a low cost in the long-term period.

In smart construction technology development, a low-power sensing technology using E-paper is being applied to prefabrication members.

The data of member behavior due to the change in the material, the environmental condition, and the construction period can be collected as it can accumulate the behavior data from the manufacturing stage to the operation stage.

This allows more active consideration of the variation of manufacture and assembly in the design stage.

Now, the research program is in its early stage, monitoring 2~3 structures to collect data.

The continuing accumulation of data will be used in the development of the Digital Twin Model.

Figure 4: Digital Engineering Models for Preassembly Check & Prefabricated Lateral beams
First of all, thank you for your time for this interview. You are very welcome and thank you for asking me for an interview.

As both our magazines, e-mosty and e-BrIM evolve around bridges, let me ask you about your relationship to bridges and how did it start?

This is easy. My father was a bridge designer, and my maternal grandfather was also a civil engineer. At a young age, I was confronted with bridges and both their design and construction.

The sound that I remember vividly was the one of the Brunsviga mechanical computing machine. Some of your older readers may still remember this wonder of mechanical engineering.

Later, I decided to study Civil Engineering in Belgrade and after my Ph.D. at the Swiss Federal Institute of Technology in Zurich, I started my career as a bridge designer.

Are there any projects special for you? What are your favourite ones? Have you worked on any of them?

I didn’t work for very long as a bridge designer, but I remained intimately connected to bridges. At the beginning of the nineties, there was a need to manage a growing number of existing bridges.

Particularly, in the USA there was a large number of relatively old bridges that required attention. It was not sufficient to only inspect these bridges but it was necessary to also store and use data for condition forecasting and maintenance planning.

This development led to the establishment of the field of Bridge Management.

I was lucky enough to be appointed by the Swiss Federal Roads Office to develop a concept and specification for a Swiss Bridge Management System.

Later, I have developed quite a few of these systems for different clients, but the first one remained my favourite.

With regard to bridge design, my favourite is also the first one. It was a replacement of the bridge slab on a small frame bridge in an environmentally sensitive area. The substructure remained intact.

What is the most personally satisfying project you have worked on? Why?

This is a tough question. I find personally satisfying projects that go beyond the application of established methods and procedures. For that reason, I find research projects particularly satisfying (or frustrating if it doesn’t go well).

I also find software development very interesting, in particular the infrastructure management system infFaros that we develop at IMC. It is very satisfying to implement complex concepts, developed in research projects, in an intuitive and playful manner.

Clearly, to see a physical bridge constructed and rehabilitated according to your ideas is also immensely satisfying.

Who has most influenced you, your career, mission and way of thinking?

I think my advisor Prof. Dr Bruno Thurlimann and my father Prof. Dr Nikola Hajdin. My father encouraged me to use computers.
I started actively programming when I was in the elementary school. Back then programming meant typing punch cards and letting them process on massive computers with only 8 kByte RAM.

My advisor taught me to use computers wisely focusing on structural analysis and design and to vigorously check the obtained results.

I still think that computers are wonderful tools that make our life as civil engineering much easier not only in design, but also in inspections, operation, and maintenance of the built environment.

Can you comment on the change in bridge technology over your career? What do you see has been the most significant technical advancement?

My interest was mostly in the maintenance and rehabilitation of bridges, so I shall focus on this area. New materials such as carbon fibres, UHPC, etc. opened new lanes to extend the service life of existing bridges. This trend will continue in particular if we want to achieve our sustainability goals.

However, I believe – perhaps I am biased a bit – that the most significant advancement in recent years is in diagnostic methods.

The interdisciplinary effort finally bears fruits in the unprecedented ability to detect dangerous developments and prevent disasters in a timely manner.

This is also imperative since with the aging infrastructure, our understanding of deterioration processes can only be enhanced with novel diagnostic methods.

The laboratory tests are also useful, but some slow deterioration processes are difficult to simulate in a laboratory. In a certain way, the whole bridge inventory can be seen as a laboratory specimen.

You are a Chair of IABSE Commission 5. Could you please say a few words about its mission and your role?

The IABSE Commission 5 “Existing Structures” is dedicated to developing and enhancing methods and tools for economically efficient, environmentally friendly, and socially reconcilable decision-making regarding existing bridges and structures.

To this end the insights gain from both pre- and post-mortem investigations of structures will be used, effectively combining forensics with diagnostics. Commission 5 will launch and support investigations on diagnostic methods and techniques regarding the value of the information they provide.

