WARSAW UNIVERSITY OF TECHNOLOGY Index 351733
FACULTY OF CIVIL ENGINEERING
COMMITTEE FOR CIVIL AND WATER ENGINEERING
POLISH ACADEMY OF SCIENCES ISSN 1230-2945

DOI: 10.24425/ace.2022.140190
ARCHIVES OF CIVIL ENGINEERING
Vol. LXVIII ISSUE 1 2022
pp. 623 –633

Research paper

BIM in the construction process – selected problems at the stage of implementation in Polish road engineering

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Abstract: The digitalisation of the construction process is a phenomenon that has been significantly accelerated in recent years. BIM (Building Information Modeling) technology is becoming increasingly popular with designers, contractors and investors and is being used, mainly in relation to buildings. In communication objects, the application of BIM is much more difficult, as confirmed by the shifting schedules during implementation trials in road design. And yet, BIM is not only about the design or execution of construction works, it is worth taking advantage of the new possibilities especially at the stage of using the facility. BIM in transportation infrastructure is already used in other countries, mainly in Scandinavia, where work on its implementation began at the beginning of this century. The preparation of appropriate procedures and standards, adjusted to national realities, requires gathering experience on pilot investments. The paper presents an analysis of the necessary initial data which will make it possible to apply BIM in the Polish road construction industry. Moreover, the main risks occurring at various stages of the construction process are presented. The aim of the article is to indicate the necessary actions that will allow the advantages of BIM technology to be used more fully in road investments. The implementation of BIM in Polish road construction is not a distant future but rather "tomorrow", so it is worth knowing the limitations and preparing for the upcoming changes.

Keywords: infrastructure, InfraBIM, BIM technology, building information modeling

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1. Introduction

The widespread use of computers and software has changed the technique of producing technical documentation. Fewer and fewer people remember how drawings were drawn on tracing paper. The first digital documentation consisted of creating flat 2D documentation, where the rapidograph was replaced by a computer mouse and printer. The advantage of the new technique was that changes and additions could be made later. The development of computers and software made it possible to create digital 3D objects, which facilitated the analysis of design solutions. We are now at the stage of the next step, the practical introduction of the digital industrial revolution into construction, which is materialising in the form of The Building Information Modeling (BIM). The idea is that the BIM model is treated as a prototype that can be tested at the preparatory stage. This makes it possible to increase efficiency in the costly execution phase and to achieve a number of other benefits in the subsequent maintenance of the building. For the purpose of introducing BIM technology to building investments in Poland, the industry community published in 2020. BIM Standard PL [1].

Currently, Poland is witnessing another step in the digitalization of construction. Since February 2021, a number of applications related to the construction process can be submitted electronically, the range of electronic services is successively extended [2].

The application of BIM technology in the investment process concerning roads, requires solving a number of issues. Their linear character makes it necessary to take into account a number of factors, such as: changing ground and water conditions, land development, technical and operational parameters. To understand the issues presented in the following section, it is necessary to mention some basic information about BIM technology.

For design involving road modelling and object parameterization, native software is used, i.e. a specific program or group of programs that allow the export of digital data to the open BIM format which is the Industry Foundation Classes (IFC) file. The use of an open format allows compatibility between software from different manufacturers, which is one of the fundamental assumptions of BIM about the unrestricted exchange of information. The IFC standard is a database with textual and numerical arguments. It consists of two key components: the geometry (Building Model) and the information associated with the geometry (Information). It is the basic BIM format and has been continuously developed since 1998 to the present day, with more than a dozen versions already created and more still being developed. The differences in the versions concern reference data, represented as definitions of property and quantity names, and formal and informative descriptions. Different encodings are also allowed, which significantly affect the file size. Road design programs mostly offer export to “IFC4”, introduced by EN ISO 16739:2016 (ISO 16739:2013) [3] and “IFC4_ADD2 TC1”, introduced by EN ISO 16739-1:2020 (ISO 16739-1:2018) [4]. A new scheme “IFC4.3 RC1” and “IFC5” are under development to be better suited for the road industry [5]. In Finland, for example, a different data exchange format based on the international LandXML format, more extensively described in national guidelines, is very popular in the infrastructure sector [6]. A description of BIM technology can be found in numerous literature, e.g. [7–9].

