UNECE

# Building Information Modelling (BIM) for road infrastructure: TEM requirements and recommendations

Trans-European North-South Motorway (TEM)

UNITED NATIONS

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

# Building Information Modelling (BIM) for road infrastructure: TEM requirements and recommendations

UNITED NATIONS

Geneva, 2021

This publication is issued in English only.

United Nations publication issued by the United Nations Economic Commission for Europe.

Photo credits: cover page – Mr. Denis Šimenić

ECE/TRANS/308

eISBN: 978-92-1-005549-9

# Acknowledgements

The paper "Building Information Modelling (BIM) for road infrastructure: TEM requirements and recommendations" was produced by the Trans-European North-South Motorway (TEM) Project and by the Sustainable Transport Division of the United Nations Economic Commission for Europe (UNECE).

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The author worked under the guidance of and benefited from significant contributions by Mr. Nenad Nikolic, Regional Advisor (UNECE).

For their invaluable inputs and comments, the author would like to thank Mr. Andrzej Maciejewski (TEM Project Manager) and Mr. Ivica Jujnovic (TEM Project Manager). For providing information, the author would also like to thank all the TEM National Coordinators.

In addition, the author would like to express gratitude to all those who provided inputs, advice and support during the preparation of this publication, and particularly to Ms. Lydia Panchenko (UNECE), and to the editor, Mr. Christopher Bloswick, Jr.

# United Nations Economic Commission for Europe

The United Nations Economic Commission for Europe (UNECE) is one of the five United Nations regional commissions, administered by the Economic and Social Council (ECOSOC). It was established in 1947 with the mandate to help rebuild post-war Europe, develop economic activity and strengthen economic relations among European countries, and between Europe and the rest of the world. During the Cold War, UNECE served as a unique forum for economic dialogue and cooperation between East and West. Despite the complexity of this period, significant achievements were made, with consensus reached on numerous harmonization and standardization agreements.

In the post-Cold War era, UNECE acquired not only many new member States, but also new functions. Since the early 1990s the organization has focused on assisting the countries of Central and Eastern Europe, the Caucasus and Central Asia with their transition process and their integration into the global economy.

Today, UNECE supports its 56 member States in Europe, Central Asia and North America in the implementation of the 2030 Agenda for Sustainable Development with its Sustainable Development Goals (SDG). UNECE provides a multilateral platform for policy dialogue, the development of international legal instruments, norms and standards, the exchange of best practices, and economic and technical expertise, as well as technical cooperation for countries with economies in transition.

Offering practical tools to improve people's everyday lives in the areas of environment, transport, trade, statistics, energy, forestry, housing and land management, many of the norms, standards and conventions developed in UNECE are used worldwide, and a number of countries from outside the region participate in UNECE work.

The multisectoral approach of UNECE helps countries to tackle the interconnected challenges of sustainable development in an integrated manner, with a transboundary focus that helps devise solutions to shared challenges. With its unique convening power, UNECE fosters cooperation among all stakeholders at the country and regional levels.

# Transport in UNECE

The UNECE Sustainable Transport Division is the secretariat of the Inland Transport Committee (ITC) and the ECOSOC Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals. The ITC and its 20 working parties, as well as the ECOSOC Committee and its sub-committees are intergovernmental decision-making bodies that work to improve the daily lives of people and businesses around the world, in measurable ways and with concrete actions, to enhance traffic safety, environmental performance, energy efficiency and the competitiveness of the transport sector.

The ECOSOC Committee was set up in 1953 by the Secretary-General of the United Nations at the request of the Economic and Social Council to elaborate recommendations on the transport of dangerous goods. Its mandate was extended to the global (multi-sectoral) harmonization of systems of classification and labelling of chemicals in 1999. It is composed of experts from countries which possess the relevant expertise and experience in the international trade and transport of dangerous goods and chemicals. Its membership is restricted in order to reflect a proper geographical balance among all regions of the world and to ensure adequate participation of developing countries. Although the Committee is a subsidiary body of ECOSOC, the Secretary-General decided in 1963 that the secretariat services would be provided by the UNECE Transport Division.

ITC is a unique intergovernmental forum that was set up in 1947 to support the reconstruction of transport connections in post-war Europe. Over the years, it has specialized in facilitating the harmonized and sustainable development of inland modes of transport. The main results of this persevering and ongoing work are reflected, among other things, (i) in 58 United Nations conventions and many more technical regulations which are updated on a regular basis and provide an international legal framework for the sustainable development of national and international road, rail, inland water and intermodal transport, including the transport of dangerous goods, as well as the construction and inspection of road motor vehicles; (ii) in the Trans-European North-South Motorway, Trans-European Railway and the Euro-Asia Transport Links projects that facilitate multi-country coordination of transport infrastructure investment programmes; (iii) in the TIR system, which is a global customs transit facilitation solution; (iv) in the tool called For Future Inland Transport Systems (ForFITS), which can assist national and local governments to monitor carbon dioxide (CO2) emissions coming from inland transport modes and to select and design climate change mitigation policies based on their impact and adapted to local conditions; (v) in transport statistics – methods and data – that are internationally agreed on; (vi) in studies and reports that help transport policy development by addressing timely issues based on cutting-edge research and analysis. ITC also devotes special attention to Intelligent Transport Services (ITS), sustainable urban mobility and city logistics, as well as to increasing the resilience of transport networks and services in response to climate change adaptation and security challenges.

In addition, the UNECE Sustainable Transport and Environment Divisions, together with the World Health Organization (WHO) – Europe, co-service the Transport Health and Environment Pan-European Programme (THE PEP).

Finally, since 2015, the UNECE Sustainable Transport Division has provided the secretariat services for the Secretary General's Special Envoy for Road Safety, Mr. Jean Todt.

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# Acronyms and Abbreviations

| | |
|---|---|
| **AEC** | Architecture, Engineering and Construction |
| **AIA** | American Institute of Architects |
| **AIM** | Asset Information Model |
| **API** | Application Programming Interface |
| **AR** | Augmented Reality |
| **BEP** | BIM Execution Plan |
| **BIM** | Building Information Modelling |
| **BIM-AM** | BIM Assessment Methods |
| **BIM-MM** | BIM Maturity Measure |
| **bSI** | buildingSmart International |
| **CAD** | Computer Aided Design |
| **CDE** | Common Data Environment |
| **CEO** | Chief Executive Officer |
| **CIM** | Civil Information Management |
| **COBie** | Construction Operations Building information exchange |
| **CSG** | Constructive Solid-State Geometry |
| **DB** | Design-Built |
| **DBB** | Design-Bid-Build |
| **DOT** | Department of Transportation |
| **EIR** | Employer's Information Requirement |
| **EU** | European Union |
| **FHWA** | Federal Highway Administration |
| **FM** | Facility Management |
| **GIS** | Geographic Information System |
| **IFC** | Industry Foundation Class |
| **iHEEP** | Highway Engineering Exchange Program |
| **IPD** | Integrated Project Delivery |
| **ISO** | International Standardization Organization |
| **IT** | Information Technology |
| **LiDAR** | Light Intensity Distance and Ranging |
| **LOD** | Level of Development |
| **LOd** | Level of graphic details |
| **LOi** | Level of information |
| **MEP** | Mechanical, Electrical and Plumbing |
| **NIBS** | National Institute of Building Sciences |
| **OSD** | Open Standards Deliverables |
| **PAS** | Publicly Available Specification |
| **PIM** | Project Information Model |
| **QTO** | Quantity Take Off |
| **RFID** | Radio Frequently Identification |
| **TEM** | Trans-European Motorway |
| **UAV** | Unmanned Aerial Vehicle |
| **VDC** | Virtual Design and Construction |
| **VR** | Virtual Reality |

# Executive summary

The construction and maintenance of road infrastructure is an important sector of most countries' national economies. At the same time, it is one of the less digitized sectors, with the presence of systemic shortcomings including an insufficient level of cooperation, inadequate information management, and limited investment in technology, research and development. These shortcomings often result in lower efficiency and higher financial risk for investors due to various inconsistencies in project documentation, as well as failure to adhere to planned costs and deadlines.

Building Information Modelling (BIM) is an effective tool for maintaining the principles of sustainable construction throughout the life cycle of road assets.

BIM can sometimes be simplified as "digitalization", but BIM is much more. BIM combines the use of computer-aided 3D modelling with information about a specific building element to improve collaboration, coordination and decision-making processes.

For road administrations, this means that the construction and management of road systems should be more efficient, the risks of cost overruns on projects lower and transparency in the use of public funds greater. BIM is becoming a global language in construction as it allows for greater levels of cross-border cooperation. It is assumed that the use of BIM will become a common component of public procurement worldwide in construction contracting. In order for TEM member countries to remain competitive in the sector, this growing trend needs to be addressed.

However, the level of implementation of BIM in transport infrastructure is several years behind BIM implementation in the construction of buildings. Most of the published BIM guidelines and standards are focused on architecture, i.e., vertical structures.

The purpose of this report is to analyse and promote the implementation of BIM in the sector of road transportation infrastructure. To this end, relevant information has been provided for instances of BIM application to road construction projects, such as the classification and description of commonly used tools, LOD definitions, interoperability issues, etc.

Important topics including collaboration on projects in the BIM environment, basic roles defined in BIM implementation and required BIM documents (e.g., BIM Execution Plan) are also covered. Furthermore, an overview of commonly used BIM maturity assessment tools is included.

The report reviews the impact of BIM implementation on the most important stakeholders like owners, designers and contractors, describing the current specifics, guidelines and difficulties (as well as recommendations for overcoming them).

The experiences and best practices of countries with the highest BIM maturity status are presented, and an overview is given of the current implementation of BIM in TEM member countries.

Finally, recommendations are presented with the aim of successfully implementing the BIM process and technology in the road sector of TEM member countries.

# 1. Introduction to BIM

## 1.1. Background and road sector challenges

Traditional ways of doing business in infrastructure management are inadequate to meet the greater challenges of today, especially in the road sector.

Managing time, costs and waste are big concerns to all parties involved in large infrastructure projects. Many problems related to control are the result of inadequate communication within contracting organizations or between contracting and other design organizations.

The amount of information produced in any project from start to finish is massive. At any stage of the project, different types of information are required by various stakeholders in various formats.

Experiences from large-scale projects reveal that many problems are attributed to the design (or communication about the design) and more than 50 per cent of contract modifications are related to design deficiencies. This suggests the need for early efforts by all project participants to identify and resolve potential problems, ensuring the delivery of complete and correct design and construction documentation.

Therefore, all infrastructure-related businesses, including road authorities, need to improve productivity, business processes and transparency to be in compliance with today's economic realities, where inefficiency is not tolerated – i.e., the authorities need to properly plan, build, maintain and operate road infrastructure to create appropriate value for their customers (in this context meaning individual road users, logistic companies or public transportation agencies).

To achieve these goals, road authorities must adopt an appropriate system which will yield the following benefits:

- Greater transparency and consistent workflows throughout the design/construction/maintenance process
- A reduction in errors and reduced change orders
- Increased productivity
- Better collaboration among stakeholders
- Cost savings

Moreover, digital technologies and processes are changing the methods of creating, delivering and managing projects. This includes Building Information Modelling (BIM), artificial intelligence, robotics, 3D printing, additive manufacturing, the Internet of things, autonomous vehicles, drones, augmented and virtual reality, etc.

In recent years, Building Information Modelling has become an important strategy for improving productivity in the construction of buildings, but the use of BIM is still waiting for wider adoption in other infrastructure construction. Nevertheless, the application of BIM for infrastructure is rapidly accelerating as owners and engineering service providers increasingly recognize the benefits of 3D modelling and the use of intelligent objects.

Creating virtual models in 3D benefits not only designers and builders; in fact, most of the benefits can be enjoyed by clients who are then able to supervise project progress, monitor performance-based cash flows, analyse performance and safety aspects, and generally manage work in a coordinated manner. Having a digital platform that securely connects different data sources can be helpful to clients for seeking information and mapping all their assets. Information models can be linked to client websites to get a clear picture of the status and location of the property.

## 1.2. BIM origins

Long before BIM was introduced into the construction industry, the essential development of 3D modelling began. According to Eastman[1], 3D modelling increasingly became an important area in research during the 1960s, resulting in software able to create simple three-dimensional structures.

Projections could be created with a new modelling method called boundary representation or B-tail, which was one of the first tools that could model solid objects. In parallel to Braid's development in 1973, another method of modelling was developed called Constructive Solid State Geometry, or CSG. Initially, the two methods competed to become a generally accepted modelling method. However, as the different methods had distinct advantages, their combination was increasingly used and later became the standard method for program modelling.

After the initial development rollout, the expansion of computer aided design (CAD) continued swiftly. A key step towards today's use of CAD was the introduction of object parametric modelling.

[1] Chuck Eastman et al., *BIM Handbook* (Hoboken, New Jersey, John Wiley & Sons, 2011).

The unique information stored in each object, together with the introduction of object rules and the classification of objects into different categories or families, formed the basis for so-called smart models that could, for example, detect conflicts or deviations from defined standards.

The development of object parametric modelling laid the foundation for all of today's BIM software. In 2000, the software company Charles River created the Revit design tool. This software was similar to previous programs, the intention of which was to allow architects and designers to design buildings in three dimensions. However, the biggest difference from contemporary software at that time was that Revit fully adopted the concept of parametric modelling based on object values in 3D modelling. The software was able to create a model that included not only geometric information but also non-geometric information – various properties, features, etc. This important addition to CAD is now a fundamental basis for all BIM software.

The term BIM was first employed by Van Nederveen and Tolman in the journal *Automation in Construction* in 1992. However, exploring the origins of parametric modelling and non-geometric information, Engelbart published a report on "Augmenting Human Intellect: A Conceptual Framework" in the 1960s (1962). In that report, he described how designers were able to create an unconventional, computer-aided construction model.

To make BIM applicable to infrastructure projects, Autodesk introduced the Civil 3D 2006 software in 2005 which applied parametric modelling to the definition of a road model. This contrasted with the preceding Land Development Desktop, which used only the CAD platform. The early versions did not have great BIM capabilities, but over time they became more significant and useful. A similar concept (the creation of a 3D corridor model of a road) was later adopted by other major software vendors (e.g., Bentley with the Open Road application).

## 1.3. Comprehensive definitions of BIM

Building Information Modelling (BIM) is an intelligent 3D model-based process to inform and communicate project decisions. Parametric design, visualization, simulation and collaboration provide greater efficiency for all stakeholders across the project life cycle to improve the design, construction and operations of facilities.

Although several definitions of BIM are available from various sources, the most comprehensive definition is given by the United States National Building Information Model Standard Project Committee, which defines BIM as:

> *A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder.*

It is important to understand that BIM is not a specific product or technology; instead, it is a collection of software applications designed to facilitate project coordination and collaboration.

In addition, BIM is also a process for developing design and construction documentation by virtual construction of a road, bridge, tunnel or other form of infrastructure – before anything is built.

At its core BIM uses:

- 3D models – components represented by digital objects that contain data regarding graphics, attributes and parametric rules that allow them to interact in an intelligent way.
- Common data environment (CDE) – the single source of information (typically cloud-based), used to collect, manage and disseminate documentation, graphical models and non-graphical data for the whole project team. Creating a single source of information facilitates collaboration among project team members and helps avoid duplication and mistakes.

The implementation of BIM has a significant impact on the entire process of developing, executing and managing infrastructure projects, which includes surveying and data collection, conceptual design, environmental review, public participation, final implementation of design and documentation, bidding, construction, operations and maintenance.

The term BIM is usually associated with architecture or, in general, what can be termed vertical constructions. That is not surprising because, as the name implies, Building Information Modelling was adopted in designing buildings much earlier than road infrastructure, and has been codified with an array of well-defined standards, procedures, libraries and tools.

On the other hand, for what might be termed horizontal constructions, the application of BIM technology started more recently. Although civil engineering projects have certain specific characteristics, BIM principles can still be applied to roads and motorways, as new motorways, tunnels, bridges and so forth are similarly 3D structures where 3D modelling can represent these objects better than traditional 2D CAD drawings.

To distinguish BIM-based road infrastructure projects from conventional BIM architectural designs, various titles and abbreviations have been created over time, including I-BIM, Virtual Design and Construction (VDC), and Civil Information Management (CIM). The Civil Information Management System (CIM) has been adopted by a number of departments of transportation in the United States. CIM includes a range of practices and tools that entail collecting, organizing and managing information on roads and motorways in digital formats to create a fully integrated asset management system.

The acronym BIM has ultimately become widely adopted across engineering professions. When it is necessary to emphasize that an application of BIM is for horizontal structures, this is usually specified with the term BIM for Infrastructure. This usage was also applied in the present report.

## 1.4. Comparison of the traditional process and the BIM approach

Typically, the construction process is described as one in which a client orders engineering services to facilitate a project's implementation. The selected designer obtains a set of requirements and, through refining the requirements in the brief from the client, the designer sets out the main performance attributes of the construction facility required. Following this, other consultants (specialist designers and engineers) work with the engineer as a design team to develop a design as a solution to meet the client's requirements. The design is developed through several stages, including concept design, feasibility study, and preliminary and detailed designs. In the traditional approach, documents related to the technical specification of the design, its cost and construction duration are produced at each of these stages.

The project team's communication is usually reduced to the exchange of 2D drawings, most often without clear protocols. Thus, many technical data are lost when switching to each subsequent phase and must be re-created. In this mode of work, it is particularly difficult to coordinate between different professions because the project review procedures are lacking and the impact of one part of the project on the other is low. Typical and common errors occur with this process – working with non-up-to-date files, mismatching of different parts of the project, and a general lack of data describing the technical characteristics and functioning of individual elements.

In road construction projects, there are always large amounts of data that cannot be properly presented and verified in the traditional way during design, so that project omissions often are not detected in time.

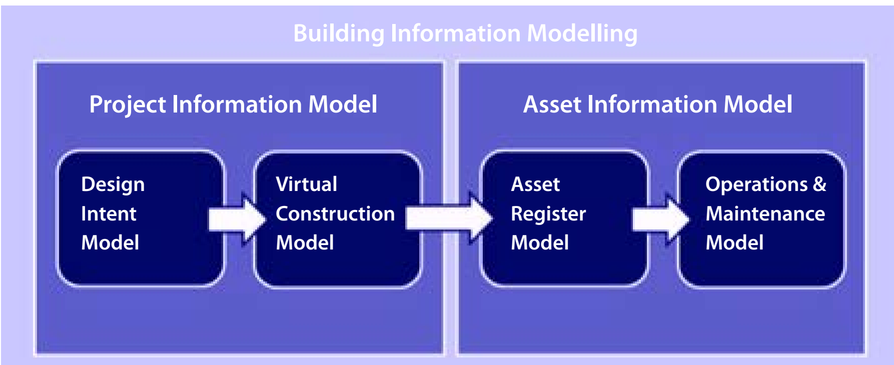
This results in the transfer of inconsistent or incorrect data to the next phase, so that errors are identified during construction, resulting in additional costs and delays.

In contrast, BIM addresses these issues in a systemic manner. For proper BIM functioning it is necessary to ensure an uninterrupted flow of data and tools for communication and coordination.

The basic concept of BIM is to develop a model through all stages of the project using the components of the building that contain information. Figure 1 shows the concept of process modelling whereby the model moves through various project stages. The naming of these model processes is defined in the British Standard PAS 1192-2:2013 which specifies the requirements for achieving BIM level 2 in construction projects.

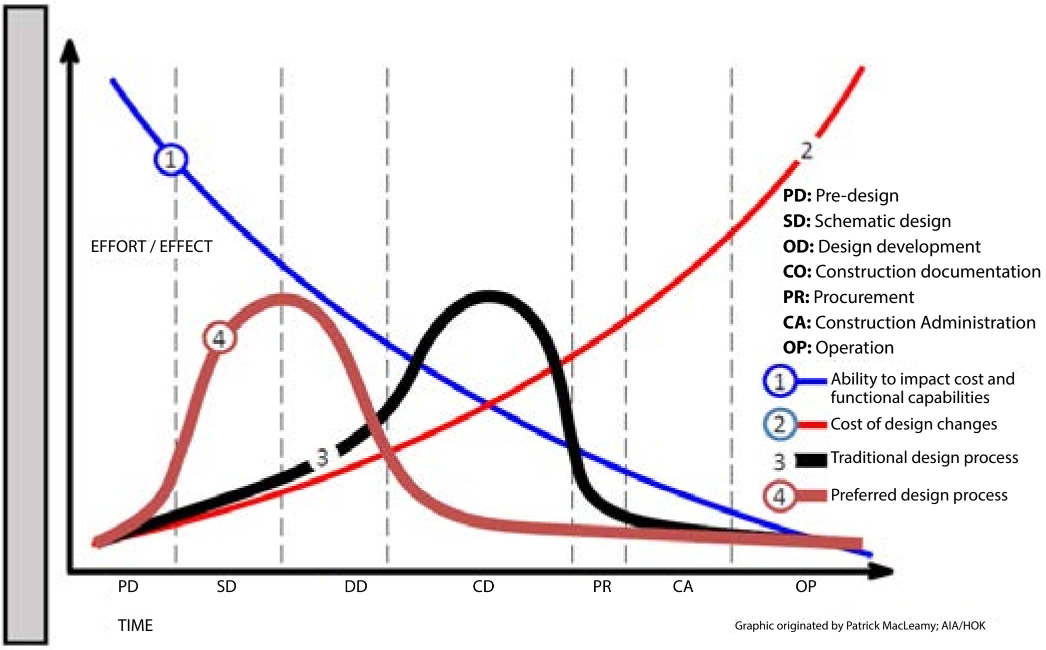
During conceptual design, the project communicates in a way that depicts spatial relationships using more general components and shapes. However, various BIM tools developed specially for the conceptual stage of infrastructure projects provide much better insight into the concept and implementation of planned solutions.

**Figure 1**
**BIM process through project stages**




*Source:* British Standard PAS 1192-2:2013.

**Figure 2**
**MacLeamy curves, cost/time reduction potential versus cost/time of making changes**




*Source:* Bob Springer, as shown in "Thoughts inspired by the ABA Forum on Construction Law", The Division 4 Triclinium, 28 June 2013. *Available* at http://division4triclinium.blogspot.com/2013/06/of-macleamy-curve-efficient-design-and.html

In general terms, the earlier a decision is made in a business process, the greater its potential positive impact on important project variables, such as cost and time, as can be seen from the MacLeamy[2] diagram (Figure 2). For example, reviewing a planned motorway route in a realistic 3D environment with all the necessary indicators such as intersections and structures, in what can be called the information phase, can have a decisive impact on preventing complex and costly changes in the construction phase.

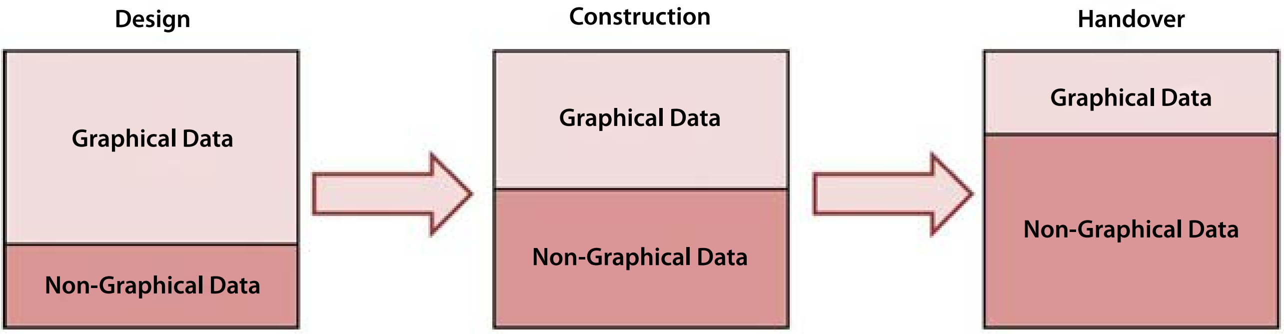
Throughout the further design process, the designers should maintain a balance between the scope, schedule and cost – in line with the client's budget and requirements. Any change can cost money and waste time. Traditional design methods usually require significant time and effort to produce cost estimates and scheduling information. However, with the use of BIM, all the design documents, schedules, quantities and other vital information are immediately available from a single source. This simplification puts the designer and project team firmly in control over the accuracy of the design process, eliminates painstaking manual verification and improves cost efficiency and collaboration.

As the project goes into detailed design, the information on components throughout the model will increase and allow further engineering analysis in support of the design. At the completion of the design, all graphical models, performed analyses and simulations, as well as non-graphical data will form the Design Intent Model.

Upon completion of the project, the digital model is forwarded to the contractor. The BIM model improves the transfer of data between designers and contractors as well. The amount of information delivered in this way, as well as its systematic organization, is far better than standard CAD project documentation printed on paper. The level of detail of components helps with cost estimation, procurement, constructability and installation, leading to the Virtual Construction Model. Furthermore, the direct import and export of data (e.g., a designed subgrade surface can be loaded directly into a GPS-guided machine control) eliminates the possibility of misreading or wrong interpretation.

[2] Patrick MacLeamy, FAIA, chairman of buildingSMART International.

**Figure 3**
**Changes to BIM model in project phases according to data type**




*Source:* Yusuf Arayici, *Building Information Modelling* (n.p., Bookboon, 2015), e-book.

BIM technology also means improved communication between the design team and the contractors during the construction process, simplifying updates and modifications, which is often necessary in motorway projects due to various reasons.

When construction works are completed, a large amount of data have been generated throughout the process and systematically linked to the digital BIM model. The next logical step in life cycle management is the transfer of this data to asset management.

This is important because the operation and maintenance stages comprise the longest period in the overall life cycle of a road. Based on all project information and project modifications during construction – data on installed equipment and all supporting documentation (as-built information) – an Asset Register Model is designed to then serve as an Operations and Maintenance Model. At this stage, the amount of non-graphic data begins to dominate (Figure 3) via data entry into the asset management and maintenance system, since 3D models are generally not appropriate for these systems.

# 2. BIM tools and technologies

## 2.1. Evolution from CAD to parametric modelling technologies

### 2.1.1. Introduction

In the construction sector, design tools have been developed from 2D CAD, through 3D modelling, to object-oriented modelling with BIM which has transformed the Architectural Engineering Construction (AEC) industry with the aim of proving benefits throughout the whole life cycle process. This technological progress has also introduced many different BIM tools and technologies specialized for various AEC tasks and activities from design to construction and maintenance. However, there is a general lack of understanding and knowledge of the main BIM functionalities and key competences, even though it is strategically important to utilize and take full advantage of BIM tools.

Several studies have revealed that inefficient use of BIM tools still takes place, and that the infrastructure CAD industry is still using CAD tools. For this reason, it is important to map BIM tools and technologies with relevant tasks and activities in the infrastructure life cycle process. This chapter will give an overview of commonly used tools for implementing BIM in infrastructure projects, following their role across the infrastructure life cycle process.

### 2.1.2. CAD

Many industries (construction, manufacturing, the automotive industry, etc.) are using CAD technology to effectively support automation in project preparation. In order to achieve the highest level of efficiency, a lot of effort must be put into programming repetitive procedures as well as customization to the desired discipline (e.g., road design) since CAD tools start out essentially generic for all technical professions. One example of CAD technology is AutoCAD software, and – with enough programming effort and discipline-specific customization – it is possible to reap some of the benefits of BIM using this software, such as scheduling, cost estimating and structural design.

In the 1990s, CAD replaced manual project preparation, but it did not significantly alter the design approach, the form of project collaboration or paper-based project delivery.

### 2.1.3. Object-based CAD technologies

Object-based CAD technologies concentrate on simulating building components on a CAD platform. They help in extracting quantity data and 2D documentation from construction parts. Furthermore, they can also support the automatic generation of various drawings such as cross sections and longitudinal profiles but based on routines that use 2D CAD entities. Certain 3D views can be obtained as a result of data processing in multiple 2D views. They can be considered BIM-compatible because they usually contain information about the designed infrastructure. Software products based on this technology are still in widespread use (e.g., Autodesk Land Development Desktop).

### 2.1.4. Parametric modelling technologies

Parametric modelling offers the most advanced level of information modelling of an infrastructure object and is more efficient than CAD and Object CAD technologies.

Object-based parametric modelling uses many features called parameters to demonstrate the properties of each object and the associated rules between objects (relationships). This form of modelling contains some non-geometric properties and features such as spatial relation, performance, manufacturer, geographical information, vendor, materials, code requirements and any other parameter related to how the object is used. A draining pipeline is a good example where several geometric data, hydraulic characteristics, materials, etc. are presented for each element (pipe or manhole).

The most common software tools using parametric modelling technology are listed in Chapter 2.3.

## 2.2. Level of development (LOD)

### 2.2.1. Introduction

Since the selection of the BIM approach on a project means model-based work, understanding the degree of information required for individual elements of the model plays a significant role in ensuring its use for its intended purpose.

Therefore, the need for a conceptual data model on which different BIM procedures can be based was noticed already at the beginning of BIM development. This is how the term level of development (LOD) was created.

Like many other terms in the BIM domain, the LOD specification is a concept adopted by the architectural industry and originally proposed by the American Institute of Architects (AIA) in 2008. The LOD concept covers a number of aspects and, among other things, determines:

- the level of graphic details / modelling accuracy (LOd)
- the quantity, quality and relevance of non-graphical data (LOi)
- the type of non-graphical data

The level of detail (LOd) determines the geometric precision of the model in relation to the actual appearance of the element. It is often identified with the level of development, which is wrong.

The second most frequently cited aspect is level of information (LOi). The importance of non-graphical data usually grows through the phases of the project and reaches its maximum in the phase of maintenance and operation.

Although all these aspects contribute to the concept of LOD, they do not define it, so the degree of development (LOD) is the summary of them all. The level of development represents the degree to which information about an element is considered reliable for the purpose of making decisions at a particular point in time. Simply put, the level of development means modelling at the appropriate level of detail for the proper use of BIM.

The most comprehensive specification of the stage of development is certainly the publication of the BIMForum[3] association. The association itself raised the importance of LOD specifications as follows:

- assists project teams in clearly articulating and presenting the elements that will be involved in BIM procedures
- assists in communication between project teams to ensure that all members are well compliant with BIM requirements
- also serves as a protocol that can be incorporated into BIM contract documents and BIM execution plans

### 2.2.2. Fundamental LOD definitions

Five levels of development are defined by the AIA to indicate the extent to which a BIM model is developed. These are described below as LOD 100, LOD 200, LOD 300(350), LOD 400 and LOD 500. These codes usually correspond to project stages such as the conceptual stage and the approximate geometry, precise geometry, fabrication, and as-built stages. The various levels require coordination among all stakeholders involved in a project to identify who will be responsible for the development of each component and to what extent the BIM model will be detailed. The fundamental LOD definitions are explained by the BIMForum as follows:

**LOD 100** (basic)

*The model element may be graphically represented in the model with a symbol or other generic representation but does not satisfy the requirements for LOD 200. Information related to the model element (i.e., cost per $m^2$ or m', etc.) can be derived from other model elements.*

BIMForum interpretation: LOD 100 elements are not geometric representations. Examples are information attached to other model elements or symbols showing the existence of a component but not its shape, size or precise location. Any information derived from LOD 100 elements must be considered approximate.

**LOD 200** (approximate)

*The model element is graphically represented within the model as a generic system, object or assembly with approximate quantities, size, shape, location and orientation. Non-graphic information may also be attached to the model element.*

BIMForum interpretation: At this level, LOD elements are generic placeholders. They may be recognizable as the components they represent, or they may be volumes for space reservation. Any information derived from LOD 200 elements must be considered approximate.

**LOD 300** (accurate)

*The model element is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, shape, location and orientation. Non-graphic information may also be attached to the model element.*

BIMForum interpretation: The quantity, size, shape, location and orientation of the element as designed can be measured directly from the model without referring to non-modelled information such as notes or dimension callouts. The project origin is defined, and the element is located accurately with respect to the project origin.

**LOD 350** (accurate, interfaces with other systems)

*The model element is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, shape, location, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the model element.*

BIMForum interpretation: Parts necessary for coordination of the element with nearby or attached elements are modelled. These parts will include such items as supports and connections. The quantity, size, shape, location and orientation of the element as designed can be measured directly from the model without referring to non-modelled information such as notes or dimension callouts.

[3] Available at https://bimforum.org/lod/

**LOD 400** (constructable)

*The model element is graphically represented within the model as a specific system, object or assembly in terms of size, shape, location, quantity and orientation with detailing, fabrication, assembly and installation information. Non-graphic information may also be attached to the model element.*

BIMForum interpretation: An LOD 400 element is modelled at sufficient detail and accuracy for fabrication of the represented component. The quantity, size, shape, location and orientation of the element as designed can be measured directly from the model without referring to non-modelled information such as notes or dimension callouts.

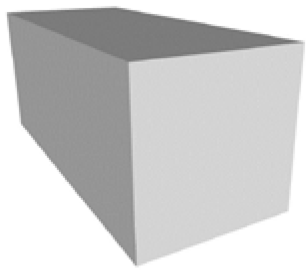
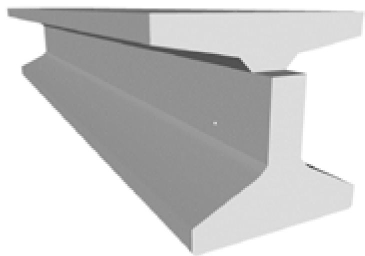
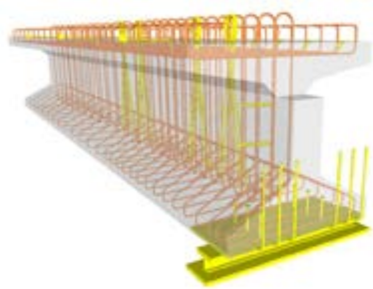
**LOD 500** (as constructed)

*The model element is a field-verified representation in terms of size, shape, location, quantity and orientation. Non-graphic information may also be attached to the model elements.*

BIMForum interpretation: Since LOD 500 relates to field verification and is not an indication of progression to a higher level of model element geometry or non-graphic information, the BIMForum specification does not define or illustrate it.

In 2019, the BIMForum released its latest iteration of the LOD guidelines. An extensive guide has been published that can help define how each model element and data set should look and how it should appear in the model. However, except for certain elements of bridges (Figure 4), other infrastructure objects do not appear in the guide at all.

**Figure 4**
**Example of bridge LOD specification**

| | | |
|---|---|---|
| 100 | | |
| 200 | Element modeling to include:<br>• Type of structural concrete system<br>• Approximate geometry (e.g. depth) of structural elements | <br>*LOD 200 Highway Bridges Precast Structural I Girder (Concrete), From Ikerd.com* |
| 300 | Element modeling to include:<br>• Specific sizes and locations of main concrete structural members modeled per defined structural grid with correct orientation<br>• Concrete defined per spec (strength, air entrainment, aggregate size, etc.)<br>• All sloping surfaces included in model element with exception of elements affected by manufacturer selection | <br>*LOD 300 Highway Bridges Precast Structural I Girder (Concrete) , From Ikerd.com* |
| 350 | Element modeling to include:<br>• Reinforcing Post-tension profiles and strand locations<br>• Reinforcement called out, modeled if required by the BXP, typically only in congested areas<br>• Chamfer<br>• Pour joints and sequences to help identify reinforcing lap splice locations, scheduling, etc.<br>• Expansion Joints<br>• Lifting devices<br>• Embeds and anchor rods<br>• Post-tension profile and strands modeled if required by the BXP<br>• Penetrations for items such as MEP<br>• Any permanent forming or shoring components | <br>*LOD 350 Highway Bridges Precast Structural I Girder (Concrete) , From Ikerd.com* |

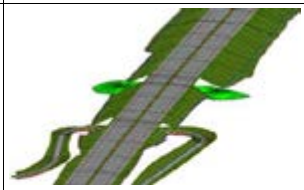
*Source:* BIMForum, "Level of Development (LOD) Specification Part I & Commentary, April 2019". Available at https://bimforum.org/resources/Documents/BIMForum_LOD_2019_reprint.pdf

### 2.2.3. Determination of optimal levels of development

Clear and understandable definitions of the level of development are important factors for the successful implementation of the BIM approach. Lack of consensus on what to achieve in a project can have negative effects, leading to inefficient coordination, schedule delays and cost overruns. Therefore, it is necessary to resolve the problems related to LOD as soon as possible to avoid misunderstandings and problems that will certainly arise during the procedure. For this reason, levels of development should be defined before starting work on modelling through major BIM documents such as the BIM Execution Plan.

Although the most common guidelines (e.g., BIMForum specifications) can be used to differentiate rules and processing methods in the context of modelling construction data, unique characteristics of motorway projects require the formulation of guidelines that are better tailored to their specific characteristics. This, together with the increased application of BIM on infrastructure projects, has triggered the development of many custom specifications and guides. One can find specifications issued by the owners (e.g., road administrations), which design or advise companies for internal use, or targeted specifications intended to implement the BIM approach on specific infrastructure projects (Figure 5).

**Figure 5**
**LOD specification example**

| LOG 100 | LOG 200 | LOG 300 | LOG 325 | LOG 400 |
|---|---|---|---|---|
|  2D model of the corridor. All necessary road elements to be provided as 2D lines. |  3D model of the standard layout for the road corridor without greater adjustments. |  3D model of the road corridor including signatures, curbs, paving, all layers of substructure and connections to exiting terrain. The corridor must be designed with superelevation and detailed design for ditches. Intersecting roads must be modelled in the same detail as the designed road. At Intersections it must be cut, so that the designed road and the intersecting road fits together in terms of both lines and surfaces. |  3D model of the road corridor including slope signatures, curbs, paving, all layers of substructure and connections to exiting terrain, interfacing structures and transitions in leveling. The corridor must be designed with superelevation and detailed design for ditches. Intersecting roads must be modelled in the same detail as the designed road. At Intersections it must be cut, so that the designed road and the intersecting road fits together in terms of both lines and surfaces. | Not relevant |
| LOI 100 | LOI 200 | LOI 300 | LOI 325 | LOI 400 |
| DDA Layers<br>Geometrical parameters. | DDA Layers<br>Geometrical parameters. | Pending | Pending | Pending |

*Source:* Building Smart Finland, "YIV Annex 3.1, Common InfraBIM Requirements, Draft 03/2019". Available at https://buildingsmart.fi/wp-content/uploads/2019/08/YIV_annex_3_1_ENG_DRAFT1.pdf

The main factor in determining the appropriate level of development is the goal of the model, i.e., its purpose for a particular BIM use.

In general, the information needed to create higher levels of development gradually becomes available as the project goes through subsequent stages. At the same time, the development of individual elements in the design process can progress at different speeds. Thus, for example, road elements in the final design may be at LOD 300 while individual services might be modelled at LOD 200. Therefore, the LOD is usually only used to describe the model element – not the complete model.

Current practice shows that cases of what could be described as excessive modelling are not uncommon. Because over modelling is a potential waste of project resources, it is important to align the required levels of development at an early stage with all disciplines that deliver 3D components for the overall BIM model.

## 2.3. BIM tools

### 2.3.1. Introduction

BIM is not one single process enabled by a single piece of software but incorporates many cross-functional processes that require a variety of software solutions. Each piece of software has different functional abilities to perform work-related tasks relevant to its business purposes. Accordingly, BIM models are produced by several BIM software packages.

Although the history of development of applications and tools in BIM for road infrastructure is shorter compared to the BIM in building architecture, a valuable set of tools are already available today.

Software tools are used at different stages of the project to achieve a specific outcome – analysis, drawing, visualization, clash and error detection, scheduling, etc. No one application can be ideal for all types of projects and tasks, so the application of BIM generally initiates the need to use several applications with clear data exchange protocols, which is the subject of the later chapter on data interoperability.

In an international market setting, the architecture, engineering and construction (AEC) industry is dominated by two major software vendors – Autodesk and Bentley. Both offer complete solutions for the application of BIM in civil engineering projects. In addition to these two global suppliers, there are numerous tools on the market tailored to local needs. They are notably developed in countries with larger markets like Germany or France, or are common to a region as with the use of Trimble (Novapoint) tools which is widespread in Scandinavian countries. An analysis of all available tools is beyond the scope of this report; an overview of the tools most widely used in TEM member countries will suffice.

### 2.3.2. Overview of BIM tools used in TEM member countries

The application of BIM in civil engineering projects cannot be achieved using only a single application. This fact has also been accepted by software vendors, who offer application packages from their portfolio as a solution.

#### 2.3.2.1. Autodesk platform

Autodesk offers the Architecture, Engineering & Construction Collection as its solution.

In terms of civil engineering and construction documentation, the main application is Civil 3D. It is based on the well-known CAD tool AutoCAD. This is both an advantage and a disadvantage. The advantage is the widespread availability of the platform and its substantial customer base, as well as its expansion capabilities through numerous plugins and extensions. The disadvantage lies in the fact that AutoCAD itself is not an ideal platform for working in a 3D environment, and it is necessary to consider the size and complexity of the model that can be stored in a single drawing file. The application supports parametric modelling by creating a so-called Corridor Road Model, as well as a highly detailed system of displaying all projected elements through display styles and marking them.

The Infraworks application is responsible for planning and designing the analysis in the conceptual design phase. Unlike Civil 3D, which works in a CAD environment, Infraworks was initially designed as a BIM application. A more modern platform and better use of available hardware resources (such as a graphic card) allow it to process and analyse a much larger set of data in a natural 3D environment. Infraworks can be successfully used to create variant and alternative solutions as well as 3D visualization.

The collection also includes Navisworks Manage, an important and widely employed software package for performing project reviews and for making 4D and 5D BIM analyses.

A significant and powerful tool in the collection itself is Revit. Although primarily intended for architectural applications, Revit has recently been used for structural projects (bridges, tunnels, various concrete structures like retaining walls, etc.), often for detailed reinforcement designs. In recent versions, the emphasis has been on improving interoperability among Infraworks, Civil 3D and Revit.

Other tools present in Autodesk's collection are:

- Recap Pro – reality capture and 3D scanning software
- Vehicle Tracking – vehicle swept path analysis
- 3DS Max – professional visualization software for 3d modelling, animation and photo-realistic rendering
- Structural Bridge Design – structural bridge analysis software
- Robot Structural Analysis Professional – a BIM-integrated structural analysis and code compliance verification tool
- Advance Steel – 3D modelling for steel structures
- Fabrication CADMEP – mechanical, electrical and plumbing (MEP) detailing and documentation software
- Insight – building performance analysis software
- Dynamo Studio – a programming environment that enables designers to create visual logic to design workflows and automate tasks

Like many software solutions, the Autodesk collection is available for subscription, usually on an annual basis. One can also rent a network version of the collection, keeping in mind that the applications only allow access by one user at a time. It is not possible with one Architecture, Engineering & Construction Collection license for a road designer to use Civil 3D while a bridge designer simultaneously uses Revit, for example.

When it comes to collaborating on projects, there are separate tools provided apart from the Autodesk collection. The Autodesk Vault tool is for internal design team collaborations, while the BIM 360 CDE platform is intended for wider collaboration by all project participants and stakeholders.

#### 2.3.2.2. Bentley platform

The approach at Bentley is a bit different. There are no predefined collections, but the user has different tools grouped by product line, brand or discipline. There are a number of applications offered by Bentley and only those directly related to infrastructure projects will be mentioned here.

Until recently, road design was split between four independent products – InRoads, GEOPAK, MX and PowerCivil. As of 2016, these products have been replaced by the more modern OpenRoad application with strong BIM features. The basic concept is similar to Civil 3D, with a corridor model consisting of functional components that allow the placement of intelligent, modifiable compound elements. Similar to how Civil 3D works in the AutoCAD environment, OpenRoad runs in the Microstation environment.

The OpenRoads ConceptStation is designed for the conceptual design of roads and bridges, preliminary cost estimates and visualization of design solutions.

There are several applications for modelling, design and analysis of all bridge types – OpenBridge Designer, OpenBridge Modeler, Leap, RM Bridge and LARS Bridge.

For model review, project coordination and collaboration among office, site and field, Bentley offers the Navigator product family (Bentley Navigator, Navigator Mobile and Navigator Web).

Bentley Descartes and Pointools enhance workflow infrastructure using point-cloud technology.

LumenRT is a Bentley solution for photorealistic 3D visuals.

Several solutions in the ProjectWise family are intended for document management in project team communication (ProjectWise Design Integration, ProjectWise Edge, OpenRoads Navigator).

Finally, the specially developed SELECT programme for licensing provides various ways of using applications under perpetual or term Licenses.

#### 2.3.2.3. BIM platform selection recommendations

Different marketing strategies lead to packages with different collections of functionalities. The following review considers BIM platforms from the perspective of their primary product (road design tools), with references to other products running on the same platform.

A brief overview of the tools available and their functionality shows that there is no significant difference in the offerings of the two major engineering software vendors.

When purchasing a software package, the buyer purchases the current product and its future upgrades as intended by the manufacturer. Future upgrade guidelines can be an important factor to consider in the decision to select a particular software package. However, the most common selection factors relate to the following:

- the current level of knowledge of the ecosystem of one of the options offered
- the availability and quality of support
- opportunities to adapt to local conditions or requirements
- tender requirements from the client
- the use of the selected platform by competitors, subcontractors and contracting authorities

### 2.3.3. Classification of BIM tools

#### 2.3.3.1. Authoring tools

BIM authoring tools are the tools used to create the actual model – the design tools. The common users of these tools are designers, 2D to 3D conversion teams and subcontractors. The tools are used from the design phase up to the construction documents phase. Representatives of these types of tools for infrastructure projects include Autodesk Civil 3D, Bentley OpenRoad, Trimble Novapoint, Revit, OpenBridge Designer and Modeler.

#### 2.3.3.2. Analysis tools

BIM analysis tools are BIM software used to analyse and predict model behaviour. They are used to validate model compliance with standards and codes. They are used by the designers and consultants and are commonly used from the preliminary design phase up to the construction phase.

For road construction projects, the most common use of these tools is in the domain of structures. Representatives are Sofistik, Robot Structural Analysis, SCIA, STAAD, Structural Bridge Analysis, LEAP and others.

