GeoDesign: Concept for Integration of BIM and GIS in Landscape Planning

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Abstract: Most construction project designs are executed by engineers and architects using CAD programs. Environmental and landscape planners use GIS to assess the environmental impacts of the construction projects and their visual, ecological and functional integration in the landscape. To fulfil the requirements throughout the entire lifecycle of a construction project, CAD and BIM data must be converted to GIS formats and combined with GIS datasets, so that the necessary environmental analyses can be performed. Using the example of the Autobahn A99 expansion in Munich, this paper describes a workflow for data conversion and integration of CAD, BIM and GIS in environmental and landscape planning.

Keywords: GeoDesign, CAD, BIM, GIS, integrated landscape planning

1 Introduction

Digitalization is one of the main trends in the construction sector (STEWART 2016). Besides data-driven design, surveillance and maintenance, drone mapping, 3D printing, virtual reality, robotics and other digital innovations, Building Information Modelling or BIM has become an important part of the construction process in the past years, and in some parts of the world it is becoming standard and even obligatory (BORRMANN et al. 2015). BIM aims to optimize the planning process. It refers to the use of digital models and information management throughout the entire lifecycle of the construction process – from planning to implementation, to management, and to decommissioning (BORRMANN et al. 2015).

Since the term was first used in 1992 (VAN NEDERVEEN & TOLMAN), BIM has evolved at different paces around the globe. In some countries, the adoption of BIM methods is quite developed, with clear government-driven BIM strategies, guidelines and standards (BORRMANN et al. 2015). In Europe, Germany has made significant advances in the past years, including pilot projects, task groups, guidelines (EGGER et al. 2013), and a road map (BMVI 2015), with BIM expected to become mandatory for large infrastructure projects in the country in the near future (BOHSEM 2015).

While BIM is becoming ubiquitous in the construction sector, relying mostly on CAD products, geographic information systems (GIS) still have a limited role in construction projects, being often restricted to some specific tasks or seen as a potential redundancy to BIM. But, in reality, GIS can bring a valuable contribution to the BIM process by providing spatial input and geospatial visualization, adding information on the construction site's surrounding environment that are essential for design decisions and approval processes. Interdisciplinary cooperation, data exchange and data transfer must occur between the engineering and environmental professionals for a successful construction project planning and environmental approval throughout the BIM lifecycle.

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This paper describes a concept for the integration of BIM and GIS with real data from the A99 expansion pilot project in Germany. It shows how environmental and landscape planners can integrate BIM and GIS to optimize the design process by assessing the impacts of construction projects and their visual, ecological and functional integration in the landscape.

2 The A99 Expansion Pilot Project

The German Federal Ministry of Transport and Digital Infrastructure (BMVI) has launched pilot projects in order to test workflows and data exchange procedures for the implementation of the German Road Map for Digital Design and Construction (BMVI 2015).

One of these pilot projects is the eight-lane expansion of the Autobahn A99 in the Munich Region, commissioned by the Highway Management of South Bavaria and executed by the SSF Group. The focus of this pilot project is the future requirements for a frictionless information sharing between engineers and environmental planners, to optimize all required environmental concerns from the start of planning, to project implementation, to completion and monitoring of the environmental measures.

3 Methods and Workflows

3.1 BIM and GIS Interoperability

The majority of construction project designs are executed with CAD programs (e. g., AutoCAD and Revit) by planning engineers and architects. Environmental and landscape planners, on the other hand, use GIS to assess the environmental impacts of the construction projects and the visual, ecological and functional integration of the project in the landscape. To meet all requirements, the CAD datasets from engineers and architects must be converted to GIS formats and combined with GIS datasets from environmental and landscape planners, so that the necessary analyses can be performed.

