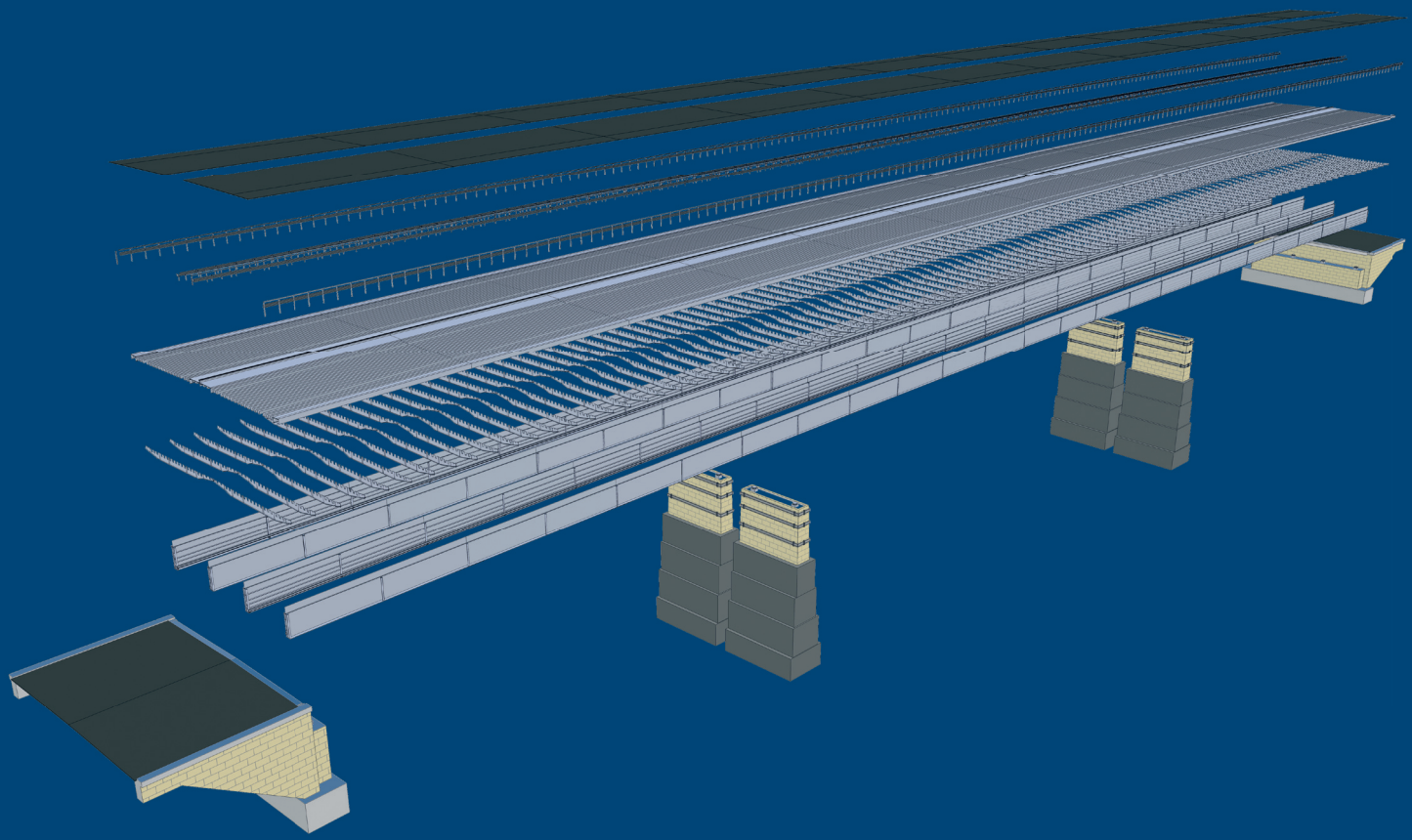
Federal Ministry
of Transport and
Digital Infrastructure

Road Map for Digital Design and Construction

Introduction of modern, IT-based processes and technologies for the design, construction and operation of assets in the built environment



Foreword

Alexander Dobrindt, Member of the German Bundestag
Federal Minister of Transport and Digital Infrastructure

Digitalization signifies a substantial economic and social revolution. It changes the conditions for growth, prosperity and the work of tomorrow – and revolutionizes, in a disruptive process, industries and services, value chains and manufacturing processes, innovation and product life cycles.

This presents a great challenge but also, above all, a great opportunity. Especially in the field of our core competencies, such as manufacturing, design and construction, digital technologies offer enormous potential in terms of quality, efficiency and speed. With their help, we can ensure early on networking, close cooperation and intensive communication between all participants when carrying out major projects. We can visualize different design options early on, standardize processes, create transparency, identify and mitigate risks - and significantly reduce construction times and costs.

