ALIGNING LEVELS OF DEVELOPMENT AND PRINCIPLES OF MEASUREMENT FOR COST PLANNING

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Abstract

BIM is capable of generating cost estimate directly from a 3D model. It can thus offer a significant benefit by creating accurate and fast cost plans during different design stages, thereby increasing the quantity surveyor's ability in cost planning and control. However, quantity surveyors are generally reluctant to adopt BIM due to their resistance to change to the model-based quantity take-off and estimate, data interoperability between BIM and estimating tools, undefined model outputs at various project stages, and incompatible BIM information classification systems with the traditional elemental cost planning formats. In order to overcome these problems, this study has proposed a BIM-based pre-contract cost planning and control framework. Based on the UniFormat information classification system for model elements, the proposed framework consists of four levels of estimate based on LOD 100, 200, 300 and 350/400 model elements, respectively. It has also incorporated the measurement principles which are formulated based on the specified amount of graphical and non-graphical information for each model element. Quantity surveyors can systemically measure individual generic and precise elements or items according to defined information contents and measurement principles, thus leading to a more accurate estimate. This study would help significantly improve the industry practice in cost planning and control and also systemically refine the existing standard method of measurement in alignment with the latest BIM development.

Keywords: BIM, Pre-contract, Cost Planning.

INTRODUCTION

Building Information Modelling (BIM) has been rapidly developed in the construction industry. It provides project team members with accurate and reliable information, accommodates various functional needs, and provides a simulated view of the building. In recent years, BIMs are increasingly used by employers, architects, structural engineers, building service engineers, quantity surveyors and contractors during the project lifecycle. As one of the most important tasks in any project, quantity surveyors undertake cost planning and control to ensure that the ultimate cost will be controlled within the approved budget.

In the United Stated, Canada and many developed European countries, BIM is very popular in their construction industries. Realising its potential benefits, the local construction industry is gradually gaining momentum in the use of BIM. For quantity surveyors, BIM provides both challenges and opportunities specifically in quantity take-off and cost planning. BIM is capable of automatically generating quantity take-offs from a 3D model. This is very time consuming if done by manual process. Therefore, BIM can potentially revolutionise the way how quantity surveyors carry out the pre-contract cost planning.

In United Kingdom, Australia, Hong Kong and other countries adopting traditional British-style practices, pre-contract cost planning is largely based on the elemental cost planning and approximate quantity methods for cost estimating and cost checking, respectively. However, owing to the inadequate confidence in the reliability of models and lack of recognised standard for categorising building works, quantity surveyors would favour to adopt the manual take-off approach using paper drawings (Aibinu and Venkatesh, 2014). Indeed, most BIM-based cost estimating tools such as QTO, Vico, Tocoman and Innovaya are developed to suit the United States and European markets without considering the UK's traditional measurement rules and estimating practices. In addition, the BIM information classification systems developed in the United States are also not compatible with the UK's traditional elemental cost analysis and cost planning formats. As a result, a BIM model cannot be directly used without certain adjustments. Therefore, quantity surveyors are slow in the use of BIM due to four main problems; namely, resistance to change to the model-based quantity take-off, suitability of information classification systems into BIM applications, determination of levels of model detail at various project stages, and data exchange between BIM and quantity take-off tools (Firat et al, 2010).

Undeniably, the construction industry needs to improve its efficiency by better coordinating the overall construction process among various project team members. Serving as a collaborative working platform, BIM projects can progress more effective and faster as it helps address much inefficiency encountered in traditional projects. By extracting quantities directly from a building model, BIM offers a significant benefit by creating accurate, fast and consistent cost plans throughout different design stages, thus enhancing the quantity surveyor's ability in cost planning and control and reducing the abortive cost of design changes. This study aims to develop a BIM-based pre-contract cost planning framework in order to overcome the problems identified above.

REVIEW OF BIM DEVELOPMENT IN COST ESTIMATING AND COST PLANNING

When BIM first came into use, it was seen simply as a 3D model of a building. However, such a basic explanation does not adequately convey the potential of digital, object-based, interoperable BIM processes and tools. Once a model is properly developed, information contained within the model can be extracted for programming (4D BIM), estimating (5D BIM), component fabrication and finally, facility management. Pre-contract cost planning is one of these important tasks that can benefit from BIM. However, it is essential to review the relevant development, limitations and corresponding changes in the current cost planning practice.

BIM-based Cost Planning Process

When preparing a cost plan, quantity surveyors traditionally start by digitising the design consultants' paper drawings or directly importing their electronic drawings into estimating software, and then manually take off quantities from these drawings. This manual take-off method may introduce human errors. By using BIM, the quantity take-off can be generated from the 3D model. When there is any change in the original model, the change can instantaneously update the quantity take-offs and estimating documents. Quantity surveyors can then monitor the cost implication of any design changes.

While the time required for preparing a cost plan varies from project to project, quantity surveyors may spend at least 60% of their time on quantity take-off. Therefore, there is a great advantage of using a BIM for cost planning. When manual take-off is no longer necessary, quantity surveyors can save both staffing cost and time, while reducing the potential for human error.

