BIM in Infrastructure

International Standards

Prof. Dr.-Ing. André Borrmann
Chair of Computational Modeling and Simulation
Leonhard Obermeyer Center
Technical University of Munich
Leonhard Obermeyer Center
TUM Center of Digital Methods for the Built Environment

- 5 TUM groups
  - Architectural Informatics, Prof. Petzold
  - Geographic Information System, Prof. Kolbe
  - Numerical Simulation, Prof. Rank
  - Photogrammetry, Prof. Stilla
  - BIM, Prof. Borrmann

- joint research:
  - digital methods on different scales

- > 60 researchers

- intense collaboration with
  - construction industry, software industry
  - and governmental organisations
BIM in Germany

BIM Roadmap

- Announced by the Minister of Transport in December 2015
- Mandatory usage of BIM methods in public infrastructure projects starting 2020
German BIM Roadmap

Stepwise Introduction of BIM

Phase 1
- Pilot projects
- Standardization
- Education
- BIM Guidelines
- Legal aspects

Phase 2
- Continuous gathering of experiences
- More pilot projects
- Update of guidelines, legal regulations

Phase 3
- Broad implementation
- BIM is standard

1st phase
- Preparation Phase
  - 2015 – 2017

2nd phase
- Extended Pilot Phase (Niveau 1)
  - 2017 – 2020

3rd phase
- BIM Niveau 1 mandatory for all new projects
  - from 2020
BIM Niveau 1

Most important characteristics

- Model-based working practices
- Integration of BIM methods into conventional procedures → minor changes in laws and regulations
- Employer’s Information Requirements
- BIM Execution Plan
- Common Data Environment: according to ISO 19650
- Data Drops for handover to client
- Usage of open, vendor-neutral data formats (IFC, OKSTRA, GAEB, etc.)
BIM in Infrastructure

Conceptual Design
- Corridor finding
- Comparison of alternatives
- Preliminary Design
- Demolition
- Recycling
- Retrofitting

Detailed Design
- Coordination
- Cost estimation
- Simulations
- Drawings generation
- Tendering
- Prefabrication
- Process simulation
- Logistics
- Progress Monitoring
- Controlling

Construction

Modification

Operation
- Inspection, Maintenance, Repair
Integration of BIM and GIS

**Conceptual Design**
- GIS → Corridor finding
- GIS → Comparison of alternatives
- GIS → Preliminary Design

**Detailed Design**
- Coordination
- Cost estimation
- Simulations
- Drawings generation
- Tendering

**Construction**
- Prefabrication
- Process simulation
- Logistics
- Progress Monitoring
- Controlling

**Operation**
- GIS → Inspection, Maintenance, Repair

**Modification**
- GIS → Demolition
- GIS → Recycling
- GIS → Retrofitting

**GIS**

© André Borrmann, 2017
Digitization in Infrastructure Construction

The digital tool chain

Geo Information
GIS-System
2.5D

Roadway Design
Roadway Design Tool
2.5D → 3D

Engineering Structures
BIM Tool
3D

InfraGML
IFC-Alignment

© André Borrmann, 2017
BIM Pilot Projects

Scientific Analysis

BIM-Pilotprojekt Brücke Petersdorfer See

BIM-Pilotprojekt Südverbund Chemnitz

BIM-Pilotprojekt Eisenbahnüberführung Filstal

BIM-Pilotprojekt Rastatter Tunnel
BIM Pilot Projects

Auenbach Bridge – Southern Link Chemnitz

- New bridge in a 4-strip federal roadway, crossing a river and a railway
- Early planning phase (conceptual design)
- Investigation of different design options
  - BIM-based cost estimation
  - Preferred option: 2 bridges and dam
- Fast and accurate cost estimation
- Communication with the public

© Obermeyer Planen + Beraten
Federal Roadway B87, near Leipzig

- Terrain
- City
- Subsoil
- GIS
- Pipelines and cables
- Roadway
- Railway
- Eng. Constructions
- Emissions
- Environment
- Traffic
- Pipelines and cables
Implementation of Phase 2 of the BIM Roadmap

ARGE BIM4INFRA

- Detailed Definition of BIM 2020 scenario
- Support of 25 new pilot projects
- In-depth legal analysis
- Guidelines, templates, recommendations for public authorities
- Data base concept: BIM cloud
- Model checking concept
Implementation of the BIM Roadmap

BIM 2020 scenario: BIM uses cases

1. Initial State Modeling
2. Design option analysis
3. Visualization
4. Coordination
5. Simulation and dimensioning
6. Design Progress Control
7. Drawing Generation: Preliminary Design
8. Safety Design
9. Release Management
10. Cost estimation
11. Bill of quantities / Tendering
12. Drawing Generation: Detailed Design
13. 4D Execution Planning
14. Logistics planning
15. Progress Monitoring
16. Billing
17. Change Management
18. Issue Management
19. As-built documentation
20. Operation and Maintenance
Use case 3: Visualisation

| Description       | ▪ Creation of visualisations from the model (images, movies)  
|                   | ▪ Support of public relations  
|                   | ▪ Support of project meetings |
| Effort            | ▪ Depends on quality of visualization  
|                   | ▪ Low to medium extra effort |
| Benefit           | ▪ Higher transparency for the public  
|                   | ▪ Support for decision making process |
# Use case 5: Coordination of design disciplines

