LI Technical Guidance Note **01/21**

Origins and project datum

Best practice for sharing projects in the UK and Ireland when using BIM and CAD software

Landscape Institute
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Contents

1 Introduction

1.1 Acknowledgements

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1.2 Foreword

This document is a collaborative initiative between the software technology developers listed above and has been compiled with the intention to demonstrate that all major CAD and BIM software platforms utilise the same fundamental approach and technology with respect to file origins and coordinates. As such, it is not an acceptable working practice to apportion any coordination issues as being the responsibility of the software. Rather, it should be accepted that this is a communication and protocol issue that should be agreed and tested by project parties at the outset of the project. It is not the intention of this document to provide full instructions for each individual software or a detailed explanation of national coordinate or georeferencing systems (but see section **6** for useful links and further reading).

1.3 Relationship with other documents

This document takes as its foundation, and provides reference to, several BIM standards. It makes reference to BS EN ISO 19650-1:2018 + BS EN ISO 19650-2:2018 + PD Guide 19650-0: 2019. It also makes extensive reference to the OS grid for practices working within the UK and Ireland.

Note: While the BS 1192 standards series has been replaced by the BS EN ISO 19650 suite, the authors recognise that, at the time of writing, the BS 1192 Project Space Statement (Annex A, p. 27) *has not been adequately replaced in the new ISO standard, or the National Annex, and is therefore still referenced in this document.*

1.4 Who is this document for?

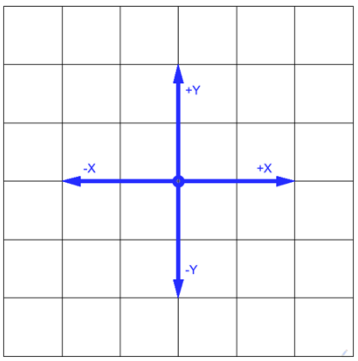
This guidance document is for any practice working with real-world coordinates within any BIM and/or CAD software and especially those working in a collaborative environment where coordinated model positioning is of paramount importance.

2 General principles

2.1 What do we mean by origin?

For the purpose of this document, an origin is defined as a datum point for measured or calculated values either in the real world or CAD and BIM systems. We refer to the measured values from the origin as coordinates, which exist in three dimensions. For two-dimensional, plan-based work we may only express locations as X and Y and for three-dimensional work including BIM, we use X, Y and Z. For expediency, we will deal first with the X and Y, 2D origins and move on to the Z dimension of height in the second part (see Figure 1).

Figure 1. An origin



The examples used for 2D X and Y coordinates in the main text use the UK OS National Grid (often called the British National Grid) produced by Ordnance Survey. We shall refer to this as the OS Grid. The principles discussed apply equally to the Irish Grid produced by Ordnance Survey Ireland (see Figure 2).

Figure 2. The OS Grids of UK and Ireland

The examples used for 'absolute' height coordinates in Z refer to vertical ordnance datum values. For UK and Ireland, these relate to mean sea levels taken from one of three places: Great Britain – Ordnance Datum Newlyn (ODN); Northern Ireland – Belfast Ordnance Datum; and Republic of Ireland – Malin Ordnance Datum.

2.2 Origins in BIM and CAD

Note: Items in bold are key terms readers might want to be able to quickly refer back to as they move through the document.

All major BIM/CAD design systems have the ability to set more than one origin (or datum). Typically, a project will be located relative to a **real-world origin** point, referred to as the **national grid origin**, from which other points can be referenced. For practical purposes and setting out on site, it is also common to define a **project origin**, and points are expressed relative to this point using **relative coordinates**, echoing the approach adopted in real-world projects (see Figures 3 and 4).

For example, in the UK we have the **National Grid** origin (i.e. the bottom left-hand corner of the OS National Grid which has the coordinate 0,0) and we often have a **project origin**, which is typically an intersection of the OS National Grid near to the project site or some other easily identifiable point also near to the site. In the UK, the **project origin** should be defined as a coordinate **relative** to the OS National Grid origin.

In the UK, we typically refer to this coordinate using an Easting and Northing coordinate. For the UK, Northing and Easting coordinates will always be positive and also correspond directly with the XY coordinates in a BIM/CAD system. In other words, an Easting coordinate = an X value and a Northing coordinate = a Y value (the third dimension of height or elevation = Z and we will deal with this later). Typically, once set, these origins remain fixed throughout a project's life. For advice on **project origin** data supplied as **longitude and latitude** see section **3.5** later in this document.

While the principles outlined above remain the same in all major software, the terminology may vary. For consistency throughout the remainder of this document, we will refer to the two types of coordinates as '**National Grid origin**' and '**project origin**'. A summary of how these terms apply to the most commonly used software platforms in landscape design is provided in Table 1 as a guide only.

