BIM in construction of underground railway

Experiences from practical application

Introduction

A new planning method is more and more applied recently: BIM. But what does this abbreviation mean? The most common interpretation is Building Information Modelling, more rarely Building Information Management. The term modelling leaves the impression that BIM is another 3D tool. In fact, with this method even more attributes can be added to a 3D model, such as a time line or costs of the structure.

BIM is most popular in building construction. During the planning of buildings and industrial projects we have been using BIM successfully for several years, though the method was used – at least at the beginning – mostly as isolated solution, called internally Little BIM or Closed BIM. However, the method shows its strengths mainly in the exchange of information with other planning partners with the so-called Big BIM.

In the following, we present two projects from the field of infrastructure planning, especially underground railway planning. In view of the integration of all planning participants and interfaces during the construction of metro stations, the challenges are similar to building designs; so this planning methods particularly suggests itself. Moreover, the client of the Metro Doha Project explicitly requested BIM.

Metro Doha Project

In the city of Doha in Qatar currently a modern metro network is being built. The million-dollar project, announced in 2011, is an integral part of the Qatar Rail Development Project or Qatar Integrated Railway Project (QIRP). The four main lines of the metro network, comprising around 90 km line (50 % tunnels) and around 30 stations (24 underground), run underground in the centre of Doha and mainly overground outside of the city.

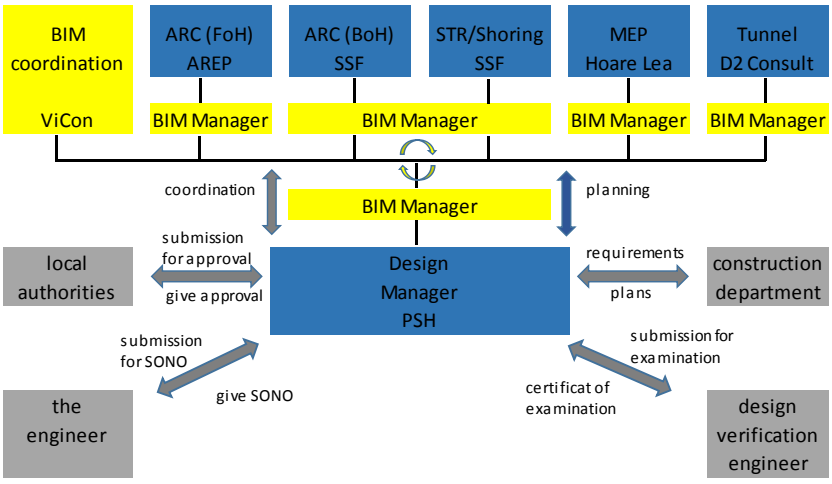
The Metro Green Line is implemented as design and build project by the joint venture PSH of Porr AG from Austrian, Saudi Binladin Group from Saudi Arabia and the local construction company HBK.

The structure's design concept was handed over by the client Qatar Rail with 2D design documents. The contract includes the preliminary design comprising the elaboration and coordination of the building concept with room planning and definition of use jointly with all participants.

Use of BIM:

The client of the Metro Doha Project in Qatar, Qatar Rail, stipulated the application of BIM in the contract. After production of the tender documents as conventional tender design in 2D, the next phases preliminary and final design require the continuous implementation with BIM in order to support the future operation of the metro.

In the disciplines structural design, architecture non-public areas (BoH), architecture public areas (FoH), building services engineering (MEP) and tunnel design, a planning team works at the permanent structures of the Green Line Underground of Metro Doha for the joint venture PSH. Each planning office as well as the design management provide a BIM manager who is responsible for the coordination amongst each other and the implementation within each company.



