From BIM to BrIM: Plus, Minus, Delta

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Department of Civil, Structural and Environmental Engineering
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NIBS/TRB Workshop January 2014
Vision:
Bridge Delivery that is
• better,
• faster, &
• more economical
based on public-domain software-neutral integrated parametric data modeling protocols that could be used to automate bridge information exchange through the lifecycle by facilitating communication (interoperability) among various stakeholders in the still-all-too-fragmented bridge industry.
Paradigm Shifting

Digital modeling mania upends the entire building team
ROI in Bridge – Related Industries

Benefits:

- **Tangible Benefits:**
  - Faster project delivery
  - Cost savings

- **Intangible Benefits:**
  - Process and work-flow re-engineering
  - Supply-chain integration
  - Risk management and claims mitigation

- **Quasi-tangible Benefits:**
  - Improved data availability
  - Complete audit trail
  - Reduced data entry and improved information management
  - Reduced rework
  - Improved timely design and construction decision making
  - Improved quality of construction
BIM Appeal (& Limitations) for BrIM

- Benefits
- Steel √, Concrete √
- But bridges are not buildings (e.g.):
  - Architect(ure) → Travelway
  - Vertical → Horizontal
  - Commercial etc → Heavy Const’n
- Etc
- Related schemas...
## Overview of Data Schemas

### Overview of Data Schemas: Bridge

<table>
<thead>
<tr>
<th>Category</th>
<th>Schema Name</th>
<th>Content</th>
<th>Developer/Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge</td>
<td>IFC-Bridge Data Model</td>
<td>An data model which extends IFC to capture information related to the whole bridge life cycle.</td>
<td>buildingSMART French Chapter, German Chapter, Japanese Chapter</td>
</tr>
<tr>
<td>Bridge</td>
<td>Steel Bridge Construction Data Model (SBCDM)</td>
<td>An data model which extends TransXML for steel bridge construction and fabrication.</td>
<td>Dr. Kannan Nagarajan</td>
</tr>
<tr>
<td>Bridge</td>
<td>AASHTO Virtis/Opis Data Structure</td>
<td>A standard data structure for bridge design and load rating, which describes superstructure of common types of girder bridges.</td>
<td>American Association of State Highway and Transportation Officials (AASHTO)</td>
</tr>
<tr>
<td>Bridge</td>
<td>AASHTO Pontis Data Structure</td>
<td>A standard data structure for bridge inspection, operation and maintenance. It includes all current National Bridge Inventory items, element quantities (optionally by structure unit), and historical condition information.</td>
<td>American Association of State Highway and Transportation Officials (AASHTO)</td>
</tr>
<tr>
<td>Bridge</td>
<td>NCHRP 20-7/Task 149, SteelBridge XML Data Model</td>
<td>A data model which extends the AASHTO Virtis/Opis Data Structure for steel bridge fabrication and construction.</td>
<td>National Cooperative Highway Research Program (NCHRP)</td>
</tr>
</tbody>
</table>
Overview of Data Schemas, cont’d

Overview of Data Schemas: Transportation

<table>
<thead>
<tr>
<th>Category</th>
<th>Schema Name</th>
<th>Content</th>
<th>Developer/Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>Highway Performance Monitoring System (HPMS)</td>
<td>A standard reporting format for highway performance information.</td>
<td>Federal Highway Administration (FHWA)</td>
</tr>
<tr>
<td>Transportation</td>
<td>National Transportation Communication for ITS Protocol (NTCIP) Standards</td>
<td>A family of communications standards for message and data transfer between ITS control devices.</td>
<td>AASHTO/ITE/NEMA</td>
</tr>
<tr>
<td>Transportation</td>
<td>SAE Advanced Travelers Information Systems (ATIS) Standards</td>
<td>An eXtensible Markup Language vocabulary for traveler information exchange.</td>
<td>Society of Automotive Engineers (SAE)</td>
</tr>
<tr>
<td>Transportation</td>
<td>Traffic Model Markup Language (TMML)</td>
<td>A data language to share data among traffic modeling software applications.</td>
<td>University of Florida Transportation Research Center</td>
</tr>
<tr>
<td>Transportation</td>
<td>Traffic Management Data Dictionary (TMDD)</td>
<td>A data dictionary for traffic management Center-to-Center communications.</td>
<td>AASHTO/ITE</td>
</tr>
</tbody>
</table>
### Overview of Data Schemas: Building

