SCSI Chartered property, land and construction surveyors

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TU DUBLIN
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BIM - Route for the QS into the 4D and 5D Digitised Workflow

1st Edition

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Foreword

The only constant in life is change! The pace of changing technology and the digital advancement of society is unparalleled in recent times. Adapting to, and harnessing technology has never been more crucial. Digitisation presents incredible potential for the Quantity Surveyor (QS).

Adaptation begins with 2D technologies, in the form of digital 'on-screen' measurement, and progresses to the data-rich 3D BIM environment, which for the QS, also encompasses the added functionality of 4D (time) and 5D (cost) BIM. Utilisation and integration of the latest technological developments into the QS workflow could augment and enhance the skill set of the professional QS. As digitisation of design, planning, procurement and management becomes ever more prevalent in the industry, it is clear the QSs traditional way of working needs to evolve, and therein lies the paradox. The end goal must remain the same (quality, time and cost) and the foundations of our skill-set must also remain intact, such as the cost plan, BOQ, change cost control etc. However, a more collaborative, more usable, and more efficient approach, could be utilised to add value to our profession.

It is encouraging to see the Society of Chartered Surveyors Ireland and the QS profession as a whole continuing to advocate and embrace this digital revolution. It is incumbent on us as professionals, employees, employers and educators to not only be part of this revolution, but to lead it and to shape it in a way that enhances our work practices and processes.

We are currently experiencing a phenomenal level of change in every area of our industry, from the implementation of the ICMS; advancements in modern methods of construction; proliferation of stringent building regulations; to a more sustainable way of working and building. With the Construction Sector Group building upon the NBC's 'Roadmap to Digital Transition', and the Government's commitment to investing unprecedented levels of capital in the development of social and economic infrastructure, it is clear we are riding the wave of change. It is time for the QS of today to become the skilled and dynamic 5D QS of tomorrow.

With all this change come many challenges, and to overcome these challenges, we need to empower ourselves with the know-how, the language and the technical expertise to collaborate effectively with all stakeholders. We should as a profession be mindful that we are not alone on this journey, our colleagues on project teams are faced with similar challenges; and our recognition of this highlights the importance of communication and collaboration in our industry.

This publication, a collaboration between Technological University Dublin and the Society of Chartered Surveyors Ireland, provides a clear and succinct introduction to the core skills required of the 5D QS. It addresses common and recurring issues we are faced with on a day to day basis as we migrate to the digital environment. **BIM – Route for the QS into the 4D and 5D Digitised Workflow** is not only an informative text, but also a 'how to' guide for QSs, and will provide much needed guidance on this exciting and ever-evolving journey.

Noel Walsh MSCSI MRICS
Chairman SCSI BIM QS Working Group

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Abbreviations

AEC	Architectural Engineering Construction
ARM4	Agreed Rules of Measurement
BCAR	Building Control Amendment Regulation
BCIS	British Cost Information Service
BIM	Building Information Modelling
BOQ	Bill Of Quantities
BSI	British Standards Institute
bSI	buildingSMART International
CDE	Common Data Environment
DWF	Design Web Format
EIR	Employers Information Requirements
GEFA	Gross External Floor Area
GIFA	Gross Internal Floor Area
ICMS	International Construction Measurement Standards
IFC	Industry Foundation Class
IPMS	International Property Measurement Standards
LCC	Life Cycle Costing
LOD	Level of Detail
LOI	Level of Information
MD	Model Derived Quantities
MEP	Mechanical Electrical Plumbing
MM	Manual Measurement
MQ	Model Quantities
MVD	Model View Definition
NBS	National Building Specification
NRM	New Rules of Measurement (UK)
NSBE	National Standard Building Elements
QSID	Quantity Surveying Identification
QTO	Quantity Take Off
RIBA	Royal Institute of British Architects
RICS	Royal Institute of Chartered Surveyors
SCSI	Society of Chartered Surveyors Ireland
SMM	Standard Method of Measurement
WBS	Work Breakdown Structure

Executive Summary

This information paper has been compiled for Quantity Surveyors (QSs) in relation to Building Information Modelling (BIM). The purpose of the paper is to discuss BIM as a technology, presenting how data contained within a 3D model differs from 2D drawings and specifications, and how BIM models can be consumed by the QS.

It is envisaged by reading this information paper, as well as the documents and media content mentioned therein, that the QS will gain a greater degree of confidence, enabling them to communicate as an informed participant in an emergent digitised construction workflow.

An understanding of model objects and data is critical because the QS must have the know-how to map 3D design information to their Work Breakdown Structures (WBSs) such as the National Standard Building Elements (NSBE) and the Agreed Rules of Measurement 4 (ARM 4). The fundamentals of a 3D model are therefore detailed, including data contained in the objects of the model.

The paper outlines the basics in 4D BIM (time/clash) and 5D BIM (cost management), and particularly how the QS can leverage the model to effectively manage client requirements, especially time and cost management. It also describes a number of mapping methods, linking data of the model, in incremental complexity, to the QS WBSs.

It is acknowledged that BIM is not currently a panacea for instantaneous cost/plan or BOQ production, but a technological process that is creating opportunities for QSs to add value, while also maintaining their high level of services. The paper therefore addresses some of the issues that QSs may encounter when generating and using BIM quantities, and outlines difficulties when transitioning from a 2D workflow to a BIM process.

This information paper does not deal in detail with BIM as a 'process', in terms of the International Standard Organisation's series of BIM standards (ISO 19650); the level 2 mandate in the United Kingdom (UK); or Ireland's BIM road-map. Even though these policies and documents are important and collaboration across all stakeholders is a key underpinning of BIM.

The paper is structured such that it may be read from start to finish (depending on the readers understanding and capabilities with BIM) or it can utilised on a sectional basis, as required.

Dr Dermot Kehily (MSCSI, PhD)

Building Information Modelling

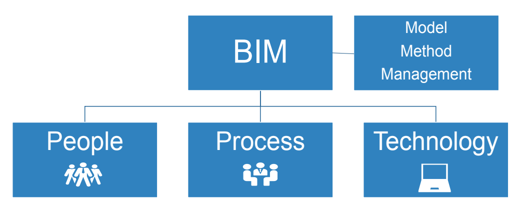
Introduction

Building Information Modelling (BIM) has the potential to increase efficiency in the construction industry by changing traditional 2 Dimensional (2D) information exchange to a method of delivery that promotes collaboration and integration across the construction supply chain. From a Quantity Surveyor (QS) perspective, BIM offers capabilities to generate Quantity Take-Off (QTO) directly from a 3 Dimensional (3D) model. This paper outlines the 4 Dimensional (4D - Planning) and 5 Dimensional (5D - Cost) process. It also addresses some of the issues that the QS may come up against when generating and using BIM quantities and some difficulties when transitioning from a 2D to a BIM process.

BIM process

BIM does not simply involve technology/software but rather a different way of thinking, a cultural change and a new approach to project delivery. BIM brings together participants in a collaborative, cooperative and proactive manner around a common source of information. No clear definition of BIM seems to be widely accepted and there is nothing in the 'BIM' acronym that suggests it is more than just a technology. However, Underwoord & Isikdag (2010) provide a good summation of BIM, describing it both as a process focused on information management among participants of the project and a technology representing a digital model, where information about the project can be stored and transferred. **Figure 1** encapsulates this analogy of BIM, whereby the "M" in BIM is often used interchangeably to mean a model, a method or management.

Figure 1: BIM Process



BIM technology

One of the key aspects of BIM is its ability to provide the QS with detailed 3D project views. It must be understood that 'views' of the Building in BIM are not individual drawings, but rather different aspects/ views of the same model. Thus one view should not contain something that the other views do not, unless it is hidden in that view, or not specific to that view. It is the information attached to objects that makes BIM more than a visual representation or a 3D isometric drawing.

Models are made of smart objects, which digitally represent the physical elements and encapsulate their intelligence. The information contained in the objects are called the 'object properties' or 'attributes', which allow for storage of useful information about the object in the model. For example, as well as BIM software illustrating a certain type of wall and its position in the model, the wall contains data, such as, the name of the wall; thickness; material specification; fire rating; thermal conductance; and the structural makeup of the wall. The designer does not physically draw this wall (outlining its constituent parts represented by lines, arcs etc.), but selects it from a library of objects and inserts it in the model. A good analogy of this is a Lego model, where pieces of Lego are selected from the box (library) and set in place (in model view) to construct a Lego model. The Lego pieces individually represent the objects, but when utilised and used in the context of constructing a model, together they represent a model version of a house, airplane, ship etc. **(Figure 2)**.

In BIM the objects that are selected and inserted into a model are intelligent. For example, a door knows it is a door, and when it is placed into a wall, the wall knows it has to have an opening to suit the size of that particular door. This allows an object in the BIM environment to update itself as its context changes. These are the intelligent abilities of the objects and in this context BIM is described as 'Parametric'. **Figure 3** illustrates the link between parametric properties (dimensions, alignment and location) and the context of its use in a wall, i.e. its offset and opening size in the wall. The arrows in **Figure 3** represent relationships with adjoining objects and these define how the wall interacts in different locations and varied parameters. All the parametric objects of a BIM combine to make up an intelligent building design that can coexist in a single 'project database or virtual building'.

BIM progression (LOD)

Projects that utilise BIM progress in much the same way as those that are based on 2D drawings, with data and graphical enrichment throughout design development. At the very early stages, models are designed in mass shapes without any object data to convey the specification. This is the massing stage of BIM progression, which provides a 3D isometric form, using planes for floors and a voluminous shape to convey the envelope (**Figure 4)**. The mass model provides geometric context but little in the way of information in terms of specification. Subsequent to massing, designers start to use visual objects which contain data.

The extent of information provided in the objects is the Level Of Detail (LOD) and the non-graphical information (such as spatial, performance, standards, workmanship and certification) is the Level Of Information (LOI). The LOD and LOI develop alongside one another as the model develops in more detail. The LOD specification

Figure 2: Model

Figure 3: Parametric

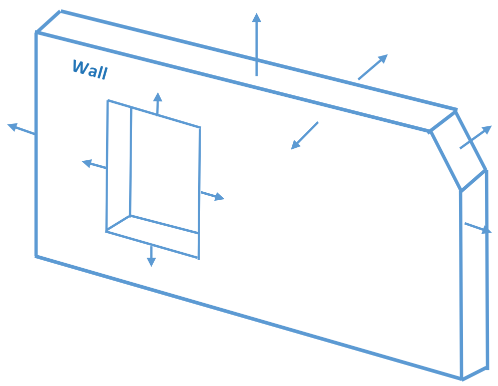
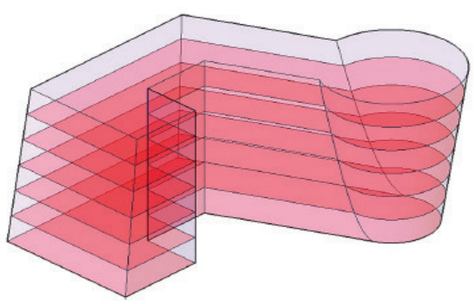
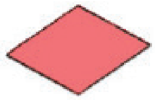
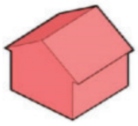
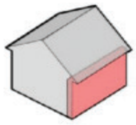
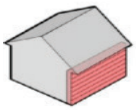
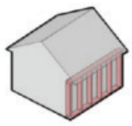
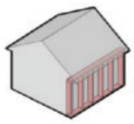


Figure 4: Mass Model



is a concept that enables the project team to design to an agreed level and maintain consistency across disciplines. From a QS perspective, the LOD should align to a certain stage of the design process, and thus, to certain stages in the cost planning process. **Figure 5** illustrates the different LODs and aligns them to the Royal Institute of British Architect's (RIBA)plan of works and the relevant cost planning stage. However, the cost plan stage to the LOD/LOI is not absolute and will depend on what is agreed in the BIM Execution Plan (BEP) and the jurisdiction the project is carried out in.

Figure 5: LOD

	RIBA Plan of Works	LOD	Info in Model		QS Stages
Stage 0	Strategic Definition				
Stage 1	Preparation & Brief	0	Block model, performance requirements, site restraints		High level Order of Cost Estimate
Stage 2	Concept Design	100	Mass model, areas, volumes		High level Order of Cost Estimate
Stage 3	Developed Design	200	Generalised systems		Cost Plan/ Approx Quanitities
Stage 4	Technical Design	300	Pre-construction model with systems		Cost Plan/ Approx Quanitities
Stage 5	Construction	400	Model suitable for fabrication/assembly /installation		Bill Of Quanities
Stage 7	In Use	500	Asset Information Model		Facilties Management

Exchanging BIM data

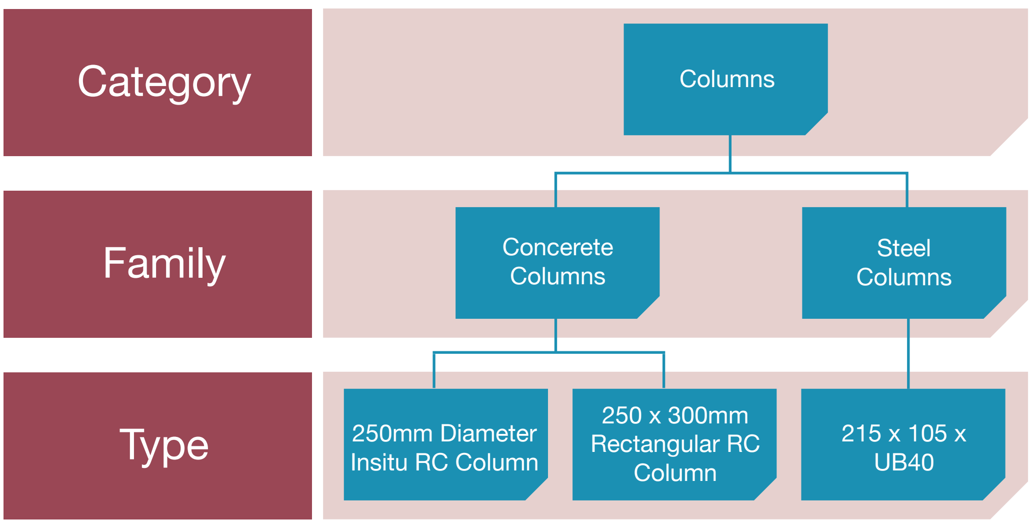
Design team members rely on their own discipline specific software to build and manage their models. The file formats are mostly proprietary to that software and cannot communicate directly with another application. However, it is paramount that there is movement of information from one BIM application to another (much like drawings and PDFs are currently shared). The sharing of information across all BIM applications and disciplines (where different software can recognise the product of another) is described as 'Interoperability'. Interoperability is the key underpinning of BIM, because it allows various stakeholders to work together by exchanging information, even if they are working with different applications. If this process is lacking, or data is lost in that exchange, full collaboration cannot be realised.

Open-proprietary file formats can be exchanged between different applications but they are usually non-editable. An example of an open proprietary file format is a Portable Document Format (PDF). However, a PDF only contains geometry, rather than data, thus it would not constitute a BIM data exchange. BIM data exchange has been improved through the establishment of Design Web Format (DWF, DWFx) and Industry Foundation Classes (IFC), which are common data 'schema' that makes it possible to exchange non editable data between different proprietary BIM software applications.

DWFx

DWFx is Autodesk's own interoperable file format, thus it is not fully open, but it can be used by third party vendors in some instances. When exporting from Revit, designers can publish individual sheets or multi-sheet 2D and 3D drawing views, all within a single DWFx file. DWFx is a popular file format for some estimating applications because there is no data loss when transferring data from Revit to 5D BIM application's such as CostX or Navisworks. When a DWFx is exported from Revit, information about the model objects are classified into a hierarchical structure of Categories, Families, and Types. This categorical structure including all associated data is replicated when exporting from Revit to a DWFx file (**Figure 6**). The exporting process (i.e. what you click and select) is simpler when compared to exporting from IFC. An advantage of DWFx is that it maintains the original Revit naming conventions, which is discussed in a subsequent section. One of the issues with DWFx is that it only exports general Revit information and does not export all the parameters of the objects. This can cause a problem when you want to export specialist coding information such as the UniClass or Omniclass, that might not be available in the exported file. However, it is unlikely DWFx will be accepted by all applications from different disciplines on a project and thus its future is untenable as an open BIM exchange.

