Status
Data Acquisition in TBM tunneling

Lars Babendererde
TBM operation without any PLC system

No data collection - documentation and quality control via written documents
TBM operators were the source for what happened during tunnel excavations.
Information Transfer in the 90’s
Significant technology jumps since the 90’s

- So did the TBMs!
TBM control today

- Live link to site and other offices worldwide
- Even remote control possible
- Documentation with specialised computer programs
Information Transfer in the 90’s
Information Transfer nowadays

- Site management
- TBM operator
- Client

Sum of information

Time
TBM control today

Increasing use of mobile applications
General setup of modern data monitoring
## Platform Comparison

<table>
<thead>
<tr>
<th>Argument</th>
<th>Local</th>
<th>Web</th>
<th>Mobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customization to project</td>
<td>No technical limits</td>
<td>More difficult, as limited to web browser compatibility</td>
<td>Only limited to device’s operation system and capability</td>
</tr>
<tr>
<td>Ease of external access</td>
<td>No installation required, uses RDP launcher, part of operating system</td>
<td>Access through browser</td>
<td>At hand and anywhere</td>
</tr>
<tr>
<td>Performance</td>
<td>Best performance through LAN on project site</td>
<td>Same performance for every one through Internet</td>
<td>Same performance as other solutions, depending on net quality</td>
</tr>
<tr>
<td>Data volume</td>
<td>High capacity within LAN, independent from access (internal/external)</td>
<td>Data display static, operations with high data volume limited in speed</td>
<td>Data display static, operations with high data volume limited in speed</td>
</tr>
<tr>
<td>Update Control</td>
<td>Full control over back end server and main application</td>
<td>Up-date of web browser by user; control over back-end</td>
<td>Up-date of app by user; full control of back-end</td>
</tr>
<tr>
<td>Application Monitoring</td>
<td>Access for QC and bug handling</td>
<td>Limited to server back end</td>
<td>Feedback by app; bug handling by app up-dates</td>
</tr>
<tr>
<td>Possession of data</td>
<td>On site</td>
<td>Virtual</td>
<td>Virtual</td>
</tr>
<tr>
<td>Server costs after TBM excavation</td>
<td>None to minimal</td>
<td>Continued rent</td>
<td>Continued rent</td>
</tr>
</tbody>
</table>
Data points by TPB type

- Geo-Monitoring: modest application for metro tunnel
Information Flood

Human being incapable of overseeing the information

⇒ Filtering and sorting required by

- Graphical processing for better overview
- Automatic reporting
- Automatic monitoring and alarming based on pre-set levels
- Saving of all data for later back-analysis as required
Project data volume

Assumption: 2000 data points (1 TBM plus modest geotechnical monitoring)

Avg. server size:
600 GB – 1 TB

Cost differences:
approx. USD 1,200

with technical enhancement:
approx. USD 6,000

⇒ Cost difference not relevant!
Main drive damage due to torque peaks

Subway tunnel project

- Bull gear damage due to peak loads from one drive motor
- Discussion between manufacturer and contractor about the overload source: geology/operation or technology/equipment
- Standard 10 sec data sampling showed torque within permissible limit
CASE 1

Main drive damage due to torque peaks

Failure investigation with 10 sec frequency showed one torque peak passing the trigger level at 80%.
Data stream with 1 sec frequency showed a lot more torque peaks than earlier anticipated. The following investigation revealed that the torque limiter was the root cause of the damage. The release mechanism of the clutch lost its pre-stressing over time. \( \Rightarrow \) Would not been detected by 10 sec frequency
Building Information Modelling (BIM)

Data Acquisition and Management Software can support BIM applications in tunnel projects with selected data and information, concerning the final structure.

- Global Position
- Type of ring (concrete, reinforcement, connectors, etc.)
- Volume of excavated material
- Orientation of the ring
- Damages and Repairs
- Grouted volumes behind the ring
BIM Collaboration Formats

The collaboration format defines the level of system integration during design and construction.

<table>
<thead>
<tr>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-BIM</td>
<td>Object-based Modelling</td>
<td>Model-based Cooperation</td>
<td>Network-based integration</td>
</tr>
<tr>
<td>Unmanaged CAD</td>
<td>Managed CAD in 2D or 3D</td>
<td>Managed 3D environment with separate BIM tools (for example Revit)</td>
<td>Open process and data integration</td>
</tr>
<tr>
<td>Paper or pdf exchange and information</td>
<td>Collaboration by providing common data environment and standard data structures and formats</td>
<td>Integration into an single exclusive model, based on the separate BIM tool.</td>
<td>Work within web-based software and in a collaborative model server. Software standards required!</td>
</tr>
</tbody>
</table>

- Level 2 is currently in the implementation in tunneling, but still needs to define THE global BIM tool for implementation. Additionally, the definition for the tunneling processes and objects need to be globally standardized.
- Level 3 would require standards for the collaborating software solutions themselves to permit seamless interaction.
Further challenge for the Data Management and Visualization Software is the implemented Level of Development for tunnels, to be exported into the BIM model.

<table>
<thead>
<tr>
<th>LoD</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Conceptual model where parameters like area, height, volume, location and orientation are defined.</td>
</tr>
<tr>
<td>200</td>
<td>General model where elements are modeled with approximate quantities, size, shape, location and orientation. Non-geometric information can be attached to the model elements.</td>
</tr>
<tr>
<td>300</td>
<td>Accurate modeling and shop drawings where elements are defined with specific assemblies, precise quantity, size, shape, location and orientation. Here too, non-geometric information can be attached to the model elements.</td>
</tr>
<tr>
<td>350</td>
<td>It includes model detail and element that represent how building elements interface with various systems and other building elements with graphics and written definitions.</td>
</tr>
<tr>
<td>400</td>
<td>Model elements are modelled as specific assemblies, with complete fabrication, assembly, and detailing information in addition to precise quantity, size, shape, location and orientation. Non-geometric information to the model elements can also be attached.</td>
</tr>
<tr>
<td>500</td>
<td>Elements are modeled as constructed assemblies for maintenance and operations. In addition to actual and accurate in size, shape, location, quantity, and orientation, non-geometric information is attached to modeled elements.</td>
</tr>
</tbody>
</table>

Source: NBIMS-US
LoD 300: The amount of data to be computed and to be transferred into BIM system could be quite substantial, though with limited variation in information.
LoD 200: With a reduction of one level down the amount of data could be substantially reduced w/o substantial lack of knowledge.
Building Information Modelling (BIM)

**BIM in the US: NBIMS-US**

**International Tunnelling Association ITA Working Group 22**

Animateur: Juri Karlovsek  
University of Queensland  
St. Lucia, Australia  

Vice Animateur: Paolo Cucino  
SWS Engineering S.p.A.  
Trento, Italy
Summary

- TBM data acquisition is continually improving as the technology permits more possibilities
- Remote live access to thousands of data points is possible
- Adequate software support is necessary to manage the flood of information
- High data rates and many data points are recommended for optional back analysis. The related costs for hardware are negligible.
- Data Management and Visualisation Systems can play a significant role as data source as well for future BIM projects.
Thank you for your attention!