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Ondrej Vystavel
ORCID: 0000-0001-5058-9931

THE USE OF BIM IN TRANSPORT INFRASTUCTURE CONSTRUCTION IN THE CZECH REPUBLIC

Brno University of Technology, Faculty of Civil Engineering, Institute of Geodesy, Brno, Czech Republic
vystavel.o@fce.vutbr.cz

Abstract

Building Information Modelling (BIM) is a modern approach of managing the process of preparation, realization and operation of building objects, including their documentation throughout their life cycle. The aim of this approach is to use a common data environment (CDE) in which the building agenda will be managed throughout the entire construction process, from the initial architectural design to its demolition, with the possibility of access to the data by the professions and participants involved. Selected contexts of BIM and surveying are presented in the paper. In the second part, a practical example of a transport infrastructure construction is used to present the method of converting the classical as-built documentation into BIM. As the construction in question is a reconstruction of a railway station; the requirements and experience of the Railway Administration from pilot projects are considered.

Keywords: building information modelling (BIM), traffic infrastructure construction, common data environment (CDE)

WYKORZYSTANIE BIM W BUDOWNICTWIE INFRASTRUKTURY TRANSPORTOWEJ W REPUBLICE CZESKIEJ

Abstrakt

Modelowanie Informacji o Budynku (ang. Building Information Modelling – BIM) to nowoczesne podejście do zarządzania procesem przygotowania, realizacji i eksploatacji obiektów budowlanych, łącznie z ich dokumentacją przez cały cykl życia. Celem tego podejścia jest wykorzystanie wspólnego środowiska danych (ang. common data environment – CDE), gdzie zagadnienie budowli będzie rozpatrywane przez cały czas – od projektu architektonicznego do jej rozbiórki, z możliwością dostępu do danych przez profesjonalistów i wszystkich, których to dotyczy. W pracy przedstawiono wybrane konteksty BIM i pomiarów geodezyjnych. W drugiej części przedstawiono przykład budowli związanej z infrastrukturą transportu, aby pokazać metodę zamiany klasycznej dokumentacji budowlanej w BIM. Omawianym przedsięwzięciem budowlanym jest przebudowa dworca kolejowego, gdzie uwzględniono wymagania i doświadczenia Administracji Kolejowej, powstałe w trakcie projektów pilotażowych.

Słowa kluczowe: modelowanie informacji o budynku (BIM), budowa infrastruktury transportowej, wspólne środowisko danych (CDE)

1. INTRODUCTION

The question of what Building Information Modelling (BIM) is, is very well answered by [1]: “BIM combines the use of 3D computer modelling with building information to improve collaboration, coordination and decision-making in construction and operation.” Thus, the basis is a 3D database model on which a lot of additional (descriptive) information from the whole lifecycle of the building is packed. It is important that all the professions involved work together in one place, at the heart of BIM – the Common Data Environment (CDE). By CDE we mean a common repository of data that can be accessed by all the parties involved in the process. The role of the surveying profession is particularly important in the BIM process, as the need for measurement and documentation is irreplaceable throughout the construction lifecycle. The issue of spatial data integration in construction management processes in the context of e-Government in the Czech Republic is addressed e.g., in [2]. A complicated process is especially the property rights preparation of large buildings, where technological support of GIS is indispensable [3]. At present, valid geodata are obtained for the given design purpose. The digital technical map (DTM) is incorporated into the process of construction preparation, which, in future, should be one of the important sources of geodata for the preparation of buildings and after construction implementation, changes in geodata will be reflected into the DTM. Major transport infrastructure constructions are leading the need for digital support and building management [4].

Regarding the introduction of the BIM approach in the Czech Republic, the primary legal act was the *Resolution of the Government of the Czech Republic of 2nd November 2016 No. 958* on the importance of the BIM approach for construction industry in the Czech Republic. The Government of the Czech Republic expressed support for the introduction of the BIM approach "in connection with its impact on the economic growth and competitiveness" of the Czech Republic [5]. The Ministry of Industry and Trade (Ministerstvo průmyslu a obchodu, MPO) was appointed as the leader of the introduction.

MPO has prepared a basic document that defines how the BIM approach will be implemented in the Czech Republic – the *Concept for the Implementation of the BIM Method in the Czech Republic* [1].

