Exploring BIM for Operational Integrated Asset Management

A preliminary study utilising real-world infrastructure data

Gareth Boyes, Claire Ellul, Daniel Irwin

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Gareth Boyes
PhD Candidate
gareth.boyes.13@ucl.ac.uk

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Gareth Boyes

PhD Research Area

Integration of GIS and BIM in Infrastructure

Can GIS be used to enable infrastructure Asset Management in a BIM environment?

In collaboration with Crossrail
The Crossrail Elizabeth Line

- **2x21 KM of tunnel under London**
- **40 Upgraded or new stations**
- **19 Boroughs passed through**
- **24 Trains per hour in COS**
- **1 World class railway**
The UK BIM Mandate

• All government contracts require the contractor to employ and handover a fully collaborative 3D BIM with all project and asset information, documentation and data being electronic

• UK Government is expecting:
  • a 33% reduction in through life cost of constructed assets
  • a 50% reduction in CO₂ emission
  • 50% faster delivery

• Capital Expenditure + Operational Expenditure
BIM and Asset Management

• Asset Information Model in the form of Federated Model in a Common Data Environment

• Asset Information Requirements

• Meets Asset Management Strategy

**PAS 1192-3:2014**
Incorporating Corrigendum No. 1

Specification for information management for the operational phase of assets using building information modelling
PAS 1192-3 requirements

• Assets must contain location information
  - Coordinate (e.g. 37.7964° S 144.9612° E)
  - Named Location (e.g. Room 36)
  - Link to a feature in external GIS

• Linking must be two-way
The Crossrail BIM Information Systems

Diagram:
- CAD
  - ProjectWise - MicroStation
- GIS
  - Oracle Spatial & ESRI
- EDMS / EIMS
  - Bentley eB
- AIMS
  - Asset Information

2-way link
The Challenge

CAD
ProjectWise - MicroStation

GIS
Oracle Spatial & ESRI

Construction-centric objects

EDMS / EIMS
Bentley eB

AIMS
Asset Information

AM/FM-centric objects
The Challenge

The Crossrail BIM Information Systems

- CAD
  - ProjectWise - MicroStation
  - File-based system

- GIS
  - Oracle Spatial & ESRI
  - ORDBMS

- EDMS / EIMS
  - Bentley eB

- AIMS
  - Asset Information
  - ORDBMS
Linking

Primary Functional Unit → Functional Unit → AIMS Asset → MicroStation Element → Family/Part
Linking

ID Link
Linking

Coordinate Link
Linking

Space Link
Linking

Class Link

Diagram showing the linking between AIMS Asset, MicroStation Element, Primary Functional Unit, Functional Unit, ID, XYZ, Geometry, Space ID, Space Link, Class Link, Class, Level, and Family/Part.
Proposed Method

• Use 3D GIS spatial query to identify the space(s) that BIM/CAD elements are located in
  - e.g. Oracle Spatial - SDO_INSIDE / SDO_ANYINTERACT
  - e.g. ESRI 3D Analyst Toolbox - Inside3D

• Use space and class to reduce links to a manageable level

• To achieve this we need:
  - Import BIM/CAD elements into 3D GIS as solid features
  - Import Spaces into 3D GIS as closed volumetric features (i.e. solid)
Proposed Method

- Extract from MicroStation
- Transform with FME Workbench
- Load into Oracle Spatial or ArcGIS
MicroStation can export (among others):

- Native MicroStation (DGN)
- Autodesk (DWG)
- Industry Foundation Classes (IFC)
- Trimble SketchUp (SKP)
- MicroStation VBA script output (CSV)
Geometric Transformation

**Transform**
with FME Workbench

Solids require transformation to OGC Simple Feature

- Boundary Representation
- Planar polygon ring faces
- Manifold construction
- Closed
- Not self-intersecting
- Voids/Tunnels permitted
Extracting via DGN

**Advantage**
- Native file format
- μS Element ID retained
- Appearance (e.g. colour) retained

**Disadvantage**
- FME cannot read surfaces (BIM object geometry most commonly exported as surfaces)
- Cell objects de-aggregated into component elements
- Issues related to curved surfaces
<table>
<thead>
<tr>
<th>Advantage</th>
<th>Disadvantage</th>
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</thead>
<tbody>
<tr>
<td>• Very well supported by FME</td>
<td>• Conversion process degrades information</td>
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<tr>
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<td>• μS Element ID lost</td>
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<td>• Cell objects de-aggregated into component elements</td>
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<td>• Unreliable geometry export</td>
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</table>
Extracting via IFC

**Advantage**
- Semantic information exported
- μS Element ID retained

**Disadvantage**
- Conversion process degrades information
- Level information lost
- Appearance lost
- Unreliable geometry export
- FME struggles to read corrupted IFC geometry
Ceiling geometry (as it should be)
Ceiling geometry (as exported via IFC)
Problems of using IFC

- FME Workbench cannot interpret some IFC geometries
- Unloadable geometries were examined in Solibri Model Viewer
Extracting via SketchUp

**Advantage**
- Appearance (e.g. colour) retained
- Level information retained

**Disadvantage**
- Conversion process degrades information
- Objects converted to B-rep
- Complex curved geometry can overwhelm FME
- Some objects split into parts
Geometric Transformation

Solids require transformation to OGC Simple Feature

- Exporting via IFC
  - Geometry mainly CSG / Extrude shape
  - Transformation to B-Rep performed in FME

- Exporting via SketchUp
  - Transformation to B-Rep performed in MicroStation

Need better awareness of when/how/where B-Rep transformation occurs
ETL Workflow

1. Read Elements from MVBA derived CSV
2. Merge IFC attributes
3. Merge SketchUp geometry
4. Merge IFC geometry (if preferred)
5. Write to required format
6. Check all elements have geometry & attributes
## Results

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<tr>
<th></th>
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Table 3. Export, transformation and loading of MicroStation Elements via IFC and SketchUp to GIS
Ticket Hall in ArcScene
Validation

• GIS objects validated with ArcGIS IsClosed tool

• 3 out of 841 objects from the Electrical BIM files not closed

• 3D spatial query performed with ArcGIS Inside3D tool
Space Geometry

• Creating 3D Spaces fit for purpose.
Space Geometry
Summary

• PAS 1192-3 requires federated models with 2-way linking to AM Systems
• Asset Information Management System Assets ≠ BIM/CAD elements
• Researching methods to link with 3D spatial query
• Investigating ETL methods to load BIM/CAD elements
• Transformation from IFC to GIS is problematic
• Geometric transformation with source software to SketchUp is successful
• Future work being carried out to generate fit-for-purpose 3D spaces