Through automating the time consuming task of quantity take-off by BIM, quantity surveyors can concentrate their attention on valuable project-specific issues such as analysing future construction market trends, evaluating different procurement strategies, examining alternative design solutions, generating accurate pricing, undertaking value engineering, evaluating risks, etc. These are essential for a high quality cost plan. This is also the real value of quantity surveyors.

Linking between BIM Software and Cost Estimating Software

The first step in any cost planning is quantity take-off according to the given design information. The computable information from a BIM model significantly minimises this quantity take-off process. There are three alternative approaches to utilise BIM for quantity take-off and estimating (Autodesk, 2007; Eastman et al, 2011). The first approach is to export BIM quantities to an estimating tool. Most BIM design tools (like Revit) are capable of extracting and exporting quantity data in a text file. On the other hand, Excel is capable of importing a text file to become a spreadsheet which enables quantity surveyors to carry out estimating. Due to its simplicity and ease of use, Excel is the most commonly used software.

The second approach is to link BIM design tool via an application programming interface (API) to a commercially available estimating tool or plug-in (like Nomitech and Innovaya). From within a BIM model, quantity surveyors export s BIM model according to the data format of the estimating tool. After importing the file by the estimating tool, quantity surveyors carry out estimating with or without an external cost database. When compared with Excel, the estimating tool provides some useful features for quantity take-off and estimating.

The third approach is to use BIM-specialized take-off and estimating tool which is capable of importing any BIM models in the IFC format. Examples of these include CostX, QTO, Vico and Innovaya. Without necessarily learning and operating the BIM tool used by design consultants, quantity surveyors directly use their own estimating tool for quantity take-off, estimating, bill production and other cost management functions. This estimating tool provides many supporting features for both automated extraction and manual quantity take-off. In addition, any subsequent changes to the original design model can also be detected by the estimating tool. It highlights old objects that have been changed, as well as new objects that have not been included in the previous estimate. When compared with the second approach, the specialized estimating tool is more powerful and becomes more popular.

Data Interoperability across Different Software

When preparing a cost plan, quantity surveyors often need to import quantity data from BIM models prepared by design consultants. A common data format is required to enable the sharing of information between project participants. In order to exchange data across various software tools, BuildingSMART has developed common data format called the Industry Foundation Classes (IFC) schema to define how information is provided and stored. As IFC is an open format, it does not belong to any software vendor. Nowadays, most (if not all) BIM applications have implemented IFC. The latest IFC 2x4 version is able to represent a very comprehensive range of construction information. As the possible construction information is huge, there are limitations in the IFC coverage.

Ma et al (2011) examined the application of the IFC standard to the cost estimate in China and found that the IFC standard, as a whole, is able to describe these seven areas of information. However, in order to support the data exchange with relevant application tools used in China, some additional property sets and proxy elements must be added to the current IFC standard.

In assessing the impact of the RICS’s new rules of measurement for cost planning (NRM1) on BIM schema, Matipa et al (2010) found that there are 53 entities in IfcSharedBuildingElements, but none is directly related to the cost planning process. The NRM1 does mention the potential application of the BIM-based data available in the market. As such, the incorporation of information requirements from the NRM1 into the IFC schema is an important step to enhance the efficiency and consistency of the UK’s cost planning process. The greatest challenge is the development of data types which can be recognized by IFC. This requires a quantity surveyor’s mind with software knowledge that models the cost planning process.

Levels of Development

In a collaborative working environment, project team members are required to produce their models using standardised processes and practices so as to enable the information exchange throughout the project lifecycle. In order to ensure the reliability of information output, the American Institute of Architects (AIA) has developed the levels of development (LOD) concept to describe the levels of completeness of a model element. The AIA (2013) defines five LODs; namely, the conceptual model (LOD 100), approximate model (LOD 200), precise model (LOD3 00), fabrication model (LOD 400) and as-built model (LOD 500).

In order to implement the LOD concept, it is necessary to further define the geometry and data content of each model element for each LOD by reference to an industry-wide standard. Based on the AIA's basic LOD definition, the US's BIMForum has developed the LOD specification to enable project team members to specify the content and reliability of BIMs at various project stages. Individual model authors are allowed to define their models, thus enabling downstream users to understand the usability and limitations of models (BIMForum, 2015). However, it is still under development stage.

Information Classification System in BIM and Cost Planning

For seamless exchange of information under a collaborative working environment, the information classification system used in BIM should be same for cost planning. In the United States, the OmniClass construction classification system provides a standardised basis for classifying information in the built environment. This is the most commonly used classification system in BIM. However, in United Kingdom, the RICS (2012) has published the new rules of measurement (NRM1) for the preparing a consistent cost plan. NRM1 is considered as the latest industry standard for pre-contract planning and control in the UK construction industry. As pointed out by Wu et al (2014b), "the measurement standards in UK (SMM or NRM) are developed independent of the BIM development process. Inevitably, their classification system and measurement rules have not been taken into consideration of the BIM development and their information structure is not fully compatible with the BIM data structure" (p. 542). While the information in BIM can be mapped to the traditional cost planning format through certain adjustments, it would be more efficiency for quantity surveyors to adopt the same internationally recognised classification system.

