Lifecycle-Driven Digital Twin Platform for Risk Management

Integrating Parametric BIM, Real-Time Geotechnical Data, and Dynamic Simulation

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Tunnel – Overview Tunnel lifecycle

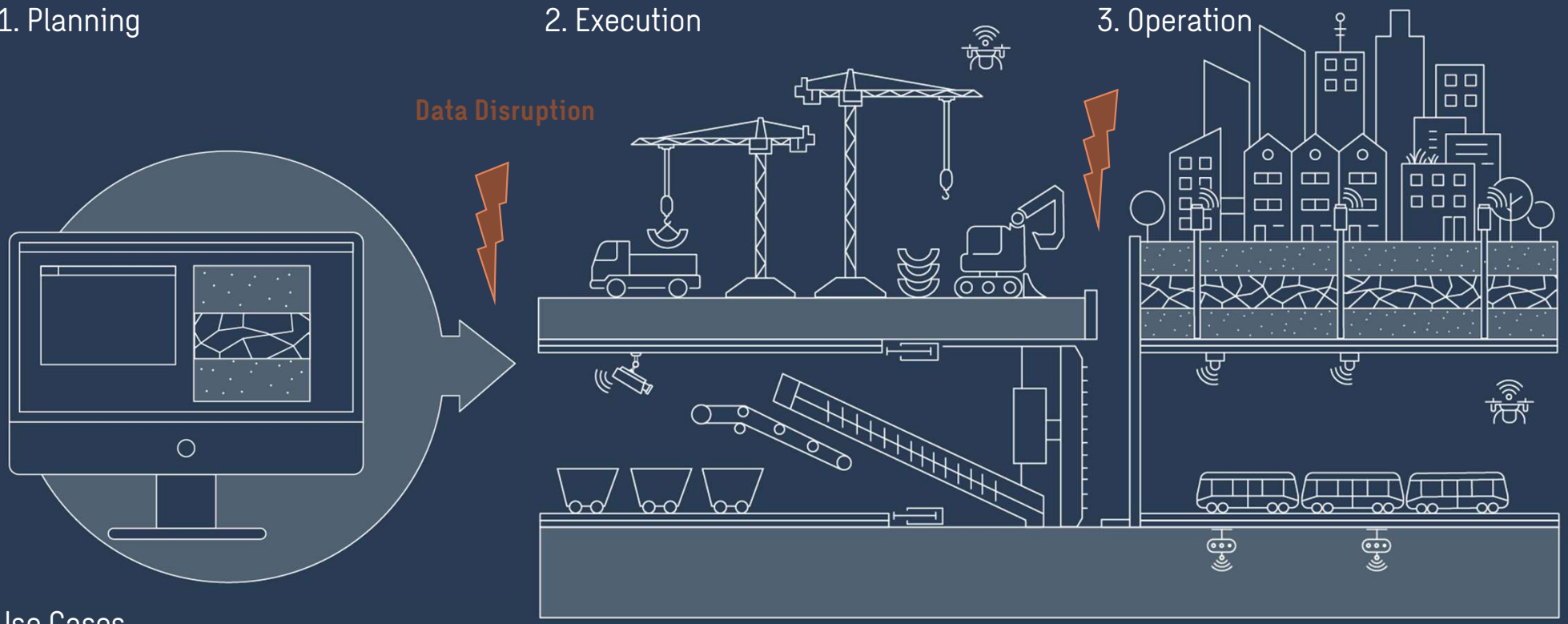
SWECO

1. Planning

2. Execution

3. Operation

Data Disruption

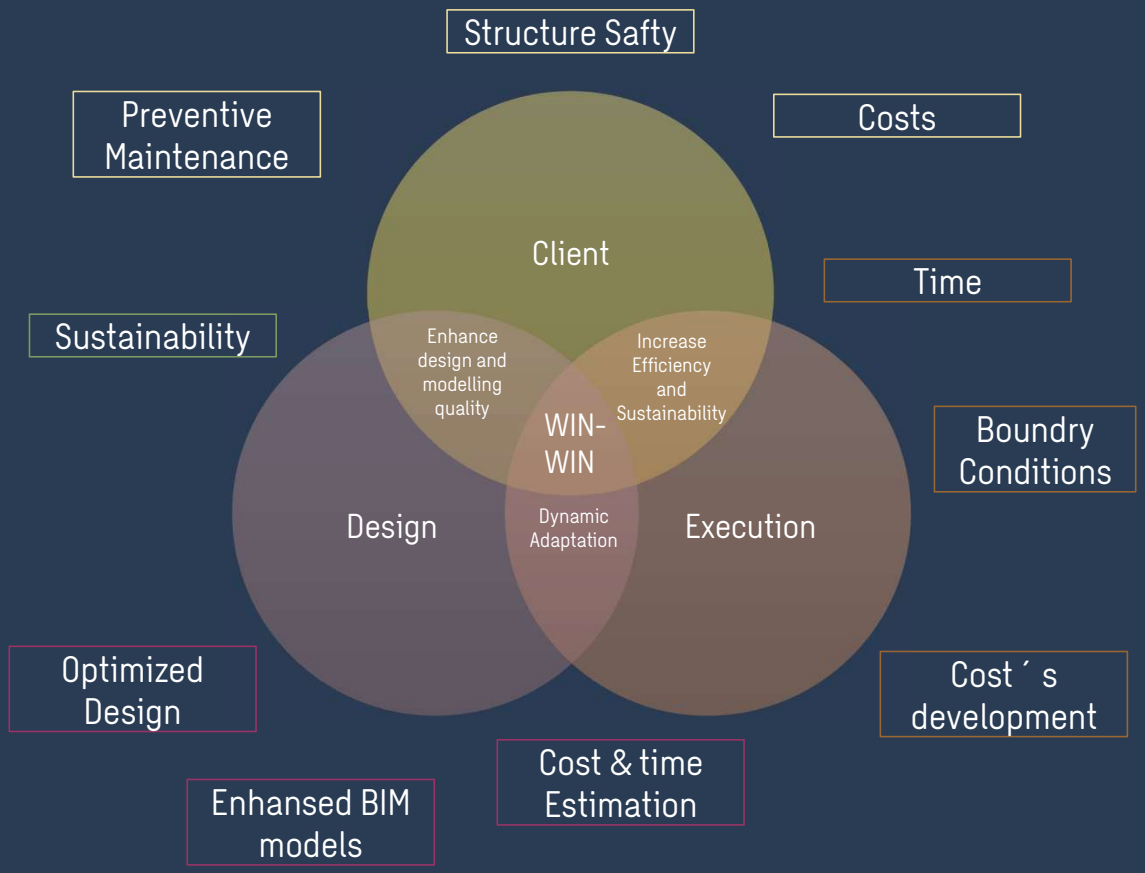


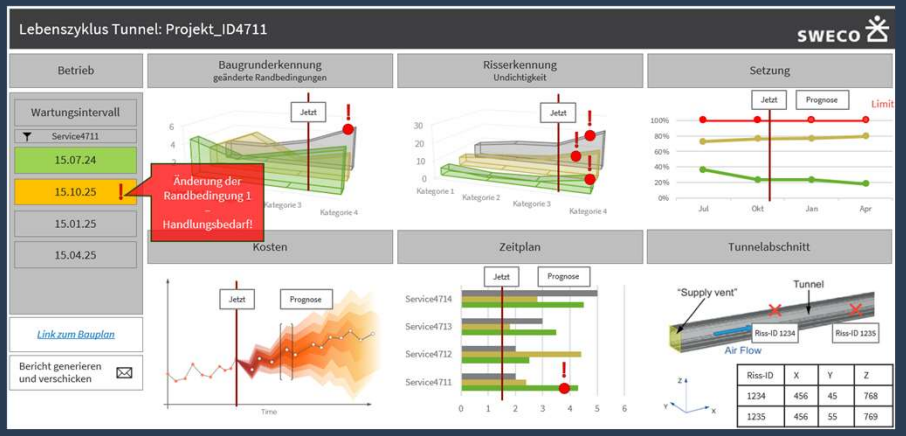
Use Cases

Geometry/Model - Base line – Tunnel axis – Reinforcement – Reports/Tenders	**Material tracking – Logistics – Soil testing**	**Leakage – Settlement – Cracks – Deformation**

Digital Twins for Tunnels

Use Cases for Stakeholders





Tunnel Digital Twin – Objectives

1 **Closed Loop of Information**

Data from construction and operation phases can enhance the tunnel design and planning