The State Fund for Transport Infrastructure (Státní fond dopravní infrastruktury, SFDI) is the BIM manager in the Ministry of Transport (Ministerstvo dopravy, MD). SFDI is very active in publishing documents related to the BIM method. The basic document is the *Rules for Building Information Modelling (BIM) for transport infrastructure constructions* [6].

The Railway Administration (Správa železnic, SZ) will play the role of a manager rather than a creator of BIM models in the BIM process. This follows from its nature. The basic document according to which the implementation of BIM technology in the SZ environment is taking place is the *Strategy for the Implementation of the BIM Process (Building Information Modelling) in the Railway Administration for 2021* [7].

Hierarchy of organisations and documents related to the implementation of the BIM approach at SZ are shown at Fig. 1.

"BIM models need to be highly standardised" [1]. For machine processing, which significantly helps with the usability of the model in the operational phase of

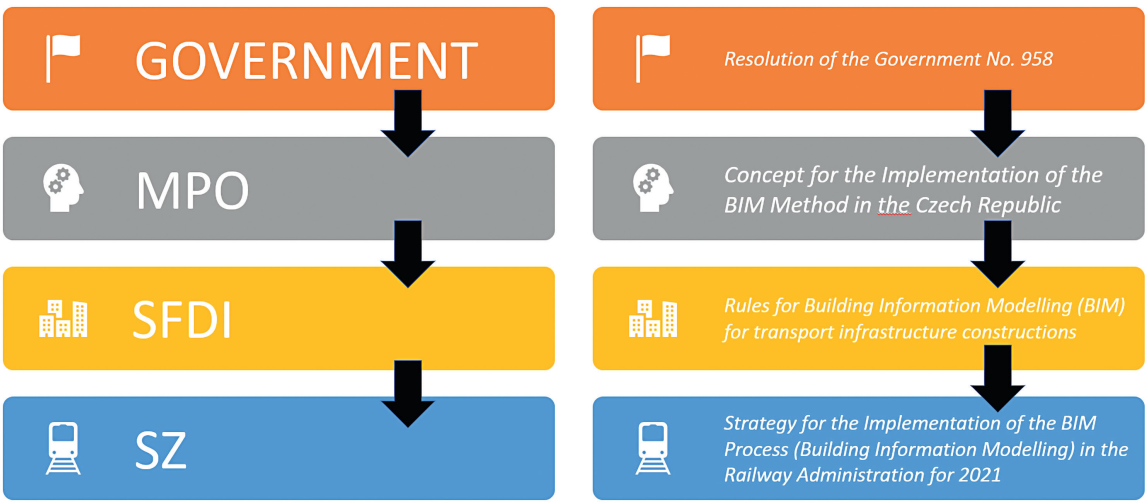

Fig. 1. Hierarchy of organisations and documents related to the implementation of the BIM approach at SZ
Ryc. 1. Hierarchia organizacji i dokumentacji związanej z wdrażaniem BIM na kolei SZ

construction, this requirement is logical and necessary. According to [1], standardization must be done in two steps:

- standardisation of the format
- standardisation of contents.

The standardization of the format is already solved. At the international level the IFC standard is used in the field of BIM, which is already implemented in the Czech technical standards (CSN). The format aims to be software neutral. It therefore serves as an exchange format between different BIM software.

Contents standardisation is more complex. The basic idea is the use of so-called Level of Information Need (LOIN). Models are often more detailed than required by the phase the model is in [1, 8]. A BIM model contains two parts (geometric and non-geometric data), therefore from the selected LOIN level, two parts can be derived:

- LOG – Level of Geometry (the level of detail of the geometric data)
- LOI – Level of Information (the level of detail of the non-geometric data).

LOG/LOI 100 (least detailed) to LOG/LOI 500 (most detailed) shall be selected for the different levels of documentation within the construction life cycle.

The analysis of the current state of the issue [1, 6–11] reveals the following key points:

- models must be georeferenced – i.e., the need for the model to be in an obligatory coordinate and elevation system (i.e., S-JTSK and Bpv),
- the models shall be produced in sub building objects,
- at the end, followed by import into a suitable CDE,
- use of the SFDI data standards,
- creation of the schedule of work and construction costs (BIM 4D and BIM 5D).

Particular importance must be placed on the choice of a uniform geodetic reference system for the entire construction, which must be correctly implemented in the chosen BIM software. It must also be considered that BIM (CAD) software coordinate systems are left-handed, whereas in surveying a right-handed coordinate system is used. Another difference is the fact that in BIM software a flat surface is used as the work plane. The Earth's curvature is not considered. More details can be found in [12] which deals with the problem of georeferencing the BIM model in IFC format.

