BIM Model Landscape_Open Spaces: An Approach for Landscape and Environmental Planning in Infrastructure Projects

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Abstract: Using the example of the landscape planning aspects of the BIM Autobahn Pilot Project A10/A24, the increased value of engineering projects using BIM to integrate landscape and environmental planning is demonstrated. The basis is the development of the Landscape_Open Space model. This leads to improved communication for all participants especially in regards to planning meetings and appointments. On this basis, the concerns of landscape and environmental conservation can be better considered during the building phase.

Keywords: Building Information Modeling, landscape design, BIM workflow, BIM elements

1   Introduction

The German federal government aims to use Building Information Modeling (BIM) for all future public infrastructure projects costing over 5 million euros. Project participants should supply obligatory performance results in digital form, and be able to participate with other project partners digitally. The long-term goal is to use BIM in construction projects over the entire process: from planning, building, and operation, all the way to dismantling (BMVI 2015). Until now landscape and environmental planning have often played only a marginal role. However, they are of increasing importance as can be seen in such projects as the second main S-Bahn line in Munich (DB Netz AG) (OTTO 2019), the autobahn intersection at the Funkturm in Berlin (DEGES) (BERGER 2020), and others.

The advantages of the cooperative planning method of BIM are seen above all in the possibility of optimizing the collaborative effort of the different trades by increasing the quality, lowering the costs, and keeping to the projected period of construction. In linked planning processes, traffic and landscape planners work together for the best possible solution for the realization and operation of traffic routes. An optimized flow of information between actors of the various areas of expertise is a necessary requirement for having high quality, interdisciplinary planning results. The integration of landscape and environmental planning in the BIM processes of infrastructure building seems therefore advisable.

Until now the use of BIM in landscape architecture has been concentrated in the area of object planning, and the first workflows have been developed (BRÜCKNER et al. 2018). In contrast, BIM has rarely been used in landscape and environmental planning. This issue was addressed in the research semester of the Master of Landscape Architecture program at the University of Osnabruck. The goal was to develop a method of integrating landscape conservation into the BIM process of road construction (REMY 2020). This was carried out using the BIM pilot project "PPP-A10/A24 (Public Privat Partnership) in cooperation with the working group ARGE A10/A24 Havelland Autobahn. ARGE is a part of the contractors' consortium and is responsible for the area of planning and construction.

There is an especially close interlinking with the BIM processes in infrastructure construction with the environmental impact assessment (LBP) as well as the landscape management detailed design phase (LAP). The basis for the BIM method is the sectoral planning, which is brought together in a 3D coordination model and tested for consistency. This follows on the basis of the international, non-proprietary interface Industry Foundation Classes (IFC) of digital descriptions of the construction models which are based on 3D models of components, volumes, etc. The IFC interface assures the open BIM process. This means that all planners can work using their own specific software. In the ideal case, the current state of planning is available for all parties involved, as rule in the cloud-based Common Data Environment CDE. The digital building models can be used as an information databank and as reliable sources for decision making during the entire life cycle of the structure.

The coordination model for the BIM Pilot Project A10/A24 at this time makes use of a 3D model for the ground surface, subsoil level, road segment, petrol and rest areas, as well as civil engineer constructions (see Fig. 1). Landscape plans are provided by the responsible landscape and environmental planners as 2D CAD plans, and therefore cannot be integrated in the overall coordination model. Weaknesses in the communication of landscape and environmental planners with other project participants as a result of differing planning methods seem foreseeable.
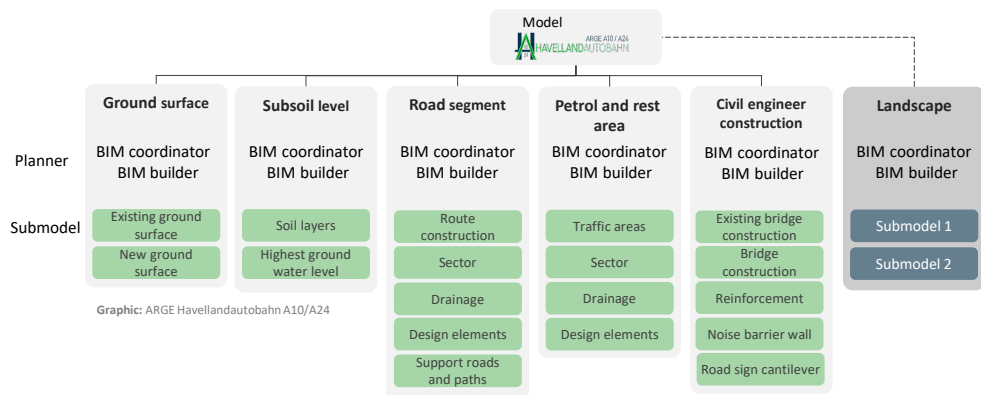

