



# **GeoBIM benchmark results: Options for geo-referencing IFC**

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# Disposition

- 1) Coordinate systems used for geographic data and in GIS
- 2) Coordinate systems used for BIM data
- 3) Georeferencing elements in IFC files
- 4) Georeferencing a BIM model
- 5) Georeferencing in a BIM program – Revit
- 6) Result of the Testbench – task 2



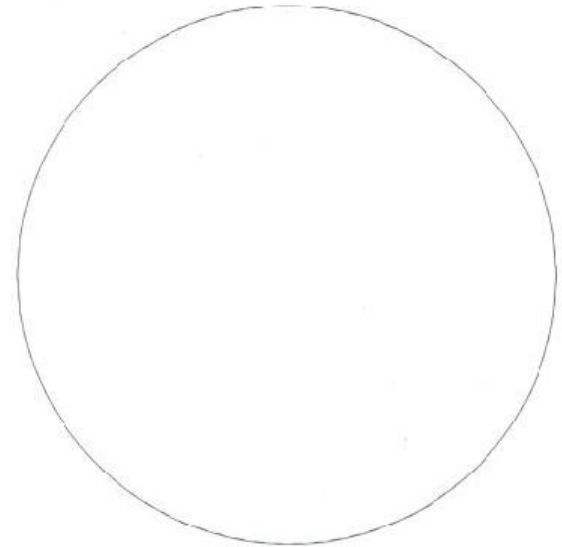
# 1. Coordinate systems used for geographic data and in GIS



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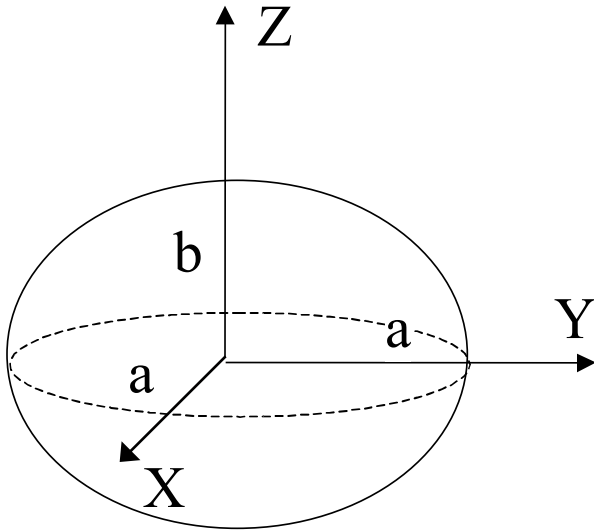
# The Earth is *almost* a sphere

A sphere (solid line) and  
the GRS80 ellipsoid (dashed line)



# Ellipsoidal earth model

- used for all geographic data today



The form of the ellipsoid is given by the constants:

$a$  = semimajor axis

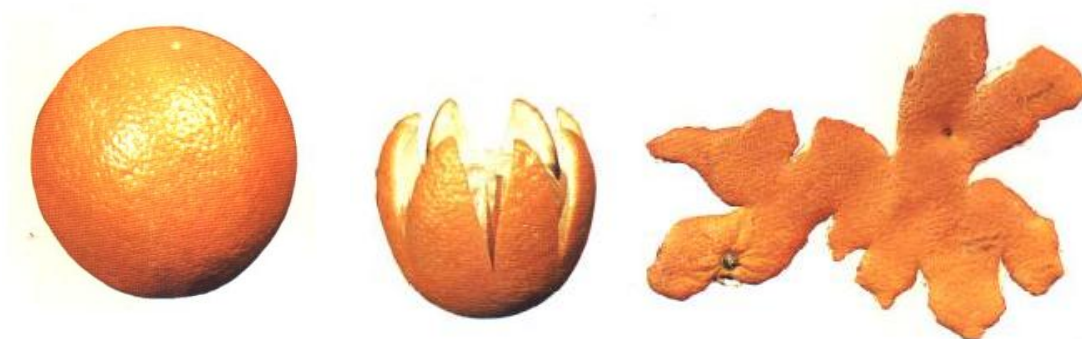
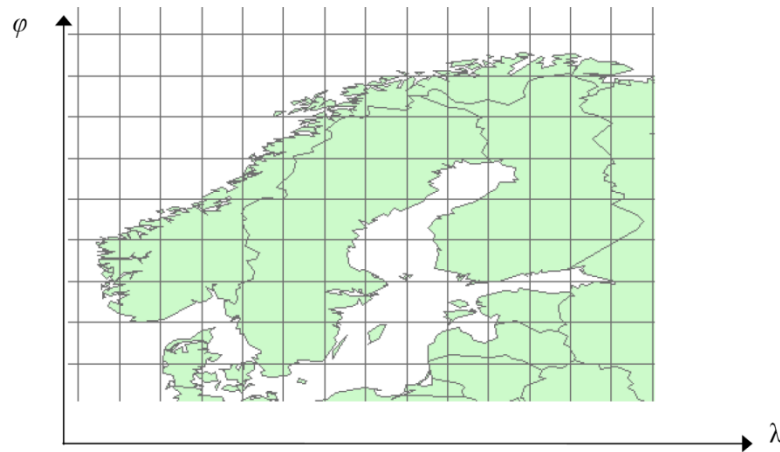
$b$  = semiminor axis