Create End-To-End BIM Models to adoptate Info from different phases

2 **Dynamic Adaptability and Visualisation**

Automatic updating of geometry, alignment, model, IFCs, plans

Visualizing changes in plans, checking impacts on the environment

Update static calculations and cost estimations according to new BC

3 **Operational Efficiency**

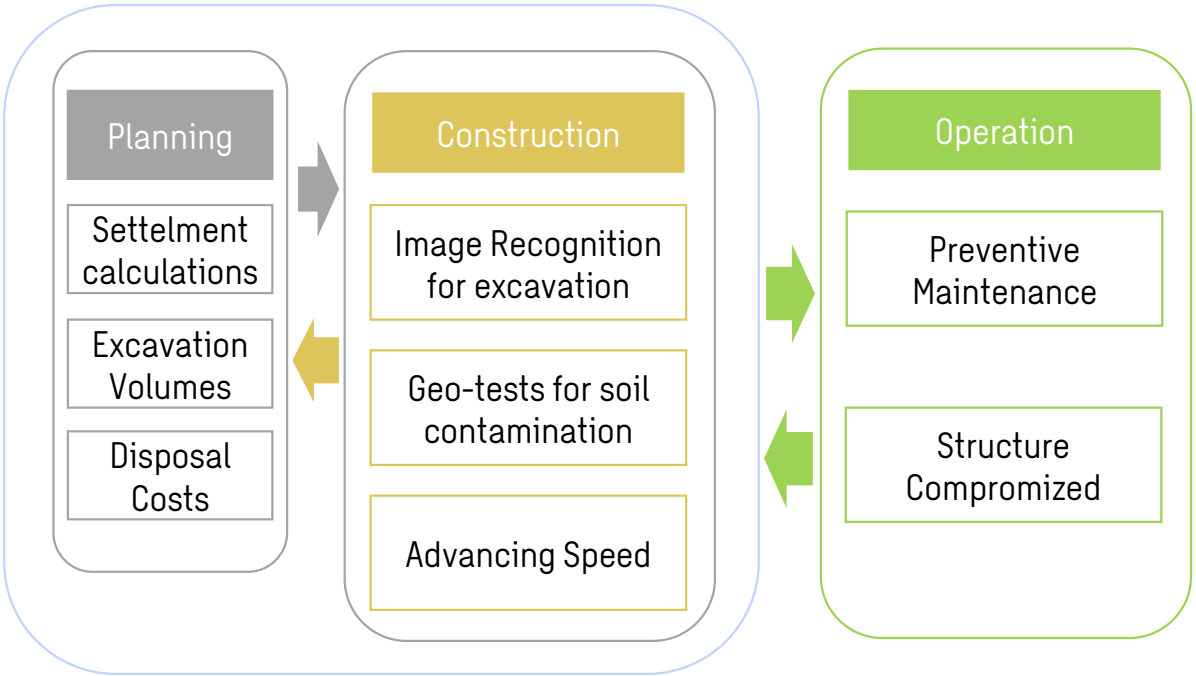
Optimizing feedback loop between planners and customers.

Real-time monitoring of operations in various phases

Data analysis and knowledge exchange for many upcoming years

SWECO

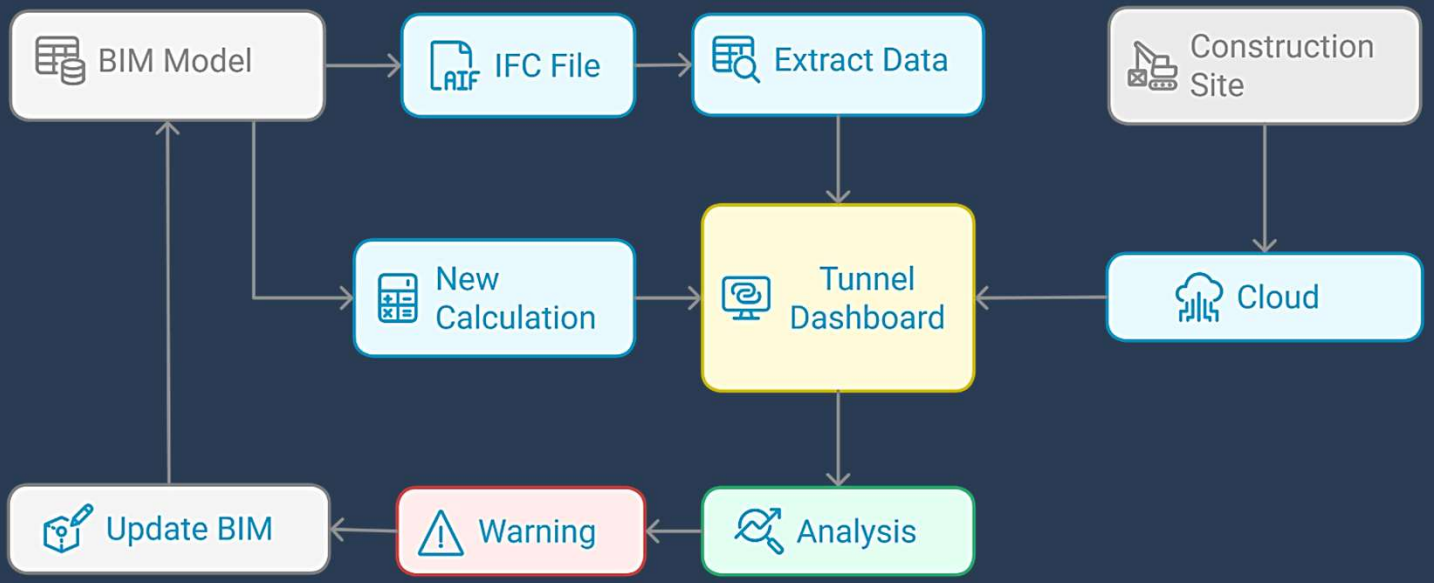
Sweco – AWS Collaboration



Implemented applications:
- Monitoring of settlement development
- Monitoring of excavation volume and disposal costs
- Monitoring of advance speed