There are some analysis tools available for roads themselves. The most used are traffic analysis, visibility analysis, noise analysis and lighting analysis for roads, tunnels or intersections. Some of these analyses (e.g., traffic and visibility analysis) can be performed in Infraworks, although this tool is primarily intended for conceptual design.

#### 2.3.3.3. Validation tools

Validation tools are important parts of Building Information Modelling because they provide accuracy and authenticity to the 3D model platform. These tools can be used to check various issues in different phases of a project, such as clash detection, code compliance or construction sequencing.

The tools in this group usually make it possible to combine multiple design models into one, and to verify that the BIM model contains all the information needed. Pre-defined quality control rules are used to interpret the data of different models correctly.

BIM elements (models) are imported from the default BIM authorization tools. Most tools available on the market allow the input of data from numerous sources so that the data exchange can use the original file formats (e.g., DWG, DGN, RTV, SKP format). There are also various add-ons that make it easier to transfer data between authorization programs and validation programs. For infrastructure projects, data from Civil 3D is often exported to Navisworks via NWC exports. The use of the IFC format, generally the most used format for exchanging data between BIM applications in architecture, has so far been less widespread in infrastructure projects for the reasons stated in the chapter on data interoperability.

Advanced conflict detection and error detection provide a critical visualization of the compliance of all parts, in addition to developing the design in advance and helping to optimize and select the final design solutions. The tools also create reports of clashes for both the individual and the combined models.

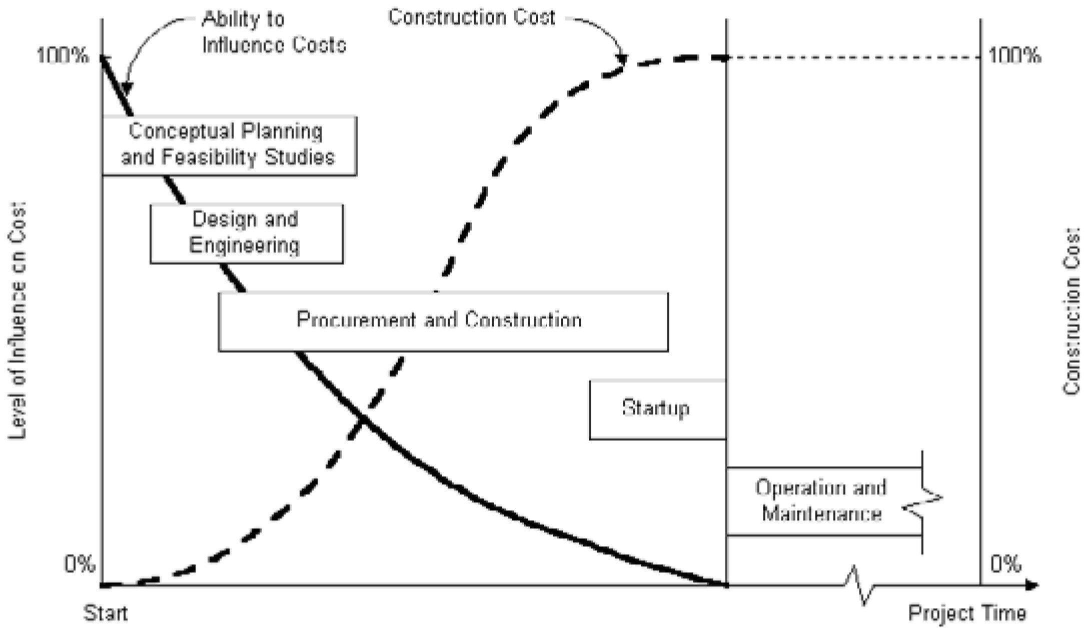
The most used tools here are Navisworks, Solibri Model Checker and Bentley Navigator.

### 2.3.4. BIM tools in the design processes

Design is the core phase in which most project information is defined. In other words, during the design phase, a considerable amount of data and information is generated by stakeholders to satisfy clients and code requirements. BIM influences the design phase more than any of the other phases, as most of the major decisions are made during this phase. In addition, a project team can find ideas and offer solutions to different concerns prior to any problems occurring later in the process. Otherwise, the occurrence of such problems due to poor decision-making in the design phase can result in a high cost impact on the project.

As illustrated in Figure 6, changes made earlier in the project life cycle can have a greater influence on the project outcomes. Whenever a change is made in the project, all the consequences of that change are automatically coordinated throughout the project. The changes could be introduced in all stages of design.

**Figure 6**
**Level of influence of decisions in projects**




*Source:* Chris Hendrickson, "Project Management for Construction", summer 2008. Available at https://www.cmu.edu/cee/projects/PMbook/02_Organizing_For_Project_Management.html

The role and process of design can be summarized from three points of view as follows:

- during the preliminary design – preliminary design tools
- during final and implementation design – BIM tools
- from the perspective of collaboration on the project – collaboration tools

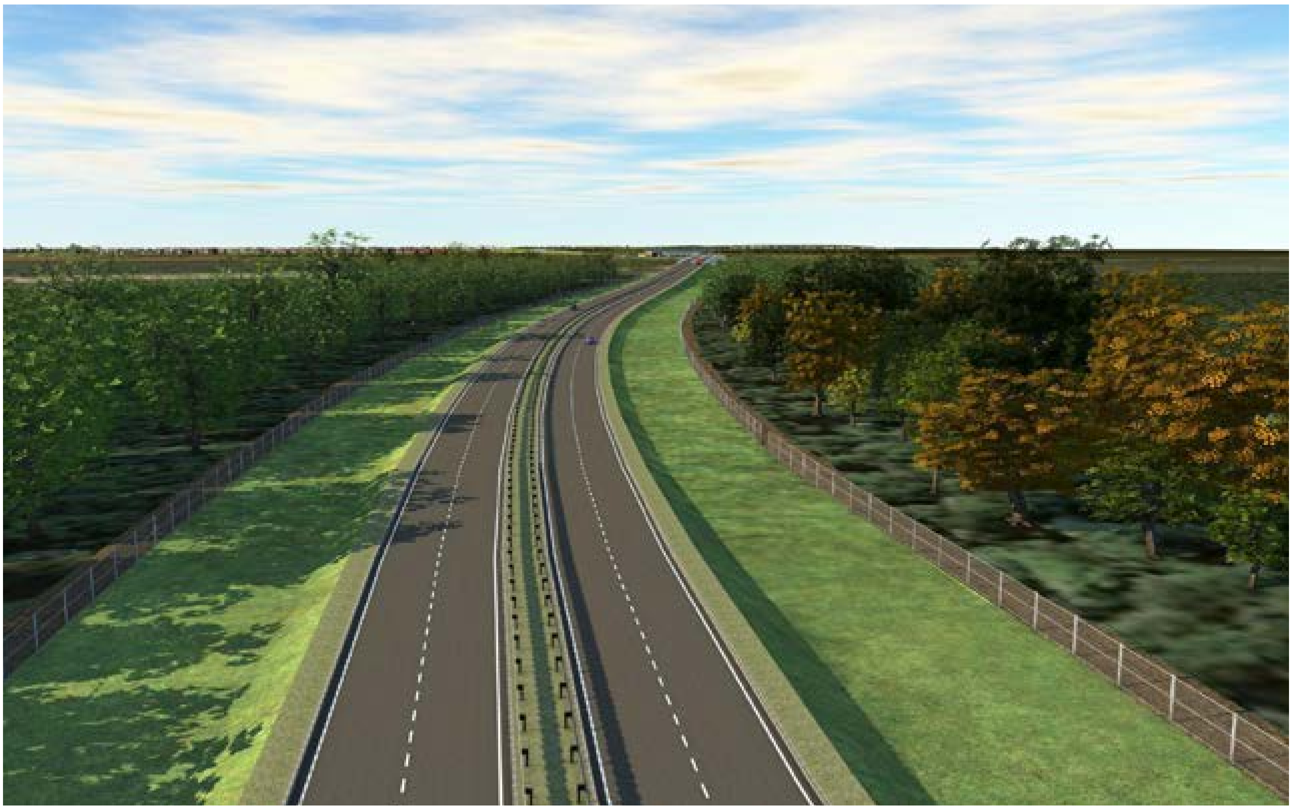
Other important considerations at this point are the further development of parametric design tools and the improvement of interoperability.

### 2.3.5. Preliminary design tools

The first of the three points of view mentioned in the preceding sub-chapter relates to preliminary design. Preliminary design determines the basic design framework that will be developed in the later stages. It is the most creative part of the design activity. Preliminary design considers all aspects of the project in terms of its function, cost, environmental impact, construction practices, and cultural and aesthetic aspects, among other things. This means significant changes in the preliminary road design philosophy compared to the traditional approach.

These initial programme and concept decisions are of paramount importance to the overall project. In the past, concept design relied almost entirely on the knowledge, experience and expertise of a leading designer, with feedback from other members of the design team. At this stage, due to the demands of fast generation and the evaluation of alternatives, the assessments are usually made intuitively. For a long time, 2D sketches in CAD tools were the dominant concept design tool.

**Figure 7**
**Preliminary motorway design in Infraworks**



*Source:* Denis Šimenić (2020).

**Figure 8**
**Preliminary design in OpenRoads ConceptStation**

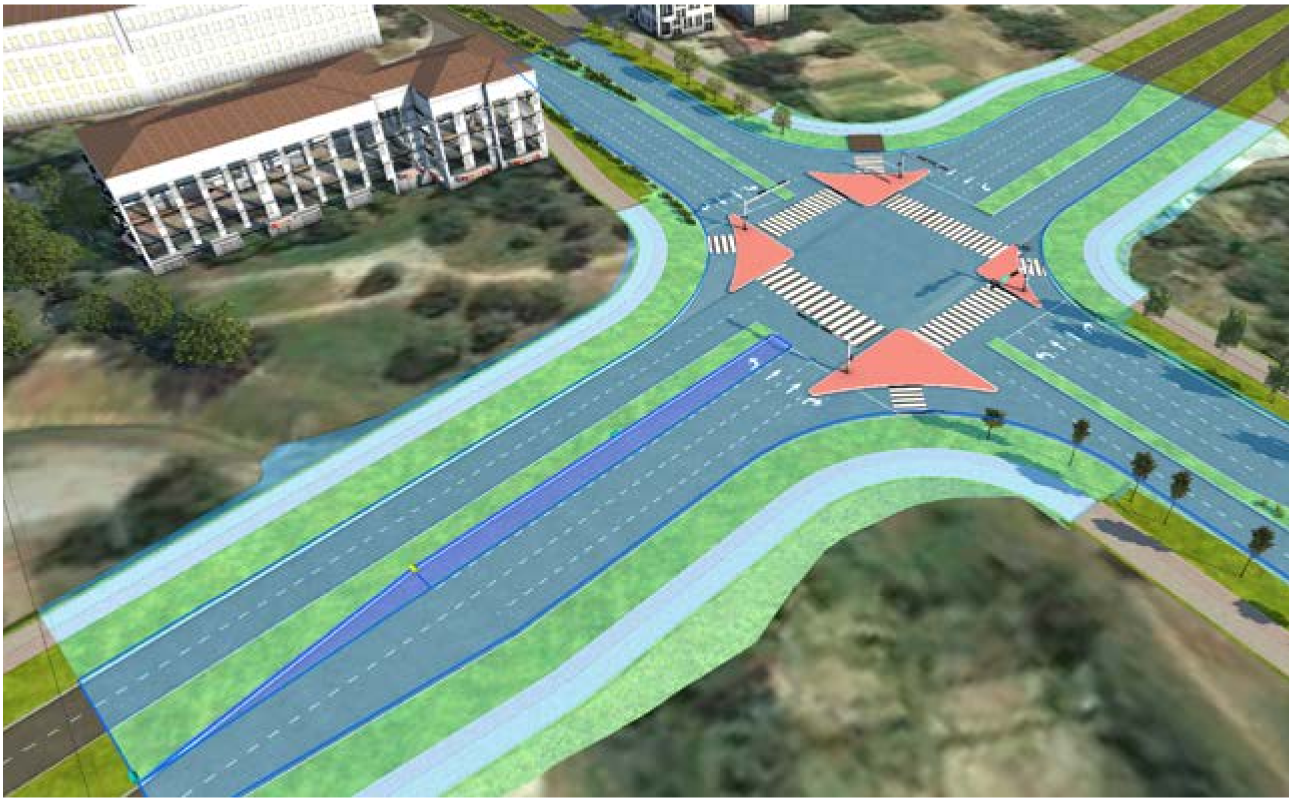
*Source:* Bentley Systems.

Due to the non-adaptability of the CAD system to the modern needs of conceptual infrastructure project design in the BIM environment, software vendors have developed completely new tools – Autodesk Infraworks and the Bentley OpenRoad ConceptStation (Figures 7 and 8).

Although both tools have certain advantages and disadvantages, the capabilities and the concepts are very similar. They share the common feature of working in a real 3D environment, and use intelligent, parameter-defined objects – one of the basic features of BIM. This is best seen in the formation of intersections where, with practically one mouse click, the user can change the standard intersection layout into a roundabout, add or subtract traffic lanes, and simply experiment with different solution corrections (Figure 9). The optimal position of the route of a future road can be explored in an accessible way because the designers have at their disposal various BIM analyses that can assist them in the design process, such as elevation analysis, slope analysis, sustainability analysis, site analysis, watershed analysis, traffic analysis, earthwork factors and so on.

All changes are immediately reflected throughout the entire model. As a special benefit, designers can make competitive visuals alone because visualization is directly linked to a live project model. In the traditional approach, visualizations were made by specialized companies, adding significant cost and time. Any further changes in design demanded reworks. With modern software, even creating a professional look for photorealistic visualizations is possible; there are easy procedures to improve the quality of Infraworks models with Twinmotion or 3D Studio Max, or ConceptStation with the LumenRT tool (Figure 10).

**Figure 9**
**Intersection model – parametric control of additional lanes**



*Source:* Denis Šimenić (2020).

**Figure 10**
**Example of Infraworks model improved with Twinmotion**

*Source:* Denis Šimenić (2020).

Although the capabilities of these tools are already impressive and represent a major step forward, there is still room for improvement. The range of existing intelligent facilities could be expanded to be able to conceptualize as many different and diverse solutions as possible (e.g., various variants of roundabouts, different load-bearing bridge structures and pillar shapes, tunnel elements, etc.). Because the programs work with intelligent objects, if an existing element does not fit a solution, the workflow is much more complex and involves the use of additional tools.

## 2.3.6. BIM design tools

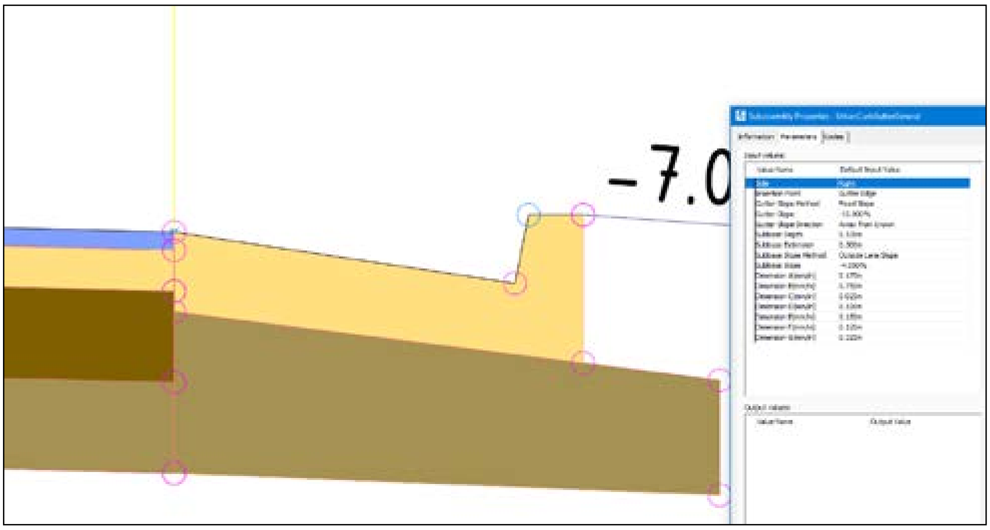
There are important differences between parametric modelling tools in the domain of infrastructure projects and those used in other industries (i.e., architectural and mechanical engineering).

Unlike other industries, infrastructure projects (especially the road sector) are about adapting constructions to unique terrain conditions, which is not easy for digital processing. Problems often do not have a general solution, which makes it hard to program effectively. The high standardization of design and technological solutions is favourable for the development of BIM technology, which is difficult to achieve in infrastructure projects. These are all challenges that parametric modelling tools need to address at the level required for final and implementation design as well as the corresponding definition of the LOD targeted in the BIM Execution Plan.

### 2.3.6.1. Corridor model

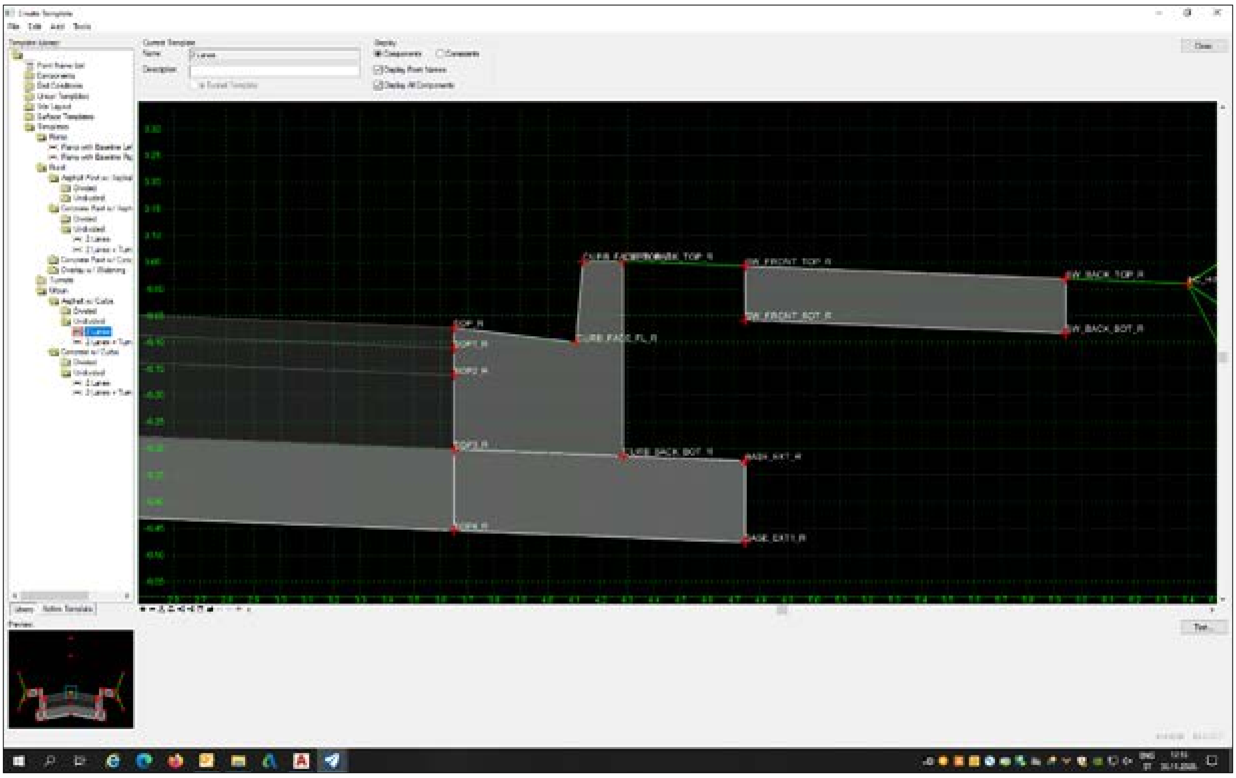
In the common authoring tools (Civil 3D, OpenRoads), the modelling process begins by selecting the cross-sectional elements of the road – predefined shapes that can be modified by parameters (Figures 11 and 12). The shapes (subassemblies in C3D, components in OpenRoads) are usually presented as 2D shapes (e.g., pavement layers, curbs and gutters, shoulders).

### Figure 11
### Subassemblies with parameters in Civil 3D, example: concrete gutter




*Source:* Denis Šimenić (2020).

### Figure 12
### Component in OpenRoads, example: curb

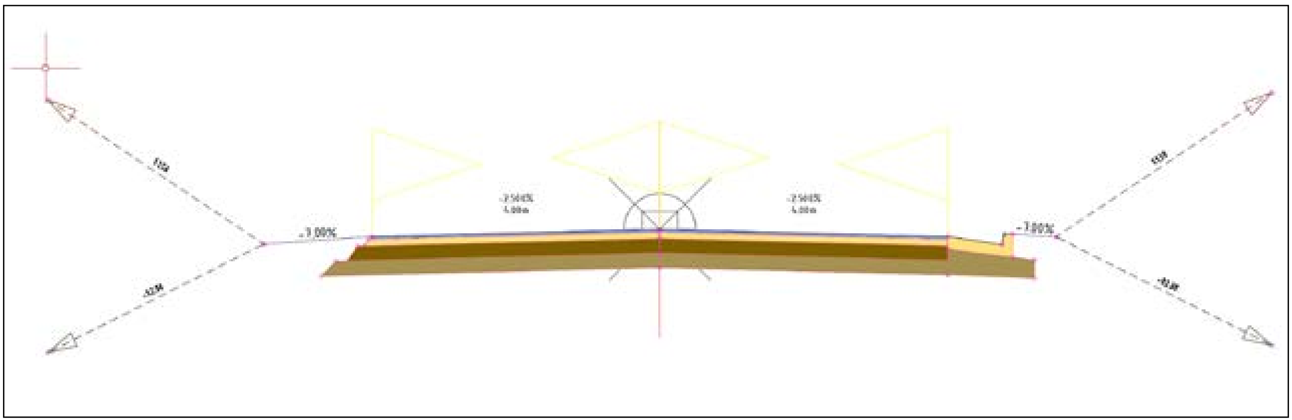


*Source:* Bentley Systems

Multiple connected subassemblies forming a more complex assembly – usually a cross section of a road or motorway – are illustrated in Figure 13.

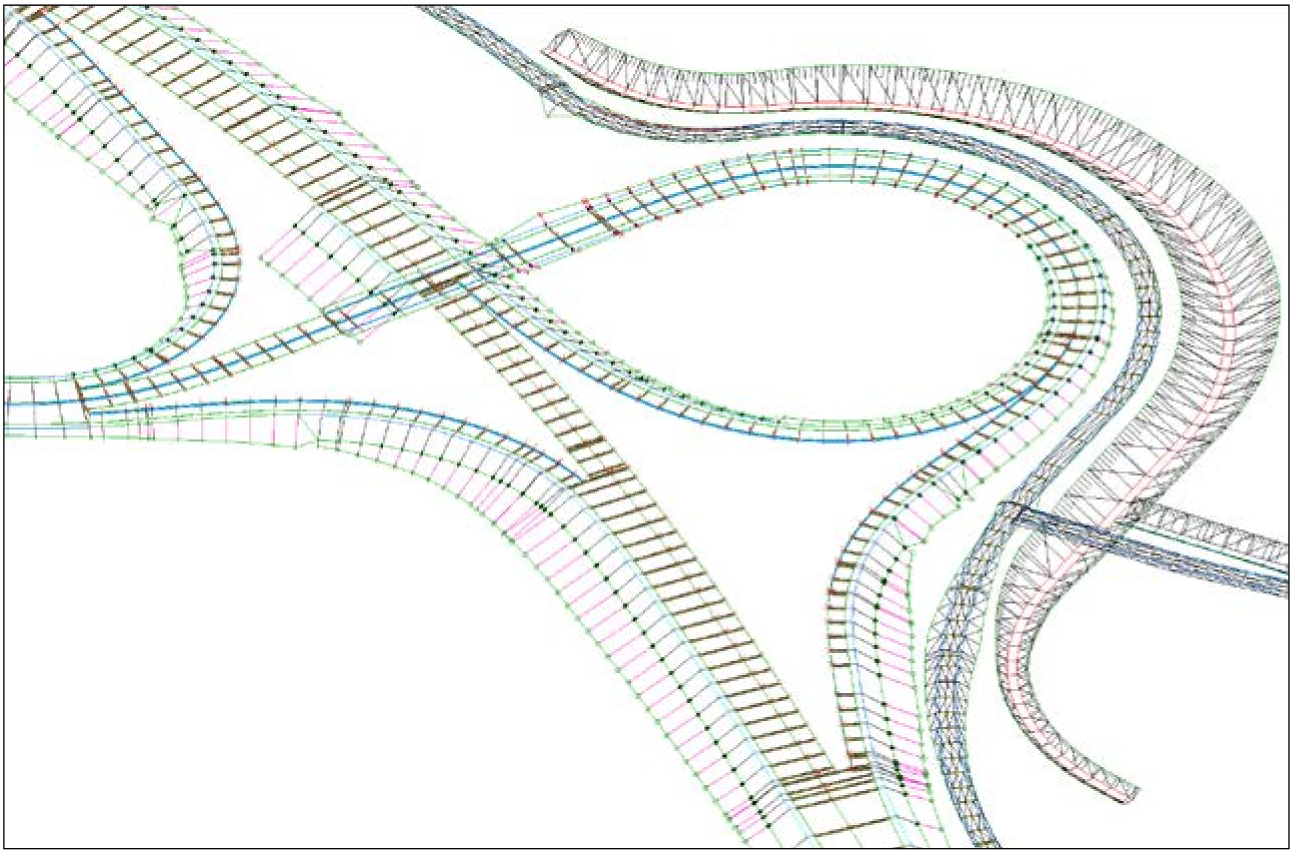
Furthermore, the assembly is positioned in space according to a given trajectory (usually an alignment with defined horizontal and vertical geometry), thus giving the elements a third dimension. As soon as the elements are uniquely defined in 3D, accurate quantification is enabled. A complex element formed in a described way is called a corridor model by software vendors, and in reality presents a digital representation of one road or motorway section (Figure 14).

**Figure 13**
**Assembly – typical road cross section**



*Source:* Denis Šimenić (2020).

**Figure 14**
**Example of a corridor model**



*Source:* Denis Šimenić (2020).

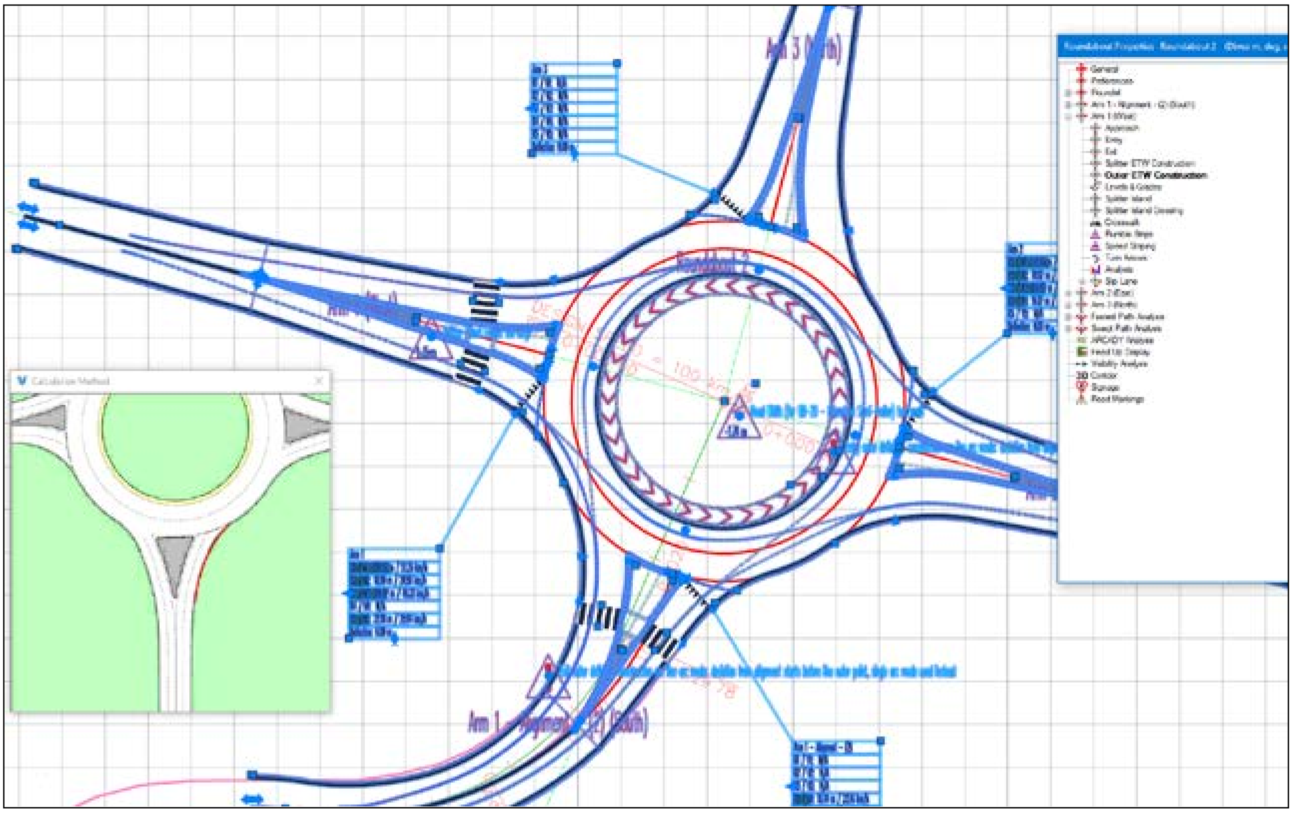
Simply changing any parameter updates the entire corridor model along with the quantities of material.

Problems usually arise when interacting with the terrain, an irregularly shaped element with behaviour that is sometimes difficult to predict. In addition, preparatory work on the rehabilitation or improvement of the terrain is often performed in road construction, which is difficult to predict at the design stage (e.g., soil replacement, additional excavation steps, etc.). For these reasons, sometimes a combined approach is also possible in which all well-formed elements (pavement, drainage, supporting structures) are defined exactly as 3D shapes, while part of the earthworks (which will not in itself be necessary for BIM uses like 3D coordination or clash detection) can be quantified in the classic way by measuring the cross sections with CAD functions.

#### 2.3.6.2. User-Defined Parametric Objects

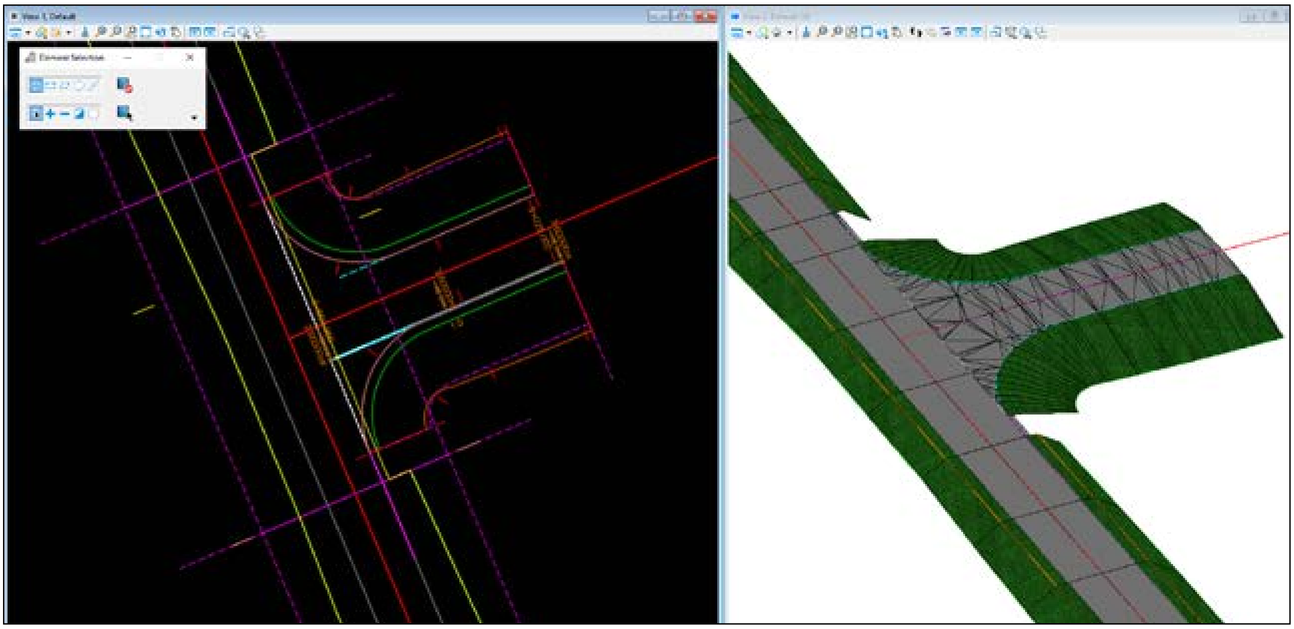
There are many additional useful features – for example, tools developed for the generation of intelligent intersection objects. Civil 3D has tools for creating standard intersections and roundabouts (Figure 15), while OpenRoad uses libraries of predefined objects called Civil Cells (Figure 16). In both examples, the result is fully developed 3D objects.

**Figure 15**
**Intelligent object – roundabout model in Civil 3D**



*Source:* Denis Šimenić (2020).

**Figure 16**
**Example of Civil Cell in OpenRoads, T-junction**



*Source:* Bentley Systems

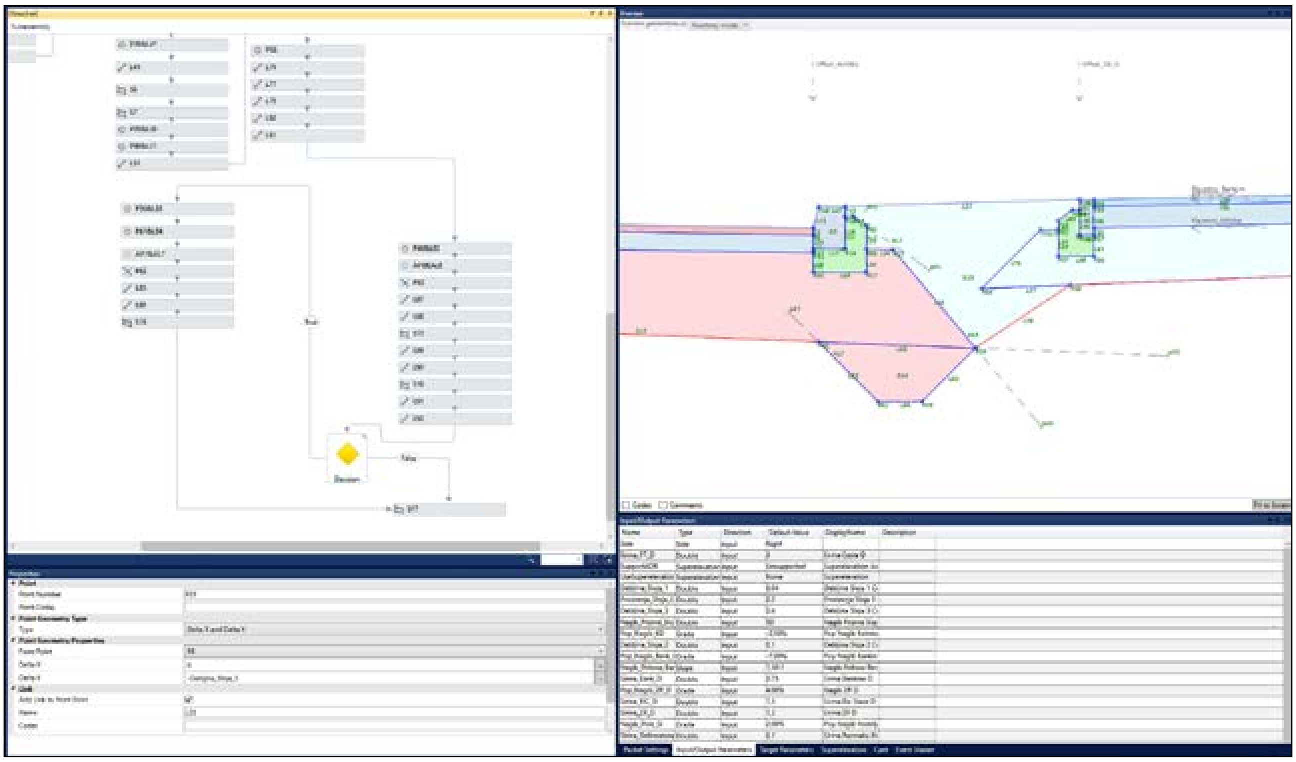
When using these features, consideration should be given to the possibilities of editing and adapting them to real projects in terms of compliance with applicable standards and elements of road safety. For example, the design of roundabouts varies considerably between countries. Therefore, when using predefined elements, besides satisfying the technological form in terms of BIM, attention should also be paid to the appropriate standards.

Choosing a comprehensive BIM approach on a project may require modelling the entire road section. This usually means the need to create additional user-defined elements that must be built into the corridor model.

There are special tools for creating such elements that require engineering knowledge from the user as well as basic programming logic. It is not realistic to expect every designer to have all the necessary knowledge to successfully perform such tasks, so the application of BIM opens opportunities for hiring new professionals who would be primarily dedicated to creating user libraries, in this case user-defined parameter objects.

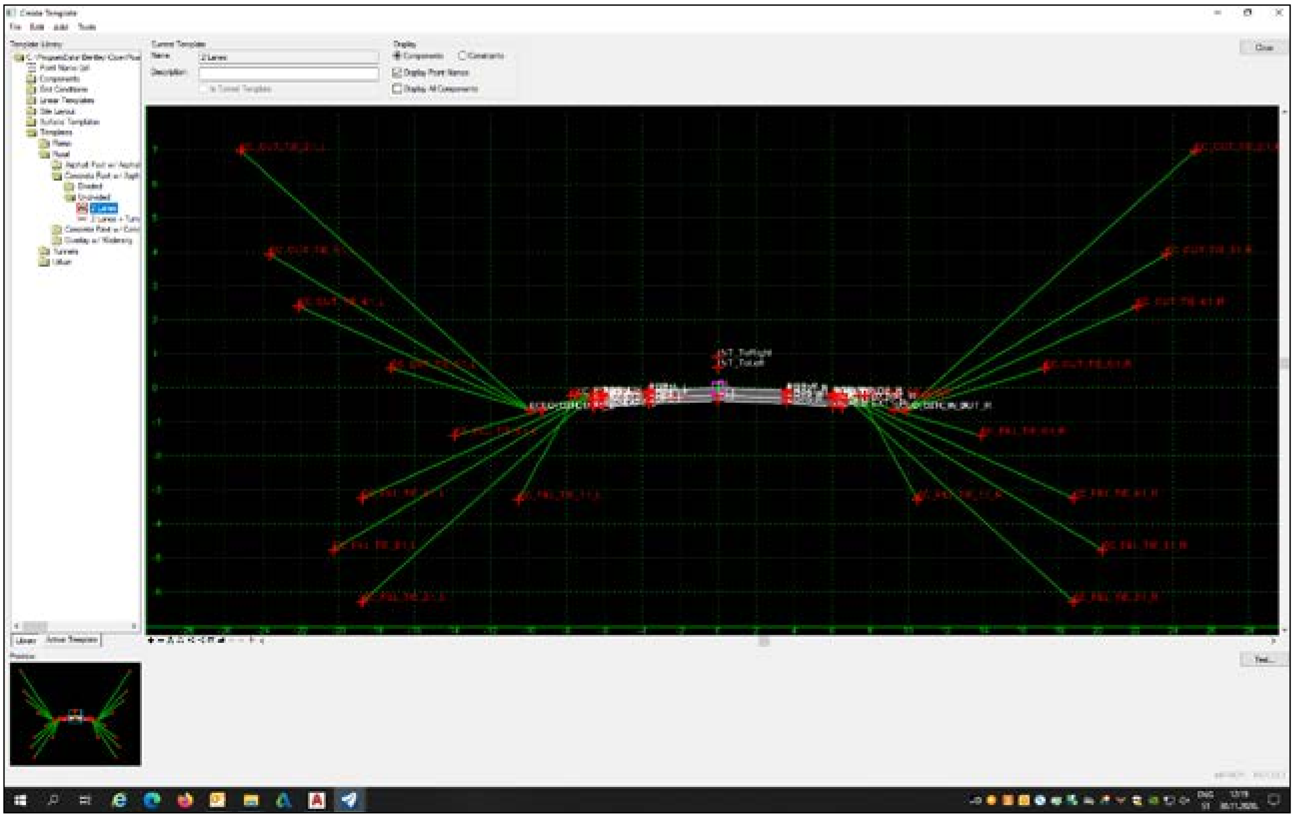
Examples of these types of tools are Autodesk Subassembly Composer and Dynamo Studio for use with Civil 3D, while OpenRoads has a built-in template editor that allows the designer to perform similar tasks (Figures 17 and 18).

**Figure 17**
**Autodesk Subassembly Composer – powerful tool for creating custom cross-sectional elements**



*Source:* Denis Šimenić (2020).

**Figure 18**
**Template Editor, OpenRoads**



*Source:* Bentley Systems

#### 2.3.6.3. Attribute data handling

Object-based parametric modelling addresses geometry and topology, but objects also need to carry a variety of properties if they are to be interpreted, analysed, priced and procured by other applications.

Different data appear at different stages of the project life cycle. For example, during design and analysis, data describing the performance of an element (e.g., maximum flow in a drainage pipe, the degree of retro-reflection of traffic signs, the level of protection of road restraint systems) are important. Various elements of the system have their own properties for structural, mechanical or electrical behaviour.

In later stages, especially during construction and in the finalizing of the in-built model, it is necessary to add data that provides information and links for forwarding work and maintenance data for operations and maintenance. The current capabilities of BIM tools in the field of infrastructure design usually allow the automatic assignment of a certain set of properties related to geometric and positional characteristics (area, volume, starting and ending stationing, etc.). Other required data (e.g., element type, material, properties) must be entered using separate tools (user-defined property data – Figure 19).

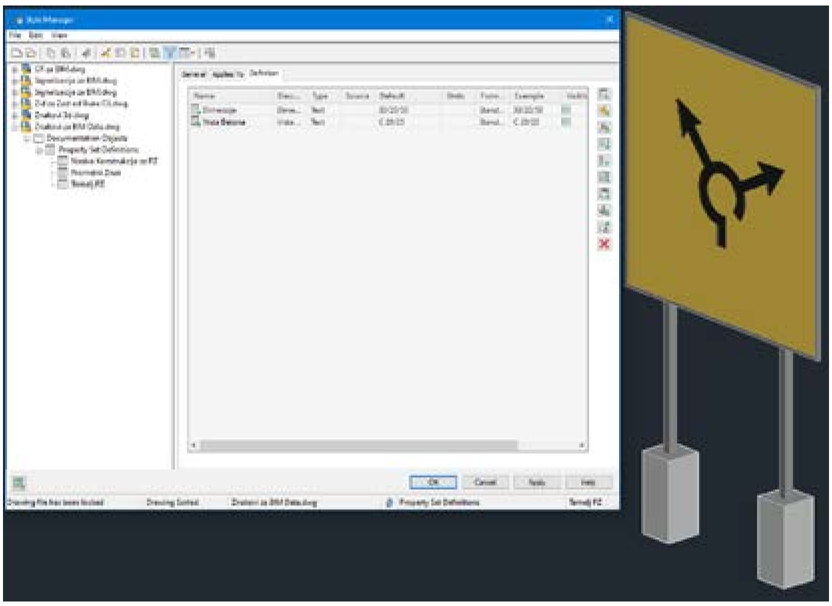
Defining the set of features of the objects required for a particular project and the corresponding object classification libraries is an important issue that needs to be addressed with the client (usually professional staff from a road authority) at an early stage, preferably during the development of the BIM Execution Plan.

#### 2.3.6.4. Drawing generation

Although a 3D object (corridor model) obtained from an authoring application has the correct geometric layout of a roadway or some long section of a project – and objects have features and specifications, and can convey much more information than drawings – drawings will still be required as specialized model views. This is especially true for drawings that require vertical exaggeration (for example, longitudinal profiles of road or pipe systems) for human perception. Existing contracting processes, although slowly changing, are still focused on drawings, either paper or electronic (e.g., PDF files).

The generation of drawings from a detailed 3D model has undergone a long series of refinements to be efficient and easy. An additional aggravating circumstance for software vendors present in the global market is the need to adapt to the local and even traditional appearance of 2D drawings, which are sometimes not used for digital data processing because they were done manually in the past.

