BIM and GIS

Digital Terrain Models, Topographic Information Models, City Models, Formats and Standards

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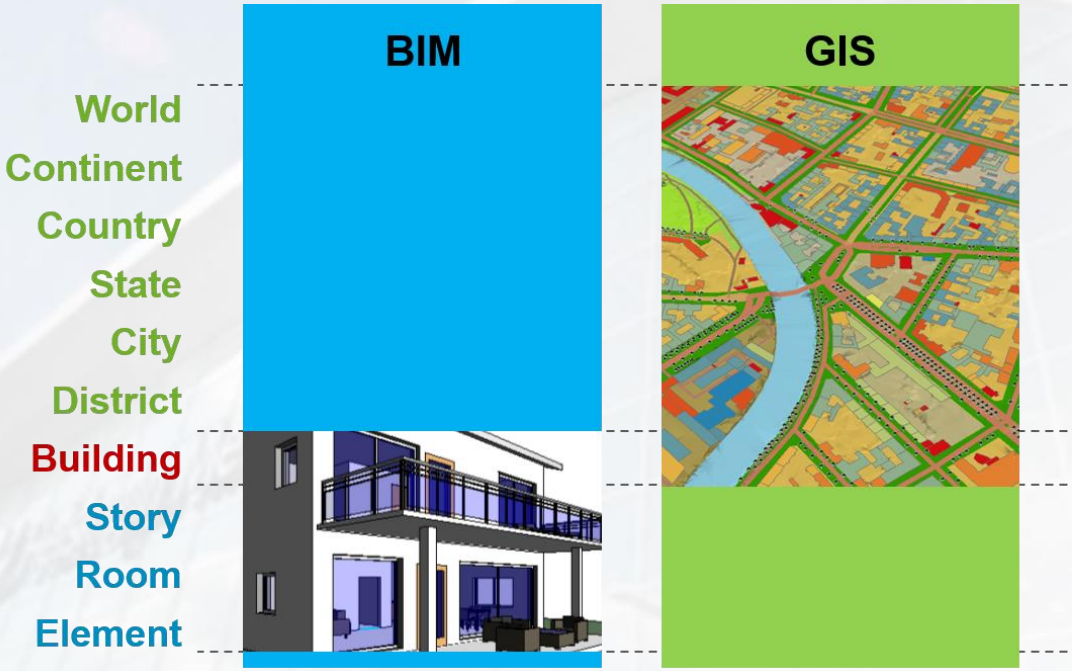
Motivation BIM and GIS Integration

Locate planed buildings within the regional/global context

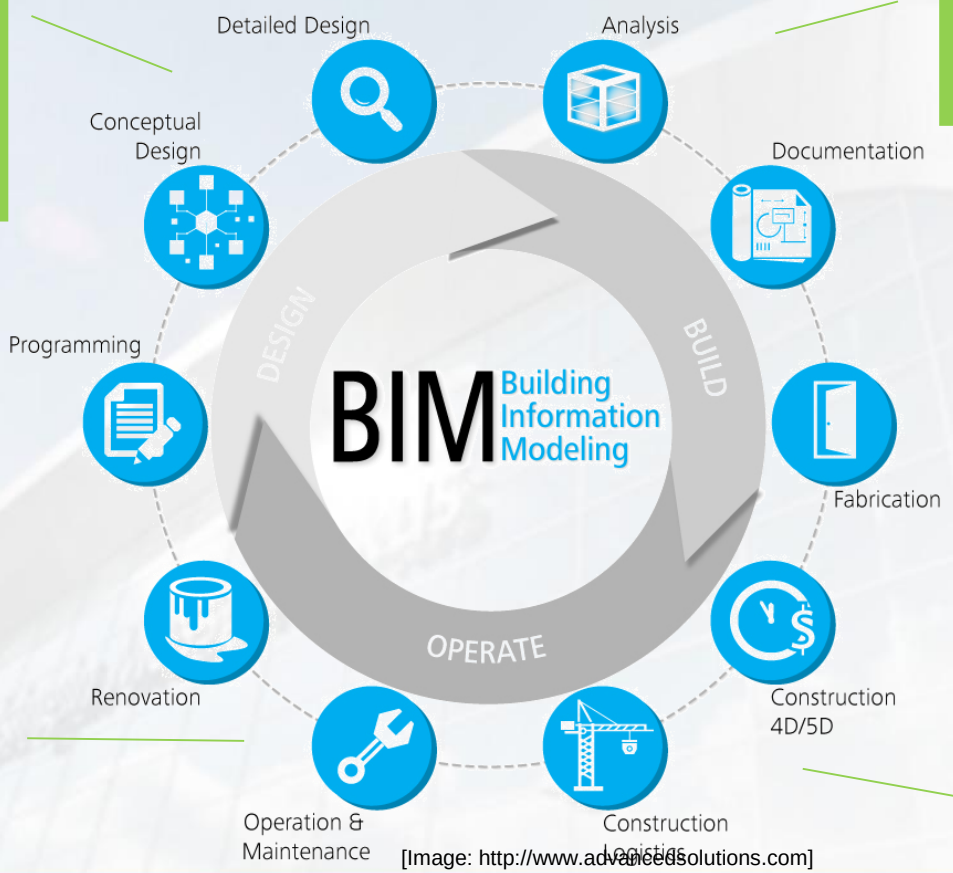
- To make use of available geodata within the design and planning phase
- To gain correct stake out data for surveying work on the building site



Examples for BIM and GIS Integration

Planning of building an infrastructure projects using geodata (e.g. DTM), georeferencing

Analyses and visualization of planned buildings within the urban context (Geodesign)



[Image: http://www.advancedsolutions.com]

Management of supply and disposal, rescue management

Supporting construction site logistics, gain surveying data

BIM GIS Integration Considerations

- **Modelling Paradigm**
- Geometry Representation
- Scales
- Standards
- Georeferencing

GIS World
vs.
BIM World

Modeling Approach Geoinformatic

- Top-Down: Real world→ Surveying → 3D Model
- The aim is the **correct representation of the real world**
- In general, only object surfaces are observable
- **Virtual 3D City Models:** Modeling of semantic objects with spatial and non-spatial properties (e.g.: CityGML)

http://www.dresden.de/media/bilder/vermessung/Canalettoblick_3d_2015_OhneLogo.png