2. Use of BIM in Polish road construction

The application of BIM technology for linear investments is not an easy task. BIM in communication infrastructure is already used in several countries, mainly in Scandinavia. In recent years, a number of countries such as Germany, Bosnia and Herzegovina or Australia and China have been conducting pilot investments in the infrastructure sector [10–13].

In Poland, pilot projects are also underway, a road project – construction of the Zator bypass within national road No. 28 [14] and a railway project – demolition and construction of a railway viaduct on railway line No. 140 Katowice Ligota-Nędza [15]. It should be noted that the railway project concerns a point object on the railway line. Another pilot project, which will cover a larger linear section, will probably be needed to prepare the procedures.

Roads in Poland are mainly constructed by public investors. Current regulations on public procurement allow for the use of an electronic construction data modelling tool, such as BIM. According to the regulations, it is possible, among other things:

– specify requirements for qualifications and experience in the use of BIM,
– use of BIM as an element of innovation, quality, etc,
– introduce requirements for the employment of BIM staff,
– the introduction of BIM as a tool for managing a construction site.

The Ministry of Development has published guidelines on how to implement BIM in Poland in 2020 [16]. The document proposes a division into 3 stages of BIM implementation in public procurement. At the beginning, it is planned to prepare a draft purchasing policy for public procurement, which will specify the obligation to use the BIM methodology in public investments commissioned by governmental institutions, for which the estimated value will exceed 10 million euros. Additionally, it is recommended that BIM elements with a minimum weight of 20% be used in the bid evaluation criteria. In the next stage, the use of BIM technology will be recommended for all public institutions. The third stage is the obligation to use BIM technology in all public procurement, regardless of the value of the investment.

In general, the Polish strategy for implementing BIM, like many European countries, is based on the UK model shown in Figure 1.

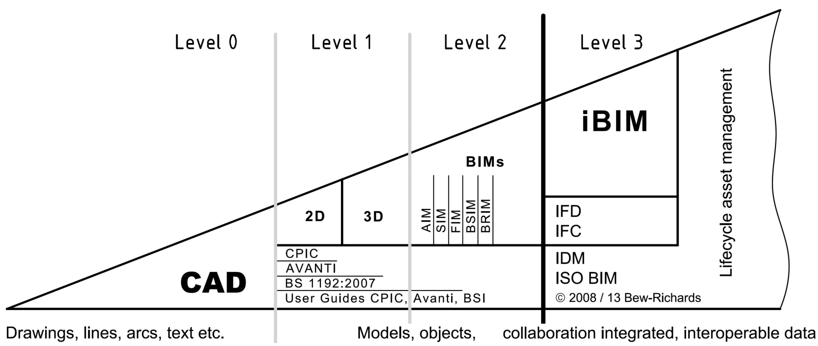

Fig. 1. Levels of development of BIM technology [17]

The British model is defined in BS 8541-1: 2012 [18], which distinguishes four levels of BIM technology implementation:

– level 0: 2D model, electronic or paper-based data exchange,
– level 1: 2D or 3D digital model, electronic exchange of some data in one standard, a number of analyses performed independently,
– level 2: 3D digital model using BIM software allowing analyses from different areas; use of a single data standard,
– level 3: 3D digital model using BIM software that is permanently available online with modelling capabilities; management of cost and life cycle information.

In the Polish road construction industry, level 1 is currently used. Simple and small objects, such as exits or pavements, are designed at level 0. This is due to the reduction of effort required for the preparation of input materials and the modelling of the object. Road engineering objects, due to their different nature, require modelling in independent software. The 3D models currently used do not take into account the geometrical details of the bridge model. Using BIM at level 2, it will be possible to analyse a common model of road and bridges [19].

The Ministry of Infrastructure has prepared recommendations for BIM in Polish road construction. In March 2021, patterns and standards for modelling information on road engineering structures (BIM-M) were recommended for use [20]. An analogous study on roads (BIM-D) [21] is likely to be published in the near future.