In order to leverage this potential in Germany, we need a new digital design and construction culture. Here, Building Information Modelling (BIM) is an essential component. BIM creates a virtual image of the whole life cycle of a construction project: from planning and designing an asset to its construction and operation up to its demolition. With this innovation, all participants obtain access to virtual plans, control of processes, comprehensive databases and 3D to 5D asset models. Architects, clients, designers, engineers, operators and building services suppliers work hand in hand.

We want to establish digital design and construction as the nationwide standard. As a major construction client, the public sector must lead and drive the cultural change. That is why we have established the Construction of Major Projects Reform Commission and formulated a clear motto: “First build digitally, then in reality”. That is why we have launched four pilot projects to test BIM. And that is why my Ministry has developed a Road Map for Planning and Building of the future that will establish BIM as the new standard for transport infrastructure projects by 2020.

This Road Map is a joint project of government and industry and a strong signal for the “Made in Germany” seal of quality. I am convinced: if we work in close partnership, we will manage to maintain design and construction as German core competencies also in the global-digital age that will continue to strengthen the foundation of our prosperity – with innovative capacity and expertise, with structural steel and concrete and with data and algorithms.

Yours,
Alexander Dobrindt, Member of the German Bundestag
Federal Minister of Transport and Digital Infrastructure

Table of contents

1 Introduction

Design and construction are internationally recognized core competencies of Germany. Every year, the German design and construction industries demonstrate thousands of times that they are capable of building efficiently and with high-quality results. Nevertheless, in a number of major projects, there have been delays and cost overruns. Therefore, the former Federal Ministry of Transport, Building and Urban Development convened the Construction of Major Projects Reform Commission to take action to prevent undesirable developments. In its final report, the Reform Commission highlighted, in addition to making numerous further recommendations, that digital methods such as Building Information Modelling (BIM) offer great advantages and should therefore be applied more widely. Specific advantages are, for instance, enhanced visualization of design options, significantly fewer design errors due to early and - thanks to clash detection - largely consistent design as well as a smooth construction process on the basis of computer-aided simulations.

The future of design, construction and operation largely depends on digital change. The creation of digital, virtual asset models that subsequently become a reality on the construction site and then serve as a basis for the operating phase will be the norm in the construction sector in a few years and will also play a decisive role in the transport infrastructure sector. This is reflected in the developments abroad: in particular in the United States, Eastern Asia, the Scandinavian countries, the United Kingdom and the Netherlands, the use of BIM is being systematically promoted.

However, the introduction of BIM in Germany cannot be achieved in one fell swoop. Working with digital models requires a high degree of coordination and collaboration and a bespoke project organization. What is more, new IT skills have to be acquired and the associated hard- and software purchased.

All this leads to uncertainty on the part of the clients and the members of the supply chain. In particular for small and medium-sized enterprises, the dynamics of digitalization lead to uncertainty regarding the speed of adjustment.

The Road Map initiated by the Reform Commission defines a common understanding of the BIM method and lays down the requirements the Federal Ministry of Transport and Digital Infrastructure will set for digital models and the collaborative work in BIM. Thus, the Road Map brings clarity for all participants regarding the future requirements they should prepare for. It also gives everybody sufficient time to make the necessary changes by setting the timetable for the gradual introduction of BIM and specifying the next steps to be taken to achieve Performance Level 1. The Road Map is mainly targeted at public sector clients in the field of infrastructure construction, as they will have to demand Performance Level 1 when procuring new projects, and at members of the supply chain, as they will have to acquire the necessary skills if they do not already have them. But also other public and private sector procurers can benefit from the Road Map as the basis for the introduction of BIM.

In order to achieve the desired outcomes across the industry, the public sector is to become a role model and catalyst for digital construction. The many small and medium-sized enterprises are to receive help in mastering the transition. For this purpose, the Federal Ministry of Transport and Digital Infrastructure will make available millions of euros, for instance to fund pilot projects to identify, in each case, the optimum approach to the application of BIM and to promote the standardization of asset descriptions. The existing interface issues with the exchange of data are to be resolved to allow for an efficient application of BIM.

The present Road Map has been developed by the “planen-bauen 4.0 Gesellschaft zur Digitalisierung des Planens, Bauens und Betreibens mbH” (planen-bauen 4.0) on behalf of the Federal Ministry of Transport and Digital Infrastructure. A more detailed document will be available from planen-bauen 4.0. The company was established by the major associations of the design and construction industries in order to advance the digitalization of design and construction in Germany. Representatives of all industries involved in design and construction as well as of public and private sector clients participated in the development of the Road Map.

2 General information

2.1 Definition of Building Information Modelling (BIM)

A basic condition for a wider application of BIM is a clear and common understanding of what BIM means.