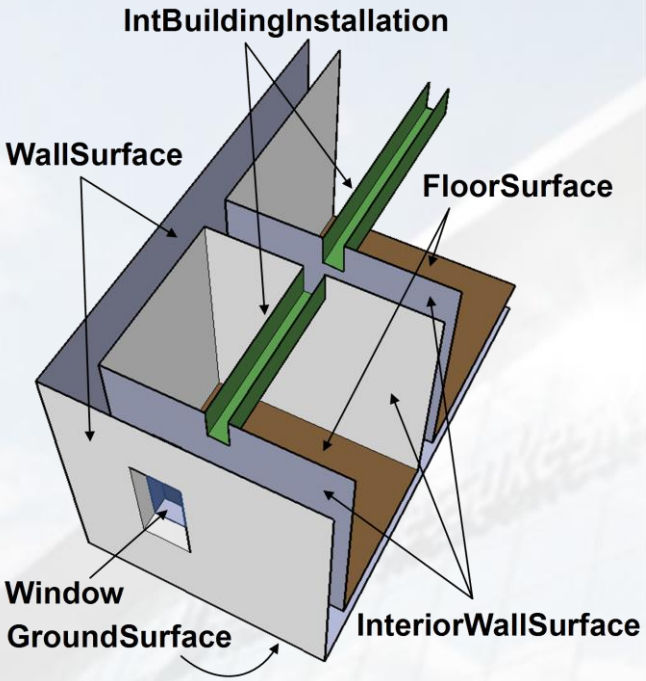
Modeling Approach AEC / CAAD

- Bottom-Up: Idea for a Building → Design model/plan → real world
- Aim is the **correct Representation of the planed world**
- Representation of construction elements, component based
- **Building Information Model (BIM):** Modeling of semantic objects with spatial and non-spatial properties (e.g.: IFC)

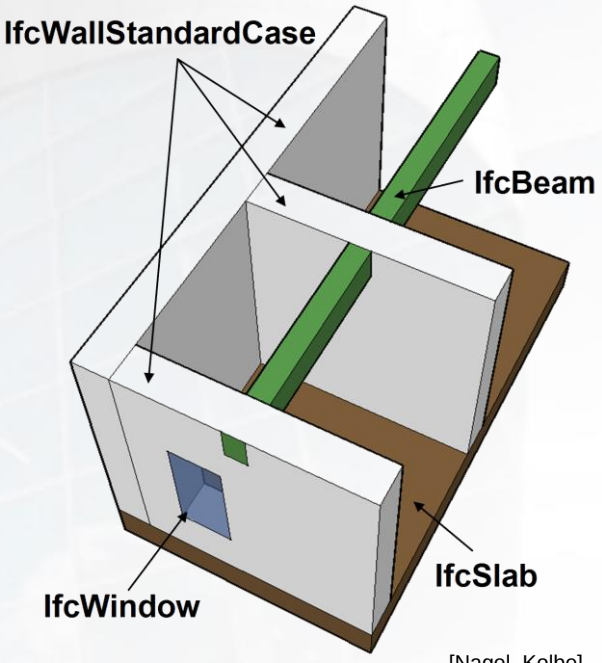
http://www.tweesnoeken.nl/default.asp?pageId=433

Modeling Approach by Comparison

GIS World
(Example: CityGML)



BIM World
(Example: IFC)



[Nagel, Kolbe]

BIM GIS Integration Considerations

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Geometric Representation of 3D Objects

GIS World

Boundary Representation (B-Rep)

Aggregation of all surfaces surrounding the volume

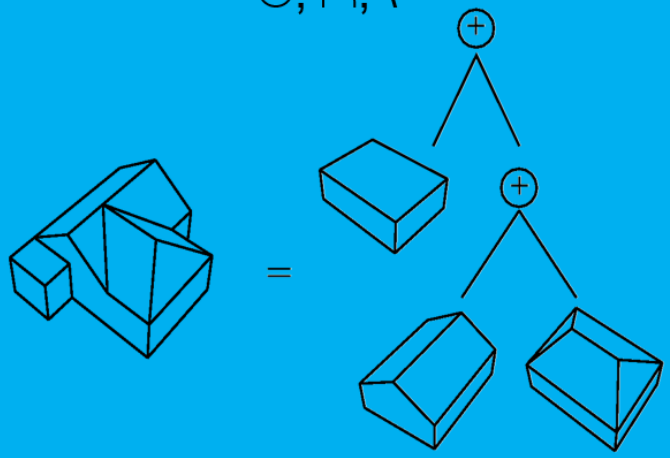
Especially suitable for acquisition from observations (measurement)