*Position on the sphere is provided by:*

*Longitude ( $\lambda$ )*

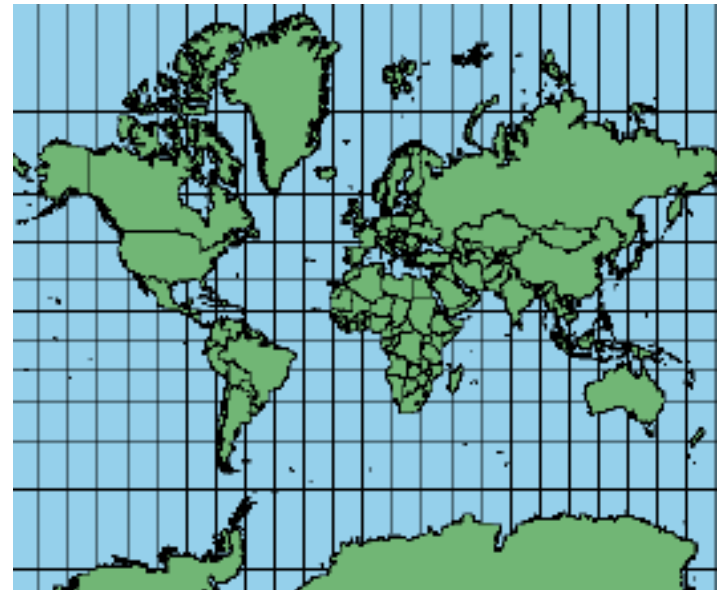
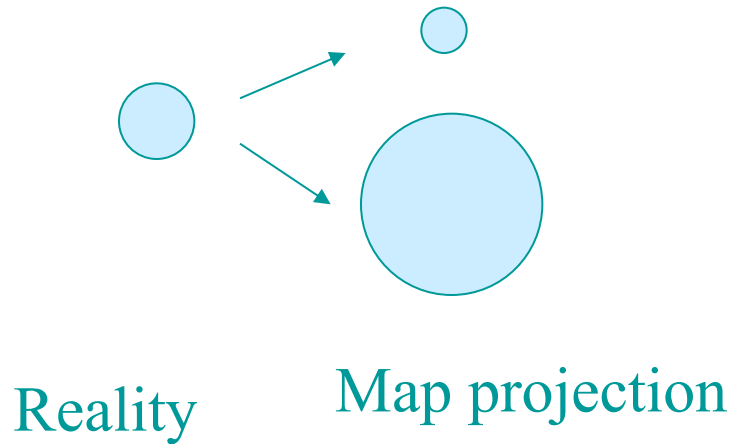
*Latitude ( $\varphi$ )*

# Map projections to provide planar coordinate system



# Conformal

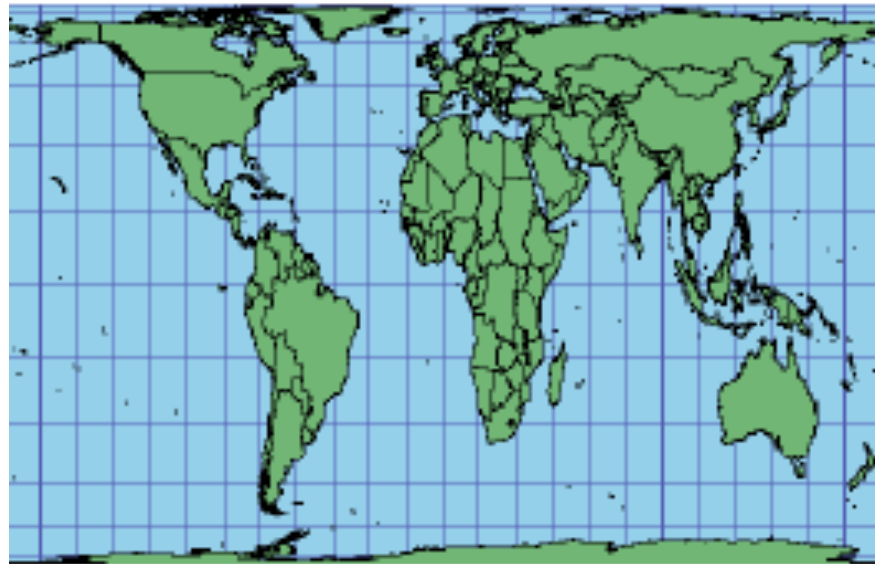
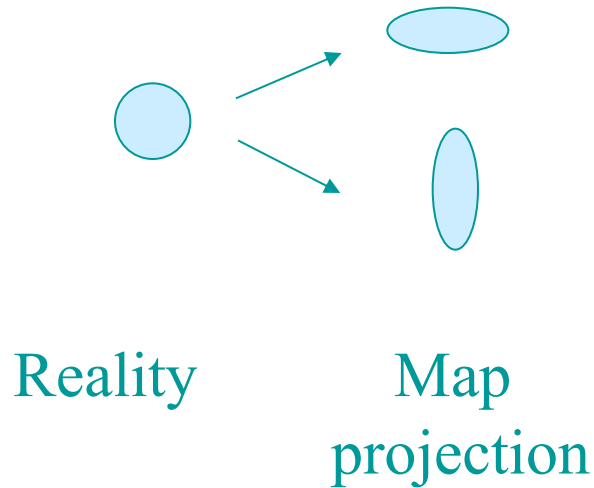
Preserve the local shapes (angles). The relative size of geographic features changes



# Equal area projection

Preserve the relative sizes of geographic features.

Distort the shape of features.





# Recommended map projections by Inspire

Spatial analysis for statistical data, etc:

*Lamberts azimuthal area preserving projection*

Small scale mapping (less than 1:500 000):

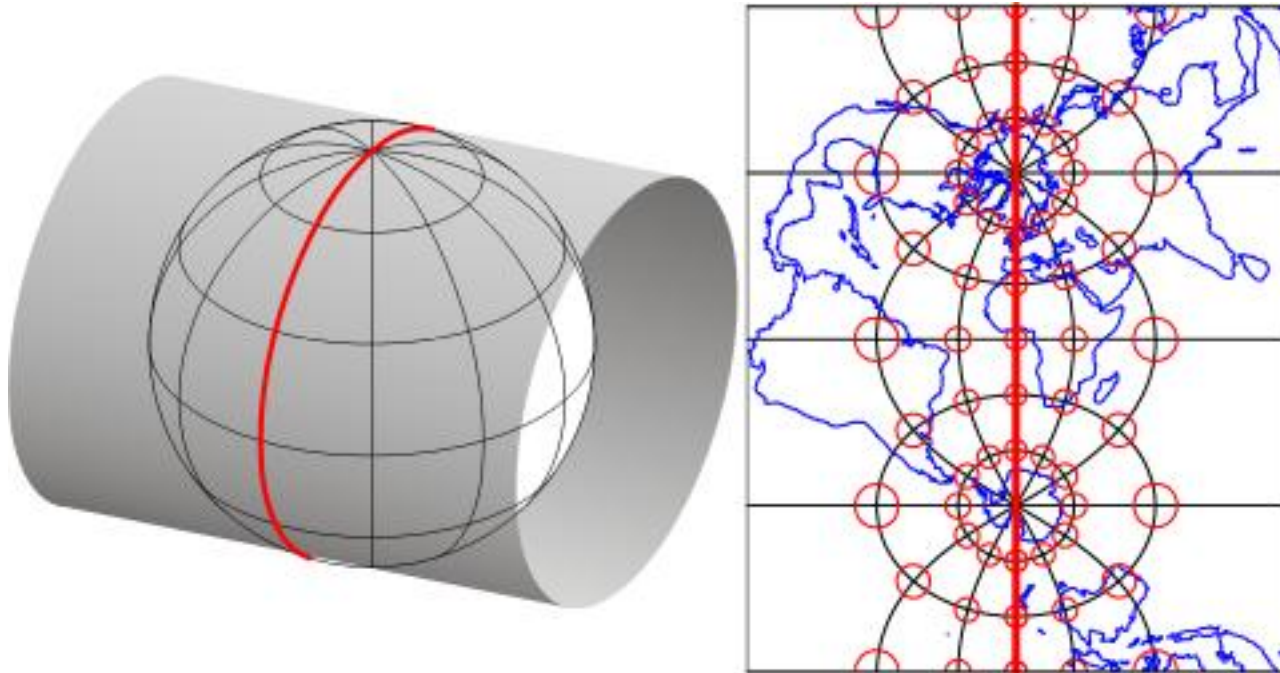
*Lamberts conical conformal projection*

Large scale mapping (larger than 1:500 000) :