By integrating the BIM planning processes into a geodatabase structure in a collaborative planning system, the corresponding information can be exchanged and processed very quickly. This approach can be used for buildings, civil engineering projects, urban development and, in particular, for large infrastructure planning. For this purpose, 2D and 3D CAD and BIM data models are integrated into the GIS data model – in full or in parts – and then assessed. The feedback of this assessment allows the parties to determine the potential impact of construction projects on the environment and the technical or infrastructure constraints, and to optimize the engineering design and construction during the project lifecycle, aiming at a sustainable and legally approvable solution (Figure 1).

New interoperability technologies and the standard-based exchange of geodata between BIM and GIS provide architects, engineers and planners with entirely new tools for optimizing their planning, as well as the information exchange between all parties involved in a construction project. The bidirectional conversion between BIM and GIS data in the A99 project was performed with Esri's interoperability extension, based on the ETL (Extract-Transform-Load) method using FME software technology, which allows easy comparison and evaluation of alternative CAD or BIM design and planning scenarios based on existing GIS databases.

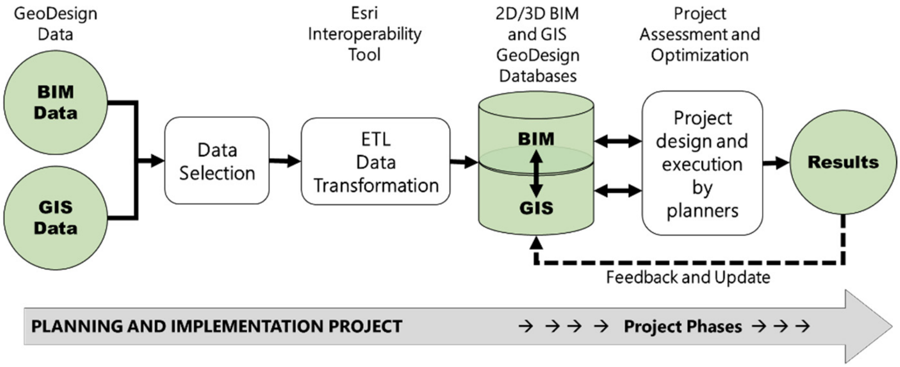

Fig. 1: The integrated data exchange concept

Figure 2 shows schematically how the layer structure of GIS base data, environmental data and BIM data were combined (from bottom to top) in a 2D/3D geodatabase for the A99 project. The applied GIS technology allows the combination of each layer in this dataset and the assessment of any impacts between relevant 2D or 3D data layers.