Figure 6: Revit Structure



Industry foundation class (IFC)

IFC is developed by buildingSMART International (bSI), a not-for-profit organisation which constructs and supports, what they describe as 'Open BIM'. Unlike DWFx, as an open format, IFC does not belong to a single software vendor, it is neutral and independent of a particular vendor's native format. IFC has gone through a number of evolutions, with the newest version IFC4 published in 2013 as ISO 16739:2013 (now ISO 16739:2018). However one of its predecessors, IFC 2.3 Coordination View 2.0, is still the most common file format used in the construction industry when exchanging files.

A Model View Definition (MVD) defines a subset of the IFC schema, which filters out unnecessary data that is not applicable to the exchange requirements of the Architecture Engineering Construction (AEC) industry. MVD 2.0 is used with IFC 2.3 Coordination View when exporting interoperable construction files. For QS purposes, IFC 2.3 Coordination View MVD 2.0 must be enabled to include 'Base Quantities' (i.e. tick 'base quantities' box when exporting - this is discussed later). Without including base quantities in the export process the QS will not have access to geometric data when the IFC file is imported into the 5D application, such as Cubit or CostX. There is a 'Quantities add-on MVD' for IFC4, but it is not fully developed and available across all vendors yet. In the MVD for IFC4, roof quantities will be available (not available in IFC 2.3) and base quantities will be integral in the export process, so you will no longer have to remember to tick the base quantities box.

In IFC the 'Base Quantity' values are calculated from the model geometry as part of the IFC export process and are not explicit properties of the host model. However if possible, the model dimensional properties should be included in the IFC as a Property Set in preference to, or in addition to, Base Quantities. Unfortunately Base Quantities are not provided in IFC 2.3 for excluded elements such as casework, plumbing, footings and roofs. Data from a proprietary software such as Revit has its own categorical structure, i.e. previously illustrated in **Figure 6.**

Figure 7 provides a visual representation of the export process where the native data format in Revit is converted (or mapped) to the IFC data structure. As illustrated in **Figure 7**, the IFC structure is made up of an overall 'ifcBuildingElement' which in turn is made up of a number of 'Entity' subtypes, such as ifcWall, ifcStair and ifcDoor. Mapping from native files to IFC is not a uniform process and sometimes data can be lost or mislabeled in this procedure. For example, if an object has no corresponding IFC entity it will be exported as a 'Proxy'.

A proxy object is represented as a general solid object (with no data) and labeled as a generic 'IfcBuildingElementProxy' element. As a general solid object, it has geometry, but no data, which is obviously undesirable and therefore to be avoided. Thus if the QS generates an automatic QTO they will see the dimensions of the proxy object but will be unable to determine what it is without a visual representation of the object.

At present, many BIM software vendors have integrated DWFx and IFC importers/exporters within their applications, so files can be shared with other disciplines. This enables models to be imported and exported from BIM authoring applications, such as Revit, into 5D estimating applications. IFC is complex and it is worth visiting the bSI website (https://www.buildingsmart.org/) to further inform yourself with IFC and its associated MVDs. The following link (video) outlines the export process from Revit into DWFx and IFC: https://youtu.be/u0hS06iv6p0.

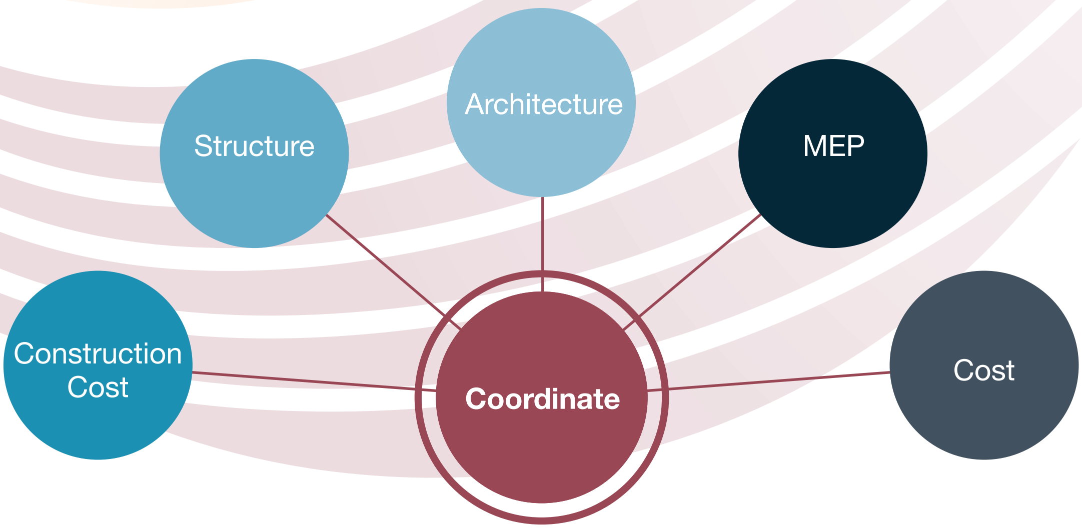
Figure 7: Revit / IFC Structure

Revit/ DWFx	IFC
Structural Framing	IfcBeam
Structural Columns	IfcColumn
Doors	IfcDoor
Windows	IfcWindow
Structural Foundations	IfcFooting
Floor	IfcSlab
Roof	IfcRoof
Stairs	IfcStairs
	IfcStairFlight
Walls	IfcWall
	IfcWallStandardCase
	IfcBuildingElementProxy

Collaboration

Collaboration in BIM does not just pertain to the movement of interoperable files amongst stakeholders. Proponents of BIM often accentuate that BIM is not a technology but a process based on information management. A new way of working requires some change to our traditional work practices such as establishing collaborate procurement and tendering procedures; enacting a contractual framework that

Figure 8: NBS Collaboration



promotes integration amongst stakeholders; and the utilisation of information management tools that can promote transparency in terms of stakeholder responsibilities and required actions. **Figure 8** illustrates a image from the National Building Specification (NBS) in the United Kingdom (UK) which outlines that effective and coordinated collaboration is essential amongst stakeholders.

Common Data Environment (CDE)

Central to this approach is an environment that can be used to effectively collaborate on BIM projects. A Common Data Environment (CDE) is a central repository that houses all information pertaining to the construction project. In using a single source of information, collaboration between project stakeholders should be enhanced, mistakes reduced, and duplication avoided. Construction is a fractious industry with many different parties contributing and receiving information throughout the supply and production chain. The CDE brings together all who work in the wider project team, such as the architect, QS, landscape consultant, structural engineer, civil engineer and mechanical and electrical services consultants. The CDE requirements in the AEC industry are defined in ISO 19650 (BS 1192), which is an essential read for the QS starting out on their BIM journey.

In the CDE, the information inputs are termed 'data drops**'** and should be agreed by the parties of the project at specific points in the project cycle from the outset. There are a number of different tools that can be used as the CDE, from off the shelf cloud collaboration tools, such as, Dropbox; MS OneDrive; or Google Drive, to a dedicated extranet for the project.

Products such as Autodesk BIM 360, Trimble Connect and Bentley Project Wise are graphical (and non-graphical) BIM dedicated CDEs, which are gaining in popularity as they are designed specifically for use on BIM projects. These tools provide a common workspace which can control access via permissions, track and manage activity, view real-time graphical and non-graphical data and provide a quality assurance process which can track and control the flow of information. The CDE should be discussed and established from the outset through its inclusion in the Employers Information Requirements (EIR) and the BEP. The QS must be aware of how the CDE works and what they need from it. This is discussed in further detail in subsequent sections.

Procurement and Contractual Framework

As well as the technical collaborative environment there needs to be a process and legal environment to enable and promote collaboration. BIM should not be seen purely in technical terms but rather as a catalyst for a deeper process. In light of significant technological change, that has lead to changes to leaner workflows, the industry needs a new approach, that can align interests, objectives and practices, through a collaborative-based BIM facilitated process.

A procurement process known as **'**Integrated Project Delivery' (IPD) is a relatively new procurement method that can facilitate the use of BIM through a contractual environment that promotes collaboration and integrated teams. To facilitate this process, IPD requires a different contractual relationship between stakeholders. IPD and BIM can promote an approach of early stakeholder involvement in the project supply chain, where decisions made early in the design process can have a greater effect on the ability to impact cost.

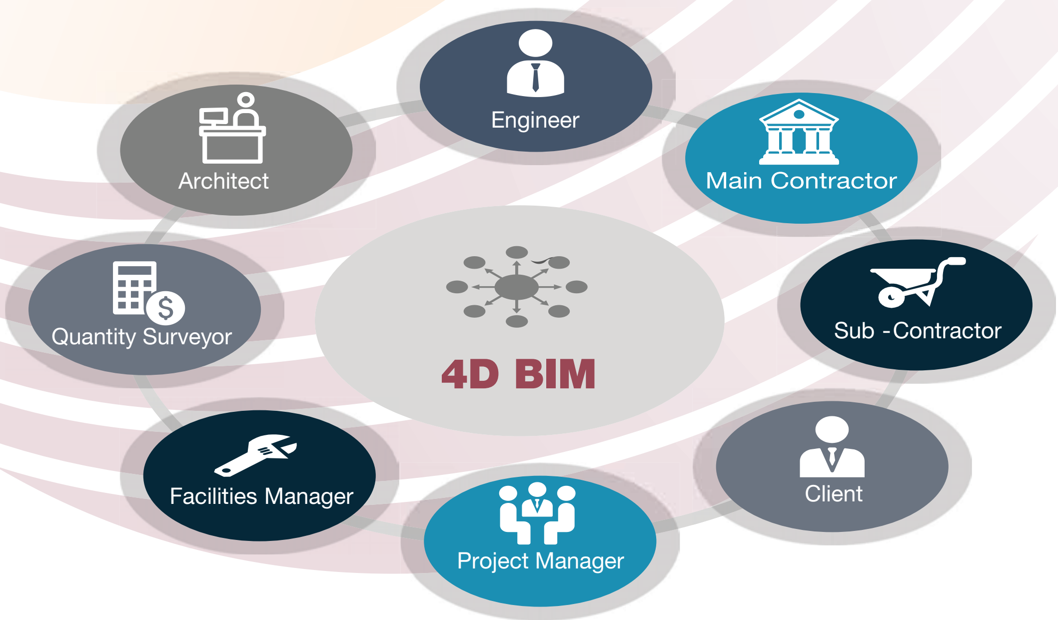
4D BIM

Introduction

The majority of this document will discuss the use of 5 BIM, but 4D BIM is also an important aspect for the QS, because it links the 3D model to the scheduling of construction activities. 4D BIM allows the construction process to be broken into construction activities set in sequence which can be visualised over time. At the planning stage, this can be useful to ensure that the construction project is scheduled safely, clearly and efficiently. The simulation of the construction project before any contractors start on site allows for greater early feedback and avoids uncertainty and expensive rework. Allowing all the stakeholders to visualise the completed project is very helpful when engaging with the project participants to ensure there are no surprises in the completed project as well as facilitating more accurate cost management.

There are several software solutions that offer a direct correlation between the project schedule and the 3D visual representation of the project. As well as linking schedules to the 3D model, 4D BIM offers several other benefits in the planning of construction projects, including analysis of constructability; space management; visualisation; clash detection; traffic management; hazard identification; and health and safety planning. Leveraging of 4D BIM has increased efficiencies in construction processes by improving the information flow between the stakeholders, and by promoting more effective communication. For 4D BIM to be successful, the traditional roles in the construction sector need to embrace technology and the synergies that can be achieved from its use. An understanding of the BIM information flow is something that all stakeholders will need to address, if 4D BIM is to be successful **(Figure 9)**.

Figure 9: 4D BIM Stakeholders



Scheduling

A 4D BIM model involves the management of graphical model components with schedule data. 4D BIM creates a visual construction sequencing model. This process allows the schedule information, that was once an isolated task, to be linked to a digital model. Linking the model to the schedule, allows the project team to assess the logic and sequence of the proposed plan of works and ascertain if the chosen methods are the most effective in terms of quality, cost and time. 4D BIM provides opportunities for alternative construction methods and sequences to be explored very quickly.

In order to successfully implement 4D BIM, there must be a high level of collaboration between the design team and the construction team. Each design team member will design in their own discipline specific software. The design teams' models are then exported and combined to form a 'federated model'. An example of this is where the architectural model, the structural model and the mechanical and electrical model are combined in Navisworks to create the federated model. These models will be uploaded to the CDE where they can be accessed, validated and interrogated. Interoperable files in the same format, such as IFC, will need to be exported from the software of each discipline and imported into the CDE to form a federated model, otherwise the files will not be compatible. The design team need to be aware of the information required to optimise the federated model, whether that be information required by the QS, or the Project Manager. In the case of the Construction Manager, having the correct information in the model allows the scheduling information to be realistically planned out. An example of this is the planning of works for in-situ concrete floor. This might be one element in the structural model, but in reality, may be part of a concrete pour sequence carried out in several parts. For a concrete pour to be properly scheduled, the concrete floor object(s) may have to be divided (per level or zone) in the authoring (design) software, prior to export into the federated environment. This can be problematic for the scheduler, if they do not have the knowledge of the design software such as Revit or Archicad. However, if the project has an agreed BEP it should communicate what is required by the downstream user, such as what is needed in the model by the scheduler and QS for time and cost planning.

For 4D BIM modelling to be successful the correct workflow is essential to ensure construction planning is as accurate as possible. As noted previously, BIM modelling software should be capable of interoperability among all the users involved in the project and a common interoperable file format (such as IFC) should be agreed, so that information being transferred from one user to another is fully compatible (**Figure 10**). The system should also allow for synchronising of data in a CDE. This allows changes to the model to be tracked by all project stakeholders, as well as allowing for real time progress on site.

The 4D BIM model allows the construction management team to track actual progress and examine the effects of delays and potential delays on the overall project schedule. The complexity of the construction site and the dynamic nature of construction processes can lead to delays and costs overruns on site. 4D BIM provides a platform that tracks and visualises construction throughout the construction process. This tracking is dependent on communication from the project team and the accuracy of the federated model. Some of the tools that can be used to manage the 4D process and to attach the federated model to the project schedule are Synchro, Navisworks, Navigator and Vico.