The core element of the BIM method is the creation of digital, three-dimensional asset models. These models contain pre-defined components and spaces. The geometric design information is successively developed and linked with further relevant information in a collaborative design process with all parties involved. This additional non-geometric information may, for instance, describe the material, service life, environmental and other characteristics, such as acoustic transmissivity and fire safety properties. Spaces are described separately on the basis of the structural components bounding them. They can be assigned properties such as volume or possible uses. The entirety of all these data serves as a basis of information during design, construction, operation and maintenance of the asset. In this way, BIM makes it much easier to assess and analyse the entire asset life cycle. If time and costs are examined in addition to the geometric dimensions, the results are referred to as four- or five-dimensional models. Special computer programmes use the data to visualize the geometry but also other desired aspects of the asset or of the design and construction processes.

In conclusion, BIM can be defined as follows:

> "Building Information Modelling means a collaborative work method that creates and uses digital models of an asset as a basis for the consistent generation and management of information and data relevant to the asset's life cycle as well as for the sharing or passing on of such information and data between the participants for further processing by way of transparent communication."

2.2 Conditions for digital design, construction and operation

For the BIM method to generate added value, several basic conditions need to be fulfilled:

Working with BIM requires clear contractual arrangements, close collaboration and a team-oriented approach to the design process. This is because the individual discipline models of all participants – e.g. architect, construction expert, structural engineer or building services supplier – that are derived from the coordinated model have to be developed in close collaboration and checked for consistency regularly.

The step towards all parties involved in the design and construction processes working in a collaborative and partnering way can be regarded as a "cultural change" and requires new roles and functions to organize smooth collaboration. The roles and responsibilities must be defined before design in BIM starts.

For the collaborative work with BIM, the data exchanged between the participants have to be compatible. Therefore, it is indispensable for making full use of BIM that all software manufacturers use the same standardized and non-proprietary exchange formats and structural component descriptions. A non-proprietary, open exchange standard is available in the form of what is referred to as the Industry Foundation Classes (IFC). For building construction, this standard is already highly developed. It is an international standard that is used in large parts of the world. In the construction of federal trunk roads, the national "Catalogue of Objects for Roads and Traffic" (OKSTRA) is currently used for the exchange of data.[1] In order to ensure the full usability of the international standard IFC also in the infrastructure sector, the Catalogue of Objects is presently being expanded with funding from the Federal Ministry of Transport and Digital Infrastructure.

[1] There are also other open exchange standards than IFC and OKSTRA which are, however, not discussed here, since they are less important in the overall context.

Another condition for the use of BIM is sufficient expertise in the application of the digital methods on the part of the designers and construction companies as well as on the client side. Clients have to be capable of defining their BIM requirements when tendering design and construction works. To this end, the public sector clients have to acquire the necessary know-how in good time. The same applies to the supply chain.

As regards the legal framework, there is no imperative need for adjustments in order to implement the Performance Level 1 presented herein. Even today, projects can be carried out with BIM – without legislative changes. However, the legal framework should be examined so as to determine whether changes would be helpful to facilitate the application of BIM. Moreover, toolkits should be developed for the parties concerned that explain what should be paid attention to when drawing up contracts or calling for BIM tenders.

In conclusion, for BIM to be applied more widely, all participants will first have to complete numerous tasks. In addition, financial resources are needed to acquire the necessary skills and establish the prerequisite technical conditions. Moreover, the new design and construction processes have to be tested in pilot projects and the findings shared.

2.3 Structure of the Road Map

The Road Map is a model that offers a transparent description of the path towards the application of digital design, construction and operation, which it invites clients and members of the supply chain to follow. The aim of the Road Map is the gradual introduction of BIM in the area of responsibility of the Federal Ministry of Transport and Digital Infrastructure. It therefore applies primarily to infrastructure construction and infrastructure-related building construction but can also be used as a model in other areas. The Federal Ministry of Transport and Digital Infrastructure, which has the lead responsibility for digitalization in the Federal Government and is the Federal Government's main investor in the construction sector, will lead by example in the implementation of the Road Map.

The introduction of BIM will be effected through a gradual application over time of Performance Level 1, as defined in chapter 4, to specific projects. Moreover, the preparatory measures required for its implementation are described for all parties involved, and it is specified as of when and to what extent it is to be applied. All parties involved are given sufficient time to prepare for the new method. This means:

- From mid-2017 onwards, a systematically increasing number of transport infrastructure projects will be carried out within the framework of an extended pilot phase, applying the BIM requirements of Performance Level 1.

- Once the basic conditions have been established, Performance Level 1 is to be applied on a regular basis to new projects in the entire transport infrastructure construction sector from the end of 2020 onwards.

Thus, the first phase covers the period from today to 2017 and constitutes the preparatory phase. This phase is dedicated, for instance, to carrying out pilot projects and standardization measures, conducting initial and continuing training, resolving potential legal issues and preparing BIM guidelines on effective approaches (processes) to design, construction and operation in BIM. In 2017, the second phase will start with the systematic scaling up of the application of Performance Level 1 in a larger number of pilot projects. From the end of 2020 onwards, the broad implementation of Performance Level 1 will begin.