Organisational chart of BIM team in Doha
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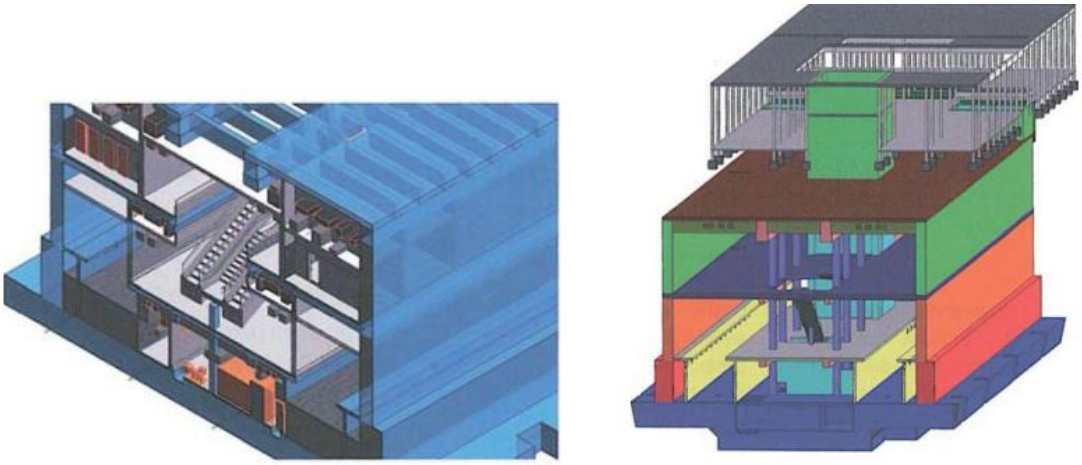
Because SSF Ingenieure produces architecture (BoH) and structural engineering, BIM coordination of both disciplines is realised by a coordinated BIM manager. There are five BIM managers for the final design of the Green Line Underground Project, assisted at the beginning by an external consultant who led the BIM coordination. The client also provides a BIM manager for each line. Depending of the discipline, the BIM manager is supported by different teams who contribute to the coordination of the BIM process.

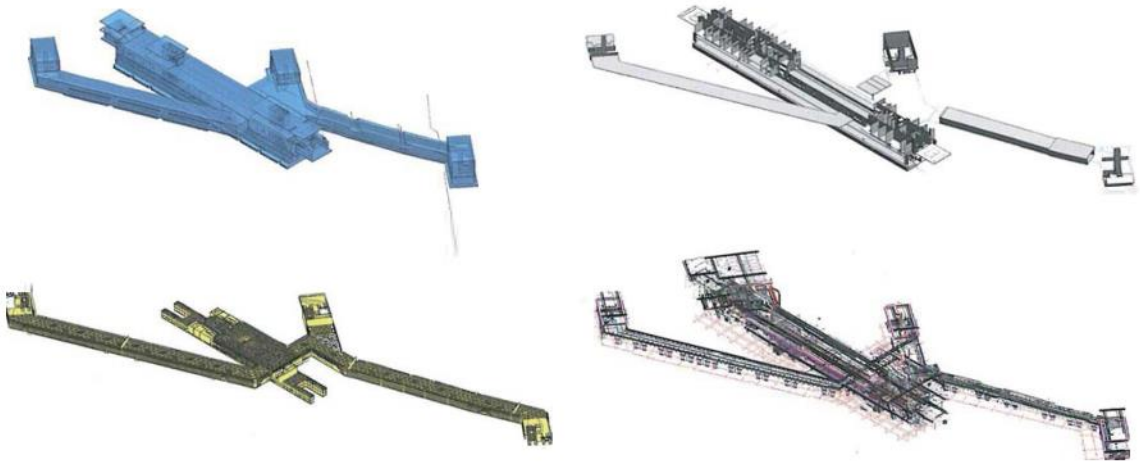
At the beginning of the project, standards were set according to which the BIM process is implemented. On the basis of employer requirements (ER), based on the British Standard BS 1192, and the project requirements, ViCon developed the initial project standards. They consisted of a BIM guideline and a BIM implementation plan for the stations and the tunnel design. The differentiation between stations and tunnels is based on the geometry of both structures; this also resulted in the use of different planning tools for the stations' and tunnels' design. After implementing the initial standards within each company, a weekly meeting with all BIM managers has been introduced to discuss all relevant BIM subjects and to continually improve BIM processes. Because of the international collaboration, the BIM experiences of the companies rely on different guidelines and projects which entails a wide-spread knowledge. As requested by the client, the project participants cooperatively apply the data management system Project Wise from Bentley which bases its workflow and responsibilities on the British Standard BS 1192. Moreover, Project Wise offers a close integration in the CAD programme Revit from Autodesk that is used by most planning participants. On this platform, all documents of the project (reports, plans, models) but mainly the models are coordinated. In this way, all participants have access to the latest models from all disciplines. The client determined Aconex as document management system: All official documents are submitted via Aconex and are then integrated into a coordinated workflow. Furthermore, the system serves as official communication platform.