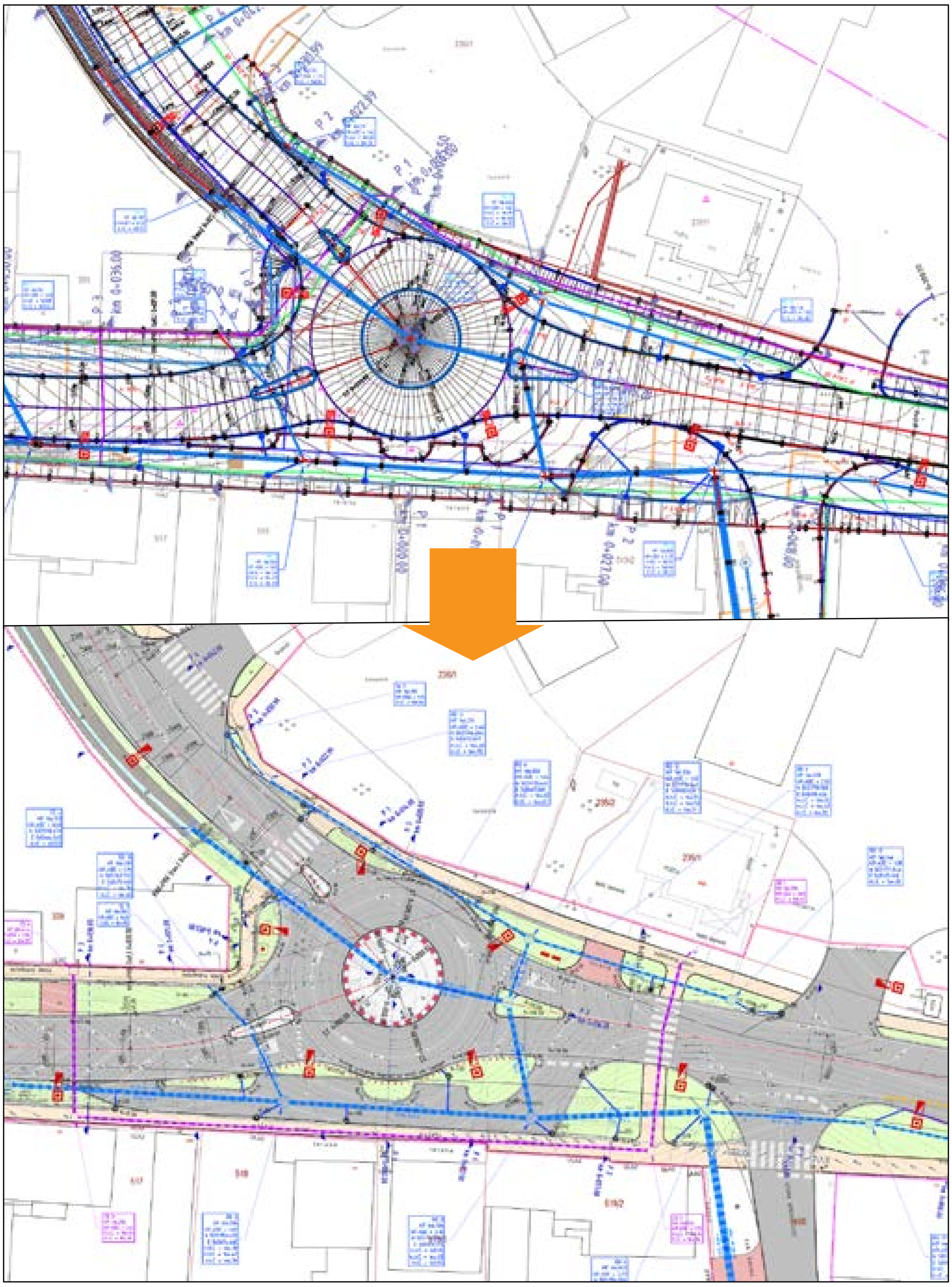
**Figure 19**
**An example of an interface for adding attribute data to model elements**



*Source:* Denis Šimenić (2020).

BIM authoring tools most commonly support the definition and use of drawing templates associated with elements for a projection type (cross sections, profiles, layouts) that automatically generate element sizing on the desired scale, assign a line weight, type and colour of lines, and generate annotations and labels from the defined attributes (Figure 20.). This greatly accelerates the initial appearance of the drawing and improves productivity, although the initial setup of each object family can be tedious. Template defaults can be overwritten, and custom annotations added. It is important that the tool offers sufficient features to allow the desired customization to local standards.

**Figure 20**
**2D layout generated directly from 3D corridor model**



*Source:* Denis Šimenić (2020).

Cross section editing functions support two-way editing between the model and the cross section. At this level, the changes are first visible in the cross section and then applied to the model. This technique is suitable for minor modifications to the model. Two-way views and powerful template generation capabilities further reduce the time and effort required to create drawings. Bidirectional views and powerful template generation capabilities further reduce the time and effort required to create a drawing.

BIM technology generally allows designers to choose the level of 3D modelling that will be used, and 2D drawings fill in the missing details. The benefits of BIM from sharing data, materials, detailed cost estimates and other actions are lost on those elements defined only in the 2D section drawings. Although it can be argued that full 3D modelling of objects is not justified, advanced BIM users are moving towards 100 per cent modelling.

### 2.3.7. Tools for collaboration in the design process

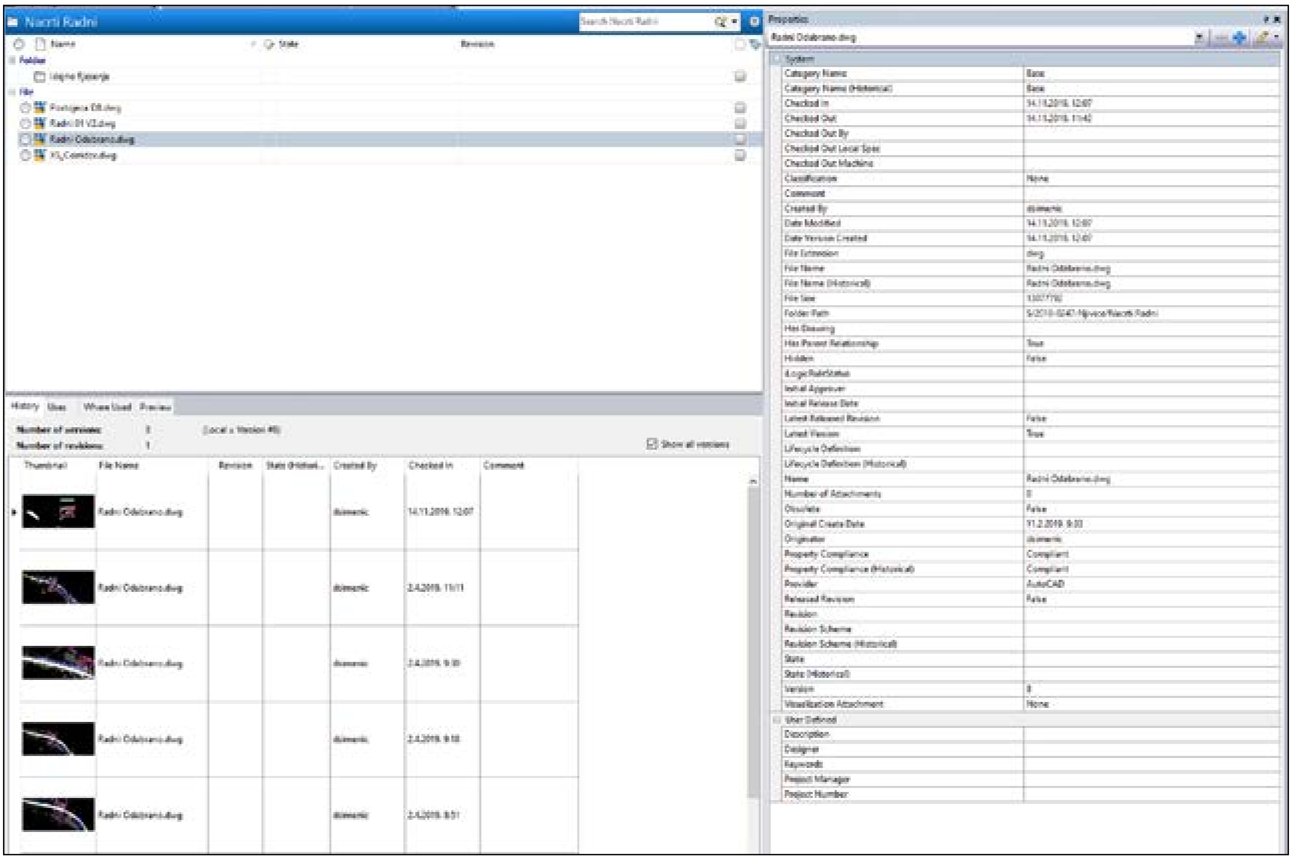
The problem that many designers encounter is keeping the model in a quick-responsive state for further development. Problems arise when the project model becomes too large for practical use. Operations become slow, so that even simple operations are laborious.

Road and motorway projects usually have two characteristics – large dimensions and the presence of many professions involved in the project. This results in the generation of a massive project-related database. With the development of digital technology, the amount of data that needs to be handled has been growing rapidly. Technology for displaying and analysing the existing terrain, such as the application of high-quality aerial photos, point clouds, etc., have had a significant impact on the amount of data compiled. The consequence is an enormous amount of data assembled even before modelling begins.

The solution is to introduce an efficient project data management system linked to advanced parametric modelling facilities. Therefore, it is necessary to divide the project into parts for separate development, but in such a way that a series of hierarchical rules can be successfully managed.

For example, for motorway projects it is logical that the main route has a separate corridor model, and if the route is very long, the model should be divided into sections. It is good practice to separate intersection designs into separate models. Of course, other professions also form their models separately (for example, a digital model of existing terrain, pipelines, bridges, etc.). The capabilities of the system must be such that it is possible to develop each model separately, but with the ability to review – during the designing – the impact on other parts of the entire structure in the native application for authoring the model. Modification of any project model is automatically updated in all workspaces where its references exist. Software that enables this type of data exchange on a project has the features of both CAD management and BIM, and should not be confused with BIM validation tools such as Navisworks as these tools also handle the lower set of project data exchange, such as alignments, profiles, surfaces and originally-created corridor models (Figure 21). On the other hand, file formats created by exporting from native models (e.g., .nwc, .ifc) are most commonly used in BIM analysis tools. Examples of such tools are Data Shortcut Management and Autodesk Vault (a much more comprehensive solution), as well as tools from the Bentley Project Wise family.

**Figure 21**
**An example of an interface for collaboration among designers participating in a project**



*Source:* Denis Šimenić (2020).

# 3. BIM uses and their impact on the existing processes

## 3.1. BIM uses in the design phase

The application of BIM is more evident in the design phase than it is in the construction and operation phases because there are many activities taking place during the design phase. These BIM applications are further elaborated in the subsections below.

### 3.1.1. Site modelling – establishing and analysing a 3D real-world environment

Before launching a project, the designer can use a variety of tools to capture existing conditions to better understand the environment and terrain. To make the environment more realistic, there are tools like adding vegetation and trees, houses, water areas, existing roads, services, bridges, etc. (Figure 22).

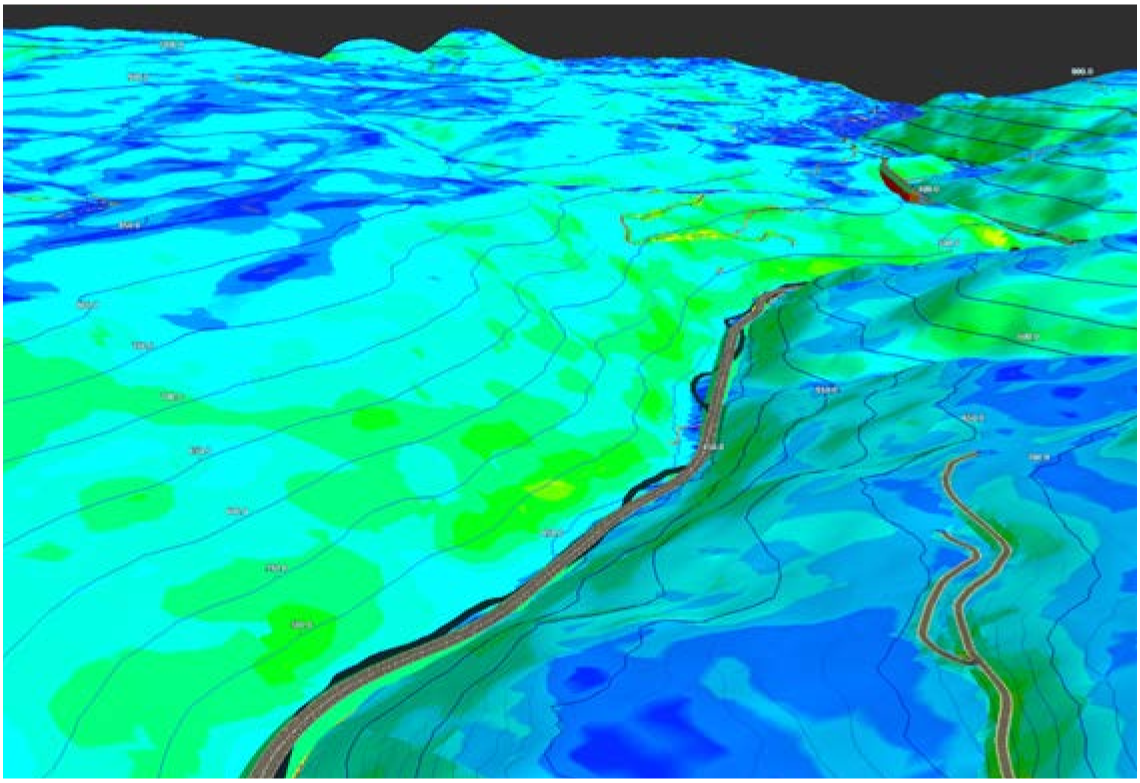
BIM-based applications can support large amounts of existing data, and they include tools for manipulating and importing raster data, geographic information system (GIS) data and reality capture data into the project space. There are several methods of data collection with reality capture technology; the most used are unmanned aerial photogrammetric vehicles (UAV) and static and mobile LiDAR systems. These features are particularly prevalent with the newer BIM tools, predominantly intended for conceptual projects, formed on newer platforms than CAD applications and initially programmed to support work in a 3D environment with large amounts of data.

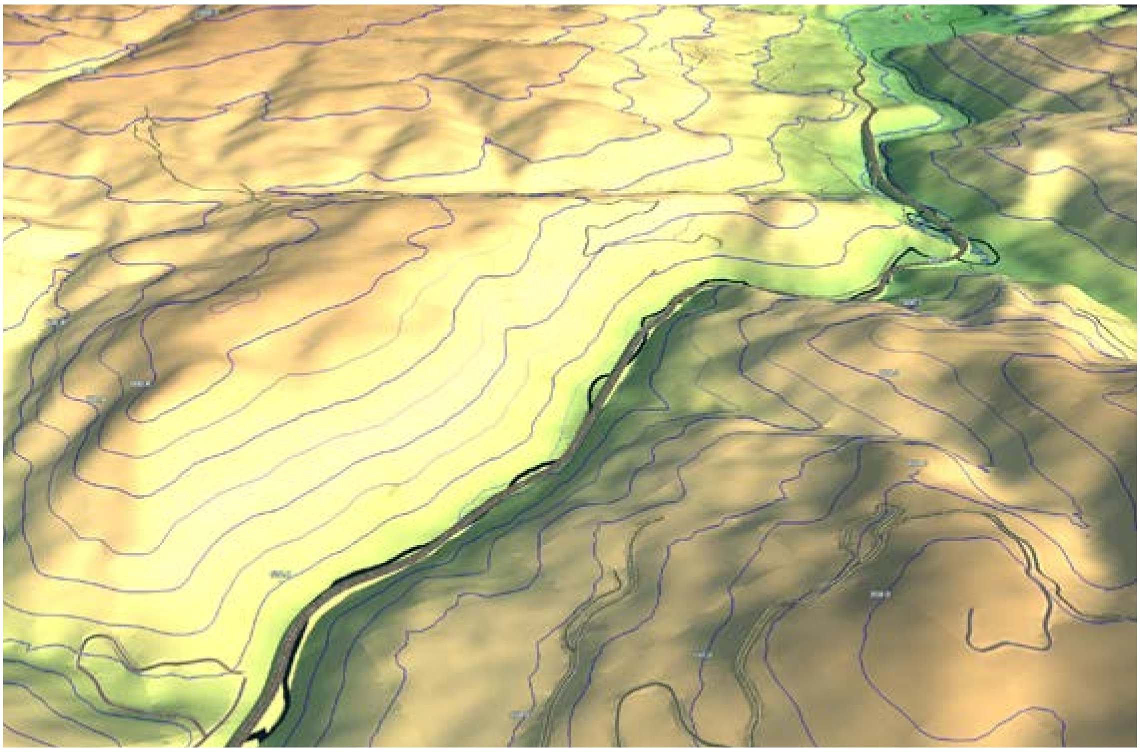
Once established, the environment is available for topographic analyses of the elevation or slope of the terrain (Figure 23). Depending on the availability or relevance of the input data (for example, based on GIS data, which have additional tabular data that can be used to create thematic maps), additional analyses are possible.

**Figure 22**
**Existing conditions in project space**

*Source:* Denis Šimenić (2020).

**Figure 23**
**Examples of slope and elevation analysis of existing ground**





*Source:* Denis Šimenić (2020).

The BIM model, properly analysed with available tools, can be used to show the optimal location of the project site or for optimal route selection. Modern BIM tools include mapping tools and websites that allow the user to view topography in a variety of ways, such as displaying a project on the Google Earth platform.

### 3.1.2. Site/route analysis

BIM and GIS tools are used to evaluate properties in a specific area to determine the most optimal site location for a future project. Conditions at a future construction site can dramatically affect development and construction costs, and it is important for clients to understand these potential effects before significant financial commitments are made. The collected location data is used to select a location and then to analyse the position of the route according to other criteria (Figure 24).

A 3D model of a motorway site or corridor can be used to show the advantages and disadvantages of a selected location based on a number of criteria, including numerous environmental impacts – on waters, noise propagation, surrounding structures, forests, historical objects, etc.

**Figure 24**
**Impact of the project on the existing environment**

*Source:* Denis Šimenić (2020).

### 3.1.3. Visualization

Model-centric technology, such as BIM, enables the creation of enhanced visualization in a meaningful way for each design phase. A 3D project model embedded in a realistic environment helps different parties better understand the design concept and details. Infrastructure projects generally affect many stakeholders – including the general public – and all of them may have an interest in understanding the proposed project.

For the project team, project visualization leads to a more precise final and detailed design, and an improvement in the quality of the design as a whole. Furthermore, visualization helps in many situations where the client and the designers must choose one of several proposed solutions.

The BIM model represented by visualization has also been used in road safety audit procedures. By looking at a future project from every angle, especially from a driver's perspective, the auditor can more easily and effectively identify possible black spots or less successful solutions, and propose improvements. The latest solutions include driving a new route with specially designed interfaces (Figure 25), as well as the application of augmented and virtual reality (AR and VR) technologies.

**Figure 25**
**New ramp in intersection from the driver's perspective in OpenRoads ConceptStation**

*Source:* Bentley Systems

It is important to highlight the ease of completing the visualization task with modern BIM tools, where a single designer can make highly competitive visualizations (Figure 26).

In the traditional approach, visualizations had to be made by specialized companies, which cost a lot more and required additional time. The other significant problem was that the visualizations were not dynamic and related to the project model. The BIM-based workflow eliminates this because the visualization is directly based on the live model.

**Figure 26**
**Examples of visualizations prepared by designer**

*Source:* Denis Šimenić (2020).

### 3.1.4. Design authoring

Design authoring is a process that uses BIM tools to develop an information model for a particular element or object in a motorway project. It is important to note that the BIM model should be developed in parallel with the design, as the subsequent formation of the BIM model based on a project completed in the classical way (2D drawings) represents a significant waste of resources and is fundamentally a flawed approach.

The set of 3D models produced includes a representation of the civil and structural design, and various other models including services, traffic design, noise barriers, drainage systems and lighting. Design authoring tools are used to create these design models and to connect them with a database containing information on specifications, schedules, costs, various properties, materials, etc.

Generally, civil design deals primarily with linear objects with the common characteristic that their cross sections are not uniform but vary gradually along the alignment. In some cases, the tools originally shipped with the purchased software are unable to meet the modelling requirements, thus it is crucial that designers have a usable tool to help them to create specific content without knowledge of programming – mentioned in the chapter on BIM design tools.

Based on the BIM model, designers can generate necessary final and detailed design drawings. Modelling tools that serve the final design in road and motorway projects depend greatly on the type of project and are therefore diverse and specific. For example, authoring tools differ significantly from road design to bridge design.

Another important characteristic to emphasize about road projects is the interactions with the existing ground (which has an irregular shape). This is a substantial contrast with established BIM modelling tools in the architectural industry – where surfaces are comparatively well-defined and precise – requiring that specific tools be developed for road planning. The preponderance of irregular shapes in road modelling was one of the reasons why BIM was so slowly adopted in civil engineering.

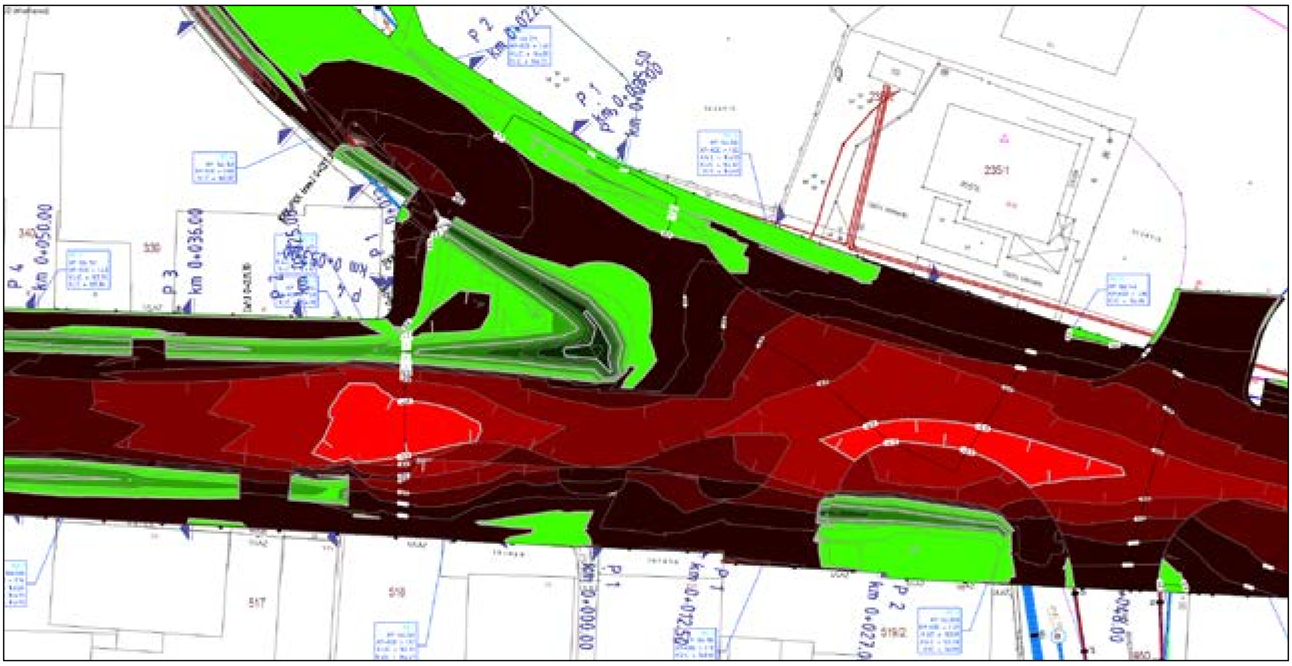
With model-based tools, even a significant change of design is more easily handled because the relationships among objects are maintained in the model rather than locked into individual sheets. Drawings of sections and profiles can easily be reprinted in a short time, and various production sheets and layouts can be quickly updated and properly labelled.

### 3.1.5. Surface analysis

The surface analysis uses of BIM are employed to perform detailed examination of model objects such as volume analysis. All the analysis performed on the existing surface can also be performed on designed surfaces. The proposed design interventions can be assessed in terms of elevation, slope, aspect and hydrology, and cut and fill calculations can also be made to balance earthworks requirements.

Additionally, in many cases surface creation and managing tools have proven to be a reasonable solution for roadway designers. Subgrade surface, daylight surface, top pavement surface and scarification surface in road rehab projects are some good examples (Figure 27). Furthermore, the use of surfaces as an entity is particularly widespread where GPS-guided construction machines are used.

**Figure 27**
**An example of a levelling-scarification surface analysis in a road rehabilitation project**



*Source:* Denis Šimenić (2020).

### 3.1.6. Design review

After initial design, various tools are available – cut/fill quantities, site-check analysis or traffic simulation analysis. From a model-centric approach, some changes (or fine-tuning) of the design are easy to make – for example, horizontal and vertical changes in design, adding a retaining wall, bridges, tunnels, etc. In that way, a designer can examine many design alternatives and check the efficiency and performance of each.

Design review is a process in which a BIM model is used to evaluate the project programme and a set of desired criteria such as layout, lighting or road safety. For example, a virtual mock-up can be produced in high detail for analysis of design alternatives and study constructability in an interactive environment.

These reviews will then lead to the elimination of possible construction problems at the early stages.

### 3.1.7. Design changes

With a dynamic framework, cross analysing surface information with pipe networks, roadway alignments, vertical profiles and site grading, 3D modelling software can quickly adapt to design changes. Modifications to a vertical curve or the replacement of adjacent sidewalks with landscaping, as well as modifications to pipe sizes or pavement depths, are immediately realized in the model and recalculated to meet site conditions.

### 3.1.8. Engineering analysis

Some analyses that are usually performed in road design have already been mentioned in the chapter on BIM preliminary design tools (site analysis, traffic analysis). The BIM approach allows analysis to take place in the early stages of the design (Figure 28).

**Figure 28**
**Site analysis on an intersection**

*Source:* Denis Šimenić (2020).

**Figure 29**
**Watershed analysis**

*Source:* Denis Šimenić (2020).

Other common analysis tools may include flood analysis and watershed analysis for the drainage design (Figure 29.), or light and shadow simulations which can be used in addition to the visualization tools.

Road and motorway projects usually cover very large areas and therefore affect a large number of plots. BIM technology can combine different types of data (2D CAD drawings, GIS data, 3D terrain models) and compare them to planned project boundaries to provide a better insight into how the project affects existing parcels and easements.

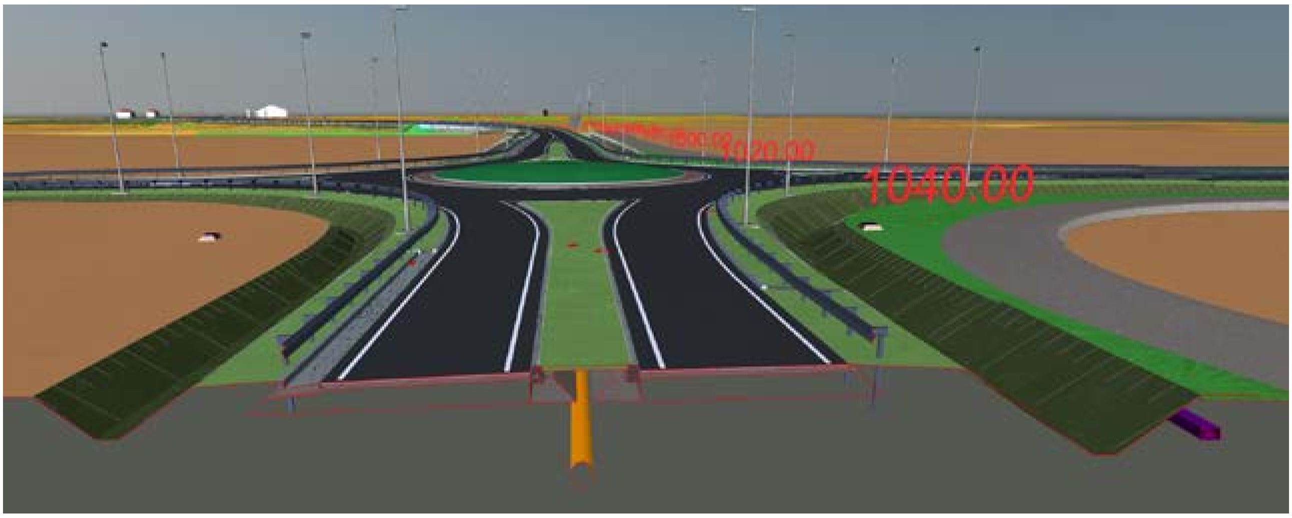
An engineering analysis is a process that, utilizing intelligent modelling tools, applies a BIM model to determine the most effective engineering method based on the design specifications. In BIM, specialized analysis tools are used to simulate and analyse the performance of designed structures (like bridges and tunnels) in different ways, such as structural analysis.

BIM data is used to determine the behaviour of a given structural system. With the modelling, minimum required standards for structural design and analysis are used for optimization. Based on this analysis, further development and refinement of the structural design takes place to create effective, efficient and constructible structural systems. The development of this information is the basis for what will be passed on to the digital fabrication and construction system design phases.

### 3.1.9. 3D, 4D and 5D analyses

A group of tools (classified as validation tools) is used to review designed solutions and find various errors and incompatibilities. BIM-based tools and processes help to more effectively identify, inspect and report problems based on a 3D project model (Figure 30). Problems may relate to inappropriate modelling or errors in the design itself.

**Figure 30**
**3D coordination on one segment of the roundabout project**




*Source:* Denis Šimenić (2020).

When a BIM model is completed and verified, it is possible to perform a 4D/5D analysis and simulations to review project details, schedules and logistics. 4D modelling allows stakeholders to visualize construction throughout the project's duration to identify potential spatial or temporal conflicts in the schedule. Adding a cost component to the process creates a 5th dimension. 5D engineered models allow stakeholders to evaluate costs and model cash flows for each phase of construction.

### 3.1.10. Code validation

Code validation is a process with BIM software to compare the model parameters with project-specific codes and standards. These codes represent essential regulatory requirements for road design, safety and the chosen level of service.

This process of cross-referencing established standards with the design requirements most often involves analysis of the design parameters used – design speed, horizontal and vertical elements of the road alignment, super elevation, and verification of efficient pavement drainage through the analysis of levelling plans. Stopping and passing visibility checks are also carried out.

Based on the BIM model created, it is possible to effectively determine the overhead clearance in the cross section – that is, to prove that no element of the model enters into the overhead clearance required on the route for bridges or tunnels (Figure 31.). This verification also applies to road signs, guardrails, noise protection elements, various manholes, etc.

**Figure 31**
**Clearance check of planned overpass**

*Source:* Denis Šimenić (2020).

Analyses of intersection and junction elements applied may include slip road characteristics and acceleration and deceleration lane design.

Some of these checks can be done very effectively with modern software as there are specialized tools for this purpose.

In different countries, difficulties may arise such as the inability to use local standards or the need to enter the standards manually. Most commonly, tools come preinstalled with American Association of State Highway and Transportation Officials (AASHTO) standards.

### 3.1.11. Cost estimation

Quantity take-off is the process for the determination of the amount of materials and number of items used in a particular construction project. BIM can be used to extract quantities automatically from the model and estimate the cost of the project. In addition, this process of utilizing BIM can help to compare the costs of various designs to make changes at the early design stages, helping to avoid budget overruns.

A quantity take-off generated by a BIM tool from the model is much more accurate and reliable than one extracted manually through traditional methods which rely on the estimator to calculate quantities from 2D drawings.

In the BIM approach, BIM tools for the preliminary design use direct links to the project model for the automated extraction of quantities needed for the cost estimation process. That is one of the advantages of the BIM approach, because the client can have relevant information about the cost of chosen solutions early in the design phase.

As the design solution improves throughout the process, cost estimation improves too due to the detailed material quantities and spatial information in the BIM model.

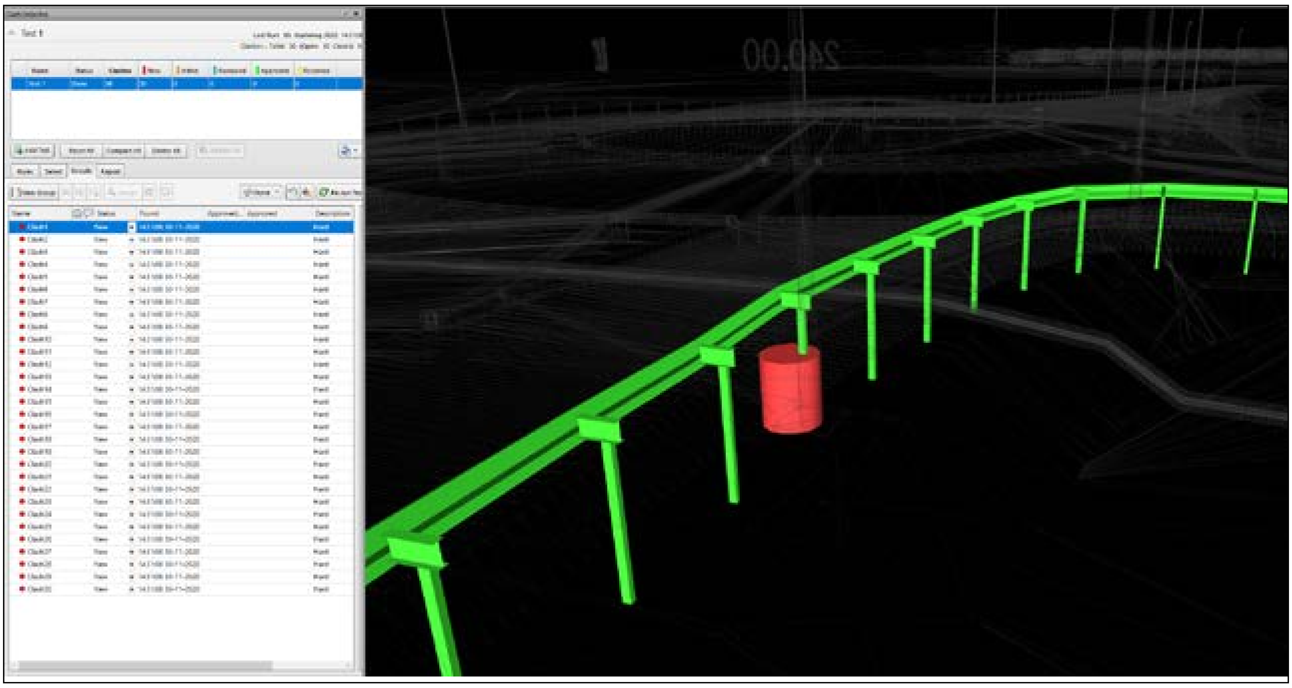
Vertical construction tools are making significant progress in this area, as standardized elements are seeing more frequent use. A combined approach is the most common in infrastructure projects, where CAD tools are used for part of the quantity statement together with the features of the selected authoring design tool (e.g., Autodesk QTO Manager), while part of the quantification is obtained directly from 3D created entities (elements of the BIM model).

### 3.1.12. Clash detection

Clash detection is a process for which (similar to 3D coordination) validation tools are used. Analyses most often check the impact of one profession on another, thus these analyses are conducted on a complex, aggregated model. This type of analysis is especially useful for the project team to better anticipate and resolve potential design issues prior to construction.

Traditionally, clashes are detected by the manual process of overlaying 2D drawings. However, BIM technology can bring systems from all the disciplines together and compare them to detect clashes before they are detected on the construction site. Automatic detection of clashes is an important approach to determining design errors or omissions. If objects are too close to each other, this is regarded as a soft clash, while if objects overlap or occupy the same location, this is defined as a hard clash.

**Figure 32**
**Example of one clash detection analysis: road equipment versus drainage**



*Source:* Denis Šimenić (2020).

In practice, each stakeholder in the design and construction uses different BIM tools and technologies to do their work. For example, the road design model can be prepared in OpenRoad, the drainage model can be designed and developed in Civil 3D, Revit can be used for structural design, while some of the models are created with CAD tools (e.g., traffic signs like 3D solids in a DWG file). These programs do not communicate with each other and subsequently cannot alert the project team when clashes occur. Therefore, there are other BIM tools such as Navisworks that can bring 3D models from different platforms into a single platform to analyse and identify clashes (Figure 32). Clash detection can reduce errors, shorten the actual construction period, reduce the cost of the project and, consequently, offer a smoother process for all stakeholders.

## 3.2. BIM uses in the construction phase

BIM offers benefits to the project team during the actual construction phase too; it provides a smoother and better planned construction process, helping to coordinate construction site activities, people and materials, minimizing conflicts and errors while saving money and time.

### 3.2.1. Usage on the site (Mobile BIM)

Human related mistakes may occur at the construction stage even though the BIM model is accurate and avoids errors and omissions in the design phase. Advanced technologies such as tablets and smartphones offer the opportunity to stakeholders like subcontractors and contractors to use BIM models on the construction site. Coordination and information extraction can be accomplished using BIM applications such as Bentley Navigator Mobile, Viewpoint for Projects Mobile app and Autodesk 360. These tools can be used to share BIM models in a web environment, and perform different activities at the jobsite including clash detection, walk through, etc.

### 3.2.2. Laser scanning

3D laser scanning technology accurately captures existing terrain details and can be linked with BIM technology to provide information about the facility for BIM modelling. It can be used to confirm as-built details or to verify other tools like Radio Frequently Identification (RFID) technology that tracks material delivery status, Global Positioning Systems (GPS) locations, and machine-guidance technology for grading and excavation activities.

Laser scanning can be considered a good quality control tool for new projects and for road rehabilitation projects. Laser scanning can accurately measure the geometry of the new pavement layers and provide excellent data to create a 3D surface model.

### 3.2.3. GPS guidance

Machine control systems on heavy equipment enhance operator efficiency and improve accuracy. Grade is controlled by the model, and changes to the design are sent wirelessly from the office to the machine. There is no better way to ensure work is being executed per the current design. As work progresses, as-built data is sent back to the model for production tracking and quality control.

Several leading site contractors utilize 3D machine control for large or complex site designs. Bulldozers, excavators and backhoes are equipped with on-board computers. Their blades and buckets are also equipped with GPS devices. Either a GPS base station is set up on the individual site or the site contractor subscribes to a regional GPS service, either of which communicates with the GPS receiver on the individual piece of equipment to precisely find where on the site the equipment is located. If the site design has been prepared using 3D design software, the site design can be transformed into a 3D model that can be loaded onto the onboard heavy equipment computer. Even if the project has not been designed in 3D, the 2D design drawings can still be sourced to create a 3D model relatively quickly.

Once the model has been created it is referenced to the site GPS co-ordinates and loaded onto the site equipment computers. The computers are linked to the GPS receivers and the equipment controls. As the equipment moves through the site, the GPS records exactly where it is and the computer records exactly where within the model the equipment sits. Depending on the type of equipment and the function one is looking to achieve, the dozer blade and the excavator bucket will automatically respond to the model and adjust to the required surface elevation or the depth of excavation. The grading of roads, parking lots, sidewalks or utility trenching and infrastructure placement has never been easier and more accurate than with machine control and the use of 3D models.

In addition to site grading and utilities, model elements may include curbing, driveways, lighting posts, fire hydrants, landscaping elements and virtually any other element that may have been part of the site design. These elements are now all entered into the GPS site control for exact location and installation in accordance with the approved design. The result is a site precisely built to the requirements of the design with minimal room for error.

### 3.2.4. Sequential construction planning, virtual scheduling and work planning

A traditional project schedule is based on a Gantt chart and shows only the sequence of each activity. It is hard to assess and evaluate the constructability of the schedule.

With BIM, project managers can easily implement virtual project scheduling to eliminate collisions between activities, such as resource collision, space collision and time collision. 4D simulation (3D models with the added dimension of time) is a powerful visualization and communication tool that can give a project team – including the owner – a better understanding of project milestones and construction plans.

Sequential planning is a process utilizing a 4D BIM model for graphically representing both permanent and temporary facilities on site together with the construction activity schedule. The temporary components include fencing, mobile facilities and numerous traffic access routes. Various other components can be included in the model as part of a logistics plan.

Infrastructure projects often have a direct impact on the surrounding roads and settlements, so there is a need for temporary traffic regulation. Using BIM can create more realistic models of traffic activities at various stages of construction and improve communication with representatives of local communities affected by the construction sites.

### 3.2.5. Site coordination plans, site layout and logistics

A site layout plan is a construction plan prepared by the contractor as part of their mobilization activities before work on site commences. The 3D model needs to include site offices, welfare facilities, offloading and storage areas, sub-contractor facilities, car parking, entrances, temporary roads, locations of cranes with radii and capacities, separate pedestrian access, vehicle wheel washing facilities, hoarding details, signage and temporary services (i.e., electrical power, lighting, water distribution and drainage, information and communications technology installations, site security systems, etc.). With BIM and intelligent algorithms, a site layout scheme can be automatically generated and dynamically optimized.

Site coordination for the construction team is critical particularly when dealing with challenging sites or dense urban environments. In this regard, BIM provides opportunities such as walk-through videos and perspectives views to present zones to site teams to avoid any conflict or clashes during certain periods of the construction, and to show vehicular accessibility, scaffolding equipment and material hoists, improving safety onsite for workers.

The challenges of organizing construction sites for infrastructure projects can be massive; various construction sites can be poorly accessible and at significant distances from each other. The construction of large bridges (often with foundations in the seabed) and tunnels is especially demanding. For these reasons, the quality preparation of all aspect of the construction site and the construction processes enabled by BIM technology can provide a significant advantage.

### 3.2.6. Progress tracking

Typical practice for tracking progress mostly depends on the daily or weekly reports of forepersons, which involves intensive manual data collection and entails frequent transcription with the possibility of data entry errors. These reports are then studied by field engineers and/or superintendents along with 2D as-planned drawings, project specifications and construction details to review the progress achieved by a certain date. After that, the construction schedule is reviewed to identify the work that was planned to be done by that date.

This requires a significant amount of manual work that may impact progress estimations. BIM models integrated with laser scanning and mobile computing are being implemented in the infrastructure industry and have demonstrated benefits for supporting progress tracking. When combining 3D object recognition technology with schedule information into a 4D object-oriented simulation, a project manager can effectively assess current construction progress and make timely decisions if a schedule delay has appeared.

### 3.2.7. Cost control

For the purpose of construction cost control, it is not sufficient to consider only the past record of costs and revenues incurred on a project. Good managers should focus on future revenues, future costs and technical problems. For this purpose, traditional cost control schemes are not adequate to reflect the dynamic nature of a project. 5D BIM refers to the intelligent linking of individual 3D components or assemblies with schedule constraints and cost-related information.

The construction of 5D models enables the various participants (architects, designers, contractors, owners) of any construction project to visualize the progress of construction activities and their related costs over time. As changes or discrepancies between the plan and the realization occur, the project schedule and cost estimates can be automatically modified.

### 3.2.8. Digital fabrication

Digital fabrication is a process that uses digitized information to facilitate the fabrication of construction materials or assemblies. It is generally less represented in horizontal structures, though some examples of digital fabrication can be seen when constructing steel structures (bridges), cutting pipes (main pipelines), designing protocols for design review, etc. This method helps to ensure that the downstream production phase has minimal ambiguities and sufficient information to produce with a minimum of waste. An information model with the appropriate technologies can be used to assemble the fabricated parts into a final assembly.

## 3.3. BIM usage in the operation and maintenance phase

Traditionally, most of the information about an as-built road is stored in paper documents, and the section of the road – as with the final product – is handed over with boxes and piles of owner warranties and manuals. One of the largest problems in dealing with end-of-project information is the large amount of documentation that owners are left to deal with.

Many problems arise when as-built drawings do not match with the actual construction or there have been engineering changes. However, BIM offers one model for storing all data about a construction (for instance, a motorway section) and its systems and components. This information can be leveraged for downstream use by facility managers, thereby making operations and maintenance of a facility more efficient. More specifically, when a model is generated by the project team and updated throughout the construction stage, it can become the as-built model which is then handed over to the owner. This model contains all specifications, maintenance and operation manuals, and warranty information.

As a result, BIM provides the ability to transfer the facility data from the design and construction stages to the operation stage, and some commercial systems offer automated transfer of facility data from Building Information Modelling tools to Computerized Maintenance Management Systems.

The international interoperability standard COBie (construction operations building information exchange) provides a framework to store data throughout the design and construction process, but so far there is no significant application of this standard for infrastructure projects (except in the United Kingdom).

### 3.3.1. Record modelling

A record model depicts an accurate representation of the physical conditions, environment and assets of a facility. The contractor hands over a record model to the owner at the end of the construction phase for the facilitation of operation, maintenance and renovation.

This model contains different information about a construction such as the pre-build specifications, the design and the actual as-built details in relation to the road section, traffic systems, structures, architecture, drainage, electrical and component information such as warranties, product data, maintenance history and schedules, and serial numbers. A record model represents an authoritative source of information that is used to plan and execute changes during the life cycle of an infrastructure asset. Therefore, a project team should continuously update the BIM model so that it will reflect the most up-to-date information for the efficient and effective use of operations and maintenance.

### 3.3.2. Asset management

Asset management should be understood as a value creation process which combines strategic, tactical and operational levels of an organisation's management through technical, engineering, and business principles and practice with economic rationale.

Asset management is enabled through an organized management system including tools, procedures and competencies for the efficient maintenance and operation of a facility and its assets. These assets include equipment, systems and the physical road or motorway elements that have to be upgraded, operated and maintained at an efficiency level with the lowest appropriate cost to satisfy the owner and users.

An organized management system assists in financial decision-making, short-term and long-term planning, and generating scheduled work orders. Asset management tools use the data contained in a record model to populate an asset management system which is then used to determine cost implications of changing or upgrading of assets. The bidirectional link also allows users to visualize the asset in the model before servicing it, potentially reducing service time. Team competencies need to include the ability to manipulate, navigate and review a 3D model and to manipulate an asset management system.

### 3.3.3. BIM tools for management of road assets

BIM road infrastructure management solutions help the user collect, maintain and analyse road assets, delivering a central platform upon which users can plan, operate and maintain an ever-improving intelligent transportation network. Included are the geospatial location of these assets, the graphic representation of these networks and their geospatial context in map form. BIM solutions include workflows to build and manage infrastructure models, analyse current working conditions of the infrastructure, plan infrastructure improvements and plan future growth – all the components necessary for effective motorway and roadway asset management. BIM provides the ability to collaborate and distribute geospatially related data, with the BIM application providing the technology framework needed for cost-effective and efficient communication.

### 3.3.4. Digital twins

A digital twin is a digital representation of a physical asset, process or system which makes it possible to understand and model its performance. Digital twins are continuously updated with data from multiple sources – making them different from static, 3D BIM models[4].

[4] Martyn Day, "Bentley on Digital Twins", AEC Magazine, 22 November 2019.

This technology makes it possible to visualize infrastructure assets throughout the asset life cycle, track changes and conduct analysis to optimize asset performance. Engineering data is combined with collected data for above- and below-ground infrastructure. Visualization and visibility analytics help owners better understand their infrastructure resources and make better informed maintenance decisions.

The digital twins of the new asset are derived from BIM design data and can then be augmented by scanning the physical asset on site. The existing infrastructure can be modelled by photogrammetry or laser scanning to obtain a real network. Alternatively, a BIM model can be created as built.

