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COMPARISON OF BIM-BASED QUANTITIES TAKE-OFF IN QUANTITY SURVEYING PROFESSION

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Abstract

Quantity surveyor (QS) plays an important role in a construction project who is responsible for the construction cost. Quantity take-off (QTO) will be conducted by QS to measure the quantities of materials needed for the construction project followed by the preparation of bills of quantities (BQ). Building information modelling (BIM) was introduced to the construction industry and brings many benefits to the QTO process such as time saving and high accuracy. However, BIM-based QTO consists of numerous issues such as 3D modelling issues, quantities extraction issues and data loss issues. Hence, this research aims to compare and analyse the application of BIM-based QTO in the QS profession. The objectives of this research cover the comparison of BIM-based QTO in BIM software as well as the analysis of quantities extraction which complies with Malaysian Standard Method of Measurement of Building Works Second Edition (SMM2). This research was conducted by using two types of BIM software which are Autodesk Revit and Cubicost TAS. This research is expected to benefit the QS profession by delivering a better understanding of using BIM for QTO with the analysis and comparison of QTO data.

Keywords: Quantity Surveying profession, Building Information Modelling (BIM), Quantity take-off (QTO), Autodesk Revit, Cubicost TAS.

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INTRODUCTION

A construction project consists of many professionals to ensure the project is constructed successfully. Quantity surveyor (QS) is one of the professionals responsible for the construction cost and contractual relationships between various parties of a construction project (Hussin & Omran, 2009). A construction project without a QS might face problems such as tight budget, low quality project and run out of funds before the project is completed (Canadian Institute of Quantity Surveyors, 2021). QS manages and controls the construction project cost by applying expert knowledge to measure the quantities of materials and works required accurately to assist in obtaining the cost for labour, materials and plants required for the construction project (Hussin & Omran, 2009). Quantity take-off (QTO) will be conducted by QS to calculate and measure the quantities of materials needed for the construction project followed by the preparation of bills of quantities (BQ).

In recent years, technology development has brought BIM as a platform for the betterment of the industry's practice (Ali et al., 2018). The BIM model is able to improve the efficiency of a construction project as the information can be shared easily among all the involved parties with the assistance of cloud-based tools and BIM-based QTO software, allowing for automation of calculation which saves time and increases the accuracy of QTO. Furthermore, the current approach of BIM within the Malaysian construction industry is improving and the implementation of BIM is expected to provide accurate calculations since BIM models are more detailed (Omar & Fateh, 2023; Reyes, 2020). The automation of QTO has become increasingly favourable among QS and eventually led to the development of BIM-based QTO software such as Autodesk Revit and Cubicost TAS (Loh, 2018).

QTO is usually done by QS and refers to the calculation for quantities of materials needed for a construction project. Traditional method of QTO is done by manually taking-off the quantities with 2D drawings and QSs are required to review the specifications and scope of work from the drawings and obtain dimensions from the drawings (ProEst, 2021). The process of traditional QTO is very time consuming and error prone because it is based on human interpretation. Alternatively, BIM has been introduced to the construction industry and one of the most useful functions of BIM is it can perform automation QTO through BIM model where the calculations will be done using the element's geometric properties and the quantities in area, volume and length will be provided in text form (Monteiro & Martins, 2013). QTO by using the BIM method brings many benefits such as time saving, more accurate calculations and visualisation (Reyes, 2020). However, the BIM-based QTO faces a few limitations and problems and they differ for each software and building elements. The accuracy of the quantities obtained through automation calculation from the BIM-based QTO software are depending on the quality of the BIM model. The closer the BIM model is to the actual construction, the more accurate the quantities obtained. If the BIM model is incorrect or incomplete, the quantities extracted could be insufficient or excessive depending on the modelling process (Khosakitchalert et al, 2019).

