Development of a Data Model for Lossless Exchange of Data in Landscape Planning – The Example of XPlanung

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Abstract: The XPlanung standard provides Germany with a technical data model and an exchange format (XPlanGML) that can be used for spatial planning, regional planning, urban land-use planning, and landscape planning. An examination of version 5.3 has revealed that further development is needed to fully map landscape planning projects. This was carried out as part of a project funded by the Federal Agency for Nature Conservation. The results were implemented in version 6.x and existing software systems. Practical tests have shown that the developed technical model can be used and integrated into GI systems. Furthermore, these standardized geodata provide an important source of information for BIM processes. However, the subject models currently in use differ, which will require the definition of transformation rules in the future. The further development of the landscape planning domain model and the legal basis for using the standard have created the conditions for accelerating planning processes in the future, improving the supply of information in BIM processes, and supporting the automated evaluation of plans and the development of domain applications.

Keywords: Landscape planning, data exchange, standardization

1 Introduction

Landscape planning provides comprehensive environmental information at various levels of detail for individual planning levels. It makes use of existing geospatial and geospatial reference data at the federal and state levels, which is provided by existing geospatial data infrastructures (BILO 2015). At the same time, landscape planning itself generates environmental information that is used for its own specialist tasks, in the context of environmental assessments (e. g., environmental impact assessments), by other specialist planning departments (e. g., water management), or for integration into overall spatial planning (SCHULTZE & BUHMANN 2008) or for BIM-projects (CARSTENS 2019, GNÄDINGER & ROTH 2021, GNÄDINGER 2023). This means that the geodatasets generated in the landscape planning process can be seen as the core of an environmental information system and can even replace it at the local level (BFN 2012). It is fundamentally possible to make the data created by landscape planning available on a platform-independent basis and to exchange it between different systems through the use of suitable information and communication technologies. This means that it can be used to address various environmental issues (e. g., developing land pool solutions) regardless of location or time (PIETSCH 2018). In practice, different software systems are used for this purpose. If data is to be exchanged between these systems within planning processes, data format conversions are often necessary, which can lead to information loss. This makes it difficult to reuse data once it has been collected and to exploit potential synergies (ARNOLD et al. 2005). To ensure lossless data exchange across different media and software, so-called subject data and object models can be used (PIETSCH & Heins 2009, MÜLLER

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& WÜRRIEHAUSEN 2013). Since landscape planning is not regulated uniformly across Germany, this poses a challenge for the derivation of a data model (JEDICKE et al. 2016). The XPlanung standardization project, along with many other initiatives (e. g., XBau, Building Information Modeling (BIM), CityGML, OKSTRA©), defines technological specifications that are relevant to landscape planning in Germany. At the same time, practitioners are calling for the provision of standardized plan symbols and standardized data/information. Among other things, this is intended to avoid media discontinuity, improve communication in the planning process, and simplify the consolidation of different planning statuses.

However, a review of version 5.3 showed that it was not suitable for fully mapping landscape planning plans. This means, among other things, that it is not possible to map the addressee reference, the multifunctionality of areas, or the analysis, evaluation, conflict and target plans in landscape planning. For this reason, further development of the technical model was necessary (SCHLAUGAT et al. 2023). Table 1 shows a comparison of the contents of the versions.

Table 1: Comparison of the contents of different versions of the XPlanung standard with regard to landscape planning

	Version 5.3	**Version 6.x**	**Version 7.x**
Content	Core model for landscape planning according to plan symbols from 2000	Core model for landscape planning according to § 9 BNatschG without analysis, evaluation, conflict and goals including addressee reference and multifunctionality	Complete subject model including analysis, evaluation, conflict, measures, addressee reference and multifunctionality
Referencing	None	Referencing content to the technical model for urban land-use planning and regional planning	Referencing content to the technical model for urban land-use planning and regional planning

This article shows how the technical model for the standard was developed, what results have been achieved, and how these have been implemented. It also briefly describes how the standard relates to BIM, as well as its added value and potential future uses.