2. SELECTED SURVEYING ACTIVITIES IN CONSTRUCTION INDUSTRY

In Decree No. 31/1995 Coll. (implementing decree to Act No. 200/1994 Coll., on surveying) we find in detail selected activities during construction lifecycle that must be verified by an authorized surveyor. The most important ones are listed below [13].

1) preparatory phase
- preparation of geodetic documents

2) design phase
- made of design of primary system (primary setting-out network)
- made of setting out drawings
- made of coordination drawing

3) realization phase
- primary system surveying
- setting out of secondary system (spatial position)
- detailed setting out
- deformation surveying, check and compliance surveying, as-built measurements

4) operating phase
- made of geodetic part of the as-built documentation (G-DSPS)
- made of geodetic part of the documentation of existing building objects (passport)

In the preparatory phase, geodetic documents are prepared here. Once everything is in BIM, it will theoretically be possible to create projects directly to documents, that will be already existing from the previous constructions. However, geodata have the unpleasant characteristics of becoming outdated. Therefore, the surveyor, at a minimum, will have to validate the data.

In the design phase, the surveyor mainly creates the setting out drawings. The geometry of the drawings can be automatically generated from the BIM model. This eliminates the need to draw the same geometry multiple times.

In these two phases, the documentation is usually made in the accuracy corresponding to the mapping accuracy class according to CSN 01 3410. Moreover, the BIM approach counts with 3D documentation. At present, in these phases mainly 2D documentations are made, so the change in style of work shall be changed. In my opinion, digital terrain models will have a more important role as a basis for designing because of its 3D nature.

In the realization phase, the surveyor is mainly involved in surveying and setting out. At this stage, BIM by being able to set out directly from them will also be used to guide the construction machines. In the realization phase, the documentation is produced with an accuracy of an order of magnitude higher, corresponding to the construction technology. Thus, BIM models must be created so that this accuracy is achievable.

In the operational phase, the main activity of the surveyor is the preparation of G-DSPS (new buildings) or simplified documentation – passport (existing buildings). It is also necessary to consider two classes of models for BIM models – full (G-DSPS type) and simplified (passport type). For existing buildings, it is often unrealistic to obtain all, especially descriptive information. Full type should integrate data both from realization and operational phase. Every piece of information should be incorporated. The different approach to modelling the two different classes is outlined in [14].

3. RECONSTRUCTION OF THE RAILWAY STATION ŠUMICE

The subject of the practical demonstration is a reconstruction of the railway station in Šumice, which is located about 85 km east of Brno, the second largest city in the Czech Republic (Fig. 2a). The construction is located on the single-track national railway line Staré Město u Uherského Hradiště – Vlárský průsmyk. It is about a 300 m long section of the railway line, on which the platform, bridge and station building were reconstructed (Figs. 2b and 2c). Along with this, the reconstruction of the railway superstructure and substructure, and cable distributions were carried out.

The basis for the creation of the BIM model of the subject construction was the geodetic part of the as-built documentation (G-DSPS) prepared in accordance with the currently valid regulations – both generally binding (laws, decrees) but also internal regulations of the Railway Administration concerning geodesy. These are the so-called governing technical acts of Regulation M20 for surveying. The existence of these internal regulations guarantees a considerable standardisation of the documentation submitted to the administrator. Several

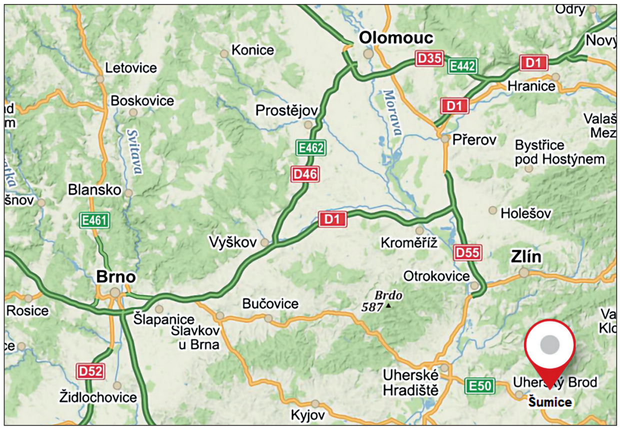

Fig. 2a. Location of the construction
Fig. 2b. Part of the railway line with a bridge
Fig. 2c. Railway station building
Ryc. 2a. Położenie budowli
Ryc. 2b. Część linii kolejowej z mostem
Ryc. 2c. Budynek stacji kolejowej

control functions are available in the software used and the work must then be submitted to the administrator for checking. Standardisation of both the contents and the

