User Guide for Geo-referencing in IFC
"How to Setup Geo-referencing in a Building or Linear Infrastructure Model"

St Olav's hospital, Central Norway Regional Health Authority, web portal tracking of equipment by their Enterprise BIM (EBIM)

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Front Cover

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Thank you all!

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1   Introduction

1.1   Target Audience

This document is aimed at all building or infrastructure (generically built asset) modellers, to robustly establish the controlling model set-out parameters - map location and site configuration - for their respective asset (BIM or Digital Engineering) models.

This Information Delivery Manual (IDM)[1] therefore defines a standardised way for setting up a multi-disciplinary geo-referenced project model using the IFC open standard format data.

This document also defines a standard way of incorporating Cadastral data as a starting point for representing land legal ownership, zoning and planning data.

This document focusses on the geo-referencing issue and demonstrates an example site imported and exported in IFC2x3 and IFC4 format embedding the geo-referencing data.

1.2   Scope of work to date

This part of the work defines a model setup template including:

- defining the cadastre, terrain, various site elements and urban context,
- setting the project reference location & facility grids
- defining paper North for documentation
- specification of the use cases and roles of the various members of the project team, and finally,
- embedding the map conversion parameters - a 2D Helmert transformation - in IFC exchange files for both IFC2x3 and IFC4 formats

A future part of the work will be to establish a model template based on the above, with a procedure to inform all project members and adopt a testing methodology to ensure consistency and compliance.

- defining storey and/or vertical/horizontal zoning
- specifying the spatial organisation structure (ifcProject, ifcSite, ifcBuilding, ifcStorey) for collaboration synchronisation
- exporting & testing of the project Master Template
- using a test object to ensure geometry, location, and object semantics
- checking IFC settings in authoring tools
- creating a native discipline model by each team member
- coordinating IFC Entity mapping with project team members
- performing iterations and validation of a team model

1.3   The Objectives

The primary objective is to ensure dimensional consistency between models in map grid coordinates - commonly used for infrastructure and civil works, and individual built asset models - buildings, bridges, other discrete structures, in ground coordinates within a diverse construction project setting.

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[1] A methodology to capture and specify processes and information flow during the lifecycle of a facility, see here...

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The IDM anticipates applications at large scale such as airports, precincts, local and regional planning, scanned point cloud data all of which need rigorous geo-referencing.

A secondary objective is to prevent situations where a collaborative model project has work commenced without definition of shared model setup. The result is when commencing design coordination, clash detection etc the discipline models are not in the same location, have uncontrolled naming conventions and settings, incomplete project information etc.

Accordingly, in this context we make some definitions: a *small Site* is one which fits into a 1 km square (although this a general guide and not a formal limitation). A *large Site* may extend over tens, or even hundreds, of kilometres.

In such a large site, there is at least one common feature that covers the whole site but usually there are also many distinct smaller sites that are worked on separately but still have to be totally coordinated within the overall site.

For example, a road over tens of kilometres would be the large site but within that site could be many bridges and/or small structures such as buildings that are part of the whole project.

We want to work with a large site (for example a long road) but also be able to bring data in from many smaller sites (Site 1, Site 2 etc.) where:

- Site 1 knows nothing about Site 2 and Site 2 knows nothing about Site 1.
- Site 1 has its own local coordinate reference system with its own local origin.
- Site 2 has its own local coordinate reference system with its own local origin.
- We want the procedures to be applicable to anywhere in the world.

For simplicity we assume that all sites use the same unit of measurement for coordinates and heights. For example, in our Australasian setting, metres.

2   Map and Model Coordinate Systems

2.1   A World Coordinate Reference System

How do you define a unique coordinate reference system that is applicable anywhere in the world when the world is not flat?

Because the world is very close to an ellipsoid (a sphere that is squashed in a bit at the top and the bottom) it is possible to fit an ellipsoid to the average shape of the Earth and use longitude, latitude and distance from the surface of the ellipsoid (ellipsoid heights).

So, we'll look at how longitude and latitude are actually defined, and what we mean by height. But first we need to set up the terminology that we will use because as we will see, without precise definitions, significant error can be made when bringing data together.

2.2   Datums and Coordinate Reference Systems

Because of the difficulties in accurately mapping the Earth, and with additional complexities such as continental drift, it is important to define the major terms being used so that everyone is working with the same vocabulary and understands why certain things are always needed in specifications. The word *datum* is regularly used in mapping. A datum is a definition of space, using the minimum set of independent parameters so there is no ambiguity.

A datum may be:

Geodetic	A geodetic datum describes the relationship of a 2D or 3D coordinate reference system to the Earth. For example, Longitude, Latitude and Ellipsoid height.

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Engineering	Flat earth
Vertical (height or depth)	For example, the Great Britain Ordnance Datum Newlyn, Dutch Ordnance Datum, or the Australian Height Datum.

A coordinate system is a mathematical model for describing a coordinate. For example, (longitude, latitude, ellipsoid height) or (Easting, Northing).

There are basically three coordinate systems of interest to Surveyors

(a) **Cartesian**. These may be

- *Earth-Centred, Earth Fixed* (ECEF) XYZ

  This is an important coordinate system.

  The origin (0,0,0) is at the centre of mass of the earth, the Z-axis a line from the geocentre through the internationally defined pole (International Reference Pole IRP), the X-axis is a line from the geocentre through its intersection with the International Reference Meridian (IRM) and the Y-axis is extended from the geocentre along a line perpendicular from the x-axis in the same mean equatorial plane towards 90 degrees East Longitude.
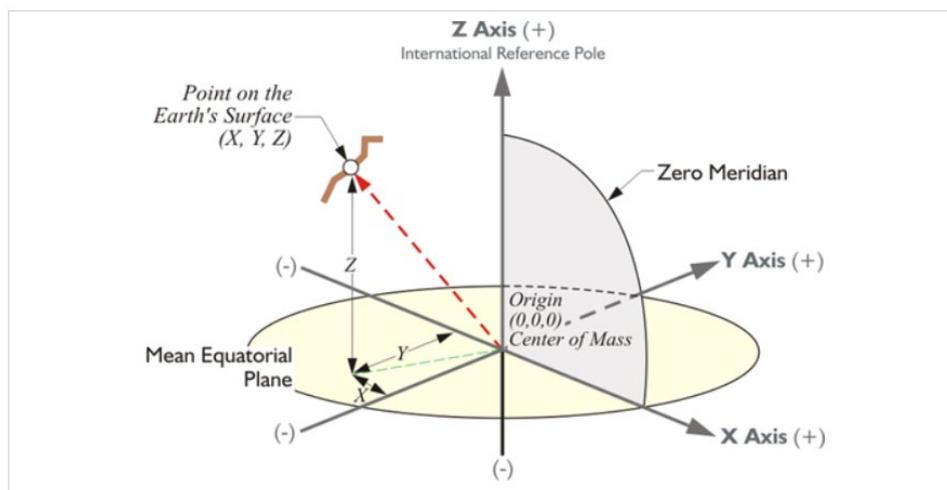
Figure 1: Three Dimensional Cartesian Coordinate (ECEF)[2].