BIM World

Parametric, Sweep, CSG

Combination of volumetric objects by Boolean operations

$\cup, \cap, \setminus$



Particularly suitable for design and construction planning

BIM GIS Integration Considerations

- Modelling Paradigm
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- **Scales**
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GIS World
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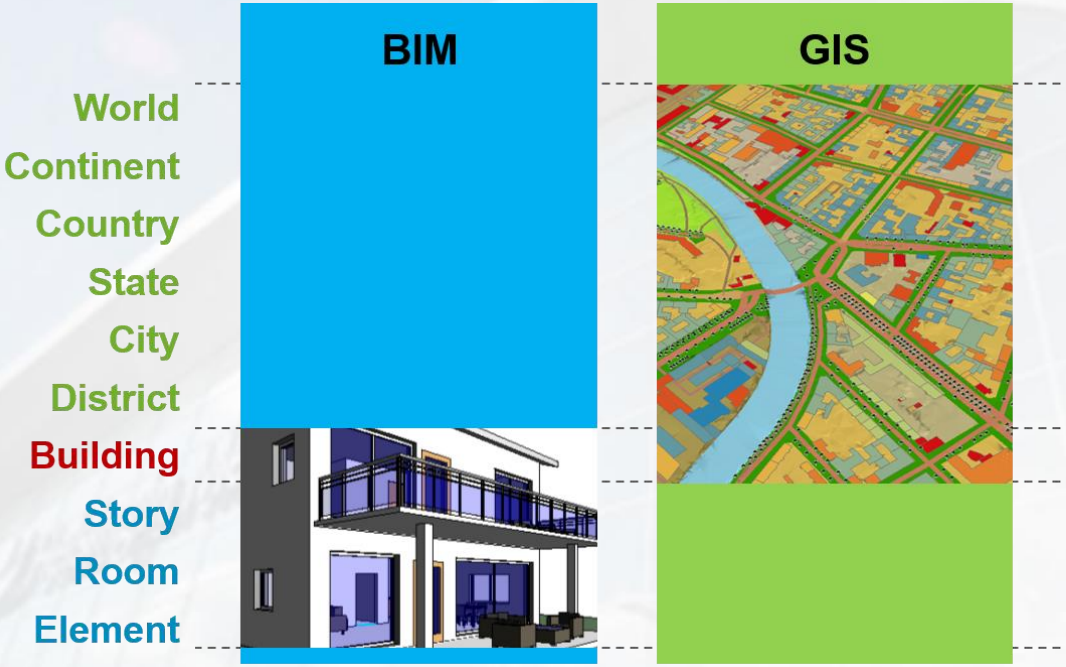
BIM World

Scales

Model content, resolution, structure and accuracy depend on:

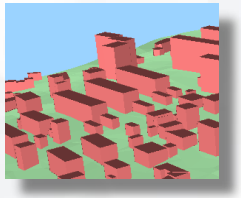
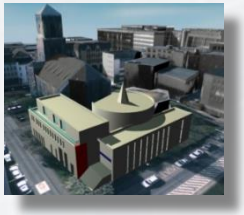
- Thematic focus or application context
- Spatial extent



Multi Scale Modeling in GIS

Different Levels of Detail (LOD) in order to handle the large scale range in GIS

- LOD 0 – Regional model
  - 2.5D Digital Terrain Model
- LOD 1 – City / Site model
  - "block model" w/o roof structures
- LOD 2 – City / Site model
  - textured, differentiated roof structures
- LOD 3 – City / Site model
  - detailed architecture model
- LOD 4 – Interior model
  - "walkable" architecture models

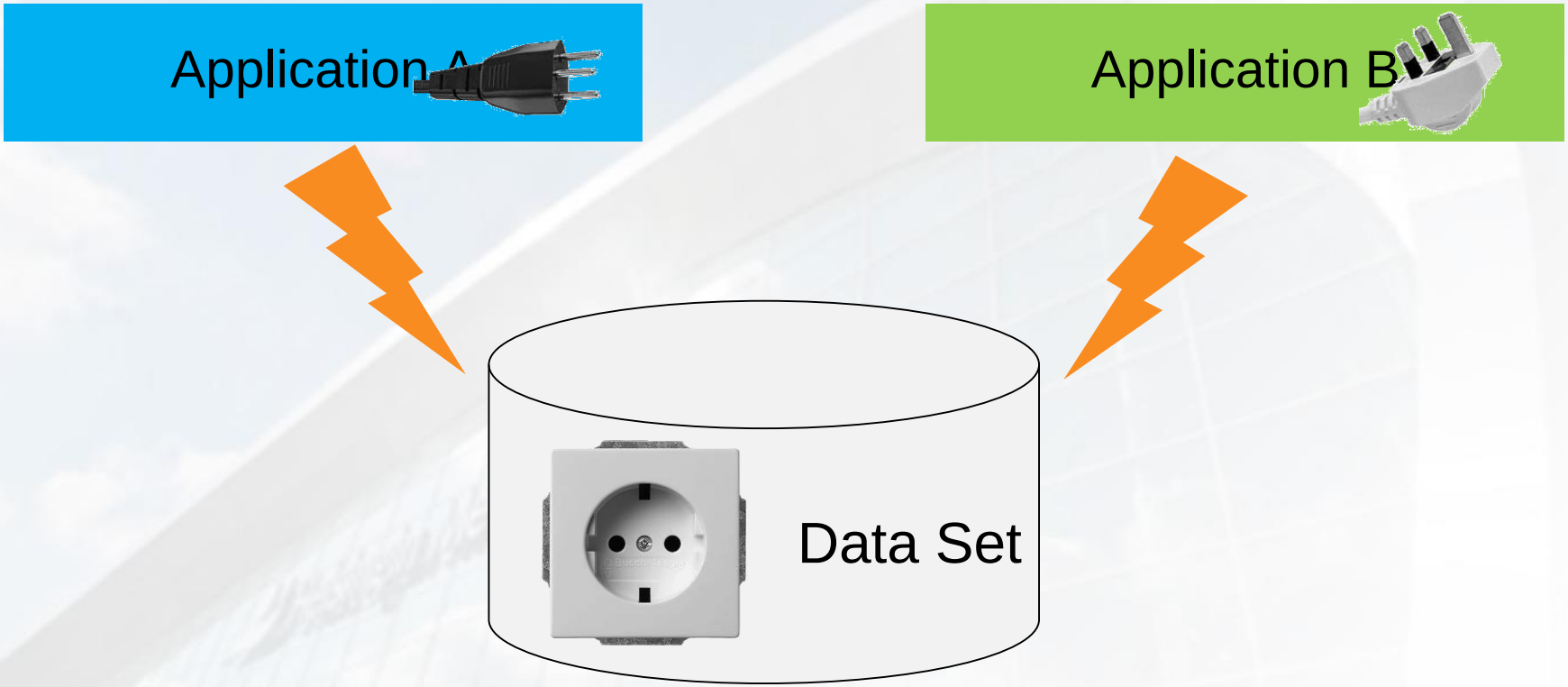
BIM GIS Integration Considerations

- Modelling Paradigm
- Geometry Representation
- Scales
- **Standards**
- Georeferencing

GIS World
vs.
BIM World

Standards are the key…

…for sharing a data set (model) for the common use in different working domains and software