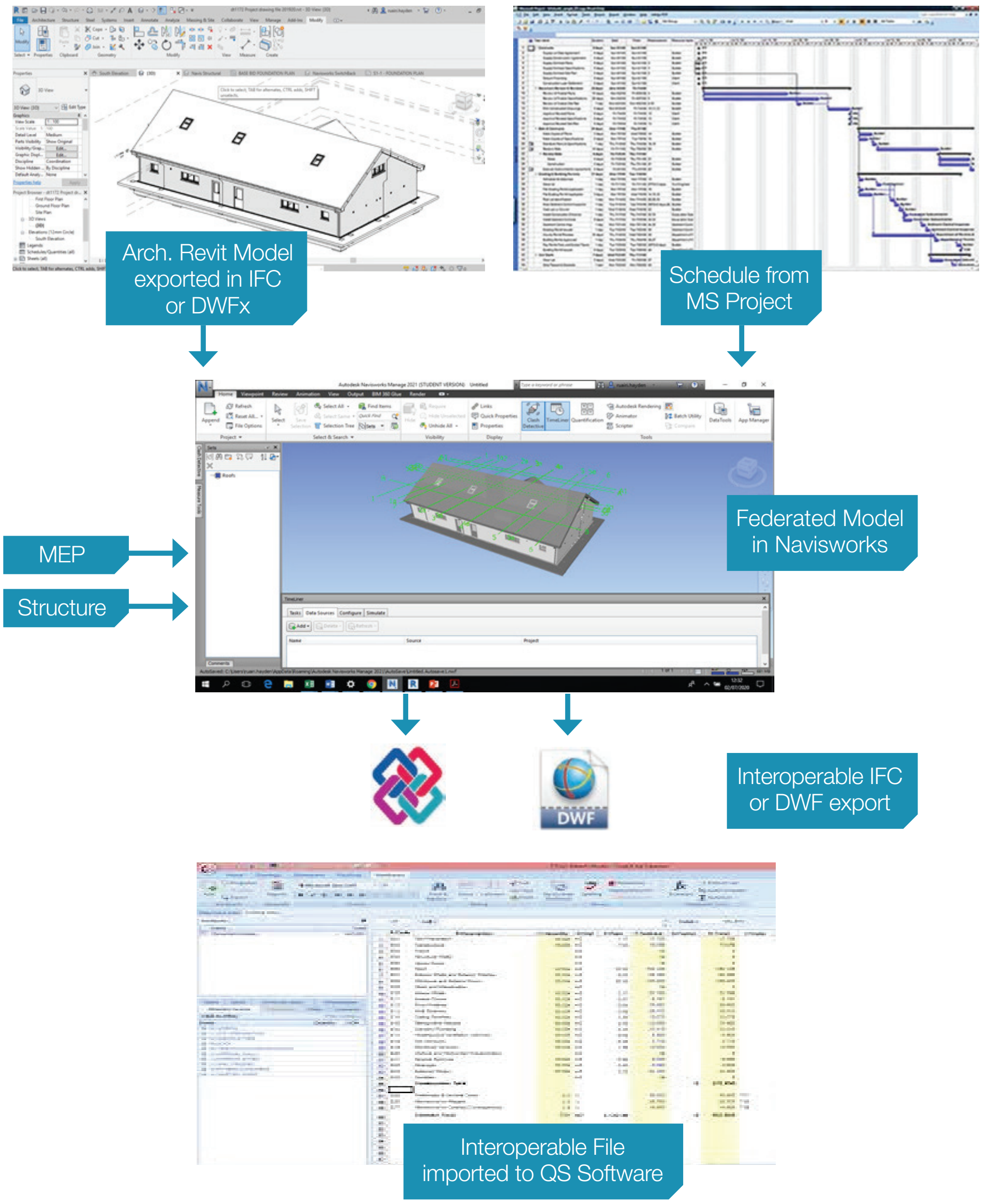
Figure 11 displays the workflow for a 4D project schedule. Each discipline exports their design in an interoperable file. The federated model is created by importing each interoperable file into 4D BIM software (in this example Navisworks). The software allows the models from different members of the design team to be combined in the 4D BIM software, as well as allowing project schedules to be uploaded from MS project, Primavera P6 or MS Excel. The schedule is imported to the timeliner (schedule) on the 4D BIM software. Each line item on the schedule can be attached to an element or a set of elements in the model. This allows the progress of the project to be visualised at a particular date on the project.

Figure 10: BIM File Management

The images in **Figure 11** illustrate the interaction from Revit, Navisworks and MS Project and the construction cost estimate in CostX. The level of detail in the digital model needs to be compatible with the schedule and the construction estimate so it is important that all stakeholders work to the appropriate LOD. As mentioned previously, the host model will traditionally be built by a particular discipline with an understanding of that discipline. The most obvious example of this would be an architect developing a Revit model as part of the design process, the architect is not responsible for the construction scheduling of the project and the proposed sequence of the work. This can be addressed by involving the QS, Construction Planner and Construction Managers at an earlier stage in the design process. Alternatively, a model can be manipulated in the host software or the 4D BIM software to allow for accurate construction scheduling. This can be done by breaking the model elements into parts or by adding customised parameters.

Some of the 4D BIM software will also allow QTO from the federated model, but as will be discussed in the latter sections, the QS is more likely to use a specific 5D software for this process. Figure 9 also illustrates that the federated model can also be exported from the 4D BIM software to the QS's specific software, this is done by exporting the federated model to DWF or IFC and then opening the file in the QS software.

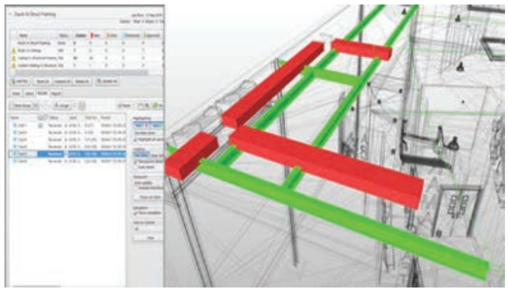
Figure 11: 4D Workflow



Simulation and clash detection

The traditional way to review the design for constructability and coordination has been for the architect and engineer to review the 2D CAD drawings. This is a very difficult review process and is often error ridden. Design errors can result in a large level of rework, cost overruns and schedule delays. Clash detection in a 4D environment can check coordination and collaboration between different design team members at an early stage of design. It is essential that the 4D model has a high degree of geometric accuracy in order to avoid conflicts and to identify and correct any problems that might otherwise arise in the construction phase. A much-touted example is the coordination between structural and MEP models. **Figure 12** illustrates a mechanical pipe intersecting through a structural column. This issue could be clearly identified by running a clash detection in 4D BIM software. This might be missed in a 2D environment and would consequently cause a delay when discovered at the construction phase of the project. Software such as Navisworks can generate time-based clashes, i.e., linking of the timeliner (schedule) to the clash detective (clashes). This enables the design team to isolate the exact moment in the schedule when the clash will occur.

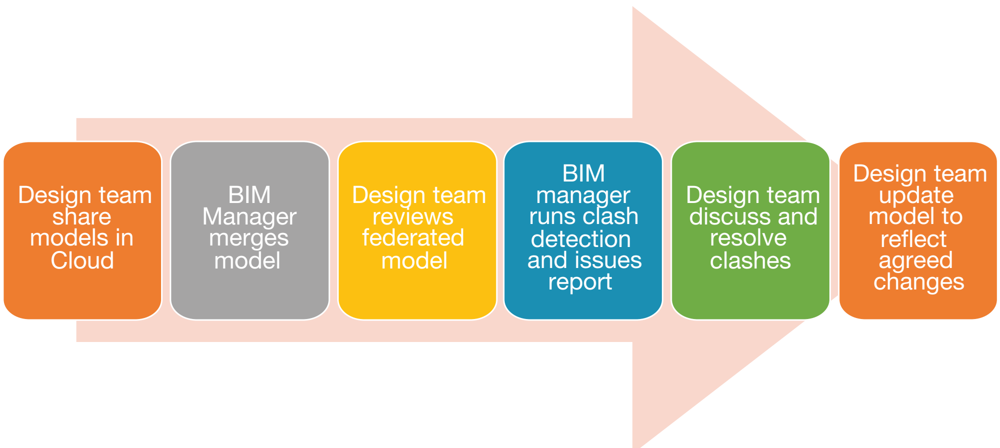
Figure 12: Clash Detection



The full power of BIM in construction is often exemplified through 4D clash detection. 4D BIM can be leveraged through the design stage to highlight issues that would normally not be evident until the project is on site. For this reason, it is important that the QS is aware of and involved in the 4D process. Clash detection will allow the comparison of difference models, or different elements of a model, within the federated environment. The clash detection tool allows the user to set tolerances and clearances for the objects within the model. Once the clash detection is run, a clash report can be created and disseminated amongst the design and construction team. Within the report, clashes can be allocated to certain members of the design team. This is especially useful on buildings where there are a high density of building services. Once the reports are created, they can be issued through a CDE allowing clashes to be resolved by the designers responsible.

Figure 13 details the workflow for successful clash detection. As can be seen, this is a collaborative environment, where all the members of the design and construction team are required to share and update data depending on the stage of the project. The BIM Manager also holds a key role in implementing the process which will normally be detailed in the BIM Execution plan.

Figure 13: Clash Detection Workflow



Constructabilty

The introduction of the Building Control Amendment Regulations (BCAR) (2014) and the increase in building standards over the last 20 years, as well as the complexity in meeting these requirements has brought about the need to use a method that can automatically run compliance for these standards. 4D BIM has functionality to run a simulation to check the model and highlight compliance with building regulations once the relevant rules are incorporated into the software.

The management of construction sites is a complex environment where the main contractor does not manage all the resources across the construction supply chain. The main contractor tends to manage several sub-contractors with responsibility for coordinating the workspaces of the sub-contractors and ensuring that the sub-contractors can work at their optimum. The traditional critical path method of scheduling is the responsibility of the main contractor and is often out of pace with what is happening at operational level. 4D BIM has been shown to be a more effective means of communicating the programme due to the dynamic interaction between the construction site, the schedule and the 3D model.

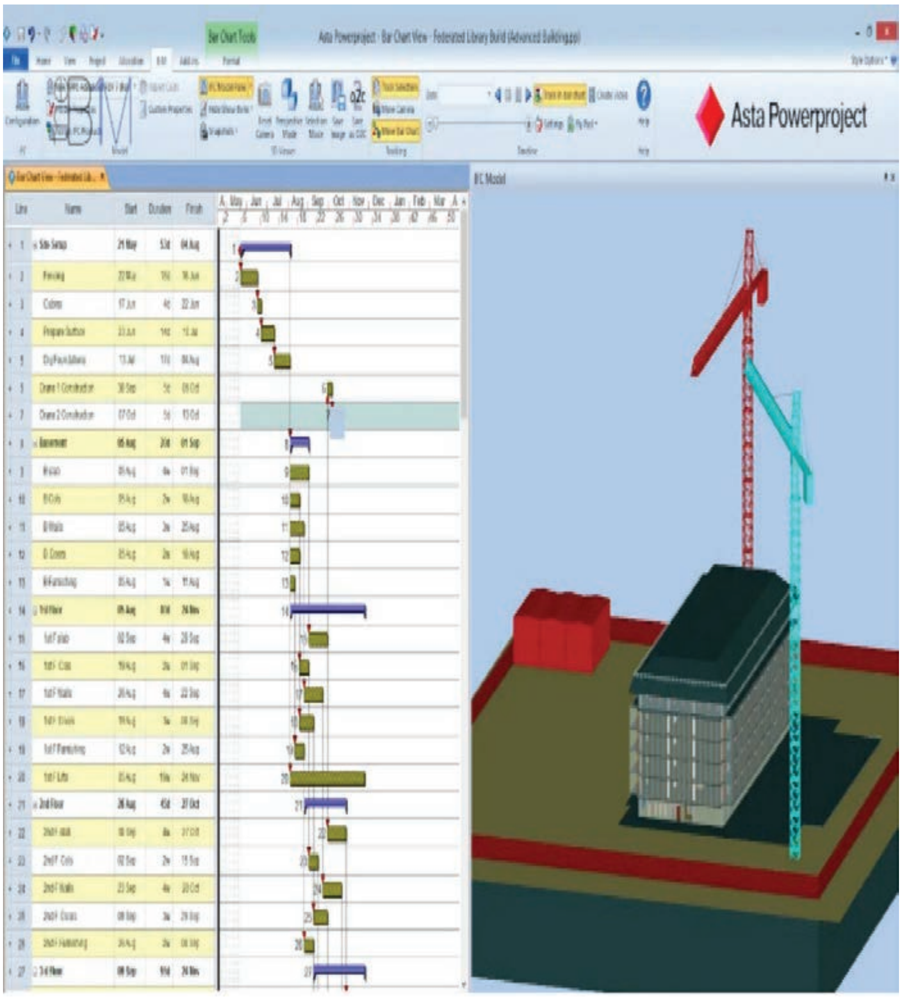
Construction interfaces (i.e. the interface between different elements of the building) has been identified as a big issue during the construction phase of a project, because interfaces may affect the project performance. If contractors want to execute activities efficiently, they need to identify the potential difficulties from initial designs before starting construction. BIM applications can be very effective in reviewing construction designs to improve the constructability. Tools within the software enable mark-ups of potential construction flaws, which can then be easily communicated to the design team. This enables a structured manner of managing data concerning this any potential flaws or issues within a fully transparent environment.

Space management & site logistics

The management of the construction site has a direct impact on the time and cost of construction processes. If the workspace is not managed correctly, it is likely that logistical and labour issues may arise leading to increased cost and increased duration on site. Using a digital representation of the building and site allows for workspace planning to develop in tandem with the appropriate stage of construction. Material storage, site logistics and the circulation areas around the site can all be represented in a digital model and can be examined along a timeline of the project, ensuring that complex construction processes can be planned well in advance. A detailed digital model of the site layout can support accurate construction site logistics and the visualisation of the model allows for the monitoring of the dynamic nature of the construction site.

When managing workflows and logistics on site the following steps illustrated in **Figure 14** should be considered. When examining logistics on site, craneage is a major element that if not selected correctly could incur extra costs or cause delays on the project. 4D BIM allows for the visualisation of the whole building giving a better understanding for cranes layout selection. As previously discussed it can also allow for the running of clash detection to mitigate the risk of a crane clash and ensure the crane selected will lift all the required loads during the construction phase. This process is also valuable for other heavy plant on site such as static pumps, mobile cranes and loading bays. The federated model allows for exercise in space management through incorporating additional objects, i.e., cranes, trucks, cabins into the schedule which can be further linked through animations. This enables the user to analyse the potential traffic pattern of these objects and when they will potentially clash with other objects.

Figure 14: Space Management



Summary

In summary, it is clear to see that the construction sector will see increased use of digital technologies over the coming years and it is therefore important that the sector prepares itself for this change and embraces its possibilities. As information technology continues to develop and construction methods advance, this will result in significant changes to how projects are constructed and how construction sites are run. BIM heralds new ways of completing construction projects, this presents great challenges but also great opportunities. Many of the large construction companies are embracing the digitisation of the industry and it is important that all stakeholders in the sector have their say on the direction the industry takes regarding digitisation.

5D BIM

Introduction

There is no magic button in BIM that will automatically produce QTO and generate a BOQ in Ireland's Agreed Rules of Measurement 4 (ARM 4) or any other QS classification schema (not yet!). Even if this was possible, it would only give you data based on the discipline environment that you are working in (i.e. structural, architectural, etc.). At the moment, 'a monolithic do everything software system' is not yet developed for all actors in the design and construction of projects. Currently design team members rely on purpose built models, including separate models for 3D architectural design, structural design, building services, energy analysis, 4D sequencing and 5D construction cost planning. Thus as noted previously, files need to move relatively seamlessly between the actors in the design/construction chain. The primary driver of discipline specific purpose-built models, is that individuals who have greater expertise in their own fields prefer to build or use their own model, in the way that suits them, with discipline dedicated technology. From a QS perspective, practitioners are currently utilising their own traditional software to extract BIM quantities into familiar programmes. This has been facilitated by existing QS and estimating software adding some form of BIM capability.