It strives to establish performance goals that comply with the societal values and can be compared to measurable key performance indicators. Commission 5 targets the establishment of the long-term forecasts of key performance indicators that are essential for decision making.

To this end Commission 5 will also investigate the usability and practicability of resilience in decision-making process.

By considering the long-term aspects it will also seek to enhance methods that allow the definition of intervention strategies for different types of structures.

These methods need to be tailored for different levels of data availability as these can vary from simple inventory lists to comprehensive information models (BIM).

In nutshell, Commission 5 supports and enhances all activities related to existing structures from technical concepts and methods to data processing.

What are the tasks and challenges for the future?

I think I have mentioned some of these challenges. Better and timely diagnostics remains the challenge in spite of undeniable advances in this field.

The accurate forecast of structural behaviour over time can be improved by the judicial use of BIM and related structural models.

The goal is to provide infrastructure owners and professionals alike with the full information on design, construction, inspections and performed maintenance interventions at their fingertips.

This includes structural analysis models and actions for which structural checks were performed. The owner and society are entitled to effortlessly obtain this information and with digitalization this goal is achievable.
How do you see the development of BIM utilization in the bridge industry? BMS is not implemented into BrIM cycle yet. What is your opinion about it?

In design and construction, BIM is being increasingly used and this trend will continue. This is however not sufficient. Potentially, the largest benefit from BIM lies with owners.

However, currently there are several misconceptions related to BIM in the bridge industry. This applies to a belief that an as-designed model can be directly used in construction or fabrication of steel members and later in asset management.

The requirements of stakeholders i.e. designers, contractors, owners, and asset managers differ significantly and their reconciliation in a “single source of truth” is a challenging task.

The data exchange between different stakeholders during the lifespan of a bridge that includes BIM should be seamless and presented intuitively as required by these stakeholders.

For instance, owners and operators mostly use Bridge Management Systems (BMS) that already have a lot of useful data that are differently structured than the BIM data used by designers and contractors. Seamlessly connecting these data structures is a goal that we pursue also in Commission 5.

How do you think it can be used in O&M of bridges and their preservation?

The advantages of BIM in inspection and monitoring are quite obvious: The localization of findings and sensors is accurate and can be directly used in assessment, rating and even in structural analysis.

Furthermore, by means of augmented reality, inspectors need not collect data on damage extent and severity but only “glue” them to a 3D model.

The BIM-based maintenance planning, which means cost and risk assessment as well as an elaboration of working programs, is expected to be more accurate.

Although the above-mentioned benefits bring substantial improvement to owners and operators, the largest benefits are to be achieved in tendering and bidding of maintenance interventions.

The BIM used in asset management together with the maintenance requirements can be exported to bidders allowing more accurate and stable bids.

After a performed intervention, the respective changes on a physical structure is to be mirrored in BIM and handed over to owners allowing them to track the history of their inventory.

Infrastructure maintenance is an ongoing concern for all governments and owners. How might engineers consider these requirements in the early stages of the development of a project?

I think that they already do. In the last twenty years, the maintainability of bridges has improved significantly. The best practice is generally followed both by designers and contractors.

Clearly, this can be improved and to this end, design engineers should consider and simulate different maintenance and rehabilitation interventions including but not limited to the replacement of superstructure and mechanical parts. This doesn’t apply to iconic bridges but rather to “workhorse” bridges, which represent the majority of bridges in the industry.

Historically not all new technologies or methods have been successful. Can you suggest how academic research organizations could assist the construction industry to deliver safe and quality assured solutions on their projects which are using advanced materials?

A technically sound concept can turn out to be impractical or too expensive. If this outcome could be predicted upfront then the research wouldn’t be performed.

What can be clarified before starting a research project is whether a relevant problem is addressed. To this end, it is beneficial to talk to professionals, which could be designers, contractors, or owners/operators.

Civil engineering projects sometimes exceed their estimated budgets and programmes. With the help of research, in what ways do you think these issues could be better managed?

My focus is again on projects related to existing bridges and at least for Switzerland I cannot confirm your observation.
In some cases, there is a change in scope in order to achieve the economies of scale and reduce societal costs.

Research can help with this regard by providing necessary methods to estimate the full impact of maintenance and rehabilitation interventions on all stakeholders and support in the estimation of the required budget.

Furthermore, precise specification of planned intervention is crucial and here BIM can also help provide accurate quantities and visualize possible inconsistencies.

What advice would you give to young engineers starting their careers?

Buzz Luhrmann correctly states: “Be careful whose advice you buy but be patient with those who supply it” since “my advice has no basis more reliable than my own meandering experience”.