Tunnel Dashboard- form Planning to Operation

Data Pipeline – Closed Loop (BIM- SofiStiK – IoT Systems)



Flow Diagram of the Closed Loop of Information between Planning and Construction

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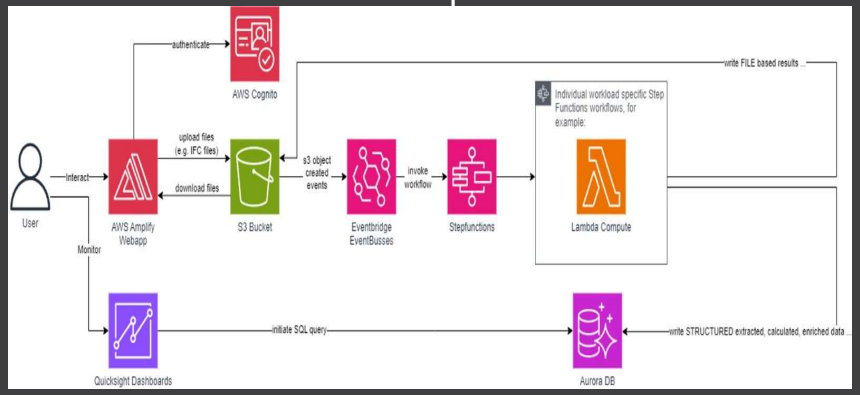
Sweco – AWS Collaboration



Architecture Diagram

1 **The dashboard gets the data**

QuickSight → Aurora (or Athena/S3): the dashboard reads KPIs by running direct SQL on your Amazon Aurora database (or Athena on S3)

2 **The dashboard can "write back" (push changes)**

QuickSight provide custom action that opens a dynamic URL
API endpoint: the URL targets API Gateway (or a Lambda Function URL) which invokes a Lambda that performs the update.

3 **AWS Lambda**

Lambda receives the payload and executes the change
Lambda parses files, calls ML, writes results
Lambda updates **IFC 4.3** property sets and Aurora rows, then drops updated files back to S3

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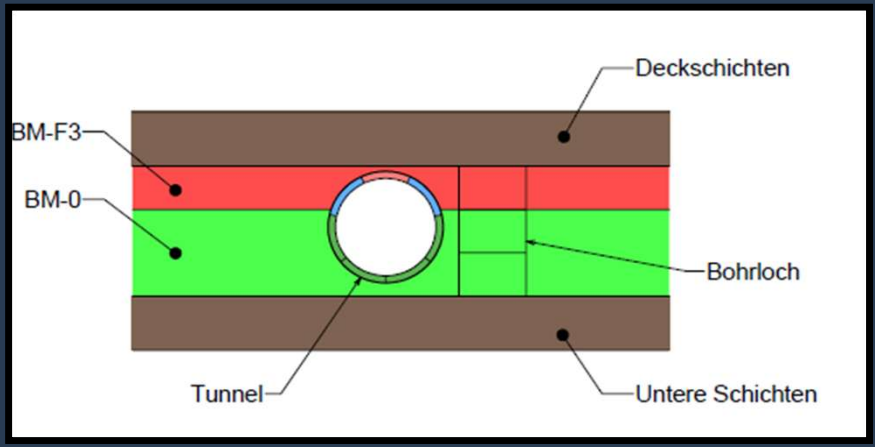
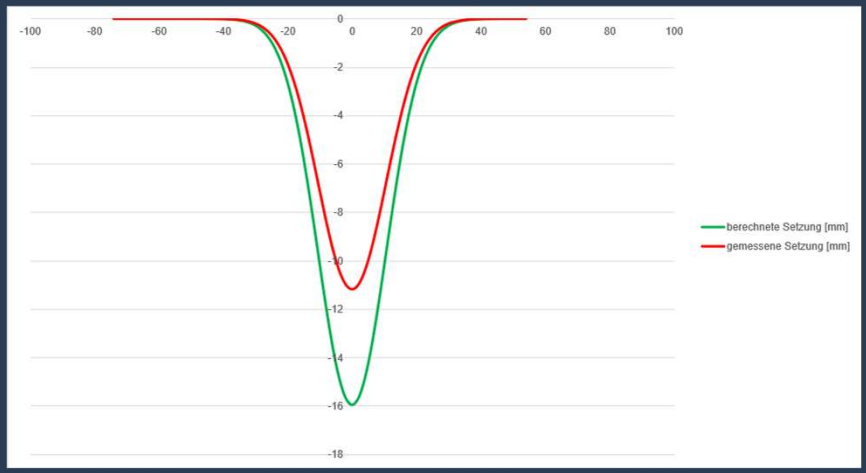
MVP - Monitoring of settlement development





