PROCESS AND LOGISTICS SIMULATION IN MECHANIZED TUNNELING

T. RAHM | M. KÖNIG | C. KOCH | K. SADRI | M. THEWES

AnyLogic Conference 2012 December 13th, 2012 Berlin, Germany
Project partner

- Simplan AG, Germany
- Collaborative Research Center 837
  Ruhr-Universität Bochum, Germany

Advisory Board:

- Hochtief Consult, Hochtief Solutions AG
- Herrenknecht AG, Germany
- Ed. Züblin AG
- Zerna Ingenieure
- Company Management Amberg Engineering AG
- Department for Bridge, Tunnel and Urban Rail Office for Transport Mgt., Düsseldorf
- Research Association for Underground Transportation Facilities (STUVA)
Tunneling projects

- **Diameter**
  - normal: 6 – 12 m
  - over 19 m (2 levels of infrastructure)

- **Length**
  - normal: 3 – 20 km
  - up to more than 50 km

Source: Herrenknecht AG, Katzenbergtunnel

Source: Herrenknecht AG, Highway M30 Madrid
Earth pressure balanced shield machine

Herrenknecht AG, Germany

Full length video: http://www.youtube.com/watch?v=qx_EjMILgqY
Process classification in mechanized tunneling

Production processes shield machine
- Advance
- Ringbuild

Support processes supply chain
- Backup system: segments, grout, hydraulics, electronics, etc.
- Tunnel: belt conveyor, rails, cross passages, etc.
- Jobsite installation: separation, concrete plant, storage, etc.
- External logistics: Segment factory deposit, energy, traffic, etc.

unplanned downtime caused by waiting or problemsolving due to: ground conditions, wear, techn. interruptions, organisat. interruptions, lack of capacity, priorities in operation, etc.
Decomposition in simulation components

Production processes shield machine:
- Advance
- Ringbuild

Support processes supply chain:
- Backup system
- Delivery system
- Subsurface jobsite
Decomposition in simulation components

Production processes
- shield machine
  - Advance
- Ringbuild

Support processes
- supply chain
  - Backup system
  - Delivery system
  - Subsurface jobsite
Simulation components for advancement
Multi-method simulation approach for advance

- **Processes:**
  - Discrete-event simulation
- **Material-flow:**
  - System Dynamics
- **Technical disturbances:**
  - Probability distribution
Decomposition in simulation components

Production processes
- shield machine
- Advance
- Ringbuild

Support processes
- supply chain
- Backup system
- Delivery system
- Subsurface jobsite
Simulation component for ringbuild
Simulation component: Erector
Decomposition in simulation components

Production processes
- shield machine
  - Advance
  - Ringbuild

Support processes
- supply chain
  - Backup system
  - Delivery system
  - Subsurface jobsite
Simulation component for supply chain
Simulation model of supply chain

Diagram showing a supply chain simulation with various processes and events such as entry of segments to job site, segment store, train source, go to loading position, output loading, waiting ready to transport, go to gantry crane, gantry crane to loading, train move to backup system, unloading with segment crane, output back to first position, end of tunneling, go back or out of system, repair disturbed train, and output disturbance.
Case study

<table>
<thead>
<tr>
<th>Project parameter</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of tunnel</td>
<td>8000 m</td>
</tr>
<tr>
<td>Diameter machine</td>
<td>10 m</td>
</tr>
<tr>
<td>Length of segment</td>
<td>2 m</td>
</tr>
<tr>
<td>Segments per ring</td>
<td>7 (6+1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Techn. disturbance parameter</th>
<th>Example Main Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>MTBF</td>
<td>50 h</td>
</tr>
<tr>
<td>MTTR</td>
<td>2 h</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>MTBF</td>
<td>150 h</td>
</tr>
<tr>
<td>MTTR</td>
<td>10 h</td>
</tr>
<tr>
<td></td>
<td>Max</td>
</tr>
<tr>
<td>MTBF</td>
<td>450 h</td>
</tr>
<tr>
<td>MTTR</td>
<td>50 h</td>
</tr>
</tbody>
</table>
Input data – soil conditions

- Connection to database

Soil conditions allow a certain speed of excavation (min, max)

- Triangular random distribution to generate a specific value
Simulation results: daily advance rate

- Consideration of alternating soil conditions
- Impact of disturbances

![Graph showing daily advance rate with consideration of alternating soil conditions and impact of disturbances.](image)
Simulation results: analysis of disturbances

Missing resources

Time share of total project

Technical disturbances
Validation with Wehrhahn Linie Düsseldorf

Ruhr-Universität Bochum
Chair of Computing in Engineering
Prof. Dr.-Ing. Markus König
Gebäude IA 6/151, Universitätsstraße 150, D-44780 Bochum
office@inf.bi.rub.de