3. Threats to Polish road investments with BIM

When analysing the investment preparation process in the BIM technology, attention should be paid to the preparation of basic input data for the road design, in the form of a map and information on the subsoil.

A vector map is necessary, containing all objects in xyz space. The basic national map has standard xy and point z-coordinate information. Unfortunately in some counties the map is only available in paper version. We can inventory the land surface very precisely, e.g. by laser scanning. This solution will not provide us with information on underground utilities.

Surveys of the subsoil and, in the case of renovation, also of the condition of the pavement, are carried out on points. Proper interpretation of the results depends on the experience of the geotechnical engineer or geologist. In order to obtain the most accurate information about the soil, it is necessary to supplement the survey programme with electrical resistivity tomography (ERT).

Issues in modern geodesy and geology are increasingly reported in the literature, e.g. [22], but publications do not reflect the rapid development of equipment.

3.1. Road design with BIM

In road design, the fundamental issue of BIM is the exchange of data in a uniform standard (IFC or LandXML), by all participants in the investment process, as shown in Figure 2.

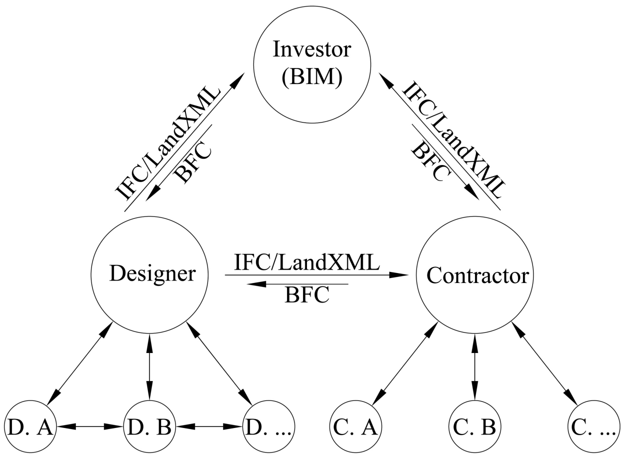

Fig. 2. Diagram of cooperation based on data exchange

Industry specific native software allows the preparation of a geometrical model together with the parameterisation of objects. Road projects very often require other specialists: a sanitary installer, an electrical engineer, a telecommunications engineer, a bridge builder and a drainage engineer, a dendrologist or a naturalist. Currently, there is no single BIM software dedicated to such a wide range of specialists. However, their cooperation is possible thanks to communication based on open data. Verification of one model, including all branches, directly contributes to the quality of design work. However, one should bear in mind the limitations of BIM model viewers, whose main use is to exchange information in the following areas: model verification, collision detection and generation of statements. It should be remembered, however, that exporting data from a native program to an open format is devoid of much detailed information.

Depending on the project phase, different levels of model detail are distinguished, defined as the level of graphical detail of the model – Level of Detail (LOD) and the level of non-graphical information of the model – Level of Information (LOI). These levels are defined from LOD/LOI 1 – the simplest conceptual model of the road course, to LOD/LOI 7 – a detailed model of the operated facility. Examples of LODs are presented in Figure 3.

The level of detail in the model should be determined by the developer before awarding the contract. The higher it is, the more work will be needed to saturate the model with information. This will have a direct impact on the cost of preparing the documentation and introducing any possible changes. Using BIM technology from the beginning of the investment process, the investor should gradually increase the level of detail in the model, which will reduce the amount of work and costs.

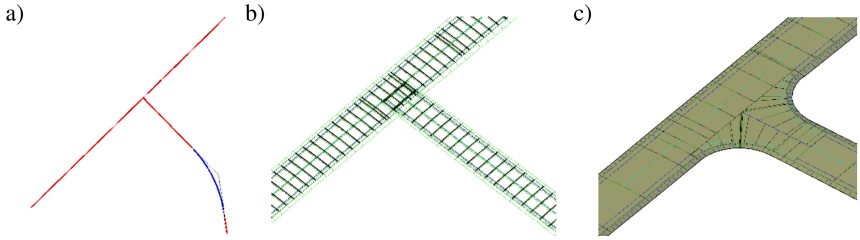

Fig. 3. Graphic examples LOD: a) LOD1, b) LOD3, c) LOD5 [21]

Full digitalization of the project requires involvement of the manufacturers of prefabricated elements. The designer does not have access to detailed information on the geometry and materials of prefabricated elements such as road signs, barriers, drainage elements, etc. Models of prefabricated elements are best prepared by their manufacturer, but this also requires additional work.