The RICS's (2012) new rules of measurement (NRM1) does not describe the exact estimating methods or cost planning techniques, but sets out measurement rules based on levels 1, 2, 3, and 4 for the group element, element, sub-element and component, respectively. The highest level 4 is to measure individual components which are used for checking individual cost targets and the overall budget. However, a BIM model is capable of generating more detailed quantities from its objects, depending on its completeness or levels of development. Therefore, the traditional cost planning practice must be changed in order to capture the full benefit of BIM.

REVIEW OF PREVIOUS RESEARCH IN QUANTITY TAKE-OFF AND COST ESTIMATING

Due to the importance of quantity take-off and cost estimating, a number of research have been previously undertaken in this area. In a study of the effects of project complexity in terms of organizational, resource and technical complexities and the use of BIM in cost estimating, Meerveld et al (2009) found that most BIM models contain insufficient information for cost estimating, thus leading to many difficulties encountered in the quantity take-off process and also inducing errors in estimating. In response to these difficulties, estimators usually spend more effort to look for the required information or add extra allowances to cover uncertainties in an estimate. This study recommends standardising the levels of detail for the model as well as documenting the information requirements in order to align the BIM model with the cost estimate. These recommendations are vital for the future development of BIM-based cost planning.

Shen and Issa (2010) evaluated the effectiveness of BIM-assisted detailed estimating tools based on four individual parameters such as accuracy, generality, efficiency and flexibility. A multi-attribute utility model is then used to assess the overall performance. This study concludes that the more complicated the estimating task is, the clearer the advantages of using BIM-assisted estimating tools are.

In a study of BIM developments in cost estimating and construction programming, Jiang (2011) found that BIM can enhance the traditional cost estimating and programming tasks. His study suggests two future developments: higher levels of detail in the model to facilitate the preparation of a detailed cost estimate, and linking cost and time parameters for delivery of a scheduled financial analysis.

Kim et al (2012) proposed a hybrid estimating method comprising historical data-based estimating and assembly-based estimating. When project information is limited, historical data-based method is used to prepare an estimate. When more project information is available, assembly-based estimating method is used by measuring the quantity of each element and assessing its unit cost. These two methods are used either separately or together, depending on the available information. Scrutinising two estimates reduces the uncertainty arising from equivocal project information.

In a study of the BIM-based design for quantity take-off, Monteiro and Martins (2013) found that ArchiCAD has an advanced take-off system, but it is not able to extract quantities without to certain extents altering the model because it does not fully meet estimators' needs in quantity take-off. This study thus recommends to develop standard modelling approaches in order to improve the output performance. Again, this is vital for the future development of BIM-based cost planning.

Since most BIM-based take-off and estimating tools are developed outside UK and based on different quantification rules and practices, Wu et al (2014b) reviewed the functional and technical capabilities of four estimating tools commonly used in UK. This study found that "majority of the tools (with the exception of BIMmeasure) do not support the UK practice automatically and additional works are required to use them in the UK projects (p.558)". This study concludes that project team members must agree the information requirement from the viewpoint of cost planning so as to facilitate quantity surveyors to use BIM more effectively.

Choi et al (2015) suggested an open BIM-based quantity take-off process for cost estimating. The quantity take-off process consists of four steps: BIM modelling, physical quality verification, property verification, and quantity take-off. The first step is to develop a building model by BIM authoring tools which support the IFC format for information exchange. The second step is verify the physical quality of the BIM model by Solibri Model Checker to ensure the accuracy of quantity information. The third step is to verify the property by extracting model elements and checking its codes before the actual quantity take-off. The quality assurance process is important for an accurate quantity take-off.

PROPOSED FRAMEWORK

In order to enable seamless information exchange under a collaborative working platform, the proposed BIM-based pre-contract cost planning framework is based on the OmniClass/UniFormat classification system for building elements and the LOD specification for individual model elements. The proposed framework consists of four levels of estimate but is based on LOD 100, 200, 300 and 350 model elements, respectively. As LODs are used to define the output information for each model element, this ensures a right amount of information for producing a consistent cost estimate. More specifically, the proposed framework has developed the principles of measurement for each model element at each LOD as shown in Table 1. As BIM is capable of fully utilising the three dimensions of all objects in the BIM model, it is not necessary to limit the measurement of building elements to its group elements, elements, sub-elements or components as the traditional quantity surveyor's practice. The principles of measurement take full account of, and are also formulated according to, the amount of both graphical and non-graphical information defined by LODs for each model element. Under this circumstance, quantity surveyors can systemically measure individual generic and precise elements/items modelled according to defined information contents and measurement principles, thus leading to a more accurate measurement and estimate.

It is realised that there is not strict correspondence between LODs and design stages (BIMForum, 2015). Nevertheless, it is assumed that levels 1, 2, 3 and 4 estimate are based on 'pure' LOD 100, 200, 300 and 350/400 models, respectively, which are prepared at the conceptual design, schematic design, design development and contract documentation stages, respectively.

