Parametric Modelling Workflows for Tunnel Information Modelling

Comparison of Autodesk Revit® and Bentley OpenTunnel Designer®

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ABSTRACT: Tunnel structures are characterised by the arrangement of recurring components along an alignment, and the resulting lengthy and repetitive modelling task requires automation through parametric design. The aim of this thesis is to present an evaluation of currently used software solutions for TIM that are able to implement parametric modelling via extensions or scripting.

Complete thesis: *https://www.uibk.ac.at/de/ibt/lehre/abgeschlossene-masterarbeiten/*

KEYWORDS: TIM, BIM, tunnelling, parametric modelling, digitalisation

1 INTRODUCTION

The University of Innsbruck, with the endowed chair "Tunnel Information Modeling (TIM)", has set the goal of developing an integral digital twin for the tunnelling field. [1]

The aim of this thesis is to compare a set of software solutions and their extensions in terms of automating the generation of the tunnel structure model as the basis for the envisaged digital twin. Based on an exemplary project, a tunnel structure is generated in selected modelling software and an overall comparison table is created to show the strengths and limitations of the solutions used.

2 SOFTWARE

While many software solutions are often referred to as BIM or TIM software, it is not strictly defined what such software must be capable of. This thesis considers software to be capable of TIM if it can represent both the physical and intrinsic properties of a structure as an object-oriented model. Further, it especially focuses on software programmes that use parametric design as the foundation of their modelling approach. The selection was further based on current usage of software in pilot projects, parametric design capabilities and market developments as of 2022. [2,3]

The authoring software packages chosen were:

- Autodesk, Revit®
- Bentley Systems, OpenTunnel Designer®

Revit® does not include any infrastructure- or tunnel-specific tools. Therefore, various software developers have created Revit® add-ons to meet the needs of infrastructure modelling. For this, the evaluation further includes two infrastructure-specific Revit® extensions, FIDES® Infrastructure Tool (FIT) and SOFiSTiK® Bridge + Infrastructure Modeller, as well as Autodesk's visual programming interface, Dynamo®.

3 METHOD

The software and its extensions were compared in a self-study on generating a tunnel structure model. For this, an exemplary simplified drill and blast tunnel project is used. However, the evaluation of the software and their workflows are equally applicable to mechanised tunnel projects.

The modelling process is split into several categories that can be evaluated independently of the overall workflow. The categories defined include the alignment, 3D modelling, split into the tunnel-block and the placement of these blocks, attribute integration (to eventually integrate 4D, 5D, … design), drawing derivation, as seen in Figure 3-1. The criteria were defined from a modeller's perspective and are subject to project-specific goals, needs and solutions. However, the evaluation does not only include the ability to accurately model the specific as-built structure in 3D, but also to further evaluate the tools and functions in terms of the replicability of the workflow for other projects as well as the flexibility to adapt to different tunnel information modelling requirements.

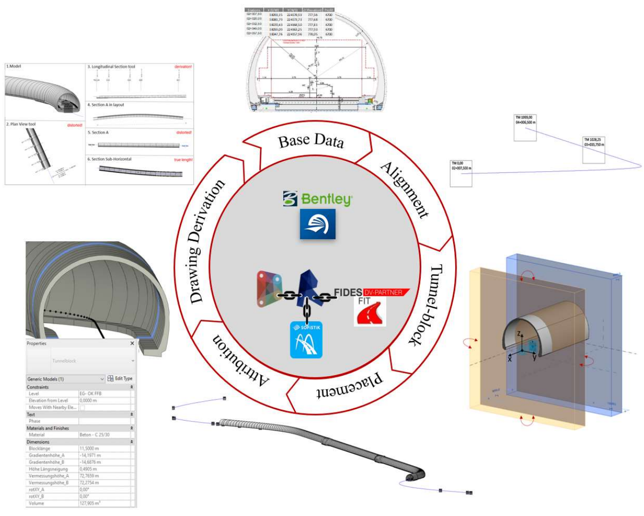

Fig. 3-1: TIM workflow

4 COMPARISON

Once the workflow was implemented and documented with each software and extension, the process was compared using the defined categories. Comparing these modelling approaches is challenging in itself, because the methods are fundamentally different. The scripting approach is limited by the range of functionalities offered by the authoring software, resulting in a wide variety of solutions to a single task, while the specifically developed tools are limited by their own functionality. A little excerpt of the findings of significant differences from a modeller's perspective is given on the next page and a little summary can be found in Table 2-1.