Fig. 1: Extension of the existing model through the Landscape_Open Space Model (ARGE Havellandautobahn A10/A24)

2 Standardizing BIM

For the successful implementation of projects using BIM, a strong structuring and standardization of the processes is necessary, especially in regards to data exchange (who delivers what, when, to whom and to which degree….). At present, necessary standards are still being developed. This holds true for the extension of the data exchange format IFC for infrastructure building objects (IFC Road, IFC Rail, etc.) which are also, to some degree, relevant for landscape architecture. At the moment, the most current IFC version (4.3 RC2), in the "candidate stage", has few elements to describe bridges and infrastructure elements on the basis of lines (IfcBridge, IfcAlignment, see BUILDINGSMART 2021). First, with IFC 5.0 will there

be comprehensive consideration: international working groups from buildingSMART will be working from here on. When compared to structural engineering, the BIM method is less developed in regards to data standards and software tools, on the national as well as on the international levels. (Overview in KÖNIG et al. 2016, BORMANN & HEUNECKE 2020). A first attempt in Norway to standardize objects in land design has not yet been integrated in international standardization processes (WIK et al 2018).

For the use of BIM in Germany, a three-step plan (BMVI 2015) was formulated by the Federal Ministry for Transport and Digital Infrastructure already in 2015. The goal was the implementation of BIM as standard on a broader basis by the year 2020. To reach this goal, a series of BIM pilot projects were carried out and supported. To support project sponsors, as well as all other project participants putting BIM to practice, the results and findings were summarized in ten guides which are readily available, and which also offer landscape architects a first orientation for the structuring of BIM projects, BIM applications, the content and development of information requests by principals (AIA), and BIM as well as winding up plans (BAP) (BIM4INFRA2020 2019). The goals of the phased plan have not yet been able to be fully realized. The work is to be further developed for both building construction and infrastructure in the newly established Center for Digitalization in Construction, "BIM Deutschland" (BIM DEUTSCHLAND 2021)

The lack of standards for required information on the national level continues to lead to the parallel development of isolated solutions.

A contribution to the (pre)standardization on the national level is the recently published catalog "BIM Classes of Traffic Routes" put together by the working group BIM Traffic Routes of buildingSMART Germany. This was supplemented by the team of specialists BIM in landscape architecture who supplied classifications of landscape and open spaces so that in the future, environmental requirements can also be represented in BIM models. There continues to be further development of features of this first version (BUILDINGSMART-FACHGRUPPE BIM-VERKEHRSWEGE 2020).

3   Integration of Landscape and Environmental Planning in the BIM Process

3.1   BIM Autobahn Pilot Project A10/A24

The autobahn project PPP-A10/A24 used a 5.5 kilometer road section to tender and be granted as the BIM pilot project. A diverse number of BIM case applications from BIM coordination on basis of the model were tried out, first as prototypes, and then finally put into practice. These ranged from visualizations to the use of BIM models in operations and in maintenance (TSCHICKARDT & KRAUSE 2019). The Deutsche Einheit Fernstraßenplanungs- und -bau GmbH (DEGES), which realizes largescale infrastructure projects in Germany, is responsible for the project. The planning and implementation of the project were carried out by ARGE A10/A24 Havellandautobahn GmbH.

The segment of autobahn used in the project is 64.2 kilometers long and belongs to one of the most heavily driven sections in the Berlin area. Within the next 5 years, it is to be upgraded and repaired while still being used. The contractor of the PPP project is to plan, build, maintain and partially finance the different construction measures over a period of 30 years.

ARGE A10/A24 Havellandautobahn GmbH has developed an overview structure for all models used in cooperation by the project participants in the BIM Coordination Model. The models can therefore be accordingly subdivided into further component models, structural element groups and model elements. The information of a model can be passed along hierarchically. The chosen project structure offers the project participants user friendly navigation in the coordination model and assures access to required information.