Table 1: Principles of Measurement for Building Works at Different Levels of Development

Model Element By UniFormat Classification System*	**Model Element Author**	**Principles of Measurement for Building Works**			
		LOD 100 - Conceptual Model	**LOD 200 - Approximate Geometry Model**	**LOD 300 - Precise Geometry Model**	**LOD 350/400 – Interface Model / Fabrication Model**
SUBSTRUCTURE					
Pile Foundations (e.g. concrete bored piles)	Structural Engineer	Measure the area of the lowest floor to the external face of external walls.	Measure approximate quantities of generic piling elements modelled.	Measure major piling items modelled (e.g. drilling, bell bottom and concrete).	Measure detailed piling items modelled (e.g. drilling, casing, bell bottom, excavation, disposal of excavated materials, reinforcement and concrete) according to the specified SMM.
Pile Caps	Structural Engineer		Measure approximate quantities of generic pile cap and beam elements modelled.	Measure major pile cap and beam items modelled (e.g. concrete, formwork, excavation, backfill and disposal).	Measure detailed pile cap and beam items modelled (e.g. concrete, formwork, reinforcement, water stops, excavation, backfill and disposal) according to the specified SMM.
Grade Beams	Structural Engineer				
Structural Slabs-on-Grade	Structural Engineer		Measure approximate quantities of generic slab elements modelled.	Measure major slab items modelled (e.g. concrete and formwork).	Measure detailed slab items modelled (e.g. concrete, formwork, reinforcement, expansion joints and water stops) according to the specified SMM.
SHELL					
Concrete Frames: Columns and Walls	Structural Engineer	Measure the total gross floor area of the building to the external face of external walls.	Measure approximate quantities of generic column and wall elements modelled.	Measure major columns and wall items modelled (e.g. concrete and formwork).	Measure detailed column and wall items modelled (e.g. concrete, formwork and reinforcement) according to the specified SMM.
Concrete Frames: Beams	Structural Engineer			Measure major beam items modelled (e.g. concrete and formwork).	Measure detailed beam items modelled (e.g. concrete, formwork and reinforcement) according to the specified SMM.
Concrete Floor/Roof Slabs	Structural Engineer		Measure approximate quantities of generic slab elements modelled.	Measure major slab items modelled (e.g. concrete and formwork).	Measure detailed slab items modelled (e.g. concrete, formwork, reinforcement, designed joints, openings and penetrations) according to the specified SMM.
Stairs	Architect/ Structural Engineer	Measure the number of storey flights (i.e. the number of staircases multiplied by the number of floors served).	Measure approximate quantities of generic stair elements including treads, risers and railings modelled.	Measure major stair items modelled (e.g. concrete, formwork and railings).	Measure detailed stair items modelled (e.g. concrete, formwork, reinforcement, railings, and posts or supports) according to the specified SMM.
Exterior Walls (Concrete)	Architect	Measure the net area of external walls based on exterior elevations.	Measure approximate quantities of generic external wall elements modelled.	Measure major exterior wall items modelled (e.g. concrete, formwork, openings, interior and exterior finishes).	Measure detailed exterior wall items modelled (e.g. concrete, formwork, reinforcement, openings, interior and

Model Element By UniFormat Classification System*	Model Element Author	Principles of Measurement for Building Works			
		LOD 100 - Conceptual Model	LOD 200 - Approximate Geometry Model	LOD 300 - Precise Geometry Model	LOD 350/400 – Interface Model / Fabrication Model
					exterior finishes) according to the specified SMM.
Exterior Windows	Architect	Measure the overall area of exterior window openings.	Measure approximate quantities of generic exterior window frame and glazing elements modelled.	Measure each type of major exterior window items modelled (e.g. fixed and operable components, glazing and hardware).	Measure each type of detailed exterior window items modelled (e.g. fixed and openable components, finishes, glazing, hardware, interface details between windows and walls, and fixing methods) according to the specified SMM.
Exterior Doors (including entrance doors, utility doors, oversize doors, special function doors, grilles and grates)	Architect	Measure the overall area of exterior door openings.	Measure approximate quantities of generic exterior door and frame elements modelled.	Measure each type of major exterior door items modelled (e.g. door, frame and hardware).	Measure each type of detailed exterior door items modelled (e.g. door, frame, finishes, glazing, hardware, jamb, head and threshold details and fixing methods) according to the specified SMM.
Exterior Louvers and Vents	Architect	Measure the overall area of louver and vent openings.	Measure approximate quantities of generic louver and vent elements modelled.	Measure each type of major louver and vent items modelled (including frames and blades).	Measure each type of detailed louver/vent items modelled (including interface details between louver/vent and walls, and fixing methods) according to the specified SMM.
Roofing (excluding roof structure which is included in concrete frames and slabs)	Architect	Measure the area of roofing to the external face of parapet walls.	Measure approximate quantities of generic roofing elements modelled.	Measure major roofing items modelled (e.g. waterproofing, insulation, finishes and expansion joints).	Measure detailed roofing items modelled (e.g. waterproofing, insulation, finishes, expansion joints, penetrations for services, rainwater drainage and skylights) according to the specified SMM.
INTERIORS					
Partitions (including fixed partitions, glazed partitions, demountable partitions, operable partitions and screens	Architect	Measure the net area of partitions based on layouts and elevation profiles.	Measure approximate quantities of generic partition elements modelled.	Measure each type of major partition items modelled (e.g. masonry/framing, openings and finishes).	Measure each type of detailed partition items modelled (e.g. masonry/framing, openings and finishes) according to the specified SMM.
Interior Windows (including operating windows, fixed windows and special function windows)	Architect	Measure the overall area of interior window openings.	Measure approximate quantities of generic interior window frame and glazing elements modelled.	Measure each type of major interior window items modelled (e.g. fixed and operable components, glazing and hardware).	Measure each type of detailed interior window items modelled (e.g. fixed and openable components, finishes, glazing, hardware, interface details between windows and walls, and fixing methods) according to the specified SMM.
Interior Doors (including swinging doors, entrance doors, sliding doors, folding doors, coiling doors, panel doors, special function doors, access	Architect	Measure the overall area of interior door openings.	Measure approximate quantities of generic interior door and frame elements modelled.	Measure each type of major interior door items modelled (e.g. door, frame and hardware).	Measure each type of detailed interior door items modelled (e.g. door, frame, finishes, glazing, hardware, jamb, head and threshold details and fixing methods) according to the specified SMM.