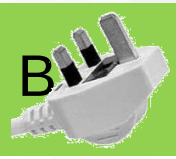


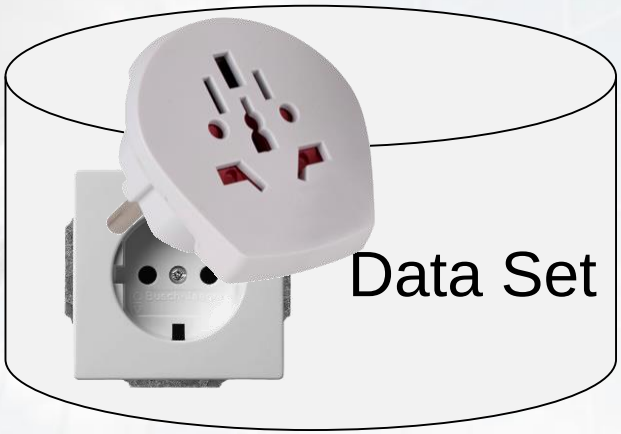
Standards are the key…

…for sharing a data set (model) for the common use in different working domains and software

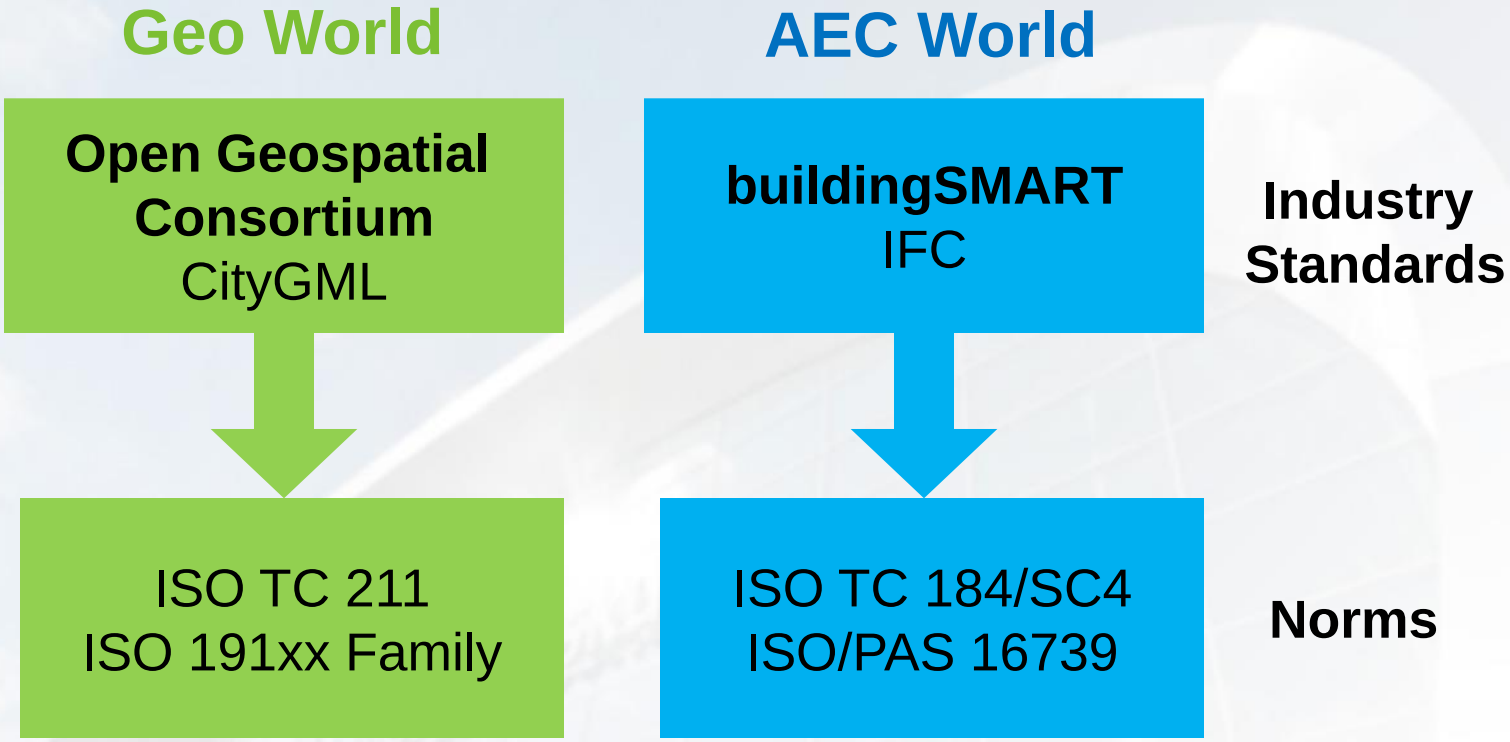
Application A

Application B





3D Standards and Organizations



Use of different modeling languages

- IFC (EXPRESS) and CityGML (UML)

City Geography Markup Language (CityGML)

- Domain independent topographic data model and exchange format **for 3D virtual city and landscape models**
- Includes various thematic areas (buildings, vegetation, relief, water, traffic, land use, etc.)
- Representation of Geometry, Topology, Semantics and Appearance
- International standard of the Open Geospatial Consortium
  - Primarily specified by the SIG 3D of the GDI NRW
  - Current version 2.0 was adopted in March 2012
- Nationwide used by the state authorities in Germany
- Used in many cities world wide
- Exchange format is based on XML

CityGML

Industry Foundation Classes (IFC)

- Comprehensive data model and exchange format **for Building Information Models** (BIM)
- ISO standard 16739 for semantic building models
- Developed by the buildingSMART International
- Representation of building models based on their geometry, topology and semantics
- Integration of different balances, i.e. material, costs, etc.
- No representation of (graphical) appearance
- Exchange formats:
  - Based on STEP
  - IfcXML is XML-based

Comparison of common GIS and BIM Data Models

	Surveying / GIS					AEC / BIM	
	X3D	COLLADA	KML	Shape	CityGML	DXF	IFC
general purpose / information model	gp	gp	gp	gp	im	gp	im
3D geometry	+	+	•	•	+	•	++
georeferencing	+	•	•	+	++		•
appearance	++	++	•		+		•
3D topology	•	•			+		+
semantics	•	•	•	•	++		++
levels of detail	+	+	•		++		•
links/embedding	+	++	++		++		
extensibility	+	++	+		++		•
fast rendering	++	++	+	+	+	+	• /+

