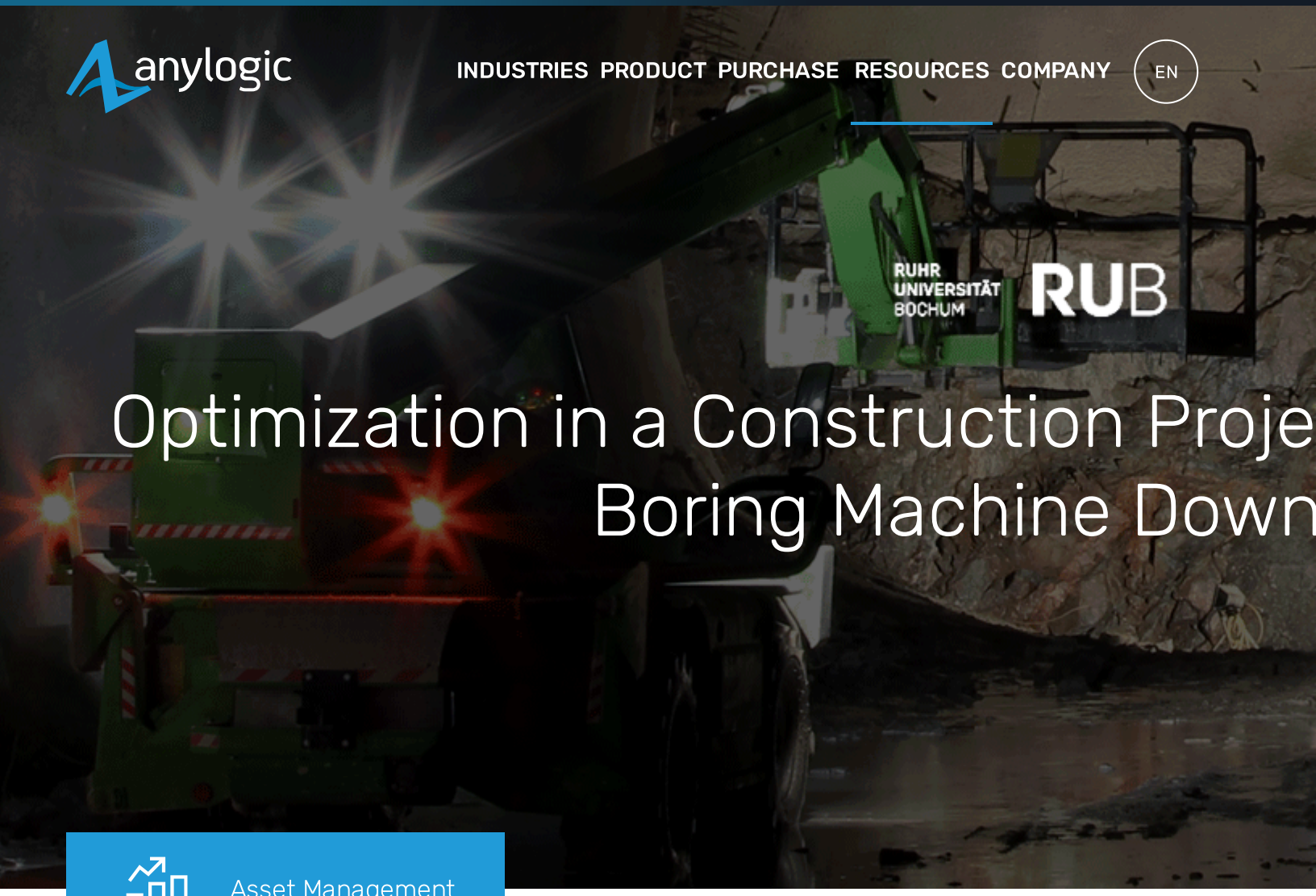


Optimization in a Construction Proje
Boring Machine Down

Asset Management

Problem:

Researchers at Ruhr University Bochum needed to reduce tunnel boring machine downtime in an inner-city tunneling project. Conventional calculations couldn't reliably capture disruptions, tight storage limits, and increasing transport distances, so they used

multiple scenario variants under city constraints. They ran Monte Carlo experiments to compare the baseline and optimized setups and select the most robust configuration.

Results:

- Reduced average total construction time **from 194 days to 169 days (–12.9%)**.
- Cut TBM downtime by **40.5%**.
- Increased average advance rate **to 17.78 m/day (+15%)**.
- Reduced spoil-transport traffic **from 103 trucks/day to 30 trucks/day**.
- Validated improvements via 1,000-run Monte Carlo comparison of baseline vs. optimized scenarios.

Overview

Big construction sites in cities are usually noisy and make traffic even worse. The researchers at **Ruhr University Bochum**, in Germany, aimed to make these tunnel construction sites more efficient. The goal of the project was to analyze and manage the construction processes by using process-focused simulation modeling.

Problem: Reduce downtime in a construction optimization project

> tunneling technology for the construction of new underground infrastructures, in particular in urban environments.
>
> — Ruhr University Bochum.

In mechanized tunneling, there are always two alternating core processes: excavation and ring construction. The processes for building tunnels require a large number of machine components and logistics elements (tunnel boring machine, external logistics, etc.). Disruption of one element can lead to the disruption of the entire system.

Among the constraints, there were limited storage areas above and below ground. Also, transport distances in the tunnel steadily increased as the excavation of the tunnel progressed.

Achievable performance rate depended on the interaction of all construction-related processes. Therefore, conventional calculation of the tunneling time was only possible to a limited extent.