Partial model: example of cross section

16 structures are planned for the Green Line Underground. SSF Ingenieure alone produces more than 30 models. To fulfil all requirements and to guarantee the standards for all of these models, SSF Ingenieure created a compilation file in Revit to manage the model standards. This is a file in which all component catalogues, necessary to create the models, are compiled as templates. In analogy to the BIM guidelines, the characteristics of the individual component catalogues are elaborated – a so-called Revit family. For example, each element is modelled according to the defined level of detail. Moreover, parameters are set to meet the level of development and as Uniclass parameters in accordance with BS 1192 to identify quantities (BOQ parameter). In addition to Revit families, the compilation file comprises templates for views, pin assignments or tables. This file feeds all models generated for the project. The BIM manager is responsible to manage the compilation file. Changed or newly created elements are saved to the compilation file where they are distributed to all models in a controlled manner. By giving a uniform designation to the construction components in all models, modifications are quickly implemented.

For the Metro Doha Project, each discipline works in its own model which is linked to those of the other disciplines; in this way only the responsible person can make changes at his model. What is more, 3D and 2D models are distinguished from each other for the production of plans.



Overall model Metro Doha after compilation
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The planning models only comprise information which is directly linked to elements. This work method offers the advantage that the model files are not too large and thus do not compromise the linking or upload to the communication platform, and that the access and processing times are shorter. Clear models are always available to check collisions and are accessible to everybody at defined moments within this system. The first round of coordination conducts a collision examination with the programme Navisworks by using the combined models, and potential collisions are solved during further coordination rounds.

All models are planned in their correct position in world coordinates (Qatar National Grid). The creation of a master file, in which all structures are saved in their correct position, allows linking the models without errors and in correct position as well as placing them georeferenced. The master file is based on an AutoCAD file as it provides a much higher accuracy than Revit. The coordination is thus also possible with parties which only indirectly participate at the Metro Doha Project, for example road construction authorities and designers of structures above the metro or adjacent buildings. It also makes a contribution to the client's effort to have all essential structures as digital models and to create a type of BIM city.

Results:

After two years of planning the Green Line Doha Underground Project, we summarise that BIM is a process which keeps evolving as the project continues. The standards defined by the project are continuously improved through new findings and developments. BIM is more than just a pure 3D planning tool and offers essential advantages.

On the one hand, the coordination with all planning partners is structured more clearly as linking the models of our own discipline with those of the other project participants provides a quick overview of the current situation. On the other hand, collision examination is simple and guarantees a flawless implementation. Another advantage is the integration of all information in one model. The elaboration of room books, for example, is then possible directly from the model and is also directly linked to the model. This helps to avoid errors when working in different systems. By defining a uniform component catalogue, BIM also guarantees the same standards in different models and creates a comparable planning.

However, it has to be taken into account that BIM only supports the planning process and not vice versa. The processes should be designed as slender as possible to result in a fast and efficient planning. BIM provides the flexibility to adapt processes to the project conditions; for example, details can be planned in 2D to complement the 3D model.

Client
Qatar Railways Company, Doha, Qatar

D&B Contractor
Joint venture PSH (Porr Bau GmbH, Saudi Binladin Group Company Ltd., Hamad Bin Khalid Contracting Co. W.L.L), Doha Qatar

Architecture *(BoH)*
SSF Ingenieure AG, Munich

Architecture (FoH)
Arep S.A., Paris, France

Structural Engineering
SSF Ingenieure AG, Munich

MEP
Hoare Lea, Bristol, Great Brittan

Tunnel Design
D2 Consult International GmbH, Linz, Austria

BIM Consultant
Hochtief ViCon GmbH, Essen

Underground Station in Munich

The example of the Munich underground station Sendlinger Tor shows the practical application of BIM for partial aspects. It is a BIM project which comprises only parts of the specialist plannings and certain objectives. In this case, the aim is a construction process simulation as conversion and modernisation of the entire station have to be implemented during ongoing underground operation. Already at an early stage of draft design, a high planning security had to be achieved and processes had to be coordinated and optimised in view of the station's operation and traffic on the surface.