<table>
<thead>
<tr>
<th>Category</th>
<th>Schema Name</th>
<th>Content</th>
<th>Developer/Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>Industry Foundation Classes (IFC)</td>
<td>A complete and fully stable open and international standard for exchanging BIM data.</td>
<td>buildingSMART</td>
</tr>
<tr>
<td>Building</td>
<td>CIMsteel Integration Standard (CIS/2)</td>
<td>Standard for steel construction data exchange across CAD and analysis programs.</td>
<td>American Institute of Steel Construction (AISC)</td>
</tr>
<tr>
<td>Building</td>
<td>Construction Operations Building Information Exchange (COBie)</td>
<td>A standard denotes how information may be captured during design and construction and provided to facility operators.</td>
<td>U.S. Army Corps of Engineers Engineer Research and Development Center</td>
</tr>
<tr>
<td>Building</td>
<td>Integrated Structural Modeling (ISM)</td>
<td>A technology for sharing structural engineering project information among structural modeling, analysis, design, drafting and detailing applications.</td>
<td>Bentley Systems, Inc.</td>
</tr>
<tr>
<td>Building</td>
<td>BIM Collaboration Format (BCF)</td>
<td>An open standard to enable workflow communication between different BIM software tools.</td>
<td>buildingSMART</td>
</tr>
</tbody>
</table>
# Overview of Data Schemas, cont’d

## Overview of Data Schemas: Geospatial

<table>
<thead>
<tr>
<th>Category</th>
<th>Schema Name</th>
<th>Content</th>
<th>Developer/Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geospatial</td>
<td>LandXML</td>
<td>An XML schema designed for exchange of civil design information, including raw and reduced surveying data, surface data, parcel data and 3D road model.</td>
<td>Industry Consortium of Partners</td>
</tr>
<tr>
<td>Geospatial</td>
<td>Geography Markup Language (GML)</td>
<td>An XML schema for encoding both spatial and nonspatial geographic information.</td>
<td>Open Geospatial Consortium (OGC)</td>
</tr>
<tr>
<td>Geospatial</td>
<td>OpenGIS</td>
<td>An open set of common, language-independent abstractions for describing, managing, rendering, and manipulating geometric and geographic objects within an application programming environment.</td>
<td>Open Geospatial Consortium (OGC)</td>
</tr>
<tr>
<td>Geospatial</td>
<td>CityGML</td>
<td>It is a common information model and XML-based encoding for the representation, storage, and exchange of virtual 3D city and landscape models.</td>
<td>Open Geospatial Consortium (OGC)</td>
</tr>
</tbody>
</table>
Overview of Data Schemas, cont’d

Overview of Data Schemas: Geotechnical

<table>
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<tr>
<th>Category</th>
<th>Schema Name</th>
<th>Content</th>
<th>Developer/Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geotech</td>
<td>Geotech-XML</td>
<td>The Geotechnical Engineering application of the new Web language, XML.</td>
<td>The World Wide Web of Geotechnical Engineers (W3G)</td>
</tr>
</tbody>
</table>
Overview of Data Schemas: Safety

<table>
<thead>
<tr>
<th>Category</th>
<th>Schema Name</th>
<th>Content</th>
<th>Developer/Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Transportation Safety Information Management System (TSIMS)</td>
<td>A proposed AASHTO system to develop a uniform approach to management of traffic safety information.</td>
<td>AASHTO/FHWA</td>
</tr>
<tr>
<td>Safety</td>
<td>Crash Records Markup Language (CRML)</td>
<td>XML tags for crash records information.</td>
<td>University of Florida Transportation Research Center</td>
</tr>
<tr>
<td>Safety</td>
<td>Federal Motor Carrier Safety Administration (FMCSA)</td>
<td>A standard data format for query central, the Motor Carrier Profile report, etc.</td>
<td>FMCSA</td>
</tr>
<tr>
<td>Safety</td>
<td>FARS</td>
<td>National fatal accident reporting system - coding manual published with all data elements</td>
<td>NHTSA</td>
</tr>
<tr>
<td>Safety</td>
<td>FRA</td>
<td>Standard reporting data formats for railroad accidents/incidents.</td>
<td>FRA</td>
</tr>
</tbody>
</table>
## Overview of Data Schemas, cont’d