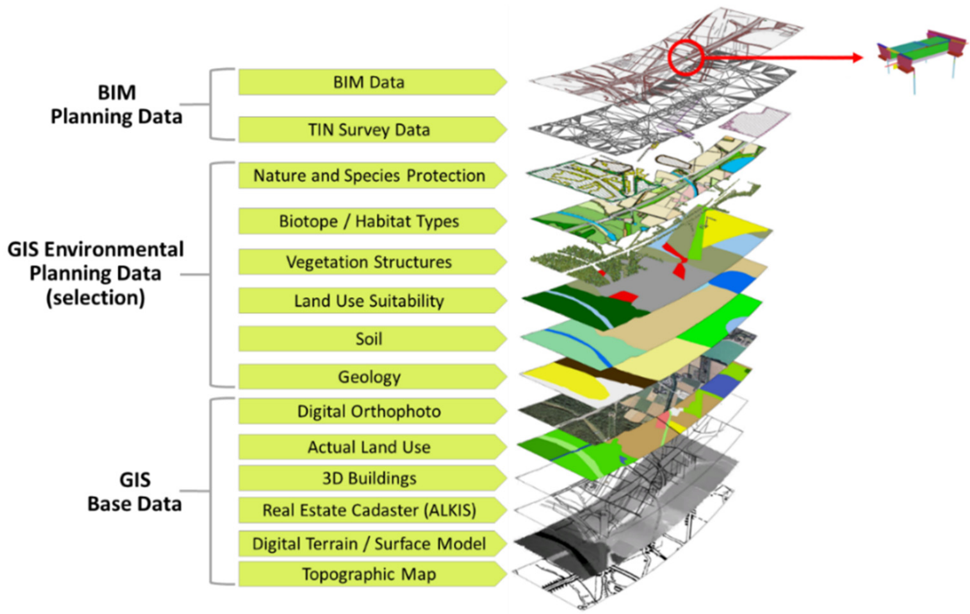

Fig. 2: Integration of BIM data and GIS environmental planning data

3.2 GIS

Esri's desktop GIS products – ArcMap/ArcGIS Pro with Data Interoperability Extension – were used for 2D and 3D GIS data processing, analysis and visualization. Esri's 3D modelling solution – CityEngine – was harnessed for the development of procedural modelling scripts and the export of CGA rule/asset packages for use in ArcGIS Pro.

To perform the GIS analysis, various types of environmental data were employed: 2D vector and raster data (including vegetation types, biotopes, road infrastructure, fauna habitats), 3D TIN and GRID data and digital terrain model (DTM), as well as digital orthophotos.

Before the GIS data could be used for any analysis, preliminary processing steps had to be performed: topology validation and semi-automatic repair, data enhancement and creation of 3D geometries. Using ArcGIS geoprocessing, a GIS topology was created for the GIS layers in order to examine and correct the geometries for common problems and to avoid spatial query errors.

In addition to its present attributes, the GIS data was enhanced with the following information through attribute table joining or geoprocessing: vegetation value points and ecological significance, infrastructure impact on vegetation, ecology data (e. g., breeding times of endangered bird species), and height information (from the DTM raster). Vegetation attributes such as vegetation type, plant distribution, plant density and maturity were placed on the surface of the geometries using procedural modelling. Small settlements and roads in the project area were also created in 3D through procedural modelling to achieve a complete 3D dataset.

3.3 BIM / CAD

The software products Autodesk Revit, Autodesk AutoCAD, Solibri Model Checker, Linear Project TILOS, and RIB iTWO were used by the infrastructure planners for modelling and planning the A99 expansion.

Processing this BIM planning data involved using the ETL process to split up the IFC (Industry Foundation Classes) data models into their components, transform them into Esri multipatch data format (while retaining their attributes) and write them into a geodatabase. No further editing was necessary. CAD data was opened as-is with ArcMap, verified and repaired and then converted into polygons and written into a geodatabase using ArcMap's geoprocessing tools.

Textual data (time/location schedules) were loaded as tables into ArcGIS and joined with m-aware freeway centerlines. In a second step, the centerline and schedule values were used to create a route event layer with an offset, resulting in points perpendicular to the centerline.

Finally, the points were used as endpoints to create lines perpendicular to the centerline using ArcMap geoprocessing. Using these lines, the vegetation geometries were split and enhanced with time attributes. These split geometries were then used as basis for vegetation clear-cut schedule validation and analysis.

3.4 Import / Export Workflows

The Esri data interoperability extension workflow facilitated the data flow from BIM into GIS and back from GIS to BIM (Figure 3 and Figure 4). BIM geometries were read in IFC format, transformed into Esri multipatch and written into a geodatabase. The resulting data was then loaded as layer to be used for analysis in GIS.