A more advanced level of BIM is outlined in chapter 6; it takes the form of a look ahead to the future, since making specific determinations is not realistic at this time.
In conclusion, the following picture emerges for the Road Map:

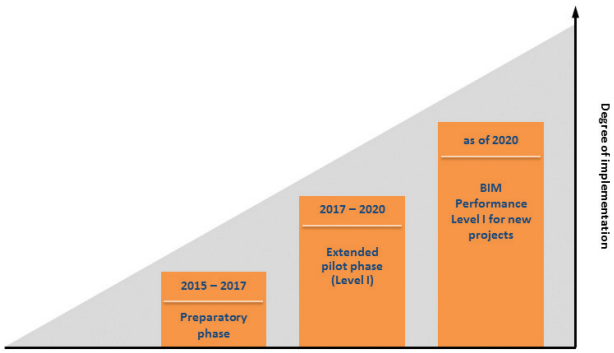


Figure 1: Schematic illustration of the Road Map (author's illustration)

All participants are invited to promote the application of the Road Map in order to achieve as wide a response as possible. The Federal Ministry of Transport and Digital Infrastructure has already started collaborating with the federal state authorities responsible for road construction to apply BIM. The German railway infrastructure provider DB Netz AG intends to start scaling up the application of BIM in the infrastructure sphere from 2017 onwards, as provided for in the Road Map.

In the Federal Government's buildings projects, too, the method has already been applied on a pilot basis. The plan is to put the BIM method to the test in further suitable pilot projects in cooperation with the respective clients.

The Federal Ministry of Transport and Digital Infrastructure will widely share and communicate its experience of BIM for the benefit of the clients and the supply chain alike. Here, the hope is that as many other public sector clients from the Federal Government, federal states and local authorities as possible and also private sector clients will follow and benefit from it. This will create incentives for the members of the supply chain – i.e. designers, contractors and operators – to quickly acquire and offer the necessary skills.

In view of the advanced international development and the pace at which digitalization is progressing, both clients and members of the supply chain are urgently advised to rise to this challenge now. Those who wait too long risk being left behind.

3 Potentials and objectives

Digital construction is the future – model-based, collaborative and efficient across all phases of a project. Design errors, unidentified risks, unexpected cost increases, disrupted construction processes and unnecessarily high costs of operation – all this will reduce significantly, leading to substantial economic gains that should be generated as soon as possible. That is the main objective of the Road Map. If it is achieved, the German design and construction industries will remain internationally competitive in the future. In concrete terms, BIM offers three key advantages that are to be exploited with the help of the Road Map:

3.1 Increasing design accuracy and cost certainty

BIM allows for the visualization of design options right from the start of the design work, thus offering significant advantages. Asset simulations facilitate better decision making and choosing the option that is best for the client or user. Cost certainty will improve, since change orders due to changes in requirements are among the main reasons for cost increases in public sector construction. With regard to public participation, which plays an important role particularly in infrastructure projects, visualizations reduce existing uncertainties and help make the public feel better informed, thus improving project acceptance and reducing the risk of public protests as well as project delays that these may entail.

Team-oriented, collaborative problem-solving mechanisms result in significant efficiency and productivity gains. Design errors or gaps can be largely avoided due to the close collaboration of the designers and IT-based clash detection as well as rule-based quality checks. Moreover, the design work can be automatically and thus more efficiently checked for compliance with various building regulations. Both of these advantages are significant, since they help to prevent change orders and cost increases. A further advantage is that the information relevant to the individual parties involved is available at all times. Important decisions can thus be taken on the basis of transparent, robust and comprehensive data.

BIM simplifies the measurement of work and construction invoicing significantly. If there are design changes, for example due to change requests by the client, the resulting costs for the overall project can be calculated more quickly than in conventional design thanks to model-based, precise determinations of quantities and costs. Errors resulting from complicated changes can be prevented through clash detection.

Thanks to the simulation of the construction processes with the help of the BIM model, interface risks can be reduced. This also improves the planning of the construction processes. The construction processes can be implemented on the construction site in accordance with the optimized planning. All relevant data are available to all participants in real time.

In conclusion, the following can be said: BIM facilitates more accurate planning, specifications of services, cost estimates and construction scheduling. Many risks, such as planning risks, technical risks, planning approval risks, interface risks, etc., can be reduced with BIM while transparency as well as acceptance, for instance in the case of public participation, can be improved. Risks are manageable to such an extent that the insurance of project cost risks for large-scale projects is to be examined in a number of initial pilot projects.