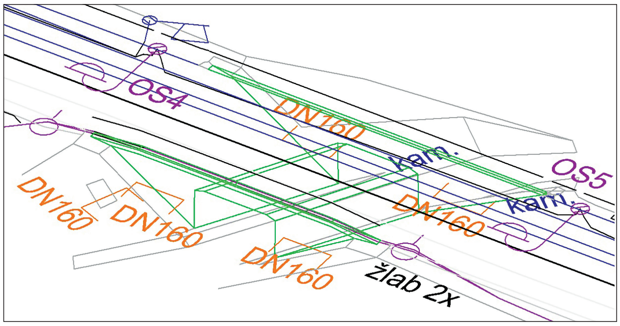

Fig. 3. Graphical part of G-DSPS
Ryc. 3. Opracowanie graficzne G-DSPS

format is therefore currently at a very high level within the Railway Administration.

The main output of the G-DSPS is a drawing of the new situation in DGN format. This is a 3D vector drawing with 2D elements that represent mostly point features such as lamps, radio... The 3D is expressed by curves, lines and map marks, not by solids. This is the main reason why it was necessary to remodell the documentation in specialised BIM softwares which is described in section Creation of BIM model.

The fact that the Railway Administration requires documentation in 3D has proven to be very useful when remodelling to BIM, as this approach requires 3D documentation and it is therefore convenient that a 3D base is already available. An example of sample documentation is shown in Fig. 3.

4. COMPARISON OF SZ AND BIM STANDARDS

The first task in the conversion of the G-DSPS into BIM form was to compare the classification of the data model elements defined by the SZ M20/MP005 Regulation (hereafter referred to as the SZ standard, [15]), according to which the G-DSPS was produced, in contrast to the classification according to the SFDI data standard (hereafter referred to as the BIM standard, [6]), according to which the BIM form of the G-DSPS was produced. Only those elements of the data model that were present in the subject matter of the practical demonstration were compared. SZ standard is divided into 8 categories with over thousands of elements. As it was a complete reconstruction of the whole track, sample with the most significant elements from each category was available (ca 80 elements).

It should be noted that the BIM standard sorting of elements is not even close to the SZ standard sorting in a 1 to 1 relationship. This fact generates a problem when converting documentation from the classic SZ form to BIM form and vice versa. Only a quarter of the elements (e.g., trackbed, cable shaft) are in the required 1 to 1 relationship. Most elements are in an N to 1 relationship.

For bridges, the opposite problem occurs, i.e., a 1 to N relationship. This is a much worse problem for CAD → BIM conversion, as it is not possible to create several different subcategories from one bridge category. The complete statistics are shown in Tab. 1. The only well usable 1 to 1 relationship corresponds to 25 % of the tested elements. The good news is that despite the imperfections described above, all elements can be somehow classified.

In this case it is a transfer of data from one structure to a completely different structure, moreover, the SZ standard has been successfully operated for several years, the BIM standard has been tested on a few pilot projects and this is its first version, which may certainly influence some imperfections of the SFDI classification.

LEGEND					
colour	relationship	number of elements	percent	example of element	description
(green)	1 to 1	10	25	trackbed	one SZ standard element corresponds to one BIM standard element
(yellow)	N to 1	16	40	culvert	multiple SZ standard elements correspond to one BIM standard element
(light blue)	1 to N	2	5	bridge	one SZ standard element corresponds to multiple BIM standard elements
(purple)	N to N	1	2,5	platform	more SZ standard elements correspond to more BIM standard elements
(orange)		6	15	shaft	SZ standard element can be incorporated into a similar BIM standard element based on experience
(peach)		5	12,5	building	SZ standard element is addressed by a different regulation

Table 1. Comparison of CAD and BIM standards elements
Tabela 1. Porównanie standardowych elementów CAD i BIM

5. CREATION OF BIM MODEL

In this example, the task was only to remodel the CAD as-built documentation into the BIM environment without taking over the documentations from previous phases. Therefore, no requirements on LOIN were placed mainly due to the provisional absence of them from the SZ, also BEP was not created.