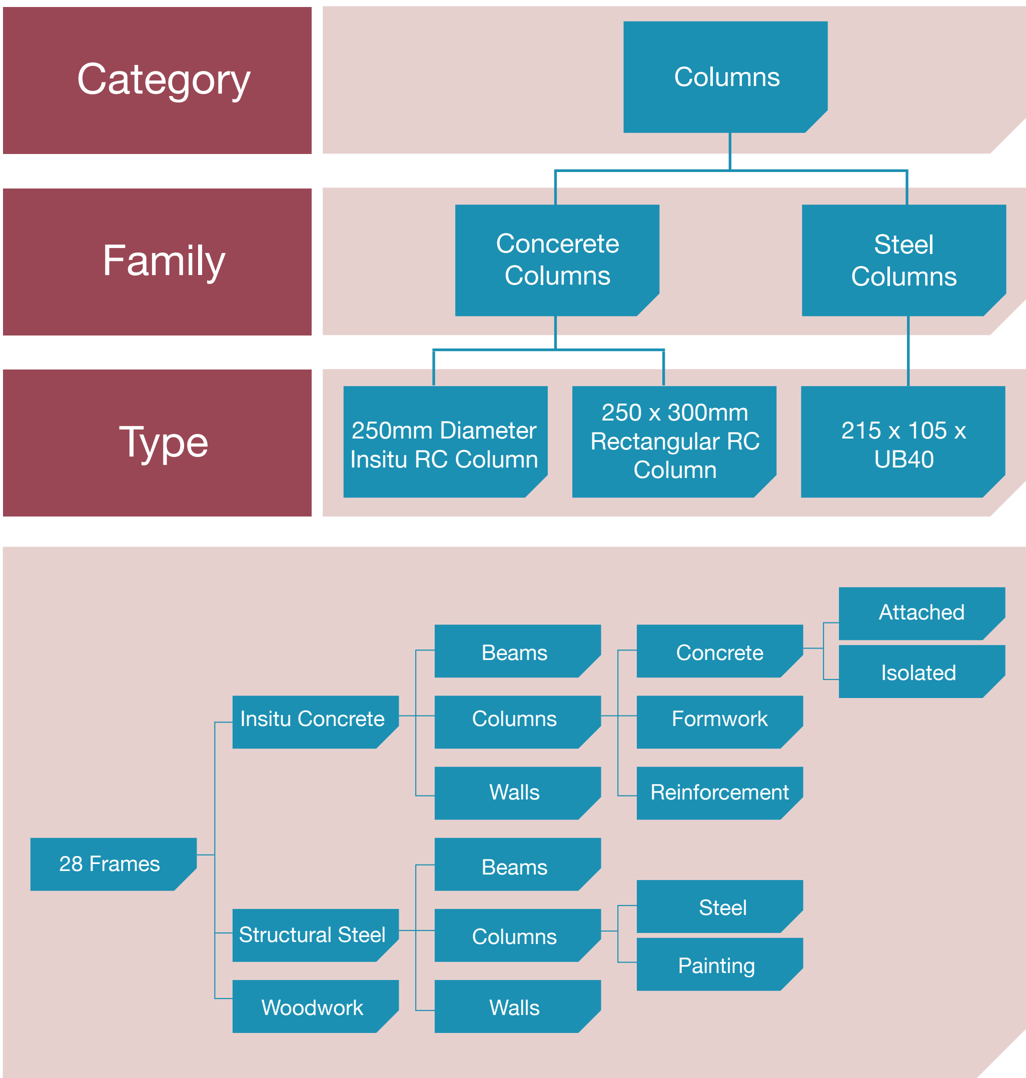
QTO in BIM is carried out by programmed routines that can perform calculations on the dimensions or geometry of the model to extract measurement data. Simply, these can be provided as an output through schedules within 3D design authoring software, such as Revit or Archicad. However, the architect's BIM tool is not sufficient for cost plan modelling, because architectural BIM schema are not compatible with the elemental or trade code structure required under QS classifications and Standard Method of Measurements (SMMs). Thus the QS will import the model via an interoperable file (DWFx or IFC) into their QS tool. **Figure 15** illustrates an example of the hierarchical structure of the Revit model schema (at the top of the image) exported via a DWFx file. Unprocessed quantities automatically extracted from that schema will output in the Revit structure (Category, Family, Type and Instance) and thus will need to be mapped to the applicable QS Work Breakdown Structure (WBS) in **Figure 15** (bottom of the image). This is predominantly carried out in the QS's 5D software.

The same applies to the IFC schema, once it is exported from the authoring software, its structure, which is outlined in **Figure 7,** will also need to be mapped to the QS schema in **Figure 15.** This essentially constitutes double mapping, especially in the context of IFC, as first, the native format gets mapped to an interoperable file structure in the export process. Secondly, the interoperable file and associated naming structure needs to be mapped to the QS classification to help produce the QS cost plan or BOQ.

5D BIM workflow

The QS has traditionally relied on the functionality and computation capabilities of the spreadsheet and take-off dimension paper (although there has been a move away from the latter in the recent past). Most QSs produce their estimates and cost reports in spreadsheet applications such as Microsoft Excel and Open Office, while many others use estimating applications, such as CostX and Cubit, that contain estimating tabulated workbooks in a variety of formats. Dimensions are either, manually measured and entered in the workbook, or QTO is measured with on-screen software and the dimensions populated in

Figure 15: Revit to QS Schema



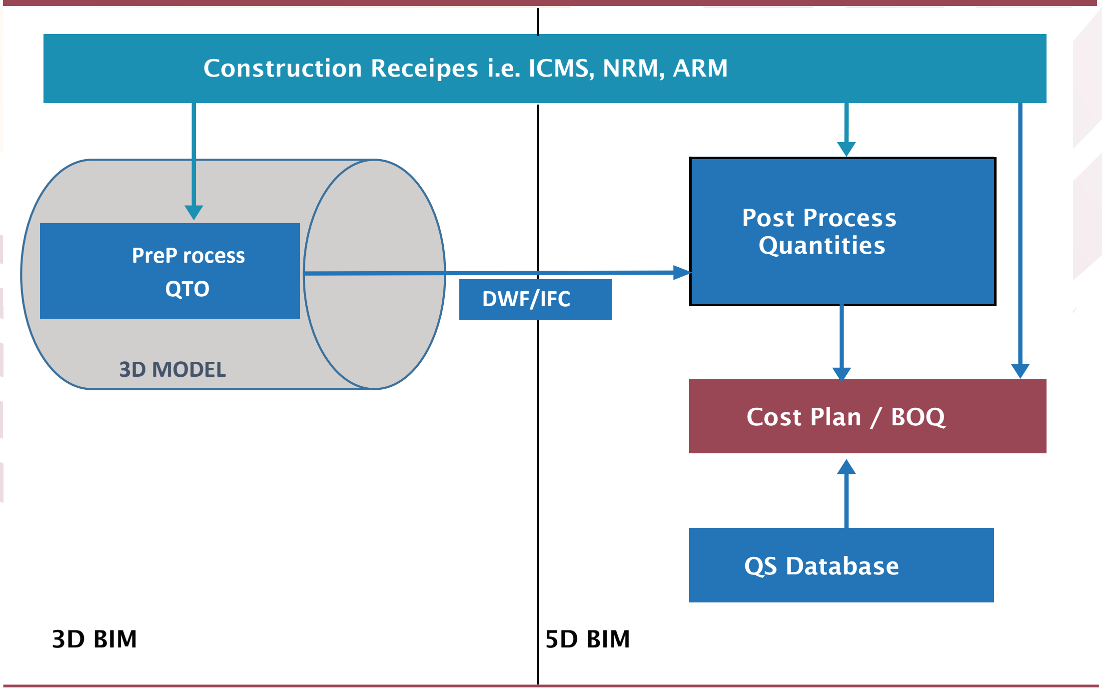
the workbook. Either way the process is manual, or simulates the manual process through digital on-screen measurement.

The estimating workbook provides an automated tool that can carry out the number crunching, while providing an adaptable format to present cost information. Some form of calculation workbook is embedded in most estimating applications where QTO, cost databases, and the workbook exist in the same product and are harnessed and linked to help produce formatted cost plans. Traditional estimating applications have not been designed specifically for BIM, nor do they need to be, because the fundamentals of the QS workflow needs to remain intact irrespective of whether the QS utilises manual measurement or BIM. However, many of the leading software estimating vendors have added a BIM interface to their existing application, turning it into a 5D BIM tool. The advantage of adding 5D functionality to the traditional QS software is that there is no need to purchase new BIM software, other than a possible upgrade to computer hardware to accommodate larger files and better graphical interface. Another advantage, is that the product maintains the functionality for 2D take off, which is still prevalent in QS practice. A good example of this is the IFC takeoff functionality in Buildsoft Cubit, which supplements the 2D Measurement Process

Figure 16 represents the 5D BIM workflow, it illustrates that QTO can be generated either in the 3D BIM tool (albeit basically), or once the model is imported via an interoperable file, in the 5D BIM tool. Through a price database in the 5D system, the QS can price the components to produce a cost plan or BOQ. Another ingredient in this process are construction recipes, which are outlined previously as the QS classification or WBS. The raw BIM quantities must be extracted from BIM in a manner that can be used in the construction estimate by filtering the quantities to the construction recipes. As illustrated in **Figure 16**, if this occurs on the 3D side, it is described as 'Pre-Processing' the BIM QTO, or if it is carried out on the 5D side, it is deemed 'Post-Processing' the QTO – this will be discussed in greater detail in the following sections.

In order to benefit form the capabilities of BIM, the QS will need to have the ability to firstly navigate the relevant quantities - this will require the QS to be familiar with the structure of the model. This is best achieved by having a limited working knowledge of a 3D authoring application, such as Revit or Archicad. The QS does not have to become a capable designer, or be able to construct a model, but that they become familiar with how a model is put together, how views are created, how sections and schedules are produced, and most importantly how information can be exported. Access to this native model would be ideal, but the design models are not always available, and thus the QS must have the language and knowledge to communicate what exactly they require from the design team, i.e. export file type; 2D views; project units; certain items filtered out, etc. (discussed in more detail in later sections).

Figure 16: 5D Workflow



Mapping BIM Quantities

Introduction

Discussed previously and demonstrated in Figure 16, processing the QS quantities can be carried out in the 3D authored model (pre-processing) or in the QS's 5D software (post-processing), or even a combination of both. Ideally, although it almost never happens, if some of the pre-processing was carried out by the architect, even to identify what objects are below ground or above ground, or what QS WBS the objects are in, it would be beneficial to the QS in automating the QTO. Alternatively if the QS classification was already in the object properties, this would be even better, much like you might see an omniclass or uniclass code in an object. However, this is unlikely given the number of WBSs and classifications from different jurisdictions. It is also doubtful that architects will spend time dividing the model and adding codes for the benefit of the QS. If the QS had authoring software they could do this themselves, but it is a time consuming process.

Pre-processing BIM quantities to QS WBS

There are a number of different ways to add QS specific properties into a 3D BIM model, such as Revit or Archicad (see videos at end of section). QS parameters are not usually contained in the object properties and thus need to be added by the user. For the purposes of maintaining consistency and because these properties can be described in many ways, this paper outlines the QS parameter as the QS Identification (QSID). There could be one or a number of QSIDs coded in the model (to signify different classification levels), but more than likely there will be no more than two, because adding QSIDs in the authoring software is somewhat labourious.

It must be noted that the QS, most likely, has no experience with or even have a license for a 3D design platform, but it is useful having at least one license for the purposes of some pre-processing of the model. **Figure 17** presents a screenshot from Revit, where two QSIDs for the New Rules of Measurement 1 (NRM1) from the UK, are added in the 'Keynote' parameter and the 'Assembly Code' respectively. The keynote and assembly code are set up by default in Revit to assign the MasterFormat and UniFormat, which are United States classification schema. However, both parameters can be customised by adding QSIDs for the NRM1, National Standard Building Elements (NSBE) in Ireland or any other QS classifications.

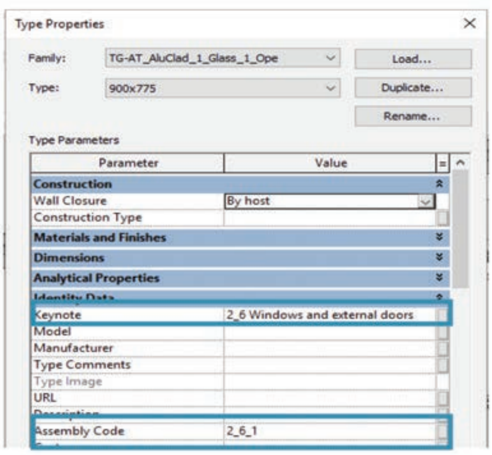


Figure 17: Revit Object with QSID

These parameters are available in the object properties when the file is exported into the 5D system. Alternatively a new shared/project parameter can be added by the Revit user and assigned a QSID, but it is easier to use an existing parameter such as the keynote or the assembly code. For more information on the different ways to pre-process the model, refer to Kehily and Mitchell (2019). The following four hyperlinked youtube videos, by Dr Dermot Kehily, illustrate a number of different ways QSIDs can be added to a model in Revit:

1. **QSID; Creating & Exporting Schedules**
2. **User Defined QS Parameters**
3. **Keynotes and Assembly Codes**
4. **Autodesk Classification Manager**

Post-processing BIM quantities to QS WBS

The most common method of carrying out processing of the model, for QS purposes, is in a 5D tool. Another name for this process is sometimes called 'model mapping'. If there has not been any pre-processing in the design software, this is the first stage of 5D processing. In this process the QS generates quantities that are in a classification schema and unit that makes it easier for them to populate their cost plan. This can eliminate / reduce the need for manual on-screen take off when done correctly. However, even after quantities are extracted in this manner, there is still considerable post-processing to include them in a cost plan or BOQ.

One of the cornerstones of BIM, from a measurement and costing perspective, is the dynamic population of the cost plan from the model. It is important for 5D BIM software to have the capabilities, whereby updating the model will also update those quantities generated from the model, and in turn change all those dimensions and quantities in the cost plan or BOQ, which are linked to the model quantity.

BASIC MAPPING IN 5D BIM SOFTWARE

***The following example describes the process of model mapping (or 5D BIM processing). It is presented in a format that does not expound the use of any particular piece of software, but rather as a set of steps/procedures that explain the process common to the 5D BIM process in any good 5D application. The technical scripts or algorithms behind the automated calculations are not addressed, as these are most likely specific computer code written for that piece of software. This is a generic example which will hopefully help QSs understand the underpinnings and methodology to automated QTO in 5D BIM.*

Figure 18 is a tabular representation of a BIM Wall Object. This example represents one instance, or part, of the total make up of this specific type of wall in the model (i.e. 'Rendered 215mm Concrete Block Wall'), much like there might be sections of a wall type on different floors, or even on the same floor plan. For example, there could be 500 instances (or parts) of this type of wall in a model, with different dimension properties, depending on how it was modelled by the architect or engineer. **Figure 18** represents just a fraction of the data that could be in the object properties of that object, but provides a general representation of what you find in parameters of BIM objects and those attributes applicable to quantity surveying. In **Figure 18** a QSID (NSBE - 21 External Walls) was added to the keynote parameter, which, as explained previously, can be added in the authoring software or in the 5D software before mapping is carried out.

Figure 18 represents the object data in a DWFx export, but the process described is the same for IFC, just the naming categories are different. You may also see replication in some of the parameters, as seen here, where both the 'Type Name' and the 'Description' have the same name. There can be a plethora of information in the data of an object that traditionally you might see in the specification or annotations on a CAD drawing. From the QS point of view, the object data represents the raw material of the model. In 2D, the QS manually takes-off quantities from the drawings, ultimately quantifying all the materials in the project and pricing them based on their specification. Once these quantities are measured, the QS

Figure 18: Data Properties of a Wall Instance

QSIDs

Identity Data	
Description	Rendered 215mm Concrete Block
Type Name	Rendered 215mm Concrete Block
Family Name	Basic Wall
Structural Material	Masonry Concrete Block
QSID	21 External Walls
Dimensions	
Width	240mm (215mm + 25mm Render)
Area	7.43m²
Length	6750.00mm
Volume	1.782m³
Constraints	
Base Constraint	Level 01
Base Offset	0
Unconnected Height	2700mm
Analytical Properties	
Heat Transfer Coefficient	6.791 W/(m² K)
Thermal Mass	20.47KJ/K
Thermal Resistance	0.1593 (m² K)/W
Fire Rating	60min
Structural	
Structural Usage	Non-Load Bearing
Strength	30N
System Properties	
GUID	uB12345tY87654345
Instance ID	3432542178

constructs their cost plan or BOQ based on construction recipes, which are what we discussed earlier as the QS classification or WBS. This is a very manual process which can be fraught with human error. 5D BIM is not the complete solution for these issues, as it does not entirely automate this process, but it can automate QTO in a structure that will make it easier to use in the estimate. So it is not about producing an automated BOQ, but rather producing an automated take-off which will align with the BOQs classification schema.

In the processing phase of 5D BIM, the data contained in the objects must be mapped into the QS WBS. **Figure 18** is colour coded, to aid explanation of how mapping can be carried out for an object such as 'Walls' in 5D BIM. In 5D BIM, the software should be able to add all the instances of this wall object together, generating an automated QTO of this specific type of wall.

In most 5D applications there is a very quick way to calculate QTO for model objects utilising a model map inherent in the 5D application. In this first basic map, the system looks for all instances of this object in the model and adds its geometry together to establish its total dimension. But how does the software tell what is the most applicable property to use as the group heading (or folder name), and what is the best attribute to use as a dimension description? In the number of 5D applications we have worked with, this dimension is usually extracted, in DWFx files, first based the on 'Family Name' which is used as the group heading (i.e. Basic Walls), and then it's 'Type Name', which is used as a dimension description. The IFC output is similar, using the 'Entity' (i.e. ifcWall) as the group heading and the 'Type Name' as the description.