### Overview of Data Schemas: Other

<table>
<thead>
<tr>
<th>Category</th>
<th>Schema Name</th>
<th>Content</th>
<th>Developer/Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>BLIS-XML</td>
<td>A methodology for encoding EXPRESS based info in XML format</td>
<td>Secom Co. Ltd</td>
</tr>
<tr>
<td>Other</td>
<td>NCHRP 20-57</td>
<td>Analytical Tools for Asset Management</td>
<td>NCHRP</td>
</tr>
<tr>
<td>Other</td>
<td>Logistics XML</td>
<td>XML standard for e-commerce activities of shippers and carriers.</td>
<td>Open Application Group (OAGi)</td>
</tr>
<tr>
<td>Other</td>
<td>RecML</td>
<td>An XML specification that defines terms for recreation areas, facilities, activities, alerts, events, and similar recreation elements.</td>
<td>Recreation One-Stop Initiative</td>
</tr>
<tr>
<td>Other</td>
<td>ISO/IEC 15962</td>
<td>The data protocol used to exchange information in a radio-frequency identification (RFID) system for item management.</td>
<td>ISO</td>
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<tr>
<td>Process Map</td>
<td>NYSDOT</td>
<td>TxDOT</td>
<td></td>
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<tr>
<td>-------------</td>
<td>--------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td><strong>Initiation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[A.I/PAL] Bridge Planning</td>
<td>Initiation</td>
<td>Section 2.1.5, PDM</td>
<td>1000 Identify Project Need and Scope</td>
</tr>
<tr>
<td>[A.I/E] Conceptual Estimate</td>
<td></td>
<td>Section 21.6.1.1, HDM</td>
<td>1010 Perform Site Visit</td>
</tr>
<tr>
<td><strong>Scoping</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[A.S/SE] Structural Type, Size and Location Design</td>
<td>Scoping</td>
<td>Section 2.2, PDM Chapter 3, PDM Section 19.1.1, BM</td>
<td>Study Requirements Determination</td>
</tr>
<tr>
<td>[A.S/E] Preliminary Estimate</td>
<td></td>
<td>Section 3.2.2.2, PDM Section 21.6.1.2, HDM</td>
<td>1400 Review Scope, Cost and Staff Requirements of Project Development</td>
</tr>
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</table>
IDM/MVD Methodologies (e.g. PCI’s)

<table>
<thead>
<tr>
<th>Preliminary Project Description 31-20-10-00</th>
<th>Design Development 31-20-20-00</th>
<th>Construction Documentation 31-25-00-00</th>
<th>Procurement 31-30-00-00</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architecture (33-21-11-00)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exchange</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering (33-21 31 00)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Selected Development in Related Fields

Varying Degrees of mutual interest (!)

- Infrastructure (e.g., IFC-Infra, buildingSMART) ∩ Geospatial (e.g., OGS)
- Steel structures (e.g., AISC, FIATECH & ISO 15926)
- Concrete structures (e.g., ACI for cast-in-place, PCI for precast/prestressed, PTI for post-tensioned, nuclear for their audit trail requirements)
- Geotech (e.g., gINT, DIGGS)
- AASHTO (e.g., TCEED, transXML/NCHRP 20-94, NCHRP 20-83(03), etc)
- Manufacturing (e.g., NIST initiatives, etc)
- Electric Power Plants (e.g., EPRI, etc)
- Emerging Technology Law (e.g., AIA and ConsensusDocs BIM Addenda 2008 NCHRP2013)
- Application software consortia (existing or perhaps yet to be constituted)
- buildingSMART for IFC (Palzar & Turk 2008) based exchange standards
- other existing and emerging exchange standards (e.g., COBie, SPIe, BIMSie, BPie, ELie, LCie, QTie, WALLie, etc)
ACI CIP Process Map (portion)
<table>
<thead>
<tr>
<th>Final Design</th>
<th>Final Design</th>
<th>PS&amp;E Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry Development</td>
<td></td>
<td>Design landscape/aesthetic plans</td>
</tr>
<tr>
<td>Design Development</td>
<td>Advance Detail Plans (ADP)</td>
<td>PS&amp;E Assembly/Design Review</td>
</tr>
<tr>
<td>[A.FD/SE] Structural</td>
<td>Section 4.4.3, PDM</td>
<td>PS&amp;E Assembly/Design Review</td>
</tr>
<tr>
<td>Design Development</td>
<td>Section 19.1.3, Bridge Manual</td>
<td></td>
</tr>
<tr>
<td>[A.FD/D] Preliminary</td>
<td>Final Plans, Specifications and</td>
<td></td>
</tr>
<tr>
<td>Detailing Design</td>
<td>Estimates (PS&amp;E)</td>
<td></td>
</tr>
<tr>
<td>[A.FD/E] Detailing Engineer's</td>
<td>Section 21.6.1.4-21.6.1.5, HDM</td>
<td></td>
</tr>
<tr>
<td>Estimate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bidding and Letting</td>
<td>Project Advertisement</td>
<td>(Final Processing and) Letting</td>
</tr>
<tr>
<td>[A.BL/SE] Construction</td>
<td></td>
<td>6000 Perform financial clearance analysis,</td>
</tr>
<tr>
<td>Documents Preparation</td>
<td></td>
<td>6100 Advertise request for bids,</td>
</tr>
<tr>
<td>[A.BL/E] Initial Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[A.BL/CM] Bid Development</td>
<td></td>
<td>6210 Award Contract</td>
</tr>
</tbody>
</table>
Vision & Bridge Lifecycle (Enterprise) Process Map

Process Map — Streamlined and Improved IT-enabled Managing Method

Portion of Bridge Enterprise Process Map (Chen et al. 2013)
For Bridges: Process Map Notation

Project Disciplines:
- Detailing
- Estimating
- Construction Management
- Fabrication
- Construction Engineering
- Inspection
- Load Rating
- Routing and Permitting
- Maintenance and Management