Moreover, the modelling of a designed building does not often achieve 100% accuracy due to challenges and limitations in 3D modelling (Czmoch & Pękala, 2014). During BIM modelling, complex elements may be replaced by simple geometric forms to perform QTO due to absence of corresponding modelling tools, thus the adjustment made for the model will result in not achieving the exact visual representation of the designed building and the modelling tools of some building elements may be absent (Monteiro & Martins, 2012). Furthermore, BIM modelling can be affected by the compound elements which consist of multiple layers of material such as walls, ceilings, floors and roofs (Khosakitchalert et al, 2019). Additionally, software such as Revit which has the feature for QTO but is a BIM design authoring software designed for building modelling, could not handle the interception of some elements such as interceptions between beams and columns (Tanko et al., 2019). Besides that, it is not possible to extract all the essential quantities as there are still issues such as lack of details from the model where up to 50% of data for QTO are absent (Vassen, 2021; Olsen & Taylor, 2017).

The limitations and accuracy of QTO by BIM model differs for each software and BIM users are unaware about the workflow of BIM-based QTO (Ngo, 2018). Thus, this research is to conduct a case study to gain in-depth understanding of BIM-based QTO software in the QS profession. Due to lack of research between Autodesk Revit and Cubicost TAS, the case study will be conducted by developing BIM models in both software, followed up by analysing and comparing the quantities extracted from the models based on SMM2.

LITERATURE REVIEW

Building information modelling (BIM) is a digital tool that can create a model of a building of a construction project digitally which consists of relevant data and precise geometry that can be used for the entire building life cycle for the planning of project, design, construction, operation and maintenance (Azhar, 2011). BIM is more than a 3D model, it has been progressively extending in the last few years and established seven dimensions of BIM from 3D to 7D (Simeone et al., 2013; Mesaros et al.,2019). BIM is able to reduce up to 7% of the construction project duration and the design and documentation of a construction project can be done concurrently which reduces up to 80% of the time taken when performing cost estimation (Latiffi et al., 2013; Memon et al., 2014; Hashim et al., 2021) Moreover, it can also increase the quality of the construction project in terms of design and documentation by providing better visualisation of the project. The information of the construction project can be obtained by involved parties from a BIM model which reduces the information loss when sharing with other parties. BIM also reduces errors such as mistakes during the design or construction stage can be identified with functions like clash detection which are ab le to save up to 10% of the contract value. It also provides functions like generating accurate quantification which reduces human errors during QTO and produces cost estimation with 3% accuracy.

Quantity take-off (QTO) is an important task which is normally conducted by QS to measure the quantities of materials required for a construction project for preparation of BQ, cost estimation and cost planning (Pratoom & Tangwiboonpanich, 2016). In Malaysia, the QTO will be done following the standard method of measurement (SMM) in order to produce an appropriate and standardised BQ (Akbar et al., 2015). BIM QTO is a process where the quantities like area, volume, length and number can be extracted from the BIM model automatically from software that supports BIM QTO function (Liu et al., 2016). According to Vassen (2021) BIM QTO can automatically generate quantities and BQ which can eliminate the long and error prone traditional QTO method and reduce human errors (Hashim et al., 2021).

Limitations in BIM Model Development

A BIM model characterises the geometry, quantities and properties of building elements which enable the extraction of quantities and properties of materials (Azhar, 2011). However, there are several limitations and constraints when developing a BIM model.

People Limitation

A BIM model can be built by construction players involved in a construction project such as architect and QS and the modelling style of each modeller are different, thus the information contained in the BIM model may be difficult to extract or lack of information for other construction players (Xu et al., 2019). In the current industry, QS builds the BIM model based on the architects' CAD drawings along with construction information for QTO and cost estimating purposes and eventually convert it to a as-built 3D model at the later stage. Moreover, construction players such as QS are used to current measurement approaches and are unfamiliar with new tools like BIM. Thus, problems like a lack of support systems, lack of communication and mutual understanding among the construction players might result in incorrect interpretation and lead to incorrect or inefficient information extraction (Soon et al., 2019).