*Transversal Mercator (Gauss Krügers projektion),*

*UTM with a suitable zone.*

# Transverse Mercator

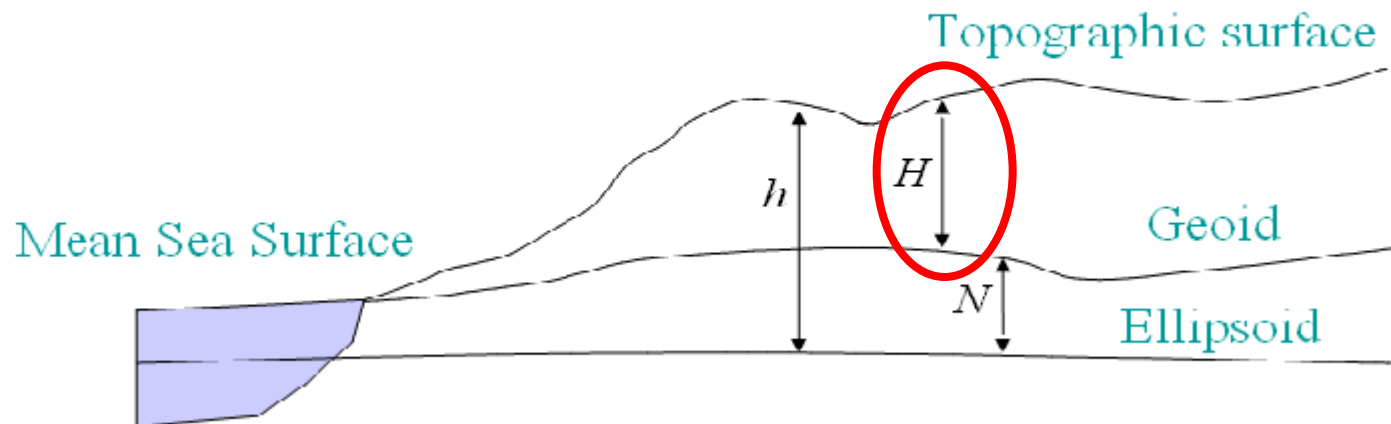


Source: Penn state University

[https://www.e-education.psu.edu/natureofgeoinfo/c2\\_p22.html](https://www.e-education.psu.edu/natureofgeoinfo/c2_p22.html)

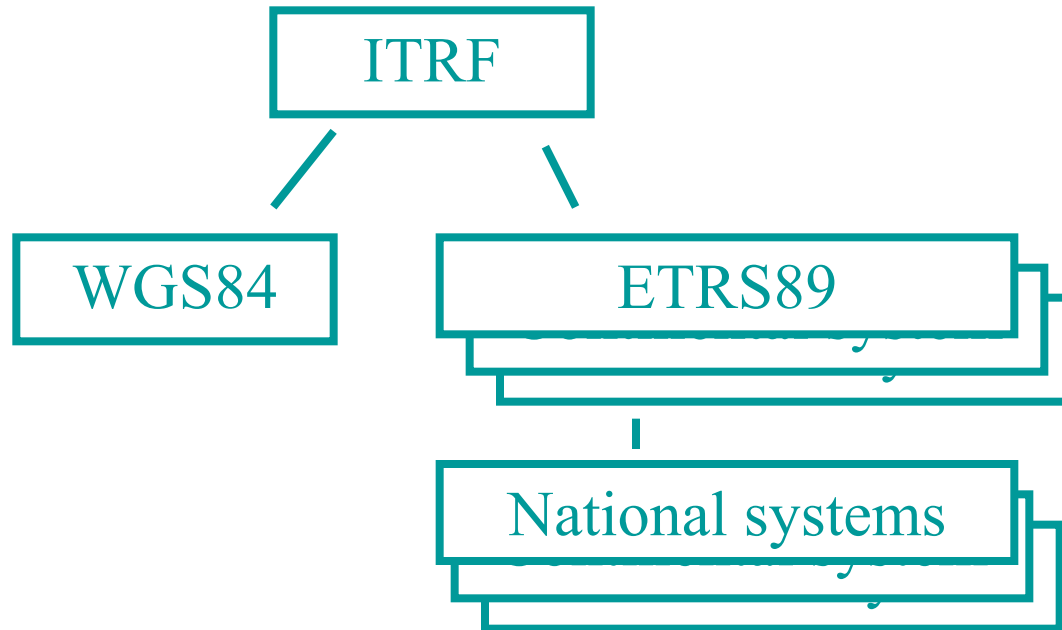
# Orthometric heights

- Defined as the height above the geoid.
- Is called *height above sea level* in daily speech.
- Height axis follows the plumb line and is not perfectly perpendicular to the map projection plane.



In reality are often normal heights used, but we skip the details here...

# Examples of earth-centred geodetic reference systems



# Coordinate reference system (CRS) for the reference point for Myran

Reference system: SWEREF 99 (Swedish implementation of ETRS89)

Map projection: Transverse Mercator, with parameters ...