The Centre for Digital Built Britain (cdbb.cam.ac.uk) has recognized some of the key benefits of digital twins as follows:

- Better asset maintenance using predictive data analytics
- Improving organizational productivity
- Better asset tracking
- More efficient use and management of equipment
- Finding ways to reduce energy consumption
- Using augmented reality to help with maintenance and inspection

These technologies are most used to analyse the performance of bridges in real conditions.

### 3.3.5. Transportation management system

Planning, executing, monitoring and taking corrective action across the entire transport system life cycle is critical in a complex and constrained transport environment. Therefore manufacturers, retailers and logistics service providers are choosing transportation management systems compatible with BIM technology to effectively manage their high-volume, sophisticated transport networks. From order management through customer service and financial settlement, such systems support the entire life cycle of the transport network. This allows customers to quickly create and modify shipping plans with the least-cost options and loads that maximize capacity utilization.

The benefits from using BIM are overall cost reduction resulting from transportation optimization, improved service levels and customer satisfaction, a reduction in damage-in-transit losses, and the ability to enhance the reliability and efficiency of the distribution network.

# 4. BIM collaboration

## 4.1. Request for data interoperability

As indicated earlier, there is no single BIM tool that includes all the functions to facilitate the technological implementation of BIM. Therefore, BIM models should be created and developed using various BIM applications during the various stages of the infrastructure project's life cycle processes. For that purpose, BIM models must be exported and imported smoothly among different BIM applications to achieve better performance. In other words, BIM software packages should talk to each other to define a building project, provide automation and integrate the design and construction processes in an integrated way. Such interoperability between BIM applications would improve collaboration in the AEC industry.

Interoperability is the ability to exchange data between applications in order to streamline workflows and facilitate automation. For instance, a survey by McGraw Hill Construction[5] revealed that a lack of interoperability can affect the workflow of the project community, impacting the project budget by approximately 3.1 per cent of project costs.

Furthermore, this survey showed that manual data transcription from one application to another is the highest portion of the cost, followed by time spent on duplicate software, time lost to checking document versions, money spent on data translators and time spent on increased processing requests for information. A lack of interoperability can lead to project delays, misinterpretations and various issues during construction.

There are a considerable number of software programs used in AEC, and applications and licenses are usually required to open a particular file for information sharing between those AEC applications, making collaboration difficult among project team members. Based on Eastman[6], there are three main ways of exchanging data between two software programs:

- Direct links – between two software programs through the application programming interface (API) of one software to extract information which can then be re-written by the receiving software's API
- Proprietary exchange format – a file-based data exchange approach which can be created by a commercial organization to support its own software product; for example, data exchange format (DXF) is a well-known proprietary exchange format in the AEC industry. This format has been developed by Autodesk to enhance the information exchange between software packages. Other proprietary exchange formats such as DWG, DGN, RVT and NWD have been defined by commercial organizations to deal with the different functions of their software programs
- Public product data model exchange formats – this relies on an open and publicly managed language and schema such as text files and XML

On the other hand, Industry Foundation Classes (IFC) were created by the BuildingSMART Alliance[7] for data exchange between different BIM programs. IFC depends on the ISO-STEP EXPRESS language and it is designed to address all building information throughout the whole life cycle of a building, from the conception phase through design and construction to operation.

In the vertical construction industry, interoperability is at a much higher level due to the widespread use of IFC formats. IFC format specifications are evolving quickly and the format in place since April 2019 is IFC 4.2. In comparison, the implementation of IFC formats in infrastructure projects is much less widespread, although sometimes required by the provisions of BIM Execution Plans – especially in mixed projects where both horizontal and vertical structures are represented. Due to the lack of IFC format support for road infrastructure projects, the BuildingSMART Alliance launched the IFC Road Project in 2018 with the aim of extending standards to support linear highway and motorway infrastructure, as well as the IFC Rail and IFC Tunnel projects. Upon completion of this programme, a much wider application of this format to infrastructure projects can be expected.

Overall, the interoperability between BIM tools, if successfully enabled, can improve value for clients, expand markets for companies, decrease supply chain communication costs, increase the overall speed of projects, provide greater reliability of information throughout the life cycle and reduce infrastructure vulnerability.

5 McGraw Hill Construction, "The Business Value of BIM for Construction in Major Global Markets" (2014). Available at https://www.construction.com/toolkit/reports/bim-business-value-construction-global-markets

6 Yong-Cheol Lee, Charles M. Eastman and Jin-Kook Lee, "Validations for ensuring the interoperability of data exchange of a building information model", *Automation in Construction*, vol. 58 (October 2015).

7 www.buildingsmart.org

**Table 1**
**Information exchange formats commonly used in the AEC industry**

| Type | Characteristics |
|---|---|
| Image (Raster) Formats:<br>JPG, GIF, TIF, BMP, PNG, RAW, RLE | Raster formats vary in terms of compactness, number of possible colours per pixel, transparency, compression with or without data loss |
| 2D Vector Formats:<br>DXF, DWG, DGN, CGM, EMF, IGS, WMF, PDF, ODF, SVG, SWF | Vector formats vary regarding compactness, line formatting, colour, layering and types of curves supported; some are file based, others use XML |
| 3D Surface and Shape Formats:<br>FBX, 3DS, WRL, STl, IGS, SAT, DXF, DWG, Vsp3D, OBJ, DGN, U3D, PDF(3D), PTS, DWF, GENIO | 3D surface and shape formats vary according to the types of surfaces and edges represented, whether they represent surfaces or solids, material properties of the shape or viewpoint information. Some have both ASCII and binary encodings. Some include lighting, camera and other viewing controls. Some are file formats and others XML. |
| 3D Object Exchange Formats:<br>IFC, NWD, RVT, IMX, STP, SKP, EXP, CIS/2 | Product data model formats represent geometry according to the 2D or 3D types represented; they also carry out object type data and relevant properties between objects. They are the richest in information content. |
| LandXML: AecXML, Obtx, AEX, bcXML, AGCxml, GENIO | XML Schema as developed for building data; they vary according to the information exchanged and the workflow supported.<br>LandXML is the most used format in infrastructure projects, with the possibility to exchange data for points, surfaces, alignments, profiles, pipes, etc. |
| DAE, V3D, X,U, GOF, FACT, COLLADA | A wide variety of game file formats varying according to the types of surfaces, whether they carry hierarchical structure, types of material properties, texture and bump map parameters, animation, and skinning. |
| SHP, SHX, GML, CityGML, DBF, TIGER, JSON | Geographical Information System formats in terms of 2D or 3D, data links supported, file formats, and XML |

*Source:* ibid., Chuck Eastman et al. (2011).

## 4.2. Common data environment

### 4.2.1. Definitions

The common data environment (CDE) can be defined as an application, generally available in the Cloud, accessible from any device (PC, tablet or smartphone) from which it is possible to manage – in a structured and unique way – project documentation, site or building maintenance information, as well as promoting collaboration between various users and stakeholders. In short, CDE is a shared information environment that represents a project's digital ecosystem. The use of CDE is beneficial in all phases of the life cycle of a building.

Building Information Modelling is now commonly regarded as the evolution that is changing more than anything else the way every stage of the building process is conducted, including planning, design, construction and management. The CDE allows for the distribution of data and creation of value for the whole chain of stakeholders involved in the process.

### 4.2.2. Why establish a CDE?

In the BIM approach, most information becomes valuable only through effective data management. Road or motorway projects usually have many types of information (graphical and non-graphical) and a large amount of data. Data come from multiple sources and disciplines across sites, companies and geographical locations; thus, a powerful tool is required that can support such a setup.

Frequently asked questions about data are:

- Where is the digital documentation located?
- What is the relevant version of the documentation?
- Is the construction schedule being followed?
- What exactly is happening on the construction site?
- How can one access up-to-date data in the field?
- Where can one check aggregated BIM models?
- How can communication with contractors and subcontractors be improved?

The common data environment systematically solves these problems and makes data available to any user with responsibility and dedicated access permissions.

BIM authoring tools (e.g., Civil 3D, Infraworks, Revit, OpenRoads, etc.) produce – in all stages of the design process – a large amount of data which enables the generation of value in later stages of the process. Unfortunately, this capacity often remains unused or underutilized for lack of better tools to manage the data outside of the application that created them.

The use of a tool such as CDE, combined with the use of BIM, can provide further cost savings, shorter construction times and more efficient building management.

The CDE allows all users involved in the design and management process to share in real-time a single database which is always available and up to date. It facilitates collaboration among team members by avoiding the duplication of information and minimizing the possible occurrence of errors at every stage of the work.

### 4.2.3. Who contributes?

Construction draws on the skills of a wide range of disciplines and the CDE brings together the information from all who work as part of the wider project team.

For example, a project might have inputs and deliverables from civil infrastructure, traffic, structural, architectural, mechanical, electrical and plumbing services staff, and these will be added to the CDE as data drops at specific points in the project set out in the employer's information requirements.

### 4.2.4. What form?

The question is, which of the stakeholders in the construction project has an obligation to establish a CDE environment? If the contracting authority already has its own information environment, it must describe it in detail in the terms of reference, so that tenderers adapt their BIM approach accordingly. On the other hand, if the client does not yet have their own information environment, it is best to establish (or hire) one for the planned project so that the client can monitor all phases of the project.

The British standard PAS 1192-2 suggests that a separate server for the project could be set up, or an extranet or some other form of file-based retrieval system. In establishing a CDE one should be mindful of the requirements of contributing parties. File and folder naming conventions – perhaps using a standard protocol – will need to be established well in advance.

In practice the CDE may be divided to create environments that serve the needs of those on the supply side of a project (for instance, working folders only for the designers) and to collate and validate the deliverables that are required in BIM Execution Plans. These environments may have distinct permissions, structures and protocols.

The main areas covered by a CDE are document management, task management and project administration. All these activities, if properly integrated into a BIM process, can improve efficiency and control. To achieve the best results, it is essential that strategic choices for the correct preparation of work management are made and shared in the early phases of the project to the greatest extent possible. All decisions and consequently planned activities must be shared in real time to allow a high level of collaboration among all users.

The adoption of a CDE overcomes geographical barriers and allows, for example, the creation of a team potentially extending to different countries or continents thanks to the ability to collaborate remotely using a shared technology platform. Collaboration in the Cloud is designed precisely to meet these needs – to share and manage data as well as ensure greater efficiency in team activities.

### 4.2.5. CDE uses

The CDE itself is not a project management tool, though it can be used with one or many such tools (e.g., Autodesk Vault or Bentley Project Wise).

The most used capabilities of CDE platforms are:

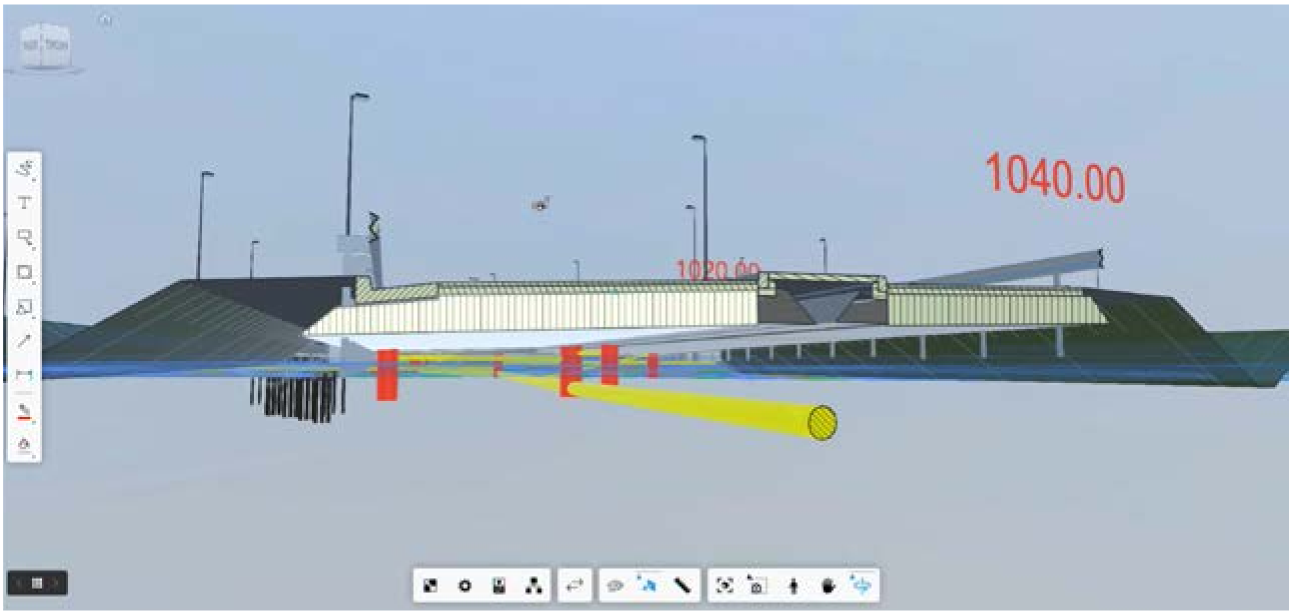
- Viewing capabilities – built-in viewers allow users to view and analyse numerous file types without the necessary installation of native applications; this makes possible the use a smartphones or tablets for real-time project collaboration (Figure 33)
- Custom project structure
- Versioning – meaning no need to rename a document; all the versions of any document (file) are available; 3D and 2D version comparison is also possible (Figure 34)
- Mark-ups, notifications and issue management

### 4.2.6. What are the advantages?

As a single source of information, there are no disputes related to reference version of the information to be used. The CDE should serve as the ultimate source and bring a number of advantages for all stakeholders, including the following:

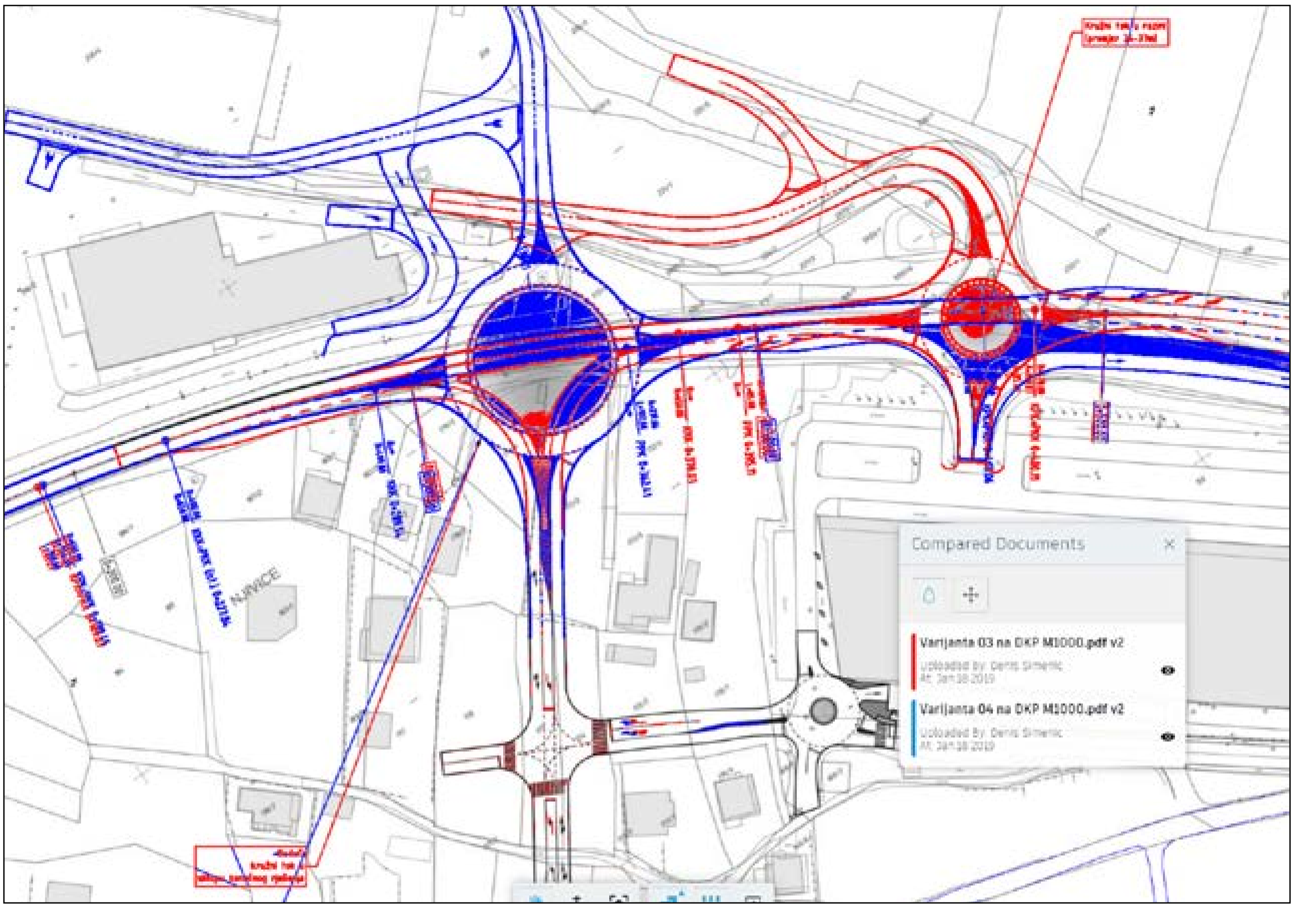
- Shared information should result in coordinated data which will, in turn, reduce both time and cost on a project
- Project team members can all use the CDE to generate the documents and views they need using different combinations of the central assets, confident that they are using the latest assets (as all others)
- Spatial co-ordination is inherent in the concept of using a centralized model
- Reducing the time and effort required to check, version and reissue information
- Extracting selections of the latest approved data from the shared area
- Reducing coordination checks (ensuring models are correct and issues like clashes between models are not evident) which are a by-product of the detailed design production process
- Reuse of information to support construction planning, estimating, cost planning, facilities management and many other downstream activities
- Reducing the time and cost of producing coordinated information

**Figure 33**
**File created with validation tool opened with BIM 360 Docs**




*Source:* Denis Šimenić (2020).

**Figure 34**
**Example of comparing two 2D drawings**




*Source:* Denis Šimenić (2020).

### 4.2.7. Data ownership and who hosts the CDE

Ownership of information within the CDE remains with the originator of that information. Individual models produced by different project team members do not interact; they have clear authorship and remain separate. This means that the liabilities of the originators are not changed by the incorporation of their model into the aggregated model. There may be complications, however, where ownership changes as the project progresses – for example, replacing design team objects with specialist subcontractor objects.

Generally, a license is granted to the client to use the information contained in the separate models for the permitted purpose (i.e., for the purpose for which that level of detail of information was intended). A sub-license from the client enables project team members to use models prepared by other project team members. The contributors retain ownership of the information they store in the CDE. Models produced by individual teams will remain separate and these are sources drawn on to produce the aggregated model.

Typically, team members will license their contributions for use by the client for a prescribed purpose (e.g., generating the federated model to the level of detail contractually set out in the employer's information requirements and BIM Execution Plan). In turn, clients can then license the range of models fed back to the CDE for use by other members of the project team for their requirements.

### 4.2.8. CDE tools on the AEC market

The rapid development of CDE platforms is underway, making it a very dynamic segment of the market. Due to the quantity of offers, it is necessary to be well informed and to study which platforms are best suited to a particular project. Sometimes this decision is not easy because many of the functionalities between different products overlap and repeat. However, most of the market is covered by six platforms – Autodesk BIM 360, Bentley ProjectWise and WorkFace, Viewpoint, Oracle Aconex and Trimble Quadri. Behind each of these marketing names is a family of other products.

Some products are predominantly intended for collaboration in the design phase (Autodesk 360 Docs, Autodesk 360 Design, Project Wise, Viewpoint for Projects), while the second group has specially developed tools for monitoring the construction process (BIM 360 Build, BIM 360 Coordinate, Bentley WorkFace, Viewpoint Team).

# 5. BIM roles and responsibilities

From the technical literature, there is a wide variety of job titles that apply to BIM specialists, many of which have overlapping descriptions and requirements. These job types fall into the categories of project roles with the primary function fitting within a project team, and organizational roles where the role is primarily performed at the company level. It is uncommon for the reviewed BIM guides and standards to distinguish between project and organizational level role definitions, but they often include descriptions of activities or role expectations that are clearly organization-based rather than project-based.

From the roles described in the many available BIM guides, a distinction has been made based on an interpretation of the different spheres of activity. BIM roles with a project integration aspect fall into two main categories which are relatively uniform in scope and responsibility. These commonly comprise an over-arching project management and coordination role, which is supported by a second tier of specialist managers or BIM coordinators from each of the design and construction teams or technical groupings. Some handbooks also define BIM roles which are concerned with organization-level BIM processes, and another two categories can be defined in this area – the organizational BIM manager and the BIM modeler (author).

## 5.1. BIM manager – project role (level)

The person or persons assuming this role can represent the lead designer, the main contractor and/or a third-party entity acting on behalf of the client. At this level, the BIM manager is responsible for the development and delivery of the BIM Execution Plan and establishing BIM protocols for the project. According to the most common descriptions, quality assurance is also a part of the role, as is maintaining oversight over BIM responsibilities and deliverables. Guiding the collaborative process is an important aspect of this role, including organizing BIM project meetings and managing project records. One area of potential ambiguity regarding the BIM manager's project role is the degree of authority held by this person. The role is often described in terms of the project stage; for example, the design BIM manager or the construction BIM manager. These roles are expected to report to the project manager who has the oversight role. However, in many of the documents, the BIM manager role is the overarching project role and is expected to pass between different parties depending on who holds the responsibility for the particular project stage.

## 5.2. BIM coordinators – project role

The BIM coordinator role is described as a secondary role under the leadership of the BIM manager, representing each individual discipline within the project framework. For sub-trades, and specialist consultants in particular, the job title often used for this role is model manager. BIM coordinators are responsible for the exchange of BIM models from their organization or discipline, including ensuring that models created within their team adhere to the agreed BIM standards and follow exchange protocols. Model coordination and clash detection is often described as falling within the remit of the BIM coordinator; within a project team the BIM manager leads the coordination activity, but each BIM coordinator takes responsibility for the coordination and management of their own model and any required propagation of changes. Other responsibilities described for the BIM coordinator role include quality control, ensuring that the discipline model conforms to the standards agreed for the project, providing guidelines for the discipline team on agreed project requirements, and communicating data transfer needs and processes with other disciplines.

## 5.3. BIM manager – organization role

Although almost all the guides and handbooks reviewed are concerned with the project-level processes involved in BIM implementation, many of them also define a BIM manager role in terms of both organizational as well as project responsibilities. Most commonly, this includes responsibility for training, as well as hardware and software issues. Training and technical support of the modelling staff are roles of the BIM manager.

Additionally, the BIM manager role is primarily at a project level and the level of interaction with clients, but various sources also stipulate the level of proficiency the BIM manager must have in the selected authoring tools and assign BIM managers the responsibility for coordinating BIM training. In practice, the BIM manager for an organization is often the BIM coordinator (i.e., the discipline-specific BIM representative) at the project level, so it is not uncommon for the same individual to undertake project and organizational tasks. However, these are not project level requirements and thus do not need to be specified by the client to achieve successful BIM implementation.

## 5.4. BIM modeler – organization role

The BIM modeler role is described as a production role in developing the BIM model, a role that has a variety of job titles including model author, BIM operator, BIM user or BIM technician.

Although BIM modelers work on project documentation, this has been classified as an organizational role because it is the documentation itself (whether the full model or other product) that is the project contribution, and not the process by which it is produced. It is generally an operational decision within an organization as to how that product is achieved.

When creating a motorway construction project, the role of BIM modeler can be to make the final improvements to a project model that he or she originally created. Complete modelling based on project data is usually performed for individual project segments such as traffic equipment, various services structures, noise protection walls, geo-mechanical structures, etc.

Table 2 presents a selection of the specified abilities and activities, grouped into the focus areas of technical, process, people and strategy. These are based on the role's previously identified categorizations. The need for many of these abilities and activities, particularly at the technical and process levels, is not universal but is dependent on the BIM uses identified for application in a specific project.

**Table2**
**Selection of the specified abilities and activities, grouped into the focus areas of technical, process, people and strategy based on the role's categorizations**

| Role | Technical | Process | People | Strategy |
|---|---|---|---|---|
| BIM manager (project role) | Ensure software is installed and operating properly | Lead development of BIM Management Plan/BIM Execution Plan | Provide BIM point of contact with client | |
| | Determine reference points used for project | Ensure compliance with BIM Management Plan/BIM Execution Plan | Train project staff | |
| | Analyse model content to ensure it is fit for purpose | Management & quality control of model dissemination; revision management | Facilitate technical meetings with BIM technicians | |
| | Carry out clash detection & provide clash reports | Coordinate file management processes | | |
| | Assist in preparation of project outputs, such as data drops | | | |
| | Assemble composite models | | | |
| BIM coordinator (project role) | Carry out clash detection & provide clash reports | Provide guidelines for discipline team on agreed project rules | Team contact person in matters connected with BIM | |
| | Ensure functionality of team contribution to merged models / integration of design models | Contribute to keeping BIM Management Plan/BIM Execution Plan up to date | Allocate and coordinate BIM tasks within own discipline | |
| | | Ensure discipline model complies with BIM Management Plan/BIM Execution Plan | Communicate with other disciplines | |
| | | Manage discipline-based quality assurance, formulation of BIM reports & data management | Represent team at interdisciplinary model coordination meetings | |
| BIM modeller (organizational role) | Production & modification of information in discipline- specific model | | | |
| | Must have appropriate technology skills to produce the model | | | |
| BIM manager (organizational role) | Implement BIM technology | Create company-level BIM processes and workflows | Engage external stakeholders | Formulate corporate BIM objectives |
| | | Develop company-level BIM standards and protocols | Collaborate with partners and internal teams | Plan & manage best practice / research |
| | | | Company-based change management and training | Prepare and manage BIM training strategy |

*Source:* Kathryn Davies, Suzanne Wilkison and Dermott McMeel, "A review of specialist role definitions in BIM guides and standards", *Itcon*, vol. 22 (October 2017).

# 6. BIM Execution Plan implementation framework

## 6.1. Introduction

To successfully implement BIM, a project team must perform detailed and comprehensive planning. A well-documented BIM Project Execution Plan will ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow. A completed BIM Project Execution Plan should define the appropriate uses for BIM on a project (e.g., design authoring, design review and 3D coordination), along with a detailed design and documentation of the process for executing BIM throughout the life cycle of an infrastructure asset. Once the plan is created, the team can follow and monitor their progress by referencing this plan to gain the maximum benefits from BIM implementation.

The BIM Plan should be developed in the early stages of a project, continually developed as additional participants are added to the project, and monitored, updated and revised as needed throughout the implementation phase of the project. The plan should define the scope of BIM implementation in the project, identify the process flow for BIM tasks, define the information exchanges between parties and describe the required project and company infrastructure needed to support the implementation.

## 6.2. Reasons for developing a BIM Project Execution Plan

By developing a BIM Plan, the project and project team members can achieve the following benefits:

- All parties will clearly understand and communicate the strategic goals for implementing BIM in the project
- Organizations will understand their roles and responsibilities in the implementation
- The team will be able to design an execution process which is well suited for each team member's business practices and typical organizational workflows
- The plan will outline additional resources, training or other competencies necessary to successfully implement BIM for the intended uses
- The plan will provide a benchmark for describing the process to future participants who join the project
- The procurement divisions will be able to define contract language to ensure that all project participants fulfil their obligations
- The baseline plan will provide a goal for measuring progress throughout the project

BIM, like other new technologies, can carry some level of additional process risk when implemented by teams that are not experienced with the implementation process or if people are not familiar with the strategies and processes of their team members. Ultimately, the entire team will gain value through the increased level of planning by reducing the unknowns in the implementation process, thereby reducing the overall risk to all parties and the project.

## 6.3. Identify BIM goals and uses

### 6.3.1. Goals

One of the most important steps in the planning process is to clearly define the potential value of BIM to the project and for project team members through defining the overall goals for BIM implementation.

Prior to identifying BIM uses, the project team should outline project goals related to BIM. These project goals should be measurable and strive to improve the successes of the planning, design, construction and operations of the facility. One category of goals should relate to general project performance including reducing the project schedule duration, reducing the project cost or increasing the overall level of safety performance of the project.

Other goals may target the efficiency of specific tasks to allow for overall time or cost savings by the project participants. These goals include the use of modelling applications to create design documentation more efficiently, to develop estimates through automated take-offs or to reduce the time to enter data into the operation and maintenance system. These items are only suggestions of potential goals that the project team may have when deciding how to implement BIM on a project. This is by no means a comprehensive list and it is essential to identify the specific goals that will provide incentive for implementing BIM in the project.

It is important to understand that some goals may relate to specific uses while other goals may not. For example, if there is a design objective to ensure the exact location of all services, geo-mechanical interventions and equipment in a tunnel, the team should consider BIM use of 3D design coordination which will allow the team to identify and correct potential geometric conflicts prior to construction. On the other hand, if the goal of the team is to increase the sustainability of the construction project, several uses can help achieve that goal.

These goals could be based on project performance and include items such as reducing the schedule duration, achieving higher field productivity, increasing quality, reducing cost of change orders or obtaining important operational data for the facility. Goals may also relate to advancing the capabilities of the project team members; for example, the owner may wish to use the project as a pilot project to illustrate information exchanges among design, construction and operations, or a design company may seek to gain experience in the efficient use of digital design applications. Once the team has defined measurable goals, both from a project perspective and a company perspective, then the specific BIM uses in the project can be identified.

### 6.3.2. Uses

A BIM use is a unique task or procedure in a project which can benefit from the integration of BIM into that process. Several examples of BIM uses include site modelling, visualization, design authoring, design review, clash detection, sequential construction planning, GPS guidance, cost estimating, asset management and record modelling. The team should identify and prioritize the appropriate BIM uses which they have identified as beneficial to the project.

## 6.4. What categories (chapters) should be included in a BIM Execution Plan

Various specific categories support the BIM project execution process. The most frequently used source for questions related to the development of the BIM Execution Plan, and thus for its content itself, is the publication "BIM Project Execution Planning Guide"[8].

Again, most of the materials available are not focused on road infrastructure projects and are designed mainly for vertical construction purposes. Therefore, some categories have been supplemented to better accommodate infrastructure projects.

Information for each category can vary by project. Therefore, the goal of the description is to address content areas and decisions which need to be made by the project team.

### 6.4.1. BIM Project Execution Plan

It is important for the project team to understand the reason that a BIM Project Execution Plan was created. This section should include information such as a BIM mission statement and other executive summary level information establishing the importance of the plan.

### 6.4.2. Project information

When developing the BIM Project Execution Plan, the team should review and document critical project information that may be valuable for the BIM team for future reference. This section could include basic project information that may be valuable for the current and future states. It can be used to help introduce new members to the project as well as to help others reviewing the plan to understand the project. This section may include items such as project owner, project name, project location and address, contract type and delivery method, a brief project description, project number(s), and the project schedule and phases (milestones). Any additional general project information can and should be included in this section. Additional project information includes unique project characteristics, project budget, project requirements, contract status, funding status, unique project requirements, etc.

### 6.4.3. Key project contacts

At least one representative from each stakeholder involved should be identified, including the owner, designers, consultants, prime contractors, subcontractors and suppliers. These representatives could include personnel such as project managers, BIM managers, BIM coordinators, discipline leads, supervisors and other major project roles. All stakeholder contact information should be collected, exchanged and, when convenient, posted on a shared collaborative project management (CDE) platform.

### 6.4.4. Project BIM goals/uses

The BIM Project Execution Plan should document the previous steps in the BIM project execution planning process. It is valuable for the team to document the underlying purpose for implementing BIM in the project as well as to explain why key BIM use decisions were made. The plan should include a clear list of the BIM goals and specific information on the BIM uses selected.

### 6.4.5. Organization roles and staffing

The roles in each organization and their specific responsibilities must be defined. For each BIM use selected, the team must identify which organization(s) will staff and perform that use. This includes the number of personnel by job title necessary to complete the BIM use, the estimated working hours, the primary location that will complete the use and the lead organizational contact for that use.

Depending in which phase of a project's life cycle this plan is completed, several items in this section may be challenging to complete. Like the rest of the plan, as much as possible should be completed and the remaining should be completed as the information becomes available.

[8] John Messner and others, "BIM Project Execution Planning Guide, Version 2.2.", Computer Integrated Construction Research Program, The Pennsylvania State University (University Park, Pennsylvania, 2019).

### 6.4.6. BIM process design

This is the central part of the plan and in various sources could be named differently, such as model objectives and application. Usually, the process design contains a comprehensive list of planned models and analysis for the whole project with specified tools and file formats. Process design also includes targeted levels of development and a file or model naming convention. Commonly, this information is presented in table form. Some examples are given below.

### 6.4.7. BIM information exchanges and model sharing

The team should document the information exchanges created as part of the planning process in the BIM Project Execution Plan. The information exchanges will illustrate the model elements by discipline and any specific attributes important to the project. Generally, it is important for the team to define the model components and discipline-specific deliverables to maximize value and limit unnecessary modelling in the project.

**Table 3**
**Planned models in BIM Execution Plan**

| Model name: | Model content: | Project phase: | Authoring company: | Authoring tool: |
|---|---|---|---|---|
| Main Route | Components of Road Design of a Main Route | Preliminary Design, Final Design | Designer Company A | Bentley OpenRoads |
| Intersections A, B | Components of Road Design, Intersections A, B | Preliminary Design, Final Design, Detailed Design | Designer Company B | Autodesk Civil 3D |
| Intersections C, D, E | Components of Road Design, Intersections C, D, E | Preliminary Design, Final Design, Detailed Design | Designer Company C | Autodesk Civil 3D |
| Bridges 1, 2, 3 | Civil and Structural components of Bridges 1, 2, 3 | Preliminary Design, Final Design, Detailed Design | Designer Company D | Autodesk Revit |
| Drainage System | Components of a drainage system | Preliminary Design, Final Design | Designer Company B | Autodesk Civil 3D, Autodesk Storm and Sanitary Analysis |
| Traffic Design | Components of a Traffic Design | Preliminary Design, Final Design | Designer Company C | AutoCAD, SketchUP |
| Noise Protection | Components of a Noise Protection System | Preliminary Design, Final Design, Detailed Design | Designer Company A | Bentley Microstation |

*Source:* Denis Šimenić (2020).

**Table 4**
**Targeted LOD**

| Model name: | Preliminary Design LOD | Final Design LOD | Detailed Design LOD |
|---|---|---|---|
| Main Route | 200 | 300 | 300 |
| Intersections A, B | 200 | 300 | 300 |
| Intersections C, D, E | 200 | 300 | 300 |
| Bridges 1, 2, 3 | 200 | 300 | 400 |
| Drainage System | 200 | 300 | 350 |
| Traffic Design | 100 | 300 | 300 |
| Noise Protection | 200 | 300 | 400 |

*Source:* ibid.

**Table 5**
**Detailed BIM use and analysis plan**

| BIM Analysis/Use | Analysis tool | Model | Analysing company | Project phase(s) | Special instructions |
|---|---|---|---|---|---|
| Route Analysis | Autodesk Infraworks | Road Design, Bridges | Designer Company A | Preliminary Design | |
| Traffic Analysis | PTV Vissim | Road Design | Designer Company D | Preliminary Design | |
| Visualization | Autodesk Infraworks | Road Design, Bridges | Designer Company A | Preliminary Design | |
| Visualization | Autodesk Infraworks, 3DS Max | Road Design, Intersections Design, Bridges, Traffic Design, Noise Protection | Designer Company A | Final Design | |
| Structural | Sofistik | Bridges 1–5 | Company C, D | Final Design | |
| Clash detection | Navisworks | Road Design, Bridges, Drainage system, Services, Traffic Design, Noise Protection | Company A | Final Design | |
| 3D coordination | Navisworks; BIM 360 | Road Design, Bridges, Drainage system, Services, Traffic Design, Noise Protection | Company A | Final Design | |

*Source:* ibid.

To allow a correct data exchange process, this section should cover the following topics:

- Geosystem used for the project – In most cases, there is a single geosystem that is officially used in the country, but in the infrastructure industry there could be projects that include more than one country. In this situation, there must be information on how this obstacle will be solved on the project level.
- Data interoperability – Depending on the content of the models planned and the file formats used, this chapter should cover protocols and procedures which will be used to achieve efficient data exchange between authoring and analysis tools.
- CDE platform – This section should contain the necessary information on the implementation of the CDE platform. The information should include the CDE platform tool selected, who set up the platform, the licensing method and the duration of the license. It also provides an overview of the intended roles and authorities, as well as guidelines for CDE use in terms of the amount, content and timeframe of placing data on the platform.

### 6.4.8. Quality control

Project teams should document their overall strategy for quality control over the model. Certain procedures must be defined and implemented to ensure model quality in every project phase and before information exchanges. Each BIM element created during the life cycle of the project must be pre-planned considering the model content, level of detail, format and party responsible for updates.

Each party contributing to the BIM model should have a responsible person to coordinate the model. This person, as part of the BIM team (usually a BIM coordinator), should participate in all major BIM activities as required by the team. Quality control for deliverables must be accomplished at each major BIM activity such as design reviews, coordination meetings or project milestones. The standard of data quality should be established in the planning process and agreed upon by the team.

### 6.4.9. Quality control checks

Each project team member should be responsible for performing quality control checks on his or her design, dataset and model properties before submitting the deliverables. Documentation confirming that a quality check was performed can be part of the BIM report. The BIM manager should be the one to confirm the quality of the model after the revisions were made.

The following quality control checks should be considered when determining a plan for quality control:

- Visual check – ensure there are no unintended model components, and the design intent has been followed by using navigation software
- Interference check – detect problems in the model where two components are clashing using conflict detection software
- Standards check – ensure that the model meets the standards agreed upon by the team
- Element validation – ensure that the dataset has no undefined or incorrectly defined elements

### 6.4.10. Project deliverables

The project team should consider what deliverables are required by the client or project owner. With the deliverable project phase, due date format and any other specific information about the deliverable should be considered.

### 6.4.11. Technology infrastructure needs

The team should determine the requirements for hardware, software platforms, software licenses, networks and modelling content for the project.

**Software**

Teams and organizations should determine which software platforms and version of that software are necessary to perform the BIM uses that were selected during the planning process. It is important to agree upon a software platform early in the project to help resolve possible interoperability issues. File formats for information transfer should have already been agreed upon during the information exchange planning step. Additionally, the team should agree upon a process for changing or upgrading software platforms and versions so that a party does not create an issue where a model is no longer interoperable with other parties.

**Hardware**

Understanding hardware specifications becomes valuable once information begins to be shared among several disciplines or organizations. It also becomes valuable to ensure that the downstream hardware is not less powerful than the hardware used to create the information. To ensure that this does not happen, one should choose hardware that is in high demand and most appropriate for the majority of BIM uses. For instance, designers usually have a powerful workstation capable of performing various analyses and simulations. However, this is not always the case for all participants in a project – for example, an investor's representative who must be kept in mind so that all participants have the technical capacity to see and analyse project data. Furthermore, since a lot of data resides on the CDE platform, actual data transfer speed is also important.

# 7. BIM impact on stakeholders with key success factors for implementation

## 7.1. Owners – public (road) authorities

Road authorities (in BIM literature, the general terms for the authorities are usually public or private owners) should benefit most from the implementation of BIM. Introducing BIM technology during the design and construction process – for use by project companies and contractors – ultimately accrues positive results for road authorities. It can be said that virtually every BIM use or application (listed in the BIM uses chapter) ultimately helps authorities execute projects on time and within budget.

As road authorities in many countries are becoming more actively involved in BIM, the opportunity is even greater to align the use of BIM with those authorities' specific goals – to collaborate more effectively with all stakeholders, to increase the value of BIM beyond construction and further into infrastructure management.

BIM, which initially began as a design tool and evolved to meet the requirements of leading suppliers, increasingly serves road authorities around the world. Considering the impact of BIM on owners, the following observations are made with the aim of assisting owners in implementing and obtaining greater value from BIM in managing their infrastructure assets.

### 7.1.1. Road Authorities should actively embrace BIM

Compelling evidence from many research studies demonstrates Building Information Modelling's significant benefits for various types of projects. Authorities should become familiar with the available resources – both from materials available online and from consultants, designers and contractors who can help road authorities to either initiate a BIM programme or expand their existing BIM use to yield greater benefits.

### 7.1.2. Determining an organization's BIM goals

There is no universal recipe for introducing BIM into a business or organization. However, one of the great advantages of BIM is that each organization (including road administrations) can uniquely apply BIM to meet its specific challenges in the areas in which it operates and adjust processes and expectations to these goals.

Owners should speak with the most common partners, BIM consultants or design-and-construction teams to help identify achievable goals based on their BIM maturity. This is an important step in the gradual introduction of BIM to define the appropriate requirements that will emerge when implementing upcoming projects.

### 7.1.3. BIM planning and prioritization is key

Once the BIM owner's goals have been identified, it is crucial to invest the time to plan the BIM at an early stage. It is useful to determine which processes and actions will be expected to benefit from the implementation of BIM in the first stage. Experience so far speaks of the need to prioritize and to set goals gradually rather than deploying BIM by administrative decisions – simply proclaiming a BIM-capable business by purchasing IT equipment and new software. The logical step is to begin application in the study, planning and design processes that have the most relevant experience and are the most documented.

### 7.1.4. Monitor progress and further improve processes

Road authorities should track the progress of the process against the goals set, analyse the results and make corrections as needed. Experienced BIM owners know that not every aspect of the plan will fully meet expectations. BIM involvement is more about changing the process than about the technology. Owners, for example, must be open to further adjusting the data exchange requirements, format and function of the handover material in various design stages.

### 7.1.5. Established BIM experiences increase BIM benefits

The results of research studies[9] show that the benefits of BIM directly increase for companies where a higher percentage of their projects involve BIM. However, organizations that are starting to implement BIM processes face a number of early-stage challenges, and it is necessary to overcome the most common initial resistance such as the desire of some employees to continue working according to earlier-established processes.

Experienced BIM owners, who have already undertaken initial efforts, costs, process changes and sometimes cultural changes are now in a position to enjoy improved project results and more advanced capabilities to use data modelled through BIM processes.

### 7.1.6. Explore the capabilities of the BIM application for maintenance processes

Road authorities must identify options for using BIM data after construction and place requirements in their initial BIM plan with design and construction companies to ensure that data is transmitted correctly and in a timely manner. The operational phase and maintenance of infrastructure assets lasts longer than any other phase of the project, so the benefits gained here have long-term effects.

The early implementations of BIM had an emphasis only on improving efficiency in design and construction processes, mostly because of the maturity of BIM tools from these domains at that time.

This goal is still significant, but recent trends focus on lowering the cost of a structure throughout its life cycle. Investors realized that the introduction of BIM is key to achieving this goal. For example, the BIM initiative in the United Kingdom (as one of the most cited implementations) includes operating and maintenance BIM as one of its main rules.

Therefore, when implementing BIM, it is necessary to investigate ways to use infrastructure models (such as build-to-build models) that would be useful in achieving the stated end goal. For vertical structure projects, the most cited term is facility management (FM), with the COBiE system serving as a catalyst for information exchange.

Not surprisingly, most current property management practices rely on retrospective asset data collected and interpreted after design and construction and on a large existing property database. As BIM has matured, it now offers significant savings in cost and effort, and improved quality and relevance if information can be acquired as an integration of BIM and asset information management disciplines.

In addition, BIM implies an improved project management level and analysis, which has an impact on the measurable performance of the entire project and is reflected in the maintenance phase. Therefore, the impact of BIM includes the following:

- Reduced repair costs after construction and operating costs due to better project control and data continuity assurance
- Linking geometrically well-defined 3D models with attribute data to asset management and facilities management systems
- Locating and identifying built facilities for inspection and maintenance activities
- Providing better estimates for the needs of rehabilitation, renovation or replacement, which will be based on better and more comprehensive information

The maintenance and repair of individual assets are carried out according to more complete organizational values that include total asset expenditures rather than isolated operating and capital expenditures.

In conducting maintenance and repair in this way, what is being applied is the discipline of managing assets from the early planning of new or upgraded assets through design and construction, rather than after construction.

In this context, the asset manager has a vital interest in receiving complete, accurate, validated and verified information, and maintaining that information throughout the life of the property. This makes the asset manager a key stakeholder in digital information, providing a clear driver for the demand for information standards.

Demand for asset management data has been recognized as one of the key deliverables and is therefore an important factor in delivery that uses BIM for both new assets and existing ones that are updated and maintained. However, standards for the delivery of this data are often overlooked in the further development of BIM for infrastructure. Thus, guidelines and standards are most often oriented toward the life cycle design phase and are concentrated on the geometric representation of the BIM components.

One of the materials available that addresses this topic in detail is the document "Infrastructure Asset Managers BIM Requirements", published by buildingSMART International[10]. This report aims to bring the requirements from asset managers into view to inform the commissioning and

9 Dodge Data & Analytics, "The Business Value of BIM for Infrastructure 2017" (2017). Available at https://www.construction.com/toolkit/reports/the-business-value-of-BIM-for-infrastructure-2017

10 Phil Jackson, 9 January 2018. Available at www.buildingsmart.org/wp-content/uploads/2018/01/18-01-09-AM-TR1010.pdf

development of future standards, including IFC, data dictionaries and object libraries. This is done by analysing the requirements and reporting them systematically in line with existing and projected standards to provide a recommended roadmap for future standards development, including potential benefits and business case.

#### 7.1.7. Explore the positive experiences of a government-backed BIM mandate in the United Kingdom

In the United Kingdom, BIM is well-designed and executed with noteworthy government influence. From the beginning, it has focused on the entire infrastructure life cycle and provides the appropriate standards, processes and materials that support BIM implementation processes. Governments looking to improve productivity in their construction industries are advised to study the United Kingdom model of applying the BIM approach and adapt it to their economies for the desired technical and technological advances. With a general framework that other governments could similarly establish, it would be much easier for road authorities to fully improve their own processes through BIM technology.