4.1 ALIGNMENT

The alignment is a fundamental part of TIM as it provides the foundation for every infrastructure project. For the tunnel structure model, an alignment is usually provided in the form of point data. Thus, importing data is a key aspect of generating an axis. This first task of implementing world coordinates already presents a challenge in Revit® due to its limited modelling boundary of 32 kilometres. Moreover, the further the elements are placed from the internal origin, the less reliable the geometries and distances that are generated. Therefore, world coordinates need to be transformed in Revit®, while in OpenTunnel Designer® world coordinates may be included.

4.2 OBJECT MODELLING AND AUTOMATION

While the alignment is a very simple component, geometry-wise, a tunnel block is more complex. The geometry of a tunnel block is defined within its cross sections as well as its extrusion or sweep along the alignment in the form of a block chain (see Figure 1). Hereby, length, angle and other dimensions and their constraints may be integrated as parameters for every cross-section component as well as the extrusion length. There are two approaches to modelling these components: creating a static or parametric 2D profile and sweeping or extruding this along an alignment, or creating a static or parametric 3D object and placing these. The latter approach usually provides more dynamic editing options compared to the former, which often loses its parametric functions once extruded. Additionally, placed 3D components are often standalone objects that can be individually edited or grouped, while extrusions may be grouped right away and may not be editable as individuals. There are ways to create standalone profile extrusions, however, this often results in manual, repetitive tasks.

The repetitive nature does not only lie in the placement of one object at different lengths along the alignment, it further includes repetition for every single component and type of the cross section. A scripting approach is able to solve these required tasks based on the flexibility and complexity of the self-coded script. In contrast to the self-coded functions, the tools integrated via the extensions provide more limited modelling solutions. Hence, depending on project specific-goals, any of the provided modelling approaches may fit best.

Table 2-1 gives a short summary of some important findings. Within the thesis, a more elaborate table, including more in-depth points and explanations for each of them, is given.

	Bentley		Revit	
	OTD	DYN	FID	SOF
Import data types	flex.	flex.	.xlsx	flex.
World coordinates	✓		x	
Alignment tool	✓	x	✓	✓
Dynamic stations	✓	~	x	✓
2D extrusions	✓	✓	✓	✓
3D objects	x	✓	✓	✓
Placement flexibility	x	✓	✓	x
Flexibility attribution	x		✓	
Direct IFC export	x		✓	
Automation potential	x	✓	x	x
Ease of use for novices	~	x	✓	✓
Coding experience needed	x	✓	x	x

Tab. 4-1: Comparison

flex* = flexible, ✓= capable/possible, x = limited/not possible, ~ = ok

5 CONCLUSION

OpenTunnel Designer® seems to have great future potential as a TIM software, but to become a competitive standalone solution, the software has to improve its modelling capabilities in terms of flexibility (for example, the integration of cross passages), attribute management and export. Currently, only when combined with other, more property-capable software developments like iTwin® or MicroStation® does it present itself as a powerful TIM tool. In contrast, Revit® limitations involve integrating world coordinates and the defined modelling boundary, while it excels at property management and data export. However, the software is only efficiently applicable in combination with extensions. While FIDES® and SOFiSTiK® support modelling beginners on a geometric basis, Dynamo® provides great flexibility for geometric modelling and, in addition, provides great support in attribute management.

Finally, a specific recommendation for one software cannot be made due to the many variables that play a factor in finding the best software for each task, project or company. However, the in-depth comparison can be used as a basis to choose an efficient software solution once a framework for the application is set.

6 OUTLOOK

While this thesis provides insight and a comparison of currently used software products and modelling solutions for generating TIM structure models, TIM is an incredibly vast field, encompassing many different topics and opportunities with ample research possibilities to explore. Therefore, keeping up with current industry developments is necessary due to rapid advancements and further software solutions should be tested and compared to gain a more detailed overview of the solutions available on the market.

The workflows created (which are attached as step-by-step modelling approaches in the appendix of the master's thesis) and the resulting models provide a good basis for further research on unexplored topics, such as quantity take-off, process simulations, the integration of sensor data, data exchange, and further TIM studies.

7 REFERNECES

[1] Flora et al., Optimierung des Baumanagements im Untertagebau mittels digitaler Infrastruktur-Informationsmodelle, Bautechnik Jg. 97, Nr. 11, 2020.

[2] Gächter et al., Possible applications for a digital ground model in infrastructure construction, Geomechanics and Tunneling 14, No. 5, 2021.

[3] Bentley Systems Incorporated, Bentley OpenTunnel Designer, accessed on February 03, 2023 from https://www.bentley.com/software/opentunnel-designer/