  Any position on Earth can be given an XYZ coordinate. Although these coordinates are useful for geodetic calculations they are not useful for everyday work.

- *Projected* (onto a plane) as Easting and Northing

  Projections will be discussed later.

- *Engineering grids* (flat earth).

(b) **Ellipsoidal** - longitude, latitude and ellipsoid heights

(c) **Height**: nominally orthometric heights/depths

A Coordinate Reference System (CRS) has two parts: a Datum and a Coordinate System.

A coordinate reference system may be 3D (three axes), 2D or 1D (height).

2.2.1 Ellipsoids and Global Navigation Satellite Systems (GNSS)

Today, it is widely accepted that the Earth's shape is best approximated by an ellipsoid that has been revolved around the Earth's polar axis. Put another way, the shape is a sphere that has been squashed at the north and south poles. The non-spherical shape is due to the earth spinning. See Figure 3 below.

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[2] Source: GPS for Surveyors

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The most common way of defining an ellipsoid is by describing the semi-major axis value and an inverse flattening value (this parameter describes the "squashing" of the ellipse).

Some commonly used ellipsoids are:

Table 1:   **Commonly Used Ellipsoids in Australasia**

Example	Ellipsoid	Semi-major axis/ Inverse Flattening (m)	Notes
Geodetic Reference System 1980	GRS 1980	6,378,137 298.2572221009	This is the ellipsoid used to define the Geocentric Datum of Australia 1994 and the new GDA2020 datum. It is used in conjunction with a UTM projection to produce MGA (Map Grid Australia) coordinates.
NZ Geodetic 49	NZ Geodetic 49	6,378,399.065 297.0	This was the ellipsoid used to define the NZ 1949 Geodetic datum. The semi-major axis given here has been adjusted to compensate for errors in units conversion from links to meters.
World Geodetic System 1984	WGS84	6,378,137.0 m 298.257223563	This ellipsoid is currently used by Global Positioning Systems. It is used for the London Survey Grid for the Crossrail project. The ellipsoid GRS80 was originally used in the World Geodetic Systems 1984 (WGS84) but this ellipsoid was later changed to WGS84. The small difference in the flattening results in a tiny difference of 0.105 millimetres in the semi polar axis.

2.2.2 Longitude, Latitude and Ellipsoid Height

Once the coordinate reference system (including the ellipsoid) is defined, a position on the Earth's surface can be uniquely described in terms of Longitude, Latitude and Ellipsoid height and these are commonly known as Geodetic coordinates.

Longitude is an angular quantity measured from the Greenwich meridian in London. It is most commonly described in terms of degrees, minutes, seconds (or a decimal number), East or West of the Greenwich meridian.

Longitude   Latitude   Earth System
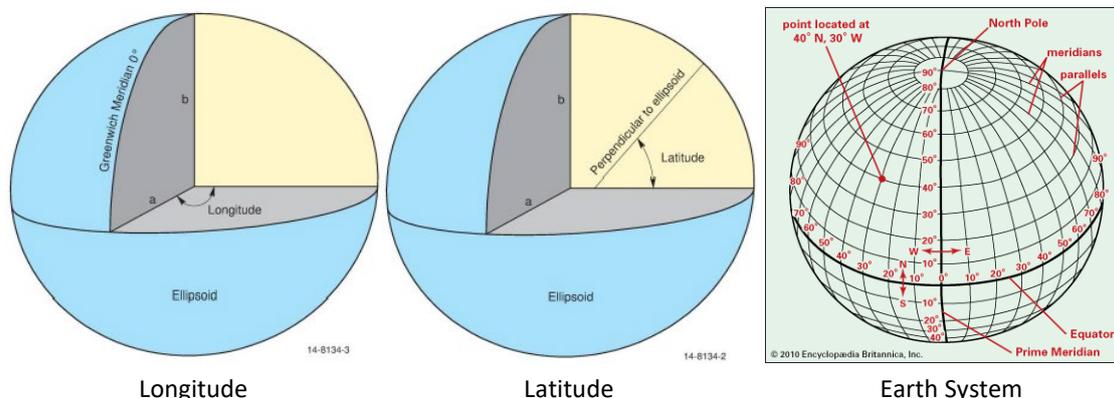
Figure 2:   (a) Longitude, (b) Latitude, (c) Earth System.

Latitude is an angular quantity measured from the equatorial plane, to the plane defined by the point position and the perpendicular line to the ellipsoid surface. It is most commonly described in terms of degrees, minutes, seconds South or North to the equator.

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Examples are 50°40'46,461"N 95°48'26,533"W or -35.89421911 139.94637467[3]

The ellipsoid height, h, of a point is the height of the point above the reference ellipsoid. With such an ellipsoid a GPS can be used to find the latitude, longitude and ellipsoid height without needing to refer to anything else on the ground.

2.2.3 Heights

Heights as most people think of them, are usually defined by the equipotential gravity field.