The exchange of BIM model information is realized via BIM Collaboration Format (BCF) files, which is described in detail in the literature, e.g. [23, 24]. The files, which can be compared to "cards", allow for the input of comments and suggestions to be included in the native models. Such a solution makes it possible to pinpoint the exact location of collisions and limits the size of the transmitted data.

Another significant threat is the nomenclature used in industry models and the standard for encoding file names. In the case of small tasks, the problem is negligible, but in the case of large and expensive investments, it can definitely hinder cooperation. This particularly concerns the ordering party, which will carry out many investments with different service contractors.

Careful preparation of the model is crucial for proper cost estimation based on BIM technology, e.g. [25–27]. he classic cost estimate for the investor is prepared with the use of the index method at the initial stages of design works and updated at subsequent stages of documentation detailing. In BIM technology, the process will look exactly the same, but the role of the object model verifier will increase, whose task will be to check the correctness of the defined parameters.

The last of the key risks in road design, according to the author, is the division of the model into sections. The possibilities of computer equipment are limited to a certain range of data. Investments located in highly urbanized areas may require the use of shorter sections. The division of roads into sections is nothing new, however, as practice shows, errors often occur at the junction of two sections, affecting user comfort and traffic safety.

3.2. Road construction with BIM

The use of BIM technology at the execution stage requires the involvement of significantly more financial resources in modern equipment and construction management. The direct benefits are increased efficiency and quality of the works. The best solution, from the perspective of the entire life cycle of the building, would be to continue working on the model using the native software used by the designer. This will allow taking over the full set of data which were created during the preparatory phase. In order to enable the full use of the model in the subsequent stages of the object's life cycle, the construction crew must constantly update the model with the information about incorporated layers (elements), in the form of test protocols, declarations of conformity, etc. Accurate model gives the possibility to order non-standard elements, often with complicated geometry. The prospect of using such an option is related to the level of digital advancement of material suppliers. If changes are made to the approved design, it is necessary to update the model to conform to the real state. Ongoing work on the model allows the contractor to achieve maximum benefit in the form of as-built completion documentation.

3.3. Road maintenance with BIM

The operation of road infrastructure is undoubtedly the most difficult stage in its life cycle. It is necessary to continue collecting data containing information on e.g. traffic, current maintenance, performed repairs etc. Based on current data, it may be necessary to update the model. Roads and engineering structures within their route, similarly to other buildings in Poland, are subject to periodical control of their technical condition. The data on technical condition constitute the basis for decision making on maintenance activities on the road network. Therefore, they should be included in the model and in current analyses. Due to the stage of implementation of BIM technology, only selected issues can be read about in the literature, e.g. [28–30]. For example, a change in traffic organisation on the road will be introduced, it will also force a change in the model. Failure to do so will render the digital twin obsolete and there will be no subsequent possibility of making reliable analyses of the road network.

The design life of a road surface in Poland is 20–30 years, while the actual life is much longer. This will have a significant impact on the validity of the road model in future software versions. Significant changes in native software are introduced every few years, so when choosing BIM software it is worth paying attention to compatibility.

4. Conclusions

Undoubtedly, the Building Information Modeling technology influences, among others, the acceleration of the decision-making process based on more precise analysis, improvement of the quality of construction works and may reduce the costs necessary to be incurred throughout the road life cycle. The issues presented in this article show the wide scope of using BIM in road construction and selected problems that need to be faced. Table 1 presents a map of selected problems that should be solved before the widespread use of BIM technology.