Coordinate system: SWEREF 99 15 45

EPSG code: EPSG::3013

Height system: RH 2000

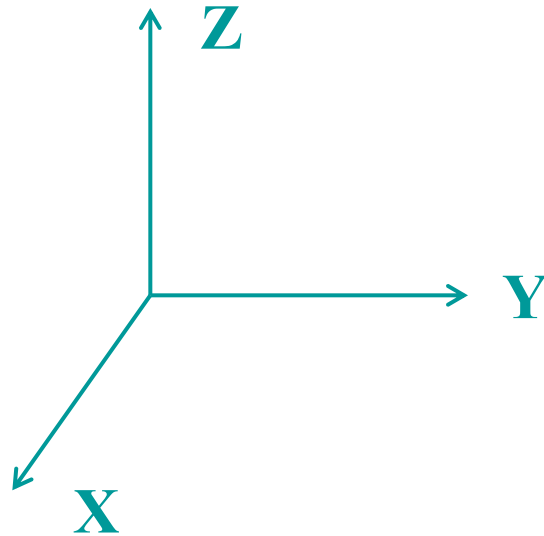
## 2. Coordinate systems used for BIM data



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# Engineering system 3D Cartesian system

- The world is flat
- Scale is constant
- Z-axis perpendicular to the XY-plane



# 3. Georeferencing elements in IFC files



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# Elements in IFC2x3

## IfcSite

*RefLatitude* and *RefLongitude* and *height*

Latitude and longitude in WGS84

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## Example from Myran

```
#588612=IFCSITE('1DGwFa8Z17QBmPE_Rf9B2I',#41,'Surface:3  
759715',$,","#588611,#588606,$,.ELEMENT.,(59,19,55,199999),(18  
,3,53,999999),148200.,$,,$);
```

Can only be used approximate georeferencing

# Additional elements in IFC4

## IfcMapConversion

*Easting and Northing*

Map projection coordinates

*OrthogonalHeight*

*Scale*

“to be used, when the units of the CRS are not identical to the units of the engineering coordinate system. If omitted, the value of 1.0 is assumed.”

*XAxisAbscissa* and *XAxisOrdinate*

Deal with the rotation around the z axis

Provided for the origin in the BIM coordinate system

## IfcProjectedCRS

*Name*

EPSG code of coordinate system

Has the capability of accurate georeferencing

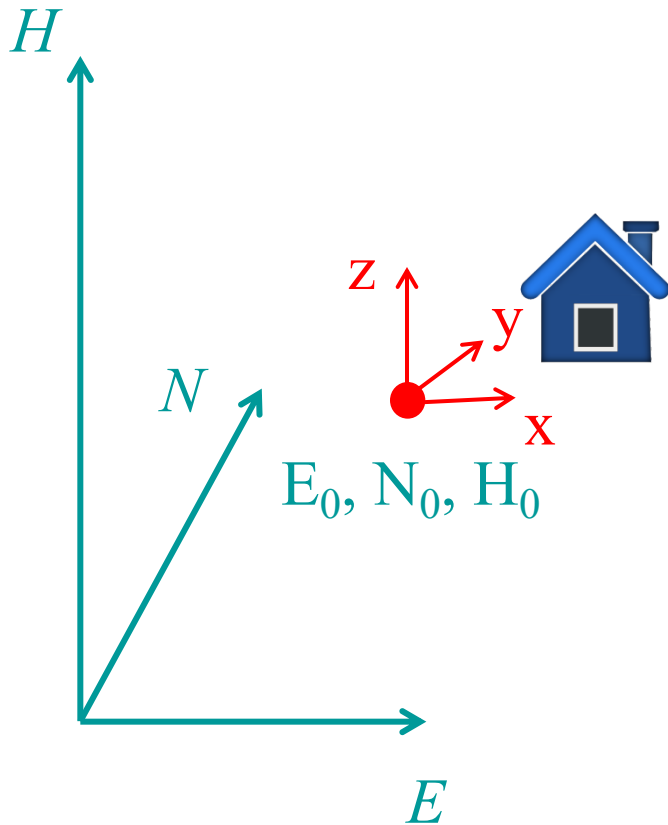
Source: buildingSMART

# 4. Georeferencing a BIM model



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# Standard solution: 3D similarity transformation



$$\begin{bmatrix} E_p \\ N_p \\ H_p \end{bmatrix} = \begin{bmatrix} E_0 \\ N_0 \\ H_0 \end{bmatrix} + mR \begin{bmatrix} x_p \\ y_p \\ z_p \end{bmatrix}$$

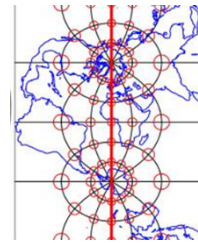
where

$m$  – scale factor (sometimes preset to 1.0)

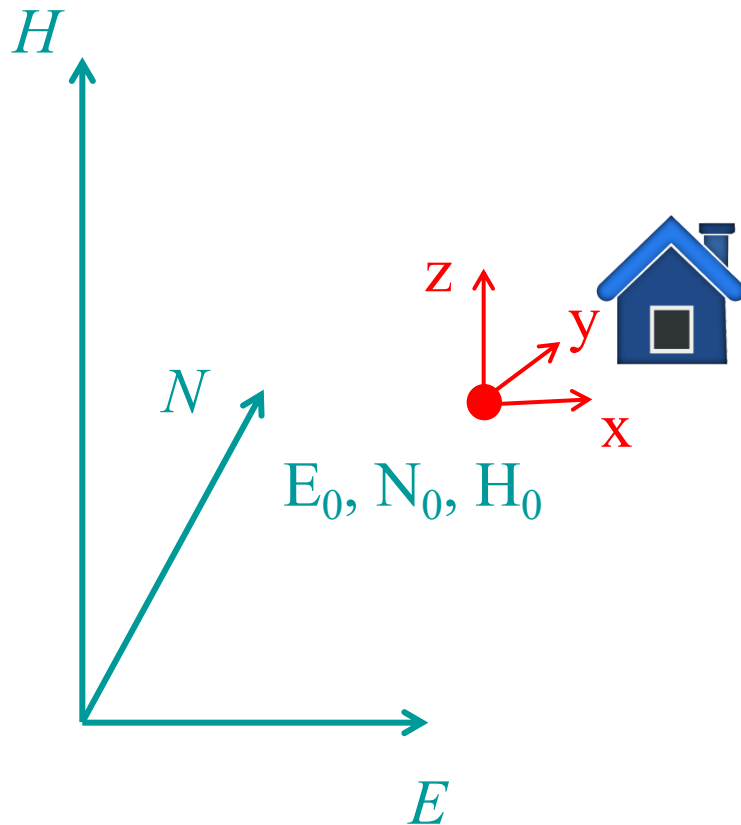
$R$  – rotation matrix. Here only rotation around  $z$  axis is allowed

# Shortcomings with the 3D similarity transformation

- 1) Scale difference is modelled as uniform in all directions.