Objective: Detect settlement drift early and auto-recalculate impacts on structures & cost

Inputs (live): Total-station/GNSS points, TBM logs, lab data; mapped by chainage/axis & IFC GUID

KPIs on the board: S_max (mm), *i* (m), **volume-loss proxy** (area)

Automations: On breach → update **IFC 4.3,** trigger **APS** (headless Revit) to sync parameters, run **SOFiSTiK** settlement re-check, return PDFs/CSV to Dashboard

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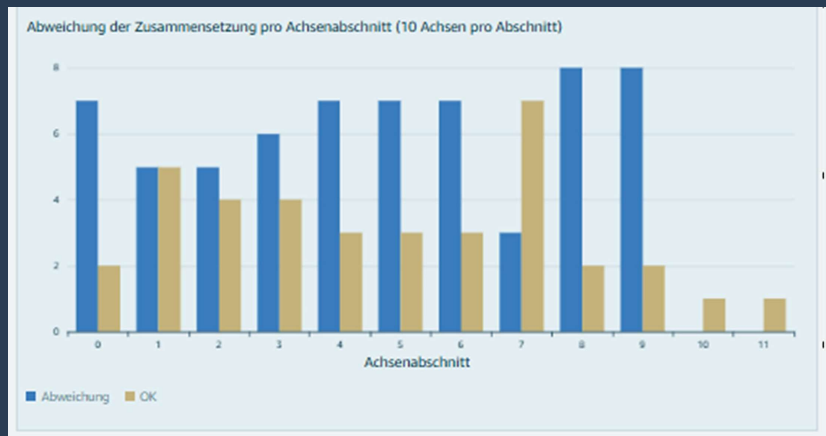
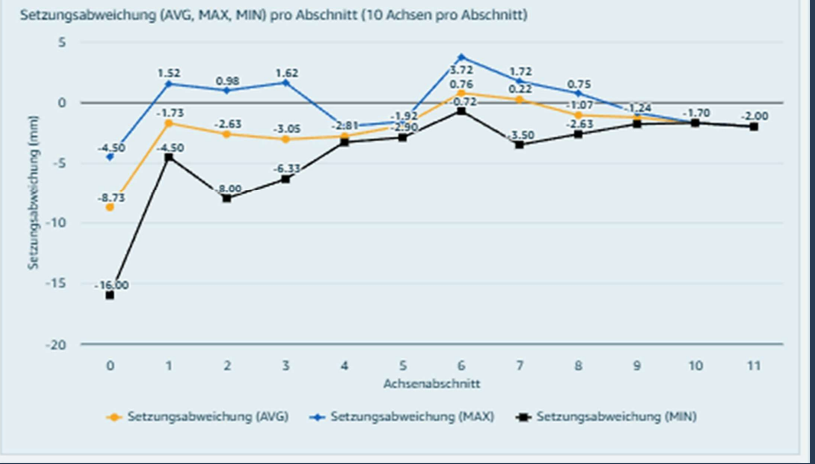
MVP - Monitoring of settlement development