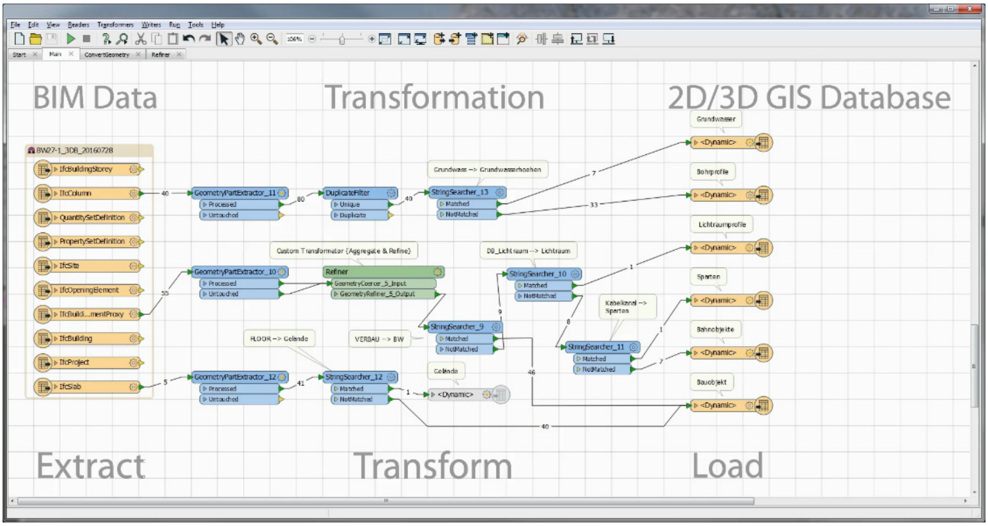

Fig. 3: BIM to GIS workflow with Esri Data Interoperability Extension

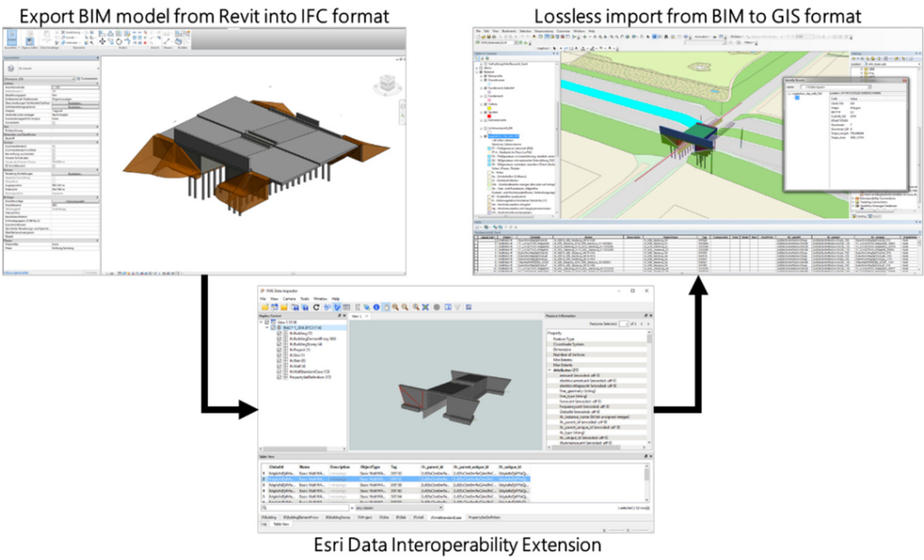

Fig. 4: Example of BIM to GIS data migration for a bridge structure

3.5 Environmental Analyses and Assessments

Once prepared, the integrated BIM and GIS dataset was used for two environmental analyses. A building (site) impact analysis was performed to assess the environmental impacts and compensation measures. A spatial analysis was carried out to determine land consumption by the building (permanent consumption) and the construction site (temporal consumption).

A vegetation clearcutting schedule validation and analysis was also carried out to prevent costly delays and to identify potential problem sites caused by protected flora and fauna (e. g., breeding areas and times). For this analysis, BIM/CAD geometries were used in combination with GIS data. Results were written into the geometries' attribute tables, ready to be exported and delivered to infrastructure planners after the analysis.

4 Results

4.1 BIM and GIS Integration

Figure 5 depicts a planned freeway A99 bridge incorporated into the area's 2D and 3D GIS database in order to link the structure with geospatial environmental and landscape planning data, and to make the necessary analyses, assessments, decisions and optimizations.