## 7.2. Surveyors

In addition to the traditional approach, typical surveying methods include aerial imagery, LiDAR and ground penetrating radar (GPR). The method used depends on the particular project or can be a combination of all the above. For instance, GPR is useful for underground utility locations. For large infrastructure projects in urban or suburban areas, 3D city models could also be an important dataset.

None of these are innovations in the profession itself. The technical approach to the performance of the works is not significantly different from the use of BIM technology, but surveyors should work closely with the other parties involved in the project to determine how their results can be more valuable together.

Over the years, surveyors have traditionally been outpaced by clients when it comes to converting recorded data into information-building models. BIM technology enables surveyors to provide more quality services and create greater value by developing intelligent models that promote a better understanding of the overall environment.

Furthermore, the surveyors must understand that they have a role in each stage of the design and construction process. With BIM technology, they need to communicate with multiple disciplines, in real time, through a project management environment (i.e., a CDE platform).

## 7.3. Designers and designer companies

### 7.3.1. The challenges

Throughout the design process, the designer should maintain a balance of the scope, schedule and cost in line with the client's budget and requirements. Any untimely change can cost money and time. Using traditional methods, it usually takes a lot of time and effort to produce cost estimating and scheduling information. However, using BIM, all the design documents, schedules, quantities and other vital information are immediately made available form a single source. This puts the designer and project team in firm control to produce accurate designs in a collaborative way, more quickly and effectively, without painstaking manual checks, giving the design team time to work on significant engineering problems.

Although most designers already use advanced software systems with a significant number of BIM-based tools, the application is usually not complete and comprehensive. This is usually due to the impacts highlighted in the following sections.

#### 7.3.1.1. Cost

Costs are an important factor for further adoption of BIM within the company. There may be a general impression that BIM represents a greater expense than traditional 2D planning and design. The management of a company must understand the long-term advantages of BIM and invest the money needed for development and research within the company. Additional costs for the implementation of BIM during planning and design should also be borne by the contracting authorities because the BIM application will reduce investment costs during construction significantly.

#### 7.3.1.2. Time

The time to implement is also a factor of successful BIM application. A lack of time or generally short planning and design phases often result in designers continuing to work with traditional 2D drawings. The lack of BIM experience sometimes leads to a fear of failure to meet deadlines and is therefore a major obstacle to the introduction of BIM. A learning period always exists, but as soon as knowledge is acquired and adapted to the new way of working, modelling in 3D is much more efficient and ultimately leads to time savings.

#### 7.3.1.3. Knowledge & Training

Insufficient knowledge or training is also an obstacle to successful implementation of BIM. It is desirable that designers have direct access to people who already have knowledge and experience in some BIM and 3D modelling segments. In this way, time constraints and lost time are avoided by looking for specific work procedures that are already known to at least some of the employees.

#### 7.3.1.4. Unclear vision of delivery format

Designers have long been taught to deliver projects in the traditional way, on paper. This did not change even in the 1990s when CAD began to appear, as the delivery format remained the same. The transition to BIM has a great impact since designers deliver a 3D model with appropriate data. Therefore, during the initial period there are frequent misunderstandings about model formation, required precision (LOD), file formats or necessary attribute data.

#### 7.3.1.5. Software limitations

Many packages exist on the market that highlight support for BIM for infrastructure (BIM ready). Software manufacturers know one tool is not sufficient for complete implementation of BIM and offer a range of products that, together, could cover the whole process at more affordable prices. In practice, however, many of the suggested workflows are hard to implement for designers. Most procedures demand knowledge of more than one primary software and even a certain level of programming, or require additional packages to finish a task. To implement BIM demands, designers must usually adopt additional knowledge, which can cost companies time and money. Transferring data from one application to another can sometimes be a problem in terms of the location (corresponding coordinate systems) and the risk of losing part of the data. An example is data exchange between road and bridge design software. For further improvement of efficiency and easier implementation, software companies should further enhance BIM tools to facilitate their use, especially for the level of final and implementation design.

#### 7.3.1.6. Collaboration among designers

Segments of road and motorway projects are often built by subcontractors (for example, noise barriers, power lines, telecommunications infrastructure, etc.). The lack of proper knowledge and experience of subcontractors in BIM can be an obstacle. If subcontractors do not use 3D modelling, this results in additional manual extraction of data from the model – usually several times – which can also cause errors and delays. It is therefore necessary to achieve the necessary level of cooperation, which will be facilitated by defining the format and types of files to be exchanged and the rules of communication on the project. These provisions are best agreed upon at an early stage of the project and incorporated into the BIM Execution Plan.

### 7.3.2. Reasons to adopt the BIM approach

Design companies must have in mind that BIM is rapidly changing the nature of how infrastructure projects are designed, built and operated, so without successful application of this software a company will no longer be competitive. Thus, the initiative needs to be taken to adopt such new technologies.

Firstly, for designers this means a mandatory model-based approach when designing. For designers already using 3D models in their day-to-day operations but not yet applying BIM to the whole process, adaptation to BIM will not be a significant problem. On the other hand, designers accustomed to traditional 2D drafting-centric design will have to invest more effort to achieve the required maturity level. One example is traditional cross section drawings that are usually detailed, but without continuity between them. This is particularly visible in intersections where the model approach only achieves the level of accuracy required for the quantity take-off and construction.

Design companies that have a well-established CAD management system and already use an advanced collaborative project system (like Autodesk Vault from Bentley Project Wise), it will certainly be easier and faster to adapt BIM at the required level.

In addition to the further evolution of the technical capabilities of software, digital technologies are introducing changes in the design and approach of solving engineering problems and dilemmas. For example, parametric design tools can effectively create variant solutions according to user-defined specifications or requirements. However, the results obtained should be properly interpreted and evaluated.

The possibility to test and optimize generative design probably becomes as important as the ability to imagine the original design. The application of modular construction methods has made it more important to standardize design elements and store them in user libraries so that they can be used repeatedly. Unfortunately, the number of standardized elements in infrastructure projects is relatively small (especially in comparison with architectural projects), but some still exist. Most often these elements are structural elements (e.g., bridges), drainage elements (manholes, separators, grid lines, etc.), road lighting and numerous elements of traffic equipment and signalling (traffic signs, portals, protective fences, etc.).

Applying these new techniques requires designers not only to learn technical skills, but also to design in new ways. Design firms should improve with new technical skills – for example, by hiring developers to build user libraries of design elements and explore the possibilities of automating specific parts of the design process (for example, various scripts for repetitive tasks). This usually means the advanced use of authorization tools (with the assistance of additional software-oriented tools) and a higher level of customization of factory-preset software to the actual needs of a project or local standards.

This means a further evolution from the traditional, linear design process to a more agile approach that consists of faster iteration in short loops for performance and other testing. Such a change requires the designer to adopt new ways of thinking, using their experience to validate model results and explore the possibilities for standardization and repetition, even when this is not possible at first glance. This mode of development furthers the ability of designers to focus on more intellectually demanding problems, such as designing, reviewing and refining design, for which the brain's engineering potential is irreplaceable.

## 7.4. Contractors

In general, BIM methodology allows better construction efficiency. The model-based approach and data continuity allow more accurate and competitive bids. Early access to models allows contractors better understanding of the projects, adding more time to evaluate various activities (logistics, earthwork activities, temporary roads, etc.). Construction companies can benefit from easier identification of cost reduction initiatives and elimination of wasteful activities.

For engineers in the field, BIM uses GPS logging, mobile computing and access to a CDE platform with the latest project and model information, which is an additional benefit.

All these known benefits, based on various BIM uses, have a positive effect for the contractors. Therefore, contractors in the infrastructure sector have, in recent years, begun to apply BIM technologies and supported processes, but companies expect their efforts to bear fruit as soon as possible.

Despite the good intentions and efforts to integrate digital technology into businesses, a significant proportion of contractor companies still show an under-utilization of BIM in their processes. There are various reasons for this, but companies can overcome them. Some of the suggestions outlined in this report will improve the chances that digital transformation will bring tangible benefits to their businesses.

Research and experience from markets with a well-formed and developed BIM framework (like the United Kingdom) show that the companies which first took decisive steps – and those companies that quickly followed – now enjoy significant benefits. For companies that have failed to do more than experiment with technology solutions, now is the time to react quickly and increase efforts.

### 7.4.1. Challenges for the systematic application of BIM in the contractor sphere

The infrastructure construction segment is one of the least digitized industry sectors, due to understandable difficulties. A typical infrastructure project has a number of standard elements, while it can be said that every project of a road or motorway is virtually unique. Road projects involve a multitude of independent subcontractors and suppliers who have little incentive to adopt new working methods during the short periods when they are involved with a particular project.

Limited R&D budgets prevent businesses from spending on digital solutions as much as companies in other sectors do. Furthermore, road construction work often takes place in remote, inhospitable environments that are not well adapted for hardware and software developed primarily for office environments.

Despite these difficulties, an increasing number of companies are finding ways to overcome these challenges in order to digitally transform projects and business processes using BIM.

For digital transformation to be successful, executives and managers must begin with a clear definition of how digitizing processes will create measurable value for the business. Transformation should encompass both operational change and technology.

Digital transformation can mean different things for different stakeholders. Operational enhancements are important to contractors, with advanced technologies and modes being used to enhance development and processes that are important in the implementation of significant projects. The success of the transformation will greatly depend on how successfully the company implements the new ways of working that the technologies enable.

Research results show that digital transformation, if properly implemented, can result in productivity gains of 14–15 per cent and cost reductions of 4–6 per cent[11].

[11] Jan Koeleman and others, "Decoding digital transformation in construction", McKinsey & Company, 20 August 2019.

However, companies from different industries say that digital transformations sometimes do not fully meet expectations. Common challenges include unclear definitions of what digital means, a vague idea of what transformation should accomplish and poor integration of digital tools with current business processes. The following features of typical infrastructure projects make digital transformation particularly challenging:

- Fragmentation – Typical motorway construction projects involve the participation of many professions, often involving multiple contractors and many subcontractors. A new construction project usually includes a new set of organizations that often work together for the first time. At the company level, workforce turnover is often high. Project-level transience and the volatility of companies and business associations make it difficult to establish new ways of working and to create new capabilities that would be transferred from one project to another. Therefore, implementation of digital solutions at the project level requires the introduction of coordinated change among different organizations, which is a difficult task.
- Lack of replication – Every major road infrastructure project is unique, often with unique requirements. Typical examples are the various geo-mechanical problems along the route and the construction of bridges or tunnels. Because equal challenges are rarely repeated in exactly the same form, it is more difficult to make systematic changes than is required by the transformation as a whole. The exception is multi-year major projects where companies can establish repetitive processes and improve them over time.
- Decentralization – Large construction companies tend to be highly federal, with business units and departments following their own established processes that are not standardized at the company level. Individual projects take place away from the company's office where it is difficult to find a suitable place to teach workers how to work in new ways or use advanced technology.

### 7.4.2. Recommendations for more effective implementation of BIM uses and processes

To counter the challenges outlined above, contractors need to be mindful in their approaches to digital transformation.

Experiences in this field suggest accepting the following recommendations to increase the likelihood of successful implementation of digital processes based on BIM technology.

Focus on improving individual processes – companies around the world are upgrading and replacing legacy information systems while deploying new systems and software to increase engineering and field productivity. In doing so, they put into use cutting-edge technology tools before they know whether these tools can improve their business. Often, these solutions do not bring tangible benefits because they are not actually accepted or implemented by actual users.

Contractors can increase the likelihood that digital technologies will make a positive difference by first identifying operational changes that will improve performance and then defining specific applications of BIM technology that will enable operational changes.

This process-centred approach helps focus each use case on a real business need. Use cases defined in this way bring greater benefits while building understanding and belief in the workforce, from the CEO to executives and frontline workers of different functional groups and decentralized business units. Such use cases are also easier to replicate across multiple projects and when involving new workers.

Concentrating on improving business processes should not cease after the first wave of use cases. Creating use cases is an ongoing effort, and new opportunities for improvement often arise after the first use cases are established. A good use case-focused approach should be as specific as possible, listing three things – process change, tools and technology needed, and expected benefit.

For example, a use case defined as "Reducing losses due to resolving service clashes in the left road shoulder km 12+000 – km 15+000 using a 3D analysis tool" is easier to understand and respond to than a use case defined as "Providing access to three-dimensional models from all devices".

#### 7.4.2.1. Use tools that promote collaboration on site

Significant losses in efficiency can occur because information is not effectively transmitted during the handover between different professions and functions on the project.

Companies should pay particular attention to activities involving multiple disciplines and groups, and apply BIM uses that enhance interactions between them. For example, reporting progress in real-time construction time (using BIM 4D analysis) can help subcontractors quickly bill their share of work, which is a powerful incentive. Multiple use cases can unlock significant value despite industry fragmentation.

Traditionally, construction site workers did not typically provide suppliers with feedback on perceived deficiencies in the elements made by the supplier. If they did send feedback, it was usually sporadic and unstructured. As a consequence, the manufacturing process faces unnecessary repair work on defective products and time delays.

Such problems can be minimized by improving the feedback mechanism to suppliers. There are many BIM construction coordination tools that support mobile applications to indicate the defects of certain building elements or BIM models, with options to save to a shared data environment (CDE platform). The supplier monitors the reports of defects in the CDE and eliminates deficiencies as needed. The benefit of enhancing communication between these previously unrelated organizations can be considerable in some cases.

#### 7.4.2.2. Improve process connectivity for a more efficient sequence of activities

Some executives mention a limited increase in productivity from the implementation of digital processes, which has little impact overall while the savings on the added productivity do not justify the cost of implementing the new software and systems.

This can happen if some processes are improved, but the following actions in the selected chain are, for various reasons, not ready to respond in time, so that unproductive time still remains. For example, there is little benefit in reducing the time required for surveying and site preparation using modern BIM surveying if construction machinery and operators are not in place to begin earthwork as soon as the surveying step is finished.

Managers can reap the benefits of increased productivity by compressing on-site schedules or adjusting critical activities. This approach requires close collaboration among the organizations working on the project, as well as clear communication about the project demands, especially with new workers who are accustomed to the existing pace of execution. Companies can also adjust contracts and propose incentives for the appropriate distribution of benefits and risks throughout the value chain.

Knowing how many improvements can be created will help with future adjustments to the level of resources, schedules and the prices of each service.

#### 7.4.2.3. Connect projects to spread the positive impact across the business

In a typical decentralized construction company, business unit managers typically focus on optimizing their own projects – neglecting current use cases used throughout the enterprise that could unlock a whole new wave of value.

Businesses should standardize their digital tools and platforms across different business units and share as much project information as possible. Using BIM tools means systematic data management, and this collected data should be further used to improve the operations of the entire company in accordance with the following aims:

- consolidate cost and scheduling data from multiple projects and business units to increase the accuracy of bids for future tenders, and thus increase profits
- gain an enterprise-wide view of resources to optimize resource loading and respond quickly when project changes are required
- create central repositories for designs at the element, package and project levels so that knowhow and valuable experiences can be repurposed on future projects

Contractors need to choose the right time to start creating enterprise-wide use cases. This will often be after scaling different project-level BIM uses developed in the first pilot projects and propagating them across the business.

#### 7.4.2.4. Recommendations for short-term investments:

- training of knowledge engineers in connection with the BIM tools (use of CDE platform, knowledge of BIM analysing tools for performing clash detection analyses, 4D and 5D simulation)
- investing in survey technology needed for the application of BIM-compatible methodologies (drones, laser scanners)
- investment in equipment that enables automated, model-based and GPS-guided grading

# 8. BIM maturity measure and overview of maturity assessment methods and tools

## 8.1. Introduction

Generally, maturity is defined as the state of being fully developed. Therefore, to become fully developed in something is not easy to achieve; one must pass through a set of evolutionary stages until reaching the desired level of sophistication. BIM maturity represents quality, reproducibility and degrees of excellence in providing BIM models. There are a growing number of BIM models and maturity assessment tools. All of these evaluation models are intended to measure the maturity of BIM for an organization, project or individual.

This section of the report aims to compare the current tools and models available to determine their suitability for measuring BIM maturity from owners to designers to contractors in the infrastructure area.

In the last decade, the development of Building Information Modelling Assessment Methods (BIM-AMs) has been the subject of considerable research. This development has led to sixteen assessment methods (AMs) introduced by academics and practitioners. Each assessment method, through its tools, provides a unique perspective on BIM performance, with different sets of measures and a different focus on assessment.

The first published method was the National BIM Standard Maturity Capability Model (NBIMS-CMM), developed in the USA by the National Institute of Building Sciences. The NBIMS-CMM consists of eleven critical BIM measures, including business process, delivery method, richness of information and accuracy of information. It focuses only on information management and is therefore criticized for not reflecting all aspects of BIM.

The emergence of new BIM-AMs sought better ways to measure BIM. Frameworks such as BIM Matrix, Virtual Design and Construction (VDC) Scorecard and BIM Maturity Measure (BIM-MM) have been designed to enhance previous models. The procedures are supplemented by various measurement areas that represent much broader dimensions of BIM. Researchers have seen the need for and benefits of BIM-AMs. They explained that BIM-AMs help companies measure their own successes and/or failures, identify areas for improvement and compare their BIM progress against other companies.

Nonetheless, the field of research for BIM-AMs as a whole continues to face fundamental challenges, such as overall experience in conducting practice assessments. Most BIM-AM studies focus on the introduction and promotion of new models rather than their application in the architecture, engineering and construction industries. In the reviewed literature, case study project publications are available in a smaller number of cases.

The following table provides an overview of existing tools and methods. As the table shows, there are sixteen models developed in different countries. The advantages and disadvantages of these models vary greatly. For example, BIM-MM primarily assesses the BIM maturity of projects. It seeks greater links between meaningful measures that reflect broader BIM perspectives rather than focusing on one area, as in NBIMS-CMM. BRE certificates require a third party to complete the assessment, which includes fees, and the process is primarily focused on meeting BIM level 2 by British standards.

**Table 6**
**Current BIM-AM and tools**

| BIM-AM | Year developed | Origin | Reference |
|---|---|---|---|
| NBIMS-CMM | 2007 | U.S. | (McCuen et al., 2012) |
| BIM Excellence | 2009 | Australia | (Change Agents AEC, 2013) |
| BIM Proficiency Matrix | 2009 | U.S. | (Indiana Univ. Architect's Office; 2009) |
| BIM Maturity Matrix | 2009 | Australia | (Succar, 2010) |
| BIM Quickscan | 2009 | Netherlands | (Berlo et al.,2012) |
| VICO BIM Score | 2011 | Global company | |
| Characterisation Framework | 2011 | U.S. | (Gao, 2011) |
| CPIx BIM Assessment Form | 2011 | UK | |
| Organisational BIM Assessment Profile | 2012 | U.S. | |
| VDC Scorecard/bimSCORE | 2012 | U.S. | (Kam, 2015) |
| Owner's BIMCAT | 2013 | U.S. | (Giel, 2014) |
| BIM-MM | 2014 | UK | (Arup, 2014) |
| Goal-driven method for evaluation of BIM project | 2014 | South Korea | (Lee & Won, 2014) |
| The TOPC evaluation criteria | 2014 | Australia | |
| BIM Level 2 BRE certification | 2015 | UK | |

*Source:* Chengke Wu and others, "Overview of BIM Maturity Measurement Tools", Journal of Information Technology in Construction (ITCon), Vol. 22 (January 2017).

## 8.2. Overview of the most appropriate BIM maturity assessment tools

### 8.2.1. NBIMS-CMM

The first BIM maturity measurement tool is the NBIMS CMM, proposed by the National Institute of Construction Science in 2007 in the United States. The model evaluates BIM implementation in 11 areas using a 10-level scale. The final maturity score of BIM is calculated by weighting the sum of all areas. The rating is mapped to a five-level maturity model to determine the degree of maturity that the BIM user is achieving. However, the weight of the measures can be adjusted by the users according to their own needs, which can reduce the objectivity of this tool.

The number of questions is small, and the structure is the simplest of all tools. The tool has some flexibility because the user can adjust the weight of the question.

Particularly in its initial versions, the quantification of evaluation was rather low and the scope of the audit was limited to the technical aspects of BIM only.

The tool has since been upgraded to Version 3 to provide a more comprehensive overview of multiple maturity models used in the construction industry, acceptable to various stakeholders (e.g., designers, owners) for evaluating information modelling and organizational processes associated with BIM. Other tools and models are offered that may be more appropriate for specific testing needs. Stakeholders can use the initial CMM as a tool to determine their current status while simultaneously planning more complex BIM implementations as targets for their future operations.

There are two versions of the BIM CMM included in NBIMS-US™:

- Tabular CMM
- Interactive CMM

**Tabular CMM**

As shown in the following figure, CMM is a matrix with x and y axes. On the x-axis, one can see 11 areas of interest in no particular order. On the y axis, maturity levels from 1–10 are visible, with 1 being the least mature and 10 being the most mature.

Because words are subjective and open to interpretation, it is possible that people will not always agree on all possible divisions or descriptions of different degrees of maturity, but rather prepare a simplified, consensus-based approach. CMM provides an evaluation tool in which numerous items are structured in a format that can be used by human operators as a starting point for classification in a somewhat standardized continuum. Finally, it is understood that these descriptions will be updated as the community progresses and dictates higher levels of BIM adoption.

**Figure 35**
**Tabular CMM matrix**

| Maturity Level | A Data Richness | B Life-cycle Views | C Roles Or Disciplines | G Change Management | D Business process | F Timeliness/ Response | E Delivery Method | H Graphical Information | I Spatial Capability | J Information Accuracy | K Interoperability/ IFC Support |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Basic Core Data | No Complete Project Phase | No Single Role Fully Supported | No CM Capability | Separate Processes Not Integrated | Most Response Info manually re-collected - Slow | Single Point Access No IA | Primarily Text - No Technical Graphics | Not Spatially Located | No Ground Truth | No Interoperability |
| 2 | Expanded Data Set | Planning & Design | Only One Role Supported | Aware of CM | Few Bus Processes Collect Info | Most Response Info manually re-collected | Single Point Access w/ Limited IA | 2D Non-Intelligent As Designed | Basic Spatial Location | Initial Ground Truth | Forced Interoperability |
| 3 | Enhanced Data Set | Add Construction/ Supply | Two Roles Partially Supported | Aware of CM and Root Cause Analysis | Some Bus Process Collect Info | Data Calls Not In BIM But Most Other Data Is | Network Access w/ Basic IA | NCS 2D Non-Intelligent As Designed | Spatially Located | Limited Ground Truth - Int Spaces | Limited Interoperability |
| 4 | Data Plus Some Information | Includes Construction/ Supply | Two Roles Fully Supported | Aware CM, RCA and Feedback | Most Bus Processes Collect Info | Limited Response Info Available In BIM | Network Access w/ Full IA | NCS 2D Intelligent As Designed | Located w/ Limited Info Sharing | Full Ground Truth - Int Spaces | Limited Info Transfers Between COTS |
| 5 | Data Plus Expanded Information | Includes Constr/ Supply & Fabrication | Partial Plan, Design&Constr Supported | Implementing CM | All Business Process(BP) Collect Info | Most Response Info Available In BIM | Limited Web Enabled Services | NCS 2D Intelligent As-Builts | Spatially located w/ Metadata | Limited Ground Truth - Int & Ext | Most Info Transfers Between COTS |
| 6 | Data w/Limited Authoritative Information | Add Limited Operations & Warranty | Plan, Design & Construction Supported | Initial CM process implemented | Few BP Collect & Maintain Info | All Response Info Available In BIM | Full Web Enabled Services | NCS 2D Intelligent And Current | Spatially located w/ Full Info Share | Full Ground Truth - Int And Ext | Full Info Transfers Between COTS |
| 7 | Data w/ Mostly Authoritative Information | Includes Operations & Warranty | Partial Ops & Sustainment Supported | CM process in place and early implementation of root cause analysis | Some BP Collect & Maintain Info | All Response Info From BIM & Timely | Full Web Enabled Services w/IA | 3D - Intelligent Graphics | Part of a limited GIS | Limited Comp Areas & Ground Truth | Limited Info Uses IFC's For Interoperability |
| 8 | Completely Authoritative Information | Add Financial | Operations & Sustainment Supported | CM and RCA capability implemented and being used | All BP Collect & Maintain Info | Limited Real Time Access From BIM | Web Enabled Services - Secure | 3D - Current And Intelligent | Part of a more complete GIS | Full Computed Areas & Ground Truth | Expanded Info Uses IFC's For Interoperability |
| 9 | Limited Knowledge Management | Full Facility Life-cycle Collection | All Facility Life-Cycle Roles Supported | Business processes are sustained by CM using RCA and Feedback loops | Some BP Collect&Maint In Real Time | Full Real Time Access From BIM | Netcentric SOA Based CAC Access | 4D - Add Time | Integrated into a complete GIS | Comp GT w/Limited Metrics | Most Info Uses IFC's For Interoperability |
| 10 | Full Knowledge Management | Supports External Efforts | Internal and External Roles Supported | Business processes are routinely sustained by CM, RCA and Feedback loops | All BP Collect&Maint In Real Time | Real Time Access w/ Live Feeds | Netcentric SOA Role Based CAC | nD - Time & Cost | Integrated into GIS w/ Full Info Flow | Computed Ground Truth w/Full Metrics | All Info Uses IFC's For Interoperability |



*Source:* National Institute of Building Sciences buildingSMART alliance, National BIM Standard – United States (n.p., 2015).w

**Interactive CMM (I-CMM)**

Interactive CMM is based on tabular CMM and as such contains the same information as tabular CMM, but focuses on a graphical user interface that enlivens static information in a way that may be simpler and more understandable for some users.

The primary and first tab of interest in the Interactive Maturity Model workbook is "Interactive Maturity Model". Areas of interest are listed in the first column to identify their importance (Figure 36).

The following column shows the relative percentage of 100 per cent that each area of interest has. Subsequently, users select their own perceived maturity levels using drop-down menus that are aligned with each area of interest.

Users can select between ten stages of maturity. After selecting the right maturity level in the desired area of interest, the number of credits automatically appears in the next column. Together, these credits are summed in the TOTAL box, which determines the level of certification achieved. The remaining "Maturity Description" and "Category Descriptions" tabs contain the same information as in the tabular CMM.

**Figure 36**
**Interactive Maturity Model diagram**

© NIBS 2012

**The Interactive BIM Capability Maturity Model**

| Area of Interest | Weighted Importance | Choose your perceived maturity level | Credit |
|---|---|---|---|
| Data Richness | 84% | Data w/ Mostly Authoritative Information | 5,9 |
| Life-cycle Views | 84% | Planning & Design | 1,7 |
| Change Management | 90% | Limited Integration | 6,3 |
| Roles or Disciplines | 90% | Partial Plan, Design&Constr Supported | 4,5 |
| Business Process | 91% | Most Bus Processes Collect Info | 3,6 |
| Timeliness/ Response | 91% | Limited Response Info Available In BIM | 3,6 |
| Delivery Method | 92% | Web Enabled Services - Secure | 7,4 |
| Graphical Information | 93% | 3D - Intelligent Graphics | 6,5 |
| Spatial Capability | 94% | Spatially Located | 2,8 |
| Information Accuracy | 95% | Limited Ground Truth - Int & Ext | 4,8 |
| Interoperability/ IFC Support | 96% | Limited Info Transfers Between COTS | 3,8 |
| | | **Credit Sum** | **50,9** |
| | | **Maturity Level** | Minimum BIM |

*Source:* ibid.

I-CMM is primarily focused on the use of information management, not architectural, engineering, construction or other management metrics. It is therefore important to note that I-CMM is very effective at measuring the management of BIM information, but should not be used as a benchmark for other areas.

The goals of both maturity models – tabular and interactive – help users assess their current maturity level and plan for future maturity goals using a generally accepted, standardized approach.

## 8.2.2. Arup BIM-MM

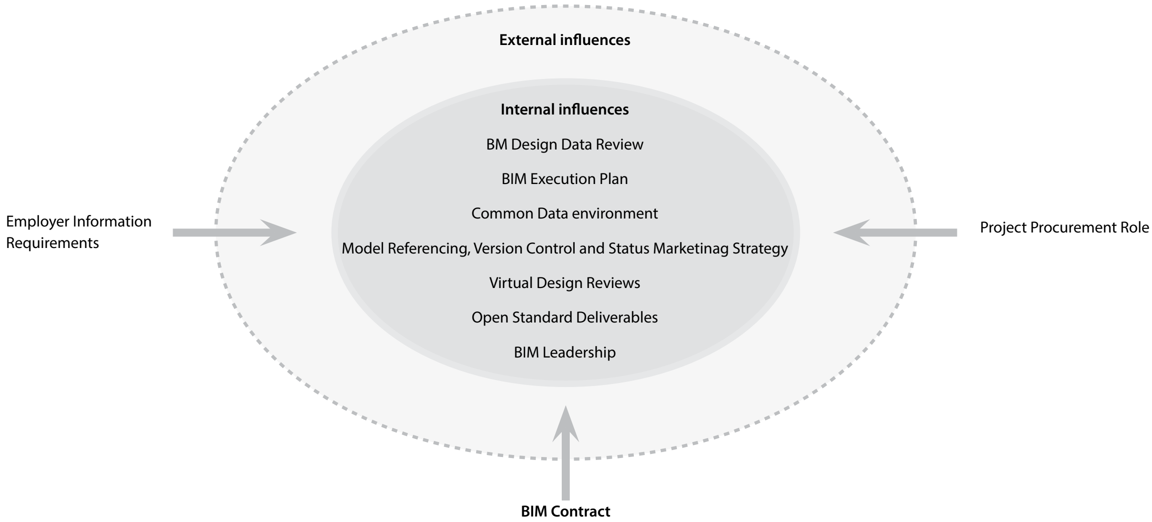
### 8.2.2.1. Tool description

Arup presented its BIM-MM maturity tool in 2014. In order to investigate the functioning of the tool on real projects, the company conducted studies that included a significant data set (the first with 213 projects in 2014, followed by the second study with 1,291 projects conducted in 2016). The BIM-MM studies are considered an analytical framework exploring how BIM is implemented in actual projects, evaluating and comparing the maturity of BIM implementation.

The method itself is based on the BIM Assessment Program (CIC, 2013) under a Creative Commons 3.0 license. The testing process is important for BIM professionals and consultants to review their progress over time, for academics to study current challenges and opportunities, as well as for board members and national policymakers to create an overall picture of BIM implementation at company and national levels. The Arup BIM-MM tool uses a self-assessment method and is free. Furthermore, BIM-MM is user-friendly and efficient, which attracts more interest than models that are detailed and complex. Further optimization will require further implementation in practice, which will increase the tool's effectiveness and lead to future guidelines for its development.

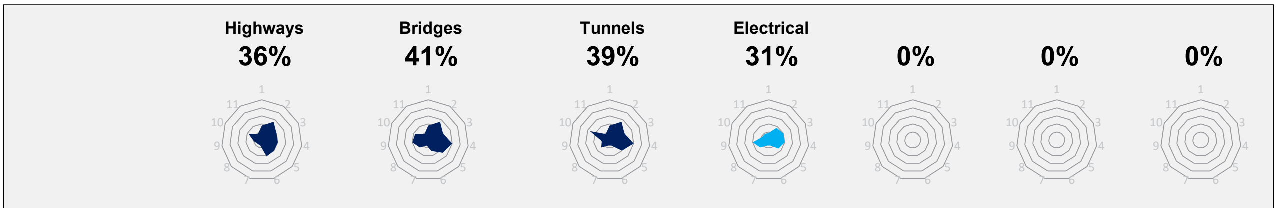
The BIM-MM consists of various measurement criteria relating to internal and external forces that affect the application of BIM (Figure 37). Internal forces reflect key BIM criteria, such as virtual design reviews and shared data environments (CDE), while external forces relate to client drivers when implementing BIM, i.e., employer information requests (EIR), project procurement paths and BIM contracts.

## Figure 37
## Internal and external forces of BIM in BIM-MM assessment method

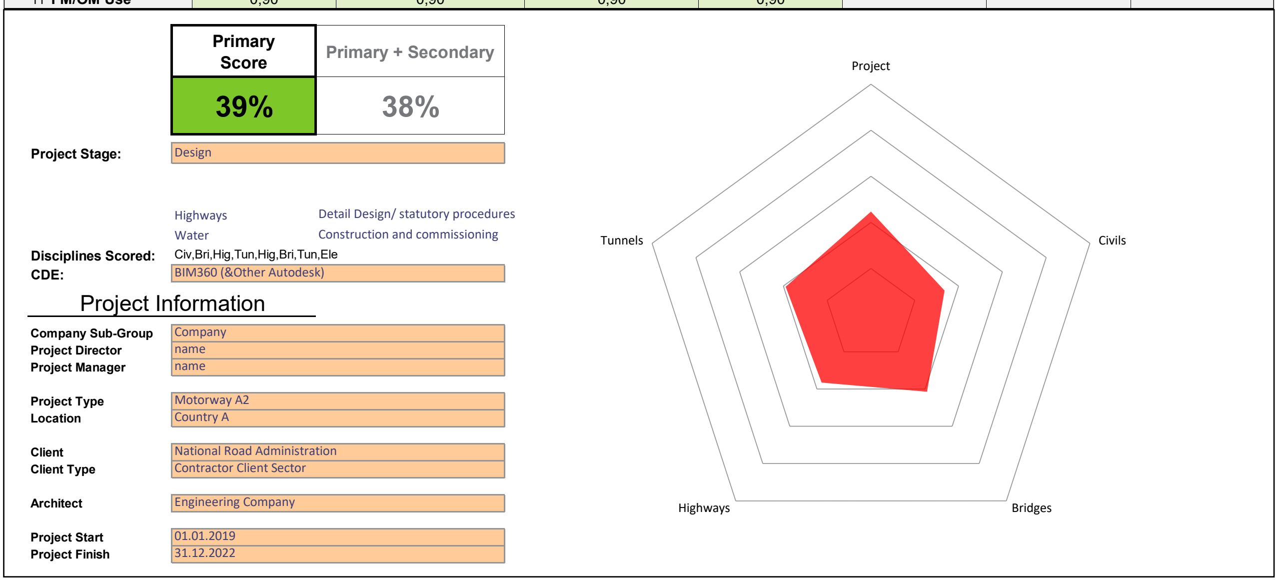



*Source:* Ammar Azzouz and Paul Hill, "How BIM is assessed using Arup's BIM Maturity Measure?", in P W Chan and C J Neilson, eds., Proceeding of the 33rd Annual ARCOM Conference, Cambridge, 4–6 September 2017.

## Figure 38
## Snapshots of the BIM-MM, average scores of the project and the assessed disciplines give a primary score of the project as a coherent whole



| | Highways 36% | Bridges 41% | Tunnels 39% | Electrical 31% | 0% | 0% | 0% |
|---|---|---|---|---|---|---|---|
| 1 **3D Model** | 1,80 | 1,80 | 1,80 | 0,90 | | | |
| 2 **Drawings** | 2,70 | 2,70 | 2,70 | 1,80 | | | |
| 3 **LoD** | 2,00 | 2,00 | 2,00 | 2,00 | | | |
| 4 **Reviews** | 2,00 | 3,00 | 3,00 | 2,00 | | | |
| 5 **Data** | 2,00 | 2,40 | 2,00 | 1,60 | | | |
| 6 **Visualisation** | 2,10 | 1,40 | 0,70 | 0,70 | | | |
| 7 **4D** | 0,70 | 0,70 | 0,70 | 0,70 | | | |
| 8 **5D** | 0,70 | 1,40 | 1,40 | 1,40 | | | |
| 9 **Analysis** | 1,00 | 2,00 | 1,00 | 2,00 | | | |
| 10 **Contractor Use** | 1,80 | 1,80 | 2,70 | 0,90 | | | |
| 11 **FM/OM Use** | 0,90 | 0,90 | 0,90 | 0,90 | | | |




*Source:* Arup Group, BIM Maturity Model tool. Available at: https://www.arup.com/perspectives/publications/research/section/bim-maturity-model.

The audit is conducted through 20 critical criteria that cover 2 main parts:

1. Project – This first part of BIM-MM assesses project-wide processes and practices. It looks at the project from an overarching perspective rather than focusing on assessing BIM in a specific discipline involved in the project. Completion of this section results in the creation of an Information Management Score (IM Score), on the left side of Figure 38.
2. Disciplines – This part assesses the specific disciplines involved in the project, such as civil engineering, architecture, mechanical and electrical disciplines (right side of Figure 38). The assessments sheets of these disciplines are mostly similar, but each has a section for user-defined specific discipline criteria.

The current version of the BIM-MM tool anticipates three main areas (buildings, infrastructure and consulting), and primary and secondary disciplines can be selected for each. To complete the assessment, participants must determine one of the six possible maturity levels for each of the measures evaluated. These levels are 0 non-existent, 1 initial, 2 managed, 3 defined, 4 measured and 5 optimizing.

Upon completion of the project evaluation (the first part of BIM-MM), a general evaluation of the information management results (IM Score) is given. In addition, the primary assessment gives average project ratings and the first four selected disciplines (e.g., highways, structures, bridges, tunnels). The ideal scenario is to complete all parts of BIM-MM to get a holistic portrait of BIM implementation across project teams. However, projects can still only be evaluated based on the project part and at least one chosen discipline – e.g., highways.

Using tools such as BIM-MM Arup aims to initiate a more open conversation about using BIM to enhance its positive impact across the project spectrum. Thus, BIM-MM can be used to engage different project teams in a wider dialogue, which adds useful information needed for the decision-making process. It is important to note that not every project is expected to receive the highest levels of BIM implementation, i.e., it is not necessary to require each project team to reach the highest maturity level at every measure. Instead, the goals should be defined by the organization so that the degree achieved is in line with the desired expectations.

#### 8.2.2.2. Conclusions from the conducted studies

The collected data can be analysed and communicated differently according to the aspect the analysis is considering. The analysis of the conducted studies emphasizes correlation between specific criteria and the overall score of projects, as well as BIM best practices across the measured projects.

There are different forces that impact the successful implementation of BIM in projects. Internal forces are shaped by the companies themselves, while external forces are driven by the client.

The studies conducted indicate associations between different BIM criteria and the average overall project evaluation. These analyses focus specifically on the impact of the BIM Execution Plan (BEP) and the review of BIM Design Data Review (BDDR) on the overall results. BEP refers to the formalization of digital design goals and specifying standards, roles, procedures and information sharing. BEP, like all other criteria in BIM-MM, has six stages of maturity of which participants must select one to define the current state of their projects. These levels evolve from level 0 at which the criterion does not apply, to level 5 at which the criterion is most optimized.

Observations of the findings show that there is a significant correlation between effective BEP and a high project maturity rating. For example, the average overall IM score with BEP 5 (68 per cent) is over 6 times the average score of projects without BEP (10 per cent). Similar findings were observed when looking at the relationship between BDDR and the total number of projects.

With the development of BIM, new roles in the AEC industry have emerged. The so-called BIM champion is one of these emerging roles being evaluated in BIM-MM. A BIM champion is a person who has the motivation and technical skills to lead teams to improve their processes, encourage the use of BIM and manage change resilience. Interestingly, project average scores are higher when the BIM champion has greater involvement in the BIM implementation process. This segment was particularly the focus of the first survey conducted in 2014. The average IM score of projects with a champion level 5 (57.6 per cent) was over 3 times higher than the average score without a BIM champion (14.6 per cent). The observed relationship between BIM champions and overall project outputs can be explained by the fact that BIM champions take action to lead the three major dimensions of BIM – technology, process and policy. By looking at these three dimensions, BIM champions ensure that teams do not treat BIM according to its fractional elements but instead look at the bigger picture. They also define the current status of BIM and direct the teams toward their desired goals.

By using tools such as BIM-MM, BIM best practices can be identified. Based on 1,291 evaluated projects, the Information Management Score in the top 10 projects is above 80 per cent (the highest is 93.4 per cent).

The Information Management Score focuses on the first part of BIM-MM – the project rather than the specific discipline. It reflects eleven criteria, including employer information requirements (EIR), BIM design data route (BDDR), BIM Executive Plan (BEP), project procurement path (PPR), common data environment (CDE), document or model referencing, version control and status (Doc Ref), marketing strategy, virtual design reviews (VDR), open standard deliverables (OSD), BIM contract and BIM champion.

Furthermore, the top-rated projects have the following features:

- Documentation, model referencing, version and status (Doc Ref). These are extremely important in model sharing (upload to a CDE platform) where recipients must know what has changed and what they can rely on. Among the top 10 projects, 9 projects have a level 5 rating. This means that these projects have project file naming, version control, and are status compliant with a recognized BIM standard.
- Using the CDE platform, which acts as the so-called sole source of truth, enables robust and controlled sharing and coordination of models, drawings, analyses, documents and data.
- PPR, which refers to the consideration of BIM during procurement talks with the customer, contractors and supply chain. This means that a procurement strategy for the use of BIM needs to be developed.
- The 10 first projects have a high level of maturity. In each project, most of the BIM measures evaluated are allocated to level 3 or higher (two exceptions are noted). All projects have BIM champions who lead teams to improve their BIM implementation, and all projects have BIM contracts that define the responsibilities of different stakeholders. Thus, the successful implementation of BIM in these projects is shaped by multiple integrated influences that reflect the internal strengths of BIM within the organization and external client engagement (all the best projects have BIM contracts and defined EIR and PPR).

### 8.2.3. BIM Maturity Matrix

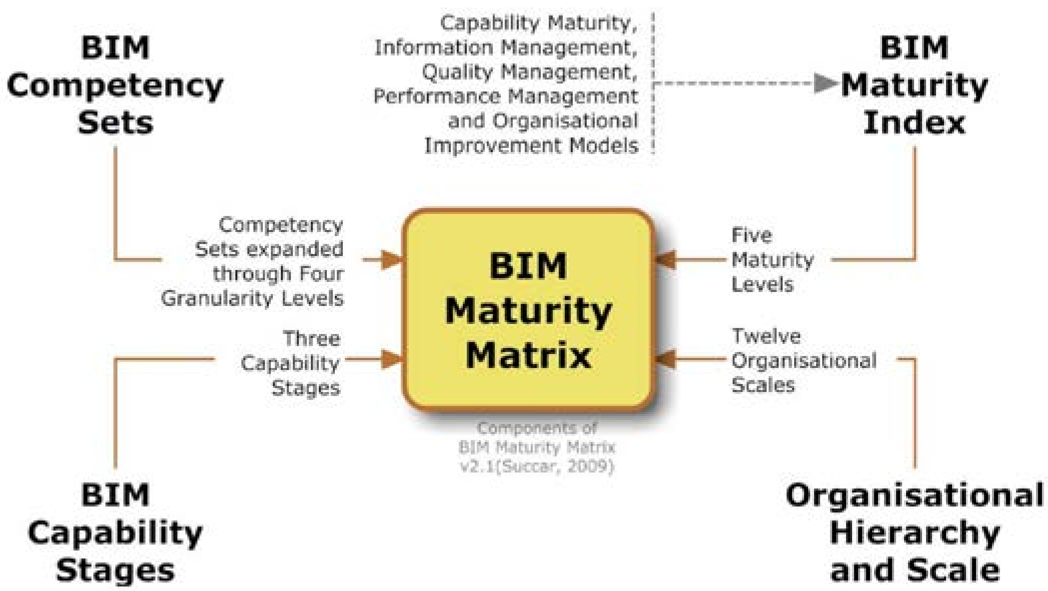
BIM theorist and researcher Bilal Succar has developed a BIM Maturity Matrix that offers a comprehensive evaluation framework based on technology, process and policy. His model is suitable for different types and sizes of organization, using 5 maturity levels based on 12 key maturity areas (Figure 39). One of the main concepts proposed by Succar is the difference between BIM capability and BIM maturity. He defines BIM capability as the ability to perform a task or deliver a BIM service or product, whereas BIM maturity might refer to the quality, repeatability and degree of excellence with which BIM services are executed.

For practical application, the tool BIM Maturity Matrix (Bim[3]) was developed based on a complex Succar's BIM framework. It is intended to identify the current BIM maturity of an organization or project team. The Bim³ has two axes – the BIM capability is placed on the vertical axis and the BIM maturity index on the horizontal axis. The matrix can be less detailed (BIMe Discovery Matrix) or very detailed (BIMe Audit Matrix).

BIM capability refers to the minimum ability of an organization or team to achieve measurable results. BIM maturity refers to the gradual and continuous improvement of quality, repeatability and predictability within the available BIM capabilities.

In order to improve the ability and maturity assessments and increase their flexibility, a special Granularity Filter with four levels of granulation (Glevels) was developed: 1 Discovery, 2 Evaluation, 3 Certification and 4 Auditing.

**Figure 39**
**BIM Maturity Matrix components**




*Source*: Bilal Succar, in Jason Underwood and Umit Isikdag, *Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies* (Hershey, Pennsylvania, Information Science Reference, 2010).

Using high-granularity levels (Glevels 3 or 4) exposes more detailed competency areas than low-granularity levels (Glevels 1 or 2). This variability in breadth, detail, formality and specialization enables the preparation of several BIM performance measurement tools, ranging from low-detailed, informal and self-managed assessments to detailed, formal and expert assessments.

The following figure show examples of a simpler scoring matrix on Glevel 1 that can be used for self-assessment at any organizational level.