5.1. Remodelling the documentation in BIM software

This step is necessary because CAD drawings have data stored in layers, whereas the BIM model is an object-oriented database, and it is therefore necessary to create objects (3D solids) to which the descriptive information will be linked. For the actual creation of the models, two software from Autodesk were used. The first one is Autodesk Civil 3D (native is the DWG format), the second one is Autodesk Revit (native is the RVT format). Civil 3D is suitable for creating BIM models of linear constructions, while Revit is suitable for creating BIM models of complicated spatial constructions (as it was primarily created for buildings). The creation of the model consists of two phases, the creation of the geometry and then its subsequent completion with descriptive information. This process is one of the pillars of the BIM method.

The 3D model environment can give the impression that the models created are flawless. This reasoning is of course wrong. A point is always determined with some uncertainty. However, another factor enters into the resulting accuracy here compared to the CAD approach, namely the accuracy of the modelling. The accuracy of modelling consists of the accuracy of the measured data and the generalization. This is particularly the case with Autodesk Revit software. This works perfectly for perfectly rectangular/parallel/vertical shapes. In reality, however, no objects are built this perfectly. Thus, the modelling process leads to a kind of idealisation of reality (Fig. 4), which leads to a slight deterioration in the resulting accuracy of every element. However, this accuracy is still, in my opinion, within acceptable limits of the accuracy with which data for G-DSPS are currently acquired (not the accuracy of documentation in realization phase).

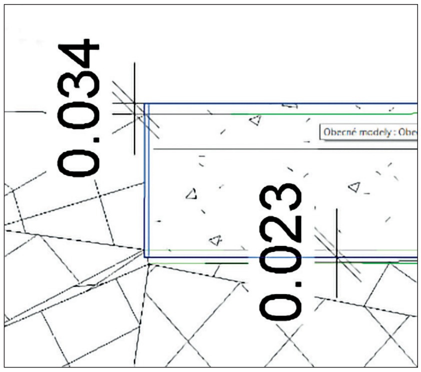

Fig. 4. Modelling accuracy
Ryc. 4. Dokładność modelowania

Another aspect related to the accuracy issue is that only selected points are subject to DSPS surveying. For example, a lamp is represented by its centre, elevation on the ground, a railway superstructure is represent-

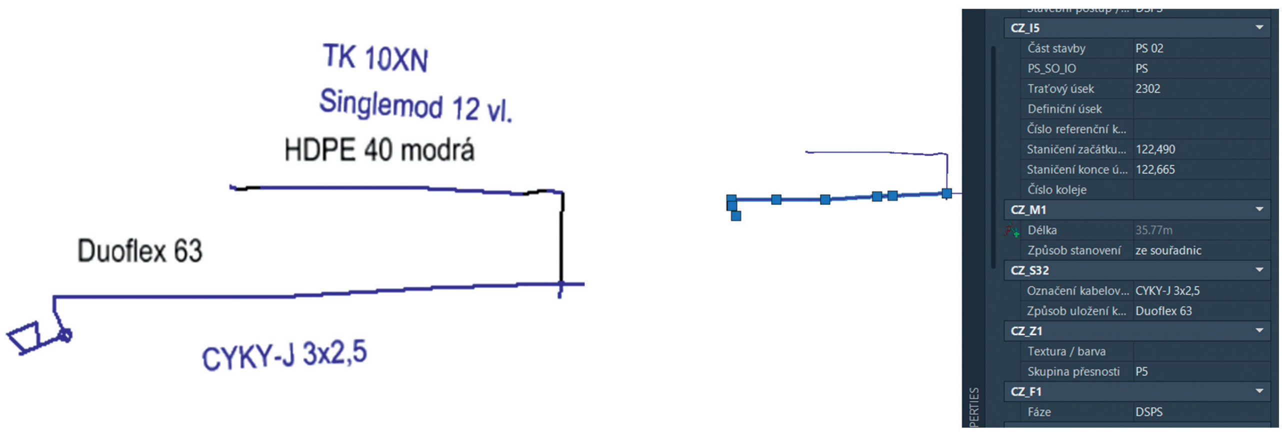

Fig. 5. Example of remodelling in Autodesk Civil 3D
Ryc. 5. Przykład przemodelowania w Autodesk Civil 3D