Figure 19 is an output of the walls based on the automated basic map outlined in the previous paragrapgh, for both DWFx and IFC. The naming structure and the way the dimensions are populated are not at the discretion of the 5D QS here, but rather the software developer that developed the algorithm. This leads to two issues, firstly (as noted previously), the naming conventions from the native software (Category, Family, Type – in the case of Revit) are not based on a schema which is completely compatible with QS WBSs. The other even more important issue, is that the quantities may not be in a unit that is in line with the unit required by the QS. For example, the QTO output of the wall in **Figure 19** is 4.57m^3, but most likely, the QS requires the Blockwork as a surface area in m^2 , per their Standard Method of Measurement (SMM), and this might not be available in the dimension properties of the object.

Figure 19: BIM Dump in +IFC and DWFx

Family Name	
Type Name	
Quantity	

Basic Walls	
Rendered 215mm Concrete Block	
Area	*225.09m^2*
Length	*15.23m*
Volume	*4.57m^3*
Width	*0.24m*

Or For IFC

ifcWalls	
Rendered 215mm Concrete Block	
Area	225.09m^2
Length	15.23m
Volume	4.57m^3
Width	0.24m

However, these crude automated quantities can be very useful if the QS software has the ability to then utilise them in the cost plan or BOQ. The quantity still may need a certain amount of manipulation, but that is where the skills of the traditional QS comes in, to utilise their experience and aptitude, in turning these quantities into bona fide BOQ items. An example of this would be if there was no surface area in the output dimension for wall area, the QS could divide the wall volume by the wall thickness to get the surface area. So their needs to be pliability in the software to accommodate this process. **Figure 20** represents a full BIM automation carried out via this process on a model in both DWFx and IFC. This is

Figure 20: BIM Dump from DWFx

IFC Export		DWFx Export	
IfcBeam		Structural Framing	
Universal Beam 305x165x40UB	55m	Universal Beam 305x165x40UB	55m
IfcColumn		Structural Columns	
Plate-Column 610x210x40UB	53m	Plate-Column 610x210x40UB	53m
IfcDoor		Doors	
IntSgl 910 x 2110mm	3nr	IntSgl 910 x 2110mm	3nr
nbl_Door_Int-Sgl-Vsn-Pnl-2.0 Type 1	1nr	nbl_Door_Int-Sgl-Vsn-Pnl-2.0 Type 1	1nr
IfcBuildingElementProxy			
HighPerforDoors_FirerDouble_Vision Panel250x700X60m	4nr	HighPerforDoors_FirerDouble_Vision Panel250x700_60m	4nr
		Windows	
NBS_Senior Architectural_Systems_ExWnd_Hybrid	$16m^2$	NBS_Senior Architectural_Systems_ExWnd_Hybrid	4nr
NBS_Senior Architectural_Systems_ExWnd_Hybrid2	$16m^2$	NBS_Senior Architectural_Systems_ExWnd_Hybrid2	4nr
IfcFooting		Structural Foundations	
Wall Foundation 900mm	$9m^3$	Wall Foundation 900mm	$9m^3$
Wall Foundation 815mm	$4m^3$	Wall Foundation 815mm	$4m^3$
Wall Foundation 1015mm	$3m^3$	Wall Foundation 1015mm	$3m^3$
IfcSlab			
Pile Cap Retangle 1800 x 1800 x 500	$26m^2$	Pile Cap Retangle 1800 x 1800 x 500	$26m^2$
		Floor	
160mm Concrete with Corus-ComFlor 51	$33m^2$	160mm Concrete with Corus-ComFlor 51	$33m^2$
Ground floor 100 Conc-50 Insul-DPM-50 Sand-225 Hard	$194m^2$	Ground floor 100 Conc -50 Insul-DPM-50 Sand-225 Hard	$194m^2$
IfcRoof		Roof	
Basic Roof Pitched Warm - Industrial	$202m^2$	Basic Roof Pitched Warm - Industrial	$202m^2$
IfcWall		Walls	
Basic Wall 100 Brick - 50 Air - 60 Insul - 100 Block	$331m^2$	Basic Wall 100 Brick - 50 Air - 60 Insul - 100 Block	$331m^2$
IfcWallStandardCase			
Basic Wall 100 Brick - 50 Air - 60 Insul - 215 Block	$59m^2$	Basic Wall 100 Brick - 50 Air - 60 Insul - 215 Block	$59m^2$
Basic Wall 215mm rising wall	$14m^2$	Basic Wall 215mm rising wall	$14m^2$
Basic Wall 300mm footing wall	$30m^2$	Basic Wall 300mm footing wall	$30m^2$
Basic Wall 415mm rising wall	$9m^2$	Basic Wall 415mm rising wall	$9m^2$
Basic Wall 100blk internal	$27m^2$	Basic Wall 100blk internal	$27m^2$
Basic Wall Timber Partition - 120mm - 1hr	$26m^2$	Basic Wall Timber Partition - 120mm - 1hr	$26m^2$
Basic Wall Internal - 12 Plasterbd - 100 Blk - 12 Plasterbd	$19m^2$	Basic Wall Internal - 12 Plasterbd - 100 Blk - 12 Plasterbd	$19m^2$
Basic Wall Internal - 12 Plasterbd - 215 Blk - 12 Plasterbd	$116m^2$	Basic Wall Internal - 12 Plasterbd - 215 Blk - 12 Plasterbd	$116m^2$

deemed a BIM 5D Dump (from the model) - where automatic quantities are generated from the model but are not attributed or separated into a QS classification, i.e. the QS has not manipulated or devised any strategy for automation to suit their purposes.

Mapping identity data to QS WBS

Some software provides the user with the ability to carry out advanced model mapping. In the context outlined above, it provides the 5D QS with the facility to create their own algorithm (formula) to extract quantities, in a manner that makes it more efficient for creating their cost plan or estimate. This is the essence of mapping and it works like a database, providing the user with the capability to filter data per the attributes in the object properties of the model.

Figure 21 outlines a basic scenario where the QS creates their own algorithm, in the 5D BIM software, to extract quantities based on mapping the objects to a more applicable or usable dimension structure,

Figure 21: Mapping to QSID

Identity Data
Description
Manufacturer
Comments
Type Name
Family Name
Structural Material
QSID

Folder Name	QSID
Sub Folder	Family Name
Description	Type Name
	Structural Material

+

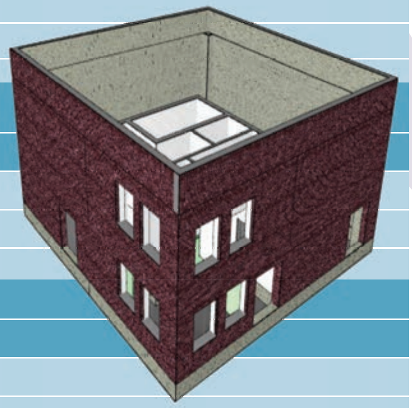
Folder Name	21 External Walls
Sub Folder	Basic Walls
Description	Rendered 215mm Concrete Block, Masonry Concrete Block

21 External Walls	
Basic Walls	
Rendered 215mm	
Concrete Block +	
Masonry Concrete Block	
Area	*225.09m²*
Length	*15.23m*
Volume	*4.57m³*
Width	*240mm*

i.e. the QS's WBS. The example given here, is not an absolute process, there may be more applicable 'Identity Data', that could be used other than the case outlined here, which uses QSID; Family Name; Type Name; and Structural Material, as the properties to map. It is up to the QS to use the most applicable model map based on the naming conventions in the objects.

Figure 22: Wall QTO from QSID Map

19 Substrcucture	
Basic Wall	
215mm rising wall	14 m^2
415mm rising wall	9 m^2
300mm footing wall	30 m^2
21 External Walls	
Basic Wall	
100 Brick - 50 Air - 60 Insul - 100 Block	331 m^2
100 Brick - 50 Air - 60 Insul - 215 Block	59 m^2
22 Internal Walls and Partitions	
Basic Wall	
100blk internal	27 m^2
Timber Partition - 120mm - 1hr	26 m^2
Internal - 12 Plasterbd - 100 Blk - 12 Plasterbd	19 m^2



Based on the object data outlined in **Figure 18,** the example in **Figure 21**, illustrates a mapping definition which selects the 'QSID' as the main folder name; the 'Family Name' as a subfolder heading; and the dimension description is devised from the text string of the 'Type Name' plus the 'Structural Material'. The resultant breakdown is outlined in **Figure 22** which provides a structure that makes it easier for the QS to link to their estimate, as it will split all the QTO based on the QSID.

If this algorithm was applied to all the wall items in the model, a crude processed QTO would be generated that could be utilised to populate the QS's BOQ or cost plan. The advantage in this more applied map is that the QTO would be in the relevant QS WBS, rather than the model schema in the BIM dump.

Figure 23 outlines the next phase in post processing, which utilises the dimension output from the QSID model map and links it to a relevant cost plan or BOQ item. In this case (because it is a blockwork wall) the QS has

Figure 23: Map to BOQ

21 External Walls	
Basic Wall	
Rendered 215mm Concrete Block +	
Masonry Concrete Block	
Area	*225.09m²*
Length	*15.23m*
Volume	*4.57m³*
Width	*0.24m*
21 External Walls	
Brickwork/Blockwork	
Concrete blockwork; Spec (F10.350E)	
Walls	
215mm thickness: solid blockwork walls	225.09m^2

selected the surface 'Area' of the '215mm Blockwork Wall', but if it was say a 'In-Situ Concrete Wall' the 'Volume' would need to be selected. The main thing is that there is an active association between the dimension output and the cost plan, i.e. if the model dimensions are updated the quantity will change everywhere this link was established.

Mapping of the quantities

Some 5D BIM software has the ability to map quantities in a similar fashion to what is outlined for the 'Identity Data' in **Figure 21.** This is different than manipulating the dimensions in the workbook, as it carries out the process within the same algorithm (or map) that is devised to extract dimensions based on the identity data of the model. Now quanity quantity data is added to the map .

Figure 24 shows the dimensions associated with a '300mm thick InSitu-Concrete wall'. Again this is just an instance or part of an overall quantity of this type of wall. Some dimension attributes are available in the object properties such as, Area; Length; Volume and Width (Thickness). As noted previously, all these dimensions may not be available, and other dimensions such as reinforcement and formwork will definitely not be available, as they are not geometric attributes of the model. The dimensions available in the model are known as 'Model Quantities' and the dimensions that can be processed from the model quantities are known as 'Model Derived Quantities'. As shown in **Figure 24,** the same naming fields are available as well as a number of Quantity Fields. As discussed previously, it is possible to have a number duplicate dimensions in an IFC export, such as the model parameters and the IFC base quantities calculated from the geometry. It is preferable, if available, to use the model parameters.

When creating the map it is best to start with matching the obvious dimension properties in the object, with their associated quantity mapping fields, i.e. Area into Area; Length to Length and Volume to Volume. There may be a number of other available user defined quantity fields which gives the user the ability to calculate Model Derived Quantities, indicated in **Figure 24** as Custom Dims 4, 5, 6 and 7. In the case of an 'In-Situ Concrete wall', the QS will need the Reinforcement Weight and the Formwork.

The other available fields in this case can be used as a means to validate and check some of the geometry properties. For example, when the Volume and Area are checked via their Length x Width x Height, the resultant quantity does not match the corresponding Volume dimension in the object properties. It is up to the QS to check and validate quantities in whatever way they can, they might check some quantities by carrying out a 2D check or they may, like in this case, carry out some custom checks within the map.

Based on experience, the difference in model quantities and model derived quantities for Volume, are because wall openings (for window and doors) are deducted in the dimension attributes of the object, while calculating quantities from the Length, Height and Width provide quantities that do not accommodate openings. Both sets of quantities are useful depending if openings are to be included in the measurement or not (i.e. in early cost planning wall areas are measured through the openings) – so it's worth having both available. A number of other issues to look out for are addressed in the next section. Similar to the example in **Figure 23,** the naming and QTO output from this process can then be used to populate the cost plan. But in this case, the reinforcement, formwork and other user defined model derived quantities are available to use in the cost plan or BOQ as the user has formed the mapping definition required for these items, as shown in custom dimensions 4, 5, and 6 of **Figure 24**.

Figure 24: Advanced Mapping

Family Name	Basic Walls
Structural Mat.	30N Concrete
QSID	21 External Walls
Area	150m^2
Volume	2.3m^3
Length	5,300mm
Width	300mm
Height	2,700mm

Model Quantities

Folder Name	QSID
Sub Folder	Family Name
Description	Type Name, Structural Mat.
Dim 1 - *Area*	Area
Dim 2 - *Length*	Length
Dim 3 - *Volume*	Volume
Custom Dim 4 -*Weight*	Volume X KG
Custom Dim 5 -*Volume*	Length X Width X Height
Custom Dim 6 -*Area*	Length X Height

Folder Name	**21 External Walls**
Sub Folder	Basic Walls
Description	RC Concrete Walls, 30N Concrete
Area	150m^2
Length	5.3m
Volume	2,3m^3
Weight	0.05kg
Volume Check	6.1m^3
Area Check	155m^2

ICMS and SMMs

Introduction

The International Standard Organisation (ISO) notes that standards are strategic tools that reduce costs by minimising waste and errors and increase productivity. The need for standardisation to address market requirements is accepted in many sectors as a means to help companies to access new markets, level the playing field for developing countries and facilitate free and global trade. Standardisation in Quantity Surveying provides a consistent approach to cost planning and the production of BOQs. Good practice in construction cost planning and cost control requires the QS to allocate the overall estimated costs into a number of cost holding categories known as 'elements'. They must also breakdown BOQs based on measurement rules in Standard Method of Measurements (SMMs). The elements are based on the functional components of the design, such as the substructure; external walls; internal walls; and doors & windows etc. SMMs usually breakdown each element into detailed items based on trades and work practices. Collectively the elements and SMMs make up the QS WBS also known as the Classification schema.

Classifications

Different jurisdictions have alternative classification systems but operate in a similar manner. In Ireland the elements are organised in accordance to the NSBE and the Agreed Rules of Measurement 4 (ARM4). In the UK these elements are arranged according to the framework from the Building Cost Information Service (BCIS) and the New Rules of Measurement (NRM). WBSs provide a system where costs can be compared to the totals and elemental totals in similar projects. They may also be compared to the cost of the corresponding element in the previous estimate, to isolate areas in the design that could have increased/decreased in cost.

Presently no single universal WBS or method of measurement is used by those responsible for the preparation or recording of construction costs. The variance in WBSs on construction projects from region to region and even within different sectors of the construction industry can lead to discrepancies in cost comparisons and benchmarking. From a BIM perspective, if the QS classification schema was already embedded in the object properties (much like you might see an omniclass or uniclass code in an object) this would benefit 5D processing. However, there are many different QS WBSs, depending on the country or jurisdiction they encompass. It would be next to impossible for BIM object developers to add all the elemental codes and classification structures into the objects for every global standard. Another issue is the amount of levels and detail in the WBSs. For example, to incorporate an applicable code(s) for an ARM4 BOQ description, approximately eight different cost codes would need to be included in the objects of a model, representing each classification level from the NSBE element (and sub-element) to the trade structure (and sub-trade) in the ARM, even down to the measurement rules which define whether an object, such as painting, is greater than 300mm in width or less than 300mm. It is impossible to construct the model in this way, i.e. models are built with objects that may represent a number of different categories in a BOQ, such as a cavity wall that includes everything from external painting, blockwork, insulation, to the internal finishes.