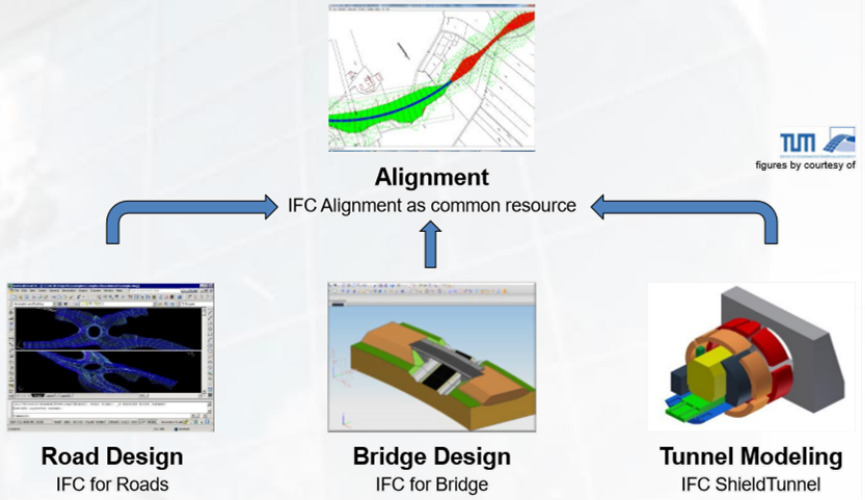
Legend: • = basic, + = sophisticated, ++ = comprehensive; empty = not supported

[Kolbe, Kaden]

Common Developments of OGC and bSI

Open Geospatial Consortium (OGC) and buildingSMART International (bSI) are developing future concepts in consultation:

- Participation of bSI in further developments of CityGML material
- Collaboration of the OGC for defining further IFC coordinate operations IfcCoordinateOperation for the georeferencing of BIM projects
- Collaboration of the bSI Expert Group IFC Rail / IFC Road with OGC LandInfra Group for the development of the Alignment concept for modeling of infrastructure projects with BIM



Liebich, T. (lead), Amann, J., Borrmann, A., Chipman, T., Lebegue, E., Marache, M., Scarponcini, P.; Model Support Group

BIM GIS Integration Considerations

- Modelling Paradigm
- Geometry Representation
- Scales
- Standards
- **Georeferencing**

GIS World
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Problem: Different Coordinate Systems

BIM

- Bottom-up approach: idea for a building → design model/plan → real world
- The aim is the correct representation of a planned building
- Representation by relative placement of constructive elements (component-based, generative)

→ Local Project Coordinate System (PCS, WCS)

GIS

- Top-down approach: real world objects → surveying → 2D/3D model
- The aim is the correct representation of real world objects
- Representation by absolute positioning of topographic elements located on the earth surface

→ Regional/global Coordinate Reference System (CRS)

Important Coordinate Characteristics

The following coordinate characteristics of the PCS and CRS must be considered when:

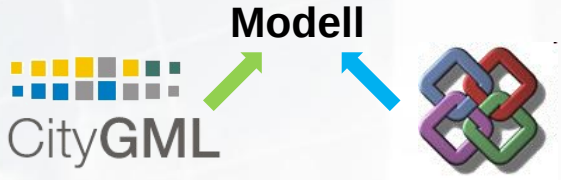
- Integration BIM projects with GIS data
- Obtain survey data from a BIM project

	PCS (e.g. local WCS)	CRS (e.g. ETRS89/UTM)
Linear Unit:	Arbitrary	Meter
Scale/Coverage:	Local (limited)	World
Zone Limitations:	No	Yes, by fixed zones
Number of Digits:	Small numbers (Origin close to the project site)	Large numbers (7-8 before and 2-3 after decimal point)
Projection Distortion:	No (1:1)	Yes (up to ~ 400ppm)
Height Distortion:	No	Yes

Examples of BIM GIS Integration

Example 1: Integrating CityGML and IFC

- Model transformation between CityGML and IFC
  - Visualization largely without problems
    - Use generic IfcProxy with IFCFacetedBrep
    - Complex parametric geometries according to B-Rep. difficult
    - Tools available (for example, BIM server plug-in for CityGML export)
  - Semantics difficult / sometimes impossible
    - n:m matching between surfaces and construction components
    - Almost no constructive elements in CityGML
    - Complex volume creation from B-Rep.
    - 1:n matching between construction components and surfaces
    - Not all IFC concepts can be mapped → Information loss
- Common superordinate model
  - E.g. "Unified Building Model" [El-Mekawy et al.]
  - Superset of IFC and CityGML concepts
  - Basis for bidirectional transformation
- Coupling/linking data models
  - On application, process, or data level



Coupling / Linking BIM with GIS Data

- Promising concept for the integration of BIM and GIS data content
- Preservation of the different modeling aspects
- State of research (selection):
  - COINS (Construction Objects and the INtegration of Processes and Systems)
    - Standard for exchanging digital information in the field of BIM
    - Creates coherent information package with several data formats, e.g. GIS (CityGML, Shape) and BIM (Revit, IFC, DWG)
    - COINS version 2.0 released in April 2016
  - EeEmbedded-Project (Dresden University of Technology)
    - Includes an ontology-based link model for integrating external information into BIM