Project stages:
- Bidding and Letting
- Post-Award/Preconstruction Planning/Detailing
- Fabrication
- Construction
- Inspection and Evaluation
- Maintenance and Management
- Management
Process Map Notation, cont’d

Activity Descriptions

<table>
<thead>
<tr>
<th>[A.I/PAL] Bridge Planning</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Planning</td>
<td></td>
</tr>
<tr>
<td>Project Stage: 31-10 14 17 Initiation</td>
<td></td>
</tr>
<tr>
<td>Discipline: 33-11 00 00 Planning, Aesthetics and Landscaping</td>
<td></td>
</tr>
<tr>
<td>Documentation</td>
<td>After a transportation problem or need from a variety of sources has been determined, engineers start initial planning of a bridge program by selecting candidate projects based on program goals. At the initiation stage, engineers describe candidate projects and how the projects address the program goals.</td>
</tr>
</tbody>
</table>
### Exchange Model Description

**[EM.PD/SE-E-PAL] Initial Structural Model**

<table>
<thead>
<tr>
<th>Project Stage</th>
<th>31-20 10 00 Preliminary Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange Disciplines</td>
<td>(33-21 31 14) Structural Engineering</td>
</tr>
<tr>
<td></td>
<td>(33-25 11 00) Estimation</td>
</tr>
<tr>
<td></td>
<td>(33-11 00 00) Planning, Aesthetics and Landscaping</td>
</tr>
<tr>
<td>Description</td>
<td><strong>Purpose:</strong> this model is created to help structural engineers select the most appropriate alternative to be advanced.</td>
</tr>
<tr>
<td></td>
<td><strong>Major content:</strong> the content of this model includes but is not limited to 1) substructure location, 2) span length, 3) full transverse section, 4) boring locations, etc.</td>
</tr>
<tr>
<td></td>
<td><strong>Level of detail:</strong> preliminary design</td>
</tr>
<tr>
<td></td>
<td><strong>Special attributes:</strong> type, size and location</td>
</tr>
<tr>
<td>Example Software: Export and Import</td>
<td>Export: LEAP Bridge</td>
</tr>
<tr>
<td></td>
<td>Import: CsiBridge, AASHTOWare Opis/Virtis</td>
</tr>
<tr>
<td>Related Exchange Models</td>
<td>EM.I/PAL-E, Bridge Concept Model</td>
</tr>
<tr>
<td></td>
<td>EM.S/SE-E, Bridge Engineering Concept Model</td>
</tr>
<tr>
<td></td>
<td>EM.FD/SE-D-TE-PAL, Final Structural Model</td>
</tr>
</tbody>
</table>
Process Map Notation, cont’d

Non-model Exchange Descriptions

[Non-model Exchange Description]

**[NME.I/E-PAL] Pre-Preliminary Cost Estimate Report**

<table>
<thead>
<tr>
<th>Project Stage</th>
<th>31-10 14 17 Initiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange Disciplines</td>
<td>33-25 11 00 Estimation</td>
</tr>
<tr>
<td></td>
<td>33-11 00 00 Planning, Aesthetics and Landscaping</td>
</tr>
<tr>
<td>Information Transmitted</td>
<td>Provide conceptual cost estimate of candidate projects throughout project phases with regard to pavement, structures, culverts, operations, and environment.</td>
</tr>
<tr>
<td>Typical Formats</td>
<td>Excel spreadsheet</td>
</tr>
</tbody>
</table>
Use Case Descriptions (e.g.)

Final Design Stage

Figure 3-41 Use Case 6 – Final Roadway Design
Final Design Stage

Figure 3-43 Use Case 10 – Initial Bridge Load Rating
Construction Planning / Detailing Stage

From A.BL/CM Bid Development

[A.CD/CM]
Construction Planning and Scheduling (General contractor and Subcontractor)

To A.C/CM
Construction Coordinating and Monitoring

EM.CD/CE-F-CM
Erection Analysis Model

Erection Procedures

[NME.CD/CE-CM]

To A.C/CE
Construction Execution

[A.CD/CE]
Erection Plan and Analysis

Figure 3-46 Use Case 13 – Bridge Construction/Erection Planning
Fabrication Stage

Figure 3-47 Use Case 14 – Final Bridge Detailing and Bridge Fabrication
Roadway Use Case

Coordinate Systems Supported by Building-Oriented Data Models [1-3]

- Cartesian Coordinate Systems
- Polar Coordinate Systems
- Cylindrical Coordinate Systems
- Spherical Coordinate Systems
Roadway Use Case, cont’d

Complex Curves involved in Roadway Alignment
- Clothoid
- Spiral
- Parabola

Major shortcomings of using building-oriented data models for bridges
- Accumulate error
- Compromise the relationship between bridge and roadway
Use Case – Roadway Design