Figure 3. OS National Grid origin

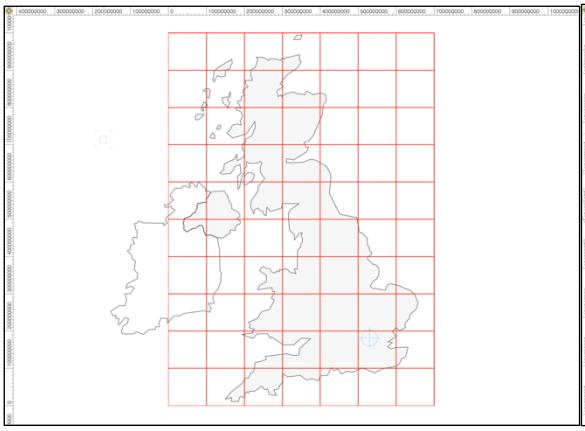


Figure 4. Project origin

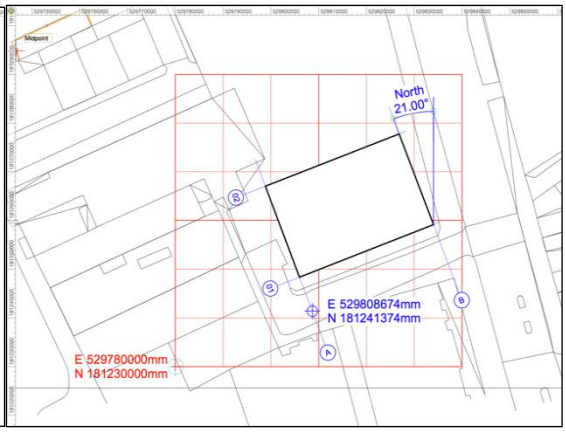


Table 1. Summary of 'National Grid origin' and 'project origin' across software platforms

National Grid origin	Project origin
Equates to Vectorworks **User Origin**	Equates to Vectorworks **Internal Origin**
Equates to ACAD **World Coordinate System Origin**	Equates to ACAD **User Coordinate System Origin**
Equates to Bentley **File Origin (Attached Library GCS)**	Equates to Bentley **File Origin (Transformed GCS)**
Equates to Revit **Survey Point**	Equates to Revit **Project Base Point**
Equates to Archicad **User Origin**	Equates to Archicad **Project Origin**

3 Concepts

3.1 The internal software origin and optimal working area

In addition to the two origin types defined earlier (real-world **National Grid** and **project**), it is important to understand that **all** BIM/CAD systems operate with concepts known as the **optimal working area** and the **internal software origin**. In simple terms, the **internal software origin** should be synchronised or at least in close proximity to (i.e. within 5km) the **project origin** (as opposed to the **National Grid origin)**. In practical terms, this means that users should ensure that project geometry is close to this optimal working area in order to maintain maximum precision and efficiency.

The vast majority of origin collaboration issues occur when this procedure has not been followed and an appropriate conversation has not taken place between respective parties.

In simple terms, **all** CAD/BIM systems are susceptible to calculation rounding issues if the drawing content has a large offset from the software internal origin. An expanded technical explanation is provided in section **3.7**. These issues can be easily prevented if you consider some simple, basic concepts while importing, referencing, linking or pasting external content.

3.2 Origin relationships

Typically, in a new document, the various origin types exist in the same position and are located at 0,0,0 (0 in X, 0 in Y and 0 in Z) by default. During project set-up, the following relationship is set up between the available origins (see Figures 5 and 6).

Figure 5. New default file – pre-project set-up

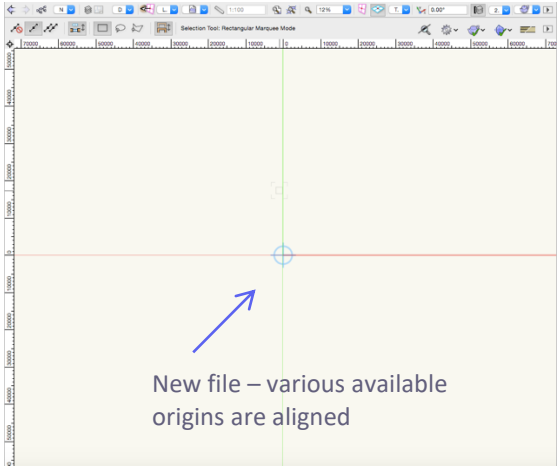
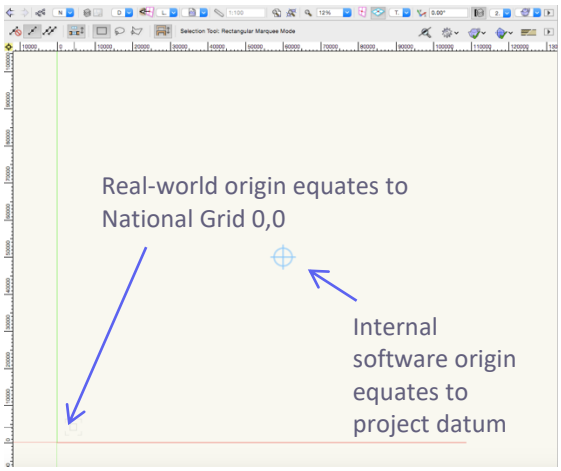