3.2 Optimization of life cycle costs

In the conventional approach, project planning and construction are often modified without giving sufficient consideration to the costs arising during the operating phase. Since these operating costs (OPEX) are usually much higher than the capital expenditure (CAPEX), there is great potential for reducing the life cycle costs. The model-based simulation of the design and construction costs together with the costs of future maintenance and replacement measures as well as the costs of operation allows for cost optimization.

The client and/or operator receives the digital model as a basis for the operation of the asset. This prevents the loss of knowledge that usually occurs during the transition from construction to operation. The model contains, in particular, information on every single structural component – e.g. material, manufacturer, costs, location in the structure, service life, maintenance cycles – and thus enables, among other things, the combined optimization of investment in maintenance and replacement. Moreover,

the model allows for the simulation of technical facilities, thereby supporting the optimization of the facilities' energy efficiency (e.g. tunnel ventilation and lighting).

In the federal trunk roads sector, life cycle assessment plays an important role, especially for public-private partnerships (PPPs). The private sector contracting partners of public sector clients not only build the roads, they also operate and maintain them for a contract period of usually thirty years. The range of services of a PPP project additionally includes the (pro-rata) financing of the project. Within the framework of a PPP project, certain design services which build on the design provided by the clients are, moreover, performed by the supply side. The tenderers have to optimize the life cycle costs in order to compete successfully.

3.3 Implementation of the Reform Commission's key recommendations

The Construction of Major Projects Reform Commission presented its recommendations in June 2015. One of the 10 key recommendations for action refers to increasing the use of BIM. However, the application of BIM also supports other key recommendations.

This applies primarily to the recommendation to intensify cooperation and collaborate in teams, both in design and construction. Implementation of the Commission's proposal to make sound risk management mandatory for major public projects is simplified significantly through the use of BIM.

The Reform Commission has proposed that the award of construction works be made dependent on quality criteria to a greater degree than is the case in existing practice. It is still too common for contracts to be awarded to the cheapest tenderers whose offers often do not even cover their own costs and who then try to remedy this shortfall by way of subsequent change orders. When designing in BIM, it is easier to detect design errors or gaps in the specifications that could lead to change orders later on. In this way, it becomes more transparent which bid actually represents best value for money.

The Reform Commission's call for more transparency and control is also supported through BIM. This is true both within the project, since BIM facilitates continuous controlling with its geometric, time- and cost-based modelling of the project, as well as for the public because of the aforementioned visualizations and the more reliable assessment of costs and risks.

4 Performance Level 1

Performance Level 1 describes the minimum requirements that are to be fulfilled from mid-2017 onwards in the extended pilot phase and later, from 2020 onwards, by all projects that are to be newly planned. By then, public sector clients that are executive agencies of the Federal Ministry of Transport and Digital Infrastructure will have to be able to apply the requirements specified herein to new design tenders. This also includes the decision as to whether the coordination of BIM activities remains with the client or is delegated to the supply chain. Members of the supply chain will have to acquire the skills to offer their services in conformity with the requirements of the clients.

The requirements can be divided into three areas – "data", "processes" and "skills":

4.1 Data

- The client has to provide precise specifications of which data it needs at what time in its "Employer's Information Requirements" (EIRs). This includes, in particular, information on when, in how much detail and in which format the requested data are to be delivered so as to enable the client to make necessary decisions on the basis of these data. The requested data should not only include the geometry but also further attributes of the asset and/or its components with relevance for the client, such as the construction materials along with their properties (e.g. thermal transmittance, sound insulation properties or ecological footprint). The client can, moreover, specify that a digital description of the construction process and a detailed break-down of the costs (5D model) have to be included, too. When preparing the EIRs, close collaboration with the future user or operator of the asset is essential.

- All deliverables are to be provided in digital form on the basis of working with discipline-specific 3D models (e.g. plans, schedules, hand-over documentation). If 2D plans continue to be prepared, these must be derived from 3D models which are to be provided to the client. The principle of designing in separate disciplines is maintained, and the distinct authoring disciplines develop their respective discipline-specific models. The discipline-specific models are to be merged to form a coordinated model and checked for consistency.

- The data delivered by members of the supply chain have to be tested for conformity with the EIRs. The client should contractually agree the test criteria and procedures so that the members of the supply chain can use these test procedures for their own validation purposes and quality improvement.

- The invitation to tender should require the provision of non-proprietary data exchange formats in order to facilitate the exchange of data. It is also possible to require a combination of non-proprietary formats, as long as a clear assignment to components, spaces or facilities is ensured.

- When awarding design services in accordance with the BIM method, it must be ensured that the hard- and software necessary to fulfil the requirements described herein is generally available. Since the software industry is following international standards, such as IFC, more and more closely, this condition is already met in many cases. Moreover, the award of services must be non-discriminatory. Prescribing specific software products is not permitted. The public sector clients, too, have to be equipped with appropriate soft- and hardware.