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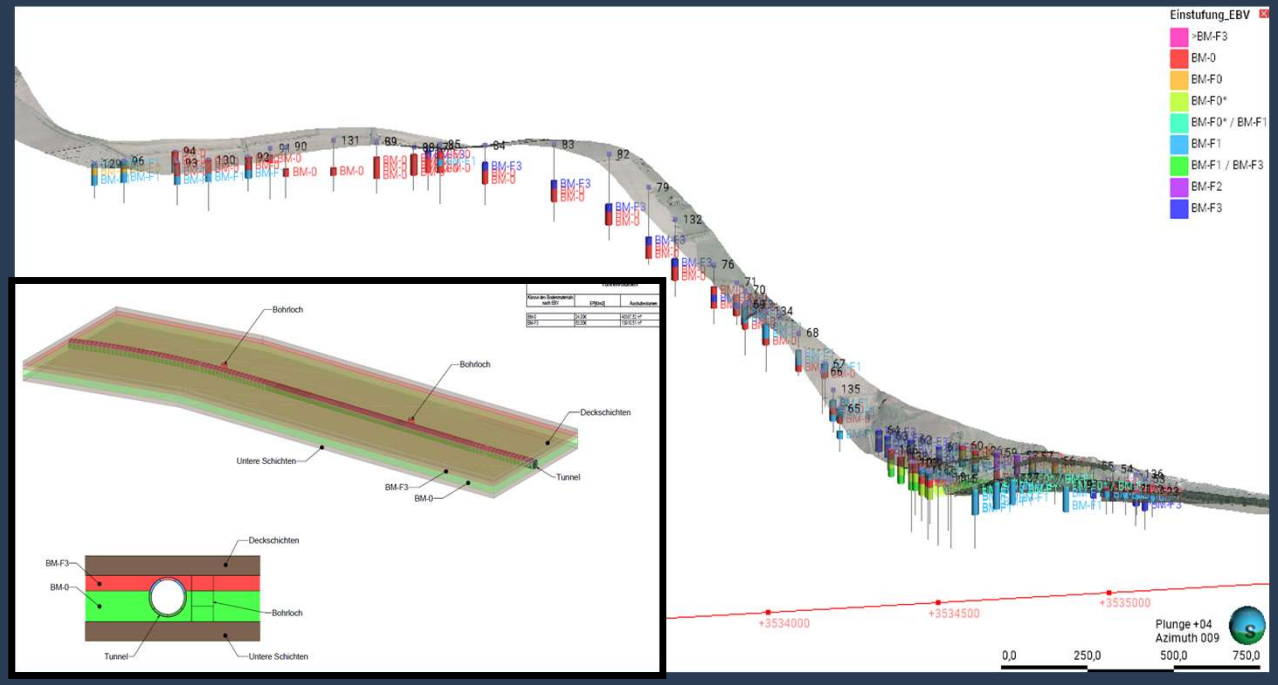
MVP - Monitoring of excavation volume and disposal costs

Objective:
Continuously classify excavated material, pick the compliant disposal route, and **re-price €/m³** against plan.

Inputs (live)
Lab assays (contaminants), image/CV soil class,

KPIs on the board
•€/m³ vs plan, Contamination class, Disposal rout



Technical Waste Classification Profile

SWECO

MVP - Monitoring of excavation volume and disposal costs

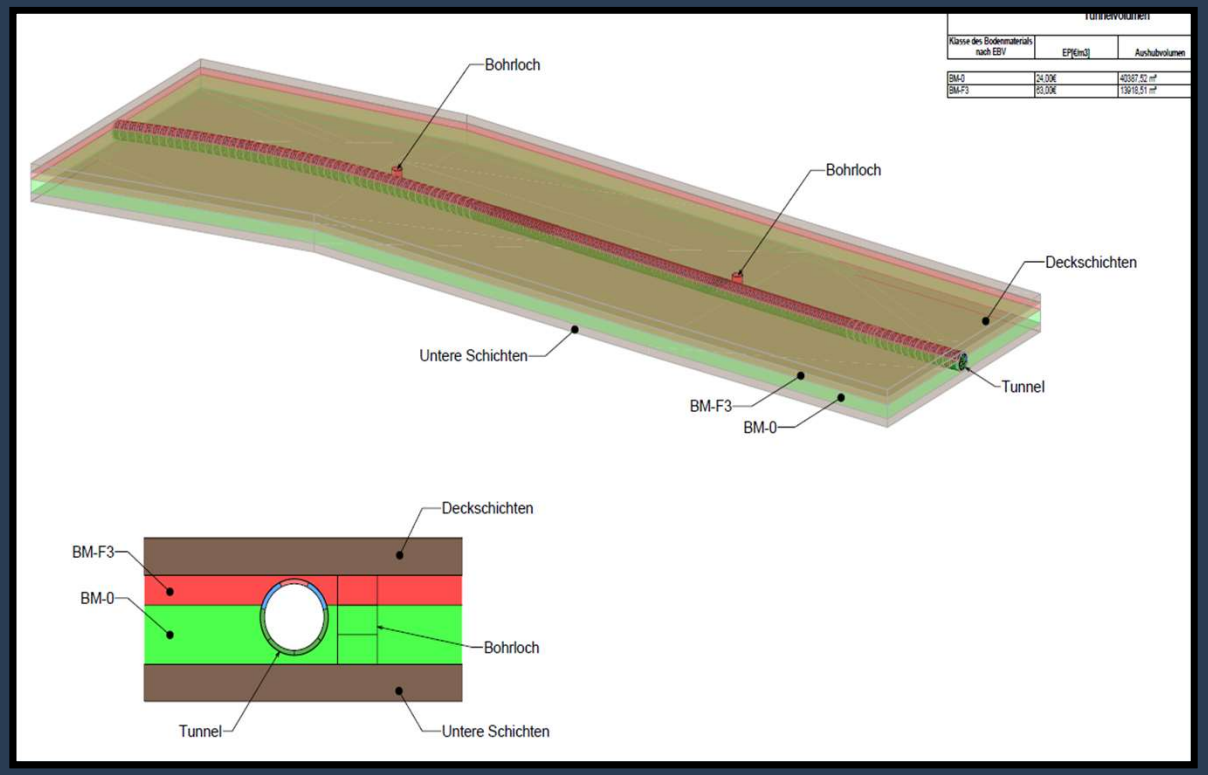
Parametrized Model

- **Material**
- **Contamination Class**
- **Volume**
- **Cost per cubic meter**

Modelling Modification

- **Define sections in the tunnel**
- **Define test points on the axes**
- **Define coordinates at the test point**