Figure 6. Post-project set-up



Typically, when you create a blank, new document the various origins are aligned. All advanced BIM/CAD software allows for the origins to be repositioned relative to each other. Essentially, this allows measurements to be taken relative either to the **National Grid origin** or the **project origin**. Such measurements may be seen on rulers, object information position palettes and dialogue boxes.

While the **National Grid origin** is also typically used by default as the alignment point when either importing or referencing files, options often exist within software to use the **internal software origin** or **project datum** as the alignment point. Therefore, when working with external partners, it is important to establish, understand, document and use the origin protocol appropriate to your project prior to beginning working. Typically, this will be the same for the users you are working with.

The relative position between the origins can be adjusted freely, although it should only really need setting at the beginning of the project in each file that you use. Setting up these origins correctly at the outset of each project allows you to work in a standard compliant manner and accommodate workflows using survey data and overlay grids such as the UK Ordinance Survey (OS) Grid.

3.3 External file import (including linking and referencing)

When first setting out project origins, survey files from other software platforms often contain information which, when correctly imported, will automatically set the correct relative positions of the origins and maintain the coordinates used in the source file.

Your software should provide specific settings to allow files to be imported in the correct relative positions. The emphasis, once again, is on communication and the establishment of a defined origin statement that all parties agree on. Equally, when sharing/exporting data with others, agreeing the project coordinate system and origin to be used will ensure your files import correctly into other software.

3.4 Collaboration with Geographic Information Systems (GIS)

Several BIM and CAD software platforms provide for **geospatial data** collaboration through built-in features, such as georeferencing projection systems or import/export of GIS based file formats, such as .shp (shape files)**.**

It is not the scope of this document to look into this topic in detail, however, when combining such data with the project geometry and the OS grid, the principle of maintaining project geometry within the optimal working area still stands.

3.5 Latitude and longitude

In general, projects within Ireland or Great Britain do not use latitude or longitude when describing internal geographic locations. Instead, as discussed, the OS National Grid conventions of both Great Britain and Ireland use Easting and Northing coordinates, which correlate with the concept of X, Y coordinates of a CAD/BIM system**.**

If your **project origin** has been supplied in **latitude** and **longitude**, it is possible to convert to an X, Y coordinate and several online resources allow you to do this (see:

http://www.bgs.ac.uk/data/webservices/convertForm.cfm and http://www.osi.ie/services/geodetic-services/coordinate-converter/)

Care should be taken with this approach and, if used, the conversion system should be agreed among all project members in order to achieve consistent conversion values.