Software Limitation

Software limitations are the most important limitations in BIM implementation. Some BIM software could not handle large amounts of data and there is lack of AEC experts with knowledge and experience in creating software suitable for all construction professionals' task and responsibility. Vassen (2021) stated that BIM modelling is still unable to reach users' expectations and satisfaction as the BIM software's adaptability for varied design settings is still insufficient and unable to provide all expected information and data. Moreover, BIM-based QTO is dependent on the BIM model developed, thus items that are not included in the BIM models are unable to be quantified. Additionally, Tanko et al. (2019) stated that software such as Autodesk Revit is a BIM design authoring software with QTO feature that is mainly for designing with BIM modelling, thus it could not manage the interceptions of some building elements such as beams and columns.

One of the significant issues with BIM modelling is managing compound elements (Monteiro & Martins, 2012). Compound element is a building element with multiple layers such as walls, floors, roofs and ceilings and usually, the layers are core structure layer(s) and finishing layer(s) (Khosakitchalert et al., 2019). During BIM modelling, the compound elements like walls and floors will be modelled as a single element in most of the BIM software and it will lead to inaccurate or excessive quantities extraction as each layer of compound elements may not have the same dimension and quantities (Monteiro & Martins, 2012). Khosakitchalert et al. (2019) also stated that modelled walls may overlap with the structural columns and beams and the overlapped parts will lead to a surplus of wall quantities.

During BIM modelling for QTO, some building elements lack graphical expression due to their inexpressive physical scale or geometrical complexity (Vieira et al., 2022). Monteiro & Martins (2012) highlighted that building elements with complex geometry can be modelled in a simpler geometric form for QTO purposes as they lack corresponding modelling tools but the replacement of geometries will cause the BIM model to fail in achieving the exact visual representation of the proposed building. Godinho et al. (2020) also stated the application of automatic tools for extraction of parametric surface and data conversion of irregular geometry is not favourable. Moreover, in order to obtain the parameterisation while preventing heavy files which will affect the BIM model usability, some geometry of elements will be simplified.

Limitations in BIM Quantities Extractions

The quantities extraction will be limited by the BIM model greatly such as the overlapping of compound elements which causes excessive quantities extracted and inadequate BIM model created by inexperienced modellers resulting in inaccurate quantities extractions. Monteiro & Martins (2012) mentioned that BIM model created with minimal budget will disregard many details of the building elements and result in irrelevant or affect the take-off parameterisation such as the majority of BIM software unable to differentiate between the window, doors or curtain walls' glass and frame and consequence in the capability to extract the quantities of opening only which compromise the quantities.

Furthermore, it is impossible to generate all the materials quantities from the BIM model as elements that are absent in the BIM model could not be quantified such as formwork, excavation and rebar, thus BIM-based QTO will still depends on manual quantities extraction to complete the QTO process for all essential quantities (Monteiro & Martins, 2013; Vieira et al., 2022). However, this limitation in BIM quantities extraction differs according to the BIM software. As stated by Monteiro & Martins (2012), the quantity extraction is limited by the parameters provided by the software to configure the measurement and quantities of each building element which means the measurement of elements through BIM-based QTO will be done according to predefined ways. Moreover, a model with high LOD is able to provide more precise quantities, there are still some activities that are required to be quantified and specified that are unable to be represented geometrically (Vieira et al., 2022).