Example 2: Import LandXML DTM into Revit

1st possibility: Parsing the LandXML file using Dynamo

- Import the LandXML file into Dynamo using a Python script
- Parsing LandXML to get all points and faces of the DGM
- Using the Dynamo node Topography.ByPoints to generate a topographic surface using a point list
- No break lines are possible in Revit
- Point density can be increased by implementing a interpolation routine

```
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```
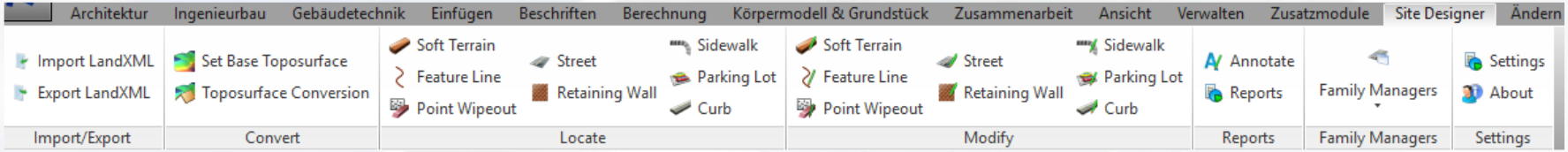
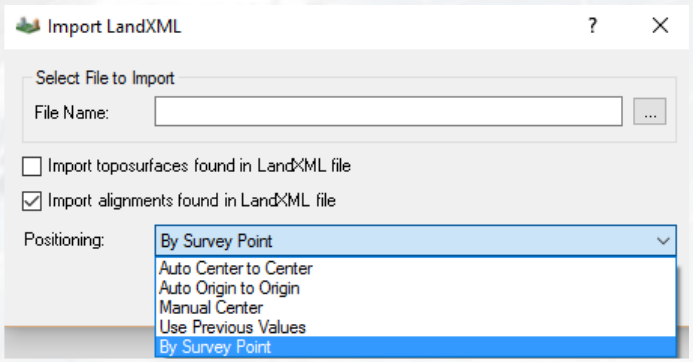

Example 2: Import LandXML DTM into Revit

2nd possibility: Using the Revit SiteDesigner plug in

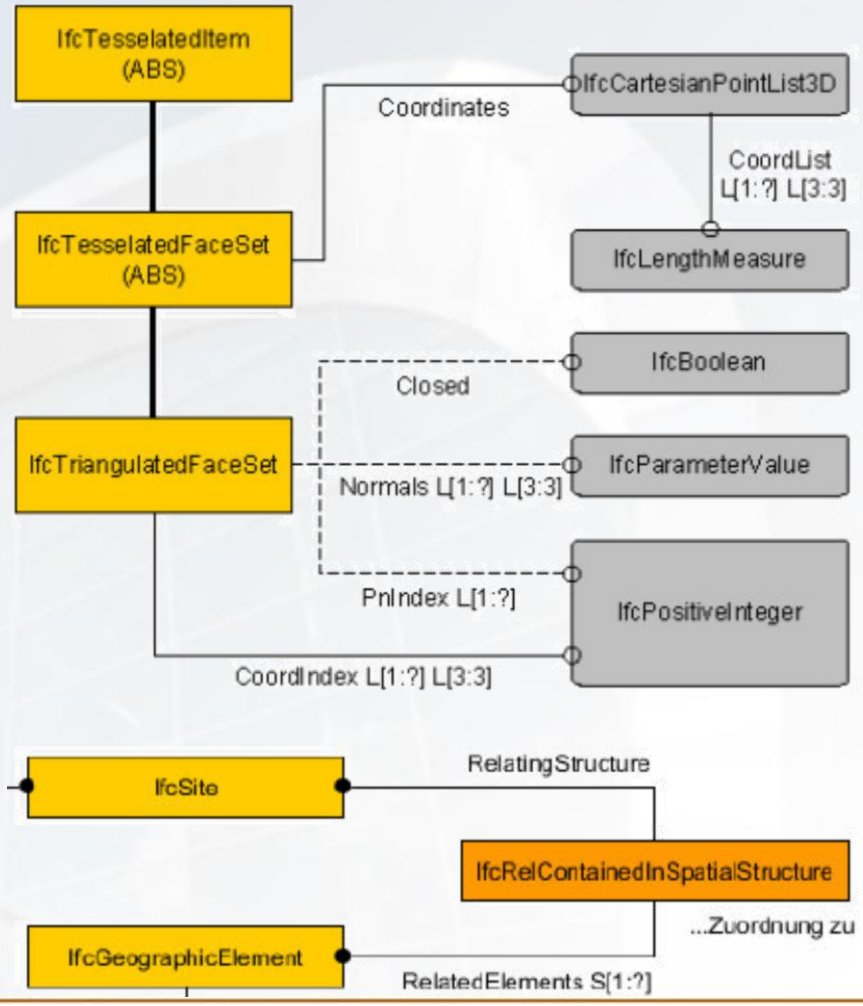
- Allows direct import of LandXML files
- Generate topographic surfaces including sub-surfaces like parking slot, road, path
- No possibility to manipulate point density





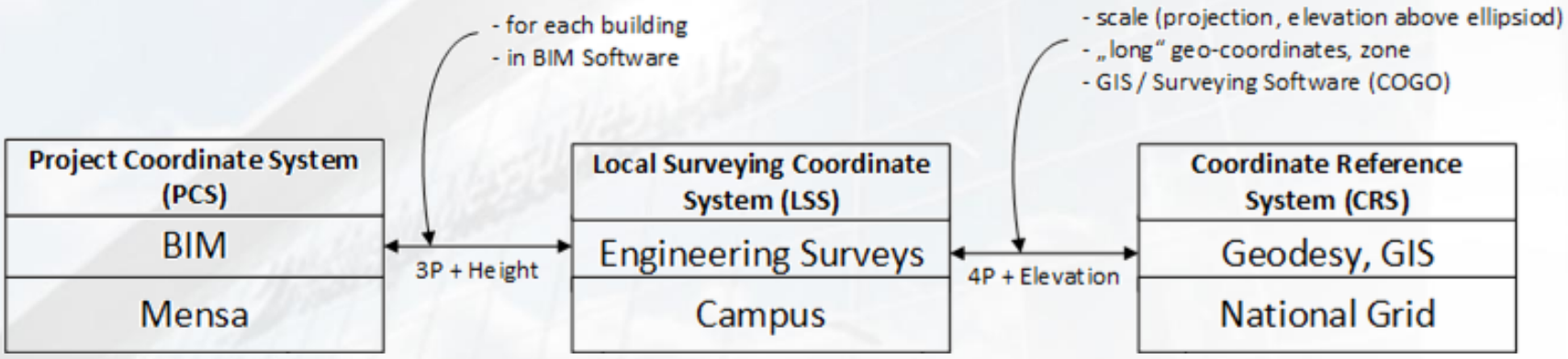
Example 3: Representation of a DTM in IFC

- Geometric representation of tessellated surfaces using the *IfcTesselatedItem* which is a specialized class of the *IfcGeometricRepresentationItem*
  - The attribute *Coordinates* of the class *IfcTesselatedFaceSet* represents the point list of the surface
  - The attribute CoordIndex of the *ifcTriangulatedFaceSet* class represents the list of triangles
- Semantic representation of the DTM using the class IfcGeographicElement which is subordinated to IfcSite



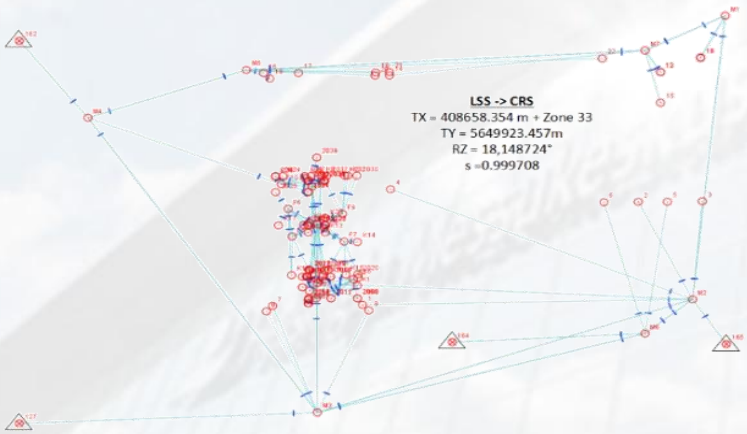
Example 4: Georeferencing in Revit

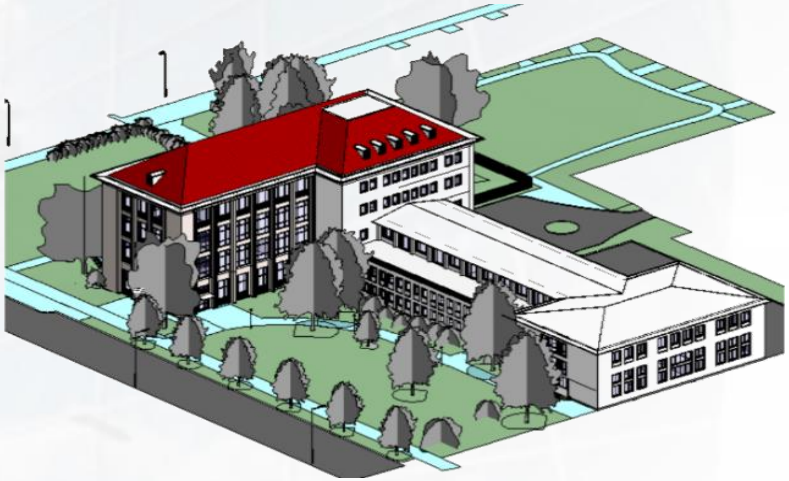
- Given: Autodesk Revit BIM project of the university (Mensa building)
- The intermediate Local Surveying Coordinate System (LSS) between the BIM PCS and the national CRS has been introduced
  - Provides a common reference system and frame with scale=1 and short coordinate values