3.2   BIM Model Landscape_Open Space

The Landscape_Open Space Model is furthermore being developed to integrate landscape and environmental planning issues into the BIM Model of the PPP-A10/A24 project. (Fig. 1) The landscape conservation implementation plan, in accordance with the predefined structure, is then organized in the Landscape_Open Space Model. The technical terminology that is used comes for the most part from the pre-standardized work "BIM Transportation Route Classifications" (BUILDINGSMART-FACHGRUPPE BIM-VERKEHRSWEGE 2020). Illustration 2. Shows the structure of the Landscape_Open Space Model. It is divided into two parts. This division is based on the State of Hessen's concept for landscape conservation implementation planning (LAP). The goal of this concept is to make the often complex landscape conservation plans more accessible in construction preparation.
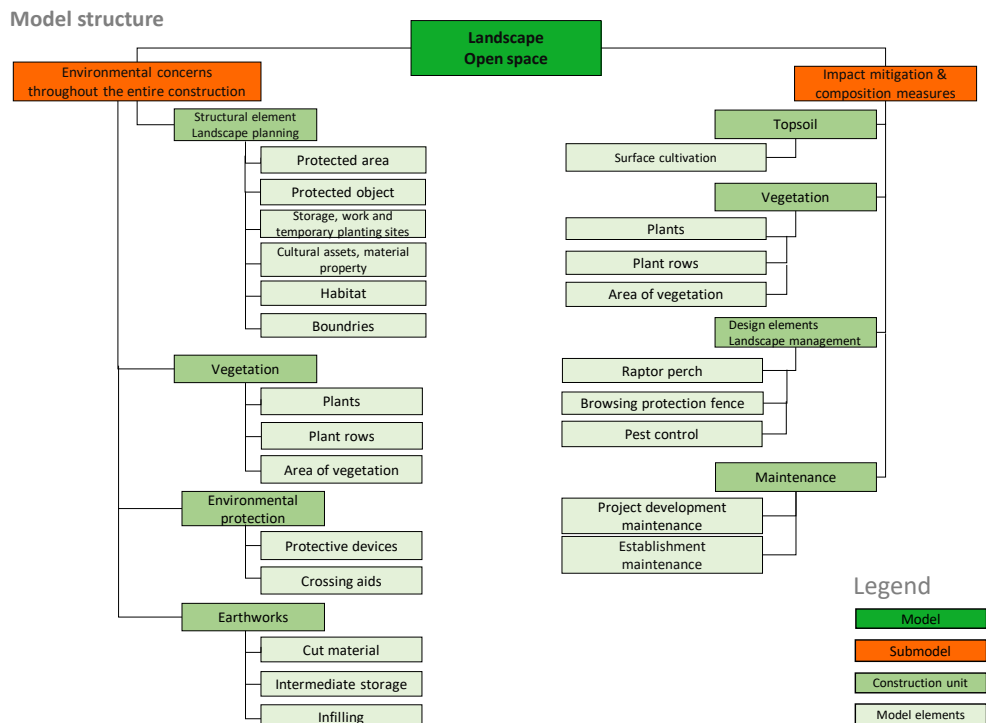

Fig. 2:   Structure of the Landscape_Open Space Model

Using the submodel, "Umweltbelange während der gesamten Bauphase" (UwbB), i. e. Environmental Concerns throughout the Entire Construction, particularly landscape and environ-

mental mitigation measures are modeled throughout the entire building phase. Model elements include protected areas; protected objects; storage, work and temporary planting sites; protected plants, or trees to be felled. This submodel is available to all project participants and is meant to serve the environmental monitoring of construction.

The contents of the submodel "Ausgleichs- und gestaltungsmaßnahmen" (AuG), i. e. Impact Mitigation and Composition Measures are primarily oriented to carrying out environmental measures. Examples are compensation planting, as well as protective objects such as raptor perches or browsing protection fences. Development, maintenance and finalization measures can also be linked to the submodel.

In general, it makes sense to divide the mitigation, compensation and design measures into two submodels in that for example the measures of the UwbB submodel are carried out much earlier than submodel AuG. It can also help make understanding details easier.

The UwbB submodel was modeled on a 2 km segment of the entire 5.5 kilometer contract section, and was integrated into the BIM coordination model of the project. All required information for the project was taken from the existing LBP and LAP. Because there were no pre-defined landscape classifications, these had to be generated generically and semantically described by means of user-specific features.

