The Test Bed
The need for interoperability and open standards in the Architecture Engineering Construction (AEC) industry – how to integrate BIM and GIS with a life cycle view

Väino Tarandi
Professor, KTH, Stockholm

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Testbed for BIM level 3

BIM levels after British Standards Institute (from ARCADIS adapted to Sweden)
Smart planning, design, construction, operation and use processes over the whole life cycle

APPLICATION CASES

TEST BED SMART INFORMATION PROCESSES

APPLICATION CASES

Test case 1
Test case 2
Test case 3
Test case 4
Test case n

TEST BED SMART INFORMATION PROCESSES

Converting, verifying (ETL)

National geo data
Municipality geo data
Real estate register
Etc ...

Export, import, linking

Geodata
Country
County
City
Block
Property
 Linked data sources

Visualisation

Lifecycle support

Transport network

BIM
Building
Floor
Room
Building element

Product database
National road db
BIM

Converting, verifying (ETL)

Export, import, linking

Etc ....
Smart planning, design, construction, and use processes over the whole life cycle

APPLICATION CASES

TEST BED SMART INFORMATION PROCESSES

National geo data
Building
Floor
Room
Building element
BIM (BIM Alliance)
Converting, verifying (ETL)
County
City
Block
Property
Country
Real estate register
Municipality geo data
Export, import, linking
National road db
Converting, verifying (ETL)
Etc ...

APPLICATION CASES

Test case 1
Test case 2
Test case 3
Test case 4

TEST BED SMART INFORMATION PROCESSES

National geo data
Municipality geo data
Real estate register
Export, import, linking

Converting, verifying (ETL)

Geodata
Country
County
City
Block
Property
Linked data sources
Visualisation
Transport network

(Swedish Geo process)
(BIM Alliance)
# Time schedule for the Test bed

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<thead>
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<th>Arbetspaket</th>
<th>2017</th>
<th>2018</th>
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<td>WP 1: Development of the platform, WP leader Torbjörn Holm, Eurostep</td>
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<td>Integration &amp; tjänsteutveckling</td>
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<td>Drift &amp; support</td>
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<td>WP 2: Information exchange construction company - municipality, WP leader Lars Harrie, Lund</td>
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<tr>
<td>Definition och utv. av testfall</td>
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<td>Test byggfag/kommun1-3</td>
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<td>WP 3: 3D property formation, WP leader Jenny Paulsson, KTH</td>
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<tr>
<td>It. metodik/juridik/visualisering</td>
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<td>Användarstudier/utvärdering</td>
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<td>WP 4: BIM for production management, WP leader Thomas Olofsson, LTU</td>
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<td>Länkning varuDB&amp;sensordata</td>
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<td>Visualisering av stomstatus</td>
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<tr>
<td>Fallstudie 1 och 2</td>
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<td>WP 5: Management, information dissemination, WP leader Väino Tarandi, KTH</td>
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<td>Projektmöten</td>
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<tr>
<td>Workshop/seminarium/refarr</td>
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</table>

Applied project Trafikverket – VERA
IFC Alignment tested in the test bed late autumn 2017

**Participants**
KTH, LTU, LU, Chalmers, Högskolan i Gävle, Lantmäteriet, Trafikverket, Boverket, Mölndal stad, Stockholm stad, Malmö stad, Helsingborg stad, Eurostep, Triona, Trimble (Vianova), Agency 9, Logiq/Finfo, NCC, Tyréns, Cementa, Betongindustri, SLL Trafikförvaltningen
Project purpose

This project proposal aims at creating a Level 3 test bed to be a national resource for testing concepts, ideas and innovations for the smart community. It involves tests of open new and existing standards, methods and processes to make available and use Geo and BIM data in several parts of the community building process throughout the project and city life cycles. The test bed will be used in cooperation between authorities like National Land Survey, National Board of Housing, Building and Planning, Swedish Transport Administration, municipalities, etc. and construction companies to develop and test a digital open, object oriented and standardized information exchange."
Multiple Systems – Integration?

Collaboration Hub
Integration of standards for buildings and infrastructure

Through Life Support - PLCS

Alignment

Net-work ISO 191xx based (NVDB, Inspire, etc.)

InfraGML

Ifc, simple ifcXML, LandXML

Common concepts

Ifc, simple ifcXML

CityGML

XML...