RESEARCH METHODOLOGY

This research will concentrate on a case study, incorporating the implementation of desk analysis. Case study is a type of qualitative research that explores a phenomenon by using different sources of data and ensures multiple details of the phenomenon can be revealed and understood (Baxter & Jack, 2008). In this case study, a double storey semi-detached house project with 334m2 of gross floor area (GFA) located in Selangor is selected. BIM models will be developed by using the project’s contract document with two BIM software which are Autodesk Revit 2022 and Cubicost TAS C-III for analysis and comparison purposes. Desk analysis is carried out by utilising a laptop or desktop. Desk analysis relies on data collected from prior research or existing sources which is then filtered, analysed and summarised with the purpose of achieving a better understanding of the topic (Juneja, 2022, Villegas, 2023). The modelling process in Autodesk Revit 2022 and Cubicost TAS C-III will involve only architectural and structural elements, excluding reinforcement work. The BIM models in this study will be developed by using Autodesk Revit 2022 and Cubicost TAS C-III. The BIM model developed will be based on the drawings obtained for a double storey semi-detached house located at Selangor, Malaysia. In Autodesk Revit, architectural and structural elements will be developed in separate templates, and these templates will later be combined into a unified BIM model within the Autodesk Revit software. In contrast, Cubicost TAS has the capability to model both architectural and structural elements within a single BIM model. Subsequently, QTO will be carried out using Autodesk Revit's schedule function and Cubicost TAS's calculate and view quantities by category function to generate quantities for their respective BIM models. In Malaysia, quantities will be measured in accordance with the Malaysian Standard Method of Measurement of Building Works Second Edition (SMM2) to generate standardised BQ (Akbar et al., 2015). Therefore, all extracted quantities will adhere to the unit of measurement specified in SMM2. Comparison between the quantities extracted from the BIM models by using Autodesk Revit and Cubicost TAS will be calculated through the following formula Eq. (1).

$$\frac{\text{Revit QTY} - \text{TAS QTY}}{\text{TAS QTY}} \times 100\% \qquad (1)$$

DATA ANALYSIS

This chapter primarily focuses on comparing the quantities of architectural and structural elements in Autodesk Revit and Cubicost TAS. It explores into the comparison of various elements such as walls, finishes, footings, columns, beams, slabs, and more. The discussion will extend to addressing data loss in the BIM model after conducting a thorough comparison of Quantity Takeoff (QTO) between the both software applications.

Architectural Elements

Table 1 shows the quantities comparison between Autodesk Revit and Cubicost TAS for external walls and internal walls. The quantity of walls in area for both software applications has a big difference up to 48.87%. This is because the QTO of walls in Autodesk Revit did not deduct the columns and beams and lead to excessive quantities. Khosakitchalert et al. (2019) also stated that the walls may overlap with the columns and beams and lead to surplus of wall quantities. The results of the quantities of walls after linking and binding the architectural and structural models in Autodesk Revit remain the same where the walls still overlapped with the columns and beams as shown in Figure 1. Moreover, the quantities of concrete in stiffeners and RC coping and fin obtained by each software have no difference but Autodesk Revit is unable to obtain the quantities of formwork.

Table 1: External and Internal Walls Quantities Comparison between Revit and TAS

Elements	Unit	Revit Qty	TAS Qty	Difference
External Walls				
Half brick wall (70mm thick) as box up wall	m2	3.17	3.29	-3.65%
Half brick wall (100mm thick)	m2	278.81	187.28	48.87%
Half brick wall (100mm thick) as party wall	m2	15.23	15.14	0.59%
One brick wall (230mm thick)	m2	72.45	59.15	22.49%
One brick wall (230mm thick) as party wall	m2	11.72	9.92	18.15%
Internal Walls				
Half brick wall (70mm thick) as box up wall	m2	18.06	17.89	0.95%

Elements	Unit	Revit Qty	TAS Qty	Difference
Half brick wall (100mm thick)	m2	281.91	224.98	25.30%
One brick wall (230mm thick) as party wall	m2	37.35	30.65	21.86%