- BIM is to be included in the contract as the design instrument that is to be used. The contract should also contain arrangements concerning the rights of use the client has regarding the 3D discipline-specific models. With a view to potential liability issues, the respective responsibilities have to be laid down in detail. Since design takes place in separate discipline-specific models in BIM, too, all disciplines, in principle, remain responsible for their part of the design work.

4.2 Processes

- The process for the production of the required data is to be defined in what is referred to as the BIM Execution Plan (BEP), specifying all necessary roles, functions, processes, interfaces, interactions as well as the technologies used. The responsibility for drawing up the BEP lies with the client; however, the latter can

contractually delegate this task to a service provider. The BEP specifies how frequently and when design meetings and clash-detection runs of the combined model are to take place, which parts of the design work have to be delivered by when and in how much detail, as well as when and to what extent visualizations, determinations of quantities, simulations of technical facilities, life cycle assessments, etc. have to be carried out. Thus, the BEP is the backbone for every BIM project as regards the creation, sharing and management of data.

- A "common data environment" (CDE) that all participants can access has to be established for the organized storage and exchange of all data created in the design and construction process. The CDE forms the basis for the processes outlined in the BEP. Common standards and rules for the efficient use of BIM within this data environment are currently being developed in the form of an ISO standard (ISO 19650). On the basis of this standard, a CEN standard is to be developed subsequently, from which a corresponding DIN standard will then be derived. The national implementation is being developed within the framework of the VDI 2552 guidelines.

- In order to ensure an efficient approach that minimizes costs and to thereby satisfy the principle of lean project execution, an excessive generation or processing of information and data should be avoided. For this purpose, the generation of data should be geared towards the requirements of the later operating phase and not towards the available technical possibilities.

- In order to promote a collaborative and partnering-oriented behaviour, the client and the members of the supply chain should agree a project charter which lays down the rules for fair and open collaboration on equal terms, taking into account the German Construction Industry Vision and Values.

- In addition, the client should establish rules for internal dispute resolution procedures and, where appropriate, also agree external dispute resolution procedures so as to simplify cooperation within the framework of the application of BIM.

For the successful generation of digital models and construction with BIM, clearly defined collaborative processes are essential. The Major Projects Reform Commission has also established the importance of such processes for projects carried out in a traditional manner if they are to be delivered to time and cost. Process descriptions, as provided in the BEP, such as the definition of the roles and tasks of the parties involved, do not require additional effort, since the necessary information must be created in any case.

Even if the implementation of processes might vary depending on the individual project, it is possible to define a generic "reference process" which describes the work phases of a project, including the use of BIM and the preparation of the BEP. This reference process defines a rough structure on which the BEP builds to define the project-specific processes. The BIM reference process outlined below (see Figure 2) is based on traditional, mature and proven construction project management activities. The consistent application of this process makes it possible to exploit the envisaged benefits of this method, such as the improvement of planning certainty, transparency and efficiency, in a cost-effective and low-risk manner.

The creation and provision of information during the design and construction phases (light and dark blue portions, work phases 1 - 8) follows the process described in the common data environment standard, which is outlined in detail in the BEP and takes place in conformity with the Employer's Information Requirements. The BEP appears twice in the reference process: once before design starts, i.e. before work phase 1, and once before construction starts, i.e. before work phase 8. The reference process therefore applies to all procurement strategies and contract types.

The following illustration of the BIM reference process shows the principle of information provision as well as the corresponding project management. Red dots indicate the transfer of data to the client. The times of the data transfers can vary depending on the individual project.

The EIRs at the beginning of the project (green portion) can already be partially based on the application of BIM, since visualizations may help the client to choose their preferred option.

Figure 2: Schematic illustration of the BIM reference process (planen-bauen 4.0 GmbH)

4.3 Skills

As part of the procurement process, it must be ensured that the members of the supply chain have the BIM-related skills needed for the implementation of Performance Level 1 and are ready to work in a collaborative way.

Relevant BIM skills and capabilities should therefore be considered when awarding the contract. BIM skills and experience are also required on the client's side to enable them to draw up proper tender documents and evaluate the incoming bids.

5 Activity areas and measures

From mid-2017 onwards, the BIM minimum requirements of Performance Level 1 are to be applied in an increasing number of projects. From the end of 2020 onwards, Performance Level 1 is to be used, on a regular basis, in Federal Government transport infrastructure projects that are to be newly planned. The purpose of the first phase, which is currently underway, is to prepare for the application of BIM by creating the necessary conditions and providing targeted support to clients and members of the supply chain alike.

The first phase also aims to help convince the market participants of the significant advantages BIM offers. At the same time, it is being examined for which types of projects BIM makes sense and in which way it should be applied. In addition, it is important that the market participants themselves gain concrete experience with BIM. For this purpose, simple projects are a good way to start. At the beginning, it may also make sense to plan and carry out projects in the traditional way and in BIM in parallel. This means additional effort but also reduces risks, especially in the initial period when BIM skills are still limited, and permits a direct comparison of alternative approaches.