2 XPlanung

XPlanung is a nationwide uniform data standard for mapping spatial planning, state and regional planning, urban land-use planning, and landscape planning in Germany (BENNER et al. 2008, LEITSTELLE XPLANUNG/XBAU 2020). The aim is to enable the lossless exchange of information between different actors and software solutions. As a communication interface for processes in the construction and planning sector, XPlanung is an essential prerequisite for ensuring that landscape planning issues, among other things, are considered in digital processes (TAIBER 2025).

2.1 Origin and Mandatory Introduction in Germany

XPlanung is based on the fundamental principles of e-government and is designed to support and accelerate electronic data processing in administrative procedures (BMWI 2006). In addition, XPlanung is a standardized technical model for the uniform storage and description of planning information. As early as 2002, the need for a data standard for spatial instruments in municipal planning in Germany was identified (BMWI 2006). For this reason, models were developed which were continuously adapted over time and published in different versions. These form the basis for the development of software solutions for using the standard.

In 2011, the standard was assigned to the IT Planning Council, which records nationwide standardization requirements and specifies their scheduled implementation within a standardization agenda (KoSIT 2014). As a result, the definition of requirements specified that manufacturer-independent, lossless data exchange must be enabled for procedures in the construction and planning sector (IT PLANUNGSRAT 2016). By February 2023 at the latest, IT procedures in the construction and planning administrations of local authorities must be able to process XPlanung-compliant data and message objects. A distinction must be made between the two recording methods: partial vector and full vector. Partial vector refers to the recording of the scope of the respective plan as an outline and all associated plan drawings as a georeferenced raster plan, with additional documents to be attached. In full vector recording, all geometries and sub-elements, including their textual provisions, are recorded in the data standard, resulting in homogeneous and evaluable data sets. This provides a legal basis for the use of the standard in Germany.

2.2 Data Model Design and Structure

The XPlanung data standard is based on Extensible Markup Language (XML). XPlanung uses Geography Markup Language (GML), which is based on XML, to map spatial objects (*features*) and their geometry (TAIBER 2025). This distinguishes XPlanung from other standardization initiatives such as Building Information Modeling (BIM).

The XML schemas have a modular structure, which allows for flexible and expandable use. Class diagrams (UML) show the classes and their structure in the **object model** (Fig. 3). Model areas summarize technical planning disciplines or plan types (e. g., landscape planning). **Object areas** bundle certain technically related classes and other UML elements into a package (e. g., landscape planning measures). **Abstract classes** define general properties that can be shared by derived classes (e. g., the class *LP_GeometryObject*, which describes the attribute position). **Instantiable classes** can then be derived from these abstract classes, which “inherit” the properties of the parent classes and in which concrete objects can be created (e. g., tree). In UML, different characteristics are represented in so-called **enumeration lists** (e. g., different biotope types). Alternatively, characteristic lists can be implemented using **external code lists** published in a GDI-DE code list register. Cardinalities indicate the number of relationships that exist:

- 0-1 times (an optional attribute with a maximum of one value)
- 0..n times (an optional attribute; multiple assignments are possible) or
- 1..n times (a mandatory attribute; multiple assignments are possible) (BENNER 2023, PIETSCH et al. 2023).

An example is shown in Figure 1.

