Model-Based Geological Prognosis in the Tunnel Information Model

The Digitalized Geological Prognosis – Basis for Geotechnical Planning and Interdisciplinary Execution Documentation

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ABSTRACT: This dissertation focuses on integrating geological planning processes into Building Information Modeling (BIM) and developing a Tunnel Information Model (TIM) for model-based geological prognosis. The dissertation demonstrates that the early determination of necessary geological and geotechnical properties, along with the continuous integration of these data into an updatable model, provides significant advantages for the planning and execution of tunnel construction projects.

Complete thesis: https://www.uibk.ac.at/de/ibt/lehre/dissertationen/

KEYWORDS: TIM, BIM, LOIN, Ground Model

1 INTRODUCTION

This dissertation analyzes and further develops model-based approaches for geological prognosis within the framework of TIM. A key focus is on defining and evaluating the Level of Information Need (LOIN) for geological properties across different project phases. The goal is to develop a digital 3D ground model that enables transparent, evaluable, and high-quality planning. This is intended to create an actionable TIM process that systematically considers geological and geotechnical requirements.

2 FUNDAMENTALS AND METHODS

BIM is a digital approach for planning, constructing, and operating structures. It encompasses 3D models that integrate geometric and alphanumeric data to enable efficient collaboration, cross-phase planning, and optimized resource utilization. Standards such as ÖNORM EN ISO 19650 and the definition of use cases (e.g., Level of Information Need – LOIN, see Fig. 1) promote structured execution and communication.

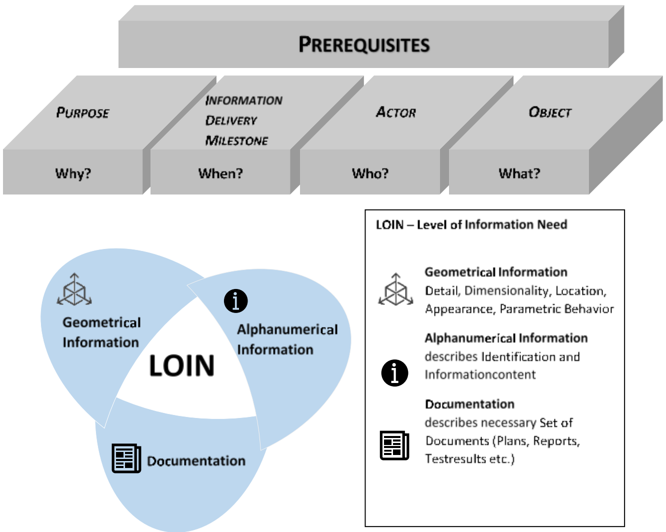

Fig. 1: Representation of the relationships of the Level of Information Need [6].

TIM transfers the BIM methodology to tunnel construction, where geological factors and uncertainties pose challenges. The digital provision of geological data, based on standards such as Eurocode 7 and ÖGG guidelines, in a 3D ground model is demanding but enables a structured and continuously updated representation

3 MAIN SECTION

Through literature research and initial expert interviews, the status quo is determined, and deficiencies in the current BIM implementation are identified. The results are published in **Article 1** [1] Based on these findings and the experiences gained from accompanying seven tunnel construction projects where the BIM method was already used in planning and execution, an evaluation of the social and economic impacts of BIM/TIM is conducted, documented in **Research Article 1** [2]. For **Conference Paper 1**, a concept is developed for creating a digital schematic, parameterized ground model that illustrates causal relationships between geology and the structure [3]. **Conference Paper 2** extends this overall process and presents a concept for construction-accompanying work preparation based on Tunnel Information Modeling (TIM) [4]. In **Article 2**, a digital workflow is developed and implemented to model-based represent prognosis (un)certainty for shallow tunnels [5]. In **Article 3**, the research results are evaluated and interpreted, and the Level of Information Need (LOIN) for ground elements is defined to specifically answer the research question [6].

Supplementary interviews on the topic "What data do geotechnics require from geology in a 3D ground model?" revealed that experts largely agree with normative requirements on the fundamental aspects of geotechnical planning. However, differences exist in the required data depth, flexibility in parameter selection, and model handling. Experts prefer a pragmatic, project-specific approach tailored to specific requirements and conditions.

4 RESULTS

The research results on model-based geological prognosis based on applicable standards establish minimum requirements for geological-geotechnical key parameters, which should be fundamentally available and maintained for dynamic model creation and evolution (model progression) from project inception through geological forecasting to geotechnical planning. However, it must be considered that the geological properties necessary for effective further planning should be determined project-specifically by clients and geological-geotechnical planning authorities.