Model Element By UniFormat Classification System*	Model Element Author	Principles of Measurement for Building Works			
		LOD 100 - Conceptual Model	LOD 200 - Approximate Geometry Model	LOD 300 - Precise Geometry Model	LOD 350/400 – Interface Model / Fabrication Model
doors and panels, grills and grates)					
Raised Floor (including access flooring and platform/stage floors)	Architect	Measure the total area of the raised floor.	Measure approximate quantities of generic raised floor elements modelled.	Measure each type of major raised floor items modelled (e.g. adjustable pedestal, floors panels, openings and penetrations).	Measure detailed raised floor items modelled (e.g. adjustable pedestals, floor panels, ventilation, outlet boxes, skirtings and edge trims) according to the specified SMM.
Suspended Ceiling (including acoustic, plaster, gypsum and special function ceilings)	Architect	Measure the total area of the suspended ceiling.	Measure approximate quantities of generic suspended ceiling elements modelled.	Measure each type of major suspended ceiling items modelled (e.g. ceiling panels, suspension system, surface finishes and access panels).	Measure each type of detailed suspended ceiling items modelled (e.g. ceiling panels, suspension system, surface finishes, access panels, cornices and the like) according to the specified SMM.
Wall Finishes (including tile wall finish, wall panelling, wall coverings, wall carpeting, stone facing, special wall surfacing, wall painting and coating and acoustical wall treatment)	Architect	Measure the total area of wall and column finishes.	Measure approximate quantities of each type of generic wall and column finish elements modelled.	Measure each type of major wall and column finish items modelled (e.g. tile wall finish, wall panelling, wall coverings, wall carpeting, stone facing, special wall surfacing, wall painting and coating and acoustical wall treatment, etc.).	Measure each type of detailed wall and column finish items modelled (e.g. tile wall finish, wall panelling, wall coverings, wall carpeting, stone facing, special wall surfacing, wall painting and coating and acoustical wall treatment, etc.) according to the specified SMM.
Floor Finishes	Architect	Measure the total area of floor finishes.	Measure approximate quantities of each type of generic floor finish elements modelled.	Measure each type of major floor finish items modelled (e.g. surface hardeners, in-situ finishes, tiled finishes, wooden finishes and other propriety flooring, etc.).	Measure each type of detailed floor finish items modelled (e.g. surface hardeners, in-situ finishes, tiled finishes, wooden finishes and other propriety flooring, etc.) according to the specified SMM.
Ceiling Finishes	Architect	Measure the total area of ceiling finishes.	Measure approximate quantities of each type of generic ceiling elements modelled.	Measure each type of major ceiling finish items modelled (e.g. in-situ coatings, sprayed coatings, decorative coverings, painting, cornices and the like).	Measure each type of detailed ceiling finish items modelled (e.g. in-situ coatings, sprayed coatings, decorative coverings, painting, cornices and the like) according to the specified SMM.
SERVICES					
Lifts	Building Service Engineer	Measure the number of schematic lift models.	Measure approximate quantities of each type of generic lift elements modelled.	Measure each type of major lift items modelled (e.g. lift car, doors, lifting equipment, guides and counter balances).	Measure each type of detailed lift items modelled (e.g. lift car, doors, lifting equipment, guides, counter balances, lift shaft and builder's works) according to the specified SMM.
Escalators	Building Service Engineer	Measure the number of schematic escalator models.	Measure approximate quantities of each type of generic escalator elements modelled.	Measure each type of major escalator items modelled (e.g.	Measure each type of detailed escalator items modelled (e.g. escalator, ancillary components, control, balustrades,