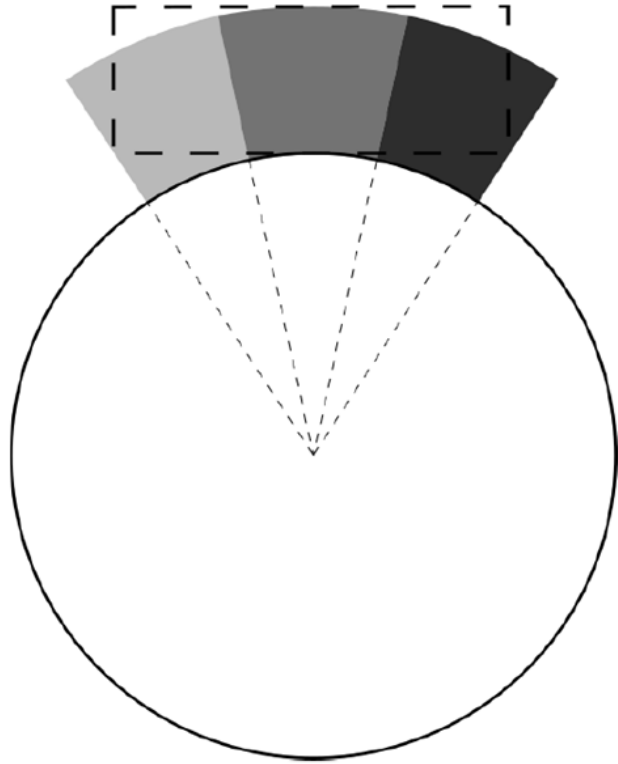


In reality there are different scale differences in the plane and in the height.



- 2) Is assuming that the  $N, E, H$  system is a true orthogonal 3D coordinate system (however, small effect)

# The BIM coordinate system does not consider the Earth's curvature – a problem for infrastructure models



The H direction changes in the geodata system while the Z direction is constant in the BIM system, i.e. it is impossible to align them everywhere.

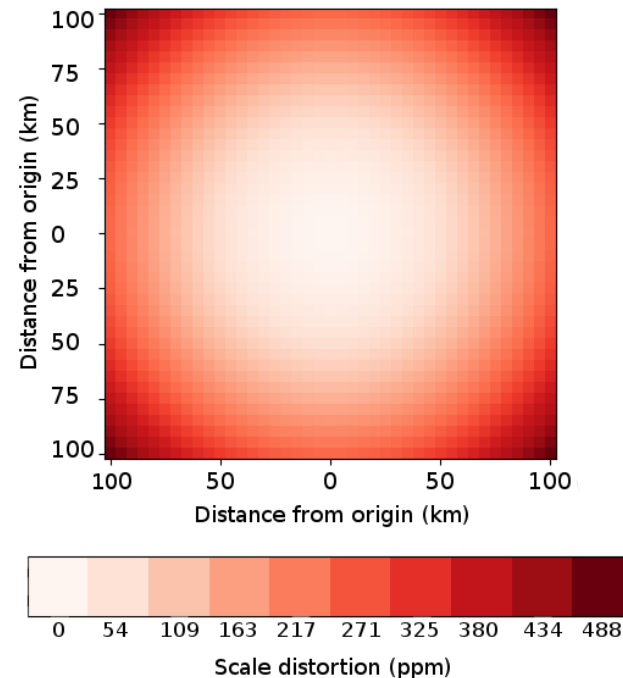
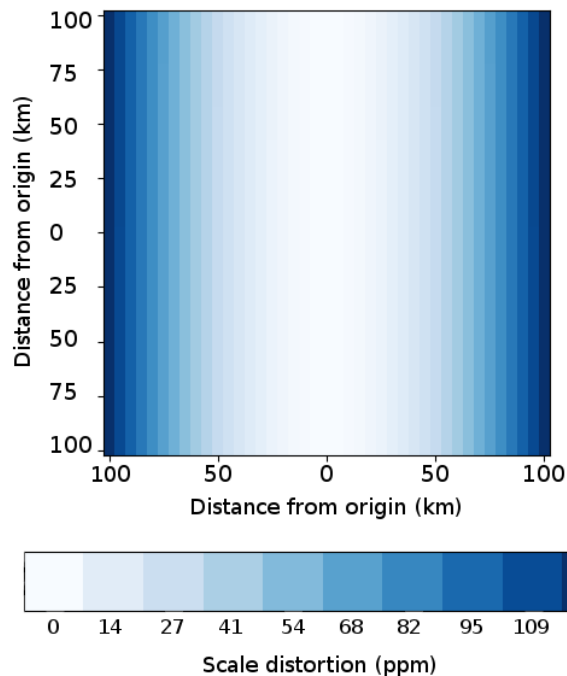
This will have the effect that points with the same x,y values but not the same height will not get the same  $N$ ,  $E$  values.

# Method that guarantee that points with the same $X, Y$ value get the same $N, E$ values

Similarity transformation

Transformation where all points have zero heights in the transformation

Heights are then added after transformation



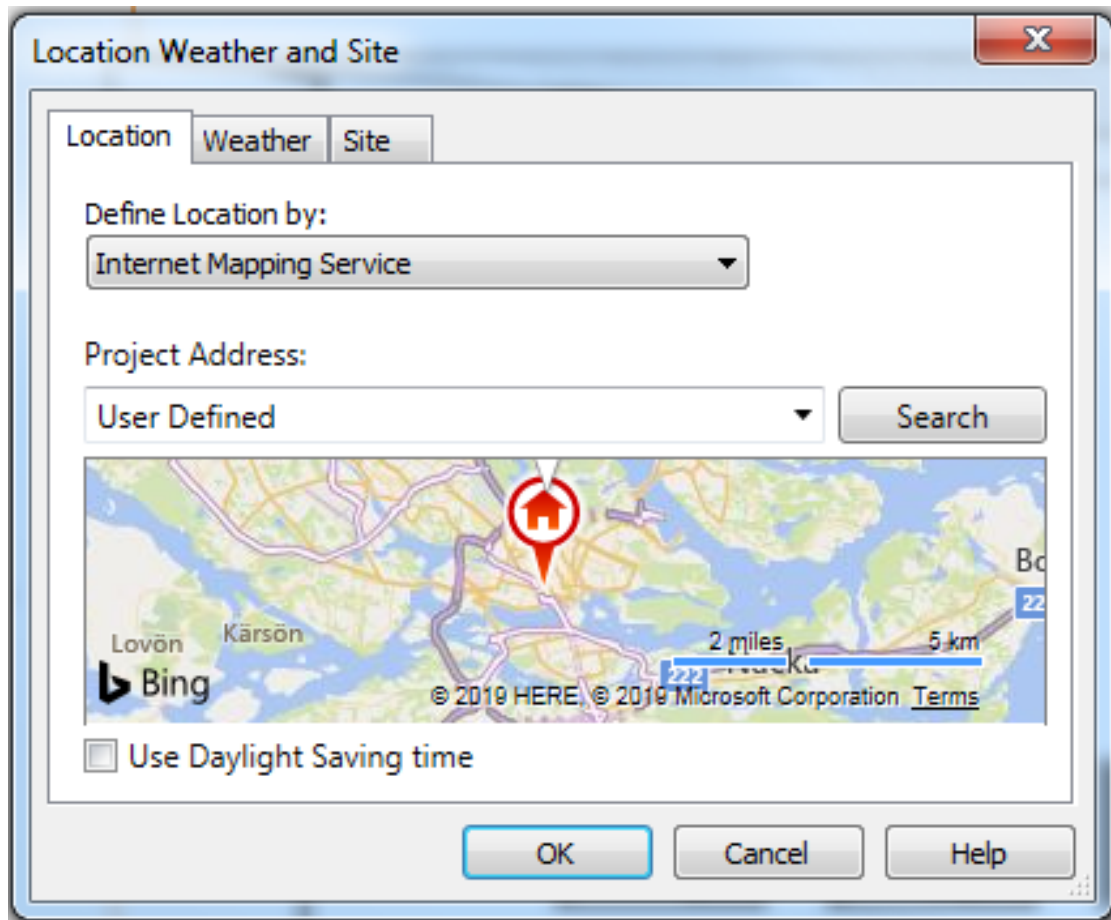
# 5. Some comments about georeferencing in Revit