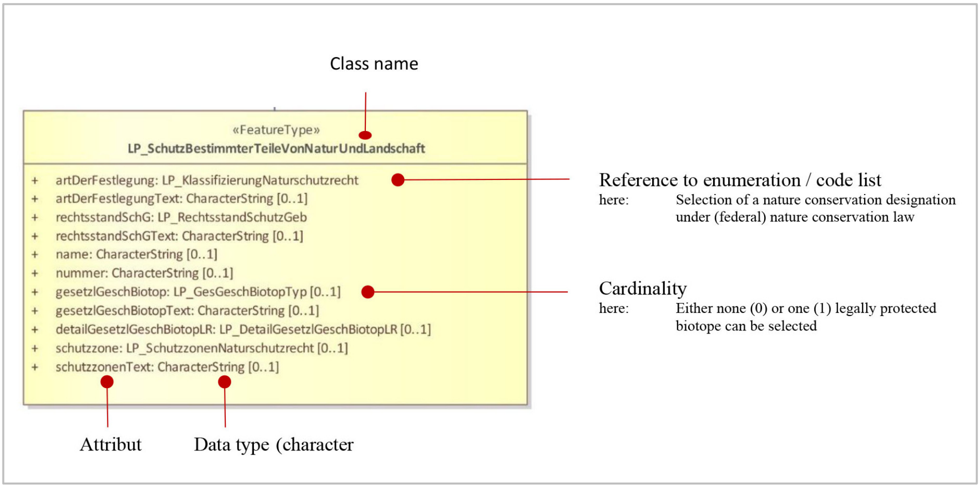

Fig. 1: Description of the contents of an object class using the example of protected areas designated under nature conservation law (BENNER 2025)

When new versions of the standard are developed, it must be checked whether transformation rules need to be defined to ensure that data from older versions can be transferred to the updated version. These serve as the basis for software development and the necessary transformation processes for existing data.

2.3 XPlanung for Landscape Planning

The Leistelle XPlanung/XBau in Germany provides and maintains specialist models for all of the aforementioned planning documents (section 2). However, an examination of version 5.3 of the standard revealed that it is not sufficient to fully represent the contents of a landscape planning plan and thus meet the requirements of media-break-free data exchange (Leistelle XPlanung/XBau 2020). For this reason, the Federal Agency for Nature Conservation awarded a research contract to further develop the standard for use in landscape planning.

3 Procedure for Developing a Data Model for Landscape Planning

A multi-stage process was developed to determine the need for expansion of the standard (Fig. 2). The first step was to examine which plans (landscape program, landscape framework plan, landscape plan, green space plan) and which specific contents could be processed. These resulted in a stage model. Subsequently, the core content of landscape planning was derived on the basis of a multi-stage data analysis. This was done on the basis of legal and technical requirements, the analysis of a selection of representative sample plans, and discussion and evaluation with a panel of experts. From this, a proposal for an extension of the technical data model was developed, which was then subjected to a practical test. The resulting need for adjustments was determined and the final draft was developed in consultation with the expert committee. This was handed over to the Leitstelle XPlanung/XBau and ultimately resulted in version 6.0, which was published in 2022.

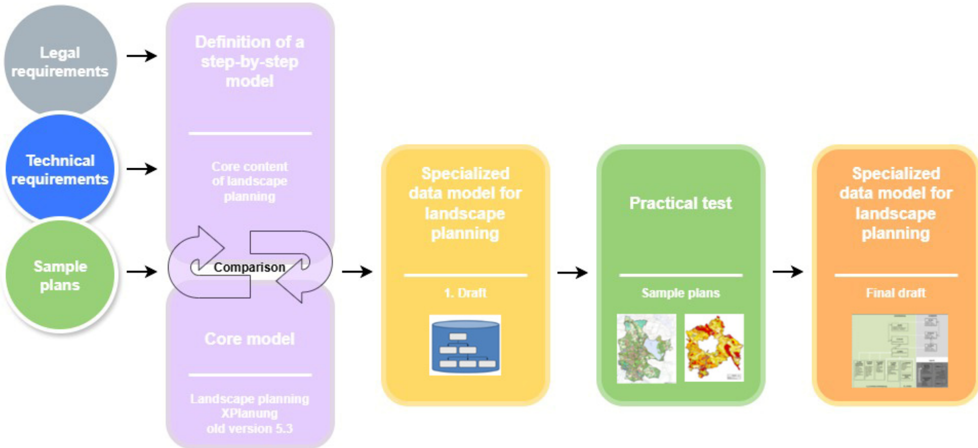

Fig. 2: Procedure for developing a proposal for expanding the core landscape planning model (PIETSCH et al. 2023)

Since this meant that "only" the core content could be displayed (chapter 4), work has been underway since 2022 in a further project by the Federal Agency for Nature Conservation to supplement the missing content. The results will then be integrated into version 7.0 of the standard. This process is not yet complete.