Or more simply, two heights are the same if water will not flow between them. One height is greater than another if water flows from one to the other. Gravity is what determines how water flows so the definition of equal heights is defined by gravity.

| Earth as an Ellipsoid | Earth as a Geoid | Earth's True Shape & its Terrain |
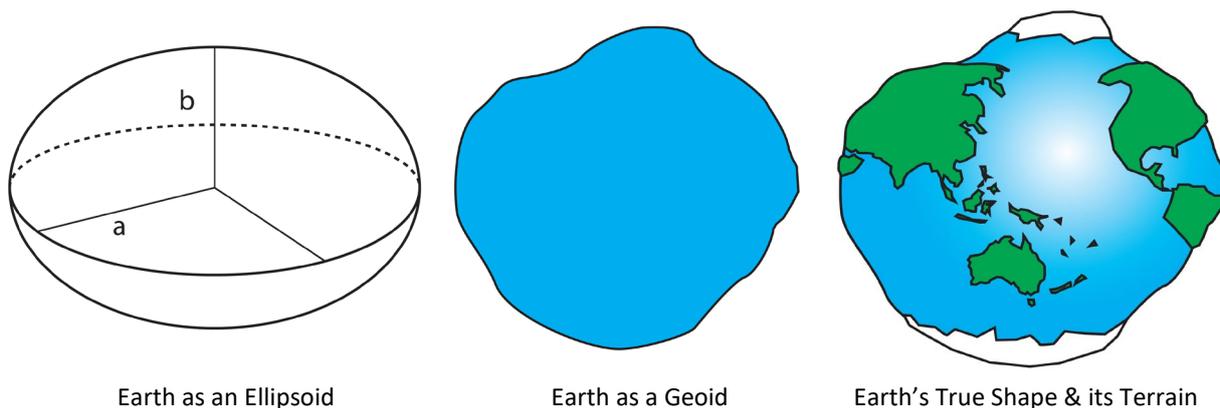
Figure 3:   Theoretical & actual representations of the Earth

2.2.4 How We Draw Things and Map Projections

Although every position on the earth has a unique Geodetic Coordinate (longitude, latitude, height) in a given coordinate reference system and you could design things in a grid of longitudes and latitudes, working in such a system would be very difficult. Just calculating the actual ground distance between two points given in latitude and longitude would be a nightmare.

So, to represent ellipsoid data on a flat surface for mapping, it is necessary to use a map projection. Map projection enables points on the ellipsoid surface to be mathematically projected onto an imaginary developable surface. That is, onto a surface that can be "rolled out flat".
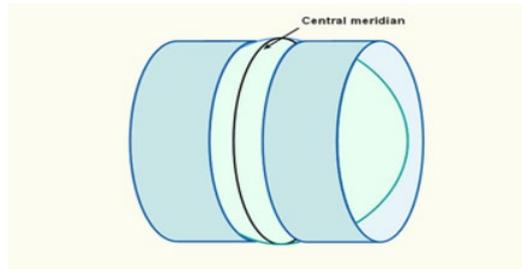
2.2.5 Transverse Mercator Projection

A commonly used map projection is the Transverse Mercator projection.

The Transverse Mercator system projects coordinates onto a cylinder that rather than being upright, is tangent to a point on the equator and the entire length of a Meridian of Longitude (called the Central meridian).

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[3] see ISO_6709 for details of the formats,

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Figure 4: Secant Transverse Mercator Projection form, reduced by a scale factor.

The Transverse Mercator projection also has a secant form where the size of the cylinder is reduced by a given factor called the scale factor of the Transverse Mercator projection.

When the scale factor is less that one, the cylinder slices through the ellipsoid along two lines - one on either side of the Central meridian.

So, looking at a slice through the equator, for the Transverse Mercator and the Secant Transverse Mercator we have:
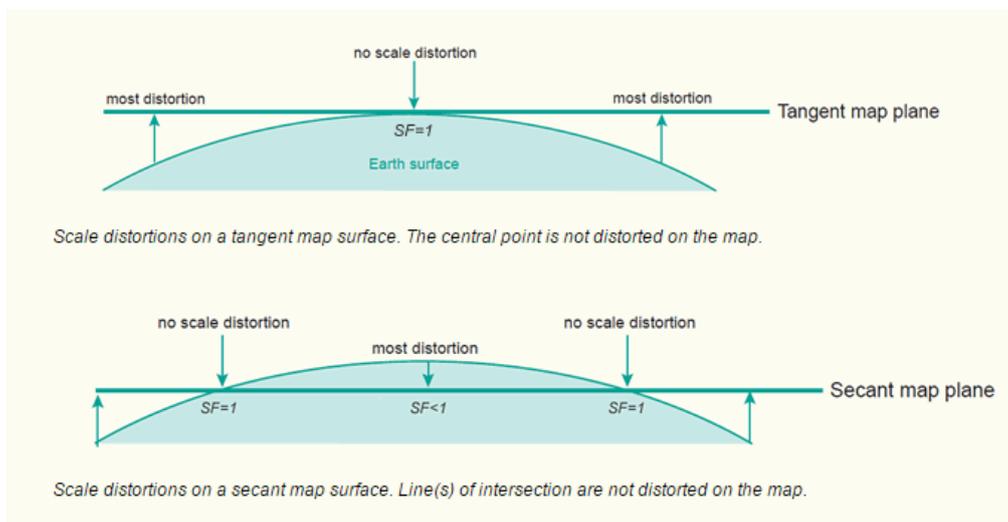
Figure 5: Transverse and Secant Transverse Mercator distortions compared.

In the diagrams it is easy to see that the distance between two points on the slice through the sphere will not be the same as on the grid on the unrolled cylinder and the distortion varies depending on the point's position in relation to the central meridian.

This distortion of scale is called the scale factor and for any map projection it varies from point to point.

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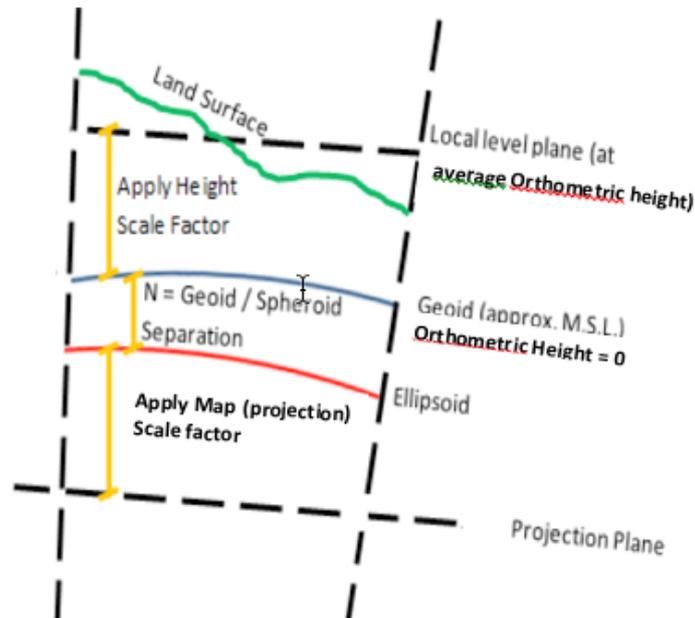
Figure 6:   The relationship of the combined factors in determining heights.