LandXML

XML...
Lifecycle + breakdown with topology

Objectified topological relation (with effectivity)

Life cycle phases

Through life support (incl. versioning)

Product breakdown [ISO 12006-2]

[PLCS ISO 10303:239]
Standards

Standardization is especially important for product libraries, as there often is a change of actors when going from design to supplier specific products in the BIM (Berlo et al., 2015).


The business objects in PLCS, ISO 10303-239 (ISO, 2012) cover the whole life cycle for products.
Heterogeneous data models mapped to PLCS

Net-work ISO 191xx

IFC

IFC++ (Infra) Alignment
Road, Railway Bridge

Through Life Support - PLCS

LandXML

CityGML

InfraGML
Using PLCS and IFC (& more)

PLCS

- ISO 10303-239
  - Change Management
  - Versioning
  - Consolidation
  - Requirement
  - Product as realized
  - Maintenance

IFC

- ISO 16739:2013
  - Building element
  - Material
  - Property
  - Geometry
  - Placement

Other domain specific stds
- LandXML, CityGML, InfraGML…
What IFC2x3 can do today

Geometry (explicit)
- B-rep
- CSG

Geometry (Sweep)
- volume - extrusion, rotation
- areas - extrusion, rotation

Topology
- element connectivity,
- schematic design

Building Elements
- Walls, Openings, Doors
- Roofs, Stairs, Ramps, etc.

Relations between
Building Elements
- Wall Connections
- Holes
- Chases
- Zones

Spaces and
Spatial Structure
- Space
- Building Storey
- Building
- Building Site

Site and Terrain
Model
- Site
- Site attributes
Architecture to implement

1. Topological & Spatial hierarchies
2. Versions and changes
3. Life cycle
4. Unique identifiers - GUID
5. Classification
6. Units
7. Coordinate systems
8. Reference geometries
9. Types – with versions
10. LOD – Level of Detail for the Geo process
11. Terrain model - granularity
12. Networks and Road alignments (IFC 4)
13. Swedish Geo process
Topological & Spatial hierarchies

**Background**

In *the GIS world*, you usually use *coordinates to search for information* rather than topological-ka relationship. In *the BIM world*, the IFC standard has evolved over a long period of time, and the structure of the *building, floor, room and building elements* has worked well to find and navigate among the different parts.

*Systems and topologies provide opportunities for analysis and comparisons* of different locations in the country with recurring similar degradations. The idea is to have a simple, quick breakdown in a few steps.

**Suggestions for functionality in the platform**

Structures from *county to city to neighborhood to property* are being built up. To these networks, breakdowns in networks for wiring, roads from the appropriate level.

Similarly, as the stories (*spatial segment* of the building) has rooms, the Infra group in buildignSMART has developed *traffic places with "spatial segments"* - lanes, walkways, etc. For example, a roundabout, station area, sports facility has "spatial segments" - this is lacking in the classification systems ....
Figure 31 - Typical 4-way local road junction showing a spatial decomposition of one road segment and the intersection
Spatial Structure – Hofplein Roundabout, Rotterdam

RotterdamCentrum: ifcSite

- StadsrouteS100: ifcRoad (COMPLEX)
  - WeenaRoadway: ifcRoad (PARTIAL)
  - HofpleinRoundabout: ifcRoad (PARTIAL)
  - PompenburgRoadway: ifcRoad (PARTIAL)

- StadsrouteS112: ifcRoad (COMPLEX)
  - SchiekadeRoadway: ifcRoad (PARTIAL)
  - HofpleinRoundabout: ifcRoad (PARTIAL)
  - CoolringelRoadway: ifcRoad (PARTIAL)

- Delftsestraat: ifcRoad

- Weena-Zuid: ifcRoad

- TramRoute8: ifcRailway
  - Meent2Pompenburg: ifcLinearSpatialSegment
  - Pompenburg2HofPlein: ifcLinearSpatialSegment
  - HofPleinTramReserve: ifcLinearSpatialJunction
  - HofPlein2Weena: ifcLinearSpatialSegment
Versions and changes

Alternatives
Versions can be handled differently, with more or less generality. The easiest thing is to just put a property that has a change date, but it does not provide history and traceability over the process.
A more complete management requires a structure with versions of the objects, linked to each other (see PLCS standard). In the Test Bed, geographical objects will also be managed and stored using the PLCS standard.