  - Allows to integrate multiple BIM projects (e.g. Mensa building, Building A, Building B)
  - The LSS is than georeferenced to a national CRS



Configuration of the LSS

- In order to spatially link the LSS and the PCS, a set of identical points was defined and measured
- This control points are specified in the BIM model and as natural targets of the engineering survey outside and inside the building
- Control points are used to carry out georeferencing of the BIM model using Revit functionalities

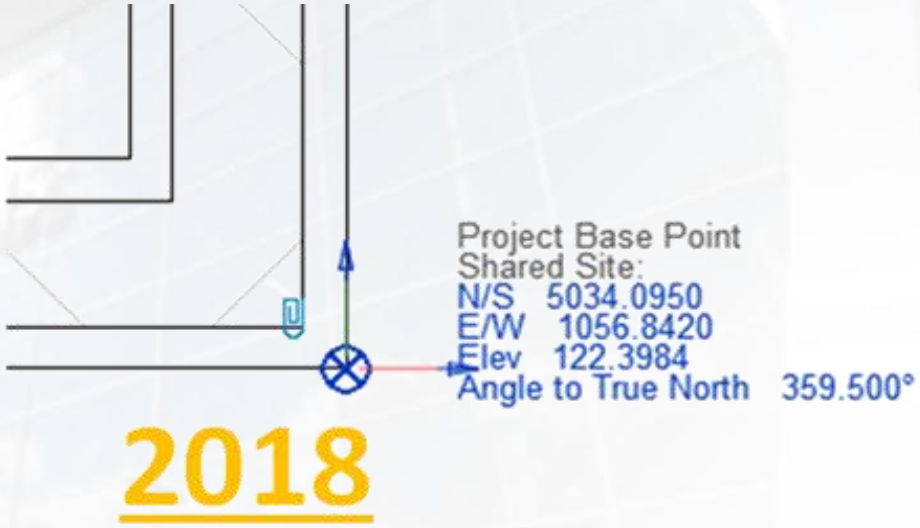




Georeferencing Using Revits Project Base Point

- A BIM model can be georeferenced by moving the Project Base Point (PBP) to a control point with known coordinates in the higher-ranked system and then rotating the system manually

1. Unclip and move the PBP to the well identifiable corner within the building model which corresponds to the pre-measured control point #2018 using the point snapping function
2. Clip the PBP and assign the LSS coordinates of the point #2018 to the PBP properties
3. Insert the pre estimated azimuth angle of 359.5° to the PBP properties



Georeferencing Using a CAD File

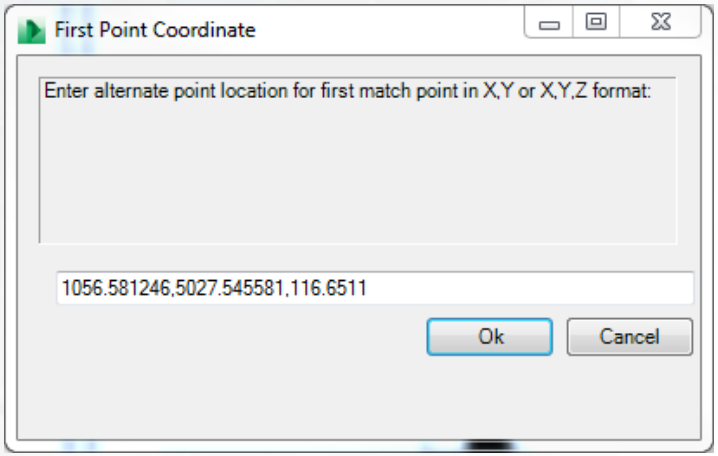
- A BIM model can be georeferenced by acquiring the LSS coordinates from a CAD file containing measured lines and polygons of the building elements

1. Link the CAD file to the Revit project using Revit linking functions
2. Placed the CAD elements (yellow) in the BIM Model (black) graphically by using the “move” and “rotate” tools as well as “Line Snapping” tool
3. Use “AcquireCoordinates” to assign transformation parameters between the Revit PCS and the LSS to the Project Base Point

Georeferencing Using the Plug-In Point Layout

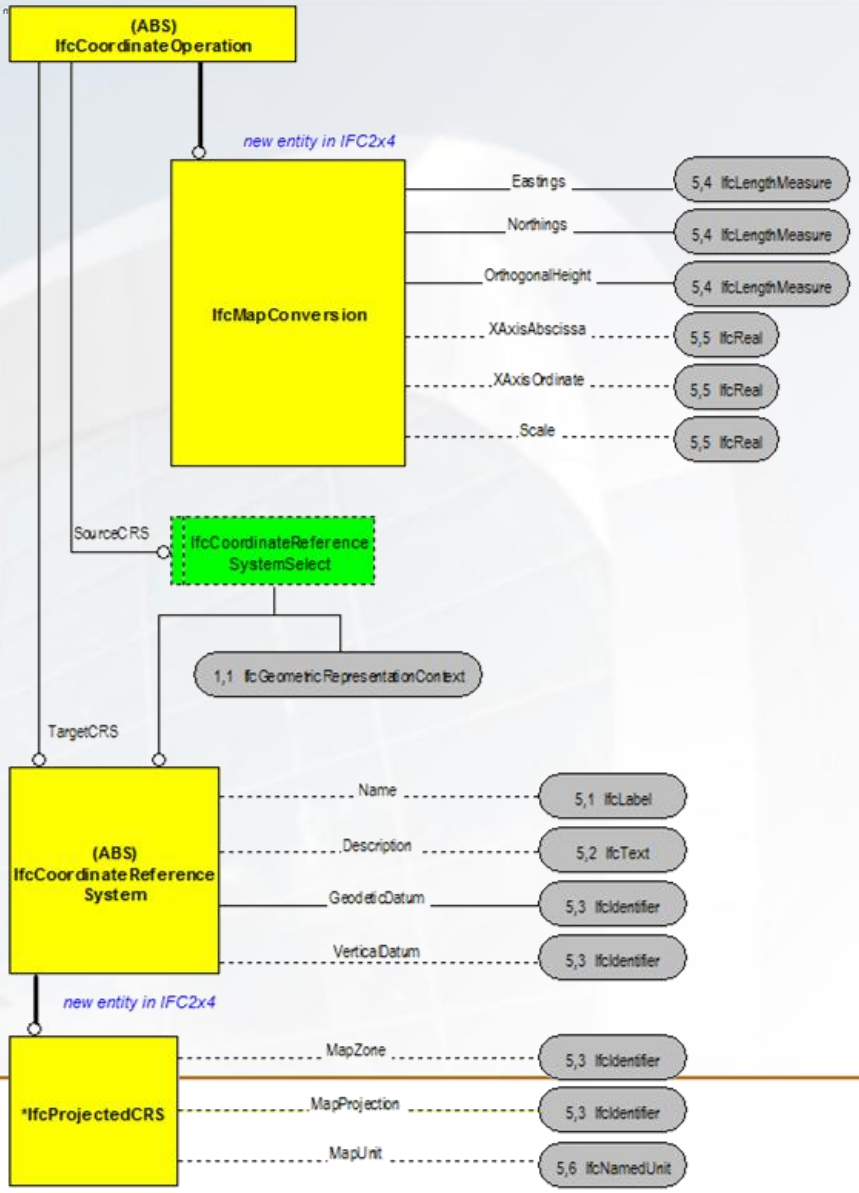