Figure 6 shows the relationship of the combined (Height Scale factor x Map Scale factor) and the change from Local Ground distance to the Grid (projection) distance.

The Secant Transverse Mercator projection is probably the most widely used around the world, especially as it is the basis of UTM described in the next section.

2.2.6   UTMs and Zones

The Universal Transverse Mercator (UTM) projection splits the world into 60 zones of 6 degrees of longitude. The zone numbering starts at longitude 180 degrees West.

A smaller example, Australia is covered by the UTM zones 49 to 56.
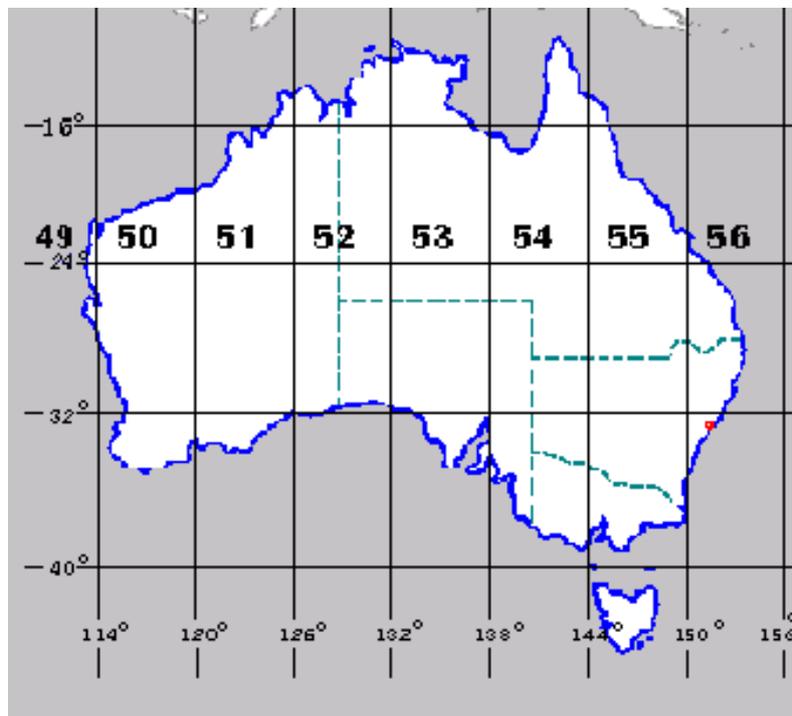
Figure 7:   UTM Grid Zones for the Australian Continent

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The UTM projection is designed to cover the world, excluding the Arctic and Antarctic regions.

To avoid negative coordinates for positions located west of the central meridian, the central meridian has been given a (false) Easting value of 500,000m. The equator has been given a Northing value of 0m for positions north of the equator, and a (false) Northing value of 10,000,000m is allocated to the equator for positions south of the equator.

This is why UTM coordinates are so large.

The Map Grid of Australia (MGA) is a UTM defined on the ellipsoid GRS80.

2.2.7 Height Scale Factor, Combined Scale Factor and Ground Distances

The ground distance between two points not on an ellipse will of course be different to the ellipsoid distance between the projection of the two points onto the ellipse.

For small distances around a given point, the orthometric height is constant and the ratio of the straight line 3D distance between the given point and a nearby point (using orthometric heights) and the ellipsoid distance for the two points is called the Height Scale Factor or the Elevation factor for that point

The Combined Scale Factor (or Ground factor) is defined to be:

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Combined Scale Factor = Height Scale factor x Grid Scale factor.
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Hence for a small area around a given point (including its orthometric height), the Combined Scale Factor for that point is a multiplier to convert the 3D straight line distance between the given point and another close point to the map grid distance between the two points.

Conversely, if you have two close map grid points and their orthometric heights, and know the Combined scale factor for one of them, then dividing the 2D map grid distance between the two points by the combined scale factor will give you the ground distance between the two points.

So for close points on a grid (map projection), it you have the orthometric heights for the points and the combined scale factor for that point at that orthometric height, then the 2D grid distance between two close points can be turned into a 3D ground distance.

In Australia, Control Marks are given in longitude and latitude, MGA coordinates (grid coordinates – Eastings and Northings), an AHD height and the Combined Scale Factor for that point at that AHD height.

Note: The Height Scale Factor is actually defined to the Mean Sea Level rather than the ellipsoid surface and the calculation of the Combined scale factor will take the N-values into consideration.

2.2.8 Azimuths (Angles) and Norths

One final point is that most maps require a North direction and angles to be shown.   However just as we have a number of different distances, we also have different Azimuths and Norths:

For example, **Magnetic North** – north as given by a compass, **Geodetic Azimuth** – derived from the inverse between two points of known latitude and longitude, **Grid North** is the north on the map grid - that is, straight up the page, **Project/Plan North** – the Grid north model can be adapted to a very localised limited area. The important thing is that these are all different and it is imperative that for the overall project it is define what is to be used otherwise errors will occur when bringing Sites together.

In particular if a local project north is used, the relationship (angle) to the overall project system is required. For example, if the Overall project is in a Map Projection, then the angle between the local Project north and Grid north is required.

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3   The Objective Resolved

3.1   Converting between Map and Ground Coordinates

Our objective was that we wanted to work with a large site such as for a long road but also need to be able to bring data in from smaller sites Site 1 and Site 2. For this to happen for the overall project, all we need is to define a suitable coordinate reference system (a datum and a coordinate system) which usually has a map projection so that Easting and Northings (longitude and latitude) and heights can be used anywhere over the entire site.

The largescale structures for the project (the road or railway, or the layout of a whole town) are designed in that selected project map projection.

The distances on the map grid are not the same as ground distances but for such a largescale project there will be people with sufficient surveying knowledge to position things correctly from the map coordinates.

But what about the designer of say a building on Site 1 somewhere inside the large overall site?

Or the people constructing the building who are wanting to use plans and drawings where the relationship to the distance on the ground is not distorted so they can use their standard tape measures to set things out?

These people need to use a local coordinate system, with an origin somewhere conveniently located in the building site Site 1, with an x-axis that lines up with something easy to use on the ground (for example the side of the building) and the units of measurement are identical to the units on the ground. That is, the units of measurement are not distorted and you can use them to set things out using tape measures etc. Also, heights on Site 1 may only be measured relative to a particular height on the site (and for simplicity we'll assume they have the same units of measurement as the units on the ground).