3.3   3D Models in CAD-BIM Software

Autodesk Civil 3D, often used as the modeling software in BIM infrastructure projects, was chosen for use in this case. It is complemented by an engineering application module. The current dominance of CAD solutions in BIM infrastructure projects can be attributed to the cooperation of Autodesk with ESRI in the development of interfaces for optimizing data exchange between BIM CAD and GIS in BIM processes. Road planners in the A10/A24 Project therefore used Autodesk Civil 3D to enable a seamless data exchange. Autodesk Civil 3D having the required IFC interfaces builds upon the functions pallet of Autodesk AutoCAD offering 3D tools for engineering and infrastructure planning as well as site modeling and processing. The last was essential in creating the submodel UwbB because the digital site model which encloses the route using BIM coordination model, needed to be allocated to different zoning areas.

Accordingly, areas of the DTM near the construction site were declared protected areas, or storage and work sites. For this, specific areas were cut out of the DTM and using the same coordinates exported as new DTM: The exported DTM could then be seamlessly connected in new data. Within the Civil 3D Autodesk software, such generated areas were assigned the function "define characteristics" of different zonings and features. Additionally, for defined work sites, the DTM was converted into solids so that soil that was to be removed could be automatically calculated already in the BIM model. Point objects in the UwbB submodel such as single plants, or linear objects such as fences or topsoil pits, were extracted as 3D solids and linked to specific features. The landscape classification Plants is used as an example in Figure 3. Because a realistic visualization is not required here, an abstract 3D tree model is sufficient.

This required a lot of individual work. Libraries having landscape objects and tools available that support modeling are necessary to enable efficient work in the future.
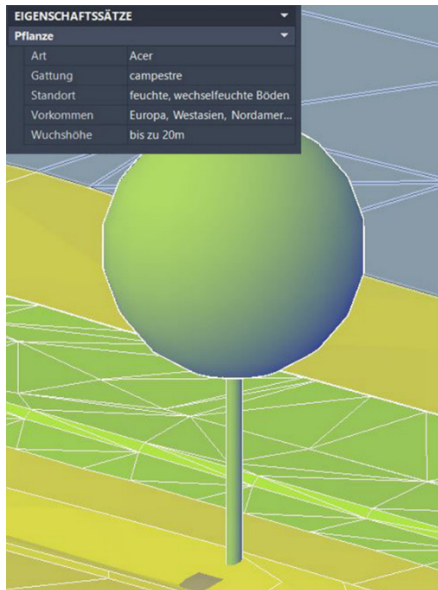
Fig. 3:
Landscape Classification – Plants

3.4 BIM Coordination Model in the BIM Management Software

To bring the individual models together in the coordination model a BIM Management software is required. Desite BIM md pro was used and the data exchange was based on IFC.

The submodel UwbB was subsequently transferred into IFC and could successfully be imported into the BIM coordination model for the PPP A10/A24 project. This means that all geometrics were available in data already entered.

With help of the BIM management software, a hierarchical data structure of the entire model and component models is realized (see Fig. 1 and 2). The installation of extensive technical data (characteristics and values) is even more user friendly than in CAD BIM software itself. An important task is checking the quality of submodels' individual disciplines, as well as the consistency of the entire model. An additional function is quantity determination. A 3D viewer is used for observation and movement in the overall 3D model. BIM management software was used primarily for data structuring and scheduling

The classification of areas in the BIM model is visible in Fig. 4 where all protected areas are presented in light green, work sites along the stretch are light brown, and storage sites for top soil are olive green. Using the example of the protected area marked in yellow, it becomes clear that landscape classifications in the BIM model are linked with information. With the building component code (BTC) for example, the existing model structure for the respective class can be comprehended. This assures the coordination of different component models and close cooperation of the planners in the BIM coordination model. Specific characteristics that were already entered in Autodesk Civil 3D are visible in the landscape planning (LAP) rubric.

On the basis of the integrated UwbB submodel, the environmental issues considered during the construction phase can be easily conveyed to other project participants in the BIM coordination model. This offers the chance to improve protection of the surrounding landscape during construction work.