Suggestions for functionality in the platform
Build version and change management on the PLCS standard. Perform studies of whether and how geographical objects should be stored with version (in PLCS or in object-lifeline representation).
"Planned" is missing in the IFC - one is primarily concerned with design. But, for the built society, such a status designation is needed. These status determinations can be made when importing to the platform by selecting different import configurations/settings (stage, actor, etc.).
Life-cycle model

From a life-cycle perspective it is important to have an unbroken information flow.

The **different phases** of the life-cycle for a construction project and the construction itself need to be **represented by several objects, not just one, over time**.

- The **designed physical element**, fulfilling requirements through its function,
- The **product as planned** realizing the technical solution and finally,
- The **product as realized** with its serial number

![Diagram showing the life-cycle model](image)
Livscyle phases

Description

All stages and types of objects will be handled for detail planning, property development, construction, operation and management processes. Requirements management, design phases, types of items should be handled. It is difficult for the actors to address the requirements on the objects to be built when the requirements are usually presented in text documents instead of attributes associated with geographical or geometrical objects.

Requirements are own objects (in PLCS) and they should not be viewed as attributes associated with the objects. In the built society there are existing buildings and facilities - they occur at different stages of determination, production, operation and maintenance. Similarly, there are planning processes in progress covering different parts of the built society.

Suggestions for functionality

The phases can be handled by giving the objects in information models different phase relations to be able to follow their changes over time. Previous work in EU projects and standardization of PLCS for manufacturing and defense industries, as well as buildings to some extent, supports that PLCS is proposed as a platform for lifecycle management in the platform, see the following pictures:
### RIBA Plan of Work 2013

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Strategic Definition</td>
</tr>
<tr>
<td>1</td>
<td>Preparation and Brief</td>
</tr>
<tr>
<td>2</td>
<td>Concept Design</td>
</tr>
<tr>
<td>3</td>
<td>Developed Design</td>
</tr>
<tr>
<td>4</td>
<td>Technical Design</td>
</tr>
<tr>
<td>5</td>
<td>Construction</td>
</tr>
<tr>
<td>6</td>
<td>Handover and Close Out</td>
</tr>
<tr>
<td>7</td>
<td>In Use</td>
</tr>
</tbody>
</table>

### RIBA Outline Plan of Work 2007

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Appraisal</td>
</tr>
<tr>
<td>B</td>
<td>Design</td>
</tr>
<tr>
<td>C</td>
<td>Brief</td>
</tr>
<tr>
<td>D</td>
<td>Concept</td>
</tr>
<tr>
<td>E</td>
<td>Design Development</td>
</tr>
<tr>
<td>F</td>
<td>Technical Design</td>
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<tr>
<td>G</td>
<td>Information</td>
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<tr>
<td>H</td>
<td>Production</td>
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<tr>
<td>I</td>
<td>Tender</td>
</tr>
<tr>
<td>J</td>
<td>Action</td>
</tr>
<tr>
<td>K</td>
<td>Mobilisation</td>
</tr>
<tr>
<td>L</td>
<td>Construction to Practical Completion</td>
</tr>
</tbody>
</table>

### Preparation
- Data drop 1
- Data drop 2

### Design
- Data drop 3
- Data drop 4

### Pre-Construction

### Construction
- Use

---

**ISO 12000-2**

"Objects at different levels in the hierarchy are resolved at different stages in the project timeline."

<table>
<thead>
<tr>
<th>Construction Result</th>
<th>Construction Resource</th>
<th>Construction Object</th>
<th>Construction Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Complex</td>
<td>Construction Product</td>
<td>Construction Object</td>
<td>Construction Product</td>
</tr>
<tr>
<td>Construction Entity</td>
<td>Construction Product</td>
<td>Construction Object</td>
<td>Construction Product</td>
</tr>
<tr>
<td>Built Space</td>
<td>Construction Product</td>
<td>Construction Object</td>
<td>Construction Product</td>
</tr>
</tbody>
</table>

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**PLC Entities**

- Requirement
- Functional breakdown
- System breakdown
- Spatial element
- Physical element

**Generic product**

- Own object
- Own object

**Manufacturer specific product**

- Own object
- Own object
- Product as planned
- Product as realized
Type object to design object

Physical_element

Part

Physical_element_version

Part_version

Physical_element_definition

Part_view_definition

Breakdown_element_realization
ODEON - Wall-hung WC pan

Unique ref.: E1080
Tillverkare: Jacob Delafor
Produktfamilj: ODEON
Produktgrupp: WC
Höjd (mm): 540
Djup (mm): 360
Datum för publicering: 2016-12-01
Versionsnummer: 1
Typ: Object (single object)