The Polish road construction industry is at the beginning of the practical use of BIM. The actions presented in Table 1 will allow the advantages of BIM technology to be used more fully in road investments. Time is needed to eliminate the risks and solve the problems

Table 1. Map of selected problems of BIM implementation in the Polish road engineering

Area of activity	Problem	Action required
Investment preparation	Output	Collection of digital GIS and GEO data by state institutions
	Team cooperation	Standardisation of project studies
	Analyses and corrections	Standardisation of digital data
Road construction	Updating the BIM model	Standardisation of digital data
Maintenance of the road	Updating the BIM model	Standardisation of digital data
Throughout the life cycle	BIM assumptions	Definition of customer requirements and expectations
	Digital data	Standardisation of digital data

signalled. The preparation of appropriate procedures and standards, adjusted to national realities, requires gathering experience from many pilot investments. Each subsequent investment with practical use of BIM technology will be easier and more effective. The ongoing industrial revolution will take road construction to a higher technical level, which will be felt by every road user.

The progress of digitalisation in construction is irreversible and inevitable. When thinking about digital evolution, it is worth mentioning how data carriers have changed. Many people still have documents on 3.5″ floppy disks, which can no longer be used in practice. Data CDs are also slowly becoming history. It is hard to imagine what the construction industry will look like once digitisation is fully implemented.

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BIM w procesie budowlanym – wybrane problemy na etapie wdrożenia w polskim drogownictwie

Słowa kluczowe: Infrastructura, InfraBIM, technologia BIM, Building Information Modeling

Streszczenie:

Cyfryzacja procesu budowlanego to zjawisko, które w ostatnich latach zostało znacząco przyśpieszone. Technologia BIM (Building Information Modeling) cieszy się coraz większym zainteresowaniem ze strony projektantów, wykonawców oraz inwestorów i jest stosowana, głównie w odniesieniu do obiektów kubaturowych. W obiektach komunikacyjnych zastosowanie BIM jest znacznie trudniejsze, co potwierdzają przesunięcia harmonogramów podczas prób wdrożeniowych w projektowaniu dróg. A przecież BIM to nie tylko etap projektowania czy realizacji robót budowlanych, warto korzystać z nowych możliwości szczególnie na etapie użytkowania obiektu. BIM w infrastrukturze komunikacyjnej jest już stosowany w innych krajach, głównie skandynawskich, gdzie rozpoczęły się prace nad jego wdrożeniem na początku obecnego stulecia. Ministerstwo Infrastruktury przygotowało zalecenia dotyczące BIM w polskim budownictwie drogowym. W marcu 2021 r. rekomendowano do stosowania wzorce i standardy dotyczące modelowania informacji o drogowych obiektów inżynierskich (BIM-M). Analogiczne opracowanie dotyczące dróg (BIM-D) zostanie prawdopodobnie opublikowane w najbliższym czasie. Przygotowanie odpowiednich procedur oraz standardów, dostosowanych do krajowych realiów, wymaga zebrania doświadczeń na inwestycjach pilotażowych.

Celem artykułu jest wskazanie koniecznych działań, które pozwolą na pełniejsze wykorzystanie zalet technologii BIM w inwestycjach drogowych.

Wybrane zagrożenia

Podstawowym problemem w przygotowaniu dobrej dokumentacji projektowej to odpowiednia jakość mapy sytuacyjno-wysokościowej. Pomiar obiektów na powierzchni nie stanowi utrudnienia, jednak podziemne uzbrojenie terenu to zupełnie inna sprawa. Praktycznie nie ma inwestycji drogowej, podczas realizacji której nie wystąpiłaby konieczność usunięcia kolizji z siecią różnego rodzaju. Na dodatek, bardzo często występują sieci niezinwentaryzowane lub o przebiegu innym niż przedstawiony na mapie. Są to jedne z kluczowych danych, istotnie wpływające na terminową realizację robót.

Stosowanie technologii BIM w obecnych realiach niesie ze sobą szereg zagrożeń. Podstawowe to konieczność użycia kilku programów natywnych i wymiana danych między nimi, bez przygotowanej standaryzacji przekazywanych danych cyfrowych. Niezbędne jest również przygotowanie odpowiednich bibliotek elementów prefabrykowanych, które aktualnie są dostępne głównie dla budownictwa kubaturowego.