Update



Technical Waste Classification Profile

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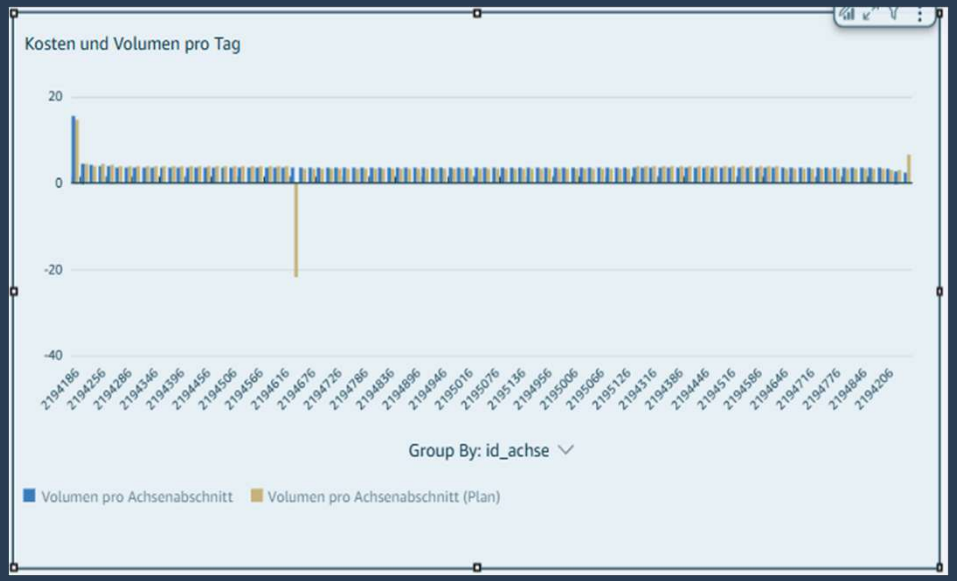
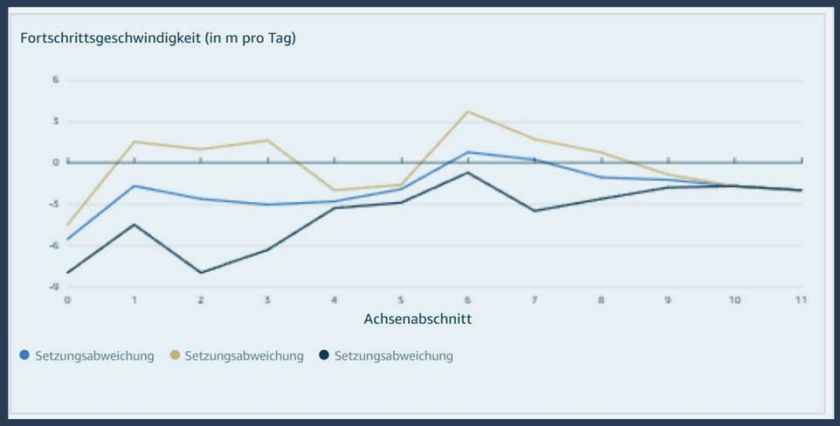
MVP - Monitoring of excavation volume and disposal costs

Waste Volumes and Disposal Costs /Day



Volums from the planning phase

Real-Time volums



Advancing Speed on Tunnel Sections

Advancing Speed per Day

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Closed-Loop Grasshopper- Sofistik

Tunnel Thcikness Optimization

Geometry

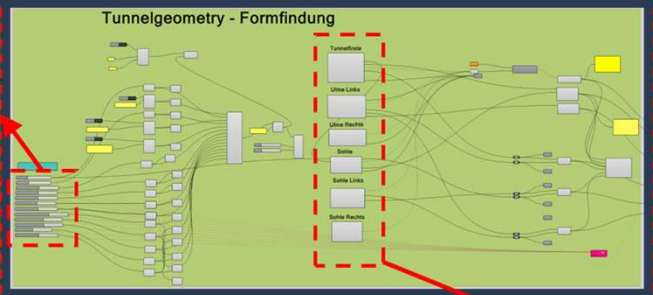
- Tunnel Radius
- Number of Segmente
- Angle Keystone
- Joint length
- Segment thickness
- Soil layers Coordinates tunnel axis