Ladda ned
Type object to planned individual

Product_as_individual

Product_as_planned

Product_as_individual_view

Breakdown_element_realization

Part

Part_version

Part_view_definition

Product_as_planned will later be replaced by Product_as_realized
Product_as_planned will later be replaced by Product_as_realized
Unique identifiers - GUID

Description
Both the BIM world with the IFC standard and the GIS world with the Swedish geoprocess see unique identifiers as fundamental to the efficient identification and use of the information in the built society. It is a big question how we deal with identities between these two worlds.

Alternative
BIM, through buildingSMART for the IFC standard, has its GUID and Swedish geoprocess has suggested a UUID that is basically the same, but with another coding (can be mapped between each other). The Swedish geoprocess proposes the use of several different IDs for each application - GIS and BIM respectively.

Suggestions for functionality in the platform
The platform should only use one and the same GUID for the individual objects. They will be created at the source - which may / should be in, for example, a municipality when buildings are planned to be built and then forwarded to the builder for reuse in the design and production process and further to the operation.
Classification

Description
The new classification system **CoClass is now ready for use in Sweden**. It covers both buildings and facilities. It has an object division that is extensive and soon also property definitions. **CoClass is also intended to be used to identify components in different system structures.**

Alternative
**Use CoClass for pure classification of building objects.** Watch out for the impact of system structures on identity setting. Other identification applications (designation) are possible as identities can be generated based on the systems and breakdowns that exist in the buildings if they are modeled correctly.

Suggestions for functionality in the platform
**Build parallel structures according to the IFC Standard** (Building, Spatial Structural Elements, Space and Building) **also for facilities** (and other "building complex" such as railway stations).

The figure below shows a sports facility that should be structured in a similar way to a construction work. It should follow the structures of IFC - a breakdown from property to building and land, which is then broken down into a spatial and physical structure.
Sport arena, utility rooms and sport areas seem to be unstructured and mixed in this example?
Units

Description

*Different units are used for length measurements of tradition.* Architects have mm in their models and the National Land Survey has m in their coordinate systems. There are major sources of error in the use of different units of measure.

Alternative

*Decide that SI units shall be used* for all projects and to be *stored in the platform, and from there* being able to be convert to desired units if necessary.

Suggestions for functionality in the platform

*BIM models imported to the platform are converted* regarding units to *follow the SI units.*
Coordinate systems

Description
The question is which coordinate system will we primarily work in when designing? You can think of three variants:

• A national system Sweref 99 TM
• A municipal system - Local map projections by Sweref 99
• Alternative - construction site-specific coordinate system

Many people think we should store in geographic coordinates and then convert. The Swedish Transport Administration only has latitude and longitude on its elongated projects - within the BIM area it is included as part of the IFC standard. Swedish geoprocess requires the Sweref 99 TM to be used (at least in their building model).
In IFC 4 they are defined for the project origo using IFC 4 geolocation, which has the following structure:
Figure 1: Translation and rotation of Engineering System

\[
E_O = \text{IfcMapConversion} : \text{Eastings}
\]

\[
N_O = \text{IfcMapConversion} : \text{Northings}
\]

Abscissa = \text{IfcMapConversion} : X\text{AxisAbscissa}

Ordinate = \text{IfcMapConversion} : X\text{AxisOrdinate}

\text{EngineeringSystem} = \text{IfcGeometricRepresentationContext} : \text{WorldCoordinateSystem}

\text{WorldCoordinateSystem}
Linking

- The BIM world is linked to the ellipsoid by a fixed point and a known orientation.
- Map projections are determined by mathematical formulas, these vary depending on map projection.
Reference geometries

Description

The IFC standard provides reference geometries for the relative locations of the individual objects (building elements) in relation to the site's origin or other building elements. These reference geometries may be insertion points, lines and surfaces for all different building components. They define the origin and rotation of the current object. Similarly, in Swedish geoprocess according to Measurement Instructions, see examples below.
**Types – with versions**

**Description**
Designed objects in a construction work or facility *early get connected to a type object*, which can be found in the BIM software, in company databases or from special product libraries at various market players. *In the design and product development stages, the construction project naturally maintains these type objects in their administrative environment in any database.* In an operational phase, this changes as the types are "as-realized" and someone else takes over the responsibility for operation and maintenance.