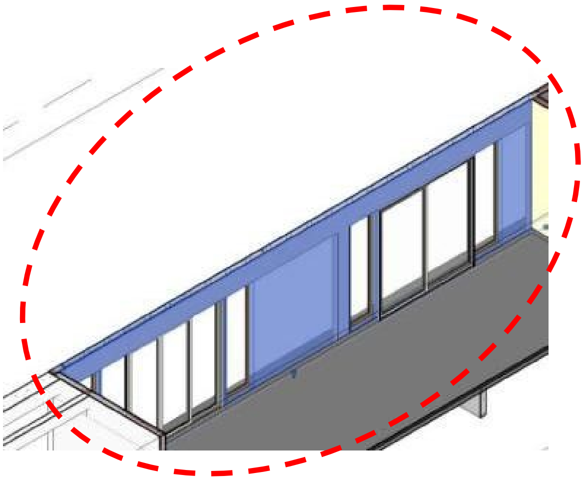

Figure 1: Wall Overlapped with Columns and Beam in Revit

Table 2: Floor Finishes Quantities Comparison between Revit and TAS

Elements	Unit	Revit Qty	TAS Qty	Difference
<u>External Floor Finishes</u>				
Cement and sand (1:6) paving	m2	21.57	21.40	0.79%
Stamped concrete with shanghai plaster border; to floors	m2	42.10	41.87	0.55%
Homogeneous tiles; to floors	m2	31.24	30.49	2.46%
Homogeneous tiles; to skirtings 100mm high	m	17.02	17.26	-1.96%
Shanghai Plaster; to floors	m2	40.39	39.33	2.70%
Ceramic tiles; to drops 100mm high	m	1.00	1.00	0.00%
Porcelain tiles; to drops 100mm high	m	7.30	7.30	0.00%
<u>Internal Floor Finishes</u>				
Ceramic tiles; to floors	m2	39.83	39.03	2.05%
Porcelain tiles; to floors	m2	137.37	133.93	2.57%
Porcelain tiles; to drops 50mm high	m	1.00	1.00	0.00%
Porcelain tiles; to skirtings 100mm high	m	46.65	40.87	14.14%

Elements	Unit	Revit Qty	TAS Qty	Difference
Timber strips; to floors	m2	120.33	117.31	2.57%
Timber strips; to skirtings 100mm high	m	95.78	94.39	1.47%

Table 2 shows the quantities comparison between Autodesk Revit and Cubicost TAS for external floor finishes and internal floor finishes. The floor finishes quantities to floors between both software are similar with a maximum of only 2.70% difference. Cubicost TAS has slightly lesser quantities compared to Autodesk Revit due to the modelling of wall thickness in Cubicost TAS included the thickness of cement plaster and paint and lead to the "Room" function applied the floor finishes to floors within the sides of cement plaster and paint instead of the side of the walls. The floor finishes to drops in both software are the same where the modelling of drops using "Wall: Architecture" in Autodesk Revit has the same result as "Vertical Floor Finish" in Cubicost TAS. However, the internal floor finishes to skirtings in Autodesk Revit have greater quantities compared to Cubicost TAS because the skirtings modelled with "Wall Sweep" overlapped with sliding doors as shown in Figure 2. Hence, QS should revise the model to in Autodesk Revit to it to ensure accurate skirting quantities.

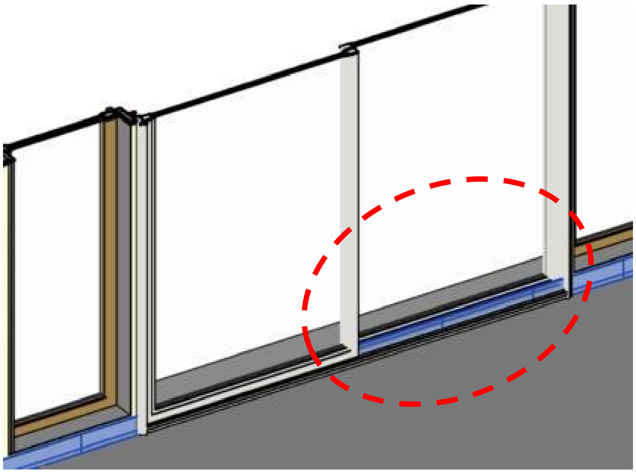
Figure 2: Wall Overlapped with Columns and Beam in Revit