Data Exchange Schemas for Describing Roadway Geometry

- LandXML [6]
- IFC-Bridge proposed by OpenInfra [7]
Use Case – Roadway Design

Description of Roadway Alignment

Elements of Horizontal Alignment:
- Straight line
- Transition curve
- Circular curve

Proposed OpenBrIM XML Schema

XML Instance Representation
Use Case – Roadway Design

Description of Roadway Alignment

Elements of Vertical Profile:
- Straight line
- Symmetric parabolic curve
- Asymmetric parabolic curve
- Circular curve

Proposed OpenBrIM XML Schema

```xml
<element name="VerticalProfile">
  <complexType>
    <choice minOccurs="0" maxOccurs="unbounded">
      <ProfilePoint Name="PVC" Station="1139000"
      Elevation="192800" Grade="0.05"/>
      <ProfilePoint Name="PVT" Station="1369683"
      Elevation="191530" Grade="-0.0491"/>
    </choice>
  </complexType>
</element>
```

XML Instance Representation
Use Case – Roadway Design

Description of Roadway Alignment

Elements of Cross Section:
- Width
- Side slope
- Location of HCL/TGL

Proposed OpenBrIM XML Schema
XML Instance Representation
# Use Case – Roadway Design

**Comparison of Roadway Geometry Models**

<table>
<thead>
<tr>
<th>Alignment Data Schema $^5$</th>
<th>Highway Object Model $^6$</th>
<th>Bridge Contract Drawings $^7$</th>
<th>OpenBrIM $^8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IfcAlignmentCurve2DHorizontal</td>
<td>Alignment</td>
<td>(Horizontal Alignment)</td>
<td>HorizontalAlignment</td>
</tr>
<tr>
<td>IfcTrimmedCurve.BasisCurve=IfcLine</td>
<td>LineString</td>
<td>(Line)</td>
<td>Straight (Line)</td>
</tr>
<tr>
<td>IfcAlignmentCurveSegment2D.StartDistanceAlong, EndDistanceAlong</td>
<td>startPoint, endPoint</td>
<td>ST, TS</td>
<td>StartStation</td>
</tr>
<tr>
<td>IfcLine.Dir</td>
<td></td>
<td>AZ(imuth)</td>
<td>StartAzimuth</td>
</tr>
<tr>
<td>IfcTrimmedCurve.Trim1, IfcTrimmedCurve.Trim2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IfcTrimmedCurve.BasisCurve=IfcClothoid</td>
<td>(Spiral)</td>
<td>(Spiral)</td>
<td>(Spiral) Curve</td>
</tr>
<tr>
<td>IfcAlignmentCurveSegment2D.StartDistanceAlong, EndDistanceAlong</td>
<td>-</td>
<td>TS, CS, SC, ST</td>
<td>StartStation</td>
</tr>
<tr>
<td>IfcTrimmedCurve.Trim1, IfcTrimmedCurve.Trim2</td>
<td>startPoint, endPoint</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

$^5$ Alignment Data Schema

$^6$ Highway Object Model

$^7$ Bridge Contract Drawings

$^8$ OpenBrIM
The Technical Part: Data Exchange Standard Development

UB BrIM Research Group Principal Focus

**Phase 1: Program**
- Process Map
- Exchange Requirements
- Information Delivery Manual

**Phase 2: Design**
- ER Models
- Generic Model View Definitions
- Gap Analysis

**Phase 3: Construct**
- Data Model Schema

**Phase 4: Validate**
- Validation
- Evaluation
Plan View – I-290 Ramp B over I-190
3D View – Steel Plate Girders
3D View – Concrete Haunches
3D View – Steel Cross Frames
3D View – Steel Cross Frames
3D View – Bearing Stiffener
3D View – Bearing Stiffener
3D View – Chevron Cross Frame
3D View – X Cross Frame
3D View – Shear Stud
3D View – Shear Stud
3D View – Concrete Pier
3D View – Concrete Pier with Steel Piles
3D View – Steel Piles
3D View – Bridge
3D View – Bridge
3D View – Bridge
3D View – Bridge
Viewer/Modeler Demo’s...
Concrete Bridge Example Case Study:
Quincy Ave. Bridge, CO (BT72)

Plan View of Quincy Avenue over I-25 and LRT
Quincy Ave. Bridge (BT72)

Section View of Quincy Avenue over I-25 and LRT
Quincy Ave. Bridge (BT72)

<!-- Roadway Geometry Definition with horizontal and vertical curves -->

<RoadwayGeometry Name="Alignment">
  <HorizontalAlignment StartStation="0" StartAzimuth="0.039">
    <Straight Length="280.32" />
  </HorizontalAlignment>
  <VerticalProfile>
    <ProfilePoint Station="381.17" Elevation="0" Grade="0.00395" />
    <ProfilePoint Station="549.32" Elevation="0.634" Grade="-0.0177" />
  </VerticalProfile>
</RoadwayGeometry>
Quincy Ave. Bridge (BT72)