3.2   The Solution - A 2D Helmert Transformation

Luckily the answer is straightforward. As long as Site 1 is small (under one kilometre) then such a local coordinate system can be set up and used just as it has been done for the past one thousand years.

But what you must then be able to do is for that Site 1, define how to uniquely go from those local (x,y) coordinates for Site 1 to the overall map projection coordinates (Eastings and Northings) being used for the overall project. And also how to uniquely go from the local heights to the Height datum of the overall site.

The secret to success is that because the site is small, the scale factor which varies at every point over the site, is very close to one constant value over the small site. So, one fixed value for the scale factor can be used for the small Site. Note that although this value is constant it would rarely be one. So, over that small Site, the square root distance between two points in map coordinates (Eastings and Northings) is simply the ground distance multiplied by the same fixed scale factor.

Hence over that small Site, you can have the local coordinates and the map projections coordinates on the one sheet of paper and straight lines and arcs will remain straight lines and arcs in both coordinate systems and the distances are related by the one fixed scale factor.

For two such 2D coordinates systems, you can uniquely define the following transformation to go between the two sets of coordinates for the points:

- The x and y translations required to take the local origin in one coordinate system to the coordinates of the same point in the other coordinate system
- A Rotation about the local origin

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- A scale factor

This combination is also known as a 2D Helmert transformation and it is being regularly used throughout the world on building sites to go from the local coordinates for one building to the local coordinates of a building on a site nearby.
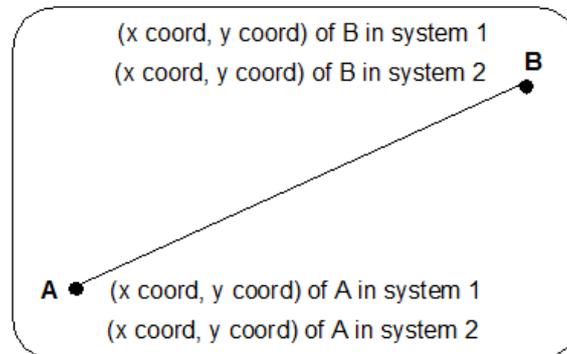
Figure 8: 2D Helmert transformation parameters

Although the 2D Helmert parameters are used to transform between the two coordinate systems, the four parameters (x translation, y translation, the rotation and the scale) are rarely directly measured. Instead the four parameters can be uniquely calculated from having the coordinates of the same two points (A and B), in both coordinates systems.

So, for Site 1, you only need the find out the map coordinates (Eastings and Northings or longitude and latitude) for two of the points you already know the local coordinates for.

From these known coordinates the four 2D Helmert parameters x translation, y translation, rotation and scale, can be uniquely calculated and then used to transform the local coordinates to the map projection coordinates.

The inverse transformation can then be used in that small site to transform map projection coordinates to the local coordinates for that small site.

For site heights, you only need the have both the overall project height and the site height known at one point on the site and the difference of those two heights (a Z shift) give you the Height adjustment that can be used to calculate the project height for any other local height.

Special Notes

1. *Because for the map projection there is a unique mapping between the map coordinates and a longitude and latitude, the coordinates for A and B can be given in longitude and latitude instead of in map coordinates. But then you must be capable of calculating the map coordinates from the longitudes and latitudes before being able to use them to calculate the parameters of the 2D Helmert transformation.*

2. *The rotation (angle) is NOT the angle to magnetic north (the direction in which a compass needle points), or true north (the direction of the North Pole). It involves grid north which is the direction northwards along the grid lines of the map projection.*

 Maps issued by the Ordnance Survey in the UK contain a diagram showing the differences between true north, grid north and magnetic north at a point on the sheet.

3. *Knowing that the calculation of the 2D Helmert transformation requires that the scale factor be virtually constant over the site gives a measure of how large a Site can be for using only local coordinates over the entire site.*

4. *Thinking of the future where dynamic datums may be more commonly used, adding a time stamp (epoch) to the reference coordinates (and hence the transformation) might be worth consideration.*

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3.3   Best Practice Recommendations

The size of the overall site determines whether a local coordinate system can be safely used for the entire project. If that overall site is too large (typically over 1 Km) then Geodetic Coordinates need to be used and to make design for the overall site more intelligible, an appropriate map projection selected for the overall site.

Once it is declared to be a large project and the map projection defined for the project, then all design work that goes over the entire site must be done in the (Easting, Northing) coordinates for that map projection.

For any work being done on a small Site within the overall site, local coordinates can be used on that particular small Site BUT two points must be uniquely identified on that small site and the local coordinates and the Eastings and Northings (or the longitude and latitudes) of those same two points must be recorded and published.

The parameters of the 2D Helmert transformation are then calculated for the small Site from these two points and they should also be recorded and published. This transformation MUST be used for converting between local coordinates and the map projection coordinates used for the entire project. The inverse 2D Helmert transformation can also be used for converting between map projection coordinates in the small site to the local coordinates for the small site.

The height in the local height datum and in the national height datum must also be known at one point and the differences in those two heights (Z shift) can be used as the height adjustment for all other local heights.

By following the above simple procedures, full coordination can be maintained on even the largest projects but people can still safely work with their local coordinates on small sites within the overall project.

Important Notes

1.   *For every small site within a large project, a Land Surveyor should be used to establish the two sets of coordinates and calculate the 2D Helmert transformation parameters. But after that, normal local procedures can be used.*

2.   *If the overall site is small, then the same principles apply when there are a number of local coordinate systems within that same small site.*

    To apply the principles there should be the one major (local) coordinate system defined for the overall site but instead of needing the map projection coordinates of the two points for a smaller site, you only need the coordinates of the two points in both the overall local coordinates (the major coordinate system) and the local coordinate system of the smaller sub-site.

3.   *Having the two points identified rather than just giving the 2D Helmert transformation parameters is very important because you can always double check on the site that the coordinates were correct.*

4.   *The two points should not be too close together. Ideally they should be at opposite sides of the site.*

5.   *When setting up the local coordinate system the average scale factor must be taken into consideration. It is not sufficient to simply apply an offset and rotation to the map projection coordinates to create the local coordinate system. It is recommended that a surveyor perform a survey of the site to establish control points and link them to the appropriate geodetic datum. If no survey is available, then the scale factor can be computed by dividing the square root distance by the ellipsoidal distance between two*

points near to the average height of the site. The ellipsoidal distance can be computed using appropriate geodetic software.

