Bridge Model Standards for Digital Delivery

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Constructivity
Project Background

• Commissioned by U.S. Federal Highway Administration
• Performed by National Institute of Building Sciences (NIBS)
  • U.S. Chapter of buildingSmart International
  • Publisher of U.S. National BIM Standard
• Evaluate existing information standards for bridge models and propose solution
• Leverage existing investments by software vendors and standards developers
• Obtain input from stakeholders – owners, engineers, vendors
• Develop strategies for quickest path of industry adoption
What are we trying to solve?

• Improve efficiencies in planning, designing, bidding, constructing, and maintaining bridges
• Add value by creating new capabilities for managing bridge information across project lifecycle
• Reduce errors by leveraging automated checking of digital models
• Adopt standard digital formats that can be contractually binding
What are we NOT trying to solve?

• Standardize design file formats
  • Focused on resulting plan/spec that gets exchanged, not design workflow
• Change software used
  • Minimize updates needed by existing software
• Change business processes
  • Same as before, but more efficient
Why use standardized and open formats?

• Enable project team to make downstream use of data
• Help ensure data is available to owner in format usable for lifetime of facility
• Separate data from software
• If a format is documented, it can be incorporated into contracts

• Alternative:
  • Must document specific software used, specific version, specific steps taken to obtain information
  • Must document differences between information that is missing, wrong, or at insufficient level of precision in potentially thousands of places. E.g. “User entered 0”, “User didn’t specify”, “Software defaulted to 0” can have significant implications.
Approach

• Evaluate existing bridge data schemas
  • Effective evaluation of data schemas requires creating real data
  • Model existing bridge in 100% detail (everything included in plans)
    • Using a reference bridge provides a tangible baseline for determining what is required and what isn’t
    • Pareto Principal applies: last 20% of detail takes 80% of the time
    • More bridges would be better, though capturing everything in a single bridge ensures no detail is overlooked, by choice or by accident
  • Based on modeling, minimal extensions are proposed for schemas

• Identify and evaluate bridge information exchanges
  • Focus on highest value exchanges first – Design Plans for Bidding

• Goal is fastest adoption in industry, with minimal additional effort
How will we validate proposed solutions?

- Develop models for existing bridge projects in **full detail**
  - For every detail shown on plans, it must exist in digital model
- First test case: steel overpass on Pennsylvania Turnpike
  Curved alignment, 3 spans, steel girders, concrete piers & abutments
- Use existing tools, make enhancements to support generating data
- Generate files in each format, documenting what’s missing
- Attempt to round-trip files between independent platforms
- Publish report for industry review
Sample Bridge: Pennsylvania Turnpike

- Alignment uses circular horizontal curve and straight vertical incline
- Steel girders, cross-framing, stiffeners
- Reinforced concrete piers and abutments
- Plans: 69 Pages
Alignment

Extensions needed

**IFC**: Alignment Positioning ("P6" extension project underway)

**OpenBrIM**: Need updated XSD that incorporates alignment definitions within schema
Extensions needed

**IFC:** sectioned spine based on vertical alignment curve

**OpenBrIM:** Tapered sweeps, profiles that vary along sweep
Girders

Extensions needed

**IFC**: profile sweeping along vertical curves with offset

**OpenBrIM**: Girder sizes that vary along alignment, connectivity
Extensions needed

**IFC**: None

**OpenBrIM**: Arcs for extrusion, connectivity for construction joints, drainage piping, rebar and pile embedding, textures
Abutments

Extensions needed
IFC: None

OpenBrIM: Tapered extrusions, textures for architectural detailing, connectivity for construction joints, networks for pipes and conduit, rebar and pile embedding
Terrain, Soil Borings

• IFC:
Structural Loads and Reactions

• Structural reactions included in plans to indicate allowable construction loads

• Reactions paired with load combinations to capture assumptions

• Structural model derived from members and connections
Information Exchanges

• Hundreds of exchanges between parties and within organizations

• Can’t solve everything; focus on highest opportunities for success

• DOTs in position to provide, but not require data – industry feedback critical before imposing requirements.