So, your readers should be careful when considering my advice that I shall dispense here. I think that digital literacy and interdisciplinarity are indispensable ingredients for future engineers. This means that for existing structures the knowledge in natural sciences e.g., physics and chemistry but also in electrical and mechanical engineering will be necessary.

Curricula at the university are getting increasingly flexible and future engineers should use this possibility. Taking a course in Electrical Engineering, Physics or Artificial Intelligence opens new doors for future collaboration.

You have been involved in Editorial Boards in the most prominent bridge magazines around the world. Based on your experience, how do you think we can make both our magazines (e-mostly and e-BriM, both with open access) more useful for the benefit of the bridge community?

Indeed, I was and am involved in several Editorial Boards of structural engineering mostly research-oriented journals.

I think that you shouldn’t try to compete with these journals, but rather orient yourself toward practical implementation of established results. It is vital to present them in an accessible manner focusing on concrete benefits for our profession.

And my last question. What are your plans for the future?

I still intend to remain active in the field, also after my retirement age, which in Switzerland is 65 years.

There are still quite a few open questions that tickle my curiosity. In particular, the integration of BIM, BMS (or IMS) and structural or reliability analysis is a very interesting topic. The information on behaviour of our built environment under different actions should be at our fingertips. There is still a lot to do to achieve this goal.

Thank you very much for your cooperation.

ABOUT PROFESSOR RADE HAJDIN

Prof. Dr Rade Hajdin is an active professional and researcher in the management of civil infrastructure with more than thirty years of experience in the field.

He is also an experienced structural engineer mostly in bridge design. He completed a Ph.D. on the design and analysis of concrete panels using stress fields in 1990.

He has designed or has been involved in the design of five bridges and numerous other structures.

In 2003, Professor Hajdin founded Infrastructure Management Consultants LLC and since then he has been the president of this company.

In May 2010, he was appointed at the University of Belgrade as associate professor of Concrete Structures and since February 2016, he has been there a full professor for Infrastructure Management.

Professor Hajdin has published many journal papers, conference papers, research reports, books and manuals.

He has been actively involved in numerous Professional Associations, Technical Committees, Scientific Committees for International Conferences, Editorial and Review Boards.

For many years, he has been actively teaching and providing mentoring and advisory services.

FULL CV

For several years, it has been the most important event regarding the digitization of the construction industry in Central and Eastern Europe.

Experts confirm that further automation and robotization of construction processes is possible only with the appropriate level of digitization.

The first step on this path must be the widespread implementation of the BIM methodology.

The organizer (European BIM Digitization Center EccBIM), and the operator (infraTEAM), decided that due to the fourth wave of the pandemic this 2021 event would be carried out online.

The technical facilities of Arena Gliwice and the operator's experience in organizing the previous edition helped with this.

Thanks to this, it was possible to achieve the global organizational and substantive level. It can be said that an entirely new way of conducting international conferences in an online or hybrid version has been correctly mapped out.

Especially that they are accompanied by the first fully professional YouTube information channel for the construction industry in the form of infraSTUDIO.

In 2021, infraBIM became even more international and more recognizable. The bar on the substantive level was raised even higher.

The event was attended by 600 participants, with nearly 150 people coming from 37 countries worldwide.

Apart from Poland, the most represented countries were the Czech Republic, Hungary, India, Norway and Germany. It shows how interest in the BIM methodology has grown in the world.

This internationalization was also visible in the selection of experts present.
Almost half of them were former representatives of countries where BIM has been accompanying investments in the public procurement market for many years, mainly Scandinavia and Great Britain.

For this reason, most of the lectures were given in English, and presentations of Polish experts were translated into English in real-time.

The participants could switch to the appropriate language channel. Their activity was visible in discussions and questions asked in the chat.

This was especially true of people from outside Europe interested in the dynamically developing BIM market in Central Europe.

The first day was traditionally devoted to BIM Hyde Park which was carried out with the participation of representatives of the Polish Public Procurement Office.

This special infraBIM event was divided into plenary sessions and discussion panels. In the first stage, the problems of using BIM in implementing investments from public funds were discussed.

The second part covers BIM educational strategies. Experts from the central administration of the Visegrad Group countries appeared, but there were also voices from outside the European Union.

The remaining two days were a series of plenary sessions, practical demonstrations and workshops.

In total, you could listen to over 40 lectures, take part in a dozen or so shows and workshops, and participate in several discussion panels.