5. *In practice, for the small site most surveyors would determine the coordinates of more than just two points in both coordinate systems and would probably use least squares to determine the 2D Helmert transformation from all points. Using more than two points may be redundant but it allows for cross checks to be made to help eliminate errors.*

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4   Model Setup Use Cases

4.1   Definition of Actors

The model setup task can occur at different stages of a project, depending on the type of owner (i.e. developer versus say a public hospital agency), or infrastructure context where the setup may be a different and a more important priority. Its task is to give a precise description of the site and its location for local, GPS and map referencing, and a framework for the set-out and spatial configuration of the built asset.

4.2   Actor Roles[4] for Geo-referencing

The local Land Registry supplies cadastral information with the title dimensions of the property. The Land Surveyor will perform a re-establishment survey to verify the title boundaries of the property.

The Land Surveyor may be engaged to do an as-built survey to capture the existing buildings, terrain and other features of the property and it's surrounds. The Land Surveyor, Architect, Building Services Engineer, Landscape architect or other party defines the site model. Identifiable points, such as the corners of the property will assume local coordinates based on the site model.

The Land Surveyor conducts a control survey to connect the site to survey marks with known coordinates in the map grid coordinate system. The Land Surveyor or another party can then use the two sets of coordinates to compute a 2D Helmert transformation.

4.3   Model Set-up Exchange Scenarios - Process Model

Figure 9 below sets out the process model, defining the tasks and relationships for establishing a model at a specific location, with its spatial set out and related attributes.
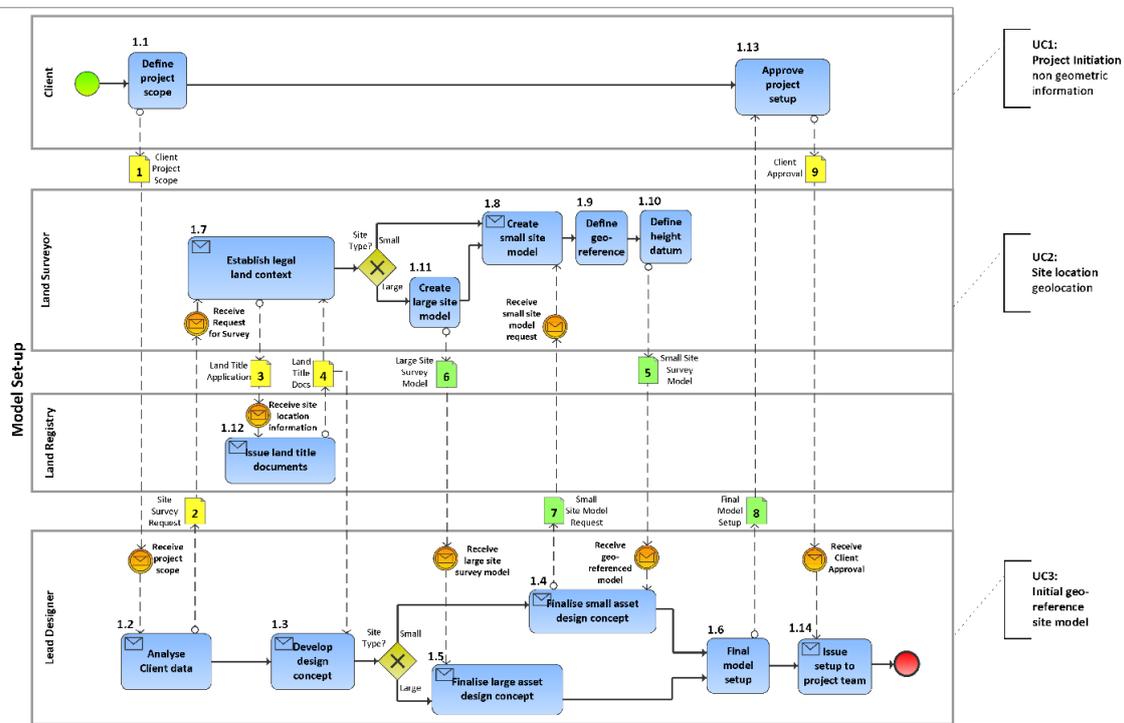

Figure 9:   Process Model

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[4] See **Appendix 1** for a detailed specification of Actor Roles

5   Embedding the Geo-Referencing Data

5.1   The IFC Site Concept

The concept that defines the cadastre or terrain, locates built assets and geographic features etc, is represented in IFC2x3 and IFC4 by the *ifcSite* entity, generally in a local cartesian grid coordinate system to suit their discrete facility model.

As the map grid coordinates are often very large, a local model origin with its offset to the map grid origin permits better application performance and visualisation, and the set out may be aligned arbitrarily according to the shape of the site or documentation requirements.

A 2D Helmert transformation is defined to capture the map conversion settings and its parameters stored in the entity *ifcMapConversion* in IFC4 or in special Property sets in IFC2x3

Table 2:   **Mapping to IFC Entities**

Mapping to IFC2x3 Entities	Mapping to IFC4 Entities
IfcProject	IfcProject
IfcSite	IfcSite
	IfcMapConversion
IfcCoordinateReferenceSystem	IfcCoordinateReferenceSystem
	IfcProjectedCRS
IfcBuilding	IfcBuilding
IfcBuildingStorey	IfcBuildingStorey
IfcBuildingElement	IfcBuildingElement
IfcBuildingElementProxy	IfcBuildingElementProxy
IfcClassification	IfcClassification
IfcPropertySet	IfcPropertySet
ePSet_ProjectedCRS: MapProjection, GeodeticDatum, VerticalDatum	
ePSet_MapConversion: Eastings, Northings, OrthogonalHeight, XAxisAbscissa, XAxisOrdinate, Scale	
ifcGrid	ifcGrid
	IfcGeographicElement