UB BrIM XML code for BT72

BT72 Girders Modeled in OpenBrIM Viewer
Quincy Ave. Bridge (BT72)

UB BrIM XML code for Deck Definition
UB BrIM XML code for Multi-Column Pier Bent

Multi-Column Pier Bent and Integral Abutment Modeled in OpenBrIM Viewer
Quincy Ave. Bridge (BT72)

UB BrIM XML code for Strands and Reinforcement

Strands, Longitudinal and Transverse reinforcement Modeled in OpenBrIM Viewer
Quincy Ave. Bridge (BT72)

Strands, Longitudinal and Transverse reinforcement Modeled in OpenBrIM Viewer
Quincy Ave. Bridge (BT72)

Strands, Longitudinal and Transverse reinforcement Modeled in OpenBrIM Viewer
Glenridge Road Bridge

Strands, Longitudinal and Transverse Reinforcement Modeled in OpenBrIM Viewer
Glenridge Road Bridge

Complete Model of the Bridge with Deck and Abutments
Spliced Girders with Post-Tensioning Ducts

Post-Tensioning Ducts shown as blue
Spliced Girders with Post-Tensioning Ducts

Individual Beams shown before splicing
Spliced Girders with Post-Tensioning Ducts

Close up of beam (transparent) and the Post-Tensioning ducts inside it
Rebar Bend Rendering in OpenBrIM Viewer

CRSI Rebar Bend Type - 1
Schema Object Template for CRSI Type – 1 Rebar Bend

<ObjType Name="crsi.Bar.1" X="0" Y="-w/2+sideCover" Z="d/2-topCover">
  <Define parameters using <Param>>
    <Param Name="A" Label="A" Value="75" Type="Length"/>
    <Param Name="B" Label="B" Value="434" Type="Length"/>
    <Param Name="G" Label="G" Value="75" Type="Length"/>
    <Param Name="J" Label="J" Value="(16.13+6.35*2)*2" Type="Length"/>
    <Param Name="dia" Label="dia" Value="6.35*2" Type="Length"/>
  </Define parameters using <Param>>
  <Define straight part using <Line>>
    <Line Color="cyan"/>
  </Define straight part using <Line>>
  <Define orientation of the section using <Orientation>>
    <Orientation X="1" Y="0" Z="0"/>
  </Define orientation of the section using <Orientation>>
  <Define extrusion path using <Point>>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*1.5)-(G+J*0.5-3.142*0.5*(J-dia))" Z="(J-dia)*0.5 * sin(3.142*1.5)"/>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*1.5)" Z="(J-dia)*0.5 * sin(3.142*1.5)"/>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*1.4)" Z="(J-dia)*0.5 * sin(3.142*1.4)"/>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*1.3)" Z="(J-dia)*0.5 * sin(3.142*1.3)"/>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*1.2)" Z="(J-dia)*0.5 * sin(3.142*1.2)"/>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*1.1)" Z="(J-dia)*0.5 * sin(3.142*1.1)"/>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*1)*Z="(J-dia)*0.5 * sin(3.142*1)"/>
    <Point X="0" Y="(B-J)-(J-dia)*0.5 * cos(3.142*0.9)" Z="(J-dia)*0.5 * sin(3.142*0.9)"/>
  </Define extrusion path using <Point>>
</ObjType>
Rebar Bend Rendering in OpenBrIM Viewer

CRSI Rebar Bend Type - T1
3D View – Multi-column Pier
Modeled separately for independent check on XML data – tagging
Project Data File:

```xml
<Object Name="Girder 1" Template="Girder_Steel_1">  
  <Location Sta="1209549" Toff="-4800" Elev="-232"/>
  <Parameters>
    <Parameter Name="l" Value="121372"/>
    <Parameter Name="d" Value="2000"/>
    <Parameter Name="tw" Value="18"/>
    <Parameter Name="tbf" Value="650"/>
    <Parameter Name="bbf" Value="700"/>
    <Parameter Name="ttf" Value="32"/>
    <Parameter Name="btf" Value="45"/>
  </Parameters>
</Object>
```

Reference to the "Object template"