Project presentation:

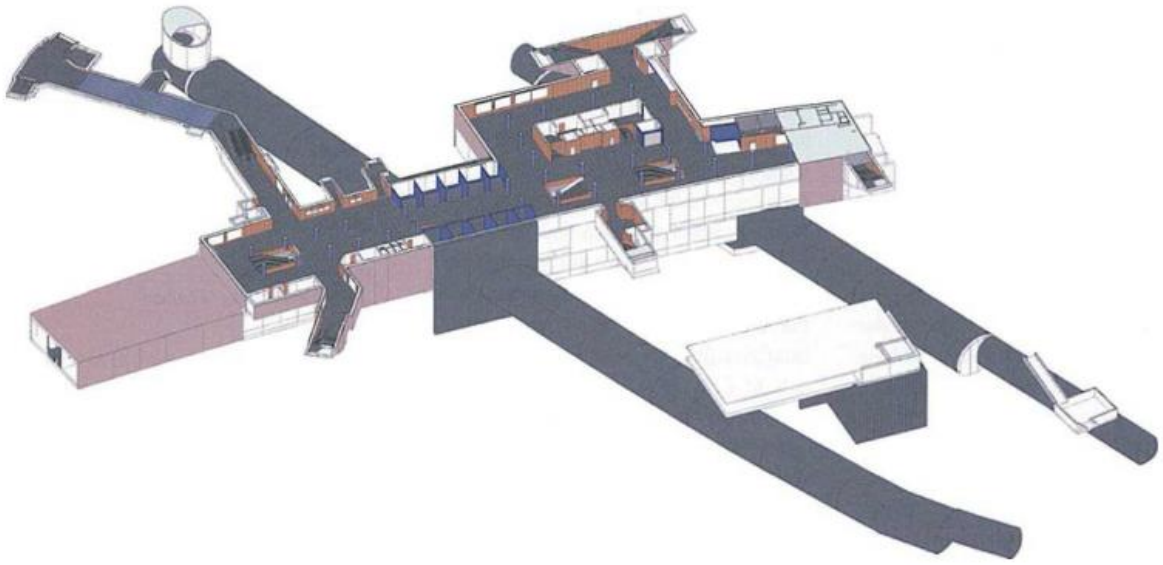
The underground station Sendlinger Tor is one of Munich's central changing stations with 145,000 passengers a day and has been operated for 45 years. Damages, detected during structure inspections, operational interruptions, passenger flow analyses and evacuation situations in case of fire, induced the client to completely converse and modernise the station in the near future. In addition to creating supplementary and wider exits (new cross cuts, wider exits) and detangling the passenger flow inside, the technical building equipment and the station's design are renewed and new shopping areas created.

Interference with the underground's operation should be as small as possible. As construction works at the station take place underneath and in the area of a highly frequented traffic node with multi-lane individual traffic as well as multi-track tramway traffic the influences on the surface play a significant role in the construction process.

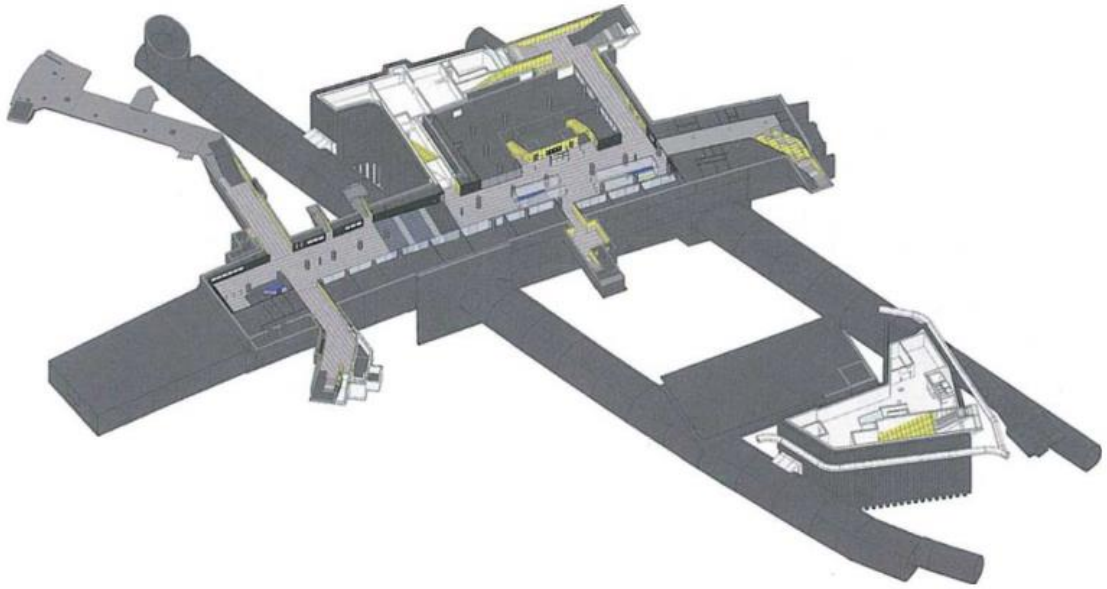
BIM application:

Aim of BIM in the project is primarily to optimise and represent clearly the construction processes. Spatial and temporal conflicts are better recognised and communicated by a visual representation of the complicated processes. Coordination between planning participants, the operation and third parties and if necessary the public are simplified by using this tool.