Table 3:   **2D Helmert Transformation Attributes**

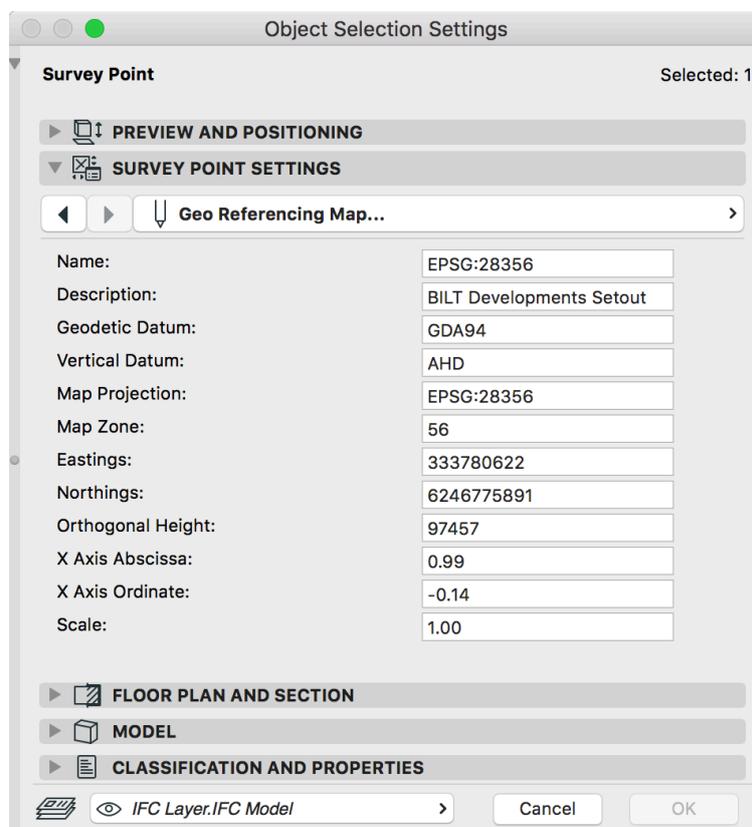| ePSet_MapConversion	DataType	Definition
ifcMapConversion attributes		*Properties that specify the transformation between the local grid coordinate system and a map grid coordinate system.*
Eastings	IfcLengthMeasure	The translation in X between the two coordinate systems
Northings	IfcLengthMeasure	The translation in Y between the two coordinate systems
OrthogonalHeight	IfcLengthMeasure	The translation in Z between the two coordinate systems
XAxisAbscissa	IfcReal	The X component of the rotation between the two coordinate systems
XAxisOrdinate	IfcReal	The Y component of the rotation between the two coordinate systems
Scale	IfcReal	The scale in X, Y between the two coordinate systems

A 2D Helmert transformation can be computed using two or more survey marks with

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coordinates in both the local and the map grid coordinate systems.

Table 4:   **Coordinate Reference System Attributes**

ePSet_ProjectedCRS	DataType	Definition
Coordinate Reference System Attributes		*Properties that define the coordinate reference system.*
Name	IfcLabel	Name by which the coordinate reference system is identified. NOTE: The name shall be taken from the list recognized by the European Petroleum Survey Group EPSG.
Description	IfcText	Informal description
GeodeticDatum	IfcIdentifier	Name by which this datum is identified. The geodetic datum is associated with the coordinate reference system and indicates the shape and size of the rotation ellipsoid and this ellipsoid's connection and orientation to the actual globe/earth. It needs to be provided, if the *Name* identifier does not unambiguously define the geodetic datum as well.
VerticalDatum	IfcIdentifier	Name by which the vertical datum is identified. The vertical datum is associated with the height axis of the coordinate reference system and indicates the reference plane and fundamental point defining the origin of a height system.
MapProjection	IfcIdentifier	Name by which the map projection is identified.
MapZone	IfcIdentifier	Name by which the map zone is identified.

Figure 10:   ArchiCAD 21 beta Survey Point Interface - Geo-referencing Data.

See **5.2 Example 2D Helmert Transformation** below, for the 2D Helmert Transformation

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calculation.

Note: For the IFC2x3 implementation the ePSets are linked to *ifcProject* as the geo-referencing specification applies to the entire project (model).

5.1.1 Small Sites

If the extents of the site are small (up to approximately 1km square (but not a limit, according to the specific project context) then a single transformation should be sufficient to relate the local and map grid coordinate systems.

5.1.2 Large Sites

For large projects, using a local cartesian coordinate system that does not consider earth curvature will result in significant errors between measured and computed distances.

If the project involves discrete infrastructure dispersed over a wide area, it may be sufficient to establish a transformation for each site. For example, a railway project might have bridges, tunnels and stations and each of these built assets will require a local coordinate system and a transformation to relate it to the map grid system. Note that this may require several contiguous sub-models of the built asset, e.g. for a tunnel 3km long.

If it is not possible to subdivide the project into a number of small sites, then the project should be based on a map grid coordinate system and use rigorous geodetic computation.

5.2 Example 2D Helmert Transformation

In this example two reference points (Ref1 and Ref2) have been defined at diagonally opposite ends of the site. The points have been connected to a local survey control by a Land Surveyor.

The resulting coordinates of the reference points in the national map grid coordinate system (Map Grid of Australia Zone 56) are:

```
Ref1   E = 333,780.622     N = 6,246,775.891   H = 97.457
Ref2   E = 333,906.644     N = 6,246,834.938   H = 98.291
```

where E is Easting, N is Northing and H is orthometric height (AHD).

All values in metres.
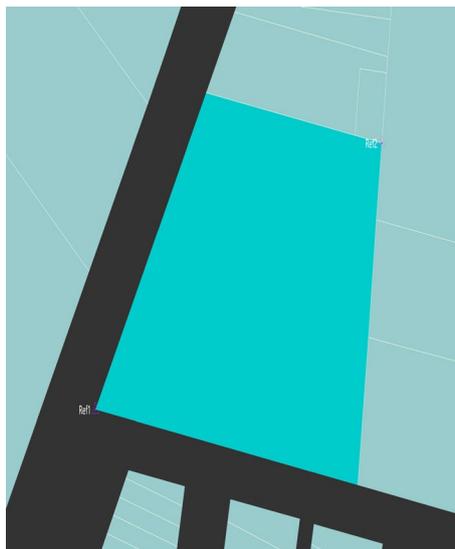
Figure 11:　　　Site in the map grid coordinate system (grid north is up the page)

A local grid coordinate system has been made for the site to reduce the size of the coordinates and to align the site to better fit on paper plans. The resulting coordinates (in metres) of the reference points in the local grid coordinate system are:

```
Ref1   X = 0.000          Y = 0.000           Z = 0.000
```