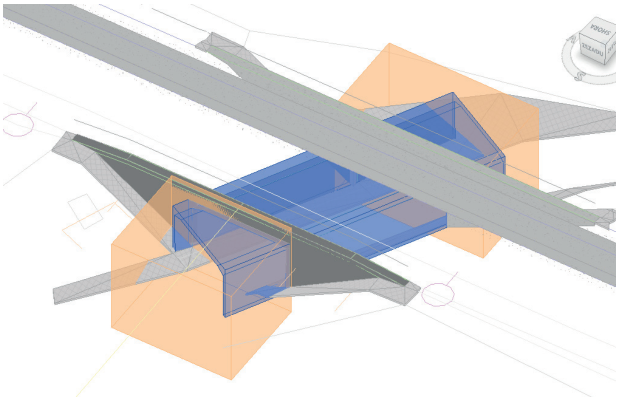

Fig. 6. Model of a bridge with excess geometry that needs to be cut off
Ryc. 6. Model mostu z zaznaczeniem niepotrzebnych elementów geometrycznych, które należy wyciąć

ed only by the spatial position of the track centreline. Therefore, it is not practical to model objects to the last detail for DSPS purposes. According to [7], the manager plans to create a library of elements like today's cell library. With the existence of the library, it then makes sense to use even a precisely modelled model for DSPS purposes, since it is not extra work.

The left part of Fig. 5 shows the original DGN drawing of the cable route, where we can see the descriptive information plotted in the text. The right part of Fig. 5 shows an example of its remodelling in Autodesk Civil 3D software. The geometry representation looks identical at first sight, but the main difference is in the way the descriptive information is stored.

Modelling in Autodesk Revit software is slightly impractical for objects with a spatial composition in the vicinity of a linear construction (especially the necessity of linking elements to floors), but the advanced modelling tools are certainly a strong point of this software. The complexity of the shape may necessitate the need to model excess mass, which must be trimmed using orange blocks (Fig. 6).

5.2. Importing the model into a Common Data Environment

The final step was the import of the model into a Common Data Environment (CDE). There are a large number of such environments, and an analysis of pilot projects available on the Railway Administration website [16] showed that the most commonly used CDE is Bentley's ProjectWise, which is why it was chosen. The native format of Revit (RVT) can be imported directly into the ProjectWise environment. Import in universal IFC is also available. The direct path is from my point of view better because some data may be wrongly converted, the conversion may not be 100 percent perfect.

At the heart of CDE is a cloud-based repository that has a 3D model viewer. Again, descriptive information

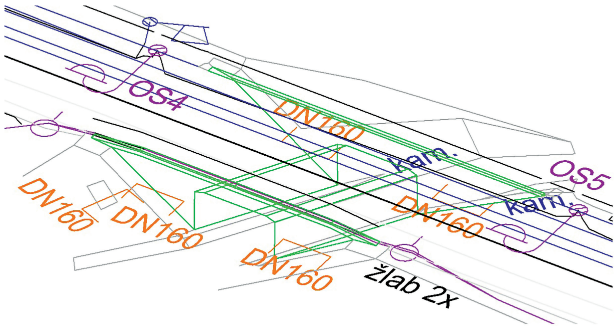

Fig. 7a. Example of the as-built documentation in DGN vector format
Ryc. 7a. Przykład dokumentacji w formacie wektorowym DGN

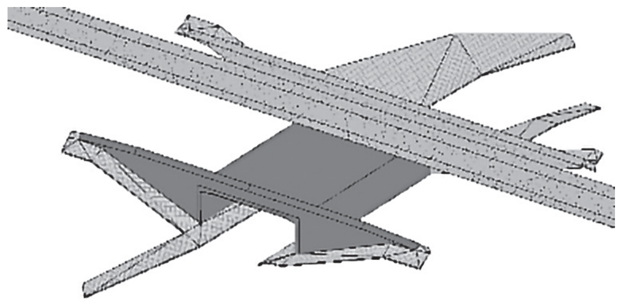

Fig. 7b. Example of remodelling into a 3D model in IFC format
Ryc. 7b. Przykład przemodelowania do modelu 3D w formacie IFC

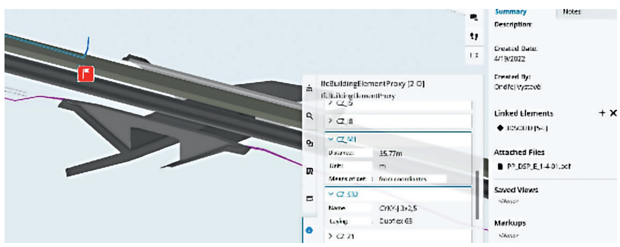

Fig. 7c. Example of transfer to CDE (BIM) environment
Ryc. 7c. Przykład przeniesienia do wspólnego środowiska danych CDE (BIM)