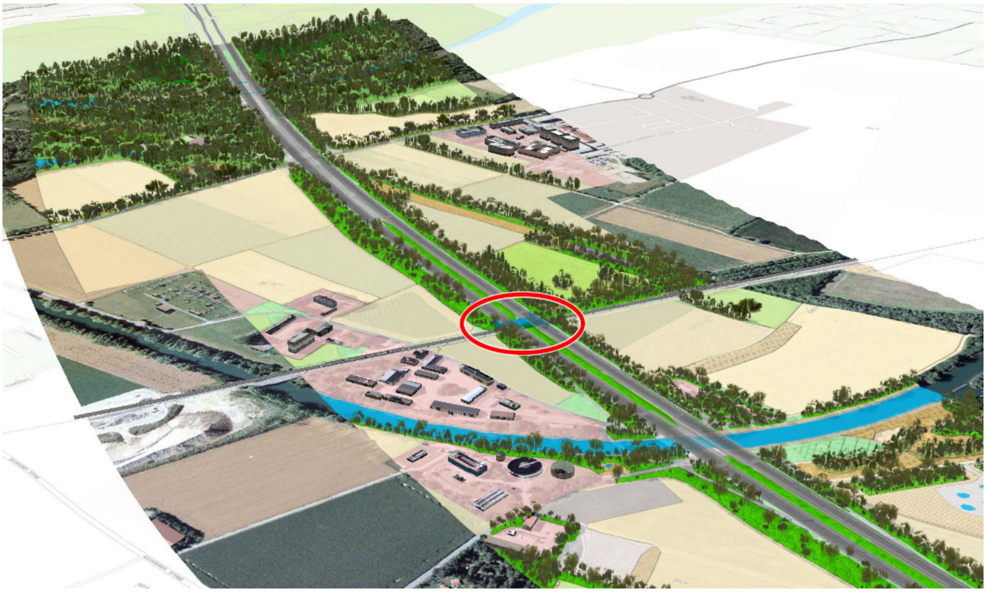

Fig. 5: Integration of Autobahn A99 BIM data (circled bridge) into the 3D GIS and environmental planning data model

4.2 Environmental Analyses and Assessments

By integrating the bridge structure into the GIS database, we were able to perform basic assessments of environmental impacts and compensation measures within the scope of a "Landscape Management Plan" (LBP, in German) (Figure 6). Figure 7 depicts the results of the building site impact analysis. Two cases were analysed – temporal impacts compared to untouched areas in the site area, and permanent land use and compensation.

Figure 8 depicts the results of the second analysis performed – the validation of the clearcutting dates from the BIM construction schedule against various environmental data from the GIS database. This allowed the identification of potential conflicts due to protected flora and fauna in the area. The lines perpendicular to the freeway show the split generated by the route event layer split technique outlined in 3.3.