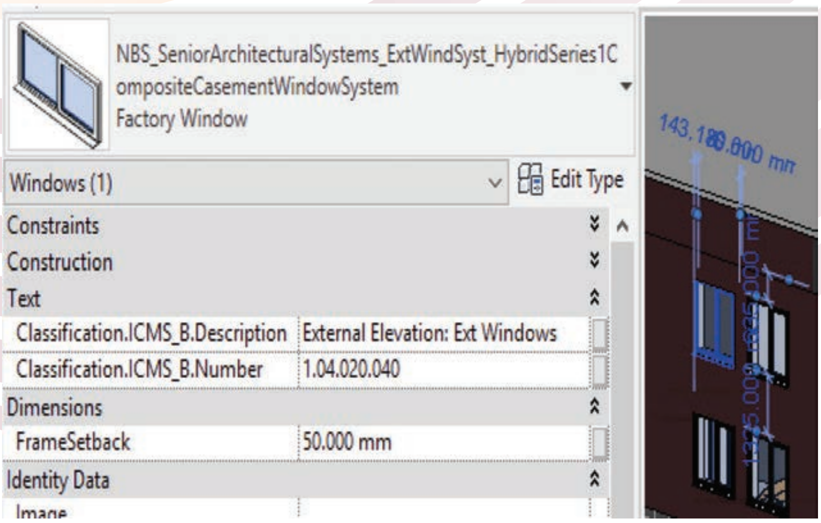
As can be determined from the 5D process outlined in the previous section, this detail requires considerable processing and manipulation to align the BIM to QS classification schema. Serious consideration will have to be made to the minimum requirements of QS WBS and SMMs to comply with the way in which models are built. This is why BIM suits Order of Cost Estimating (OCE) and elemental cost planning rather than full BOQs production, because the level of detail required in early estimating aligns with the component makeup of BIM, rather than the granular detail in a BOQ. For example, the production of cost plans are generally based on composite rates for a composite description of components. In an early cost estimate a composite rate is applied to the ground floor (conc, sand, DPM, hardcore) which aligns to how the ground floor is constructed in the model (composite object with parts), whereas in a BOQ all the parts of the model object have to be separated and listed separately in the BOQ.

In terms of processing the model for BOQs, it is recommended that BIM dimensions are firstly mapped to the higher level codes, such as the NSBE in Ireland and then the subsequent coding and descriptions are constructed in the workbook of your estimate, much like is currently carried out in 2D QS practice, i.e. a two stage process, whereby some element of measurement is carried out followed by subsequent correlation of data into workbook format.

International Construction Measurement Standards

It is has become apparent that issues exist within the construction industry and in the QS profession where there is discrepancies across different elemental breakdown structures in different justifications. It is important to have a universal system globally that will lead to aligned cost reporting and better benchmarking, but also take account of progression into a digitised workflow. The first International Construction Measurement Standard (ICMS) was published in 2017 and focused on capital costs. The ICMS 2nd edition was published in September 2019 and includes Life Cycle Costing (LCC). The ICMS provides a universal system for comparing international project costs on a "side-by-side" basis for the first time. The first edition of the ICMS establishes a basis for the comparison of international construction measurement costs, across the various construction sectors. For consistency, the ICMS took the definition of Gross Internal Floor Area (GIFA) and Gross External Floor Area (GEFA) as defined within International Property Measurement Standards (IPMS). Each of the organisations of the coalition have agreed to adopt and promote the use of the ICMS. The standard is backed by the United Nations (UN), International

Figure 25: ICMS Codes



Monetary Fund (IMF) and the European Union (EU). The ICMS will replace the NSBE in Ireland. The ICMS has four levels of codes to two in the NSBE. For more information on the ICMS please click here: https://icms-coalition.org/.

ICMS and BIM

In subsequent editions it is envisaged that the ICMS will be expanded to cover a more integrated approach to construction cost information within BIM. However, the coding structure is set up in a way that can be easily utilised as a BIM schema. The ICMS is constructed in a manner, depending on the Level of Detail (LOD) in the model, that an ICMS code or codes could be embedded in the object properties. For example, once the architect selects their object and places it in the model these attributes will be embedded in the object properties, just like you might see a fire rating for a door or a thermal resistance property in a wall object.

Although adding ICMS to BIM object properties will not eliminate post-processing, it could reduce the QS's workload in this regard and help standardise cost management globally. However, this is currently some time off development and architects do not have the knowledge and time to spend adding codes in the BIM model and neither do they get a fee to do so. Other design team members must do the same and know what code to apply to what object. So it is up to the QS to carry out the processing either through the pre or post-processing procedures outlined in the previous sections. Kehily and Mitchell (2019) outlines some good examples of how you can add ICMS codes to the authored model as well as the video on "Autodesks Classification Manager". **Figure 25** outlines an example where the QS input a ICMS code into the objects of the model as a new Type parameter. This was carried out per the actions described in the linked video above.

Troubleshooting 5d BIM

Introduction

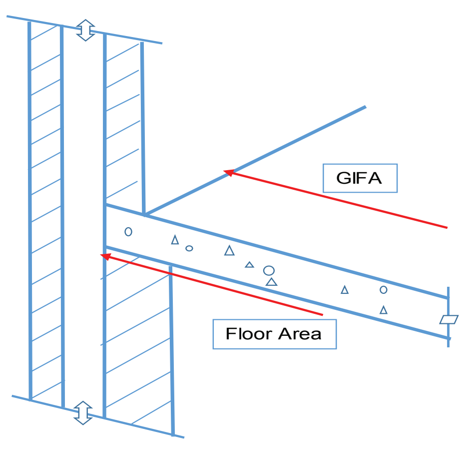
The following issues are outlined to give the QS advice on what to look out for when utilising BIM QTO. The main thing is that you do not take and use the BIM automated QTO verbatim. This is not because the quantities are not accurate, but they might not be generated in a manner that suits the way the QS needs them, or the geometry of the model may not utilise the dimensions correctly, or you may be reading them incorrectly. The model quantities are a reflection of the model, so if the QS is given an improperly designed model, the quantities will be similarly impaired. This is where the skill and experience of the QS will be utilised in the investigation of the model, providing costs on an incomplete design.

QS measurement vs geometry from model

The way dimensions output from a BIM may not be in line with the measurement rules in quantity surveying. The best example of this is the calculation of GIFA. The GIFA is not available or automatically generated from the model. The GIFA is a combination of all the floor areas (less the roof) in the building, measured from the inside face of the external wall through openings and internal walls. The automation of quantities in 5D BIM does not have the intelligence to navigate this rule, it will measure the surface area of the floors to the perimeter edge of a floor slab excluding openings (i.e. the true area of the floor slab itself) **(Figure 26)**.

The software will not know that the area must not deduct openings for stairs, lift shafts and internal walls. The GIFA could be built up from the spaces/rooms data of the model, but consideration would need to be accounted for the thickness of walls between the spaces. It is often quicker to calculate the GIFA from the 2D views. The QS should ask for the 2D views as well as the 3D model, so that they can measure quantities that cannot be devised from the BIM QTO.

Figure 26: Model Floor Area to GIFA



When measuring quantities for an elemental cost plan, outline dimensions are required, such as, the length of strip footings; the overall external wall area; total internal wall area; external window and door areas; internal door counts; and roof area. As stated previously, measurement rules in QS practice may not align to the geometric output from the model. For example, if following the NRM1 for elemental cost planning, quantities for the total external wall area will need to be measured on the internal face of the external wall and through openings. However, BIM dimensional output will provide areas for each wall type over its actual length, and will also deduct for openings. The QS may choose to measure this via 2D views, but elemental quantities can be extrapolated from

BIM quantities with some adjustments. For example, external walls can be built up from the individual wall elements with adjustments for openings, jambs and other detailing. Strip footings per the NRM1 are required to be measured in linear meters, rather than the volume of concrete. If the BIM output for strip footings is in cubic meters, the length can be calculated through mapping or simply dividing the volume by the footing's cross sectional area. Again, validation and extrapolation is key for the QS when it comes to BIM take-off.

Model quantities and model derived quantities

Not all quantities necessary for the production of a cost plan or BOQ are available in the model. As noted previously, the dimensions available in the model are known as 'Model Quantities' and the measurements that are processed from the model quantities are known as 'Model Derived Quantities'. A good example of this is a concrete column, where the volume of concrete will be available as a dimension parameter, but the weight of steel reinforcement or the area of formwork will not, as they are non-graphical items. These will need to be processed from the model either through 'model mapping', utilising the user defined quantity fields, or by calculating their quantities in the workbook. This was outlined previously in 'Advanced Mapping' and illustrated in **Figure 24.**

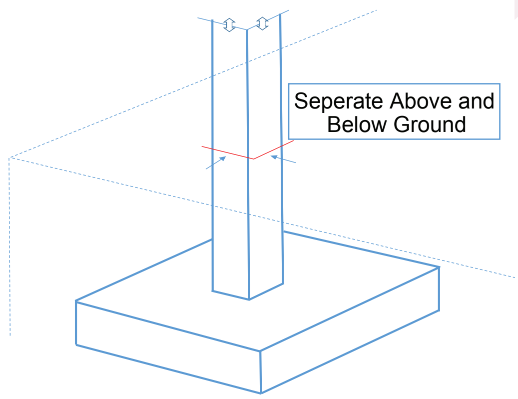
Missing objects / objects used in the wrong context

The content of the model, not unlike traditional drawings, can especially be limited in the early design stages. The 5D QS must ensure that all work is estimated by utilising their experience and supplementing the quantities generated from the model with 2D measurement, i.e. cull whatever you can from the model, but measure from the 2D views if necessary. Be aware that designers are also on a learning curve with BIM, they may not have constructed the model from the viewpoint of the downstream user, such as the QS or contractor, but from the perspective of a visual design. An example of this is where the designer is concentrating on how the BIM looks in 2D, rather than how it is constructed. They may use objects out of context, such as a roof object as a floor object; an external door as an internal door; or internal walls used as external walls, and vice versa. So it is worth spending time navigating the model and viewing both the visual objects and data in those model objects.

Below ground / above ground quantities

most designers will not be familiar with quantity surveying measurement rules. One rule common to most QS classifications is that objects must be divided into what is below ground and above ground, to provide an elemental structure that includes a 'Substructure' element **(Figure 27)**. The substructure encompasses all the building objects including and below ground floor level. For the most part this isn't a major issue, as it is relatively easy to isolate the objects in 5D software that are below the ground floor, if they are drawn correctly. However if objects are not split in the authored model at ground floor level, it is difficult to separate them in the 5D application, as the model is read-only in the DWFx or IFC file formats. For example, if walls in a BIM are not divided per level it is difficult to quantify what is associated with that particular level. To address this

Figure 27: Split at Ground Floor Level

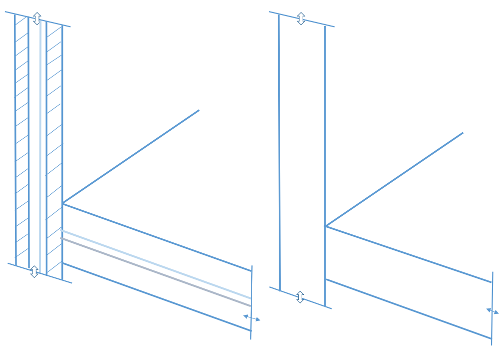


in a model, the QS can draw a split into all the relevant objects, such as columns and walls, but you will not always have access to the authored model, so it is worth advising the architect that this separation is essential.

Assembly items

In 3D BIM multiple objects can be combined into a single assembly item. When a model is exported from 3D and imported into the 5D software, if the constituent parts in the structure properties of these objects are not enabled, the assembly item will only be visible as a solid composite object. For example, as shown in **Figure 28,** in a cavity wall or floor, the layers that make up the constituent parts of that wall or floor will not be visible. It is very important for the QS that the component details are communicated in full. Preferably there should be a description of the make-up of these elements in a text parameter of the object properties, such as the 'Description' or the 'Comments' parameter (i.e. for the composition of a cavity wall, it should be manually noted in one of these blank fields).

Figure 28: Assembly Object

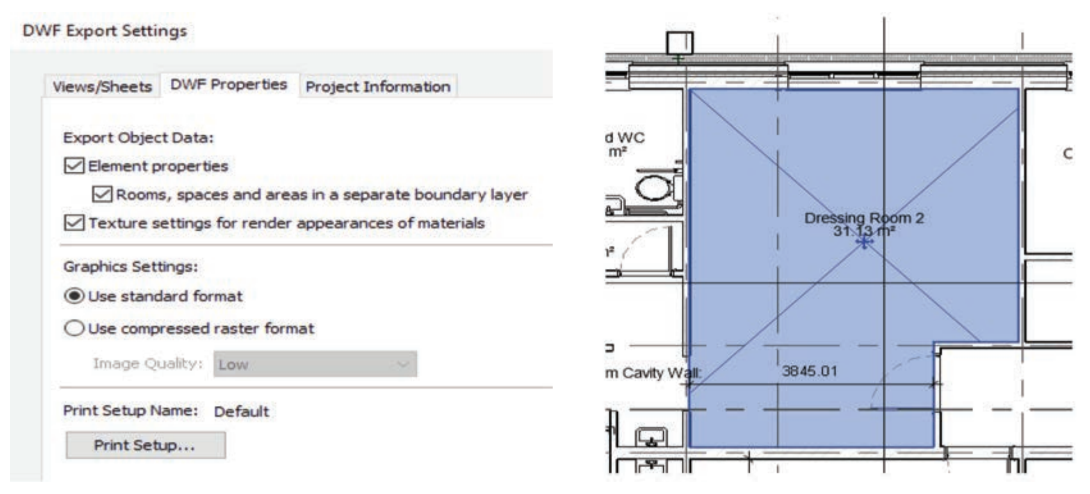


Also making available 2D sections and 2D details of the model will help in this regard. Alternatively, if the QS requires the constitute parts in the exported file, they must communicate with the designer to export the BIM with those assemblies divided. This is carried out by 'creating parts' in the 3D software (Revit) for those assemblies that need to be separated. The advantage is that each part can be quantified for each layer of the assembly item. This is important if you are taking off a wall item where the outer leaf will have a higher quantity than the inner leaf. If these parts are not enabled, the solid object dimension will be measured on the outer surface area of the composite object, and thus it is not accurately attributable to all dimensions in the assembly. The Video on 'Mining and Filtering' BIM data in Revit by Dr. Dermot Kehily provides some examples of how issues such as object names and assembly items can be resolved.

Rooms

Room and area data are very useful for QS purposes, particularly for an OCE, where composite rates per elements are used to develop budget estimates. **Figure 29** illustrates, when exporting the file, that the DWFx Properties tab in the export dialogue window should be clicked and the user should tick the 'Export rooms and areas as polylines' checkbox. The room data will now be exported with the file. As noted previously, the video on 'Exporting DWFx and IFC' fles from Revit visually narrates this process. If a schedule was produced in the 3D model and specification data entered for the finishes, such as wall, floor and ceiling finishes, this data will be available as object properties for each room. Model mapping can be devised in 5D software to extract wall, floor and ceiling finishes without physically having to measure room areas in the 2D views. Be careful here, as the boundaries of all the rooms in a model must be fully created by the designer if automated QTO for room areas is to work effectively.

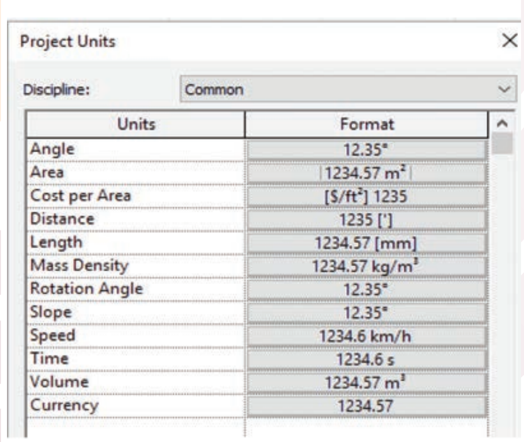
Figure 29: Room Boundary and Export



Project units - decimal places

As noted previously, the total quantity of each object type is the cumulative value of the dimensions of each individual object. The 'Project Units' icon (in the Manage Tab) in Revit, illustrated in **Figure 30,** outlines the amount of decimal places dimension parameters will have, including the applicable unit (i.e. m for length, m² for area, m³ for volume). If the project units are set to whole numbers (which may be the default setting), each dimension will be rounded off, which will affect the cumulative total. This could be detrimental on larger projects. Therefore the project units need to be set to the correct unit (m³, m², m etc.) and to two or preferably three decimal places, to provide an accurate cumulative total. Once the model is exported the dimension object properties will export with the set number of decimal places allowing for greater accuracy when using model quantities and model derived quantities.