### Figure 40
### BIM Maturity Matrix example, Granularity level 1, Technology and Process sheets

BIM CAPABILITY SETS

| TECHNOLOGY based on Capability Set v5 | Key Maturity Areas at Granularity level 1 | a<br>INITIAL<br>(score 0) | b<br>DEFINED<br>(max score 10) | c<br>MANAGED<br>(max score 20) | d<br>INTEGRATED<br>(max score 30) | e<br>OPTIMIZED<br>(max score 40) |
|---|---|---|---|---|---|---|
| | **Software:** applications, deliverables and data | Usage of software applications is unmonitored and unregulated. 3D Models are relied on to mainly generate accurate 2D representations/deliverables. Data usage, storage and exchanges are not defined within organisations or project teams. Exchanges suffer from a severe lack of interoperability.<br>score | Software usage/introduction is unified within an organisation or project teams (multiple organisations). 3D Models are relied upon to generate 2D as well as 3D deliverables. Data usage, storage and exchange are well defined within organisations and project teams. Interoperable data exchanges are defined and prioritised.<br>score | Software selection and usage is controlled and managed according to defined deliverables. Models are the basis for 3D views, 2D representations, quantification, specification and analytical studies. Data usage, storage and exchanges are monitored and controlled. Data flow is documented and well-managed. Interoperable data exchanges are mandated and closely monitored.<br>score | Software selection and deployment follows strategic objectives, not just operational requirements. Modelling deliverables are well synchronised across projects and tightly integrated with business processes. Interoperable data usage, storage and exchange are regulated and performed as part of an overall organisational or project-team strategy.<br>score | Selection/use of software tools is continuously revisited to enhance productivity and align with strategic objectives. Modelling deliverables are cyclically being revised/ optimised to benefit from new software functionalities and available extensions. All matters related to interoperable data usage storage and exchange are documented, controlled, reflected upon and proactively enhanced.<br>score |
| | **Hardware:** equipment, deliverables and location/mobility | BIM equipment is inadequate; specifications are too low or inconsistent across the organisation. Equipment replacement or upgrades are treated as cost items and performed only when unavoidable.<br>score | Equipment specifications – suitable for the delivery of BIM products and services - are defined, budgeted-for and standardised across the organisation. Hardware replacements and upgrades are well-defined cost items.<br>score | A strategy is in place to transparently document, manage and maintain BIM equipment. Investment in hardware is well-targeted to enhance staff mobility (where needed) and extend BIM productivity.<br>score | Equipment deployments are treated as BIM enablers. Investment in equipment is tightly integrated with financial plans, business strategies and performance objectives.<br>score | Existing equipment and innovative solutions are continuously tested, upgraded and deployed. BIM hardware become part of organisation's or project team's competitive advantage.<br>score |
| | **Network:** solutions, deliverables and security/ access control | Network solutions are non-existent or ad-hoc. Individuals, organisations (single location/ dispersed) and project teams use whatever tools found to communicate and share data. Stakeholders lack the network infrastructure necessary to harvest, store and share knowledge.<br>score | Network solutions for sharing information and controlling access are identified within and between organisations. At project level, stakeholders identify their requirements for sharing data/information. Dispersed organisations and project teams are connected through relatively low-bandwidth connections.<br>score | Network solutions for harvesting, storing and sharing knowledge within and between organisations are well managed through common platforms (ex: intranets or extranets). Content and asset management tools are deployed to regulate structured and unstructured data shared across high-bandwidth connections.<br>score | Network solutions enable multiple facets of the BIM process to be integrated through seamless real-time sharing of data, information and knowledge. Solutions include project-specific networks/portals which enable data-intensive interchange (interoperable exchange) between stakeholders.<br>score | Network solutions are continuously assessed and replaced by the latest tested innovations. Networks facilitate knowledge acquisition, storing and sharing between all stakeholders. Optimisation of integrated data, process and communication channels is relentless.<br>score |

| PROCESS based on Capability Set v5.0 | Key Maturity Areas at Granularity level 1 | a<br>INITIAL<br>(score 0) | b<br>DEFINED<br>(max score 10) | c<br>MANAGED<br>(max score 20) | d<br>INTEGRATED<br>(max score 30) | e<br>OPTIMIZED<br>(max score 40) |
|---|---|---|---|---|---|---|
| | **Resources:** Physical and knowledge infrastructure | The work environment is either not recognised as a factor in staff satisfaction or may not be conducive to productivity. Knowledge is not recognised as an asset; BIM knowledge is typically shared informally between staff (through tips, techniques and lessons learned).<br>score | The work environment and workplace tools are identified as factors affecting motivation and productivity. Similarly, knowledge is recognised as an asset; shared knowledge is harvested, documented and thus transferred from tacit to explicit.<br>score | The work environment is controlled, modified and its criteria managed to enhance staff motivation, satisfaction and productivity. Also, documented knowledge is adequately stored.<br>score | Environmental factors are integrated into performance strategies. Knowledge is integrated into organisational systems; stored knowledge is made accessible and easily retrievable.<br>score | Physical workplace factors are reviewed constantly to insure staff satisfaction and an environment conducive to productivity. Similarly, knowledge structures responsible for acquisition, representation and dissemination are systemically reviewed and enhanced.<br>score |
| | **Activities & Workflows:** Knowledge, skills, experience, roles and relevant dynamics | There is an absence of defined processes; roles are ambiguous and team structures/dynamics are inconsistent. Performance is unpredictable and productivity depends on individual heroics. A mentality of 'working 'around the system' flourishes.<br>score | BIM roles are informally defined and teams are formed accordingly. Each BIM project is planned independently. BIM competency is identified and targeted; BIM heroism fades as competency increases but productivity is still unpredictable.<br>score | Cooperation within organisations increases as tools for cross-project communication are made available. Flow of information steadies; BIM roles are visible and targets are achieved more consistently.<br>score | BIM roles and competency targets are imbedded within the organisation. Traditional teams are replaced by BIM-oriented ones as new processes become part of organisation/ project team's culture. Productivity is now consistent and predictable.<br>score | BIM competency targets are continuously upgraded to match technological advances and align with organisational objectives. Human resource practices are proactively reviewed to insure intellectual capital matches process needs.<br>score |
| | **Products & Services:** Specification, differentiation and R&D | 3D models deliverables (a BIM product) suffer from too high, too low or inconsistent levels of detail.<br>score | A "statement defining the object breakdown of the 3D model" is available.<br>score | Adoption of product/ service specifications similar to Model Progression Specifications, BIPS 'information levels' or similar.<br>score | Products and services are specified and differentiated according to Model Progression Specifications or similar.<br>score | BIM products and services are constantly evaluated; feedback loops promote continuous improvement.<br>score |
| | **Leadership & Management:** Organisational, strategic, managerial and communicative attributes; innovation and renewal | Senior leaders/ managers have varied visions about BIM. BIM implementation (according to BIM Stage requirements) is conducted without a guiding strategy. At this maturity level, BIM is treated as a technology stream; innovation is not recognised as an independent value and business opportunities arising from BIM are not acknowledged.<br>score | Senior leaders/managers adopt a common vision about BIM. BIM implementation strategy lacks actionable details. BIM is treated as a process-changing, technology stream. Product and process innovations are recognised; business opportunities arising from BIM are identified but not exploited.<br>score | The vision to implement BIM is communicated and understood by most staff. BIM implementation strategy is coupled with detailed action plans and a monitoring regime. BIM is acknowledged as a series of technology, process and policy changes which need to be managed without hampering innovation. Business opportunities arising from BIM are acknowledged and used in marketing efforts.<br>score | The vision is shared by staff across the organisation and/or project partners. BIM implementation, its requirements and process/ product innovation are integrated into organisational, strategic, managerial and communicative channels. Business opportunities arising from BIM are part of team, organisation or project-team's competitive advantage and are used to attract and keep clients.<br>score | Stakeholders have internalised the BIM vision and are actively achieving it. BIM implementation strategy and its effects on organisational models are continuously revisited and realigned with other strategies. If alterations are needed, they are proactively implemented. Innovative product/ process solutions and business opportunities are sought-after and followed through relentlessly.<br>score |

*Source*: https://bimexcellence.org

**Figure 41**
**Maturity Discovery Score – hypothetical maturity assessment at level 1**

MATURITY DISCOVERY SCORE

| BIM Maturity Matrix<br>Assessment at Granularity Level 1 | | a<br>10 Pts | b<br>20 Pts | c<br>30 Pts | d<br>40 Pts | e<br>50 Pts |
|---|---|---|---|---|---|---|
| **Technology** | Software | | | ● | | |
| | Hardware | ● | | | | |
| | Network | | ● | | | |
| **Process** | Leadership | | | | ● | |
| | Human Resources | | | ● | | |
| | Infrastructure | | ● | | | |
| | Products & Services | | ● | | | |
| **Policy** | Contractual | | ● | | | |
| | Regulatory | | | ● | | |
| | Preparatory | | | | ● | |
| **Stage** | Collaboration [2] | | | ● | | |
| **Scale** | Organisation [9] | | ● | | | |
| **Subtotal** | | **10** | **100** | **120** | **80** | **0** |
| **Total Points** | | | | | | **310** |
| **Maturity Score** | | | | | | **25.83** |
| NOT SUITABLE FOR CERTIFICATION | | | | | | |

*Source:* BIMe Initiative tool. Available at https://bimexcellence.org/resources/300series/301in/

The scoring system for Glevel 1 (Discovery) shown here follows a simple arithmetic model:

- There are 12 individual scores relating to 10 competency areas, 1 capability stage and 1 organizational scale.
- Maturity levels are assigned a fixed number of maturity points – level a (10 points), level b (20 points), level c (30 points), level d (40 points) and level e (50 points).
- The Maturity Discovery Score is the average of total points subdivided by 12.

A hypothetical maturity assessment is given in Figure 41.

Various stakeholders in civil engineering can use the Maturity Matrix tool (Bim$^3$) to:

- Increase their capability across a pre-identified range of technology, process and policy steps
- Accurately assess their own maturity as well as that of potential partners or competitors
- Obtain a Certificate of Maturity or similar; such rewards or certifications are potentially useful for product or service differentiation as well as market positioning
- Continuously assess and improve their BIM performance

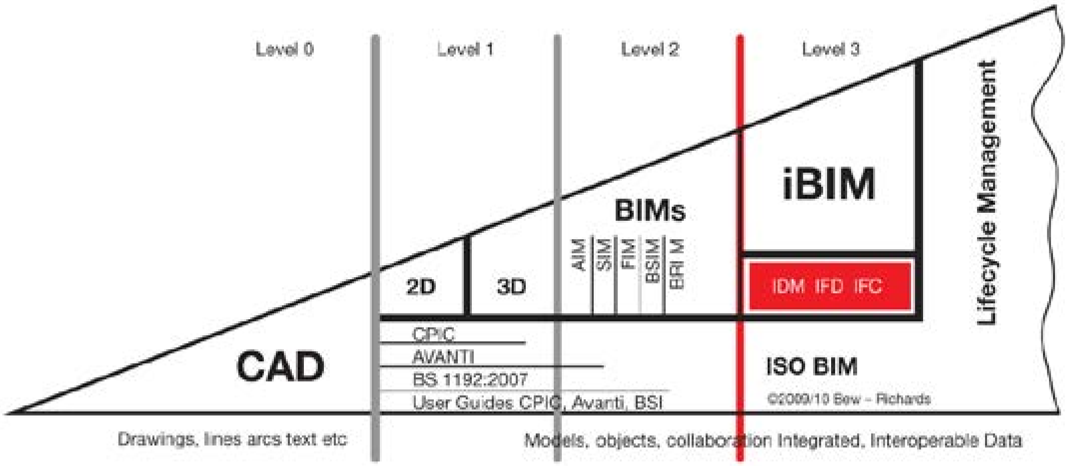
The BIM Maturity Matrix and its underlying BIM framework have been further developed and expanded. An online interactive tool suitable for low granularity and self-maturity assessment is available. The ability and maturity templates, questionnaires, guides, knowledge models and detailed scoring systems continue to be researched, developed and tested.

### 8.2.4. United Kingdom BIM maturity model

In 2011, the Government of the United Kingdom announced a strategy to reduce the cost of assets financed from the state budget, which required the use of BIM level 2 (as defined by the Bew-Richards BIM maturity model displayed in Figure 42) for all public procurement projects by 2016. Though it was a condition for government projects only, the use of the BIM process has been widely accepted in other projects due to the obvious advantages.

The United Kingdom BIM maturity model defines BIM in terms of three levels of maturity. Each level supports the standards that cover BIM management and modelling. For example, the British Government's goal for 2016 was to achieve BIM level 2.

**Figure 42**
**Bew-Richards maturity model**




*Source:* Bew and Richards "BIM Maturity Wedge", as shown in "About BIM", Applecore Designs. Available at https://www.applecoredesigns.co.uk/bim

Level 0

Using CAD as a drawing tool. Drawings (such as CAD files, PDF or printed) are used as a basis for communication and collaboration between teams. Level 0 is not really considered a BIM.

Level 1

BIM level 1 introduces standards for consistent approaches to CAD and 3D modelling and establishes collaboration management practices. BS 1192 provides the basis for BIM level 1, documenting processes for quality control, information sharing, document naming and designation of CAD drawings – the basis of the common data environment.

Level 2

Creating an information model that combines geometric elements into three dimensions with attribute data. All project data and asset information are electronic, with 3D-coordinated design. BIM level 2 is applied at all stages of the project, focusing on the transfer and exchange of information between them.

Level 3

The vision for BIM level 3 is a fully integrated approach to asset management and project management. The information will be available to those who need a format that enables different stakeholders to reuse the information for different purposes. BIM level 3 begins to connect with other digital innovations such as asset management systems and smart cities.

The model is simple, and most can easily understand it. The compliance of organizations with the specifications stated within the model is a measurement system of maturity. This philosophy of measuring maturity cannot measure organizational performance or market maturity. From the point of view of infrastructure projects, the Bew-Richardson diagram is only acceptable for brief estimation.

# 9. Current trends in the development of the BIM approach

## 9.1. The role of the public sector as the initiator of BIM implementation

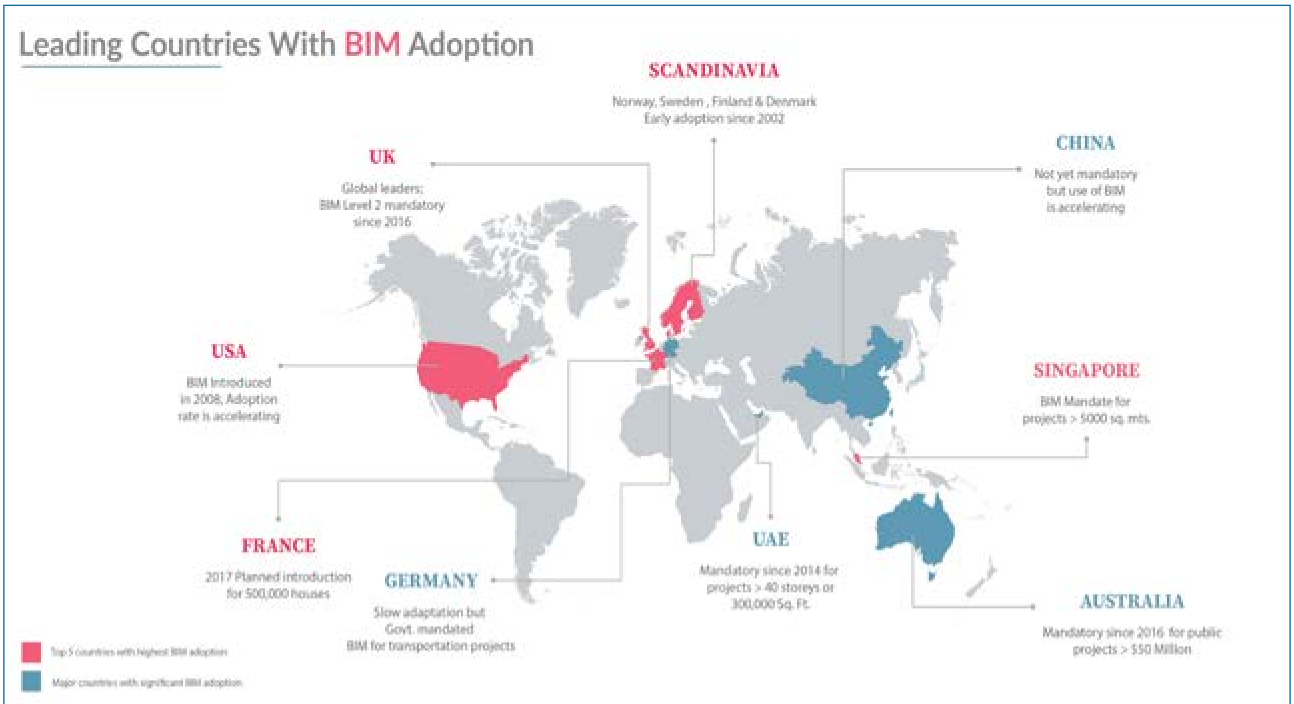
The most successful BIM implementations clearly show the trend that the use of BIM is increasing from the moment the public sector takes the stand to promote its implementation. Therefore, the public sector plays a fundamental role in the development and use of BIM in infrastructure projects. The prevalence of BIM is advancing with greater agility in countries where the government encourages and adopts BIM strategies. As a result, the level of implementation of BIM in each country is closely linked to current government legislation and the intention to promote BIM in public contracts.

Government support is an important factor that encourages the use of BIM and enhances its implementation. Public sector intervention creates an environment of acceptance for new technologies because it gives them not only credibility but also legal or regulatory weight. Therefore, the adoption of BIM by the entire sector is simplified and more efficient.

An important trigger for all European Union member states was the decision of the European Parliament in January 2014 to modernize European public procurement rules by recommending the use of electronic tools such as BIM. The adoption of the directive, officially called the European Union Public Procurement Directive (EUPPD), meant that all 28 European Union member states could encourage, designate or mandate the use of BIM for publicly funded construction projects in the European Union by 2016. Italy and Spain (2019), the United Kingdom (2016), the Netherlands (2012), Denmark (2007), Finland (2007) and Norway (2007) already require mandatory use of BIM for publicly funded construction projects. Germany has done the same since the beginning of 2020. France plans to do so in 2022. This obviously has potentially significant consequences for the implementation of BIM in the region, including TEM member countries.

Figure 43 shows the level of application of BIM, mandatory or recommended, for its use in the public sector worldwide. It should be said that the map takes into account the use of BIM in the construction sector in general and not just for infrastructure projects.

**Figure 43**
**Level of application of BIM, mandatory or recommended, for its use in the public sector worldwide**




*Source:* United BIM, "Leading countries with BIM adoption". Available at https://www.united-bim.com/leading-countries-with-bim-adoption/

The implementation of BIM in different countries is divided into three categories:

- Mandatory use of BIM in public projects – countries that, through government entities, require the use of BIM throughout the project life cycle and that are required to include it in their procurement methods
- Recommendations for the use of BIM in projects – countries whose public sectors have made some efforts to promote the use of BIM through the development of standards, guides, pilot projects, BIM implementation programmes, etc.; however, the use of BIM is optional
- Independent and private initiatives to use BIM – countries whose governments have not taken concrete steps to promote the implementation of BIM; however, in these countries BIM is also used by individual companies (designers, contractors), but in an isolated and independent way

Many countries around the world use BIM tools and technologies. However, the vast majority are focused on the vertical construction sector or implemented through isolated initiatives, which is often the case in TEM member countries.

On the other hand, there are relatively few countries that have included BIM in public contracts and government legislation. The United States is one of the pioneering countries in adopting BIM, as they have incorporated this technology and methodology into several public sector bodies promoting its implementation. Another country that stands out as a leader in public sector BIM implementation is the United Kingdom since it launched the Government Construction Strategy in 2011, which declared that by 2016, all projects with the government should use BIM. Other countries with compulsory use of BIM by public authorities are Norway, Finland, Sweden, Singapore, Hong Kong, South Korea and Australia.

In some countries, governments recommend the use of BIM, acknowledge its benefits, make efforts to encourage its use and play a leading role in implementing BIM, including the Netherlands, Denmark, Belgium, Luxembourg, France, Germany, Italy, Malaysia, Spain, Switzerland, Ireland, Japan, China, Taiwan, New Zealand and Canada.

This report will mention the cases of the United States, United Kingdom, Sweden and Finland, treating them as good examples of how the use of BIM should be supported through the public sector.

## 9.2. Evolution of contractual approaches in construction

### 9.2.1. Traditional contractual approaches

Infrastructure projects in TEM member counties are generally carried out by road administrations as policymakers of governments in the road infrastructure sector. Accordingly, governments are the owners of projects through road administrations, defining the specifications and how the projects should be implemented throughout their life cycles.

Therefore, the best way to adopt new methods and technological systems is to require their implementation under contract from the owner or client. Governments should therefore be a leading promoter of BIM adoption, including mandatory use for public infrastructure projects, as this would be the most effective way to encourage the implementation of BIM. For road construction projects, a common procurement method is known as Design–Bid–Build (DBB). It is a linear contracting method in which the first drafting of project documentation is contracted, and then a call for tenders is announced to define the contractor who will build it.

Therefore, the team working on the project is independent of the contractor who will later build it. Also, when different contractors submit their bids, the project is already fully defined. This bidding process is similar to others that select the lowest bid in most cases. The main factor is the price that the contractor offers. This method rarely values other relevant aspects such as time and quality, so it does not guarantee maximizing project value. Likewise, the selection largely determined by the bid price encourages bidders to submit low-bid proposals and then try to make up for their losses by changing the terms. This usually leads to the generation of annexes to the initial contract, which also results in higher costs for the client.

This method of project management is not ideal for the application of BIM as there is certainly some interruption of the data flow between the design and construction phases. During the design process, the designer has no insight into the technological capabilities of the future contractor, so generic technical solutions must sometimes be applied.

However, this contracting model is still significant in infrastructure projects because of the need to use the various funds available to TEM member countries. For the use of funds (e.g., European Union Structural and Investment Funds), governments must often prepare fully defined projects and associated costs, which encourages the application of the Design–Bid–Build method.

Despite these drawbacks, BIM still offers considerable benefits in this method. For example, all BIM uses in the design phase (Chapter 3) can be applied in conjunction with all the significant benefits they bring. Additionally, the use of the

CDE platform is essentially the same, except that construction team members appear later than other stakeholders already present since the start of project activity.

However, due to the discontinuity between design and execution, different scenarios may arise in practice regarding the continuation of work on the BIM model after contracting.

- Scenario A: The BIM model was not even created during the design work. Such cases will occur for some time until the creation of the BIM model is mandatory and considered a routine part of the design work. In this case, the BIM model is made entirely during the preparation of the construction and during the construction itself. The contractor is responsible for its creation, and the development of the BIM model should be one of the contractual items. If the contractor does not have the necessary expertise and technology, this segment is entrusted to the subcontractor or consultant. The BIM model is based on the terms of reference and project documentation provided by the client, and in the process all information obtained directly from the construction process is used. Upon completion of the project, it is logical that this model also represents an as-built model.
- Scenario B: The BIM model was created during the design work by the design companies, in accordance with the requirements of the contracting authority through EIR and BEP documents, with the technology available to the company during project design. The contractor assumes the BIM model (preferably before submitting a tender, for better insight into the project) and further develops it in order to use some of the BIM features during the construction as mentioned in Chapter 3. The as-built end model is the same as Scenario A above. Ideally, engineers assigned to work on the BIM model continue to work directly on the data set provided by the designers. However, for various reasons (e.g., the interoperability issues described in Chapter 4.1, inadequate modelling methods for displaying construction phases, using different technology, etc.) some elements will need to be re-formed in one of the authorization tools. For this work to adapt and refine the existing BIM model, it is necessary to anticipate the appropriate experts, time and cost.

Another procurement method used is the Design–Build (DB) principle. In this case, the contractor is responsible for both the design and the construction itself. Bidders make technical and economic proposals based on the requirements and design parameters defined by the contracting authority. In the BIM model segment, this method is much clearer since it involves the collaboration of the designer and contractor throughout the life of the project. Thus, one BIM model goes through all the project phases. As the project team does not change, most problems related to interoperability and the general adaptation of the BIM model to actual construction needs can be avoided on time.

Other project delivery methods are Design–Build–Operate or Design–Build–Finance–Operate. These methods are predominantly used in public-private partnerships. In such cases, the same contractor is responsible for the design, construction, financing and operation of the project. Therefore, the contractor – who is also responsible for the entire project – must also finance part of the project, with the invested funds returned during the operational phase.

### 9.2.2. Integrated Project Delivery (IPD)

Based on the above, it is evident that traditional procurement models in the construction industry often promote opposing processes along the supply chain built into the delivery process. Therefore, non-traditional models that facilitate communication, reduce risk and maintain reasonable profits are currently being developed worldwide.

Together with the development of BIM, it will be necessary to adapt existing and even apply innovative contracting methods that should be more compatible with the development of this methodology.

Integrated Project Delivery (IPD) is one such model, where integrating organizations and processes can create environments that work better and more efficiently with the full use of new technologies. The aim is to maximize knowledge from the early stages of the project by integrating all technical areas.

The development of a project procurement system based on Integrated Project Delivery (IPD) systems is considered crucial to the effective implementation of BIM and all the potential benefits it can bring to a project.

Integrated Project Delivery (IPD) is a project implementation approach that integrates people, systems, business structures and practices into a process that collaboratively utilizes the talents and insights of all participants to reduce unwanted actions and optimize efficiency across all design and construction phases.

The IPD is not tied to one type of contract but forms a set of principles that can be applied to different contractual arrangements. Table 7 shows the key differences between traditional project delivery models and IPD.

Ideally, IPD brings in the expertise of key participants as early as possible in the project. This enables the production of infrastructure assets that are optimized for quality, efficiency, constructiveness, accessibility, timeliness and a smooth flow of life cycle management. In addition, greater integration of the design and execution process can have long-term benefits across the industry.

The principles of integration and cooperation will, over time, become the way the industry is organized. With the increasing acceptance of these principles, the new skills of the tenderer and the definition of new contractual clauses will represent key steps towards a more integrated project environment. This will encourage more efficient and profitable linear infrastructure construction projects.

**Table 7**
**Differences between traditional project delivery models and IPD**

| Traditional Project Delivery | | Integrated Project Delivery |
|---|---|---|
| Fragmented, assembled based only on the necessary or minimum required bases, strongly hierarchically controlled | Teams | The integrated team is made up of key project participants, gathered at the beginning of the process, open, collaborative |
| Linear, separate; segregated, knowledge gathered only as needed; data accumulated; silos of knowledge and expertise | Process | Simultaneous and multi-level; early contributions of knowledge and expertise; information is openly shared; stakeholder trust and respect |
| Individually managed, transferred to the greatest extent possible | Risk | Collectively managed, appropriately shared |
| Individually pursued; minimum effort for maximum return; (usually) based on the first cost | Compensation / reward | The success of the team is related to the success of the project; value-based |
| Paper, two-dimensional; analogue | Communication / Technology | Digitally based, virtual (3D,4D,5D); BIM, CDE |
| They encourage one-sided efforts; unilateral risk; no sharing | Agreements | Encourage, promote and support multi-lateral open sharing and collaboration; risk sharing |
| Individually focused, emphasis on composition | Education | Team-based, integrated, collaborative, technologically inclusive |

*Source:* AIA Contract Documents. Available at www.aiacontracts.org

Although IPD projects can be implemented without the use of BIM, the full potential benefits are only achieved if used together. BIM researcher Succar[12] goes a step further, stating that "IPD is the ultimate goal and final stage of maturity of BIM implementation."

[12] Bilal Succar, "Building information modelling framework: A research and delivery foundation for industry stakeholders", *Automation in Construction, vol. 18, No. 3 (May 2009).*

# 10. International best practice examples

The effective implementation and use of BIM remain important issues for the construction industry in general and the infrastructure sector in particular. The purpose of this chapter is to explore the initiatives and approaches used by countries that are leading in this field.

## 10.1. United Kingdom

In the United Kingdom, the government identified the construction sector as a major driver for its economic strategy and decided to become a world leader in BIM. This decision was followed by a concerted effort between government and industry that led to a series of legal, economic and operational reforms.

Promoting the use of BIM has become widespread since May 2011, when the "Government Construction Strategy" was published. This document sets a savings target of up to 20 per cent in construction. To achieve this target, one of the defined strategies was to make it mandatory for all public projects to apply BIM level 2 by 2016. Consequently, to achieve this objective and to increase the capacity to implement BIM by the public sector, a BIM Task Group was created. This group brought together experts from industry, government, various clients, professionals from different disciplines and academia with the aim of supporting the government and companies as they moved to implement BIM. The group implemented training programmes and published guidance on the implementation of BIM. Similarly, other government institutions implemented protocols and standards that supported the government target, such as the Construction Industry Council and the British Standards Institution.

Subsequently, the BIM Task Group, government entities and non-profit organizations published standards for BIM implementation. By 2015, the United Kingdom had 18 standards, 3 of which were created by the government and 15 by non-profit organizations. Most of these included performance plans, modelling methodologies and component presentation styles. In addition, a considerable number of BIM technical guides have been developed to meet government objectives. Moreover, the United Kingdom has developed three new project implementation systems involving early-stage contractors, promoting the integration of all stakeholders following the principles of IPD described in the previous chapter.

## 10.2. United States of America

The United States is one of the largest manufacturers and consumers of BIM products in all areas of architecture, engineering and construction. In the public sector, the entity most active in promoting BIM is the General Services Administration (GSA), which is responsible for the construction and operation of federal facilities. In 2003, the agency, through the Public Building Service (PBS) and the Office of the Chief Architect (OCA), launched a national 3D–4D BIM programme that sought to implement BIM in more than 200 projects valued at more than $12 billion, thereby optimizing designs and increasing the efficiency and quality of construction. In addition, the GSA established a goal requiring the use of BIM in all its projects since 2007. In support of these policies, the GSA gradually developed 8 BIM guidelines. In 2007, 28 per cent of the industry used BIM, while five years later (2012) when the law came into force, 71 per cent of the industry implemented BIM in their projects.

The National Institute of Building Sciences (NIBS) is another public sector entity that has played a relevant role in promoting the implementation of BIM. This institution has published two versions of the National BIM Standard – United States. This is a series of documents, guidelines and standards aimed at defining BIM best practices, standardizing languages, sharing BIM data among different stakeholders, and recommending best methods and processes, among many other topics. State governments and other governmental institutions have followed such behaviours, promoting the use of BIM in various projects. In addition, NIBS created research groups and guidelines for BIM implementation.

At the same time, the public sector launched BIM programmes and committees, as well as held courses and conferences. The United States has also created a variety of standards to effectively implement BIM. By 2015, 47 BIM public standards were developed, 17 of which were created by the government and 30 by non-profit organizations. Most standards are execution plans and modelling methodologies.

It is worth mentioning that various contracts have been written in the United States to include BIM, seeking to make procurement methods compatible and profitable with the use of BIM. Consensus DOCS 301, AIA E202 and AIA E203 (Building Information Modelling and Digital Data Exhibit) documents should be highlighted. The first document is an example of a contract that includes legal and administrative issues about

BIM; its purpose is to serve as an adjunct to the agreement for all parties involved. It also includes a project execution plan to determine dependency on the BIM model and to apply BIM best practices through standardized formats.

The other two aforementioned documents, created by the American Institute of Architects, are intended to establish the parties' expectations for the use of digital data and project modelling and to provide a process for developing detailed protocols and procedures that will govern the development, use, transmission and exchange of digital data in the project. These contracts are periodically updated and improved.

From all the above, the leading role of the architectural sector as a carrier of BIM in the United States is evident. A strong framework for using and promoting BIM has been successfully created, thus facilitating pathways for infrastructure projects as well. For the most part, state road administrations (Departments of Transportation) do not yet require the mandatory use of BIM, but many initiatives have been taken to implement it. Most Departments of Transportation have well-developed guidelines, standards, tools and templates for 3D CAD design available for download (Figure 44). Additionally, the structure and formats of digital data delivery are defined in detail (example in Figure 45).

**Figure 44**
**Examples of templates and tools available for download**

FDOT

**CADD Manual**

*In Reference to the Plans Preparation Manual (PPM)*

| 3D DELIVERABLES SUPPORTING AMG for 3D PROJECTS | |
|---|---|
| **File Name** *(put in \3DDeliverables\)* | **Description** |
| **Design Alignments and Profiles** | |
| AMG-ALGN##.xml | All Alignments and Profiles extracted from the \Roadway\ALGNRD, PROF or model files and \Roadway\DSGNRD or CORRRD files in LandXML format. |
| **2D Proposed Planimetrics Design** | |
| AMG-2DSGN##.dwg/dgn | 2D proposed Roadway design extracted from the \Roadway\DSGNRD file. (Production of this file for construction is at the designer's discretion.) |
| AMG-2DRPR##.dwg/dgn | 2D proposed Drainage design extracted from the \Roadway\DRPRRD file. (Production of this file for construction is at the designer's discretion.) |
| AMG-2PDPL##.dwg/dgn | 2D proposed Pond design extracted from the \Roadway\PDPLRD file. (Production of this file for construction is at the designer's discretion.) |
| **2D Existing Survey** *(Note: These are being considered to merge into a single survey Planimetrics file)* | |
| AMG-2TOPO##.dwg/dgn | 2D proposed existing Topography extracted from the \Survey\TOPORD file. (Production of this file for construction is at the designer's discretion.) |
| AMG-2DREX##.dwg/dgn | 2D proposed existing Drainage extracted from the \Survey\DREXRD file. (Production of this file for construction is at the designer's discretion.) |
| AMG-2UTEX##.dwg/dgn | 2D proposed existing Utilities extracted from the \Survey\UTEXRD file. (Production of this file for construction is at the designer's discretion.) |
| **3D Existing Survey Surfaces** | |
| AMG-3SURFACEEX##.xml | 3D existing terrain surface to be exported from the \Survey\GDTMRD file as LandXML format. (Production of this file for construction is at the designer's discretion. This file will be produced if the 3D Existing Surface dwg/dgn file(s) are not produced.) |
| AMG-3SURFACEEX##. dwg/dgn | 3D existing terrain surface to be exported from the \Survey\GDTMRD file. (Production of this file for construction is at the designer's discretion. This file will be produced if the 3D Existing Surface LandXML file(s) are not produced.) |
| **3D Proposed Surfaces** | |
| AMG-3SURFACEPR##.xml | 3D proposed finished (top) surface to be exported as LandXML format from the \Roadway\MODLRD file. |
| AMG-3SURFACEEW##.xml | 3D proposed finished (bottom) surface to be exported as LandXML format from the \Roadway\MODLRD file. This file will be used to generate surface to surface earthwork volumes. |
| **3D Proposed Break Lines** | |
| AMG-3DSGN##.dwg/dgn | 3D proposed Roadway design extracted from the \Roadway\DSGNRD file. (Production of this file for construction is at the designer's discretion. This file will be produced if the 3D Proposed Surface(s) LandXML file(s) is not produced. Geometric elements should be in vector.) |

*Source:* Florida Department of Transportation. Available at www.fdot.gov

**Figure 45**
**An example of digital data delivery formats**

| Supplemental Information | File Format(s) | File Name(s) | Notes |
|---|---|---|---|
| Mapping files (3D) | MicroStation .DGN | exmanu.dgn | Include complete original mapping (existing manuscript) delivered from the aerial survey data or ground collected data. |
| Existing Ground Digital Terrain Data | InRoads .DTM and .XML in the LandXML Schema | exground.dtm and exground.xml | The existing digital terrain data of the project area. |
| Coordinate Control Data | ASCII | coordata.csv | Include all primary and supplemental coordinate control information (including right of way monumentation) in the following form: Point Number, Northing, Easting, Elevation, Description NOTE: Elevation is not needed on right of way monumentation points. |
| Alignment Geometry | InRoads .ALG and .XML in the LandXML Schema | geometry.alg and geometry.xml | These files will contain all centerline horizontal and vertical alignments for the project. Name the alignments the appropriate route number or name. |
| InRoads' Superelevation Report | Report in .XML in the LandXML Schema | super.xml | Data file will contain information about the superelevation. |
| Earthwork Calculations Spreadsheet ( If available) | Report in Excel or other recognizable Spreadsheet | earthwrk.xls | Some Designers use spreadsheets to calculate earthwork information. Please include this file, if available. |
| Proposed Roadway Model (including InRoads' Features) & Design Information | InRoads .DTM, .ITL, & .IRD files and the Proposed Roadway Model in the LandXML Schema | roadmod.dtm, typicals.itl, roaddesign.ird and roadmod.xml (Include InRoads' Features & exclude triangles in roadmod.xml.) | The proposed digital roadway model and design data is for informational purposes only. This proposed roadway model will likely be inaccurate and/or incomplete. This data is "User: Beware." The designer must include InRoads' features & exclude triangles when creating the Proposed Roadway Model in the LandXML Schema. |
| Proposed Manuscript (3D information showing the roadway design | MicroStation .DGN | propmanu3d.dgn | Include existing contours, existing planimetrics, proposed features, and control points. Data should be at proposed coordinates & elevations. This data is "User: Beware." NOTE: If roadway was designed by "sheet" method instead of manuscript, reference all sheets into one DGN file and save as "propmanu3d.dgn" |

*Source:* Kevin Martin, Kentucky Transportation Cabinet, slide from a presentation prepared for the iHEEP meeting, Poland, June 2019.

It can be summarized that a strong transition from a well-designed CAD-based system to a full-fledged BIM environment is underway. This process has been actively supported in recent years by the Federal Highway Administration (FHWA), which is making efforts to research and advance BIM through the following programmes:

- Construction Inspection for Digital Project Delivery
- Leveraging Augmented Reality (AR) for Highway Construction
- Integrating 3D Digital Models and other Building Information Management Data into Asset Management
- Identifying Data Frameworks and Governance for Establishing Future BIM for Infrastructure Standards
- Developing an FHWA National Strategic Roadmap for deployment of BIM within the U.S.

## 10.3. Finland

In Scandinavia, Finland is a pioneer in BIM implementation. The RATAS project (which stands for Computer Design and Construction) emerged from a discussion in 1982 about the need to integrate information technology (IT) applications into construction.

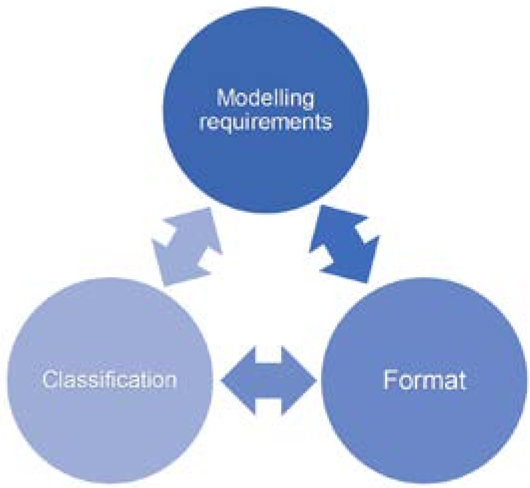
The RATAS project identified BIM as the central issue of using IT for a more efficient construction industry and brought together most of Finland's key industry players in the development of the roadmap. Today, Finland requires the use of BIM for government procurement and is considered one of the BIM leaders in Europe. Of particular interest is the application of BIM in infrastructure, for which specific requirements defined through the InfraBIM programme are defined.

BuildingSMART Finland (bSF) is a collaboration forum founded by Finnish real estate owners, consultants, software vendors and construction companies responsible for publishing the joint requests of InfraBIM. The aim of the forum is to disseminate information about BIM and to support member companies in implementing BIM-based processes. The goal is to fully digitize processes in the design, construction and maintenance of infrastructure by 2025.

The document "Common InfraBIM Requirements" provides general guidance and requirements for information modelling along with InfraBIM classification and specifications for data exchange formats (Figure 46). Modelling requirements, classification and formats form the three pillars of information management. Each of these components must be correct and unique to properly manage information. InfraBIM requirements are used as technical reference documents in procurement.

The InfraBIM's common requirements cover the entire life cycle of an infrastructure project – initial material, various stages of design, construction, documentation and – in the future – operation and maintenance. The Modelling Guidelines aim to guide, harmonize and improve modelling practices across the entire infrastructure sector. The guidelines are based on current best practices and are regularly updated as knowledge and tools evolve.

**Figure 46**
**Three pillars of information management – Common InfraBIM Requirements, InfraBIM Classification and the specifications for data exchange formats**




*Source*: https://buildingsmart.fi/en/infrabim-en/

In the "InfraBIM Common Requirements" document, the requirements and guidelines sections are highlighted to pinpoint their importance in the text. The requirements section presents the minimum requirements for modelling and content of model data. Compliance with these minimum requirements is required in all infrastructure projects. The guidance section presents practices that are recommended to be used in projects but are not absolute minimum requirements.

An important document is also represented by the guidelines of YIV annex 3, which details the minimum requirements for data exchange between project phases. The guidelines are given in table format for numerous constructions works, elements and structures. The table clearly identifies the modelling requirements that a particular element must meet (Mandatory), those which depend on the specifics of the project itself (Project-specific) and those which are not mandatory for a specific project phase (Not relevant to the design phase).

**Figure 47**
**Minimum requirements for data exchange between project phases – example**

| | | |
|---|---|---|
| ***181100 Embankments***<br>***1811.1 Earth embankments***<br>***1811.2 Blasted rock embankments*** | | |
| **Handover geometry** | | |
| ProD, PreD | • embankment surface level and slopes are modelled as surfaces, possible layers are not to be modelled | P |
| RoD, RaD, StD, PaD | • embankment surface level and slopes are modelled as surfaces, possible layers are not to be modelled | M |
| FiD | • embankment surface level and slopes are modelled as surfaces, possible layers are not to be modelled<br>• *In addition to the surface, the handover material includes the break lines that form the surface* | M |
| ABM | • Modelled as a surface<br>• Earth embankments are modelled to building element 2012 (Lowest combination of surface)<br>• Blasted rock embankments are modelled to building element 1812 | M |
| **Properties** | | |
| • embankment material properties<br>• required compaction and load-bearing capacity<br>• maximum allowable rock size<br>• choke layer properties<br>• required compaction and load-bearing capacity | • Property information that cannot be exchanged with the IM4 format but that is normal design-related information presented in other design documents. | |
| **Data exchange** (see 4. Handover phase and data exchange) | | |
| • Geometry | • Mandatory part of the handover material according to the IM4 specifications. | |
| **Additional information** | | |
| | | |

| | | |
|---|---|---|
| ***214100 Bonded pavements***<br>***2141.1 Final contracted pavement course*** | | |
| **Handover geometry** | | |
| ProD, PreD | • Not to be modelled | N |
| RoD, RaD, StD, PaD | • 3D area boundary* | P |
| FiD | • 3D area boundary* | P |
| ABM | • Modelled as a surface in the XYZ coordinate system.<br>• Asphalt pavements are modelled as in designation 2010 (Highest combination of surface) and must be based on data measured on-site.<br>• On a project-by-project basis and as specified in the invitation to tender, a separate 3D area boundary is formed from the building element, and it is then included as a separate set in directory 2010 (Highest combination of surface). | M |

*Source:* ibid., Building Smart Finland.

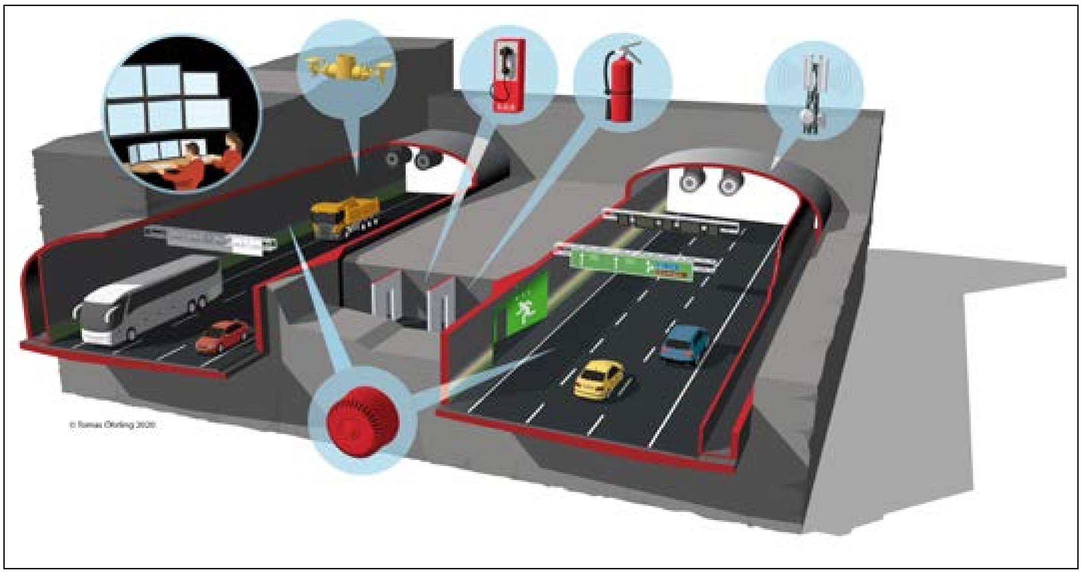
## 10.4. Sweden

Sweden has followed Finland's steps and emphasized increasing the implementation of BIM at the national level. This led to the launch of the non-profit organization OpenBIM (later BIM Alliance) in 2009 to establish BIM standards in Sweden. Public organizations such as the Swedish Transport Administration also approved the use of the 2015 BIM as part of a national efficiency programme. As part of its strategy, the Swedish Transport Administration has also developed legal guidelines for the digital delivery of construction work in collaboration with the construction sector through the Swedish Construction Industry Development Fund (Swedish abbreviation – SBUF).

Although the Government of Sweden did not formally request mandatory BIM implementation at the time, it did ask agencies to increase productivity, which led to the Swedish Transport Administration requiring BIM from 2015 onward.

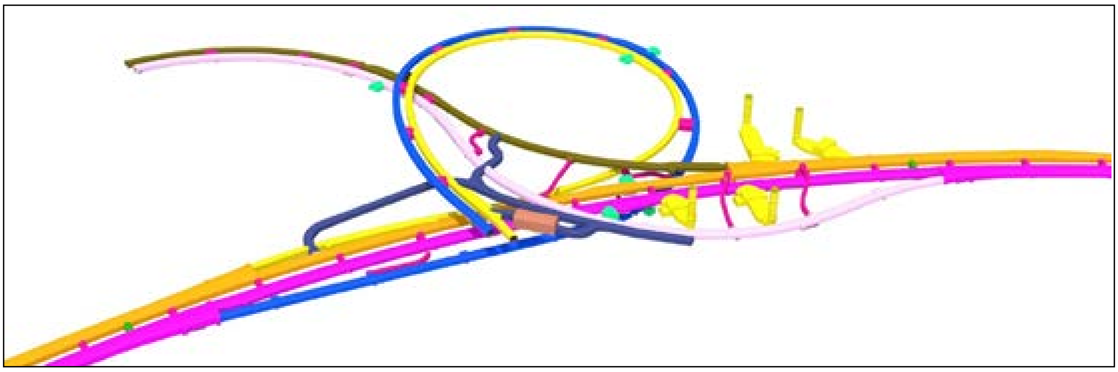
Since 2013, BIM was used to design and build large and complex projects, such as the Stockholm bypass and the new Stockholm city line. The Swedish Transport Administration said they are making significant financial and time savings when planning projects by avoiding bad decisions that would otherwise be revealed only during the construction phase.