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```
Ref2   X = 116.611          Y = 75.960          Z = 0.834
```

where X, Y, Z represent a right handed Cartesian coordinate system with Z equivalent to up.
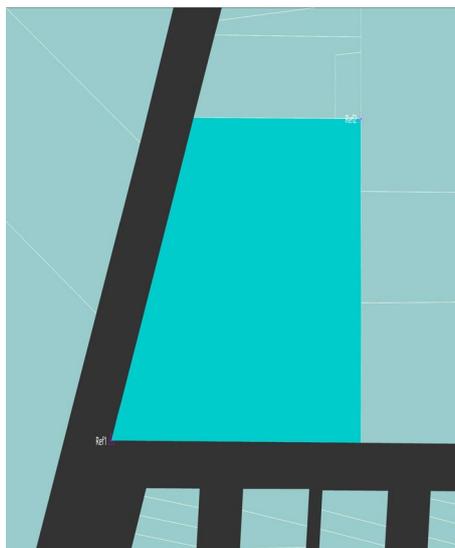
Figure 12:   Site in the local grid coordinate system (Y is up the page)

A 2D Helmert transformation can be computed from the coordinates of the two reference points. The parameters of such a transformation are:

```
X Shift = 333,780.622
Y Shift = 6,246,775.891
Z Rotation = -7°58'28"
Scale = 0.9999989
```

The corresponding IFC parameters are:

```
Eastings = 333,780.622
Northings = 6,246,775.891
OrthogonalHeight = 97.457
XAxisAbscissa = 0.990330045
XAxisOrdinate = -0.138731399
Scale = 0.999998
```

The transformation is applied as follows to convert coordinates from local to map grid:

```
E = (A * X) - (B * Y) + Eastings
N = (B * X) + (A * Y) + Northings
H = Z + OrthogonalHeight
```

where

```
A = Scale * cos(Rotation),
B = Scale * sin(Rotation), and
Rotation = atan2(XAxisAbscissa, XAxisOrdinate)
```

```
9 The scale of 0.99998 is only in the X and Y(not Z).
```

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6   Validation of the Project Model Template

Tasks in this future part of the Model Setup project comprise:

- defining storey and/or vertical/horizontal zoning
- specifying the spatial organisation structure (ifcProject, ifcSite, ifcBuilding, ifcStorey) for collaboration synchronisation
- exporting & testing of the project Master Template
- using a test object to ensure geometry, location, and object semantics
- checking IFC settings in authoring tools
- creating a native discipline model by each team member
- coordinating IFC Entity mapping with project team members
- performing iterations and validation of a team model

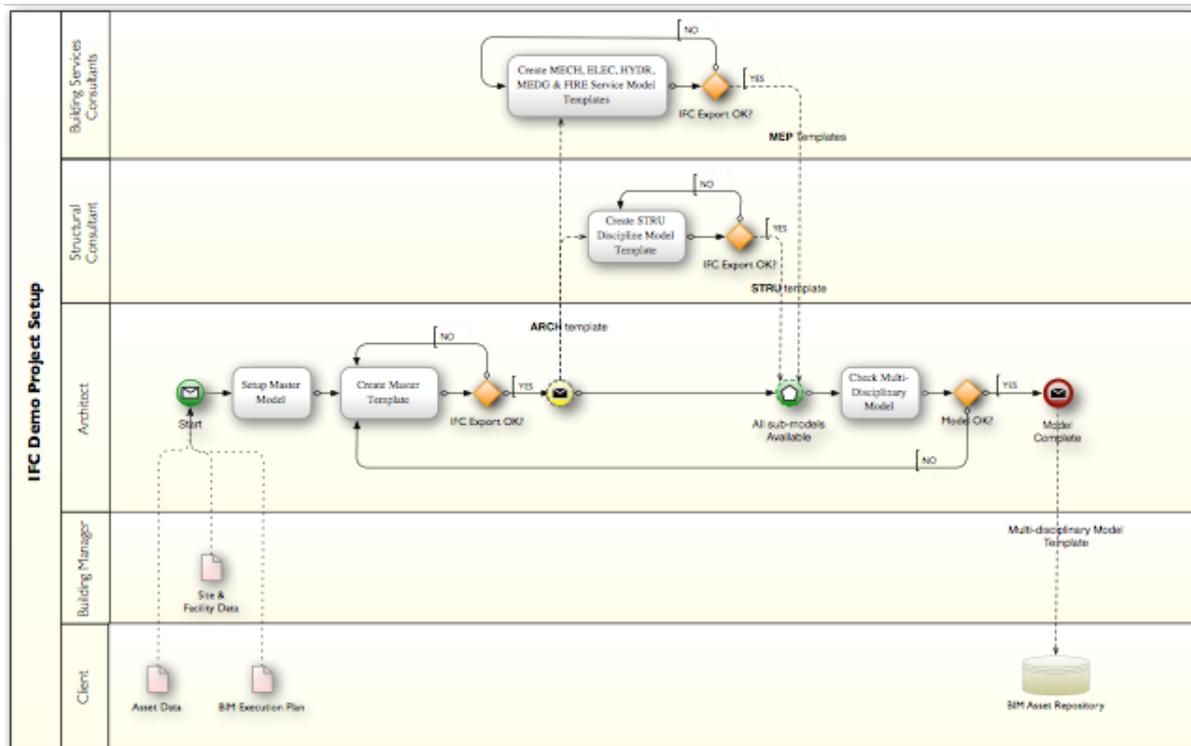Figure 12 below sets out a draft process for a shared, validated model setup.

Figure 13:   Model Setup Validation Overview (Future development)

7   References

Wikipedia, [Helmert transformation](#)

ISO 19161-1 is currently under preparation. It will describe the International Terrestrial Reference Framework, and how to establish national terrestrial reference frameworks. The ITRF is managed by the International Earth Rotation and Reference Systems Service; the UN would like it to be more formally recognised.

ISO 19127:2005 describes how to manage a register of Coordinate Reference Systems. ISO TC211 and the International Association of Geodesy have established a "Control Body for the ISO Geodetic registry network" to manage the ISO "register of registers". ISO 19127 is currently under revision to better describe this.

A Guide to Coordinate Systems in Great Britain, Copyright Ordnance Survey 2018, [D00659](#) v3.3.

ESRI resources: Tables 1 and 7 in "Geographic_coordinate_systems.pdf" provide a list of geodetic and vertical datums used in various areas of the world, respectively. Table 2 in "Projected_coordinate_systems.pdf" provides a list of projected spatial reference systems with their area of use.

http://resources.arcgis.com/en/help/main/10.1/018z/pdf/geographic_coordinate_systems.pdf

http://resources.arcgis.com/en/help/main/10.1/018z/pdf/projected_coordinate_systems.pdf