<table>
<thead>
<tr>
<th>Description</th>
<th>Combine discipline models into a coordination model in regular intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Systematic conflict resolution</td>
</tr>
<tr>
<td>Effort</td>
<td>Establishment of processes and protocols for conflict resolution</td>
</tr>
<tr>
<td>Benefit</td>
<td>Early identification of conflicts</td>
</tr>
<tr>
<td></td>
<td>Early conflict resolution</td>
</tr>
<tr>
<td></td>
<td>Improved design quality</td>
</tr>
<tr>
<td></td>
<td>Reduced costs in construction phase</td>
</tr>
</tbody>
</table>
# Use case 10: Cost Estimation

<table>
<thead>
<tr>
<th>Description</th>
<th>Effort</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model-based Quantity Take-Off</td>
<td>Significant reduction of effort compared to manual quantity take-off</td>
<td>Correctness and transparency of the quantities is improved</td>
</tr>
<tr>
<td>Association with cost groups from standard catalogues</td>
<td>Introduction of software products required</td>
<td>Reduction of cost risks</td>
</tr>
</tbody>
</table>

www.rib-software.com
BIM Pilot Project in Bavaria

Highway A99: Bridge BW27/1

- BIM Pilot Project of the Bavarian Highway Administration
- Widening of Highway A99
- Replacement of Bridge BW27-1
- Separated tendering for
  - conceptual design
  - detailed design
  - construction
BIM Project Execution

**Conceptual Design**

- **EIR** (Client) → Tendering → **BEP** (Bidder) → Award → **BEP** (Contractor) → Design → Models (Contractor)

**Detailed Design**

- **EIR** (Client) → Tendering → **BEP** (Bidder) → Award → **BEP** (Contractor) → Design → Models (Contractor)

**Construction**

- **EIR** (Client) → Tendering → **BEP** (Bidder) → Award → **BEP** (Contractor) → Construction → Models (Contractor)
Employer’s Information Requirements
Highway A99: Bridge 27/1

Auftraggeberinformationsanforderungen

der Autobahndirektion Südbayern

für das BIM-Pilotvorhaben
8-streifiger Ausbau A 99 - Bauwerk 27/1

Ausführungsplanung
Employer’s Information Requirements

Contents

- BIM Goals:
  higher quality, more transparency, less cost risks

- BIM Use cases:
  visualization, coordination, quantity take-off, etc.

- Extent of the model

- Level of Development
  - Level of Geometry
  - Level of Information

- Classification System:
  Uniclass, ASB-ING, DIN276

- Coordination System (Gauß-Krüger, UTM, …)
  incl. project’s point of origin
## Employer’s Information Requirements

### Model Element Table

<table>
<thead>
<tr>
<th>Bauteiltyp</th>
<th>Kategorie</th>
<th>LOD</th>
<th>Attributierung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappen</td>
<td>Hauptbauteil</td>
<td>400</td>
<td>Betongüte, Bewehrungsgrad, Betonstahl, Expositionsklassen</td>
</tr>
<tr>
<td>Fahrbahnbetrag</td>
<td>Nebenbauteil</td>
<td>200</td>
<td>Schichtenaufbau</td>
</tr>
<tr>
<td>Ortbetonergänzung (Überbau)</td>
<td>Hauptbauteil</td>
<td>400</td>
<td>Betongüte, Bewehrungsgrad, Betonstahl, Expositionsklassen</td>
</tr>
</tbody>
</table>
| Fertigteile (Überbau)    | Hauptbauteil       | 400 | Betongüte, Bewehrungsgrad, Betonstahl, Expositionsklassen,
|                          |                    |     | Oberflächenrauhigkeit, Angaben zu Spanngliedern                               |
| Widerlager               | Hauptbauteil       | 400 | Betongüte, Bewehrungsgrad, Betonstahl, Expositionsklassen                     |
| Bohrpfähle               | Hauptbauteil       | 400 | Betongüte, Bewehrungsgrad, Betonstahl, Expositionsklassen,
|                          |                    |     | Betonzugfestigkeit (Rissbreite)                                              |
| Fundamente (Bestand)     | Hauptbauteil       | 400 | Betongüte, Bewehrungsgrad, Betonstahl, Expositionsklassen                     |
| Lärmschutzwand          | Ausstattungselement| 200 | Typ                                                                           |
| Fugen                    | Ausstattungselement| 200 | Typ, Richtzeichnung                                                           |
| Entwässerung             | Ausstattungselement| 200 | Typ, Richtzeichnung                                                           |
| Geländer                 | Ausstattungselement| 200 | Typ                                                                           |
## LODs