3.6 Height data

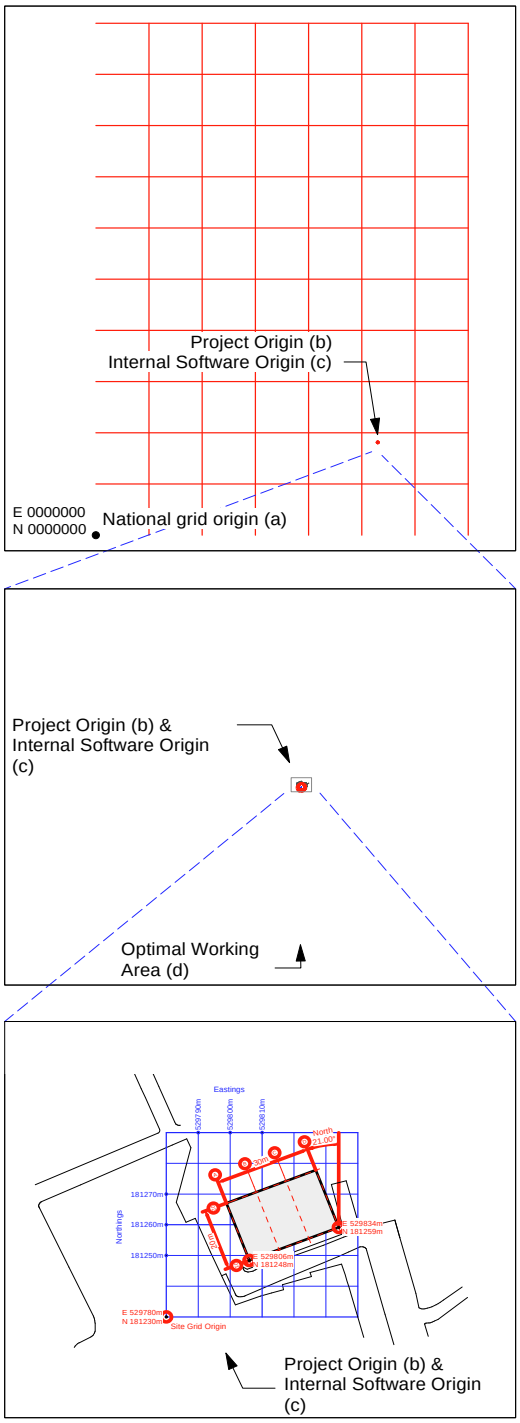
Heights in Britain and Ireland are measured relative to national ordnance datum points. Coordination errors can occur between different parties, especially when taking into account that different disciplines default to different height datums due to longstanding discipline traditions. For example, while a landscape architect will naturally use ordnance datum spot heights, a structural engineer may have defined local zero height as the structural ground slab and an architect may have defined it as the finish floor level.

It is equally important, therefore, to define a Z height spatial definition within the project team at the outset of the project. For clarification, elevations from both the national datum and relative project datum may be included.

3.7 Optimal working area – technical information

As outlined in section **3.1**, all CAD BIM software works with the concepts of the **optimal working area** and software **internal origin** and typically this area has a radius value of up to 5km, the centre of which is the internal software origin. Users of any such system should keep their project within this area. Figure 7 explains the relationship of the **optimal working area** and the **software internal origin** to the **project origin** and **National Grid origin**.

Figure 7. Origins and the optimum working area



Origin (a) equates to the National Grid 0,0 coordinate. Origins (b) & (c) define the Project Origin and the Internal Software Origin.

[Zoom scale 1:3000000]

The Project Origin (b) is synchronised or close to Internal Software Origin (c) and within the Optimal Working Area (d).

[Zoom scale 1:500000]

The synchronisation (or close proximity of the Project Origin to the Internal Software Origin (c) allows BIM/CAD software to use large coordinate values whilst simultaneously keeping internal software calculation values to the required 16 digit 'floating-point' precision limit.

[Zoom scale 1:200]

Projects contained within the optimal working area are easily dealt with by the software's internal calculations. However, projects thousands of kilometers away from the software internal origin can lead to problems during calculations performed by the CAD/BIM application. This optimal working area value limitation is due to the calculation methods used in advanced BIM/CAM software and which are related to the mathematical concept of 'floating point precision'. Floating point calculation uses calculations based on a certain number of digits (regardless of decimal placement). It is for this reason that all calculations are based internally relative to the internal origin (which is the center of the optimal working area).

Software applications deal with this issue in fundamentally the same way. They allow users to model or draw within the required **optimal working area**, centred around the software **internal origin** and **project origin**, while at the same time being able to establish a **National Grid origin**, which may be a substantial distance outside of the optimal working area (see Figure 7).

It is important to understand that it is the internal calculation values that are affected by floating point mathematics, and not the use of large coordinates in themselves. In other words, it is **acceptable** to work with **large coordinate values** such as those experienced when working with the National Grid and Easting and Northing values. The important point is that you will need to establish a spatial definition for your project, such that the position of the user defined origin (e.g. 0,0 of the OS Grid) is relative to the drawn/modelled elements, which in turn are close to the internal software origin.