**Figure 48**
**Safety concept of the Stockholm bypass**



*Source*: Trafikverket, "BIM – the work approach of the future". Available at https://www.trafikverket.se/en/startpage/projects/Road-construction-projects/the-stockholm-bypass/bim--the-work-approach-of-the-future/

**Figure 49**
**Detail of the BIM model-Stockholm bypass**



*Source*: ibid.

Four main pilot projects for the implementation of BIM and VDC have been launched, in line with the Virtual Road Construction (V-Con) initiative. V-Con is a project launched at the initiative of the European Union in cooperation with the national-level regulatory authorities of Sweden (Swedish Transport Administration) and the Netherlands (Directorate-General for Public Works and Water Management).

The aim of the V-Con project is to increase the efficiency and effectiveness of national road authorities by improving the data exchange in the civil infrastructure sector by applying the BIM approach. V-Con had two main goals – the first was the establishment of a draft version of the standardized data exchange structure, and the second was the procurement and testing of software systems that would be consistent with this proposed structure. This would solve the well-known problem of interoperability, especially in infrastructure projects – as described in Chapter 4.

# 11. Identification and review of the current situation in TEM member countries

In order to collect data on the current status of BIM implementation in TEM member countries, a questionnaire was sent to their representatives. The questionnaire included the following topics:

- Status of mandatory implementation of BIM in road/motorway projects
- Personnel training and education
- EIR and BEP documents (does the road authority know about these documents)
- CDE platform
- Pilot projects
- Locally defined levels of development for road/motorway projects
- Most used design and modelling tools for the preliminary and final road design
- Approximate current BIM level in the road/motorway industry, according to Bew-Richards diagram
- Estimation of the greatest loss of information between project stages (Plan–Design–Build–Manage)
- Availability of local libraries and tools

Furthermore, Highway Engineering Exchange Program meetings took place in Warsaw and Krakow during the month of June 2019. A workshop was held during the meetings called "Current situation in TEM member countries: implementation of BIM in the road infrastructure sector".

Finally, part of the information was also collected through an independent survey of published professional and scientific articles covering the subject of BIM technology in member countries.

## 11.1. Armenia

To evaluate the adoption of BIM in Armenia, data were used from surveys collected through interviews and questionnaires among businesses, non-governmental organizations and regulatory bodies.

As in most countries, acceptance of BIM is most prevalent in architectural and design work in the Republic of Armenia, with cost estimates, time management and project management in construction being the biggest advantages. Seventy-four per cent of survey participants rated the existence of a national BIM implementation programme as important[13].

With the advancement of BIM technologies, many countries have developed legislation and standards in the field of construction that govern the use of BIM technologies. Many countries are trying to make BIM part of their legislation, but this is not the case in Armenia.

AutoCAD was listed as the most used BIM software in Armenia, which suggests that a significant transition from CAD to BIM has yet to occur.

University curriculum also emphasized the use of CAD. This has resulted in the widespread use of CAD software by professionals, architects, electricians, plumbers and engineers of heating, ventilation and air conditioning systems, among others. Among the experts mentioned above, only architects adapted to BIM software relatively quickly, using tools like Revit and ArchiCAD for their design work.

Therefore, there is a need to develop programs and integrate BIM software courses for engineering students so that they can be ready to enter a job market where BIM has become the standard. There is a demand for professionals to teach students. In addition, it is important to develop texts in Armenian related to the topics of BIM usage.

Some private schools have recognized this problem and are offering programmes related to the use of BIM technology in Armenia. However, even in these programmes, the proportion of engineers who should gain the knowledge to carry out infrastructure projects is small – around 20 per cent – while most are architecture students.

The result of this state is often a mismatch between engineers and architects on projects, as architectural studios use BIM software in the design process but are unable to integrate

13 Marine Ghazaryan, "Pecularities of BIM adoption in Armenia", 22nd International Scientific Conference: Construction the Formation of Living Environment, E3S Web of Conferences, 29 May 2019.

their BIM-compatible files into a common system with CAD engineers, so the BIM workflow is interrupted early on.

On the engineering applications side, there are companies that design heating, ventilation and air conditioning, as well as plumbing engineering, with BIM technologies. Those companies are able to surpass their competitors by obtaining higher service rates. The application of BIM technology in road infrastructure is rare and, so far, insufficiently articulated and documented. There is a lack of data on which tools to use and how, thus it can be assumed that the implementation of BIM is not required at present for projects implemented by the road administration.

Apart from education, there is also the problem of regulations and standardization, but government assistance in collaboration with architects and engineers is expected in the near future.

In the meantime, companies (as in other countries) are taking the initiative to develop their own templates, though this is far from creating a complete package to support projects based on BIM technology.

International experience can and should help Armenia integrate BIM technologies more easily into public projects, including into road sector projects. Based on this brief overview, it is evident that in Armenia BIM is being used more by architectural organizations, while only a few infrastructure engineering companies are using the BIM methodology in their projects. The reason for the limited use of BIM software is the lack of larger, more complex, commercial and infrastructure construction projects that would serve to drive BIM implementation. In this sense, the future construction of large urban projects could be a catalyst for change or at least the beginning of the application of the BIM approach in the infrastructure sector.

## 11.2. Austria

Unlike building construction, which is very well defined in Austria by various standards (e.g., ONORM A6241-1 and ONORM A62241-2), there is still no complete standardized data structure in the infrastructure area.

Therefore, the BIM VI research project was launched to define the data structure for road and rail transport infrastructure taking into account ISO 16739 and the functional requirements of roads, railways, bridges, tunnels and technical equipment.

The development of data structures for the application of BIM is carried out by experts from different disciplines comparing proposals for standardization of infrastructure such as IFC and IFC Rail and Road with the national requirements of the Austrian infrastructure operators Austrian Federal Railways (Austrian abbreviation – ÖBB) (railway) and the Motorway and Expressway Financing Corporation (Austrian abbreviation – ASFiNAG) (road transport).

As these two IFC standardization proposals are still under review, there are still opportunities to incorporate national requirements into standardization. For example, there are already very good data structures by ÖBB (System Directory, RailTopoModel) and ASFiNAG (Technical Stock Documentation) that could be incorporated into this standardization.

The main objective of the BIM VI research project was to develop a data structure on existing and future objects of transport infrastructure. This was created by the involvement of transport infrastructure operators from all areas, taking into account internationally developed data structures for the correct location of transport infrastructure objects. Because line structures (traffic structures) can extend over several kilometres, spatial reference is important so that the appropriate elements can be located properly.

The project is divided into the following areas: bridge, technical equipment, railway, road and tunnel construction. As a basic result of the research project, a report was created which documents the overall concept of the data structure and serves as a basis for further R&D activities.

A three-step process was selected, whereby individual components of the data structure were developed independently and continuously in separate teams. These parts were then combined into the overall structure. In order to present such a complex system, a custom pie chart was selected. This structure diagram, which can be seen in Figure 50, is primarily intended to show the interaction of individual components of a data structure.

An important result was the development and description of element classes (classification of components according to their geometry and function) with associated element types (more details of element classes) along with their hierarchical classification in the data structure. Furthermore, the required properties and characteristics of the elements have been identified.

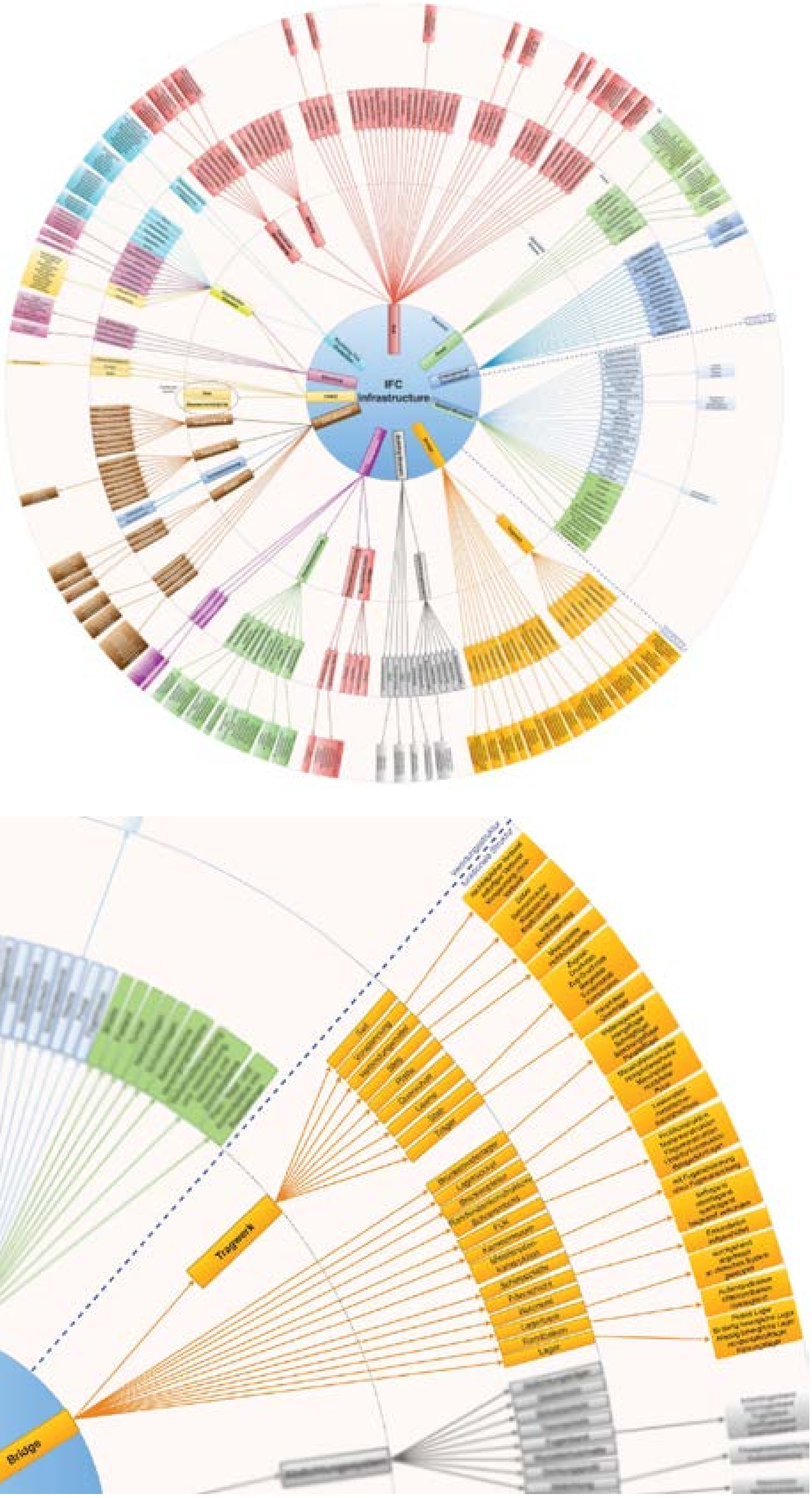
Austria plans to further pursue this project in order to properly integrate Austrian interests into international standardization (ISO 16739, IFC).

The use of the BIM approach is visible on all significant infrastructure projects, such as the construction of the S 1 outer ring motorway between Schwechat and Süßenbrunn with the Lobau Tunnel (Figure 51).

In addition, various activities are required to implement BIM, such as creating an ASFiNAG-BIM-CAD standard, establishing a central database for all infrastructure objects, compiling ASFiNAG-BIM-drawing libraries, redesigning construction tendering and contracting regulations, and redesigning internal building processes.

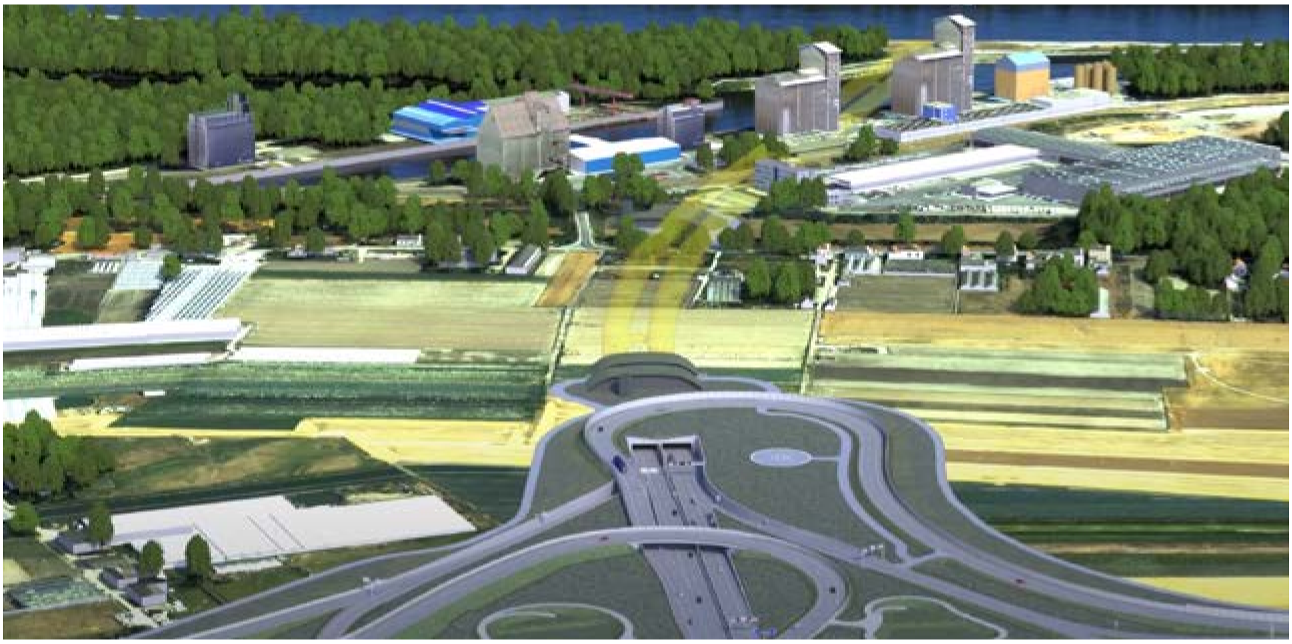
The new second tube of the Karawanks Tunnel is also an important, complex pilot project, as it is a cross-border construction project involving Austria and Slovenia. The characteristics and description of the implementation of BIM on this project are given in the text related to the Republic of Slovenia.

**Figure 50**
**Diagrams of the structure of data on existing and future building of transport infrastructure**




*Source:* FFG Projektdatenbank. Available at https://projekte.ffg.at/projekt/2738358

**Figure 51**
**Lobau Tunnel on the Schwechat–Süßenbrunn motorway**



*Source*: ASFiNAG, "S 1 Wiener Außenring Schnellstraße Neubau Schwechat bis Süßenbrunn". Available at https://www.asfinag.at/verkehrssicherheit/bauen/bauprojekte/s-1-wiener-aussenring-schnellstrasse-neubau-schwechat-bis-suessenbrunn/

## 11.3. Bosnia and Herzegovina

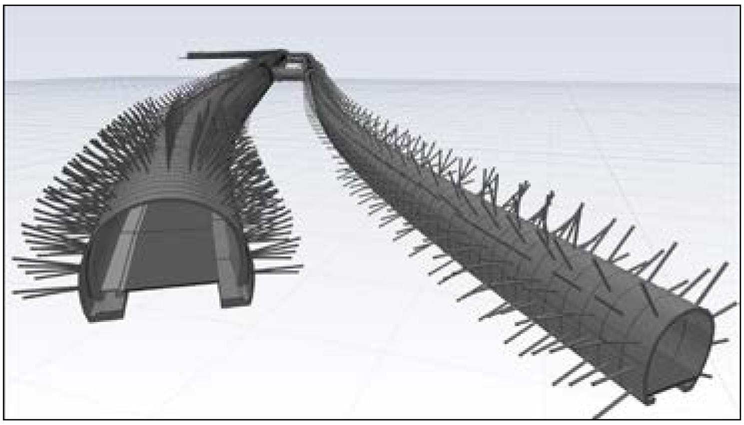
In Bosnia and Herzegovina, BIM is not yet in widespread use as there are no coordinated public sector actions to encourage activities, such as the development of BIM standards, education, etc. However, there are certain activities that aim to increase the use of BIM. In 2016, the BIM Alliance BH was established at the initiative of ten companies, with the main emphasis placed on the application of BIM in vertical structures. However, the fact that BIM is also applied to infrastructure projects is evidenced by the numerous published papers of designers at road conferences mainly focused on BIM procedures during highway design – especially visualization and the use of BIM approaches for tunnel and bridge projects. Significant design companies have participated in international projects where the use of BIM has been mandated, and their tasks were successfully accomplished. This means that designers are following the trends, which is confirmed by the test results obtained at the Faculty of Civil Engineering in Sarajevo where 95 per cent of respondents stated that they were familiar with the concept of BIM, while 60 per cent used some BIM procedures in their daily work.

For the time being, road administrations do not seek to apply BIM during the design process; however, they are doing some preparatory work, such as organizing seminars to familiarize employees with the implementation of BIM.

The application of BIM technology for major highway construction projects has become desirable. Thus, for the 5 km section of corridor Vc on the Johovac–Rudanka section, mandatory use of BIM technology is expected, and an employer information request (EIR) is included as part of the tender documentation for execution and supervision of the work. It is a demanding section, which includes bridges, intersections and numerous overpasses.

There are already some positive examples of BIM pilot projects currently being implemented on projects under construction. BIM projects are carried out by contractors who have identified the benefits that BIM implementation will bring to them, as they are challenging projects in complex field conditions. The design and monitoring of BIM models during construction is entrusted to consulting companies. The first project is the Žaba Tunnel, 1 km long on the M17 road, and the second is the Buna–Počitelj highway section, 7.2 km long.

**Figure 52**
**BIM model of the Žaba Tunnel**



*Source*: BEXEL Consulting, "Tunnel Žaba, Bosnia and Herzegovina". Available at https://bexelconsulting.com/projects/tunnel-zaba/

**Figure 53**
**BIM model of route Buna–Počitelj**

*Source*: BEXEL Consulting, "Buna-Počitelj Motorway, Bosnia and Herzegovina". Available at https://bexelconsulting.com/projects/buna-pocitelj-motorway/

**Figure 54**
**Visualization of the Pocitelj Bridge on the TEM Vc Corridor**

*Source*: WalterAEC "Pocitelj bridge – Corridor VC". Available at https://walteraec.com/cases/pocitelj-bridge-coridor-vc

It is evident that BIM is increasingly present in the field of road construction projects. So far there are no binding provisions for implementation in the initial stages of projects (planning and design), although designers use BIM procedures independently. There is also a lack of significant support from other state bodies.

## 11.4. Bulgaria

BIM in infrastructure is not widely used in Bulgaria to date. There are activities to promote the application of BIM in the construction sector as well as in individual universities, but these efforts are mainly driven by individual initiatives.

As in most countries with similar issues, programmes first emerge regarding the application of BIM in architecture. Companies like coBuilder Bulgaria and Nemetschek Group carry out significant education and outreach activities about BIM for the Bulgarian construction sector. For example, through the Green Building Products at BIM programme, coBuilder Bulgaria is actively involved in defining the essential parameters of sustainable construction. The general idea is to establish a construction process that will be able to avoid resource depletion and prevent environmental degradation caused by facilities and infrastructure throughout their life cycle.

Topics related to the implementation of BIM are also present at various professional conferences. Among other things, the issues discussed have involved current forms of public works contracts (only related to construction works, design or supervision services), which cannot fully take advantage of the BIM methodology.

Given that the degree of maturity of BIM implementation in Bulgaria is not yet sufficient for practical implementation, it is logical that public clients, including the Road Infrastructure Agency (RIA), do not require BIM to access their projects.

In the near future, a significant increase in BIM implementation activities in Bulgaria and the road sector can be expected. There are initiatives to set up a Bulgarian BIM task force to educate Bulgarian experts and guide them through the implementation of BIM. The working group plans to involve the academic community, designers, contractors and administrative staff (e.g., through the Ministry of Regional Development and Public Works).

## 11.5. Croatia

In the Republic of Croatia, the term BIM has become increasingly prevalent in the construction sector, especially in the last two years. Among the state bodies, the most involved is the Ministry of Construction and Physical Planning which, since 2017, is an equal member of the European Union BIM TaskGroup and actively participates in the promotion of BIM in Croatia. The working group HR BIM TaskGroup was formed, consisting of representatives of the architectural and engineering chamber as well as state administration bodies.

The complete legal and regulatory framework has not yet been established in Croatia, so the application of BIM is usually not mandatory – although there are already examples of mandatory implementation. As BIM is not yet widely used in practice, professional associations are working to further promote and educate their members. With regard to holding international meetings on BIM, the Croatian Chamber of Architects is active, and organized international BIM conferences in 2016 and 2017. Informal organizations also exist, such as BIM Croatia, which are more oriented towards applying BIM in architecture.

The Croatian Chamber of Civil Engineers released the publication "General Guidelines for the BIM Approach in Civil Engineering" and, at the beginning of 2021, the publication "Guidelines for the application of BIM in infrastructure projects" will be published.

In terms of education, BIM is not yet represented through special programmes at universities, but students still gain some knowledge through courses such as project management and quality management in construction projects. In the coming years, BIM is more likely to be represented at Croatian universities.

The implementation of BIM in infrastructure projects started in 2018, initiated by the Road Administration (Croatian Roads) which operates the network of state roads in Croatia. The BIM implementation project was launched as part of a wider digital transformation of this state-owned company, with the first activities including the formation of an EIR for design services. Given the lack of standards and guidelines at the time, a tailored bottom-to-top approach was adopted that included descriptive definitions of LOD and LOI throughout the entire design process (studies, preliminary design, final design). Particular attention was paid to the applicability of the prescribed definitions for designers in Croatia with regard to the tools and technology that are currently most used.

Significant progress was made on better collaboration between different stakeholders during the preparation of project documentation through the mandatory creation of a CDE platform for each new project. So far, the versioning of documents and the general benefits of shared communication have been particularly well received in practice. The existing EIR document, which is part of the tender documentation for increasingly complex Croatian Roads projects, is periodically updated and enhanced with new experiences and insights. In order to determine the optimal levels of detail and content of BIM models for typical state road projects, in 2019 a pilot project using the BIM model of construction for the DC34 section of the 3.534 state road section was undertaken, with emphasis on workflow descriptions for developing BIM models for the preliminary and final design stages (Figure 55).

**Figure 55**
**BIM model example for preliminary and final design**

*Source:* Denis Šimenić (2020).

Aside from new projects, the application of BIM technology is required for the most significant projects that are already under construction but designed earlier without the use of the BIM approach. The vast majority of infrastructure projects in Croatia use the Design–Bid–Build type of contracting, so the BIM models are taken over by contractors on the basis of project documentation created in the traditional way using CAD tools. With this approach, several projects are currently underway, including the construction of the Pelješac Bridge, state road DC 403 in Rijeka and the bypass of the city of Omiš.

The construction of the Pelješac Bridge, together with the access roads, is currently the largest construction site in the Republic of Croatia. The construction of the bridge enables the continuity of Croatian territory to be achieved, thus its construction is of the utmost importance to the country. The bridge itself is designed as a suspension bridge, with a total length of 2,400 m (Figure 56).

**Figure 56**
**Visualization of the Pelješac Bridge**

*Source:* Pipenbaher Consulting Engineers, "Pelješac Bridge". Available at http://pipenbaher-consulting.com/project/peljesac-bridge/36

The foundation conditions are extremely complex; the location of the bridge is subject to strong winds and is also in a zone of high seismic activity. In order to adequately connect the bridge to the existing network of national roads, it has also been necessary to anticipate the construction of interconnecting roads over a total length of almost 35 km. Due to the difficulty of the terrain, other important structures are located on the route, such as the Ston Bridge (Figure 57), the Debeli Brijeg, and the Polakovica and Supava Tunnels.

**Figure 57**
**Visualization of the Ston Bridge**

*Source:* Denis Šimenić (2020).

BIM technology was used during the design (application of 3D models, visualizations and many structural analyses), while an as-built model is being produced during construction which will be used for efficient maintenance of the infrastructure after construction. Building site experience to date has confirmed the advantages of the BIM approach in terms of significantly more efficient construction coordination among numerous construction participants. The CDE platform BIM 360 was applied, to which numerous documents are regularly uploaded (e.g., quality control of various structural segments), featuring updated versions of detailed designs in the project documentation as well as 6D construction workflow simulations.

In Croatia it is realistic to expect an increase in activities to strengthen BIM implementation in both the construction sector in general and in infrastructure projects. This includes the further development of BIM implementation in Croatian Roads (e.g., maintenance and management activities – i.e., asset management) and the gradual introduction of BIM into other major state-owned companies such as Croatian Highways – and, in particular, Croatian Railways in view of ambitious railway construction and reconstruction plans.

## 11.6. Czech Republic

BIM as a method was widely discussed in the Czech Republic in 2011. This was a consequence of the activities of innovative design companies that saw their development in the transition to the 3D model. However, there was not much talk about the transfer of BIM data between different project phases and its relevance to the life cycle of a building.

Starting from 2012, work began on the gradual adoption of ISO and CEN technical standards for BIM, though it was quickly observed that their application required the elaboration of use cases (i.e., creating examples of their application in practice).

In common practice, BIM modelling is most often found in architectural and construction solutions during project design and partly in structural calculations.

During the construction phase, some construction companies have already discovered the benefits of applying BIM methodology, such as collision prevention, better workflow planning, prefabrication and automation, and greater quality control of the work performed.

The facility maintenance and management phase of the practical use of BIM is the least represented due to the lack of technical standards on information contained in 3D models.

In general, BIM is currently used mainly in the commercial sector, especially in relation to the design and operation of 3D models. This begins with the practice of developing a BIM Execution Plan (BEP) and beginning the gradual resolution and use of the basic processes of the BIM method. The actual practice is hindered by still-insufficient knowledge as well as the narrow commercial interests of some of the software tool suppliers.

Educational institutions in the Czech Republic have also started to respond to the new trend of BIM. Some high schools and universities are trying to introduce BIM into their curricula, but they face many problems such as staff shortages. BIM is also reflected in the provision of lifelong learning and the increasing expertise of consulting companies that assist in the implementation of BIM. Obstacles to the proper implementation of BIM in education include the lack of established practice and unstandardized views on procedures for the proper implementation of BIM.

The Ministry of Transport of the Czech Republic (MoT) and its subordinate organizations, such as the State Transport Infrastructure Fund (Czech abbreviation – SFDI), the Road and Motorway Directorate (RMD), the Railway Infrastructure Administration (RIA) and the Waterways Directorate (WD) are responsible for the construction, modernization, repair and maintenance of transport infrastructure. In line with technical policy and development needs, the Ministry, in cooperation with the aforementioned bodies, is continuously creating new and upgrading existing regulations in the field of transport infrastructure.

The role of the contracting authority in the case of state-owned transport infrastructure is played by three important investment organizations (RMD, RIA, WD). The traffic structures implemented by these contracting authorities are funded through the SFDI, indicating that there is a high degree of concentration of authority and responsibility for transport infrastructure projects. This makes decisions about using information models in transport structures easier; however, the actual implementation of the BIM process in practice requires solutions tailored to the needs of the state administration of each individual infrastructure object.

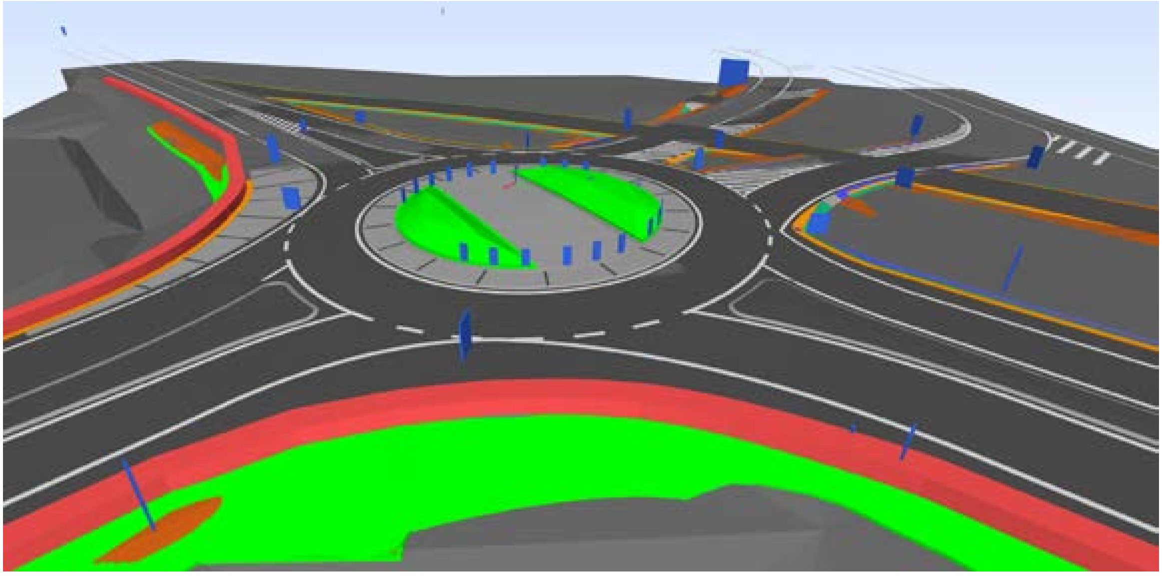
Therefore, from 2017–2019 the State Transport Infrastructure Fund prepared specific technical requirements for the application of BIM technology, which are freely downloadable from their web site. So far, materials covering generally BIM-related infrastructure are available, as well as elements such as the common data environment (CDE), the creation of EIR and BEP documents for infrastructure projects, and the BID protocol methodology for contract standards under FIDIC. Given the general lack of standards, rules and procedures for implementing BIM in infrastructure, such documents are very welcome (Figure 58).

**Figure 58**
**Example of technical requirements for the CDE**


*Source:* KoncepceBIM, Společné datové prostředí (CDE) – Přehled atributů pro výběr. Available at www.koncepcebim.cz/741-spolecne-datove-prostredi-cde-prehled-atributu-pro-vyber

The Road and Motorway Directorate of the Czech Republic also launched pilot projects in 2017 to verify and further optimize the implementation of BIM procedures on road infrastructure construction and reconstruction projects (Figure 59).

**Figure 59**
**Example of a BIM pilot project, modification of I / 32 and II / 125 intersection at exit 42 of the D11 motorway**



*Source:* Josef Šejnoha, "BIM Implementation in ŘSD ČR", slide from a presentation prepared for the iHEEP meeting, Warsaw, 2019.

The launch of pilot projects continues to an even greater extent, with each pilot project having specific objectives and tasks defined (Figure 60) to improve the maturity of BIM implementation in road construction projects in the future.

The mandatory implementation of BIM technology for all major public works is planned for 2022. From this brief overview, it is evident that extensive preparations and efforts are being made in the Czech Republic to complete the BIM framework by this deadline.

**Figure 60**
**Some of the upcoming BIM pilot projects**

| | | Level of preparation or realization | Required BIM models | Referential construction or project | What is to be checked and goals for EIR |
|---|---|---|---|---|---|
| **Area 1**<br><br>**Preparation of the building, link to the location of the building in the area** | 1.1 | Plan (Study) | Links between the pre-investment phase of preparation and the investment phase for motorway construction | Motorway D35 Staré Město - Mohelnice | **LoD / LoI (for plan and design), CDE and workflow, requirements for GIS, connection with map services, a link to the real estate cadastre, digitization of property law settlement of land…** |
| | 1.2 | Plan and Base Design (DÚR) | Links between the pre-investment phase of preparation and the investment phase for road construction | Road I/34 Pelhřimov bypass road | |
| | 1.3 | Plan and Base Design (DÚR) | Links between the pre-investment phase of preparation and the investment phase for tunnel construction only | Motorway D11 1109 Trutnov - state border (BIM only for tunnels objects) | |
| **Area 2**<br><br>**Building design, link to a technical solution and requirements for the building permit** | 2.1 | Design (DSP) | BIM-DSP model and setup procedure for BIM-PDPS, VD-ZDS conversion | Motorway D35 Opatovice - Časy | **LoD / LoI (for design), CDE and workflow, specification and model preparation for state permitting processes (DSP = building permit)…** |
| | 2.2 | Design (DSP) | BIM-DSP model and setup procedure for BIM-PDPS, VD-ZDS conversion | Motorway D3 310/II Hodějovice - Třeboň | |
| | 2.3 | Design (DSP) | BIM-DSP model and setup procedure for BIM-PDPS, VD-ZDS conversion | Motorway D11 1106 Hradec Králové - Smiřice | |
| **Area 3**<br><br>**Selection phase of the contractor (Red FIDIC), realization of the construction and BIM model for a real execution of the construction** | 3.1 | Public Tender, Realization (PDPS, RDS, DSPS) | BIM-PDPS, BIM-RDS, BIM-DSPS of some parts of the building (interchange, bridge, motorway rest) | Motorway D35 Časy - Ostrov | **LoD / LoI for implementation phase, use of a model during construction, schedule (4D) and budget (5D), reconciliation workflow between customer and contractor, BIM model for a real execution of the construction** |
| | 3.2 | Public Tender, Realization (PDPS, RDS, DSPS) | BIM-PDPS, BIM-RDS, BIM-DSPS only for a particular construction section - a tunnel | Motorway D3 310/I Úsilné - Hodějovice - Tunnel Pohůrka | |
| | 3.3 | Public Tender, Realization (PDPS, RDS, DSPS) | BIM-PDPS, BIM-RDS, BIM-DSPS for all sections of the construction | Motorway type intravilane road I/42 Brno VMO Žabovřeská I, phase I | |

*Source:* ibid.

## 11.7. Lithuania

In Lithuania, the importance of the construction sector is high, as can be seen from its share of 6–10 per cent of the country's GDP. The sector provides 7–12 per cent of jobs while about 50 per cent of all tangible investment in the country is used in buildings and infrastructure projects.

Due to unstable price levels, relatively low labour productivity, rising costs of resources and the lack of qualified human resources, Lithuania needs major changes in the construction sector. The first coordinated steps in this direction have already taken place with the implementation of a digital construction programme for the period 2014–2020. To this end, the Digital Construction institution (*Skaitmeninė statyba*) was established for cooperation among the Lithuanian private sector, science and government.

The Digital Construction institution is taking action to develop unique infrastructure for the implementation of digital construction models in Lithuania, meaning active encouragement of the application of BIM in construction. This initiative defined the application of BIM technology with three main points:

1. Develop a strategy for the design, construction and operation of construction projects based on computer-aided object modelling technologies
2. Ensure integrated management of graphical and information flows of data
3. Integrate individual tasks into processes for better, cheaper and faster execution of life cycle operations of construction projects

To this end, the following actions are planned:

- Design a unique information structure and classification system for the construction sector; create an e-environment and provide the preconditions for improving the productivity of work in business enterprises of the Lithuanian construction sector
- Analyse digital building e-solutions available worldwide, in the European Union and in Lithuania; choose the most suitable solutions and apply them to the Lithuanian market
- Develop and promote the experience of e-entrepreneurship in the Lithuanian construction sector
- Develop international cooperation; promote local and international relations between business and educational institutions with the aim of developing e-building solutions
- Implement education and training activities in the field of e-construction solutions

The basic concept is to carry out the projects according to the planned schedule, budget, scope and quality. Ultimately, the following goals are planned to be achieved:

- 20 per cent lower costs – in public sector projects, it is also important to calculate planned life cycle maintenance costs, not less than 20 years for all projects
- 80 per cent of projects on time – build-in the agreed scope and quality, as close to the established time and speed as possible
- 50 per cent higher exports – reduce the trade gap between total exports and total imports of construction products and materials
- 50 per cent lower emissions – reduce greenhouse gas emissions in the built environment

For long-term activities, a strategy was selected that relies primarily on the observed good practices of other countries, adapting the selected solutions as well as creating new solutions, but only after assessing specific needs. The main activities envisaged are the following:

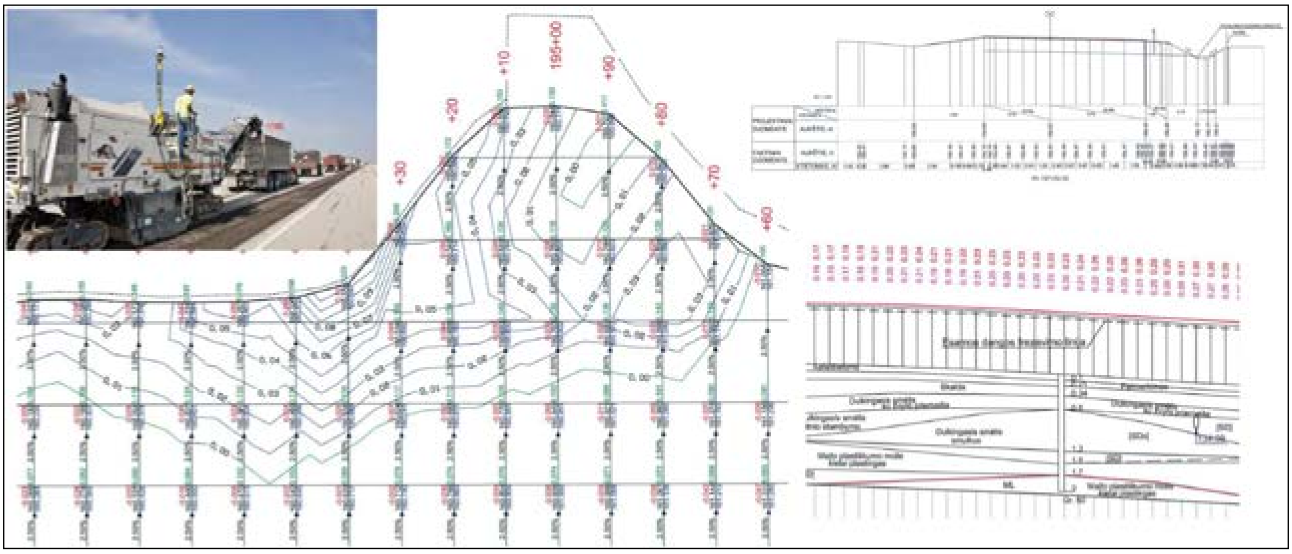
- WEB portal of the Digital Construction institution
- BIM itinerary
- Consolidating terminology
- Defining requirements for BIM models
- Introducing a classification and coding system
- Determining data exchange processes and formats
- Developing a Public Procurement Regulation and model contracts (developing to adapt to other countries' practices)
- Publishing BIM guides, templates and a library of BIM elements
- Conducting research studies and evaluating the maturity of BIM implementations
- Training, certification and continuous training
- Implementation of pilot projects

Meanwhile, BIM in Lithuania is used on individual projects, so far without unique classification systems, data exchange formats or standards. BIM is used by designers to optimize the design process. In engineering practice, visualization and digital models of roads and railways are used (Figure 61). Additionally, automated pavement milling is often used on projects for the reconstruction of existing roads in order to optimize the use of pavement materials and ensure the accuracy of performance (Figure 62).

**Figure 61**
**One example of project visualizations from Lithuania**

*Source:* Darius Šimkūnas, "BIM in Lithuanian infrastructure projects: Actual experience", Kelprojektas. Available at https://www.unece.org/fileadmin/DAM/trans/main/tem/temdocs/2014/Bim_Infrastrukturoje0616_V1_EN.pdf

**Figure 62**
**Model application for resurfacing of existing roads**




*Source:* ibid.

Judging by inquiries conducted involving various stakeholders from the construction sector, approximately 15–20 per cent use BIM, and approximately 50 per cent have knowledge of the BIM domain but are not currently using it. However, as many as 77 per cent of respondents plan to use BIM technology in future activities and projects.

There are good examples of the use of BIM in road construction works in the form of a project for the Lithuanian Road Administration under the Ministry of Transport and Communications of the Republic of Lithuania. The project covers the design and construction of roads from the 183.90 to 187.90 kilometres of the A12 Riga–Šiauliai–Tauragė–Kaliningrad highway, also known as the eastern bypass of Panemunė, with a bridge over the Nemunas River and overpasses.

The planned route passes through the floodplain of the Nemunas River, which necessitated the design of a levelling road at a height of 9.25 m above the floodplain. The use of BIM procedures for 3D parameter modelling helped the project team quickly find the optimal solution. A central data exchange system was also used, which allowed for significantly greater cohesion among project participants. One example is the efficient delivery of project data directly to construction crews in support of automated machinery management. All the above has led to greater efficiency and improved quality in project implementation.

## 11.8. Poland

Although the use of BIM methodology is not yet mandatory in Poland, BIM elements (such as the application of 3D design software) are used in Poland for numerous linear infrastructure projects (roads, bridges). Work on the implementation of relevant regulations and standards in the Polish legal system has already begun from several directions.

The Polish Ministry of Infrastructure and Construction (MIC), with the assistance of the Public Procurement Office, launched a series of expert working meetings aimed at assessing and validating the requirements for the introduction of BIM into the Polish legal system, as well as analysing different scenarios for BIM implementation from accumulated experience and recognized good practices.

The project "Strengthening the Legislative Potential within the Investment and Construction Process – Phase I" exists within the Operational Programme of Knowledge, Education and Development 2014–2020. As part of the project, employees of the Department of Civil Engineering engaged in a series of international study visits that included the United Kingdom, Sweden and Denmark, during which they gathered information on the experience of other European legislation regarding the application of BIM in the construction industry.

Given the need to implement the provisions of Directive 2014/24/EU, measures have been taken to introduce BIM in investment processes in Poland. The Public Procurement Law, amended in this regard, recommends that BIM technology be applied during the implementation of public procurement contracts in the field of construction investment projects, without explicitly referring to the name of that technology.

Furthermore, the Polish Ministry of Infrastructure and Construction is conducting an analysis covering issues related to the implementation of BIM, including – inter alia – an analysis of Polish regulations from the perspective of current BIM implementation options, and in particular as part of investment projects carried out by public investors.

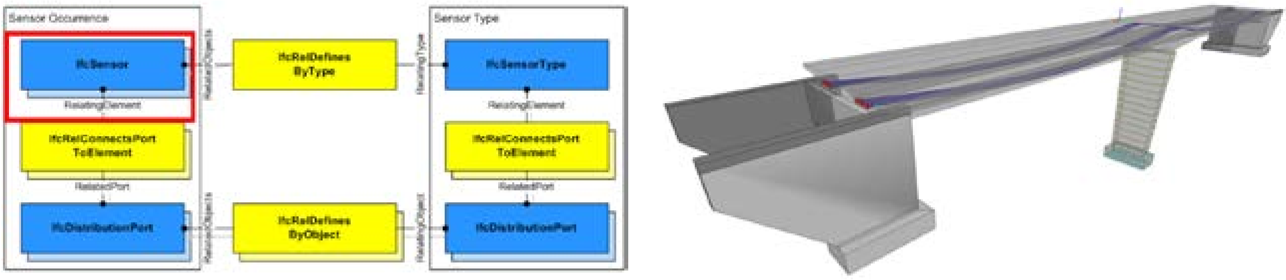
In 2015, the V4 BIM Task Force also started operating in Poland (the Polish branch of the V4 Group constitutes the BIM Working Group of the Visegrad Group of four Central European countries). It is a social (professional) initiative for the cooperation of two scientific and technical organizations (the Association of Polish Architects and the Polish Association of Engineers and Construction Technicians) as well as the Inspector General for Building Control. The agreement signed by the above parties aims to prepare draft legislation, launch scientific and research works related to infrastructure projects, and determine the communication strategy for target groups.

The activities of the V4 BIM Working Group continue to develop the classification standards recommended in Poland, to promote activities, and to cooperate with local governments and the state administration in developing good practice principles and regulations regarding BIM. The V4 BIM Working Group is also involved in the production of background documents based on British forms that will be further adapted to the V4 regional conditions and in determination of the principles of using BSI copyrights in the translation, adaptation and publication of documents such as BS and PAS documents.

There also exists formal BIM education in Poland, initiated by universities in Krakow and Poznan and later joined by other universities. In addition to undergraduate programmes, there are advanced postgraduate courses.

The General Directorate for National Roads and Highways (Polish abbreviation – GDDKiA) has been using advanced digital technologies such as laser scanning, photogrammetry and 3D GPR for a long time, as well as research into the application of deep machine learning to monitor bridge objects (Figure 63).

**Figure 63**
**Monitoring of bridge objects**




*Source:* Dariusz Kasznia and Tomasz Owerko, "Building Information Modeling in Poland", slide from a presentation prepared for the iHEEP meeting, Warsaw, 2019.

Significant application of BIM technology was noted during the construction of the A1, Gdansk–Torun highway, which is one of the most important transport routes in Poland and part of the Trans-European Transport Network.

During the performance phase, new ideas and technologies were used to meet investor demands. About 60 machines of different types – excavators, diggers, bulldozers, graders and asphalt pavers – were equipped with three-dimensional GPS systems, loaded with three-dimensional models prepared by the designers.

To communicate effectively with the investor, the project team used their own 3D software to prepare visualizations. In addition, three-dimensional models were used to calculate the balance of earthworks, temporary road infrastructure and construction site simulations. Precision work and time savings, together with quality and flexibility of machine use, have led to the conclusion that BIM will be implemented on future road construction projects.