To reduce downtime, extensive analysis of the advanced support processes with the aid of process simulation was required. The aim was to achieve more robust planning of logistics and maintenance processes that could also consider uncertainties, especially in the input data.

Solution: Creating a construction optimization model

Since optimization should always be carried out with as few variables as possible, different areas of tunneling were optimized in different AnyLogic models. The model developers considered city constraints such as:

- noise regulation,
- traffic congestion,
- and environmental compatibility.

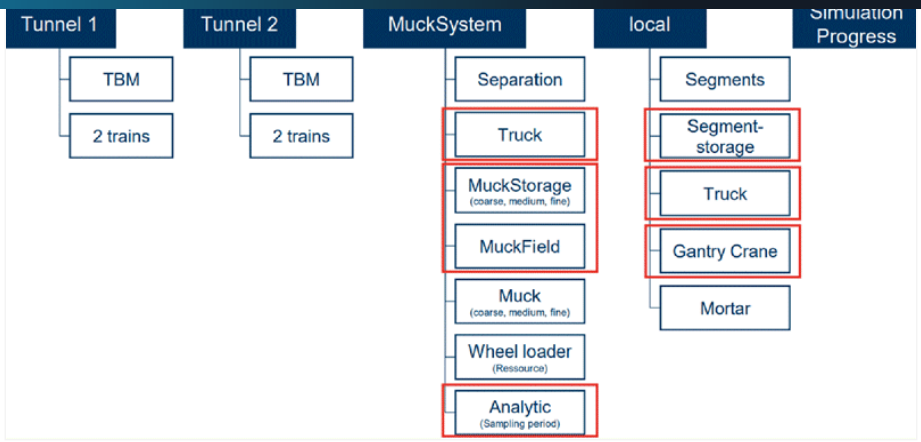
The goal was to decrease the tunnel building area and keep construction time as low as possible. In addition, the research team wanted to understand if process simulation could be employed in earlier planning phases of mechanized tunneling construction projects.

Two key processes, that significantly determine where these areas can be located:

1. The supply of lining segments
2. The disposal of the soil

The model was divided into 4 main agents: 2 tunnels, the soil disposal of the muck system, and the local constructs inside. There was also an agent to track the simulation progress, but this was only for easy evaluation.

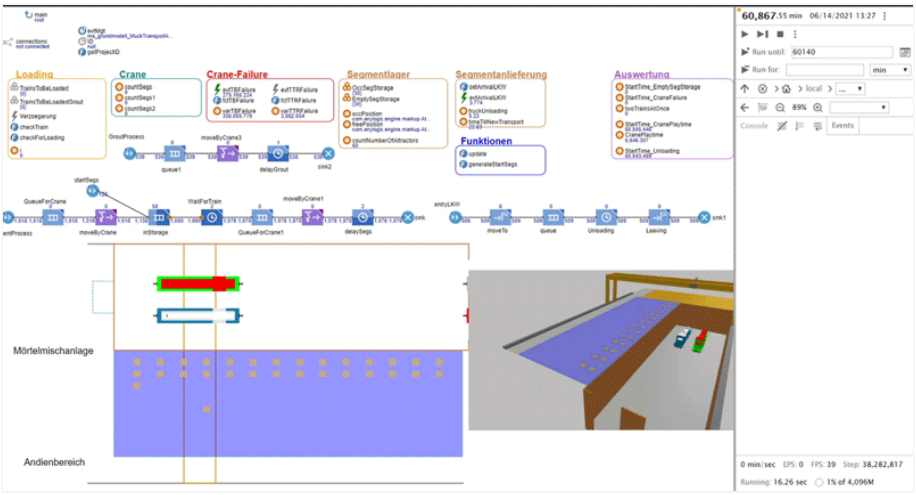
In the model, the team tested different construction optimization scenarios. In this way, it was possible to optimize the logistic processes of mechanized tunneling considering a number of inner-city boundary conditions.



The basic structure of the construction optimization model

The agents marked in red in the picture above were modified slightly for each model variation. AnyLogic simulation software enabled the researchers to model the intrinsic behavior of individual agents and the interaction of different agents. Additionally, in mechanized tunneling, it was necessary to integrate fluid flows.

On top of that, 2D and 3D modeling representation in AnyLogic simplified verification and validation of the model for developers.



time and machine downtime

Based on the analysis of model variations, an optimized model was created which was suitable for inner-city constraints and able to show possible construction time.

In this construction optimization model, the disposal of muck was implemented with trains instead of trucks. The size of the storage was increased minimally. Two histograms of initial and optimized models illustrated below, show the tunnel construction time achieved in a Monte Carlo simulation with a thousand iterations per model.

Tunnel construction time for the initial and optimized models

The top two charts in the diagram below illustrate the results of the initial model. The lefthand chart shows the total tunnelling time, which includes excavating, ring building, and inoperability (downtime). The righthand chart shows the reasons for this downtime, including regular maintenance, equipment failures, and so on. The bottom charts give the same information, but for the optimized model.

Construction time and tunneling machine downtime for the initial and optimized models

Downtime is much less in the optimized model than in the initial model. The total construction time with the initial model was 194 days on average, while the total

a day instead of 103 trucks).

With the help of process simulation for tunnel construction optimization, specialists could already compare different variations of site logistics in the early planning phase. AnyLogic enabled the researchers to consider uncertainties in process simulation when designing the construction processes.

Since the AnyLogic model can be easily modified, action alternatives to varying conditions can be quickly examined. Therefore, it is beneficial to apply process simulation in the execution phase of mechanized tunneling as well.

The case study was presented by Judith Berns, of Ruhr University Bochum, at the AnyLogic Conference 2022.

The slides are available as a PDF.

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