Table 3: Ceiling Finishes Quantities Comparison between Revit and TAS

Elements	Unit	Revit Qty	TAS Qty	Difference
External Ceiling Finishes				
Skim coat to concrete soffits and sides and soffits of beams	m2	11.61	11.28	2.93%
Plaster board with weather shield paint	m2	12.37	12.37	0.00%
Moisture resistant plaster board with weather shield paint	m2	25.71	22.58	13.86%
Internal Ceiling Finishes				
Plaster board with emulsion paint	m2	234.94	226.63	3.67%
Moisture resistant plaster board with emulsion paint	m2	54.72	55.25	-0.96%

Table 3 above shows the quantities comparison between Autodesk Revit and Cubicost TAS for ceiling finishes. The ceiling finishes obtained between Autodesk Revit and Cubicost TAS have slight differences as 2.93% and 3.67% which are acceptable. The “Automatic Ceiling” function in Autodesk Revit and “Room” function in Cubicost TAS results in similar quantities. However, the calculation of suspended ceiling in Autodesk Revit did not deduct the beams that overlapped with the suspended ceiling and ended up with excessive quantity with 13.86% of difference from Cubicost TAS. Lastly, the quantities of windows and doors obtained in number from Autodesk Revit and Cubicost TAS are the same. Autodesk Revit and Cubicost TAS are able to count the windows and doors modelled accurately. The QTO for roof covering and roof gutter for both types of software have no difference as the area of roof covering obtained from Autodesk Revit and Cubicost TAS is reliable if the modelling steps are appropriate. The modelling of roof gutter in Cubicost TAS with “Custom Line” able to obtain the same length as Autodesk Revit. Furthermore, majority of quantities for staircase structure and staircase finishes are unable to be obtained or are inaccurate in Autodesk Revit but is accurate in Cubicost TAS. However, the length of handrailing can be obtained in both software but Cubicost TAS obtained a shorter length due to the staircase modelled is not continuous and led to breaking of railing and resulted in a gap.

Structural Elements

Autodesk Revit is unable to model the excavation, thus it is also unable to generate quantities for excavation while Cubicost TAS has the tool to model the excavation and QTO. However, the QTO for filling of hardcore for both software is the same as the sketching of boundary lines of the ground slabs including hardcore layer in Autodesk Revit which has the same measurement and calculation method as Cubicost TAS.

Table 4: Pad Footing and Column Quantities Comparison between Revit and TAS

Elements	Unit	Revit Qty	TAS Qty	Difference
Lean Concrete	m3	3.29	3.29	0.00%
Grade 25 reinforced in-situ concrete	m3	24.34	24.34	0.00%
Formwork; <0.25m high	m	-	13.80	-
Formwork; 0.25m – 0.50m high	m	-	113.30	-
Grade 25 reinforced in-situ concrete in column stumps	m3	1.53	1.55	-1.29%
Grade 25 reinforced in-situ concrete in columns	m3	6.46	6.61	-2.27%
Formwork to sides of column stumps	m2	-	19.94	-
Formwork to sides of columns	m2	-	122.18	-

Table 4 above shows the quantities comparison of pad footings between Autodesk Revit and Cubicost TAS. The quantities of lean concrete blinding and RC concrete of Autodesk Revit and Cubicost TAS are the same with 0.00% difference. The modelling of pad footings in Autodesk Revit is only able to obtain the volume of RC concrete but not the length of formwork. However, modelling of pad footings with Cubicost TAS can generate quantities for both RC concrete's volume and formwork's length. Vassen (2021) also mentioned that the quantity of formwork is usually unable to be obtained from the BIM model. The volume of RC concrete obtained for column stumps and columns for both types of software are more or less similar but the volume obtained from Autodesk Revit are lesser than Cubciost TAS. The quantities of formwork for column stumps and columns are unable to be obtained from Autodesk Revit but is accurate in Cubicost TAS.