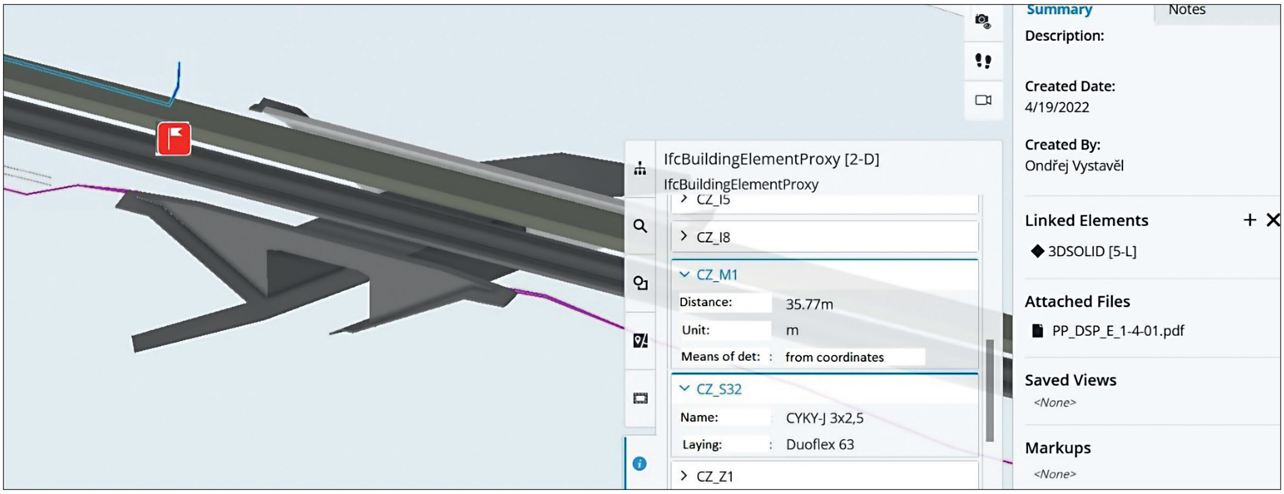

Fig. 8. The final model in a common data environment
Ryc. 8. Model końcowy we wspólnym środowisku danych

can be viewed here. In ProjectWise, using the red flag, it is possible to comment on elements in the model and to assign tasks (called troubleshooting) to individuals who can comment on them. In this way it is also possible to attach, for example, a PDF with the contents of the detailed implementation documentation to the individual elements.

The Figs. 7a, 7b and 7c show schematically the subphases of the process of reworking the as-built documentation from CAD drawing to BIM model with conversion to CDE environment. The final step is shown on Fig. 8.

6. CONCLUSIONS

Currently, the realization phase ends with the preparation of the as-built documentation, which is stored in the archives of the client. The BIM approach is intended to streamline the use of this documentation during the operational phase, whereby the BIM model can be suitably used, for example, for planning maintenance work.

The BIM process is only effective if the entire construction process is managed in BIM mode from the start. For existing buildings that have not been managed in BIM from the outset, it will not be possible to produce BIM models of the same quality by simply reworking the as-built documentation as if the construction process were managed entirely in BIM. Two classes of models will need to be distinguished. Simplified ones for existing buildings (or buildings without design documentation) and full ones for new buildings (or existing buildings for which the design documentation is preserved). In fact, something similar exists now in the distinction between G-DSPS and simplified documentation (passport). The conversion of existing conventional building documentation into BIM form, without the existence of a BIM project, is very time- and cost-consuming and it is up to the building operator to decide whether a simplified model, managed by BIM tools, will bring the necessary benefits (for example in terms of traceability of some data).

From the point of view of the necessary record-keeping accuracy of data acquisition for the DSPS, it is not necessary to create backward BIM models of the DSPS in such detail as if it were a phase of documentation for construction realization (RDS). The DSPS should fulfil the purpose of documentation of changes to the RDS in the sense of comparison with the designed state. If the prescribed deviations are not exceeded, the design condition will be valid, otherwise the design will need to be amended by adding the necessary information. The DSPS should be used to verify what has been built.