By standardizing LOIN based on project-specific geological-geotechnical properties, model-based geological prognosis in the Tunnel Information Model can serve as the foundation for geotechnical planning.

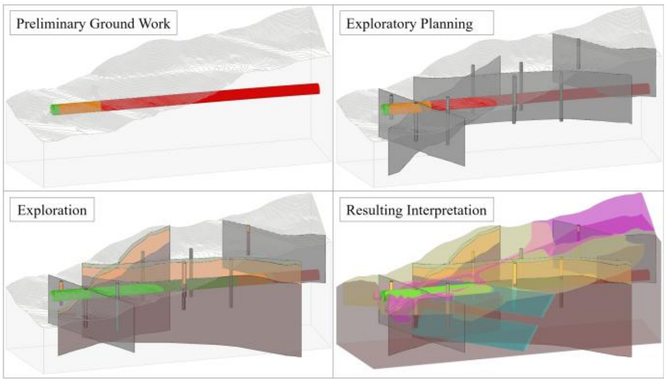

Fig. 2: Geological planning phases in a TIM model [5].

Application Objective: Provision of geological-geotechnical information for geotechnical planning		**Object:** Deep outcrop, borehole	**Object:** Deep outcrop, borehole	**Object:** Deep outcrop, borehole	**Object:** Deep outcrop, borehole
Milestone Phase:		**Phase 1a+b:** Basic data collection, field survey, evaluation	**Phase 2:** Exploration planning based on the initial geological prognosis	**Phase 3:** Exploration	**Phase 4:** Interpretation for geotechnics
Actor: Geological specialists					
Geometrical Information	**Detail**	simplified	simplified	detailed	reduced to rock types (GA)
	Dimensionality	3D	3D	3D	3D
	Location	Absolut, coordinates	Absolute, coordinates, inclination/direction planned	Absolute, coordinates, ground surface and final depth	Absolute, coordinates, ground surface and final depth
	Appearance	Cylinder, schematic	Cylinder, schematic	Cylinder, realistic	Cylinder
	Parametric Behavior	yes	yes	yes	yes
Alphanumerical Information	**Identification**	Outcrop type, borehole identification	Outcrop type, borehole identification	Outcrop type, borehole identification	Outcrop type, borehole identification
	Information-content	• Coordinates: ground surface and pipe top • Diameter • Final depth according to borehole profile and evaluation • Casing • Usage • Layer structure • Geological description • Water level …	• Coordinates: ground surface, • Inclination-Direction, and planned final depth • Borehole diameter and planned casing • Usage • Predicted layer structure • Predicted geological description • Predicted water level • Planned in-situ and laboratory tests …	• Coordinates: ground surface and final depth • Diameter • Casing • Usage • Layer structure • Geological description • Absolute water level • Depth or coordinates of core samples and in-situ/laboratory tests …	• Coordinates • Diameter • Final depth • Casing • Usage • Layer structure • Geological description • Geotechnical description • Absolute water level • Depth or coordinates of core samples and in-situ/laboratory tests
		Further properties according to Phases 1a+b or project-specific definition	Further properties according to Phase 2 or project-specific definition	Further properties according to Phase 3 or project-specific definition	Further properties according to Phase 4 or project-specific definition
Documentation		• Borehole profile • Existing geological-geotechnical reports • Field protocol • Evaluation, deficiencies • Water level data	• Property • Ownership • Existing geological-geotechnical reports • Installations	• Borehole profile • Photo documentation • Borehole measurements • Water level data • Existing geological-geotechnical reports	• Borehole profiles • Borehole reports • Water level data • Test reports • Laboratory results • Photo documentation • Borehole core photos • Project-specific geological-geotechnical reports

Fig. 3: Level of Information Need for the Element Borehole [6].

Fig. 3 illustrates how LOIN can be defined and described for the element borehole.

5 SUMMARY AND OUTLOOK

The research demonstrates that a precise definition of the Level of Information Need (LOIN) for geological properties and the harmonization of relevant standards (e.g., Eurocode 7, ÖNORMEN) are crucial. The developed methods enable structured, continuous integration of geological data into digital models, refining geotechnical planning and improving interdisciplinary collaboration in construction execution.

Future research should further test the application of the methods in practice, adapt geological base properties to specific projects, and utilize technologies such as machine learning and AI for automated model updates. Additionally, national and international harmonization of standards is sought to ensure cross-border consistent and interoperable geological models.

6 REFERENCES

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