### Railings

<table>
<thead>
<tr>
<th>LoG</th>
<th>Beschreibung</th>
<th>Darstellung</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>- Äußere Abmessungen des Geländers (Platzhalter)</td>
<td><img src="image1" alt="Abbildung 3.12: LoG 200 Geländer" /></td>
</tr>
<tr>
<td>300</td>
<td>- Einzelne Bestandteile des Geländers (Pfosten, Handlauf, Holm) &lt;br&gt; - Exakte Höhe der Pfosten &lt;br&gt; - Fußplatte als Volumenkörper mit ungefähren Maßen</td>
<td><img src="image2" alt="Abbildung 3.13: LoG 300 Geländer" /></td>
</tr>
<tr>
<td>400</td>
<td>- Exakter Abstand der Pfosten &lt;br&gt; - Fußplatte mit exakten Maßen inklusive symbolischer Darstellung der Befestigungsobjekte &lt;br&gt; - Fuge zwischen Fußplatte und Kappe &lt;br&gt; - Darstellung der Erdung sowie der Montage- und Bewegungsfugen des Geländers als Platzhalter</td>
<td><img src="image3" alt="Abbildung 3.14: LoG 400 Geländer" /></td>
</tr>
</tbody>
</table>
A99: Conceptual Design
A99: GIS for Environment Analysis

© Prof Schaller UmweltConsult GmbH
A99: Conceptual Design

Model Checking
A99: Detailed Design
Model Checking: Consistency of Models and Drawings
Standards
Vendor-neutral Data Exchange Standards

Why?

- fair competition between software vendors
- public authorities must not demand products of one specific vendor
- competition results in better products & better prices
- many success stories: HTML, XML, SQL, USB, ISO 216: paper sizes
- important: purpose of data exchange
  - Data handover to the client
  - Coordination of disciplines
  - Model handover to following design phase
    (reference vs. modifiable)
Industry Foundation Classes
Vendor-Neutral Data Exchange Standard
Open Geospatial Consortium (OGC)

Vendor-Neutral Data Exchange Standard
buildingSMART Infra Room

- IFC5: Extensions for Infrastructure
- Roadways and Railways incl. bridges, tunnels, retaining walls
- harmonized with GIS standards → strong collaboration with OGC
OGC & buildingSMART: Joint Developments

- Memorandum of Understanding
- Joint conceptual schema (UML)
  - Alignment
  - Linear positioning
  - Terrain
  - StringLine Representation
  - Surface Representation
  - Cross Sections
- Implementation in EXPRESS / GML
- Harmonized development allows for easy conversion
Alignment standardization approach

Combine traditional 2D and new 3D approach

- Horizontal alignment

- Vertical alignment

- Cross-section profile

→ established method
→ reduction of design complexity
IFC-Alignment

- based on the conceptional model
- introduces alignment elements
- linear positioning
- geodetic coordinate systems
- IFC 4.1 contains alignment → published in February 2017
IFC-Alignment Deployment

- Autodesk Civil3D
- Bentley Road MX
- Dassault CATIA
- Nemetschek Allplan
- Vianova
- CARD/1
- Obermeyer ProVi
- uvm.
OGC InfraGML

- LandXML was not adopted as OGC standard
- OGC standard with similar functionalities has been defined
- InfraGML: released in June 2017
- same conceptual model as IFC-Infrastructure
OGC InfraGML
TUM Open Infra Plattform

www.oip.cms.tum.de
IFC-Infrastructure

Alignment & Overall Architecture

Common resources

Roadway Design
IFC-Road

Railway Design
IFC-Railway

Bridge Design
IFC-Bridge

Tunnel Design
IFC-Tunnel
IFC-Bridge

- **International standardization project**
- **started** in February 2017
- **involvement of**
  - France
  - USA
  - Germany
  - Nordic Countries
  - China
- completed by end of 2018
Example Bridges

- Railing
- Bridge Cap
- Deck
- Carriageway
- Part of IfcRoad
- Safety guard
- Slab
- Girder

Diagram:

- IfcRelContainedInSpatialStructure
  - IfcFacilityPart
    - PredefinedType = Superstructure
  - IfcRailing
  - IfcElementAssembly
    - ObjectType = "Deck"
  - IfcBeam
  - IfcSlab
  - IfcSlab?
IFC-Road

- international standardization has started in November 2017
- Lead: Finland, Korea
- very comprehensive proposal from Korea
Conclusion

- BIM for infrastructure enables efficiency gains
- selection of BIM use cases plays an important role
- integration of BIM and GIS technology is required to unlock the full potential of digitalization in infrastructure construction
- well-defined standards are required for lossless data exchange
- standardization activities on international level