Model Element By UniFormat Classification System*	Model Element Author	Principles of Measurement for Building Works			
		LOD 100 - Conceptual Model	LOD 200 - Approximate Geometry Model	LOD 300 - Precise Geometry Model	LOD 350/400 – Interface Model / Fabrication Model
				escalator, ancillary components, control and balustrades).	cladding to sides and soffits, and builder's works) according to the specified SMM.
Sanitary Appliances	Architect	Measure the number of schematic sanitary appliance models.	Measure approximate quantities of each type of generic sanitary appliance elements modelled.	Measure each type of major sanitary appliance items modelled (e.g. WC pens and cisterns, sinks, basins, baths, shower units and taps, etc.).	Measure each type of detailed sanitary appliance items modelled (e.g. WC pens and cisterns, sinks, basins, baths, shower units, taps, sanitary ancillaries, builder's works, etc.) according to the SMM.
Cold Water System	Building Service Engineer		Measure approximate quantities of schematic layout of generic cold water elements modelled.	Measure major cold water system items modelled (e.g. cold water distribution pipelines to sanitary appliances and equipment, pipe fittings, valves, pumps, pressure booster sets and control components).	Measure detailed cold water items modelled (e.g. cold water distribution pipelines to sanitary appliances and equipment, pipe fittings, valves, pumps, pressure booster sets, water tanks, control components and builder's works) according to the specified SMM.
Hot Water System	Building Service Engineer		Measure approximate quantities of schematic layout of generic hot water elements modelled.	Measure major hot water system items modelled (e.g. hot water distribution pipelines to sanitary appliances and equipment, pipe fittings, valves, pumps, boilers/heaters, storage cylinders, insulation and control components).	Measure detailed hot water items modelled (e.g. hot water distribution pipelines to sanitary appliances and equipment, pipe fittings, valves, pumps, boiler/heaters, storage cylinders, insulation, control components and builder's works) according to the specified SMM.
Flushing Water System	Building Service Engineer		Measure approximate quantities of schematic layout of generic flushing water elements modelled.	Measure major flushing water system items modelled (e.g. flushing water distribution pipelines to sanitary appliances and equipment, pipe fittings, valves, pumps, pressure booster sets and control components).	Measure detailed flushing water items modelled (e.g. flushing water distribution pipelines to sanitary appliances and equipment, pipe fittings, valves, pumps, pressure booster sets, water tanks, control components and builder's works) according to the specified SMM.
Soil, Waste, Ventilation and Rainwater Disposal Systems	Building Service Engineer		Measure approximate quantities of schematic layout of generic soil, waste, ventilation and rainwater disposal elements modelled.	Measure major soil, waste, ventilation and rainwater disposal system items modelled (e.g. soil, waste, ventilation and rainwater pipes, pipe fittings, traps, access points, collars and sump pumps).	Measure detailed soil, waste, ventilation and rainwater disposal items modelled (e.g. soil, waste, ventilation and rainwater pipes, pipe fittings, traps, access points, collars, sump pumps and builder's works) according to the specified SMM.
Heating Systems	Building Service Engineer	Measure the area serviced by the respective system models.	Measure approximate quantities of schematic layout of generic heating elements modelled.	Measure major heating system items modelled (e.g. boiler plant and ancillary equipment, distribution pipelines to heat	Measure detailed heating system items modelled (e.g. boiler plant and ancillary equipment, distribution pipelines to heat emitters or other equipment, pipe fittings,

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		LOD 100 - Conceptual Model	LOD 200 - Approximate Geometry Model	LOD 300 - Precise Geometry Model	LOD 350/400 – Interface Model / Fabrication Model
				emitters or other equipment, pipe fittings, valves, fans and control components).	valves, fans, control components and builder's works) according to the specified SMM.
Cooling Systems	Building Service Engineer		Measure approximate quantities of schematic layout of generic cooling elements modelled.	Measure major cooling system items modelled (e.g. cooling plant and ancillary equipment, distribution pipelines and ductwork, fan coil units, air handling units, pumps, fans, grilles, filters, other ancillary components, insulation and control components).	Measure detailed cooling system items modelled (e.g. cooling plant and ancillary equipment, distribution pipelines and ductwork, fan coil units, air handling units, pumps, fans, grilles, filters, other ancillary components, control components, insulation and builder's works) according to the specified SMM.
Ventilation Systems	Building Service Engineer		Measure approximate quantities of schematic layout of generic ventilation elements modelled.	Measure major ventilation system items modelled (e.g. distribution ductwork, terminal units, fan units, grilles, filters, other ancillary components, insulation, and control components).	Measure detailed ventilation system items modelled (e.g. distribution ductwork, terminal units, fan units, grilles, filters, other ancillary components, insulation, control components and builder's works) according to the specified SMM
Firefighting Systems	Building Service Engineer	Measure the area serviced by the respective system models.	Measure approximate quantities of schematic layout of generic hose reel and dry/wet riser elements modelled.	Measure major firefighting system items modelled (e.g. fire reel and dry/wet riser systems, its distribution pipeline, pipe fittings and ancillaries, pump sets, inlet valves and boxes, outlet/landing valves, and control components and panels).	Measure detailed firefighting system items modelled (e.g. fire reel and dry/wet riser systems, its distribution pipeline, pipe fittings and ancillaries, pump sets, inlet valves and boxes, outlet/landing valves, control components and panels, water tanks and builder's works) according to the specified SMM.
Fire Suppression Systems	Building Service Engineer		Measure approximate quantities of schematic layout of generic sprinkler and gas firefighting elements modelled.	Measure major fire suppression system items modelled (e.g. fire reel and dry/wet riser systems, its distribution pipeline, pipe fittings and ancillaries, pump sets, inlet valves and boxes, outlet/landing valves, and control components and panels).	Measure detailed fire suppression system items modelled (e.g. fire reel and dry/wet riser systems, its distribution pipeline, pipe fittings and ancillaries, pump sets, inlet valves and boxes, outlet/landing valves, control components and panels, and builder's works) according to the specified SMM.
Electrical Systems	Building Service Engineer	Measure the area serviced by the electrical system models.	Measure approximate quantities of schematic layout of generic main and sub-main distribution, power and lighting elements modelled.	Measure major electrical system items modelled (e.g. transformers, switchgears, distribution boards, HV and LV cables, trunking, busbar trunking,	Measure detailed electrical system items modelled (e.g. transformers, switchgears, distribution boards, HV and LV cables, trunking, busbar trunking, conduits, cables, socket outlets, switches,