Fig. 4:   Submodel UwbB in BIM coordination model

3.5   4D Scheduling

Another advantage of using BIM is seen in the so-called 4D planning. Here, various landscape classifications of the sub-model UwbB are linked with scheduling. On this basis, a 4D construction workflow visualization can be produced. For example, areas bordering the construction site can be presented with their according protection status over time. The same is true for protective fences that need to be erected and then taken down again, for the setup of work and storage areas, and for clearing the building site. The depiction is presented as a table as well as diagram, and is clearly illustrated through the visualization as animation of the changes in the 3D model.
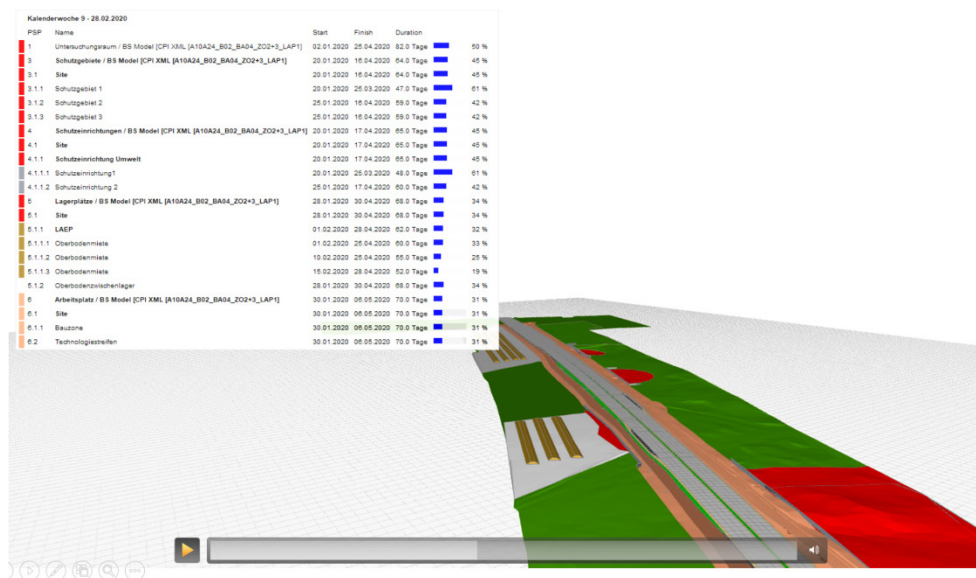

Fig. 5:   Submodel UwbB – 4D Visualization

On the basis of this 4D visualization, potential conflicts of time between the building plan and specific environmental requirements can easily be recognized in the BIM model and therefore avoided. This also aids others involved in the project, such as route planners and civil engineers, carry out the various stages according to landscape and environmental conservation.

A further step would be to realize the second submodel, Impact Mitigation and Composition Measures (AuG), according to the methods presented. It is to be expected that the coordination of different construction phases using 4D visualization would be beneficiary here as well. Information required during the operation phase would be essential for the successful development of the AuG submodel.

4   Discussion and Outlook

The necessity of integrating demands of landscape and environmental planning in BIM processes has already been recognized and formulated. SHILTON (2018) discusses how the British approach to digital twin and the three levels of BIM can be carried out in landscape design and emphasizes the necessity of an IFC standard for landscape elements. WIK et al. (2018) present a Norwegian standardization project with a hierarchy of objects for infrastructure and land design with the goal of integrating this into international standards, allowing developers to create the necessary support for landscape objects in their software. Another approach is to convert CAD and BIM data to GIS formats and combine it with GIS datasets so that the necessary environmental analyses can be performed. An appropriate workflow is presented by SCHALLER et al. (2017) using the example of the Autobahn A99 expansion in Munich. CARSTENS (2019) reports on the improvement of interfaces between BIM and GIS.

In the future, the phase of operations and maintenance should come increasingly into focus because exactly here lies the greatest potential for an increase in value in the "green" sector. The increased integration of BIM and GIS could make an important contribution. The goal of green space management would be to increase the quality of maintenance and with this the quality of the appearance of the roadside vegetation. A special challenge for further research would be to find a workable approach of taking into account the development of vegetation over time.

The transition to the 3D planning presented here means considerably more effort in terms of landscape and environmental planning, especially in the initial phase. The participation in BIM cannot just be self-serving, rather is only justifiable through significant improvement in the course of the project. This requires an explicit definition of the desired BIM goals. Using the example of the BIM pilot project A10/A24 and the defined applications of UwbB and AuG within the framework of the landscape management implementation plan, the advantages for integrating landscape and environmental planning into existing BIM processes is clear. By means of the central storage in the Landscape_Open Space Model, communication with other project participants is faster, more direct, and more understandable. With this, the chance arises that landscape increases in value using the BIM method in the construction program, and that landscape and environmental protection can be improved during the building phase.

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