Figure 30: Project Units



Proxy objects

As noted previously when exporting from 3D design software to IFC, if an object has no corresponding IFC element type, it will be exported as a proxy. A proxy object is a general solid object mapped to the category 'IfcBuildingElementProxy' in the mapping process because no appropriate IFC element exists for that object. As a general solid object, it has geometry but no data, which is obviously undesirable, and therefore to be avoided. Thus, if the QS generates an automatic QTO, they will see the dimensions of the proxy object, but will be unable to determine what it is without a visual representation of the object. There are automatic IFC exporters in most design software such as Revit, Archicad and Bently. An IFC export extension can also be added to some of these softwares. These add-ons are more sophisticated giving the user the ability to manually map from the native schema, add additional IFC parameters to the IFC schema, and pick up those objects that may have been missed in an automatic export.

Replica dimensions in same object

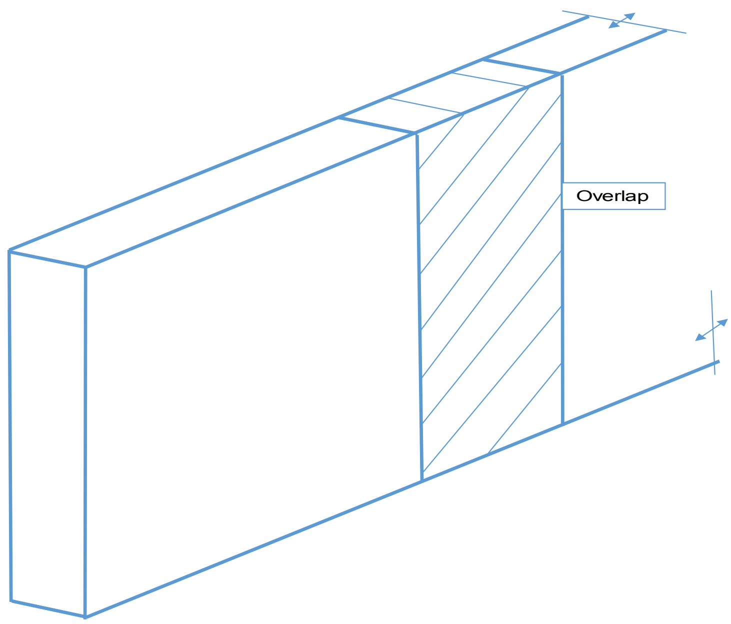
When the QS imports an IFC into their 5D software, they may potentially see three sets of quantities for the same dimensional property, such as the Volume (m^3) of a wall. The first one is the model dimensions that are part of the parameters of the object; the second type are the IFC base quantities that were calculated from the model geometry on export; and possibly (depending on what 5D software is being used) a third set of quantities, that are also calculated from the geometry of the model on import into the 5D software, such as those calculated in 'Solibri Model Checker' and 'Cubit'. Of these, the model dimensions are preferred because they are explicit properties of the model itself, next are the base quantities. But it is good to look across all available dimensions to check any differences.

Over measurement - duplicates and overlaps

In some cases objects can be duplicated in a federated model. For example sanitary fittings could be both illustrated in the architectural model and the MEP model, and thus, these quantities could be double measured. Structural elements may also be in both the architectural and structural models and thus be duplicates if automatically measured.

If you open the model in your 5D software and carry out a full BIM quantity dump on the entire model, you will get a lot of items/quantities that you may not need, again the software (unless it is hidden in view) will not know that Grid Lines; Mullions (in windows); Annotation Lines etc, are not to be measured. The software will automatically quantify what is visible in the view. Overlaps in objects and thus in measurement can occur even within the same discipline specific model. This is a clash issue and should be picked up in a clash detection, but occasionally walls will overlap with each other and other objects, and thus create an over measurement for that item **Figure 31**.

Figure 31: Overlap in Walls



Different LOD in the same model

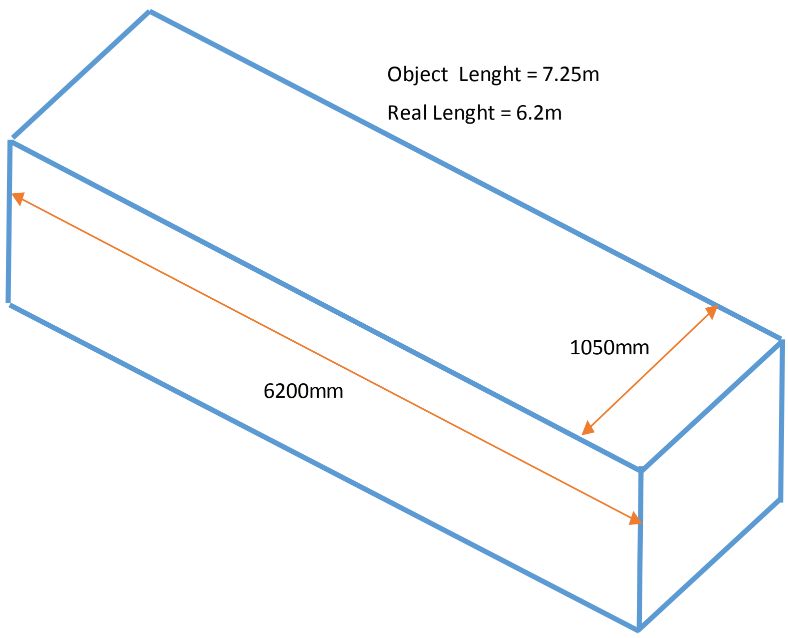
Another issue you might find, is that you receive a model that does not have a consistent LOD. The LOD was previously illustrated in **Figure 4.** It is not uncommon for architects and engineers to use objects from a BIM library that either do not have enough detail for the relevant stage of design (i.e. has geometry but limited specification information) or has too much detail (i.e. they downloaded and selected a manufacturers object from a BIM library such as the NBS). Having too much detail in the object may not be an issue, but the architect/engineer may be using it as a place holder and it might not reflect accurately the design intent.

Another issue is that consultants may be using different LODs at certain design stages, for example, the architect is designing to LOD 200 at concept stage but the engineer is designing at LOD 300. Using different LODs in the same model can also lead to confusion. A consistent agreement on LOD must be established in the BEP, where each design stage and associated cost plan should be delivered to an agreed LOD.

Missing quantities and geometry inaccuracies

In a number of cases certain dimensional properties in the model may not be correct. We have found this is particularly evident in solid objects such as foundations and walls, In strip foundations for example, the 'Volume' model dimension tends to be correct, but if you calculate the volume from the Width x Length x Height object properties, the resultant volume does not match. We have found that in some models the 'Length' dimension is not a measure of the true length of the object, but a combination of two or more sides, i.e. the dimension is actually the length plus the width of the object **(Figure 32)**. Of course if you use this dimension to measure the length of a foundation, or the length of walls, the item will be significantly over measured. We have learned over the years, as previously illustrated in **Figure 24**, to calculate quantities in a number of ways (if possible) so that these issues can be isolated, for example, supplementing model quantities with model derived quanties as well as cross checking model quantities with 2D take off.

Figure 32: Length Dimensions



You may also find that some objects, do not have any dimensional properties, or are missing some of them. For example, you may see a wall that has a 'Volume' and 'Width' dimension but no 'Area' or 'Length' properties, or vice versa. This is particularly evident in IFC files, where maybe the Base Quantity add-on was not selected on export. Or it may be that the base quantities were enabled on export, but the Revit model parameters were not selected. Also note that even if base quantities were selected on the IFC export, some objects will be missing dimensional data, because IFC 2X3 MVD 2.0 still cannot calculate geometry for all the items of the model – that is why it is necessary to export with model native parameters enabled.

Labelling

One of the greatest challenges in the 5D process is that the information is forever changing. For the QS this can create issues in mapping, where if the string of information that makes up the mapping from IFC/DWFx to the QS tool becomes broken, then BIM information mapped to a dimensional output in the estimate will in turn be compromised. So a designer might consider a typo to an object name in Revit as a very small change, but for a QS it can lead to errors in what should be an easy update. Because the previously mapped elements are now broken the mapping process has to be repeated.

An example of this is where the architect changes the structural properties of a cavity wall, i.e. they change the thickness of the blockwork or the type of insulation in the cavity. What happens here is that the BIM ID, that alpha/numerically (e.g GUID 675P42987654) represents this object in the model does not change and thus this change is not picked up by the revision tool in the QS software. This can be a costly anomaly, because if this change has not been communicated, it may be missed. What the architect needs to do is delete the old object and replace it with a new object that has a completely new BIMID. In summary, be careful when using revisioning tools and do not take them as an automatic update without asking the designers what has changed, just in case the software has not picked up the change.

Views and Details

When receiving drawings from the design team in 3D and 2D, no matter what view is received, from a BIM perspective, they should be a representation of the model. However, designers sometimes add further information in the form of annotations, tags and even additional 2D details, that are not embodied in the model. This is common when detailing foundations, rising walls, junctions and sections. Sometimes the architect may even have converted a 2D view to a CAD drawing and added further detail to the CAD drawing. This supplemental detailing may not be in the views of the parametric model. When the model is exported this additional information/detailing may not be exported with the model 2D views. This is why it is important to understand file types and the export process. It is also important to keep an open dialogue with the design team and question anything that is amiss.

Depending on how the views were exported and what was hidden in the views, other important information can be missing. The 2D drawing views may be missing important content such as; a legend key; a scale; annotations; the project grids; section tags; and the models not being aligned to the same point of origin. There are many reasons why this information is missing when transferring files. With increasing sophistication in design software, an abundance of data proliferates. This often leads to the downstream user becoming hostage to what they receive rather than what is available. Be aware that you may not receive a full cohort of design information. This can happen where the architect simply selects the wrong views (i.e. work in progress views rather than publication views); certain layers are turned off; and some objects are hidden in views.

Planning the measurement process with BIM

Introduction

It is necessary for the QS team working on the project to follow their company practices and procedures in order to work towards a homogenous delivery. This will allow to plan ahead and reinforce the project deliveries at peak workloads with additional resources. It is important that the QS understands what data will be received and when, and plan accordingly, i.e. will you receive a native file format (Revit, Archicad) or are you receiving an interoperable file such as IFC or DWFx? This is important because you may not have the native software to open the model or your QS software may not be compatible with receiving certain file types. If a BIM export file is available (IFC, DWFx), ask for both 2D and 3D views. If you receive 2D files on PDF ask if there are 3D files available – it is not uncommon where the architect or engineer are designing the project in 3D and issuing drawings in 2D. The following sections outline a number of recommendations and good practice when carrying out QS services on a project that is designed in BIM.

Agree a common data environment

With the proliferation of digitisation in the construction industry and the different type of export formats from these software applications, complexity within interoperability can lead to confusion, unless a CDE is agreed from the outset. For example, the QS could receive BIM data from the design team in a number of different formats. They may receive;

- A BIM Revit or Archicad model from the architects and PDF 2D drawings from engineers
- A federated model, which includes all the design disciplines in the same model or separate models from each discipline in varying file formats.
- IFC files from an engineer or DWFx files from architect.

This is why it is very important to be aware of what the different types of file formats are and whether you have the software and hardware capabilities to receive them. Most QS applications accept IFC files but not all of them can work with DWFx. It is also worth investing in a copy of Autodesk Revit, as it is the predominant design software in Ireland and a QS (as demonstrated previously) can carry out data mining and filtering in the design model and export the model in a manner that works best for them. Ultimately it is more practical to be provided with editable design information such as the Revit file, rather than protected DWFx or IFC files.

Familiarise yourself with the model

If you are completely new to BIM, a good action when you receive a BIM file is familiarise yourself with the model. Navigate the model by browsing the model structure using the software navigation tools (most navigation tools are similar – pan/zoom/rotate/hide/walk-through). The model will be presented in a model structure or model tree. Highlighting certain elements within this structure list will in turn highlight those categories in the model view. For example, use the software's navigation functionality to investigate all the components of the model by highlighting certain categories in the model (i.e. selecting only the wall objects) or hide objects so that you can view the internal areas of the model. Some software has the ability to walk-through the model much like you might in a gaming console. Other applications have the capability to cut through the model to see isometric sections and even to pan/zoom within these sections. Even if you carry out all your measurement from the 2D views, if nothing else, spending time investigating the BIM model will help you understand the drawings and aid manual measurement.

Generate a BIM quantity dump

Most QS applications that utilise BIM models have a quick way to automate quantities (as discussed previously and illustrated in **Figure 19**). After you have navigated the model, generate an automatic 'BIM QTO Dump' from the model and determine what quantities are usable. Be aware that these quantities are not measured as per QS measurement standards or rules, but some of them are very useful. You will notice that the model generates counts (doors, sanitary ware, pipe fittings etc.) without error – if it is in the model, it's counted! Also check some of the wall and floor area calculations and see if your 2D quantities match these areas. This approach will aid your proficiency and understanding incrementally in the BIM process. Importantly a progressive approach will build your competency and trust in this new way of working, before you take further steps with BIM.

Planning your 2d and 3d measurement

If you are becoming more proficient with BIM and BIM measurement, start using a Hybrid approach (both 2D and 3D) to QTO. Decide which quantities can be: Manually Measured (MM); which can be automated directly from the model, i.e. are Model Quantities (MQ); and those quantities which can be derived from the model quantities - Model Derived quantities (MD). Also investigate the quantifiable scope not present in the graphical material (similar to how you would do this in the 2D process – i.e. what is not there). Even in a fully detailed model there will be a need for manual measurement.

The following list outlines some examples:

- Door Counts (MQ)
- Concrete in Columns (MQ)
- Reinforcement in Columns (MD)
- Formwork for Columns (MD) (will not even be shown on the drawings)
- GIFA (MM)
- Excavation of Footings (MM) or (MD)
- Earthwork Support to Excavations (MM) or (MD)

Often you receive a model that does not contain any information regarding earthwork and excavations. There may not be any levels to work from, so communication with the design team will be necessary to measure many of the substructure items as well as requesting additional 2D sections or details on groundworks.

Assess what is not in the model

Quantities and costs are frequently required by clients on design information that does not appear on a model, especially at the earlier stages of a project. For example, there may be items that are yet to be modelled; the LOD of BIM design information may include geometric data but no specifications; or items have unknown quantities as further investigations are required. So treat the model at early stages of design like you do your traditional 2D information and carry out your order of magnitude and elemental costing from quantities that are available from both 3D and 2D views, as well as non-graphical information such as specifications, health and safety documentation, employer's requirements and conversations and meetings with the design team. Your experience on other similar projects will inform what is not showing on the model and price accordingly.

Carrying out order of cost estimates (early estimating)

In the early stages of a project you may receive what is termed a Mass Model (**Figure 3**). This is a 3D view with plates illustrating floor areas and enclosed in a voluminous shape represented with single panes. Most early estimates are carried out as an OCE calculated 'superficially' from the GIFA. Mass Models do not contain objects but rather illustrate the scope of the project in panes and shapes, thus, you will not be able to calculate a GIFA from extracting the floor plate quantities, as they only include the geometry to the outer edge of the floor area and not the inside face of the external wall. Some extrapolation of these areas will need to be carried out to calculate an accurate GIFA. This is a good example of how some traditional QS measurement rules do not align with BIM geometry and methodology.

In 2014 the RICS published a research paper investigating how BIM can support the New Rules of Measurement 1 (NRM1). The NRM1 *"provides guidance on the quantification of building works for the purpose of preparing cost estimates and cost plans".* The RICS research suggests that the NRM1's rules (which do not have the same level of detail as BOQ SMMs, such as the NRM2 or ARM4) can be supported efficiently by BIM. The NRM1 classification structure can be easily applied in the model and/or processed in quantity surveying software, because the number of levels and detail in the classification schema are a lot less than SMMs for BOQs. This is demonstrated in the 'Mapping BIM Quantities' section outlined previously, where automated QTO is processed and mapped to one or two levels of coding, to produce a dimension output which can easily align to an early estimate. As noted previously, this does not eliminate the descriptions and additional dimensions that may need to be measured to produce the complete estimate, but if the dimension output from the model is already aligned to the NRM1 main headings or the ICMS headings (if carrying out an ICMS estimate) later processing of the estimate is made significantly easier.