Model Element By UniFormat Classification System*	Model Element Author	Principles of Measurement for Building Works			
		LOD 100 - Conceptual Model	LOD 200 - Approximate Geometry Model	LOD 300 - Precise Geometry Model	LOD 350/400 – Interface Model / Fabrication Model
				conduits, cables, socket outlets, switches, luminaries and lamps, lighting controls, and earthing and bonding components).	luminaries and lamps, lighting controls, earthing and bonding components, and builder's works) according to the specified SMM.
Communication Systems	Building Service Engineer	Measure the area serviced by the communication system models.	Measure approximate quantities of schematic layout of generic telecommunication, data transmission, public address, fire detection, smoke detection, fire alarm, television and other communication elements modelled.	Measure major communication system items modelled (e.g. individual systems, conduit and wiring, controls, indicator panels and ancillary equipment).	Measure detailed communication system items modelled (e.g. individual systems, conduit and wiring, controls, indicator panels, ancillary equipment and builder's works) according to the specified SMM.
EQUIPMENT AND FURNISHINGS					
Equipment (including vehicle and pedestrian, commercial, institutional, residential, entertainment and recreational and other equipment)	Building Service Engineer	Measure the number of schematic equipment model.	Measure approximate quantities of each type of generic equipment elements modelled.	Measure each type of major equipment items modelled.	Measure each type of detailed equipment items modelled according to the specified SMM.
Furnishings (including fixed and movable furnishings)	Architect	Measure the number of schematic furnishings model.	Measure approximate quantities of each type of generic furnishing elements modelled.	Measure each type of major furnishing items modelled.	Measure each type of detailed furnishing items modelled according to the specified SMM.

Note:

* Other internationally recognised classification system can also be adopted as long as agreeable by all project team members.

Level 1 Estimate at LOD 100

The main purposes of the level 1 estimate are to provide a reliable cost estimate to compare with the employer's budget and also to set cost targets for individual elements so that when the design further progresses, cost targets are checked and modifications are made to the design (where necessary) in order to control the overall cost within the budget.

Level 1 estimate is prepared after the completion of the conceptual design when the detailed scope of works, schedule of accommodations and other key performances are fully defined or agreed. Model elements are based on LOD 100. At this stage, many of the building elements are not yet modelled. Nevertheless, many descriptive data prepared by design consultants provide useful information for preparing the level 1 estimate. Such data may include the project location, site constraints, building stories, space types, structure types, exterior enclosure types, internal walls, stairs, equipment, vertical circulation system, plumbing fixtures, cold, hot and flushing water systems, soil, waste, ventilation and rainwater disposal systems, HVAC systems, fire fighting and suppression systems, electrical system, communication systems, and building performance (sustainability) requirements, etc. The principle of measurement is based the measurement of elemental quantities in terms of the relevant area or number as shown in Table 1. Realising the limitations of a conceptual model, quantity surveyors must ensure that all available (graphical and non-graphical) information which may have an impact on the estimate is taken into consideration.

The pricing of each measured elemental quantity is based on the corresponding elemental unit rate obtained from cost analyses of previously similar projects or benchmark analyses. Level 1 estimate provides the frame of reference for level 2 estimate.

Level 2 Estimate at LOD 200

Level 2 estimate is a progression of the level 1 estimate. The main purposes of the level 2 estimate are to provide a more accurate cost estimate and also to check cost targets set for individual elements/sub-elements in order to control the overall cost within the budget.

Level 2 estimate is prepared after the completion of the schematic design stage. Architectural, structural and building service model elements are based on LOD 200. Model elements are generic and without specific details, but provide useful graphical and non-graphical information for preparing the level 2 estimate. At this stage, a comprehensive range of generic models is available including pile foundations, structural frames and slabs, stairs, exterior walls, windows and doors, louvers and vents, roofing, partitions, interior windows and doors, raised floor, suspended ceiling, wall, floor and ceiling finishes, equipment, lifts and escalators, sanitary appliances, cold, hot and flushing water systems, soil, waste, ventilation and rainwater disposal systems, HVAC systems, fire fighting and suppression systems, electrical system, communication systems and building performance (sustainability) requirements, etc. Since each of model elements at LOD 200 is approximately modelled in terms of quantities, size, and shape, the principle of measurement is based on the measurement of composite items modelled as shown in Table 1.