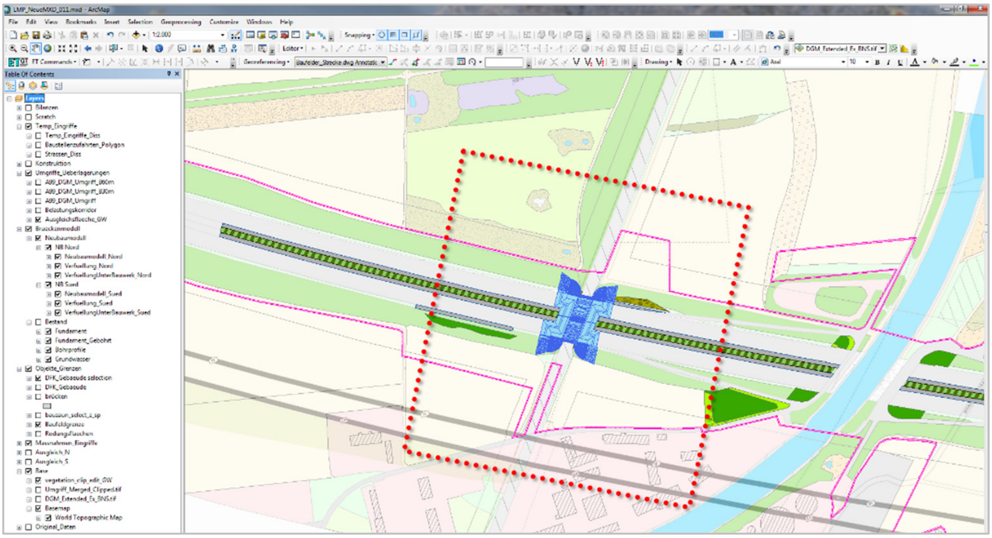

Fig. 6: A99 bride construction site impact analysis using planning, environmental and base data in a GIS environment

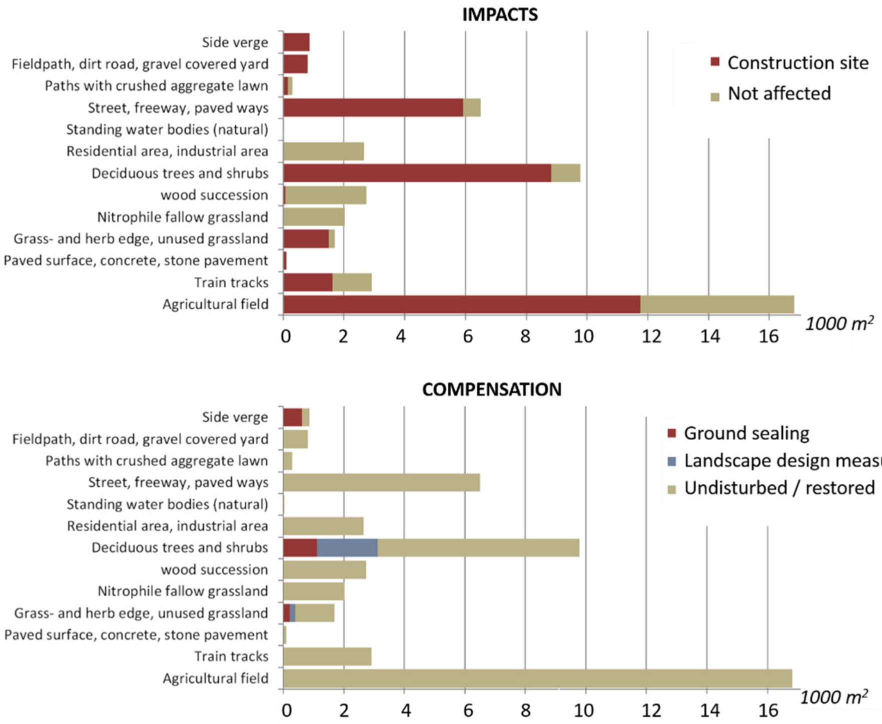

Fig. 7: A99 bridge site impact analysis and necessary compensations for the Landscape Management Plan (LBP) – Temporal impacts vs. untouched areas (top); permanent land use vs. impact compensation (bottom)