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# Only for rough georeferencing



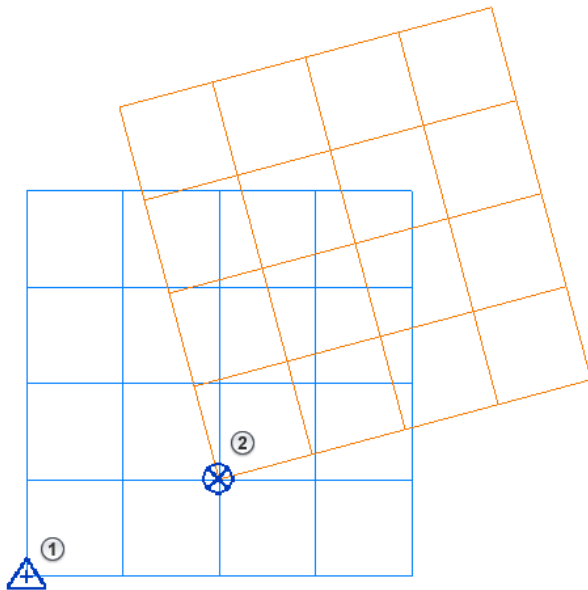
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## About Coordinate Systems



Revit uses 2 coordinate systems: a survey coordinate system and a project coordinate system.

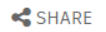
- ① The **survey coordinate system** provides a real-world context for the building model. It is intended to describe locations on the surface of the earth.
- ② The **project coordinate system** describes locations relative to the building model. It uses a selected point within the property boundary or within the extents of the project as a reference for measuring distances and positioning objects in relation to the model.



The origin of the internal coordinate system provides the basis for the survey and project coordinate systems. See [About the Internal Origin](#).

You can also use a shared coordinate system to position imported or linked models in relation to a host Revit model. See [About Shared Coordinates](#).

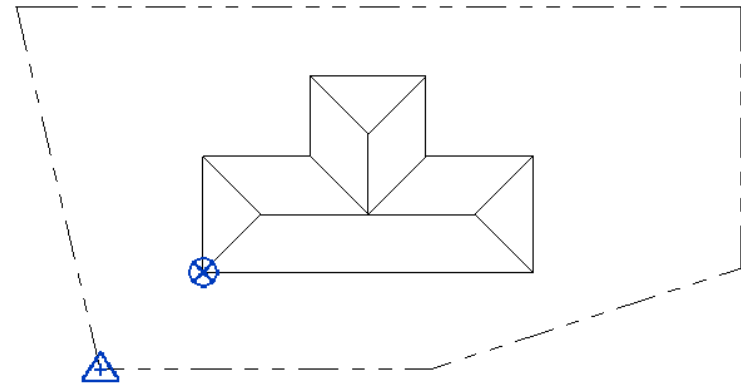
## About the Survey Point



The survey point provides a real-world context for the Revit model.

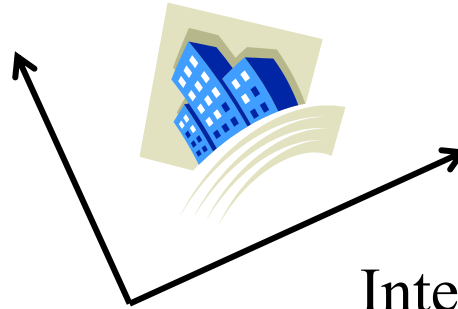
It represents a known point in the physical world, such as a geodetic survey marker or the intersection of 2 property lines. The survey point is used to correctly orient the building geometry in another coordinate system, such as the coordinate system used in a civil engineering application.

In a Revit model, the survey point defines a reference point for the survey coordinate system. In a view, it looks like this:

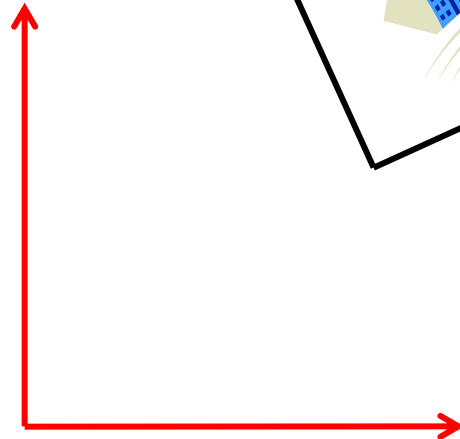


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# Three coordinate systems in Revit