The tasks to be tackled in the coming years involve financial effort that will be shared among the public sector and other clients, associations and chambers but also the companies of the design and construction industries.

The Federal Ministry of Transport and Digital Infrastructure is already providing funding totalling € 3.8 million for four BIM pilot projects including accompanying research in the road and rail sectors. The research findings will be available in 2017.

In the federal trunk roads sector, the Federal Ministry of Transport and Digital Infrastructure is funding two road construction projects that are being carried out by DEGES (Deutsche Einheit Fernstraßenplanungs- und -bau GmbH). In coordination with the 16 federal states that are responsible for the implementation of BIM on behalf of the Federal Government and that were already involved in the preparation of the Road Map, the Federal Ministry of Transport and Digital Infrastructure is currently planning further road construction pilot projects. The Federal Ministry of Transport and Digital Infrastructure is also devising pilot projects within the framework of the PPP procurement option in the federal trunk roads sector. BIM is to be applied in the first project of the "new generation" – the A 10 / A 24 in Brandenburg – on a road section that is still to be determined. For this purpose, the Federal Ministry of Transport and Digital Infrastructure and DEGES, acting as the procurement agency on behalf of the State of Brandenburg to which administrative powers have been delegated by the Federal Government, are working in close collaboration.

For the rail sector, the Federal Ministry of Transport and Digital Infrastructure will – in addition to the pilot projects already underway – assist the German railway infrastructure provider DB Netz AG in carrying out further BIM pilot projects in the years 2016 to 2018 by making available eight-figure sums. DB Netz AG is aiming for a rapid introduction of BIM and implementation of the Road Map in the infrastructure sector. DB Station & Service AG has progressed the implementation of BIM to such an extent that it is looking to design and construct all stations in BIM from 2017 onwards.

For the waterways, too, pilot projects for the systematic application of BIM are to be launched. A concrete project proposal from the Federal Waterways and Shipping Administration already exists.

5.1 Data

5.1.1 Employer's Information Requirements (EIRs)

The initial impulse for a wide take-up of BIM is to come from the client side through the EIRs. Clients have to learn to use BIM and need to be enabled to formulate project-specific requirements for digital construction.

Measures:

- Public sector clients should develop catalogues of model requirements that cover a major part of the typical requirements. Specific requirements can be added in accordance with the needs of the project. The requirement catalogues should be developed for different types of infrastructure and buildings projects. Within the framework of the research accompanying the pilot projects of the Federal Ministry of Transport and Digital Infrastructure, concrete EIR recommendations for road and rail

are being developed. For the waterways, these recommendations are to be evolved.

- Moreover, recommendations on the drawing up of contracts including apportionment of liability, fee distribution, ownership and intellectual property rights (IPR) are being prepared.

- Furthermore, advice is being prepared on when the application of the BIM method is only advisable for some parts of the project or not at all, e.g. in very simple projects or projects with special and unique characteristics.

- The clients should conduct pilot projects that also cover the early phase of a project including the preparation of EIRs. For this purpose, the Federal Ministry of Transport and Digital Infrastructure is expanding its pilot schemes. The clients should develop rules for the testing of digital data against the requirements specified in the EIRs in order to be able to check the data they receive from their service providers. The Federal Ministry of Transport and Digital Infrastructure as the competent authority is examining funding options for this purpose.

- BIM databases should be set up in which certain BIM use cases (clash detection, visualizations, bills of quantities, etc.) and parameter templates for components of assets are linked with the necessary information requirements. These databases should also contain information on the typical BIM requirements (EIRs) and levels of detail (LoD) for the data drops in the individual work phases. To support these databases, classification systems for asset components and corresponding databases of functional properties of components are needed. The Federal Ministry of Transport and Digital Infrastructure will identify the best approach to achieve this and present a suitable approach for the infrastructure sector.

5.1.2 Non-proprietary data formats and standards

The development of the non-proprietary data format IFC is taking place at international level; it is already available as ISO 16739. The IFC format has the advantage that it is used around the world and thus serves international competition. The development of IFC, which is already very advanced for buildings, is currently being progressed at international level for road and rail by buildingSMART. Subsequently, the outcomes are to be used for the further development of ISO 16739 and, based on that, become part of a European and/or DIN standard. While IFC is still insufficiently developed in certain areas, users can fall back on other already available formats, such as OKSTRA.

Measures:

- The public sector should ensure that German experts participate in the international standardization processes in order to introduce the lessons learned from the German standards, such as OKSTRA, into these processes and safeguard German interests. To this end, the Federal Ministry of Transport and Digital Infrastructure is promoting German participation in the development of IFC for road and rail. This process is expected to be completed in 2017.