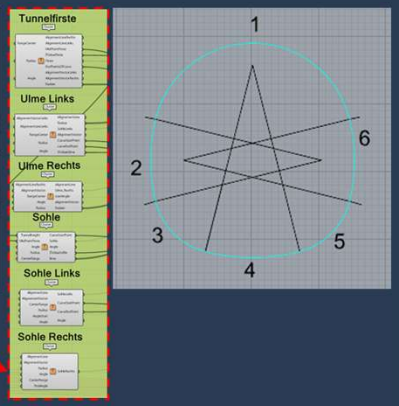
Model Simulation

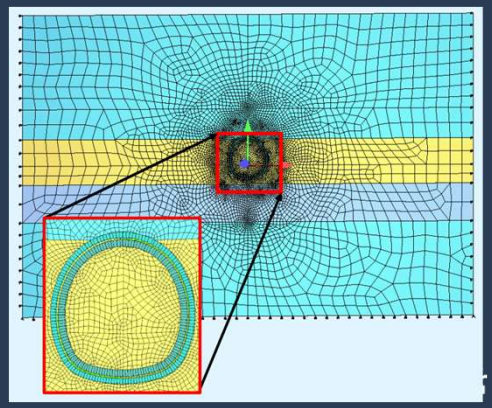
- Mesh Generation
- The Load / Load Case Combination
- Material properties

Calculation and design

- Reading the parameters
- Calculation of internal forces
- Design of segments







Closed-Loop Grasshopper- Sofistik

Segment Thickness Optimization

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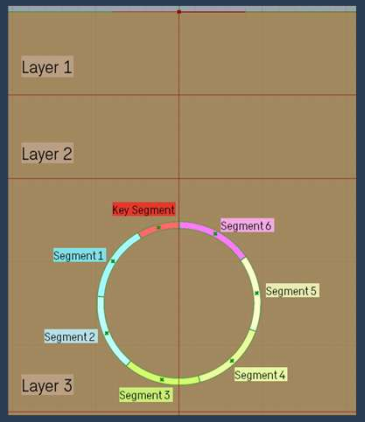

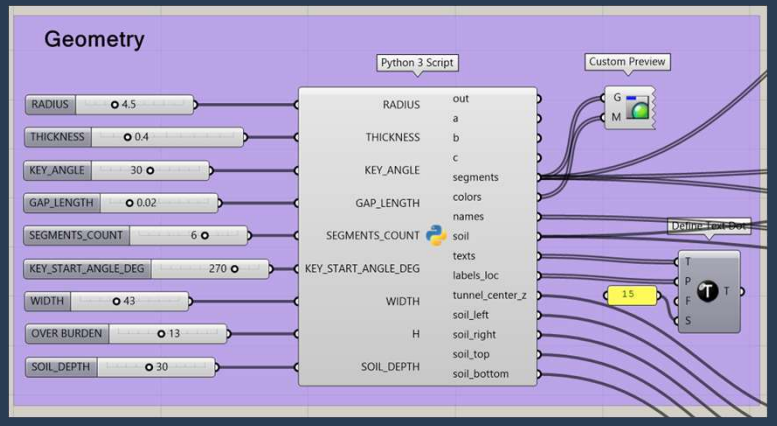

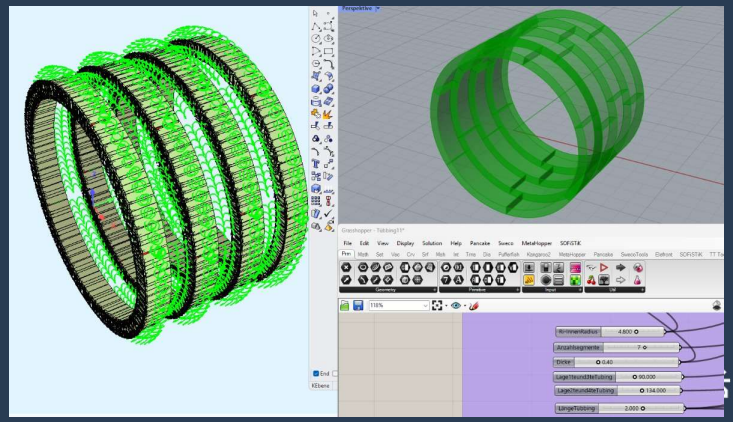

Conclusions

- **Need for Approach**: Addresses challenges in tunnel infrastructure projects, improves accuracy and efficiency.
- **Investigation**: The project investigated a lifecycle-driven digital twin platform for tunnel risk management.
- **Benefits**: Enhanced risk assessment, cost management, and project timelines.
- **Collaboration Success**: Effective integration of BIM, IoT, and AWS technologies.
- **Future Work**: Further integration with statics software, automated workflows.


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