• Initial focus: plans for bid – prerequisite for anything else that references bridge data in detail
Design Plans Exchange: Highlights

• Geometry for all components: structures, drainage, grading, finishes
• Parameters for standard layout information
• Materials and composition within components, e.g. rebar
• Representations for fabrication input, e.g. camber
• Connectivity between components, e.g. construction joints, plates
• Structural load cases and results at members (for construction)
• Soil test borings and material properties at each layer
• Quantities related to components
Concepts

• Concepts evaluated: Geometry, Parameters, Relationships, Extensibility

• In evaluating various approaches, a notion of “levels” is used for comparison; higher levels mean more complete information
  • The numbers used for levels are used as a tool for analysis and are not based on any authoritative reference

• Specific use cases require information at a particular level for particular concepts, such that data must meet or exceed such level
  • Example: Visualization of bridge models only requires Geometry at Level 1 or higher, quantity takeoff and structural analysis require Geometry at Level 2 or higher, while fabrication requires Geometry at Level 3 or higher for most structures.
Review of related information models

**Data Schemas:**
- IFC
- LandXML
- OpenBRIM
- Bentley iModel
- AASHTOWARE

**Data Formats**
- XML : XSD
- STEP : EXPRESS
- JSON : Java
- HDF5 : SQL DDL
- DCOM : IDL

*A data schema describes the structure of data, which can be encoded in any format. Each schema is commonly published in one or more data formats (green arrows)*
Industry Foundation Class (IFC)

• Scope: Describes buildings, recently extended into infrastructure
• Geometry: NURBS, CSG, extruded, B-Rep, tessellated
• Parameters: constraint model separate from values
• Relations: composition, template, assignment, connectivity
• Size: ~800 explicit classes with various dynamic extensions
• Documentation: www.buildingsmart-tech.org
• History: Autodesk created in 1995, now international org, ISO 16739
• Usage: ~160 apps listed, including Autodesk, Bentley, Trimble
LandXML

- **Scope:** Describes land topography and infrastructure
- **Geometry:** extruded polylines, tessellation
- **Parameters:** N/A
- **Relations:** composition, connectivity
- **Size:** ~200 data types
- **Documentation:** N/A previously, but recently documented at OGC
- **History:** Created in 1999 by Autodesk and DOT members
- **Usage:** ~14 apps listed, including Autodesk, Bentley
OpenBrIM

• **Scope:** Describes parameters for bridges, but not resulting detail
• **Geometry:** extruded polylines, B-Rep
• **Parameters:** any attribute may use formula
• **Relations:** composition, template
• **Size:** ~10 generic classes relying primarily on dynamic extensions
• **Documentation:** N/A
• **History:** FHWA funded effort in 2013
• **Usage:** 1 app - Red Software
Bentley iModel

• Scope: Describes parameters for bridges, but not resulting detail
• Geometry: N/A (included in Microstation DGN, not iModel)
• Parameters: Parameters defined but not formulas or results
• Relations: N/A (No way to traverse from detailed model back)
• Size: ~20 primary data sets
• Documentation: to be published in 2016 (according to Bentley rep)
• History: to be published in 2016 with upcoming OpenBridge app
• Usage: LEAP Bridge app generates Microstation DGN (one-way)
# Schema Comparison Summary

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<th>IFC</th>
<th>LandXML</th>
<th>OpenBrIM</th>
<th>iModel</th>
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<table>
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<tr>
<th>File Size for Sample Bridge</th>
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<th>LandXML</th>
<th>OpenBrIM</th>
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Report

• Report describing data models published for industry review
• Backing bridge data files and detailed schema analysis also provided

• Volume A: Information exchanges and requirements
• Volume B: Evaluation of schemas and required extensions
• Volume C: Detailed components applied to sample bridge model
Preliminary Conclusions

• OpenBrIM and Bentley iModel are well suited for defining overall design parameters, but would need additions to capture detailed design, connectivity relationships, structural loading, and relating parameters to detailed design components and back

• OpenBrIM simplicity may be easier for industry newcomers

• Industry Foundation Class (IFC) is well suited for detailed design, but would need documented extensions for design parameters

• IFC has largest industry support (160+ apps), full documentation, and backing organizations in all major countries
What’s next for this project?

• Review proposed extensions with software vendors
• Harmonize proposed extensions with international efforts
• Develop specification for software standard (model view definition)
• Promote in industry at conferences and webinars

• Possible future efforts: model additional information exchanges, model additional bridges, develop validation tests for software
How will we know if this effort is successful?

• Milestone 1: DOT agencies make plans/specs available in proposed digital formats for “informational purposes”, not contractually binding
  • Prerequisites: Specification available, Software vendors implement

• Milestone 2: Contractors make use of digital formats and become confident in relying upon information

• Milestone 3: Digital formats become contractually binding
Questions

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