As standards have not yet been introduced for the application of BIM in Germany, so-called specifications and implementation concepts have to be established for these projects. In addition to the objectives, the organisation, responsibilities and obligations of each participant are defined. Moreover, the procedure of establishing and processing the models, the type of data exchange, contents and detailing depths are determined. In the present case, the BIM manager established the specifications under the lead of the project management and together with the BIM participants. The participants agreed to an Open BIM, i.e. no defined uniform software and data exchange via an open format (IFC files). The IFC files are exchanged, examined and evaluated in view of consistency and conflicts by the BIM coordinator. To reproduce the construction process simulation, all objects are given systematic names which have to be transmitted via the data exchange interface as well as controlled easily to link the objects to the schedule. In addition to the objects' names, elements and object size are defined allowing a sufficient variability to optimise the construction processes.



Overall model of the existing underground station



Overall model of planned new construction and conversion
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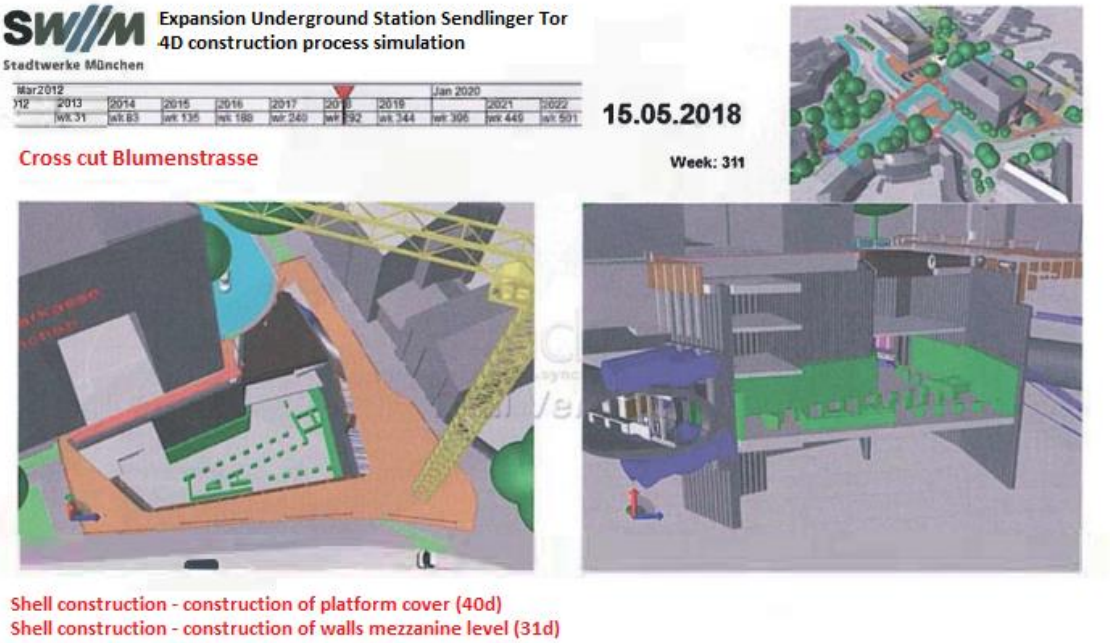
After having completed those preliminary steps and set the bases for the reproduction of the model, the processing of the models started; however, the 3D planning began with the draft design. Basis were the completed preliminary design in 2D and, because of the conversion of an existing structure, as-built measurements. The as-built data had to be transferred to the model in an appropriate form. The produced shell construction model then served as basis for the interior construction models.

Once the interior models are created, the BIM coordinator examines them in view of consistency and collisions, compares them to one another and to the shell construction model. Only after their approval, the models are handed over to the engineer responsible for construction logistics and construction processes who, together with the BIM manager, links the models or objects and schedules to generate the construction process simulation. The models are linked by a programme which reads almost any file format and combines them to one overall model; this also allows linking 2D traffic management plans and thus representing the influences the construction works have on the surface.