The pricing for each measured composite item is based on the corresponding composite unit rate by grouping the current market price of several items together or a specific database for composite items at LOD 200. Level 2 estimate provides the frame of reference for level 3 estimate, and also provides a cost check against each cost target established at level 1 estimate. Level 2 estimate may be used for value engineering applications before the completion of specifications and design drawings.

Level 3 Estimate at LOD 300

Level 3 estimate is a progression of the level 2 estimate. The main purpose of the level 3 estimate is to check cost targets of individual elements/sub-elements in order to control the overall budget.

Level 3 estimate is prepared after the completion of the design development stage where technical designs and specifications are available. All model elements are based on LOD 300. Quantity surveyors traditionally measure detailed construction works according to their published standard method of measurement. Since each model element at LOD 300 is accurate in terms of quantity, size and shape, the principle of measurement is measured based on the specified standard method of measurement (SMM) whenever possible. The resulting pricing document comprises a large number of items in each work section/package similar to an (approximate) bills of quantities.

The pricing for each measured item is based on the corresponding unit rate obtained from a database on market prices. Minor items not modelled are ignored in the measurement, but are taken into account by adjusting the unit rate by an appropriate percentage. Level 3 estimate provides a cost check against each cost target established at level 2 estimate.

Level 4 Estimate at LOD 350 / LOD 400

Level 4 estimate is the pre-tender estimate. The main purpose of the level 4 estimate is to provide an accurate preview of the tender figure in order to alert the design team to the possible cost problems and allow them to quickly effect any changes where necessary. However, some quantity surveyors consider that this exercise serves no useful pre-contract cost control purposes, as the whole design have already been completed.

Level 4 estimate is prepared after the completion of the contract documentation stage where all designs, specifications and tender documents are available. For the preparation of bills of quantities, model elements at LOD 300 may or may not be adequate, depending on the particular standard method of measurement used. In some (but not all) elements, the level of model details required may be up to LOD 350 or even LOD 400 so that various interface and fabrication details can also be measured and incorporated in the tender documents. Therefore, the principle of measurement is based on the specified standard method of measurement (SMM). The resulting pricing document is bills of quantities.

The pricing of each measured item is based on the corresponding unit rate obtained from a cost database. Pricing bills of quantities provides the most accurate estimate of the likely tender figure. It can be used to evaluate the reasonableness of returned tenders.

Estimates for Different Procurement Strategies

While the above four levels of estimate are based on its pure form, the same principle is applicable to various procurement strategies. For instance, an architectural model up to LOD 200 is prepared for a design-and-build project. Under such a situation, the generic model can be measured and priced according to the principle as described for the level 2 estimate.

In addition, a particular project may be broken down into various work packages (such as foundation works, precast concrete components, curtain walls, building service installations and other specialist works) which are tendered under different procurement methods and at different project stages. Again, the appropriate work package models can be measured and priced according to the principle as described above.

DISCUSSIONS AND CONCLUSIONS

Quantity surveyors prepare cost plans 1, 2 and 3 based on the measurement and pricing of group elements, elements, sub-elements and components (RICS, 2012), whereas the proposed levels 1, 2 and 3 estimate based on the measurement of LOD 100 sub-elements, LOD 200 generic elements and LOD 300 precise elements respectively provide a more detailed measurement and pricing, thus leading to a more accurate estimate. In addition, quantity surveyors' traditional cost plans heavily rely on the availability of information and there is no explicit information requirement to be exchanged at each design stage. However, based on the proposed framework, the information output for each model element is clearly defined with reference to LODs. This ensures that reliable information is available for preparing the appropriate levels of estimate. Furthermore, when preparing a traditional cost plan, there is no explicit rules for the measurement of detailed items other than simple measurement rules for elements, sub-elements and components (RICS, 2012). In order to ensure a systematic measurement, the proposed framework has incorporated specific measurement principles for each model element at different LODs. This ensures that model elements at different LODs are measured according to specified information contents and measurement rules.

In order to help quantity surveyors capture the benefits of BIM, this study has proposed a BIM-based cost planning framework which comprises four levels of estimate. Each level of estimate aligns with four key parameters; namely, (1) the model elements based on the internationally recognised OmniClass/UniFormat classification system, (2) the output information defined at LOD 100, 200, 300 and 350/400, (3) the project stages such as the conceptual design, schematic design, design development and contract documentation stages, and (4) the principles of measurement formulated according to the specified amount of graphical and non-graphical information at different LODs. For the preparation of each level of estimate, quantity surveyors can systemically extract quantities from individual generic/precise elements/items modelled according to specified measurement principles, thus providing a more accurate estimate. It is expected that the proposed framework would help improve the industry practice in cost planning and also help review the existing standard methods of measurement in alignment with the latest BIM development.

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