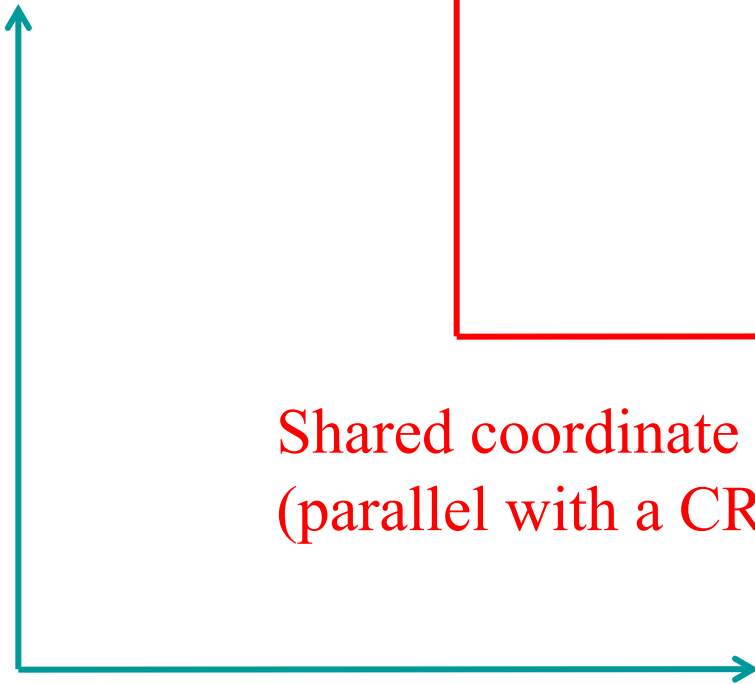


Internal coordinate system



Shared coordinate system  
(parallel with a CRS)

If the coordinates get numerically too large there is a graphic problem in Revit. Therefore *Shared Coordinate System* is recommended if geodata is needed in a project.



Project coordinate system (geodetic reference system – CRS)

# 6. Result of the Testbench – Task 2

## Options for georeferencing IFC

To test and describe **available georeferencing procedures for IFC** inside and outside BIM software tools

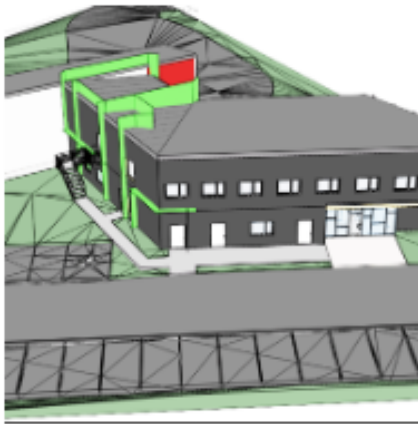


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# Example questions

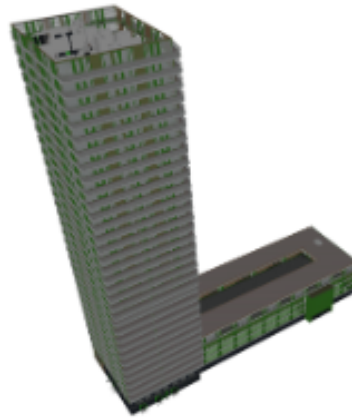
- How long does it take, approximately, to: Zoom, Pan, Rotate, Query, Inspect, Analyse, Edit the model
- Are georeferencing tools available in the standard version of the software or are specific extensions or plugins required?
- Can you give a short definition about the object CRS and/or the project CRS are defined and what are their specific features
- Can you list the supported geographical and/or projected CRS
- As part of the georeferencing process:
  - does the software allow the user to rotate the model in order to set the correct orientation towards cartographic North?
  - does the software allow the user to move the model to the correct 'world' coordinates?
- Can all the supported coordinate reference systems and projections be used while performing the 'move' operation?

# Testdata for Task 2



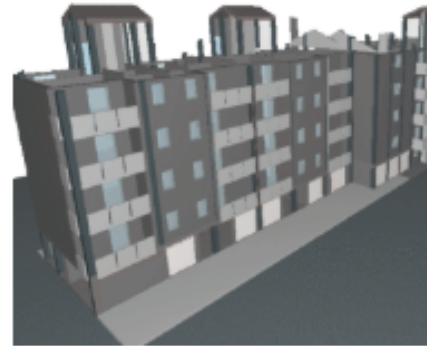
Myran

IFC model



Up:Town

IFC model



Savigliano

IFC model

# Software used in Task 2

Software	Vendor	Proprietary/ open source	Kind of software
ArcGIS Pro	Esri	Proprietary	GIS
eveBIM	CSTB (Scientific and Technical Center for Building, France)	Proprietary	3D viewer for BIM
FME Desktop 2018.1	Safe Software	Proprietary	Extract/Transform/Load
FZKViewer	Karlsruhe Institute for Technology	Proprietary	3D viewer for BIM
IfcGeoRefChecker	Dresden, University of Applied Sciences	Open source	Update georeferencing in IFC files
Revit 2020	Autodesk	Proprietary	BIM

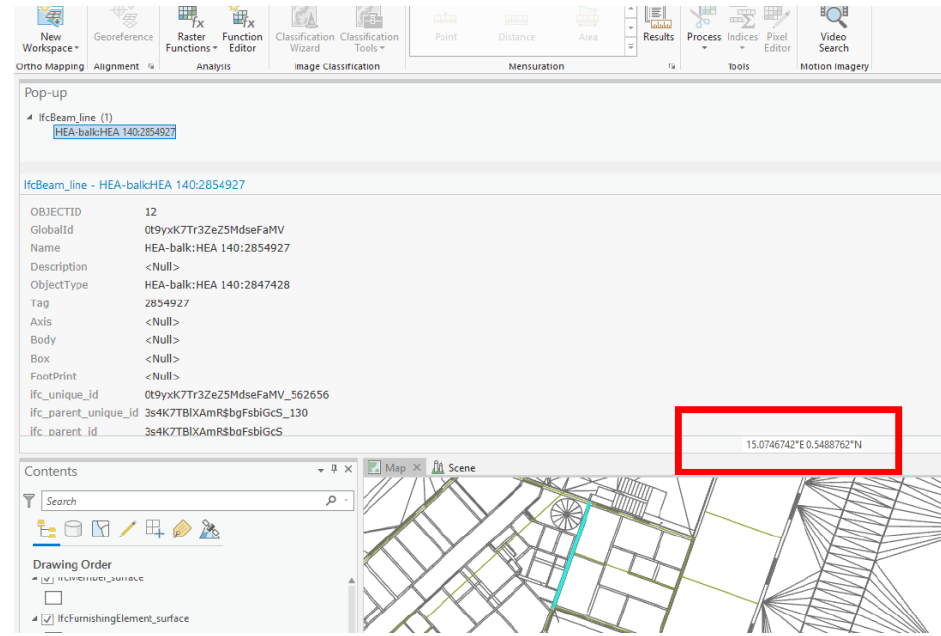
# Experience from users

*The following slides are based on result and comments from the test persons, some were expert users while some where beginners. We cannot guarantee that everything is correct.*