"Location" for object placement

Parameters values that define the girder. Based on the reference template, the viewer uses these parameters to generate a 3D visualization of the girder.
Horizontal and vertical curvature is applied to the girder using the “Roadway Geometry” node.

```
<ObjectTemplate Name="Girder.Steel.I" Label="Steel I Girder" Category="Girders">
  <Parameters>
    <Parameter Name="l" Label="Length" Value="160" Type="Length"/>
    <Parameter Name="d" Label="Web depth" Value="7.0" Type="Length"/>
    <Parameter Name="tw" Label="Web Thickness" Value="0.052083" Type="Length"/>
    <Parameter Name="tbf" Label="Top Flange Width" Value="1.666667" Type="Length"/>
    <Parameter Name="ttf" Label="Top Flange Thickness" Value="0.083333" Type="Length"/>
    <Parameter Name="bbf" Label="Bottom Flange Width" Value="1.750000" Type="Length"/>
    <Parameter Name="btf" Label="Bottom Flange Thickness" Value="0.125000" Type="Length"/>
  </Parameters>
  <Geometry>
    <Line Color="yellow">
      <Orientation X="0" Y="0" Z="1"/>
      <Point X="sta" Y="toff" Z="elev"/>
      <Point X="sta+1" Y="toff" Z="elev"/>
      <Polygon>
        <Point X="-tbf/2" Y="ttf"/>
        <Point X="-tbf/2" Y="0"/>
        <Point X="-tw/2" Y="-d"/>
        <Point X="-tw/2" Y="0"/>
        <Point X="-ttf/2" Y="-d-btf"/>
        <Point X="-ttf/2" Y="d-btf"/>
        <Point X="ttf/2" Y="-d-btf"/>
        <Point X="ttf/2" Y="d-btf"/>
        <Point X="tw/2" Y="0"/>
        <Point X="tw/2" Y="d"/>
        <Point X="tbf/2" Y="0"/>
        <Point X="tbf/2" Y="ttf"/>
      </Polygon>
    </Line>
  </Geometry>
</ObjectTemplate>
```
Related: ACI (Sept. 2013)

Figure 3. Aggregation of reinforcing elements (a) individual rebar, (b) array of rebar, (c) a rebar assembly or cage.
Implementation Roadmap

Overview
A range of recent and emerging state-of-art technologies have the potential to transform the efficiency, effectiveness, reliability, cost-effective life cycle management of the bridge asset network in coming decades. The proposed roadmap outlines how to “get there from here.”

Approach Recommended:
Roberts Leadership and Management Model
## Implementation Roadmap

### Examples of Roberts Model Elements

<table>
<thead>
<tr>
<th>Roberts Model Element</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vision</strong></td>
<td>As a result of BrIM-standards based interoperability being implemented, owners dealing with construction claims could quickly access the searchable electronic “audit trail” that is a byproduct of BrIM – enabled processes to quickly assess the merits of claims just as easily as a contractor with suitable access to model data can interrogate it instead of issuing RFI’s.</td>
</tr>
<tr>
<td><strong>Authorizing Environment</strong></td>
<td>Increasing interconnectedness of pieces of the workflow is increasingly realized by software translators, and the integrative Vision embraced by various stakeholders (owners, designers, contractors, etc.) in the bridge lifecycle in a given owner’s jurisdiction</td>
</tr>
<tr>
<td><strong>Organizational Capacity</strong></td>
<td>In an owning agency organization and the consulting firms serving them, long standing animosities between previously separated highway design and bridge design squads reduce over time; re-tooling of CAD technicians and bridge engineers to productively use 3D modeling tools, possibly partially subsidized using MAP-21 funds incentivizing deployment of ABC technologies.</td>
</tr>
<tr>
<td><strong>Working Space</strong></td>
<td>Progressive CEO’s and managers clearly understand and champion the vision throughout the organization in an energetic and sustained manner to facilitate the migration from initially non-interoperating software operated by a not-fully-IT-savvy workforce to collaboratively influence that agency’s next-gen CAD standards and associated workflows to implement Task 12 – generated data exchange standards (or suitable derivative(s) thereof)</td>
</tr>
</tbody>
</table>
Implementation Roadmap

Shorter-Term (first 18 months)

• Various educational briefings and targeted stakeholder engagement should be mobilized for schema vetting and periodic (web)meetings

• Identify principal legal issues and add-ons in “BIM Addendums” to standard construction contracts in related fields and adapt them as appropriate to Highway and Heavy Construction Contracts
  • D/B
  • D/B/B
  • CMGC
  • etc

• Test-drive emerging openBrIM standards on suitable demo projects; incorporate revisions to these standards based on lessons learned.

• Identify options and preferred standards-issuing shepherding mechanisms (& associated advocacy strategies) (& pro’s and con’s)
Implementation Roadmap

Intermediate-Term (18 months – 5 years)

• Standards emerging for a bridge structure, for example, will need to be mapped from “plain English” (or “stylized English”) that a bridge engineer would use, to the (IFC or XML or ISM) Model View Definition (MVD) that a software implementer would use.

• Disincentives to address/overcome include the following:
  ➢ Designer reluctance to share models, which is “for good reasons”
  ➢ “reasonable man” legal reasoning (works against early adopters)
  ➢ Insufficient institutional memory (e.g., where did that (archaic) spec come from?)