Compared to working in CAD mode, it is necessary to consider the accuracy of the modelling as a factor that affects the final accuracy of the model. It will be necessary to idealize the objects when creating the model. As far as modelling detail is concerned, it is not necessary for a DSPS model to be made with high detail.

Importing into the CDE is a step that will be performed repeatedly as part of the data update process in the construction lifecycle. The advantage of CDE and thus the biggest benefit of the whole BIM is in the archiving and availability of documentation.

REFERENCES

1. Concept for the implementation of the BIM method in the Czech Republic. In: Concept *BIM*; Czech standardization agency: Prague, Czech Republic, 2017. Also available online: https://www.koncepcebim.cz/koncepce
2. Bartoněk, D.; Bureš, J.; Švábenský, O.; Ježek, J. On the problems of integration of spatial data of construction Procedures In The Context Of The E-Government Of The Czech Republic. In: International Conference on Cartography and GIS. Bulgarian Cartographic Association: Sofia, Bulgaria, 2020; pp. 176-182.
3. Bartoněk, D.; Bureš, J.; Švábenský, O.; Ježek, J. Technological GIS support of property settlement of large structures. In: International Conference on Cartography and GIS. Bulgarian Cartographic Association: Sofia, Bulgaria, 2020; pp. 183-190.
4. Bureš, J.; Havlíček, R.; Vystavěl, O.; Švábenský, O. Digital technical map and BIM in the transport construction sphere in the Czech Republic. International Conference on Cartography and GIS. Bulgarian Cartographic Association: Sofia, Bulgaria, 2022; pp. 67-72.
5. Resolution of the government of the Czech Republic of 2nd November 2016 No. 958. In Prague, Czech Republic, 2016. Also available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj58onz7vT3AhXVUOUKHQHOAvEQFnoECAYQAQ&url=http%3A%2F%2Fwww.ckait.cz%2Fsites%2Fdefault%2Ffiles%2Fusneseni_vlady_c._958_cj._1353_16_bim.pdf&usg=AOvVaw2C4vgZATm8TdMCOOwGTDF4
6. Rules for building information modelling (BIM) for transport infrastructure constructions. State Fund for Transport Infrastructure, Prague, 2019. Also available online: https://www.sfdi.cz/bim-informacni-modelovani-staveb/
7. Strategy for the implementation of the BIM process (building information modelling) in the railway administration for 2021. Railway Administration, state organization, Prague, 2021. Also available online: https://www.spravazeleznic.cz/digitalizace/bim/implementace-procesu-bim-strategie-21
8. Pilot BIM projects in the Czech ministry of transport. Association of Building Entrepreneurs of the Czech Republic, Prague, 2021. Available online: https://www.ceskenoviny.cz/zpravy/zive-jak-pokrocily-projekty-bim-v-resortu-dopravy/2040102
9. Summit of concept BIM. Czech standardization agency, Prague, 2022. Available online: https://summitkoncepcebim.cz/
10. Vitásek, S. Construction project in BIM mode. In: Training course *SŽ*. Railway Administration, state organization, Brno, 2021, 75 p.
11. Raška, J. BIM in the railway administration. In: Professional webinar materials to maintain proficiency and knowledge. Railway Administration, state organization, Prague, 2022, 79 p.
12. Uggla, G.; Horemuz, M. Georeferencing methods for IFC. In Proceedings of the 2018 Baltic Geodetic Congress (BGC Geomatics), Olsztyn, Poland, 2018; pp. 207–211.
13. Decree No. 31/1995 Coll. (implementing decree to Act No. 200/1994 Coll., on surveying). In *The Collection of Laws*. 7. 11. 1994.
14. Pavelka, K.; Matoušková E; Pavelka K. Jr. The Contribution Of Geomatic Technologies To BIM. In The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences. Dhulikel, Nepal, 2019; Volume 42, pp. 85–89.
15. Methodological guideline for the production of spatial data for large-scale maps: *SŽ M20/MP005*, change no. 4, 17 pp. Available online: https://www.tudc.cz/wp-content/plugins/pritomnost/geo_doc/SZ_M20LMP005_20210901.zip
16. Pilot projects. *Railway Administration: Building Information Modelling (BIM)*. In Railway Administration, state organization, Prague, 2022. Available online: https://www.spravazeleznic.cz/digitalizace/bim/pilotni-projekty