Therefore, GDDKiA decided, as a pilot project, to carry out one entire road construction project subject to the mandatory implementation of the BIM methodology. The pilot project involves the preparation of project documentation by BIM technology for the construction of the 2.1 km Zator bypass on National Road no. 28. The Contractor is required to create a multidisciplinary BIM model as well as to improve the communication and approval process through the CDE platform. As a result, the greater integrity, efficiency and functionality of the innovative approach and tools will ensure better project management in the design, construction and maintenance phases.

Special attention has been given to the preparation of the tender documentation. The foundation European Centre for BIM Certification (EccBIM) has been hired as a consultant for the preparation of the competition. EccBIM is a non-profit organization that combines different groups interested in effectively introducing BIM technology in Poland.

**Figure 64**
**Application of BIM on the Gdansk–Torun section of highway**

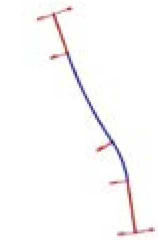
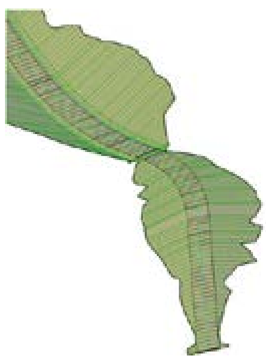
*Source:* Skanska, "BIM in Civil Projects A1 Motorway, Gdańsk – Toruń: Rusocin to Czerniewice, Poland". Available at https://group.skanska.com/48e49b/siteassets/about-us/building-information-modeling/bim-projects/bim-a1-motorway.pdf

For the purposes of this competition, EccBIM has created an EIR in which a significant portion of the space is dedicated to defining LOD (level of development) and LOI (level of information) standards, which the contractor on this project will have to adhere to. The need for such a document has arisen because of the lack of universally accepted LOD and LOI definitions for infrastructure facilities, which was addressed in this report in Chapter 2.2.

LOD and LOI definitions have been systematically given for the different project phases, from the project definition to the maintenance phase – a total of eight. Specific definitions are then given for particular types of work (e.g., terrain, earthwork, canal, road, intersection, structures and bridges, installation, etc. – presented in Figures 65 and 66.

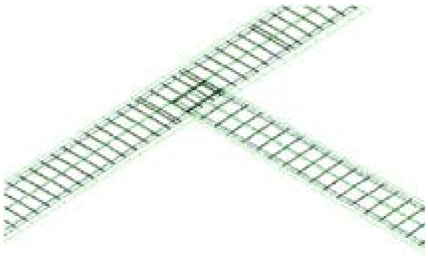
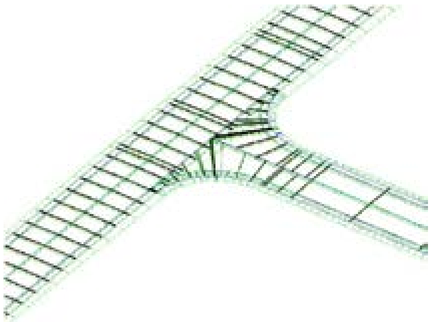
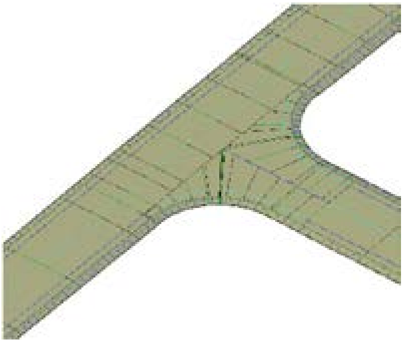
The experience gained from such a well-prepared pilot project will certainly have a positive impact on the further development and application of BIM methodology in infrastructure projects in Poland.

**Figure 65**
**Example of the LOD/LOI definition for a road corridor**

| LOD | GRAPHIC REPRESENTATION | DESCRIPTION |
|---|---|---|
| **LOD0/LOI0** | - | - |
| **LOD1/LOI1** |  | LOD: 3-dimensional axis of the road<br>LOI: Layer plus automatically generated attributes in accordance with geometry of modelled component |
| **LOD2/LOI2** |  | LOD: Corridor with width parameter (standardized width of land adjusted for particular road class<br>LOI: Layer plus automatically generated attributes in accordance with geometry of modelled component |
| **LOD3/LOI3** |  | LOD: Corridor correlated with road terrain and profile, road represented as the 3D surface of the top of the roadway with embankment or cut slopes. Sections generated from the model<br>LOI: Like LOI2, plus all the necessary attributes resulting from the model geometry that have not been defined automatically, and basic material information |
| **LOD4/LOI4** |  | LOD: LOD3 plus the lower surface and construction layers of the road added to the model, the lower surface of slopes, embankments and excavations, details such as ditches, telecommunication channels, sections generated from the model.<br>LOI: LOI3 + specific data for producers and products, e.g., physical properties |

*Source:* ECC BIM Foundation, "Standardy BIM Fundacji EccBIM. Propozycja definicji poziomów LOGD/LOMI dla projektów infrastrukturalnych i liniowych", (Warsaw, n.d.).

**Figure 66**
**Example of the LOD/LOI definition for an intersection**

| LOD | GRAPHICAL REPRESENTATION | DESCRIPTION |
|---|---|---|
| **LOD3/LOI3** |  | LOD: The corridors connect and are vertically coherent, no development of the intersection area<br>LOI: Like LOI2, plus all the necessary attributes resulting from the model geometry that have not been defined automatically, and basic material information |
| **LOD4/LOI4** |  | LOD: LOD3 + complete intersection area model<br>LOI: LOI3 + specific data for producers and products, e.g., physical properties |
| **LOD5/LOI5** |  | LOD: Complete representation of all intersection elements (e.g., installation, equipment, culverts, drainage)<br>LOI: LOI4 (see table above) + data on products, manufacturers, assembly dates, durability, service requirements |
| **LOD6/LOI6** | - | - |
| **LOD7/LOI7** | - | - |

*Source:* ibid.

## 11.9. Romania

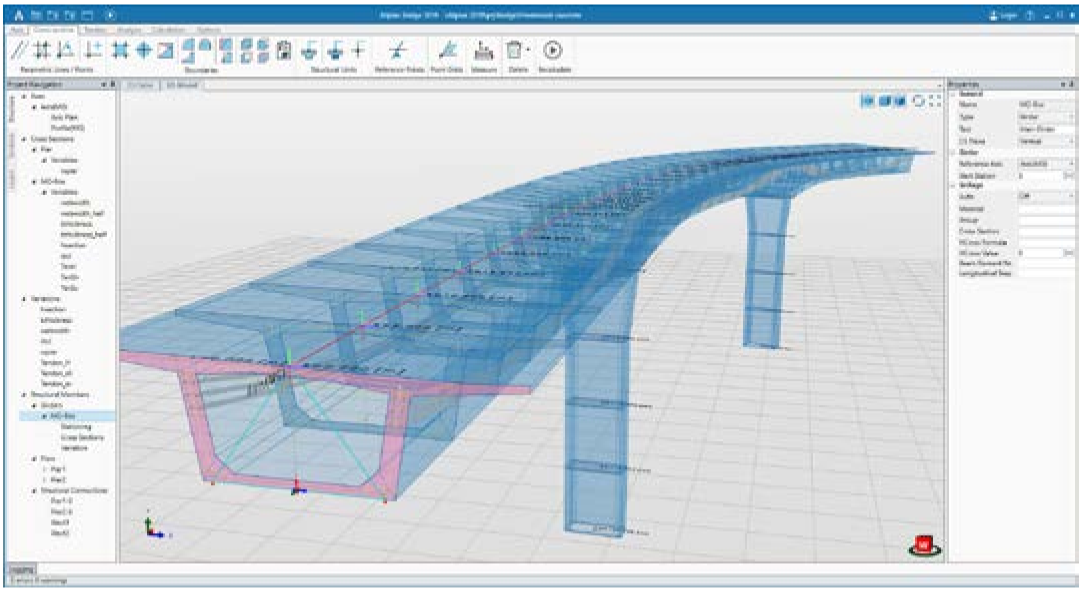
Recently, there has been increasing interest on the part of stakeholders in the architectural and construction sector in introducing the standardization and digitization process in Romania, including the use of BIM, as it is estimated that the construction sector has a lot of room for progress.

Currently, BIM implementation is relatively limited. Romanian state institutions are not technologically inclined thus far, and very few are adopting digital documents even in simple PDF format. Therefore, opportunities exist to enter the market with new solutions such as BIM technology. According to some studies (for example by the Factor Regional Development Centre – FRD) conducted with significant stakeholders, BIM is expected to become an important factor for the entire construction industry and the key to driving digital transformation in Romania.

The general benefits of using BIM solutions have been recognized, and requirements for the implementation of BIM – especially for complex works and public sector tenders – are expected (although no deadline has yet been set).

The Ministry of Regional Development and Public Administration is drafting a building code that incorporates BIM processes, but it is not clear at this time what the provisions will be and when they will begin to apply. Given the current lack of a legislative and professional framework governing the use of BIM technology in the construction industry (especially for infrastructure work), road administrations do not yet require the application of BIM on their projects. This is still in line with EU Directive 214/24/EU which recommends the use of BIM for public works but does not impose its mandatory application.

**Figure 67**
**Example of bridge design in a BIM environment**



*Source:* Allplan, a Nemetschek Company, "Allplan Bridge". Available at https://www.allplan.com/products/bridge/

According to the FRD Centre's interviews with key stakeholders, the most used BIM solutions in Romania are Autodesk Revit and Graphisoft software in the domain of vertical structures. BIM compatible solutions are also used for road design, for now on an individual basis by design companies, such as the application of Allplan software for bridge design (Figure 67).

In general, BIM is used in private projects and is often supported by foreign investors who require its use in their building construction projects.

The Regional Operational Programme 2014–2020 also finances projects for the implementation of BIM in Romania. The programme at a national level is managed by the Managing Authority at the Ministry of Regional Development and Public Administration. One example of a project funded through this programme is "Implementation of Building Information Modelling in the Activity of Fragmentum SRL" in Cluj Napoca.

There has been a recent increase in the number of conferences, roundtables and presentation seminars focusing on the benefits of the BIM approach. Some examples are as follows:

- In June 2017, the Romanian Building Law Society organized, in partnership with the Technical University of Civil Engineering in Bucharest, a seminar on "Building Information Modelling: Realities and Perspectives". In October 2017, they organized the third edition of the "Conference on New Perspectives in Construction" with a focus on implementing BIM in construction projects.
- In December 2017, Novart Engineering organized a course in Bucharest called "BIM Management - implementation in companies and projects in Romania". Several years earlier Novart Engineering, in collaboration with Viewpoint for Projects, organized the "Building Information Modelling (BIM) event - the way of the future in the construction industry in Romania".
- The Romanian Order of Architects (OAR) organized the "Introduction to Building Information Modelling" course in Bucharest in January 2017 and the "BIM in Europe" Internet conference together with the Council of Architects in December 2017
- In May 2019, BIMcon, an event organized by BIMTECH – Association for the Research, Development and Application of Building Technologies, was held in Bucharest. The event attracted the attention of state institutions and market players in BIM. The aim of the organizers was to promote the benefits of widespread adoption of BIM concepts such as sustainability, greater efficiency and reduced time, design and implementation costs. BIMTECH also presented a pilot project at BIMcon to modernize a significant building in Romania, the Bucur Obor Shopping Centre, which was built in 1975. The BIMTECH project for the new Bucur Obor Shopping Centre assumes that the complexity of the work, especially installation systems, will require a significant degree of digitization. The necessary approvals have been obtained from the BIM model and the project is now under construction.
- An infrastructure project was also introduced applying BIM procedures – the Tarnaveni Bridge in Mures County, implemented by the Austrian company Strabag

The trend of using BIM is certainly on the rise in Romania. However, more widespread implementation can be expected after undertaking the necessary activities, such as clear public sector support, standardization, training and education, etc.

## 11.10. Slovenia

Awareness of the many benefits that the application of BIM brings to projects in the construction industry has been widespread among Slovenian experts and academics for many years. The first insights into the potential of BIM were shared by the universities through scientific publications and the participation of scientists at international conferences.

Satisfactory attempts have been made to introduce BIM approaches in Slovenian construction companies. These BIM applications were made regardless of the lack of investor requirements or government instructions and were implemented as individual projects without specific guidance for the continued use of the models created. As these applications were successful, the BIM paradigm continued to expand into the Slovenian construction sector.

The establishment of the BIM Association of Slovenia (siBIM) in 2015 marked a more intense shift in the systematic introduction of the BIM approach in Slovenia. SiBIM has been developed as a voluntary, independent and non-profit organization bringing together professionals from academia and industry active in the BIM field. The association's main goal has been to provide professional development, training, networking and collaboration based on the experience of applying BIM technology. The association now has over 170 members from academia, government and businesses.

The first BIMForum was another significant event for the implementation of BIM in Slovenia, which took place in Bled in June 2016. The organization of this event was motivated by the demonstration of good practices and the exchange of ideas for putting the national BIM implementation strategy into practice. The event hosted many prominent BIM experts, and members of the European Union BIM Working Group sponsored by the European Commission. The Slovenian participants consisted of siBIM members, directors and other decision makers active in industry and the public sector. Representatives of the Ministry of Infrastructure, the Ministry of the Environment and Spatial Planning, the Ministry of Public Administration, the Ministry of Health, the Ministry of Defense and the Chamber of Engineers of Slovenia participated in the activity.

The successes of past events have motivated siBIM to set challenging goals for the future, including the implementation of national BIM research activities, the creation of working groups to establish Slovenian BIM guidelines, the development of a register of successfully completed BIM-supported projects and an increase of membership in bulidingSMART.

The membership of Slovenia in the European Union BIM Working Group represents another important milestone in the further introduction of BIM. The primary intention of this group is to unify national efforts into a common and harmonized European methodology for digitizing the construction industry. As a direct government activity, the Ministry of Economic Development and Technology implemented the Action Plan for Introduction of Digitalization for the Built Environment in Slovenia. The main objectives set out are the preparation of the eConstruction Platform for 2021, which creates the conditions for the mandatory implementation of BIM for public works (which is planned for 2023).

The Slovenian Chamber of Engineers also joined in encouraging the implementation of BIM, which in March 2018 issued the BIM Guidelines for Construction Projects (Figure 68). The guidelines clarify general BIM terminology, access to BIM projects, provisions for EIR, handover materials, etc.

In the education sector, Slovenian universities have adopted BIM topics in the curricula of their civil engineering courses, and the learning content is being updated periodically in line with ongoing achievements. Good examples are the IT and AEC master programmes of the University of Maribor, and the BIM A + European Master in BIM of the University of Ljubljana.

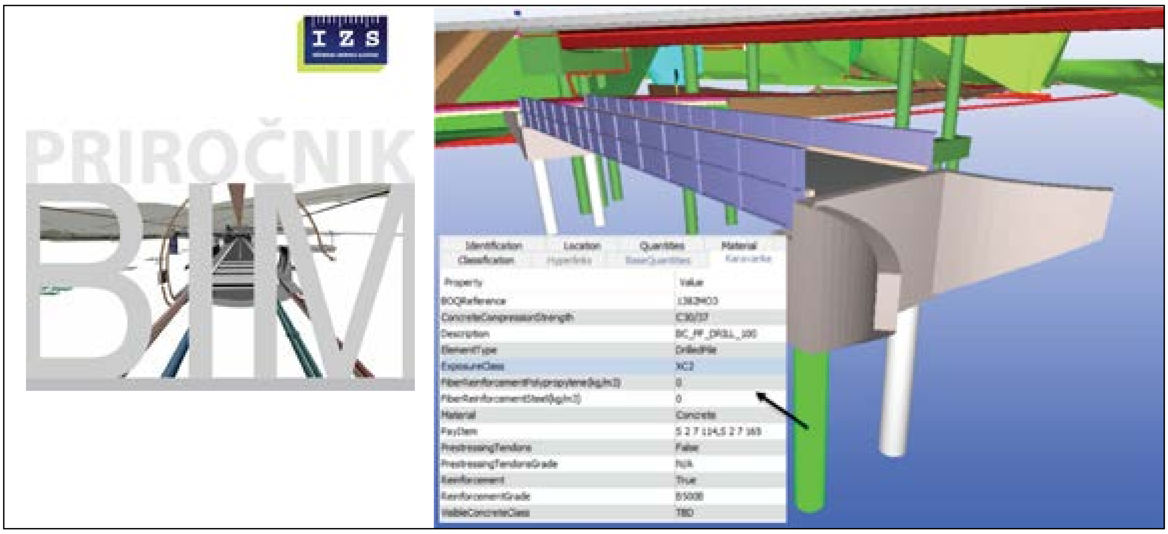
Successful applications of BIM already exist in the Slovenian construction sector and can be used as examples of good practice. The first example of a public project requiring the mandatory implementation of BIM is the Vinarium Tower in Lendava, which was completed in 2014.

Successful BIM implementation examples also exist for infrastructure projects, the most influential being the project to build a second tube of the Karawanks Tunnel. As mentioned above, this is a joint project of Austria (implemented by ASFiNAG) and Slovenia (implemented by the Motorway Company in the Republic of Slovenia – DARS).

The Karawanks Tunnel connects the A2 motorway in the Republic of Slovenia with the A11 motorway in the Republic of Austria. The total length is 7,864 meters.

The tunnel was originally designed as a twin tube tunnel, but due to the lack of traffic, it was first built as a single tube placed into service in 1991. As a consequence of increased traffic flows and insufficient traffic safety, it was decided to build a second tunnel tube. Construction from the Austrian side began in September 2018, and work from the Slovenian side began in March 2020. The planned completion of the works is February 2024.

**Figure 68**
**BIM Guidelines for Construction Projects**




*Source:* Ksenija Marc and others, *Priročnik za Pripravo Projektne Naloge za Implementacijo BIM-Pristopa za Gradnje*, Slovenian Chamber of Engineers (Ljubljana, 2018).

The goal of the BIM Pilot Project itself is to systematically implement BIM methodology in the project and to explore the benefits derived from the implementation of BIM, including:

- Creation of comprehensive employer's information requirements (EIR) for use by the road administration (DARS) in future projects
- Development of a comprehensive BIM Execution Plan that the client will also use in future projects
- 3D, 4D and 5D modelling, model-based quality control
- Geological and geotechnical modelling
- Use of modelling in the operational phase
- Further development of the existing computerized object management system

The pilot project is complex, involving a tunnel, a motorway and several smaller roads, 3 bridges, supporting structures, portal buildings, utilities, landfills, etc. There is also complexity in the project organization (2 client organizations, 1 monitoring company, 10 design companies) and diversity of BIM software (5 different design tools).

Approximately 190 separate models have been created to harmonize and coordinate with each other using IFC and BCF standards for interdisciplinary collaboration. To improve interoperability and quality assurance, a tunnel data structure has been developed based on existing IFC standards so that it can be used for advanced BIM purposes (e.g., 4D, 5D modelling). The interchange of 4D and 5D models between different software solutions (design team, supervision and contractors) is another challenge that will be managed by custom interoperable solutions.

In the early stages of design, BIM provided an opportunity for visualization and communication with all stakeholders in the project (Figure 69). It was the first time that all planned objects, geology and infrastructure (divided into three different project coordinate systems – Austrian and both the Slovenian national and local coordinate systems) were combined in one single model. Initial quantification and cost estimation (4D and 5D models) were created at this stage, which resulted in a better understanding of the project.

**Figure 69**
**Tunnel portal visualization**

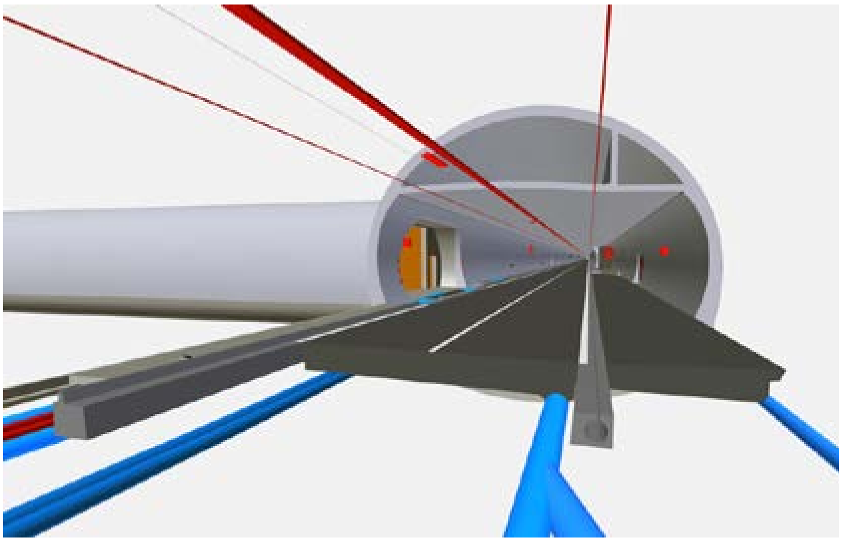
*Source:* IC Group, "Karavanke tunnel". Available at https://www.elea.si/en/portfolio/karavanke-tunnel

During elaboration of the detailed design, the project team conducted ongoing quality checks (identifying mismatches between partial models, assessing design changes, verifying communications and implementing design changes). Design changes during the collaboration and design development process were carried over to other discipline models (and, consequently, to model drawings) more effectively using the BCF standard for model-based communication (Figure 70).

160 partial models were used to double check the quantities provided in different design disciplines and to generate more accurate cost estimates. Maintenance services have been able to influence design solutions using accurate 3D models from the outset and optimizing individual solutions against available equipment.

Autodesk Navisworks Manage software was used to combine all partial models created in three different coordinate systems and to link elements to a timetable, resulting in a comprehensive 4D model used to analyse and optimize the activity timeline (Figure 71).

**Figure 70**
**BIM model, section of the tunnel**



*Source:* ibid.

**Figure 71**
**4D BIM model**

*Source:* ibid.

The same timing and partial models were used to build 5D models and analyse cost estimates. The 3D geological model combined with the Revit Tunnel models provided the basis for 3D numerical analysis for tunnel excavation and support. A separate code has been developed to allow direct communication between geological and numerical models.

The project used two forms of collaboration – internal and interdisciplinary.

Internal collaboration is used in the disciplines that use Revit as a design tool. Integrated communication and model sharing accelerate internal coordination and design development, as many designers can work on the same models at the same time.

Interdisciplinary collaboration entailed open BIM and the application of IFC and BCF standards for the exchange of models between disciplines. The reason for this was the involvement of 10 design companies in the development of the design and the use of different design tools.

The common data environment (CDE) is used to exchange files between disciplines and to connect IFC reference models to design tools, coordination models, and 4D and 5D models. All other documents (drawings, reports, etc.) are also exchanged and stored on the same CDE platform.

In the application of BIM methodology in the project phases to date, the following results have been achieved:

- High consistency and accuracy of project documentation
- Improved communication among stakeholders in the project (shared data environment, model-based audit, visualizations, model-based communication)
- Improved cost estimation and control, and optimization of construction technology (sequencing)
- One of the main requirements implemented through BEP in the modelling process has been fulfilled – the consistent definition of the LOD and LOI. The classification of elements and attribute tables was created in collaboration with the client and implemented in models on a special set of IFC properties. Attribute tables will be further developed over the life of the project.

## 11.11. Turkey

As in most countries, the implementation of BIM is common in Turkey for major public and commercial building projects (offices, hotels, shopping malls, etc.).

A survey conducted in the construction sector showed that as many as 54 per cent of respondents claimed to have used BIM in their projects, while those who did not intend to use it were only 1.58 per cent. It can therefore be said that there is already a general and widespread awareness of the importance of these processes in Turkey.

The survey found that BIM is most used by architects, while construction and electrical engineers have shown slightly less interest. It has also been determined that the size of the company influences the application of BIM, since most of the technical experts who claim to already have experience with BIM work in companies with 30 or more employees.

The main obstacles to broader BIM processes in Turkey are a distrust of the academic world, the inadequacy of vocational education, the lack of involvement of institutions and the lack of a plan or commitment that would yield the gradual introduction of BIM in Turkish construction processes.

Broader integration of BIM processes within the Turkish construction sector is only possible with adequate institutional support, both in terms of academic training and awareness of the impact of innovation in this sector through specific regulatory measures.

However, there are good examples of BIM implementation in infrastructure mega-projects in Turkey. The Istanbul Kabataş–Mecidiyeköy–Mahmutbey Metro Project, managed by the Istanbul City Municipality (IMM), is a mass transit rail system and the first implementation of BIM for the Istanbul Metro.

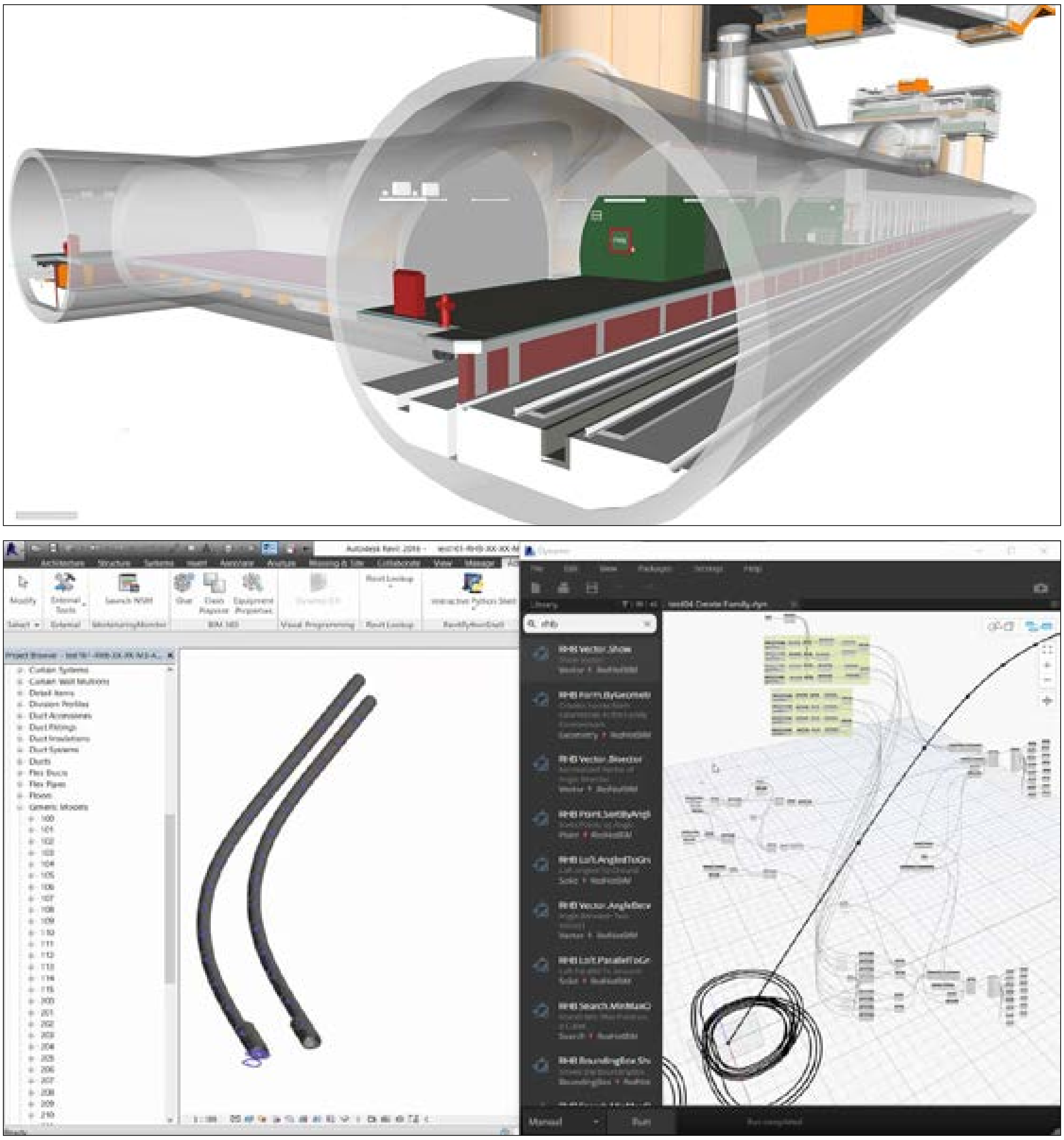
The metro line is located in one of the busiest and most popular parts of Istanbul. The main objective of the project is to provide high quality and safe passenger transport services and reduce traffic problems by encouraging people to use public transport. Sustainability and energy efficiency are also important for the project, which aims to reduce carbon emissions, save costs and follow an energy efficiency strategy for each phase of the project and commissioning.

The KMM Metro Line is one of the first major BIM-based infrastructure projects in Turkey and the first BIM-mandated project in the public sector.

The implementation of BIM has substantially contributed to addressing the major challenges the project has encountered. For example, due to irregular and intensive settlement in Istanbul, it was difficult to find suitable locations for shafts and stations. Minimal expropriation and optimal intervention in social life were achieved by using BIM procedures during the design work with significant use of 3D models.

Use cases for the BIM project included current state modelling, 3D coordination, clash detection, cost estimation, 4D phase planning, room data, virtual mock-ups and site utilization planning (Figure 72). Construction and architectural models, MEP models, existing terrain models and coordination models were included. BIM models will be available for use in the operation and maintenance phase. An estimated 18 per cent savings was achieved during the project due to the comprehensive implementation of BIM.

**Figure 72**
**Examples from the BIM model of the Istanbul Kabataş–Mecidiyeköy–Mahmutbey Metro Project**



*Source:* ProtaBIM, "First Metro Project in Turkey Designed on a BIM Platform", 14 November 2017. Available at http://bim.prota.com.tr/first-metro-project-turkey-designed-bim-platform

The use of the CDE platform has reduced the significant coordination problems of the large project team as well as the various contractors. Most of the problems arose from the BIM adaptation process as most project participants experienced the application of BIM technology for the first time in a complex infrastructure project.

It is important to note that investing in the implementation of BIM on this project was considered a cost of R&D in order to encourage a similar approach for all major transport projects in Turkey, which is a positive example. For construction projects of approximately 635 km of metro line, the application of BIM was requested after observing the contribution of BIM to this project.

BIM was also one of the key factors in the construction of the new Istanbul Airport (the Istanbul Grand Airport – IGA), one of the world's largest airport projects in the Turkish district of Arnavutköy.

Due to the large size of the airport, the project was divided into 4 phases. Following the completion of the last phase, the project will cover nearly 6.7 million square meters, supporting up to 3 thousand take-offs and landings each day with 2 million passengers.

With such a large project, it is crucial to maintain control of the whole process in order to achieve strategic goals in terms of time and value management. The complexity, size and duration of the project are challenging, and BIM played a major role during the engineering and design process.

During construction, BIM enabled contractor and subcontractor control while eliminating unexpected and unnecessary costs. With such a complex project, it is important to realize that the main advantage BIM provides is not only a technical matter but also bringing people together in a collaborative environment.

Therefore, one of the most important points in the process of applying BIM to the project was to coordinate project individuals (designers and subcontractors) with the use of BIM products. Another applied segment was the placement of Integrated Project Delivery into a virtual room, also known as the BIM Room, which was provided by the main contractor to coordinate, collaborate and make decisions with subcontractors and designers.

The most important part of the application is how these key points are reflected, since it is done through the mass use of tablets, including all coordinated BIM models used by architects and engineers. In addition to the 3D model, standard 2D drawings are also used and exchanged. All operations have taken place on the Autodesk 360 Field CDE platform. This project has generated the largest 4D model in the world thus far, integrating more than 30,000 activities into the model to track daily and monthly progress to dynamically monitor project development.

**Figure 73**
**Examples of the BIM model on the Istanbul Grand Airport project**

*Source:* BIM Community, "BIM in Turkey: the use of BIM on the Istanbul Grand Airport", 17 September 2019. Available at https://www.bimcommunity.com/experiences/load/142/bim-in-turkey-the-use-of-bim-on-the-istanbul-grand-airport

The BIM methodology will make it possible to obtain necessary information for the airport's operation, solving future problems in working with airport systems during the pre-commissioning and maintenance phases. 6D analysis is planned, which will include facility management and a life cycle management phase.

With this project, IGA began to lead and set benchmarks in the AEC industry and digital construction. The Istanbul Grand Airport project, involving many engineers, will conceivably have the effect of accelerating the adoption of BIM in Turkey and in the design, construction and maintenance of road infrastructure.

# 12. Recommendations on deployment strategies and implementation framework

## 12.1. Introduction

In order to develop recommendations that TEM member countries should follow in the implementation of BIM in infrastructure projects, a survey was conducted of actions adopted by leading BIM countries around the world.

Subsequently, the roles and actions to be taken to promote the use of BIM in infrastructure projects were identified. Key findings were as follows: the importance of coordinated government support and leadership as a critical driver of BIM implementation, development of national and global BIM standards, legal protocols to address liability issues, BIM certification, education and training, and articulating a business case for implementing BIM.

## 12.2. Leadership of government and significant stakeholders in the sector

The research has clearly shown that the most critical factor for the successful implementation of BIM is national leadership and coordination in order to maximize efficiency and avoid problems created by partial and inconsistent approaches.

Leadership should come primarily from government bodies but needs the support and cooperation of the main actors in the infrastructure sector. These include the most significant clients in the public sector (e.g., road administrations), parts of the private sector (project and consulting companies), contractors, professional associations (chambers), as well as scientific and educational institutions.

Given the global nature of construction activities, there is also a need for commensurately high-level leadership to support BIM implementation in the construction sector. The European Union Public Procurement Directive (EUPPD), adopted by the European Parliament to encourage, determine or authorize the use of BIM for its publicly funded projects, is an excellent example of this high-level leadership.

Such broad-reaching international initiatives should also be supported by international BIM standards and protocols, which are borderless and can be implemented without major differences in many countries. There is generally much duplication of efforts in the development of BIM, thus much could be achieved by global leadership through coordinating activities for mutual benefit and the resulting synergies.

BIM has the highest chance of success if driven by the owners of major infrastructure assets, and government mandates seem to be the most effective. BIM mandates set by government entities in the United States and the United Kingdom provided successful catalysts for moving the industry toward BIM. Project companies and contractors were faced with the reality that if they were not capable of meeting the BIM standards, they would not secure future work with government entities – which proved a strong motivating factor. Professional associations and organizations also play an important role. Their roles must be collaborative in order to adopt multidisciplinary approaches.

Contracting and advisory organizations are also required to encourage efforts to comply with the requirements for BIM implementation, for example, by preparing the documents required for the implementation of IPD contracts.

There are a number of organizations in different countries with different roles influencing the adoption of BIM and new information technologies. However, most often there are no national umbrella organizations to coordinate efforts that would lead to a coordinated implementation of BIM in infrastructure construction. Based on the research conducted on this issue, it can be concluded that either the government or the body composed of all state transport infrastructure and industry agencies is in the best position to address this need, to provide direction and consistency.

Therefore, in countries that do not have coordinated activities due to the absence of a functional central body, it is advisable to form a new entity (such as the BIM Task Group in the United Kingdom) that can reverse the trend of functional fragmentation that impedes efficiency, and at the same time facilitate the implementation of BIM.

## 12.3. Awareness of gaining competitive advantage

Achieving competitive advantage provides a significant motivation for BIM implementation. In the construction industry, it is common for companies to adopt a wait-and-see approach. But as businesses increasingly see their competitors gain an edge by obtaining BIM expertise, the incentive to participate in the trend increases.

Achieving competitive advantage also has global consequences. Companies need to be globally competitive even if they are not currently working on international jobs as they will increasingly compete even on domestic projects against international companies with high levels of BIM maturity.

BIM business value reports in major global construction markets are a good example of what it takes to communicate business benefits. Large-scale surveys conducted in North and South America, Europe and Asia show that 75 per cent of companies have had a positive return on investment from their BIM programme, with reduced errors and omissions and lower construction costs achieved, which are listed as key benefits. Significant companies predict that the presence of BIM in their work will increase by at least 50 per cent over the next two years, making it clear that investing in BIM is crucial for construction companies as they could otherwise face serious business consequences.

To advance BIM capabilities and expertise, companies need to rethink their business practices. Although software and technology usually require some investment, the biggest expense lies in training and developing staff. Although the goal is to harness the knowledge gained and the competitive advantage in the long run, the costs of development are significant, especially for market sectors where competition is high and profit margins are low. Many companies have limited financial reach to invest in current and future digital technologies and capabilities.

An additional complication is that technology is constantly evolving, so resources can be spent on software and training with uncertain outcomes. The pioneering path can be a risk as companies themselves become pilot pilots for certain technologies, while their competitors wait to see if such experimentation will result in commercial value and competitive advantage. Such a wait-and-see approach is no longer feasible for companies looking to be key players in the construction market.

Companies often state that their clients do not necessarily require the use of BIM as a reason for not investing in the technology. Moreover, the resistance often relates to organizational conservatism and the inability to adapt part of the staff.

However, there is a growing trend of demand for BIM implementation in many countries, especially where major clients (e.g., road and rail administrations) are seeking an obligation to implement BIM. As this occurs, construction professionals realize that unless they develop technology and expertise, they simply will no longer be competitive.

## 12.4. Implementation of pilot projects

Pilot projects are useful to validate positive research results with practical examples while demonstrating the readiness of the results. Well-implemented pilot projects can increase acceptance and accelerate implementation of proposed BIM processes. Furthermore, they are an important factor in adopting new technologies and ways of working. As a rule, contractors, designers and contracting authorities point out that pilot projects help to understand real implementation problems as well as quantify benefits. Pilot projects are also used as examples and internal tools for learning and development. In particular, they may be useful for completing internal procedures, technical tools and standards.

## 12.5. Development of national and global standards

In terms of BIM for infrastructure projects, the lack of support (clear guidelines, standards) is still present. Using published references and guides to implement BIM and best practices is a good starting point, but there is no road map that will fit the situation of every organization.

However, diverse approaches in the development and implementation of BIM should be avoided. It is understandable that each state (or road administration) wants to highlight its specific features or business practices, but they need to be systematized for the optimal application of digital technologies such as BIM.

In this regard, consistent national and global standards are required to achieve the efficiencies envisioned by this technology. Global leadership and experience can help ensure national and international collaboration. It is particularly important to study BIM best-practice protocols to support participant collaboration on the project – that is, actively promote collaboration through CDE platforms. Further development of the IFC format in the domain of infrastructure facilities will be an important factor in the future.

Good standards provide clear requirements that set minimum compliance specifications and strike the right balance between too many and too few conditions. Standards serve many purposes, including – among other things – the efficient use of resources, shortening time, improving quality and enabling compatibility and integration.

Recent research conducted on the subject of BIM standards in the United Kingdom shows that only 24 per cent of respondents agreed that the current level of standardization was adequate[14]. This suggests that a greater degree of standardization is required to ensure the successful adoption of BIM. This becomes even more important if placed in the context of increasing globalization and international providers. Common standards and processes allow for a higher level of cooperation across international borders.

The diversity of standards causes frustration among contractors and designers and impedes information sharing. This problem is sometimes present even within the same organization between different offices.

Therefore, there is a need for a coordinated approach to setting technical standards around BIM. It is recommended that this be done in consultation with professional organizations and private partners (designers, consultants), but also under the guidance of government agencies. This, in turn, would ensure that the greatest benefits of BIM adoption are realized.

## 12.6. BIM product databases and libraries

The development of standard databases of BIM products and libraries is also important for the implementation of BIM.

Free and easy access to data on BIM construction products and libraries is likely to have a major impact on the implementation levels achieved. Unfortunately, as already mentioned in Chapter 3, the application of standard elements in a typical road or motorway construction project is present to a much lesser extent than for the construction and equipping of a building. The initiative of the Government of the United Kingdom to provide free universal access to its BIM National Library is certainly a positive example, but the infrastructure content is very limited.

Nevertheless, the development of BIM product libraries still makes sense in the road construction sector for such areas as road signage and traffic equipment, standardized drainage elements, different windows, segments of telecommunication sewerage, geotechnical elements, etc. For example, there is no need for every design company to design a digital traffic signs database in 3D. Road administrations can commission a traffic sign library to meet current standards in their country and place it on their web site as BIM content.

These libraries allow designers to access digital 3D elements that are BIM compatible, in a well-defined format, fit for purpose and capable of being properly integrated into the project model.

## 12.7. BIM protocols and legal agreements

Legal and contractual problems with the use of BIM models are another critical category. Legal uncertainty arises from the large number of project participants contributing to the BIM model and relying on the accuracy and quality of all information in the model.

A number of initiatives are still being developed in various countries to address this. The American Institute of Architects has developed a document for BIM Protocols (Contract Terms), which is often cited as a good legal model. This protocol establishes a binding relationship among the parties to agree on key issues – protocols, level of model development and model elements. The American National Institute of Building Sciences has been researching the establishment of project liability insurance coverage to reduce the risks associated with an integrated design and construction approach.

Using BIM, the customer – besides owning the motorway, bridge or tunnel – also buys data that supports better decision-making throughout the project and the infrastructure life cycle. In this way, the increased importance of information increases the value of the process itself.

Although the application of BIM reduces risks and costs in projects and the life cycle of assets, BIM is not free. Instead, it should be seen as an investment that needs to generate a return. BIM requires more effort up front, and for designers this usually means additional time spent creating the required models while ensuring the accuracy of the data provided in the appropriate format.

Suppliers who are required to operate the BIM without any further guidance should inform buyers of the need for employer's information requirements, and the BIM protocol attached to the contracts with the exact expected results and the definition of special conditions. This process protects all parties, ensuring that the expected results are achieved.

Since BIM for infrastructure is in the phase of intensive development, the EIR process can be painful because it considers both strategic and very detailed issues, but the benefits are considerable since flaws that would appear in implementation can be revealed in the design of the project itself. Suppliers are thus able to tailor their processes with confidence that they will satisfy the client and that there will be no unpleasant surprises regarding the incompatibility of technology or processes.

Issues related to intellectual property rights and data ownership also need to be defined. Many companies are afraid to share their databases and information that they see as their intellectual property, which gives them a competitive edge. An example is user-developed design solutions or different databases collected through years of work.

[14] RIBA Enterprises, *NBS National BIM Report 2014*, (n.p., 2014).

## 12.8. Model quality and BIM Execution Plan

The information model is at the heart of the BIM process. The level of model details and the amount of information must be defined for each phase of the work. Creating and modelling this information requires a certain level of knowledge and time, which has its own price. However, the lack of essential information leads to bad decisions, which in the end may be much more expensive (e.g., late detection of model faults during the construction phase or – worse – during maintenance).

By adopting the optimal definition level for a 3D model and associated non-graphical information, engineers can ensure that the right amount of information is created at the right time to achieve the maximum life cycle benefits.

The conducted research shows that one of the present problems with BIM models is the quality of the model – if the parties do not trust the information in the model, it will have certain negative consequences. For example, engineers working in quantification and costing still tend to use traditional quantification methods rather than the ability to automate the quantity in BIM models because of concerns about the accuracy of the data in the model. The required accuracy of the BIM model entails clients being prepared to invest in the necessary resources to achieve the right level of quality, which is sometimes difficult to put into practice.

The experience of successfully completed projects so far shows the paramount importance of a well-defined BIM Execution Plan, where these issues need to be addressed as early as possible in order to effectively implement BIM in the project. For infrastructure projects, it is vital to consider the specifics of each project since each highway or road is a unique construction.

## 12.9. BIM education, training and research

BIM education, training and research are key to driving not only implementation but further development of the industry.

The lack of experienced and educated BIM practitioners and teachers is hampering the entry of BIM into the construction and especially infrastructure sectors.

It is clear that higher education institutions, with the support of government and industry, must fully integrate BIM education into their curricula in order to enable the AEC industry to produce graduates who are ready to work in a collaborative BIM environment.

At present, BIM education mainly focuses on the use of certain BIM software (most commonly Autodesk Revit) from the point of view of application in architecture – that is, mostly vertical structures. For the most part, this is also the case for research, resulting in the continued production of scientific and professional papers on BIM in vertical structures where many segments have already been well researched and defined by numerous guidelines and standards. Therefore, there is a strong need to initiate research and educate students to work specifically on infrastructure projects.

Universities should be encouraged to include such content in BIM curriculum. BIM education should not only focus on managing software that supports its implementation but should also teach BIM methodologies and collaborative processes that dominate significant infrastructure projects.

Finally, the focus should be on project clients (e.g., road administrations), as they ultimately have the most impact on the implementation of BIM in their projects. This education should first cover BIM awareness, followed by business benefits and return on investment, development of technical skills, and understanding of BIM as a collaborative working environment.

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# Building Information Modelling (BIM) for road infrastructure: TEM requirements and recommendations

The construction and maintenance of road infrastructure is an important area of most countries' national economies, but also one of the least digitized sectors. It suffers from the presence of systemic shortcomings including an insufficient level of cooperation, inadequate information management, and limited investment in technology, research and development. These shortcomings often result in lower efficiency and higher financial risk for investors due to various inconsistencies in project documentation, as well as failure to adhere to planned costs and deadlines.

There is signicant potential for improvement through the digitalization of processes and application of the Building Information Modelling (BIM) approach, a methodology suited to improving eciency in the road sector.

BIM emphasizes the integration of processes – specically the creation and distribution of digital information by all stakeholders throughout the life cycle of the infrastructure asset. The benets of using BIM technology have been recognized by the Trans-European North-South Motorway (TEM) Project, which has commissioned this report.

The aim of the report is to provide relevant information for the application of BIM approaches and technology in the road infrastructure sector, with an emphasis on motorway construction and maintenance projects. For this purpose, the report examines BIM tools and technology, the benefits of their implementation, the most important stakeholders, and new roles and documents that arise from the application of the BIM approach. The report also summarizes the current status of BIM implementation in TEM member countries, with recommendations for further implementation of the BIM approach in the TEM Network.

Information Service
United Nations Economic Commission for Europe

Palais des Nations
CH - 1211 Geneva 10, Switzerland
Telephone: +41(0)22 917 12 34
E-mail: unece_info@un.org
Website: http://www.unece.org

Layout and Printing at United Nations, Geneva – 2017495 **(E)** – May 2021 – 55 – **ECE/TRANS/308**