Table 5: Beams Quantities Comparison between Revit and TAS

Elements	Unit	Revit Qty	TAS Qty	Difference
Lean concrete	m3	1.20	1.25	-4.00%
Grade 25 reinforced in-situ concrete in ground beam	m3	14.34	14.35	-0.07%
Grade 25 reinforced in-situ concrete in upper floor beam	m3	16.09	16.11	-0.12%
Grade 25 reinforced in-situ concrete in roof beam	m3	10.46	10.50	-0.38%
Formwork to ground beam 0.25m – 0.50m height	m	-	42.60	-

Elements	Unit	Revit Qty	TAS Qty	Difference
Formwork to ground beam 0.50m – 1.00m height	m	-	247.35	-
Formwork to upper floor beam	m2	-	211.67	-
Formwork to roof beam	m2	-	178.12	-

Table 5 shows the quantities comparison of beams between Autodesk Revit and Cubicost TAS. The quantity of lean concrete for ground beam in Cubicost TAS is 4% or 0.05m3 more than Autodesk Revit because the lean concrete in Cubicost TAS did not deduct the volume where it intersected with the column stumps. However, the quantities of RC concrete for beams in both software are similar as the calculation method is the same by taking net length x width x height of the beams where net length is the length that has deducted the column stumps and columns, the height of ground beam is the height without deducting the thickness of ground slab, while the height of upper floor beam and roof beam is the height that has deducted the thickness suspended slab. The quantities of formwork for beams are unable to be obtained from Autodesk Revit but is accurate in Cubicost TAS.

Table 6: Slabs Quantities Comparison between Revit and TAS

Elements	Unit	Revit Qty	TAS Qty	Difference
Mass Concrete	m3	1.00	1.03	-2.91%
Grade 25 reinforced in-situ concrete in ground slab	m3	22.01	21.98	0.14%
Grade 25 reinforced in-situ concrete in upper floor slab	m3	23.64	23.53	0.47%
Grade 25 reinforced in-situ concrete in roof slab	m3	12.42	12.09	2.73%
Grade 25 reinforced in-situ concrete in roof kerb	m3	0.07	0.07	0.00%
Formwork to edge of ground slab	m	-	38.43	-
Formwork to soffit of upper floor slab <3.50m high	m2	-	114.19	-
Formwork to soffit of upper floor slab 3.50m – 5.00m high	m2	-	34.01	-
Formwork to edge of upper floor slab	m	-	4.38	-
Formwork to soffit of roof slab <3.50m high	m2	-	50.38	-
Formwork to roof kerb	m2	-	1.30	-
0.25mm thick polythene sheet	m2	220.07	220.07	0.00%

Table 6 shows the quantities comparison of slabs between Autodesk Revit and Cubicost TAS. The quantities of concrete for slabs in both software are similar with a difference not more than 0.11m3 except for the quantity of RC concrete in roof slab. The volume of RC concrete for roof slab in Autodesk Revit is higher than Cubicost TAS due to the incapability to model the desired edge of slab and lead to greater quantity. The quantities of formwork for slabs are unable to be obtained from Autodesk Revit but is accurate in Cubicost TAS. The quantity of waterproofing in m2 for both software is the same as the sketching of boundary lines of the ground slabs including waterproofing layer in Autodesk Revit has the same measurement method as Cubicost TAS.

CONCLUSION

Through this study, the BIM models are developed successfully and the comparison of QTO and limitations in modelling are analysed. It is found that the modelling process, methods and modelling experience for each BIM software are different. Some modellers' limitations in the BIM modelling can be addressed through manual checks. Hence, it is essential to manually verify the connection of elements to ensure they are correctly joined. The QTO results differ depending on the BIM software used. Certain quantities, such as formwork and excavation, are challenging to obtain in Autodesk Revit. The QTO of walls in Autodesk Revit did not deduct the columns and beams and lead to excessive quantities. However, Autodesk Revit, being a unified software covering Architectural, Structural, Civil, MEP, etc., is convenient and offers better visualisation of BIM models. In contrast, Cubicost TAS stands out in QTO as it offers more precise modelling tools for various elements.

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