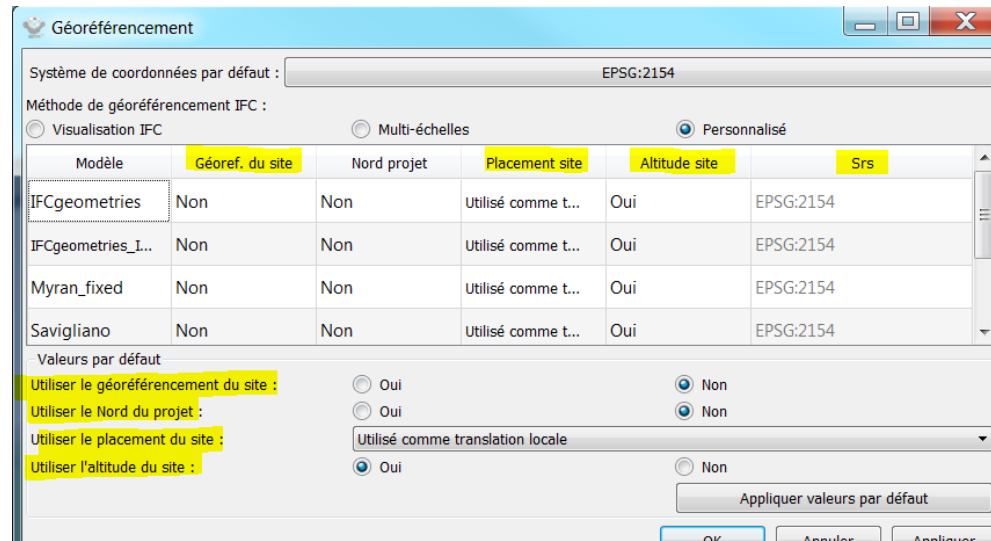
# ArcGIS Pro

- It is almost immediate to zoom, pan, rotate, query, inspect links and make analysis or edits in the model
- Georeferencing tools are available in the standard version
- It is **not allowed** to use the georeferencing tools on the IFC file
- It is **not** possible to rotate the model towards cartographic North or to move the model to the correct 'world' coordinates
- Comment: *Even if the project was uploaded with the correct CRS, ArcGIS pro did not position it in the right place. So all the coordinates, even if are shown for each feature, are not correct.*



# eveBIM

- It is almost immediate to zoom, pan, rotate, query, inspect links and make analysis to the model, and less than a minute to make a simple edit
- Georeferencing tools are available in the standard version
- It is possible to rotate the model to a correct orientation towards cartographic North and to move the model to the correct 'world' coordinates
- The supported coordinate reference systems can be used in the 'move' operation
- Comment: “*eveBIM use only IFC models so its already exported in IFC*”

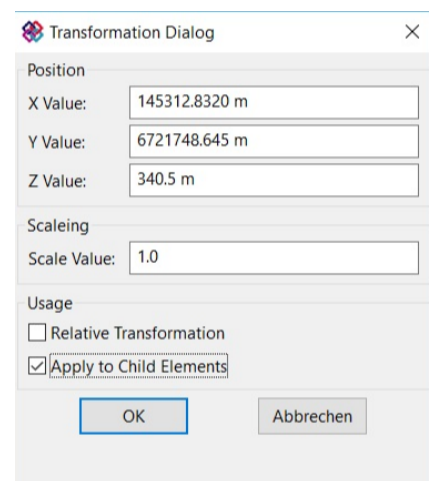


# FME Desktop

- It takes less than a minute to zoom and it is almost immediate to pan, rotate, query and inspect links in the model
- Simple analysis and edits in IFC can take from seconds to hours of processing
- Georeferencing tools are available in the standard version
- Height reference systems are not explicitly supported
- It is possible to rotate the model towards cartographic North and to move the model to the correct 'world' coordinates
- The supported coordinate reference systems can be used in the 'move' operation

# FKZViewer

- It is almost immediate to inspect links, less than a minute to zoom, pan, and query, and less than 5 minutes to rotate the model
- FKZViewer does not allow edits
- Georeferencing tools are available in the standard version
- Height reference systems are not supported
- It is **not** possible to rotate the model towards cartographic North
- It is possible to move the model to the correct 'world' coordinates, but there are no option to change the CRS during this operation
- Comments:
  - FKZViewer reports error on import and export of the IFC files
  - After transforming Savigliano the model cannot be displayed, zoomed, panned or rotated



The image shows a 'Transformation Dialog' window with a close button (X) in the top right corner. It contains three sections: 'Position' with input fields for X Value (145312.8320 m), Y Value (6721748.645 m), and Z Value (340.5 m); 'Scaling' with a 'Scale Value' input field (1.0); and 'Usage' with two checkboxes: 'Relative Transformation' (unchecked) and 'Apply to Child Elements' (checked). At the bottom are 'OK' and 'Abbrechen' buttons.

Section	Field	Value
Position	X Value:	145312.8320 m
	Y Value:	6721748.645 m
	Z Value:	340.5 m
Scaling	Scale Value:	1.0
Usage	<input type="checkbox"/> Relative Transformation	
	<input checked="" type="checkbox"/> Apply to Child Elements	

# IfcGeorefChecker

- The system does not allow to zoom, pan, rotate, query, inspect links, make analysis or edit the model
- Georeferencing tools are available in the standard version
- It is possible to rotate the model to a correct orientation towards cartographic North and to move the model to the correct 'world' coordinates
- The supported coordinate reference systems can be used in the 'move' operation

---

Geographic coordinates referenced by IfcSite (Latitude / Longitude / Elevation)

-----  
Referenced in #588612=IfcSite:

Latitude: 59.3319999997222

Longitude: 18.0649999997222

Elevation: 148200

LoGeoRef 20 = True

---

Local placement for uppermost Elements (usually an instance of IfcSite or IfcBuilding)

The placement of those elements is only relative to the WorldCoordinateSystem (see LoGeoRef 40) but not to other IFC-Elements

-----  
Referencing Element:#588612=IfcSite

Placement referenced in #588610=IfcAxis2Placement3D

X = 0

Y = 0

Z = 0

Rotation X-axis = (1/0/0)

Rotation Z-axis = (0/0/1)

LoGeoRef 30 = False

# Revit 2020

- It is almost immediate to zoom, pan, rotate, query, and make a simple edits
- Georeferencing tools are available in the standard version
- It is possible to rotate the model towards cartographic North and to move the model to the correct 'world' coordinates
- Comments:
  - Revit reports error on import of the IFC files
  - The import of Myran and Savigliano takes around 4 minutes, the import of UpTown takes 4 hours and 27 minutes
  - It seems that some roofs in the Savigliano IFC file cannot be visualized (for example, IfcGUID= 2W3r2Zrw12RQ5NDhqyzMP\_)