4 Result of Version 6.x

As a result of the analysis, specific core content was defined in accordance with the legal norm of section 9 (2) BNatSchG, in particular the concrete objectives of nature conservation and landscape management, as well as the requirements and measures necessary for their implementation. To this end, three higher-level object classes were defined for the landscape planning model: *LP_Plan* (e. g., content relating to the type of plan, such as a landscape plan), *LP_Area* (further specification, e. g., to individual sub-maps such as the development map), and *LP_Object* (e. g., statements on legal status or integration into other specialist planning). Four technical object classes represent the areas of objectives, requirements, and measures for nature conservation and landscape management, protected areas under nature conservation law, biotope networks, and impact regulation. The class *LP_ZieleErfordernisseMassnahmen* bundles the core content of landscape planning. The UML diagrams are shown in Figure 3.

Fig. 3: UML diagrams of the landscape planning domain model (BENNER 2025)

This ensures that all essential content can be captured, stored, and exchanged in full vector format.

Fig. 4: UML diagrams of LP_PlaninhalteLandschaftsplanung (BENNER 2025)

Figure 4 shows the UML diagram of *LP_PlaninhalteLandschaftsplanung* with the respective enumeration lists, the relations to the geometry objects, individual attributes, data types, and cardinalities.

From version 6.x onwards, it is possible to prepare landscape planning statements on an address-based basis. This ensures that the database already shows who the landscape planning statements are aimed at, as these requirements are formulated for nature conservation authorities as well as many other specialist authorities such as water management, forestry, agriculture, or urban planning authorities. Another important aspect is the possibility of multifunctional planning statements. Many landscape planning objectives and measures can have an impact on different protected resources. For example, planting a hedge has positive effects on biodiversity, can store CO_2, and minimize wind and water erosion.

Another important innovation is the modeling of integration possibilities into spatial and urban planning. In Germany, there are different forms of integration. As part of a weighing process, the statements of municipal landscape planning are transferred to the categories specified in the Building Code. To support this process and make it more effective, it is now possible to reference objects directly within the specialist model between object classes of landscape planning and spatial and urban land-use planning. This can support future adoption and thus exchange at the various planning levels. A similar approach was chosen for objects within the landscape planning specialist model. For example, arable land that is to be converted into grassland (measure) can simultaneously function as part of a biotope network corridor.

By defining cardinalities and enumeration lists, it is possible to standardize the content of landscape planning. In particular, the definition of mandatory attributes ensures the quality of data sets. However, further coordination will be necessary in the future, as the content presentation and technical processing of landscape planning in Germany has not yet been standardized.

The version has now been implemented in existing software systems that support the standard and is available for users to apply in practice.

5 Testing the Usability of the Standard in Practice

Two existing plan examples were selected to test their practical usability. These were the Cottbus landscape plan and the Hameln-Pyrmont landscape framework plan (Fig. 5). The test focused on the following questions:

- Which class can be used to capture the content presented in each plan?
- Can all subject content be captured using the defined attributes and enumerations, or what additions are needed in the model design?
- Can the content be represented sufficiently concretely using the enumeration lists that have been created?
- Are there any attributes or relations missing for mapping the existing plan content?