- Plug-in “Autodesk Point Layout” (APL) provides functionalities for the surveyor’s work within the BIM, i.e. assigning the transformation parameters from the Revit PCS to the LSS

1. Start the APL tool “Coordinates”
2. Select the desired unit (e.g. meter, millimeter, feet)
3. Click on two control points and enter the corresponding LSS coordinate values
4. The azimuth of the transformation is determined from coordinates



Example 5: Georeferencing Using IFC

- Georeferencing a IFC project using the IfcSite element
  - A single reference point with WGS84 coordinates (Longitude, Latitude and Elevation) can be defined
  - This point defines the origin (0,0,0) of the LocalPlacement of all other objects which are hierarchically below, e.g. IfcBuilding → relative positioning w.r.t. the local system of the site element
- Georeferencing a IFC project to any other CRS (other than WSG84) using the IFC elements IfcCoordinateReferenceSystem and IfcMapConversion



Conclusion

- **Common use of GIS and BIM** data supports a holistic planning during all BIM lifecycle phases
- Integration of GIS data in BIM projects **requires a comprehensive consideration of characteristics** such as modelling paradigms, geometry representation, scales, standards and georeferencing and is not straightforward for all cases
- The worlds of BIM and GIS are about to **move towards** each other
  - Ongoing research on system and data integration methods
  - Common and matched developments of bSI and OGC
- Available BIM software and data models **provides more and more GIS integration functionalities**
  - Autodesk Revit's georeferencing functionalities and the SiteDesigner for integrating and modeling topographic terrain
  - Autodesk NAVISWORKS and INFRAWORKS provides functionalities to integrate large GIS data
  - Since IFC 2.4, a simple geodetic georeferencing is possible to exchange building models w.r.t. its location on earth