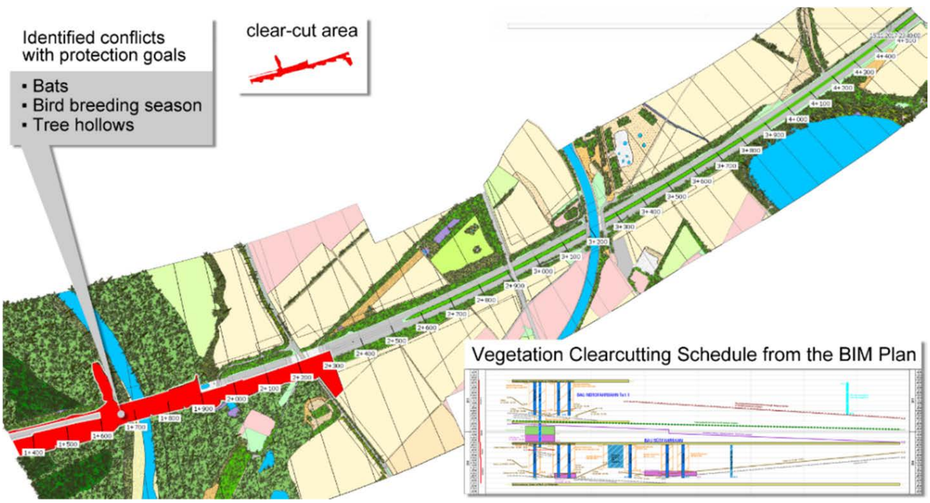

Fig. 8: Identification of potential conflicts between the BIM schedule for vegetation clear-cutting and protected flora and fauna

5 Discussion and Conclusions

The A99 expansion pilot project showed how GIS is an indispensable component of the BIM process, and that the necessary collaboration and exchange of information among the planning stakeholders is well supported in this environment.

According to German planning legislation and requirements, every stage of the engineering process (from initial project drafts to plans, execution, management, and rebuilding) has to be accompanied by environmental and landscape planning procedures. Figure 9 depicts how the interdisciplinary cooperation, data exchange and data transfer must occur between the engineers (who perform the procedures presented in the inner ring), and environmental / landscape professionals (responsible for procedures of the outer ring) throughout all phases of the project for a successful construction process within the BIM lifecycle.

Although some difficulties were faced when implementing CAD geometries into the GIS dataset, such as the substantial amount of manual editing required to attach attributes to the CAD data, the A99 expansion pilot project highlighted many key advantages of the integration of BIM and GIS in the planning practice:

- Spatial Intelligence: Spatial analysis of the project area with existing GIS data allows planners and other stakeholders to understand the implications of the project design and implementation. Even prior to project start, it is possible to optimize the conceptual designs in terms of environmental compatibility.
- Professional Data Management: GIS plays a key role in BIM processes as a professional and sophisticated data management system for spatial data, especially for large datasets with multi-user management.
- Network & Logistics: GIS supplies important components and spatial models for the transport of materials, supply and disposal, mobility of people, etc.
- Modelling & Prediction: GIS provides important planning information, not only for environmental impact assessments, but also modelling methods for reviewing legally binding specifications, e. g., noise limits, water quality, protection areas etc. GIS can also provide real-time sensor information of a project and its surrounding areas.
- Monitoring: GIS continuously provides up-to-date monitoring data on construction progress and environmental impacts (noise, air pollution, etc.).
- Information Exchange: GIS manages and provides interoperability of data and processes that enable constructive cooperation of all parties involved. In particular, via GIS, the geospatial data and the data of specialist planners can be made available to all project partners to be used for fulfilling their respective requirements.
- Visualization & Web: 2D maps and plans, 3D web scenes, models and dashboards help to communicate efficiently throughout the planning process between the planners, other stakeholders, and, above all, the non-specialized public.

In the future, all federal infrastructure projects in Germany are to be carried out using BIM technology (BOHSEM 2015). For this reason, other pilot projects from the federal government and practical examples from engineering and planning offices are currently being developed in order to test the integration of BIM processes with GIS and GeoDesign methods, and to define the necessary workflows.

Based on the A99 project experience, we suggest that a common data standard should be developed to meet both the planner's and GIS analyst's requirements. This includes closed geometries, attributes attached to entities via extend AutoCAD entity data or similar methods. If not possible, attributes written as text entries should be consistently placed, so standardized data processing workflows can be used to convert CAD data into intelligent GIS data.

To conclude, the methods outlined in the A99 pilot project prove that a BIM and GIS integration with the existing interoperability technology is possible. However, to streamline the process, standards, documentation, and interdisciplinary understanding of the involved engineers and environmental planners, as well as their requirements and workflows are necessary.