Estimate to the agreed design/cost plan stage

The cost report should be based on the stage of design agreed in the BIM execution plan and not necessarily a complete reflection of the content of the model. You may receive a detailed LOD model when you are carrying out an OCE and of course sometimes you get a mass model when you need more detail, per a later stage in the design process. Similar to your traditional QS process, the content of the design does not always reflect the level you need for your estimate. However, it is up to you to produce the most accurate estimate based on the information you receive, the information you ask for (conversations and non-graphical data) and also based on your previous experience on similar projects.

Carrying out your estimate must also be within your fee structure and too much time spent on quantifying a BIM model at OCE could be detrimental to profitability on the project. So try to implement an approach that harnesses the efficiency of the model, but does not add unnecessary time quantifying elements and objects that do not align to what is required in the cost plan. As you become more proficient with BIM you will notice that the earlier cost plans can be carried out quickly, because the BIM LOD at earlier stages aligns well to the methodology in producing cost plans (See previous section previously – 'carrying out OCE').

Separate and label your measurement

If you are using a hybrid approach (i.e. utilising 2D MM and 3D MQ/MD), your manual measurement should not alter the model in any way, i.e. do not change objects or elements in the model to suit your 2D quantities (this is difficult anyway if you receive a read only IFC or DWFx). It is recommended to separate your 2D measurements and 3D measurements in your QS software. This is good housekeeping, but it is also necessary as change management in 2D quantities and 3D quantities are very different when revising estimates. It is also recommended to separate fully automated BIM quantities from those that you processed. For example, if you carried out a BIM Dump, place those quantities in a BIM dump folder or group. If you carried out Model Mapping, as outlined previously, put those quantities in a different folder. This helps avoid duplicates and confusion on how you measured your quantities and also helps in revisioning. For example, if you run a revision on an updated 3D model the 3D QTO may be changed but this will not change your 2D manual measurement. So be aware of the multiplicity of your measurement.

Same report at the same stage

The QS is somewhat unique in the BIM process, as the quantities extracted from the model are independent of the model itself. As discussed previously, this is the action of 'Processing' the model, which is a quasi-manual/automated process, where the QS extracts 3D quantities, adds further MD quantities and possibly even carries out MM. All these quantities, irrespective of how they are generated, are used in their cost plan or BOQ. This is an important qualification in the 5D BIM process, because not only does the cost plan/BOQ exist outside the model but the quantities themselves also exist independently, due to the rules and interpretations the QS has to apply in the quantification process. Ultimately quantities and costings are generated products of the model and not completely inherent in the BIM (although other professions may argue otherwise). This is unusual in BIM and even runs counter to its ideology, as BIM is presented as a homogeneous process.

Where most other design disciplines contribute within the federated environment, the QS, for the moment, exists outside it; validating; qualifying; troubleshooting; and mining the model data, to produce an accurate reflection of the costs. As manual measurement is still currently very much part of the 5D process and these measurements will require a greater amount of time than pure digital take offs, as well as the time it takes to carry out 5D BIM processing. It should be stressed that a cost plan will be performed once per phase and not on a real-time basis (i.e. similar to the traditional cost planning process - a cost plan for each "milestone" of the design process).

Responsibility and validation

Even if the design team follow excellent modelling practice in accordance with the BEP and complete the design to the LOD agreed, the QS will still need to ratify the quantities. The QS is still responsible for their use of the data extracted from the model. Many QSs question this, as they feel the model and software is responsible for the QTO. However, as outlined previously there are a number of ways that the QS measures from a BIM model and they must validate all their quantities irrespective of source. Validating the model quantities is one of the key values a QS can bring in the quality assurance of design information. By automating this process too much we run the risk of missing elements that are wrongly classified or designed.

Clash reports

The project BIM coordinator will run clash detection and issue clash reports as defined in the BEP, and the QS will be a recipient of these reports. From the QS perspective, it is important to be aware of what are the clashes, as these issues have a cost implication if not solutioned through the design. These issues are usually communicated through the CDE and each design discipline will be given a list of what is clashing to resolve the issue.

Different work stages will deploy different tolerances to allow appropriate data clash reports to be produced (the tolerances reducing from design to as-builts – for example, from 200mm to 5mm for hard clashes). These tolerances are usually identified in a clash test matrix for the different stages and will be set to suit the project and type of clash. Clashes identified can include hard clashes, duplicate objects, design/modelling issues and missing objects. These reports can be used as part of the checks and balances procedures and can lead to a more co-ordinated design process between architect, structural engineer and MEP engineer.

BIM execution plan (BEP)

To avoid many of the issues outlined in the 'Troubleshooting' section and to properly 'Plan' your measurement and costing with BIM, it is important to communicate your requirements for consideration in the BEP. BEPs are becoming more common place on Irish construction projects over the last number of years and it important that the QS is also communicating their requirements and intent in the BEP. This will inform the rest of the design team and construction team of the QS requirements and lead to the QS becoming an active member in the BIM workflow.

The Main points to be considered in the BEP for QSs are:

- How many buildings will the project will be split into? Is there a need for an independent model file, and an independent specification document, for each of the buildings or will they be combined in the BIM?
- Agree the design outputs, i.e. 3D Model only or both 2D and 3D drawings and specification.
- Agree the export requirements from the design software - i.e IFC or DWFx file formats, room properties selected, base quantities selected, revit parameters enabled.
- Agree how other design information will be communicated i.e 2D details in DWG, PDF or DWFx; schedules; landscaping information; finishes; inventory and equipment.
- Agree what design material supersedes all others (i.e. specification, models or drawings). So when an error is identified a decision can be taken.
- Agree who is responsible for Clash Detection, i.e. BIM coordinator, project manager, architect, QS or other.
- Agree at what stage the models will be federated – up to then you will receive single discipline models.
- Agree the design stages (i.e. data drops to stakeholders) and align cost plan stages.
- Agree what Object Library will be used (i.e. NBS, Revit UK, other).
- Agree a QS Classification system (i.e. NSBE, NRM, ICMS, other). It may be different levels per different stages.
- Agree what Level of Detail and Level of Information is required at each stage.
- Agree with Design Team on a standard object naming convention. Agree a coding convention as a means to code Type parameters as well as if an instance of these types is different and thus needs an Instance code. i.e. a Concrete Wall Type which has different reinforcement details or formwork types - will have the same Type Code but different Instance Codes based on different reinforcement/fomrwork details.
- Agree with design team that the BIM will be delineated per zone and level (make sure architect creates a substructure differentiation)

Conclusions

BIM is a new way of working for the QS, but it doesn't change QS deliverables and must complement the current QS work processes. Ultimately the QS still has to provide sound cost advice to clients, often with little information. From a technology perspective, BIM is a tool that will enhance productivity if used properly, but will also lead to issues if not used correctly. This information paper outlines the dimensions of 4D and 5D BIM and provides guidance in processing BIM data for QS purposes. The paper also troubleshoots some common issues with models and outlines a planned approach to getting the best out of your 5D BIM practice. Based on the content in this information paper; the reading and video recommendations contained herein; and some training in BIM technologies, the QS will gain a greater degree of confidence and be able to ask questions of others, integrate with other systems and challenge methods of working and required outputs. Only by challenging what they are told, in conjunction with understanding the QS current work flow, will they be able to maximise the benefits that can be achieved from BIM. The QS of the future will be digitally enabled and recognise the value of data, the most valuable commodity in tomorrows world.

The following sections outline the main recommendations from this paper:

Workflow: Do not completely change your current 2D workflows. 2D information is still necessary when working with QS WBSs and SMMs. Educate yourself and your company, as discussed previously and incrementally introduce what will work best for your organisation based on the software you use and the culture within your company.

Education: It is important that QSs educate themselves in digitsation and BIM for construction. Read BIM documentation such as ISO 19650 standards; UK's level 2 mandate documentation including PAS/ BS1192; and Ireland's 'Roadmap to Digital Transition'. It is also worthwhile investing in training on some of the 5D applications and even 3D design applications such as Revit or Archicad. Request training from your 5D application vendor and associated training materials. View youtube videos on BIM software. Also determine the capability of the software you are using which may have BIM functionality already.

Hardware and Software: Most modern desktops and laptops have the necessary hardware to run 5D BIM applications. Your current 5D software may already have BIM functionality. Other software applications mentioned here such as Revit, Archicad, Solibri Model Checker and NavisWorks have trial versions, which can be used free for a limited period.

4D BIM: It is important for the QS to be aware of the functionality of 4D and its capabilities. There is an intrinsic link between the planning and sequencing of works and cost management. **"4D BIM"** can be used for effective space management; clash detection; construction simulation; and scheduling.

QTO Automation: QTO leveraging BIM is not presently a fully automated process. Current practice is to process quantities in-line with the QS WBS and then utilise these quantities in a template or library of descriptions to build your cost plan or BOQ. There is rapid innovation in this field through mapping and machine learning, which will certainly progress automation of QTO in the near future.

Troubleshooting: Be aware of the issues to look out for in 5D BIM. Digest the section discussed previously in **"TROUBLESHOOTING 5D BIM".** However, nothing compares to utilising the software and progress through the learning curve of BIM by reflective practice.

Planning your BIM process: Produce a checklist or staged process for carrying out your measurement. In doing so, consult the sections outlined previously in **"PLANNING THE MEASUREMENT PROCESS WITH BIM"**and determine the best approach for progressing in a digitised workflow. As noted previously take incremental steps, but be conscious of the issues that can arise when utilising BIM.

Mapping: Mapping is the process of appending cost codes and associated descriptions to the BIM schema. This paper outlines a number of different approaches to mapping, utilising both 3D design software and 5D BIM software **("MAPPING BIM QUANTITIES")**. It is vital that the QS understands the different types of BIM files and the limitations of each file type. It is also very important that the QS knows what information is contained in a BIM object, how additional parameters can be added and coded for QS identification. Having a limited knowledge of design software helps in this regard.

ICMS: The International Construction Measurement Standard is now available. As discussed in the **"ICMS AND SMMs"** section, it provides a universal coding structure for the QS across the globe. The ICMS has a coding structure that can be mapped to BIM classifications to help automate 5D internationally.

Managing Expectations: Current models have between 61 - 80% (at best) BIM enabled automated quantities. The following points outline some take-aways from the paper.

- The quality of the information within the BIM affects performance and outcomes (rubbish in, rubbish out).
- Think of BIM as a value creator not as a cost factor. Become more aware of current trends and upskill.
- Be realistic & pragmatic in your expectations and consider that BIM is not a perfect digital solution but an imperfect digital advancement with great potential.
- Realise there is always some quantifiable data in BIM, even in bad models. Most importantly the QS needs to know how to navigate the model and articulate their requirements to stakeholders.
- Note that this an ever evolving journey and you need to work with what you have and incorporate changes as they occur, such as the ICMS and the revised ARM 4.

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Definitions

3D BIM	The process of creating graphical and non-graphical information and sharing this information in a Common Data Environment (CDE)
4D BIM	Adds information in the form of scheduling data and planning of construction works
5D BIM	Drawing on the components of the information model being able to extract accurate cost information
6D BIM	Sometimes referred to as integrated BIM or iBIM, 6D BIM involves the inclusion of information to support facilities management and operation to drive better business outcomes
Architectural model	Model made up solely of Architectural components/model elements.
As built Model	As built is defined as the record drawings and documentation that capture changes to the design in the finally constructed facility.
Asset information model	Term used to describe the set of information (documentation, graphical model and non graphical data) collected and collated over the entire life of the asset.
Authored Model	Model created by a design discipline i.e. to be consumed by downstream user.
BIM Execution Plan	A plan prepared by stakeholders to explain how the information modelling aspects of a project will be carried out. Informed from EIR.
bSI buildingSMART International	A non-profit international organisation focused on improving the exchange of information between software applications used for the built environment sector.
Buildingl Information Model	A digital representation of the physical and functional characteristics of a facility using a collection of elements or information that serves as a shared knowledge resource for design, construction, operation and retrofit/demolition of a built environment asset.
Clash Detection	Process of identifying or detecting possible collisions between elements in a building information model generally from two different disciplines (sometimes all referred to as collision detection or coordination).
Classification	A standardised system of headings and subheadings to ensure that data can be indexed and structured to make it easily accessible.
COBie	A structured facility information for the commissioning, operation and maintenance of an asset.

Common Data Environment	A single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process.
Computer Aided Design	Drawings that are represented with 2D information such as lines and arcs.
Construction recipes	The complete work breakdown structure and classification of QSs outlining how cost plans/BOQs are to be created, described, coded and formatted.
Data drops	Digital equivalent of 'stage reports' where information is delivered from the Building Information Model to the client.
Design model	A model of those aspects of the facility/asset/project that are designed and expressed by an Architect/Engineer.
Design Web Format	An open interoperable file format used across Autodesk products.
Employer's Information Requirements	A document that allows clients to confirm what information they want from a model and to set out the uses of this.
Federated model	A Building information model consisting of linked but distinct component/disciplinary models.
Gross Internal Floor Area	The area of a building measured to the internal face of the perimeter walls at each floor level, which includes: Areas occupied by internal walls and partitions. Columns, piers chimney breasts, stairwells, lift-wells, other internal projections, vertical ducts, and the like.
Industry Foundation Classes	Open source information model for sharing data and to facilitate interoperability (not controlled by a software vendor).
Integrated Project Delivery	A construction project delivery method that seeks efficiency and involvement all participants; promotes collaboration from stakeholders.
Interoperability	The ability of two or more (computer or software) systems or components to exchange information and to the use the information that has been exchanged.
Level Of Detail	This is the specific resolution of graphical information required for a particular element at a particular phase of the project.
Level of Development	This is the specific resolution of graphical and non-graphical information required for a particular element at a particular phase of the project.
Level Of Information	The description of non-graphical content of models at each of the stages defined.
Mapping	Linking two or more classifications systems or schemas, so that the attributes in one schema are aligned to the same attributes in the other.
Mass Model	A conceptual representation of a BIM in shapes and panes.
Model Derived Quantities	Quantities that are derived from the Model Quantities.

Model Quantities	Quantities that are directly automated from the Model.
Model View Definition	The subset of IFC data model necessary for supporting the specific data exchange requirements of the AEC industry during the life cycle of a construction project.
NRM 1	RICS New Rules of Measurement 1: Order of cost estimating and cost planning for capital building works: Rules for measurement throughout the elemental cost planning process
NRM 2	RICS New Rules of Measurement 2: Detailed measurement for building works: Detailed rules for measurement and description of building works. Trade-based classification system.
Object Attributes	Some properties of an object are absolute. These fixed properties are termed Attributes.
Object Properties	Attributes or properties that can be added to the object as additional parameters.
OmniClass	OmniClass Classification system as used in the USA similar to (but not directly interoperable with) UniClass.
Parametric	Where a change to one of the objects in the model will be represented and changed in all model views.
Pre-Processing	Processing quantities with a QSID in the authored model prior to exporting into QS software.
Post-Processing	Processing quantities by mapping to the QS classification schema within the 5D environment.
QS IDentification (QSID)	A unique code associated with (or added to) an object of the model, that represents the QSs Classification code or Work Breakdown Structure of the country or jurisdiction that the project is being carried out.
Schema	Organisation of Data into a structured format of codes and subcodes.
UniClass	Unified classification for the Construction Industry used in the UK: This groups objects into numerical headers to allow things to be arranged or grouped according to a type or class. Can be applied throughout the asset life cycle.
UniFormat	The elemental classification for building specifications, cost estimating and cost analysis produced by the US department of commerce.
Views of Model	Describes a certain view of the model, such as a 2D plan, 2D Elevation, 2D Section or 3D View. Each one is a representation of the same model not an individual drawing.
Work Breakdown Structure	The classification structure used by QSs, which outlines the hierarchy of elements and descriptions in a BOQ or Cost Plan.

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