• Bottom-Up processes to consider include the following:
  ➢ Develop model guidelines for training/retooling rank & file staff
Implementation Roadmap

Intermediate-Term (18 months – 5 years)

- Top-Down processes to consider include the following:
  - Track UK HMG government BIM mandate ramp-up & deployment experiences in forcing BIM-enabled processes into the mainstream of construction project delivery; best practices, pitfalls to avoid, etc.
  - Add-on to (or modified!?) NBI reporting requirements along with element-level reporting already required by statute (MAP-21)
  - Exploit MAP-21 provisions encouraging the submission of digital data documenting federal-aid construction projects
  - Promulgate Model version & Guidelines for tweaking Owner-specified exchange standards (think next-gen CAD standards) and “as built” (or “as constructed”)

- Influence and exploit MAP-21 extensions
Implementation Roadmap

Longer-Term (5+ years)

- Recognizing and identifying overlapping interests, both nationally and internationally, and forging targeted collaborative efforts without undue bureaucracy to leverage resources and consolidate/refine evolving/maturing EM (Exchange Model) descriptions and associated MVD mappings.

- Transform transportation infrastructure owning agencies around their integrated stewardship of lifecycle asset data management down to the nuts and bolts.

- Moving forward to "maintenance mode" (and associated shepherding mechanism) for the BrIM data exchange standards.

- Assemble and publicize (e.g., 1-PDH webinars) periodic syntheses of successful case studies (including IPD), lessons learned from early adopters, and emerging best practices.

- Proactively influence BIM/BrIM related committees with partially overlapping interests to ensure that bridge data of interest is included in the broader efforts to define and implement data exchange standards for the constructed infrastructure.

- Utilize and influence emerging & evolving BIM certification mechanisms.
# Short Term (ST), IT, LT in the Roberts Model

## Table 3 Implementation Roadmap Activities

<table>
<thead>
<tr>
<th>Roberts Model Element</th>
<th>Bottom-Up</th>
<th>Task Force</th>
<th>Top-Down</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stakeholder Category</strong></td>
<td><strong>Authorized Environment</strong></td>
<td><strong>Organizational Capacity</strong></td>
<td><strong>Vision (and Policy Mechanisms)</strong></td>
</tr>
<tr>
<td>Owner</td>
<td>ST3; IT1d,e; LT1</td>
<td>ST1k; ST2; IT2; IT3d</td>
<td>ST2; IT1e; IT2; IT5; LT6c,d</td>
</tr>
<tr>
<td>Discipline</td>
<td>ST1a-j; ST3; ST5; IT3c; IT4a; LT2a,b; LT6d</td>
<td>ST3b; IT1f</td>
<td>---</td>
</tr>
<tr>
<td>TRB/AASHTO</td>
<td>ST1e,g; IT1g; LT3</td>
<td>ST3a; IT1c; IT6; LT4; LT6a</td>
<td>ST4a,b; IT3b,c; LT2d; LT7b</td>
</tr>
<tr>
<td>Data Exchange Standards Committe</td>
<td>ST1a1-4; ST1h,I; IT4b,c; LT5</td>
<td>ST4a-d; IT1a,f,g</td>
<td>ST4c; IT3a; IT4b,c; LT7a,c</td>
</tr>
<tr>
<td>Technology Solution Provider</td>
<td>ST1a3; ST1c; ST5; IT1b1; LT2c, LT6b; LT7</td>
<td>IT1b2</td>
<td>---</td>
</tr>
</tbody>
</table>
Technological + Organizational Considerations

Principal Assumptions:

• Technological
  ➢ A neutral format (e.g., IFC, XML)
  ➢ Software solution providers continue supporting integrative technologies
  ➢ Data quality specifications

• Organizational
  ➢ Most existing institutions and organizations continue providing framework for the organizational capacity and authorizing environment needed to implement the integrated process vision.
  ➢ ROI (documentation of quantified benefits and emerging “best practices”, including in related fields).
Summary, Conclusion and Recommendation

1. Current data schemas used by building industry cannot be directly borrowed and used for bridge projects.
2. A bridge-oriented data schema based on roadway alignment is necessary.
3. The schema was developed under the guidance of the Process Map, which reflects use cases of bridge project.
4. The schema is able to support parametric modeling, which can reflect the design intent.
5. Domain Dictionaries!
6. Alignment and Steel and Concrete Schema Developments
7. Adapted Roberts Model recommended for Implementation

Status: draft reports under review

Ongoing Synergies Recommended:
• buildingSMART International
• AASHTO/NSBA
• ACI
Acknowledgements

1. Federal Highway Administration (B. Kozy, COTR) through ATLSS
2. Association for Bridge Construction and Design
3. New York State Department of Transportation & other DOTs
4. Bentley Systems, Red Eqn Corp., and other Bridge and other Software Solution Providers
5. University at Buffalo, Istanbul Technical University, and University of Engineering and Technology
6. Others on UBrIM team: I.-S. Ahn, S. G. Karaman, Y. Ji, A. Nilsen
7. A. Koc
8. AASHTO/NSBA Collaboration
9. Other Collaborations (e.g., bSI, ACI BIM, etc.)
10. Etc.