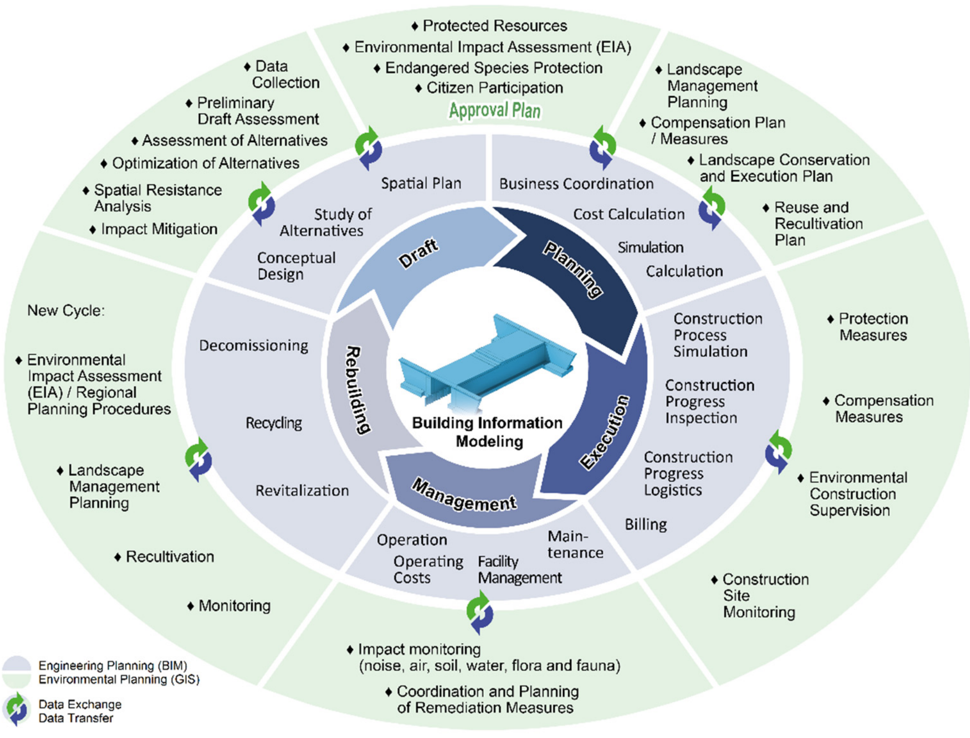

Fig. 9: Data exchange and data transfer in the integrated BIM/GIS environmental and landscape planning process, according to German planning regulations (Source: SCHALLER 2016 modified from BORRMANN et al. 2015)

References

BMVI (German Federal Ministry of Transport) (Ed.) (2015), 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. BMVI. 20 p. http://www.bmvi.de/SharedDocs/EN/publications/road-map-for-digital-design-and-construction.pdf?__blob=publicationFile.

Bohsem, G. (2015), BIM-salabim: Verkehrsminister Dobrindt will der Digitalisierung beim Bauen zum Durchbruch verhelfen. Süddeutsche Zeitung, Nr. 289, 15 Dec. 2016.

Borrmann, A., König, M., Koch, C. & Beetz, J. (Eds.) (2015), Building Information Modeling: Technologische Grundlagen und industrielle Praxis. VDI-Buch. Springer. 591 p.

Egger, M., Hausknecht, K., Liebich, T. & Przybylo, J. (2013), BIM-Leitfaden für Deutschland: Information und Ratgeber – Endbericht. AEC3 & OPB, 109 p.

Schaller, J. (2016), GeoDesign: Das Konzept zur Integration von GIS und BIM (presentation). INTERGEO 2016, Hamburg.

Stewart, R. M. (2016), The Construction Business Goes Digital. The Wall Street Journal Australia, 18 Sep. 2016. http://www.wsj.com/articles/the-construction-business-goes-digital-1474250580.

van Nederveen, G. A. & Tolman, F. P. (1992), Modelling multiple views on buildings. Automation in Construction 1 (3), 215-224. doi:10.1016/0926-5805(92)90014-B.