Kolejne istotne zagrożenie to stosowana nomenklatura w modelach branżowych oraz standard kodowania nazw plików. W przypadku małych zadań problem jest pomijalny, jednak w przypadku dużych i kosztownych inwestycji może zdecydowanie utrudnić współpracę. Dotyczy to szczególnie zamawiających, który będą realizować wiele inwestycji z różnymi wykonawcami usług.

Ne etapie realizacji inwestycji niezbędna jest dalsza praca nad modelem z wykorzystaniem oprogramowania natywnego. W przypadku wprowadzenia zmian względem zatwierdzonego projektu, niezbędne jest zaktualizowanie modelu do zgodności ze stanem rzeczywistym. Aby umożliwić pełne wykorzystanie modelu w kolejnych etapach cyklu życia obiektu obsługa budowy musi stale aktualizować model informacjami o wbudowywanych warstwach (elementach), w postaci protokołów z badań, deklaracji zgodności itp. Dokładny model daje możliwość zamawiania nietypowych elementów, często o skomplikowanej geometrii. Bieżąca praca nad modelem pozwala osiągnąć wykonawcy maksymalne korzyści w postaci dokumentacji powykonawczej.

Na etapie eksploatacji infrastruktury drogowej niezbędne jest dalsze gromadzenie danych, zawierających informacje np. o ruchu drogowym, bieżącym utrzymaniu, wykonanych remontach itp. Przykładowo wprowadzona zostanie zmiana organizacji ruchu na drodze, wymusi ona również zmianę modelu. Drogi oraz obiekty inżynierskie znajdujące się w ich ciągu, podobnie jak inne obiekty budowlane w Polsce, podlegają okresowej kontroli stanu technicznego. Dane o stanie technicznym stanowią podstawę w procesie podejmowania decyzji o działaniach utrzymaniowych na sieci drogowej. Dlatego powinny zostać ujęte w modelu oraz bieżących analizach. Zaniechanie tych czynności spowoduje dezaktualizację cyfrowego bliźniaka i brak późniejszej możliwości sporządzania rzetelnych analiz sieci drogowej.

Projektowany okres eksploatacji nawierzchni drogowej w Polsce wynosi 20 – 30 lat, a rzeczywisty trwa znacznie dłużej. Będzie miało to istotny wpływ na aktualność modelu drogi w przyszłych wersjach oprogramowania. Co kilka lat wprowadzane są istotne zmiany w programach natywnych, warto zwrócić na to uwagę wybierając oprogramowanie BIM. Trudno dziś oszacować, czy będzie możliwa migracja modelu między programami, bez utraty części informacji.

Podsumowanie

Niewątpliwie technologia Modelowania Informacji o Budowli ma szereg pozytywnych cech i może być szeroko stosowana w budownictwie drogowym. Pozwala na przyśpieszenie procesu decyzyjnego opartego na dokładniejszej analizie, podniesienie jakości robot budowlanych oraz redukować koszty niezbędne do poniesienia w całym cyklu życia drogi.

W artykule przedstawiono wybrane zagrożenia występujące na różnych etapach procesu budowlanego, utrudniające zastosowanie BIM w polskim drogownictwie. Jesteśmy na początku praktycznego wykorzystania BIM. Przygotowanie odpowiednich procedur oraz standardów, dostosowanych do krajowych realiów, wymaga zebrania doświadczeń na wielu inwestycjach pilotażowych. Każda kolejna inwestycja z praktycznym wykorzystaniem technologii BIM będzie łatwiejsza i bardziej efektywna. Pierwsze inwestycje pozwolą również na dokładniejsze zdefiniowanie problemów.

Trwająca rewolucja przemysłowa pozwoli na przeniesienie drogownictwa na wyższy poziom techniczny, który odczuje każdy użytkownik dróg. Wdrożenie BIM w polskim drogownictwie to nie odległa przyszłość a raczej „jutro”, dlatego warto znać ograniczenia i przygotować się do nadchodzących zmian.

Received: 6.09.2021, Revised: 16.12.2021