The topics of the session included such issues as:

- Management of BIM libraries and resources at manufacturers, suppliers and designers (BIM Content);
- Various industry components, such as roads, railways, bridges, cubature (BIM Components);
- Use of BIM models at higher levels of project implementation, like the analysis of schedules, costs, life cycle or CO2 footprint (BIM Dimensions);
Open data exchange standards that ensure the interoperability of BIM tools and are therefore particularly important for public procurers (OpenBIM);

Problems of managing teams and investment processes in the context of their digitization (BIM Management);

New approach to the implementation of construction projects through their virtualization (Virtual Design & Construction, VDC);

Integration of 3D reconstruction techniques in photogrammetry, laser scanning and the use of georadars (3D Reconstruction).

The key BIM HydePark discussion panel devoted to public procurement was attended by: Tomáš Funtik (BIM asociácia, Slovakia), Jaroslav Nechyba (Czech Standard Agency), Justyna Pożarowska (Polish Public Procurement Office) and Mark Zagoracz (BIM Association, Hungary).

The conversation began with comparing the state of BIM implementation in individual countries of the Visegrad Group.

For example, only the Czech Republic has a fixed date for introducing the mandatory use of BIM in investments carried out under public procurement. And, according to the regulations, it is supposed to be mid-2023.

Later on, the issue of motivating public procurers to use the BIM methodology and supporting them through substantive assistance at the stage of selecting a contractor or during project implementation and through additional funds, training, or publications was discussed.

In addition, issues such as the impact of implementing the BIM methodology on legislative changes were discussed.

This is related not only to the contractor selection procedure but also to the form of technical documentation or specific provisions relating to the protection and management of intellectual property rights.

The BIM Components session was up-to-date; it was devoted to the BIM strategy in the Solidarity Transport Hub (CPK) project in Poland.

First, Michał Latała (BIM team manager and BIM project leader) discussed the general assumptions of this strategy divided into the most critical departments of the airport and rail.

He also presented the essential BIM document in the CPK in Organizational Information Requirements (OIR) that the CPK will apply when implementing his project.

Later, Jacek Filipiuk (BIM Manager) and Patryk Żak (BIM Document Control Manager) focused on the railway division.

They discussed the requirements that the CPK railway division had just prepared and the method of cooperation between the employer and contractors.

On the other hand, in the BIM Dimensions session, attention should be paid to a series of papers that showed the possibilities of using the BIM methodology and models to calculate the carbon footprint.

It was combined with traditional costing (Maciej Kindler, Infrabyte Poland) and even considered the entire life cycle of the infrastructure facility (Samson Adesope, Nigeria).

As usual, the speech by Sławomir Heller (HELLER Ingenieurgesellschaft mbH, Germany) was very intriguing and informative.

He has faced the stereotypes and misunderstandings that arise when implementing the BIM methodology in road infrastructure management processes.

This is because most owners and managers of road infrastructure in the world still do not see solutions in the BIM methodology that are oriented to their needs.

So far, it seems to everyone that BIM is addressed almost exclusively to participants in the design or construction phase. Unfortunately, the longest phase of operation is too often overlooked.
For three full days, the participants of infraBIM 2021 could learn about the latest trends in the development of BIM methodology in the world.

It was possible thanks to the invited experts, nearly half of whom represented countries with the highest level of BIM implementation.

In addition to the presentation of various BIM tools of all leading manufacturers globally, there was also an opportunity to learn about new ways of using models and BIM methodology, whether it be in building life cycle analysis or in management processes.

This management concerns both libraries and project teams, and resources were the responsibility of administrators and owners of the infrastructure.

It is also worth paying attention to an inevitable evolution of the BIM methodology, which manifests itself in a new VDC approach (Virtual Design & Construction).

This methodology, derived from Stanford University, is the virtualization of design and construction processes, which affects even more effective management of investment projects.

This may be one of the most important directions of BIM development in the future.

Finally, it is worth emphasizing that participation in the event was free of charge for all participants.

Furthermore, the organizers are very thankful for the honorary patronage given by many central institutions, universities and professional associations:

- The Polish Ministry of Development and Technology,
- The General Directorate of National Roads and Motorways,
- PKP Polish Railway Lines,
- The Embassies of the Republic of Poland in Bratislava, Budapest and Prague, and
- The British Embassy in Warsaw.

Detailed information on infraBIM 2021 V4 Expo & Multi-Conference and video archive materials can be found at www.infraBIM.info and on the channel https://www.youtube.com/c/infraSTUDIO.
Consequences of aged infrastructure and poor maintenance and lack of monitoring lead to disasters.

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