The assignments were presented in tabular form and unclear or missing assignment options were identified. Since the geodata was available for both plans, it was possible to check the transfer to the standard. The results showed that the necessary classes were available for all content in the sample plans (question 1). With a few exceptions, all objects could be fully mapped with the defined attributes and enumerations (question 2). There were uncertainties in the assignment of the enumeration lists for the attributes "right character" and "spatial concretization," so both attributes were presented and discussed in detail at the third expert workshop. As a result, additions were made. Additions were also necessary with regard to spatial concretization (spatially concrete representation of plan contents). The content (question 3) could also be transferred in sufficient detail. Furthermore, it was found that no attributes or relations were missing (question 4). In addition, the data model design was implemented in existing GI systems from a technical perspective. The results showed that the implementation of very extensive enumeration lists in geodatabases and GI systems in particular posed a major challenge. The subsequent preparation of plans can lead to room for interpretation, as in some cases it is not possible to clearly derive the specific spatial characteristics of some plan content (e. g., air corridors, habitat corridors). In principle, all content could be mapped completely. It was also possible to implement multifunctional aspects and addressee references in the geodata, which had not been possible previously.

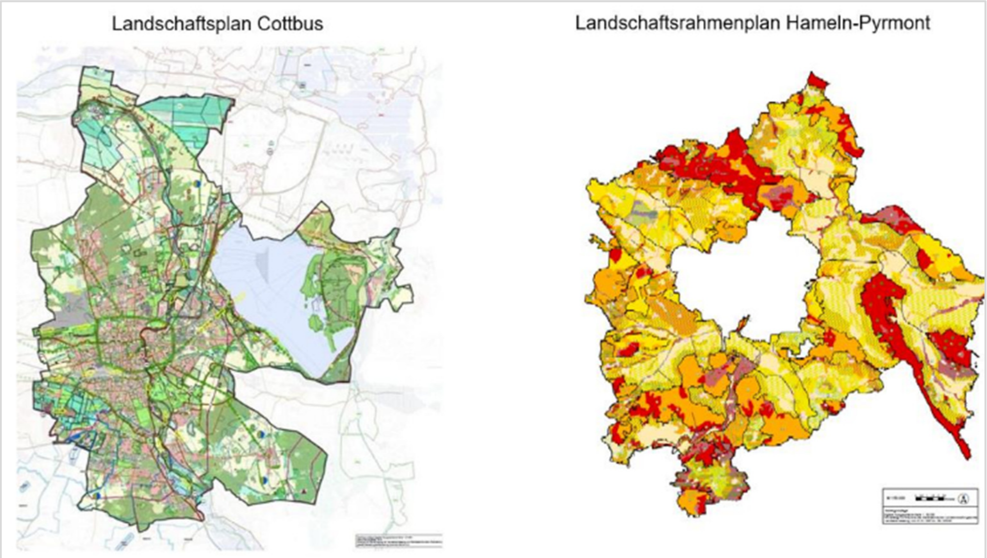

Fig. 5: Selected sample plans for the practical test (City of Cottbus 2016, Hameln-Pyrmont district 2001)

6 Relationship Between XPlanung and BIM

As mentioned at the outset, the XPlanung standard was developed for spatial planning, state and regional planning, urban land-use planning, and landscape planning, while the building information modeling (BIM) method is used in the planning sector to map the life cycle of construction projects. In terms of landscape planning, the specialist scheme in XPlanung forms the basis for what is known as precautionary landscape planning, which is usually carried out across an entire state, region, city/municipality, or parts of a municipality. There are various specialist models for BIM processes that include project-related landscape planning and its instruments, such as the FFH compatibility assessment, the environmental impact assessment, the landscape conservation accompanying plan, or the landscape conservation implementation plan. These culminate in a digital twin and ensure the supply of information for the entire process of planning, implementation, and operation (CARSTENS 2019, GNÄDINGER & ROTH 2021, GNÄDINGER 2023). The following table compares the two approaches using Germany as an example.