The result, the construction process simulation, serves to verify if the processes are in no temporal or spatial conflict; coordination with the operators is done by means of simulations. As the simulations have only been finished recently, the experience with their use itself is still limited. However, it is already clear now that the anticipated results of the simulation in view of clarity and verifiability of processes will not disappoint. The processes are transparent, simple and fast to comprehend by uninvolved third parties. Furthermore, any views and sections can be created to observe and analyse processes in partial areas and on different levels. Videos of processes can be produced from fixed or variable perspectives and detailed analyses can be made at any speed of any area or time frame.



Section of construction process simulation
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Results:

Compared to 2D planning, the elaboration of 3D models results in the well-known effects: At an early stage, a comprehensive planning depth is required which leads to a change in the processes compared to conventional planning. The models allow a simple examination, also by the client, and thus increase the transparency of the design and the planning state. Collision verifications guarantee the consistency of the planning. Especially for large-scale public infrastructure projects, the option to simply and quickly create visualisations to integrate the public in the process is a great advantage.

The advantages of Open BIM are evident: Planers work on the project with an application they are familiar with and know well, which allows them to work fast and effectively. They do not have to switch to unknown products. However, it should be mentioned that the data transfer via IFC interface is not completely flawless. At the moment, there is no other solution but to examine the complete submitted documents even in case of only small changes; this inevitably leads to more work within the processes. For a flawless submission, the interface must be optimised in the future. As already explained, at an early stage a completely thought-through model has to be produced to limit later changes. In the case of a construction process simulation this means that objects have to be divided additionally so they can be used later on to optimise the construction process. For example, concreting sections or construction section boundaries have to be set whilst creating the objects – or a correspondingly small division of objects has to be selected so that boundaries can be moved without remodelling. Taking these requirements into account only afterwards, inevitably creates more work which can, however, be reduced by diligently preparing the planning. The present objective is thus a demanding but resolvable task.

Client
Stadtwerke München GmbH, Munich

Project management, BIM management
baustein GmbH, Munich

Project planning engineering structures, structural engineering and BIM coordination
SSF Ingenieure AG, Munich

Project planning interior works
Raupach und Bohn Architekten, Munich

Construction process and logistics planning
pwb GmbH, Munich

Summary

The BIM method is a practical solution for infrastructure planning. Depending on the scale of the project or the number of participants the best type – Small BIM, Big BIM or Open BIM – should be selected. Each variant has its advantages and limits. SSF Ingenieure choose Big BIM for its daily work. Many project participants, at different locations and even in different countries, work together at one project. Beforehand, the programmes and their versions are determined. The great advantage is that the interfaces are reduced to a minimum, thus simplifying the data exchange. Software manufacturers already offer a wide-ranging portfolio of programmes so that in theory every task can be solved. It should, however, not be neglected that planners must be familiar with these different programmes to achieve good results. The training, tests and analyses present big problems for smaller offices.

In general, BIM is a planning method which follows defined processes. It is important that during application processes are clearly defined in advance, as for example a model comprises much more information than a 2D plan. For this reason, the plan derivation should only be done at the end when all changes are integrated into the model. If 2D plans are modified afterwards, the relevant information will not be automatically transferred to the model.

The aim of the BIM planning is decisive for the creation of the models. BIM is a vast term and promises a lot. There is a variety of possible BIM contents; however, no standards or principles are set defining which contents are indispensable for a BIM project and which repercussions are linked to it. The client must decide in advance which objective he aims at – which flowers he picks from the entire BIM bouquet. The client should make this decision before contracting his planners; in any case, before starting the planning work. His decision is decisive in view of which process are required during planning, how the models are structured and which contributing specialist plannings are integrated into BIM. Due to the currently missing standards, for each project, specifications or implementation concepts are to be established, determining the contents as well as appropriate processes. The client should be aware of this as well as the consideration of sufficient time during the process before making his decision.

Independently from the client's project specifications, we will continue to use BIM applications for future projects. Long-term positive experience, BIM pilot infrastructure projects in Germany, recent recommendations from the reform commission "Large-scale projects" as well as the announcement of the Federal Government to introduce and standardise BIM nationwide, show that we are on the right path. We consider BIM and the accompanying possibilities to be a chance to reinforce the construction industry's reputation and to increase the attractiveness of our profession for future generations.

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