**Alternative**
*The type objects can be connected to the platform for each building and maintained there.* An alternative is to replace the references in the platform with copied properties and geometries at the respective location in the model where they occur. There will be bigger models, but maybe easier to administer.

**Suggestions for functionality in the platform**
*The types are proposed to be linked to the respective construction works* and made searchable across the platform for the possibility of maintenance of a particular type in many places in, for example, a city.
LOD – Level of Detail for the Geo process

Description
The test beds should be able to keep information and geometry for the various objects that build the built society. Several different representations should be kept for both information and geometry using property sets and 2D / 3D models, respectively. On the GIS side, CityGML has its definition of LOD0, 1, 2, 3 and 4. For the BIM side, for example NIBS (USA) has its values 200, 300 etc.

Alternative
The LOD geometry on the building level (for Swedish geoprocess / CityGML) can be generated from BIM models (with appropriate software) or it can be created by using separate tools in the planning process to be independent of the design work. Determination of building components will be created in the design process and directly linked to the BIM objects.

Suggestions for functionality in the platform
Generate LOD 0, 1, 2, 3 and 4 from the BIM models when they are imported to the platform. Placeholders are created at the building level for geometries (and properties) classified as respective LOD level. The LOD descriptions for the Swedish geoprocess are linked to the relevant version of the building as the details are developed. FME is a candidate as a tool. The determination on the building level is imported via the BIM model and is linked to the respective stage and version.
OGCs Level of Definition
GIS standards vs BIM standards

BIM-model

Geodata-model

Element-based volume model (IFC)

Surface model (CityGML)

Source: Nagel och Kolbe
Terrain modell - granularity

Description

Construction projects need to handle masses. In the individual project you want to cut an area along the road or the block where you build. Excavations and fillings need to be provided with geometric descriptions, properties and at the same time identified and handled. The national terrain model (GSD Elevation Data) should be used. You should also bring back the new information with the new version for future use! What is the process like today for updating the National Height Data Base? Underground information also needs to be handled - different layers and sampling. SGU keeps that information today.

Alternative

Today there are different divisions in map squares with identities that can be used as a base. All the squares that you influence will be able to cut out and take into the design. A square division and reference system can be transformed with index systems based on the Sweref 99 TM. For detailed areas, the National Elevation Database is not sufficient which makes it necessary to use municipal or project-based data sets with better accuracy.

Suggestions for functionality in the platform

Base the terrain model on the property boundary and capture the terrain model within the property. The masses are object oriented in the same way as building elements and are classified and provided with properties for materials, etc. The terrain model is linked to site in the BIM model. In the platform it is linked to the appropriate division into the breakdown of country, counties and municipalities - see also the topology section.
Soil layers: Solid representation
Network and Road Alignments (IFC 4)

buildingSMART

Verifying IFC Alignment (1.1) & InfraGML – Sweden
Lars Wikström, bSI Summit Barcelona, 2017-04-05
Swedish Geo process

Smart planering för byggande
1. Underlag för planering
2. DP med byggrätt i 3D
3. BIM för redovisning av 3D fastighetsbildning
4. BIM för bygglöv och digitalt gränssnittsstöd
5. Återanvändning av relationsntningar till geodatabas

Process flows and information deliveries?
The roads, walkways, buildings, parks are imported from various converted formats into IFC models from the city of Eskilstuna 2015 by 4 Master students from Mälardalens Högskola.

An IFC BIM model has been imported into one of the parks to test versioning and planned buildings.
Object Instance: Wall

Building Element Construction Type: Vegg - 45+170 triangel sten, panel, 304 304
Building Storey name: Våning 2
Container Name: Våning 2
Container Object Class: Building Storey
Layer Assignment Name: A270—E: Håndtorgväggar
Name (original): uppsåke-lodrätt Mineralislit-diffusionspapper-hæklehytte, spkk-spr-fips, utvagg - 45+170 triangel sten, panel, 304 304
Name for BÅB 98 (classification): VV 02
Name: VV 02
Object Class: Våg
Produced type (type): NOTDEFINED
Tag (type): 26B5E40C-07B8-1B63-414A-6FB83D84EB43
Tag:
4D40D8B9-7AC5-C443-600E-64A0D4EE4AF8

Hold down Ctrl+Ctrl+Shift to see more properties.
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Thank you!