Table 2: Comparison of the XPlanung standard and the Landscape_OutdoorFacilities domain model from buildingSmart Germany

	XPlanung	**Fachmodell Landschaft_ Freianlage (BIM)**
Status	Version 6.1	Version 2.0
Dimension	2D	3D
Exchange Format	XPlanGML	IFC
Content	Planning tools for precautionary landscape planning	Planning instruments for project-related landscape planning
Organisation	XLeitstelle	buildingSmart Deutschland

This example clearly shows that specialist models are developed and used for different purposes. Nevertheless, there is enormous potential for developing synergies for the provision of information in the planning processes to be mapped. In BIM processes, data compiled in the context of landscape planning can be used as an important source of information. For example, areas for compensation measures are required when working on road construction projects. As part of municipal landscape planning, area scenarios are developed that can be used as a basis for the BIM process. These can currently be found with the corresponding attributes in the class *LP_ZieleErfordenrisseMassnahmen*. However, a comparison of the two specialist models has shown that the attributes of the measures and their structure currently differ in the two specialist models. For this reason, transformation rules must be defined that enable the integration of data from the XPlanung standard into BIM processes. To this end, pilot projects are currently being carried out in Germany to ensure the integration of data sets in the future.

7 Discussion

With the landscape planning model in the XPlanung standard in version 6.x and its implementation in existing software systems, it will be possible in the future to ensure lossless data exchange between different software systems. However, not all content and maps (e. g., soil, climate/air, water) can currently be displayed. These can only be displayed partially vectorially in the standard. Current work on expanding the specialist model should close this gap from version 7.x onwards.

During the development of the domain model, particularly in discussions with the expert committee, it became apparent that the high degree of abstraction in the standard made discussion difficult. For this reason, it was necessary to provide extensive training for those involved in order to establish a uniform understanding and work on development in a targeted manner. Another challenge is the lack of technical standardization and up-to-date plan symbols for the further development of the technical model. This led to comprehension problems during coordination and required a more complex representation of the technical content within the standard. The different methodological approaches used in practice and the integration models for landscape planning into overall spatial planning also made modeling more difficult. For this reason, the option of specifying text fields was made available for a large amount of content. Although this ensures that all conceivable content can be mapped, it complicates the automated evaluation of the geodata generated. For this reason, it would be desirable in the future to develop a kind of "minimum standard" for landscape planning content among experts in order to ensure the maintenance and further development of the standard.

Even though the technical requirements have been pointed out, the current version of the standard and the XPlanGML exchange format provide an important building block for the seamless exchange of geodata in a horizontal perspective (between landscape planning and overall spatial planning) and in a vertical perspective (between the planning levels of landscape planning). This offers the possibility of automated evaluation of existing plans at different administrative levels and the derivation of specialist applications (e. g., compensation cadastre). Web-based information systems can be developed using the geodata. This is another important building block in the use of standardized, quality-tested data in other planning or decision-making processes. This will provide another important source of information for BIM processes in particular in the future. However, initial tests have shown that the specialist models need to be checked and that suitable transformation rules need to be developed. This should be tested in further pilot projects and for different use cases in order to further increase the usability of the data, which is costly to generate.

It can be assumed that the provision of standard-compliant data will accelerate planning, participation, and approval processes in the future. However, to achieve this, it must be ensured that the developed specialist models are continuously maintained and adapted to current requirements.

In addition to providing technical solutions and maintaining the domain model, another important factor in increasing acceptance and use in practice is informing and training users, especially planners. The use of the standard changes the way geodata is generated. This has a direct impact on the development of the respective plans and must be integrated into the processes of the offices. The same applies to the commissioning administrations, which must also familiarize themselves with the application of the standard. This requires the definition of responsibilities, quality control of generated data, and the adaptation of processes.

8 Conclusion

Work is currently underway to expand the standard to include the missing content for municipal landscape planning and the landscape framework plan. These will be incorporated into version 7.0. This will enable the complete mapping of landscape planning content in the future. Implementing this version in software systems will make it easier for planners and administrations to use. It will be interesting to see how acceptance develops in practice. The experience gained in the further development of the specialist model can be used to contribute to the development of specialist models in other fields or for other processes or planning documents in landscape planning. With the almost comprehensive provision of this standardized data, a number of AI applications and other specialist applications are sure to be developed that will make an important contribution to digitization and accelerating planning.

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