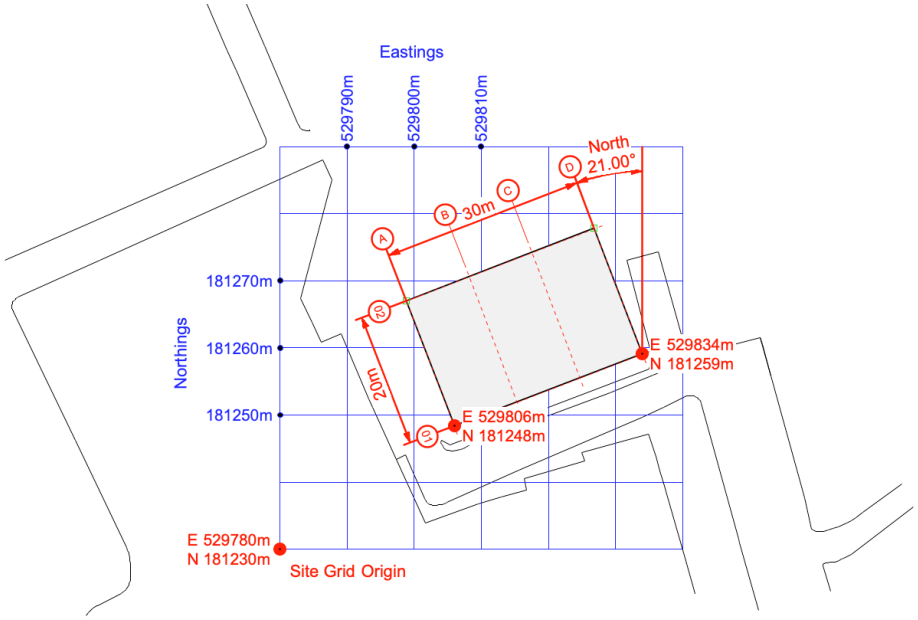
The major software companies involved in the preparation of this document have verified that their software functions in the same way with regards to relative origins, optimal working areas and floating point precision. As such, it is not an acceptable working practice to apportion any coordination issues as being the responsibility of the software. Rather, it should be accepted that this is a communication and collaboration protocol issue that should be agreed and verified by project parties at the outset of the project.

In summary, the **National Grid origin** can be offset from the **internal origin** many thousands of kilometers. BIM/CAD programmes can handle this without any problems. It is important, however that drawn/modelled elements remain near the software **internal origin.**

4 Project spatial definition

Figure 8 and its numbered list provide an example of a spatial definition. This pulls together all information discussed previously in section **3**, in a form-based format which can be provided to all parties at the outset of a project. Full requirements can be found in BS EN ISO 19650-2 (section **8.3**).

Figure 8. Example of a spatial definition



1. **Standard Named Projection:** UK Ordnance Survey Grid

   or

   Named Global Geospatial System: EPSG 27700 OSGB 1936 / British National Grid
2. **Elevation Datum:** ODN (Ordnance Datum Newlyn)
3. **Project Origin**

   Easting (mm): 529806000mm

   Northing (mm): 181248000mm

   or

   Latitude (Decimal Degrees): -0.13068800

   Longitude (Decimal Degrees): 51.51525100
4. **Project Origin Elevation** (Metres): 000

5. **Plan Orientation to Geospatial North**:

Rotation:	21.00000000 Decimal Degrees
or	
Local Grid Point 1:	529806000mm / 181248000mm
Local Grid Point 2:	529834000mm / 181259000mm

6. **Units (SI):** Metres for Infrastructure / Landscape Millimetres for Building

5 Conclusion

This document set out to demonstrate that all major CAD and BIM software platforms utilise the same fundamental approach and technology with respect to file origins and coordinates. As such, origin and project datum synchronisation is a communication and protocol issue that should be agreed and tested by project parties at the outset of the project. In summary, it is important to get to know how origins are set up in your chosen software and also how the terminology used in your software relates to others on the market.

We have also referenced the specific clauses in the standards which relate to origins and spatial definitions. Finally, we hope you will take with you the importance of collaborating with all members of your project team at the outset of the project, ensuring that a spatial definition statement is in place in order to smooth your model and information exchange process.

6 Useful links

The following resources provide further information relating to coordination systems and mapping projections.

OS Guide to coordinate systems in GB:

https://www.ordnancesurvey.co.uk/documents/resources/guide-coordinate-systems-great-britain.pdf

ArcGIS help choosing a projection:

http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Choosing_a_map_projection/00130000004z000000/

QGIS help with projections:

https://docs.qgis.org/3.4/en/docs/gentle_gis_introduction/coordinate_reference_systems.html#

https://docs.qgis.org/2.8/en/docs/user_manual/working_with_projections/working_with_projections.html

EPSG registry for relevant projections:

http://www.epsg-registry.org/

or, for more user friendly versions: https://epsg.io/registry.org/ or https://spatialreference.org/

JavaScript (D3) information and visualisations of projections:

https://www.d3indepth.com/geographic/#projections-1

https://www.d3indepth.com/blocks/geo/projection-configuration/

7 References

BS 1192: 2007 + A2: 2016, *Collaborative production of architectural, engineering and construction information. Code of practice*. London: BSI.

BS EN ISO 19650-1&2: 2018 and PD 19650-0:2019 Kit, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM): Information management using building information modelling*. London: BSI.