- The private sector should develop certification procedures for the assessment of software with a view to the implementation of IFC. Flawed implementation can, for instance, result in data loss during the exchange of data or errors during data processing. In addition, for the purposes of quality assurance, the private sector should develop software-independent checking rules for implementation in testing tools for the validation of data exchanges within projects. Both should be done in a coordinated manner so as to avoid duplication of work and parallel development.

5.2 Processes

A basic characteristic of BIM is the collaborative way of working within a framework of processes – who does what, when and how – specified at the start of the project. For this purpose, a BIM Execution Plan (BEP) is developed that clearly defines the interfaces between the different parties involved as well as their roles and interactions. The basic principles and rules for the creation, use, administration and sharing of information are described in ISO standard

19650 (under development). This leads to the following measures:

Measures:

- The German standardization bodies should actively participate in the development of a European mirror standard for ISO 19650 and progress the development of national implementation guidelines.
- Guidelines and model examples for BEPs should be developed that outline the ideal processes for different types of assets. The Federal Ministry of Transport and Digital Infrastructure will make a significant contribution to this in the infrastructure sector through the ongoing and upcoming pilot projects.
- The private sector should develop training courses on BIM-based design and construction processes for clients and estate owners, project managers, future BIM managers, designers and other members of the supply chain in order to ensure the transfer of knowledge.

5.3 Contract award, drawing up of contracts and skills

The condition for the use of BIM is that both clients and members of the supply chain have adequate BIM skills and capabilities and are ready to work in a collaborative way. Moreover, BIM must find its way into higher education and vocational training in order to meet the growing demand for specialists.

Measures:

- During the procurement process, it must be ascertained whether the BIM skills of a bidder are sufficient for the task. Therefore, their BIM skills, and also their readiness and ability to work in a team, should be verified by way of suitable questions.
- Public sector clients whose skills are still insufficient should use the negotiated procedure or the competitive dialogue procedure for the award of contracts, taking into account the applicable procurement law. The competitive dialogue procedure is permissible if the client is objectively incapable of specifying the technical means needed to fulfil its wishes and requirements.
- The academic education of architects and engineers should take account of BIM and the requirements resulting from Performance Level 1. All parties involved in design and construction should actively approach the institutions of higher education and identify together with them ways to meet the technical needs of a modern construction industry.
- In vocational training, the skills necessary for the application of BIM must be taught within the framework of the German dual training system. This is a task for the professional associations.
- According to the current state of knowledge, the application of BIM does not entail an imperative necessity to change the HOAI (Official Scale of Fees for Services by Architects and Engineers). 3D and 4D modelling are explicitly mentioned as “special services” in the service profile for buildings. If “special services” are performed when using BIM, the fees can be agreed freely. With a view to a broad-based introduction of BIM, it should however be examined to what extent a better incorporation of BIM services into the service profiles could simplify the agreement of fees and make it more transparent.
- The Federal Ministry of Transport and Digital Infrastructure will evaluate whether the development of model contracts may be helpful. Where appropriate, checklists should be developed that indicate the contractual arrangements that need to be agreed for a smooth implementation of BIM, such as arrangements regarding the transfer of data to the client.

6 Looking ahead

Performance Level 1 was specified in such a way that it can be achieved within the current legal and technical frameworks. The Federal Ministry of Transport and Digital Infrastructure will expand its pilot schemes and progress the broad-based introduction of BIM within its area of responsibility from 2020 onwards.

The pace of digital change is so fast that it would not make sense to define concrete and specific targets for the time after 2020 at this early stage. Nevertheless, we must give thought early on to how the requirements for asset models will develop in the future and what adjustments will become necessary as a result of these developments.

Today, the operation, servicing and maintenance of assets can already be partially automated using modern management systems. Currently, the data required for this purpose stems only partially from the design and construction phases of an asset; but in the future, it will be possible to make increased use of BIM data for their generation. Due to the increasing level of automation, these data will play an even greater role in the future, in particular in the operating phase.

At the same time, information acquired during the operating phases of different assets can be re-used in the life cycle assessment of projects that are to be newly planned. Measurements of sensors, facilities and mobile devices are producing an ever-wider data basis. Thus, data on temperature, humidity, energy consumption, user behaviour, occupancy, failure or down-time provide ever more information on the state and performance of assets.

Therefore, a higher future performance target will primarily focus on the improvement of the functional performance of assets. Especially in the case of highly complex assets, such as hospitals or airports, the costs of poor performance can exceed the actual design and construction costs many times over.

An improvement of performance can be achieved primarily by re-using data generated during the construction and particularly during the operating and maintenance phases in the specifications for the design of new assets; this means that the currently usually linear flow of information from design to construction to operation and demolition will, in the future, change even more to become the feedback loop illustrated by the reference process (Figure 2). In order to achieve this, information must be better integrated into a shared data environment than it currently is.

The efficient structuring of this feedback loop will be at the core of a post-2020 performance target and should be fleshed out further in the coming years.

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