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Building Information Modeling-Based Approach for Automatic Quantity Take-off and Cost Estimation

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***Abstract*—**Architectural, engineering, construction and operations (AECO) industry practitioners have been well adapting to the dynamic construction market from the fundamental training of its disciplines. As further triggered by the pandemic since 2019, great steps are taken in virtual environment and the best collaboration is strived with project teams without boundaries. With adoption of Building Information Modeling-based approach and qualitative analysis, this paper is to review quantity take-off (QTO) and cost estimation process through modeling techniques in liaison with suppliers, fabricators, subcontractors, contractors, designers, consultants and services providers in the construction industry value chain for automatic project cost budgeting, project cost control and cost evaluation on design options of in-situ reinforced-concrete construction and Modular Integrated Construction (MiC) at design stage, variation of works and cash flow/spending analysis at construction stage as far as practicable, with a view to sharing the findings for enhancing mutual trust and co-operation among AECO industry practitioners. It is to foster development through a common prototype of design and build project delivery method in NEC4 Engineering and Construction Contract (ECC) Options A and C.

***Keywords*—**Building Information Modeling, cost estimation, quantity take-off, modeling techniques.

I. Introduction

AECO industry has been transformed into a more digital project lifecycle environment which is further triggered by the pandemic since 2019. The supply chain of construction industry activities is increasingly dynamic over the globe in a virtual process with social distancing restriction.

Building Information Modeling (BIM) is a core technology driven by various government policies and widely adopted by the government authorities: Hong Kong [1], Australia, Canada, China, Denmark, Hong Kong, United Kingdom, United States, etc. [2]; professional institutes: buildingSMART International (bSI), the Hong Kong Institute of Building Information Modelling (HKIBIM), Hong Kong Institute of Civil and Building Information Management (HKICBIM), etc.; academia and private developers.

II. Design and Build

In New Engineering Contract NEC4 ECC Options A and C based on activity schedule, the Client wishes to have a single point responsibility with a Contractor undertaking the design and construction of the works.

The works include in-situ reinforced-concrete construction, design, fabrication and installation of MiC modules and/or Design for Manufacture and Assembly (DfMA) off-site.

Project Manager is usually undertaken by its delegates including architect, engineer and cost manager/quantity surveyor.

The Contractor is usually led by key persons, for example, designers, construction manager, quantity surveyor (QS) and modular construction coordinator who have been well adapting to the changing construction market from the fundamental training of its disciplines. The Contractor is responsible for provision of BIM models under NEC4 ECC Secondary Option Clauses X10 Information modelling and X15 The Contractor's design [3] throughout the contract including delivery of the clash free MiC modules off-site [13] and its detailed integration of the structure on-site designed and built to high level of accuracy.

For NEC4 ECC Option A - Priced contract with activity schedule, the Contractor is entitled to be paid for completed activities. While Option C - Target contract with activity schedule is a cost-plus contract subject to a pain/gain share mechanism by reference to an agreed target cost built up from the activity schedule [4]. Contractors are also incentivized under both options.

AECO multi-disciplinary project team collaborates with each other via BIM models under design and build approach in NEC4 ECC [12].

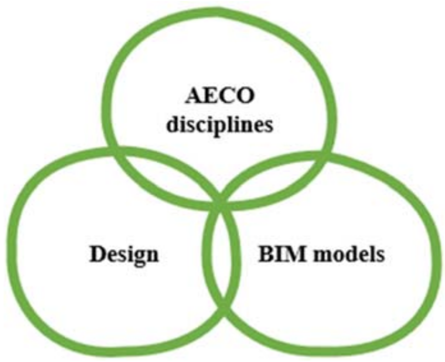

Fig. 1 Design and build collaboration

2D design drawings are inevitably provided in the Client's requirements to facilitate the Contractor's proposal submission for design and build projects delivery. 3D BIM models are prepared from the drawings for QTO (measurement of

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quantities) and cost estimation in connection with the design stated in the Client's requirements and the Contractor's design.

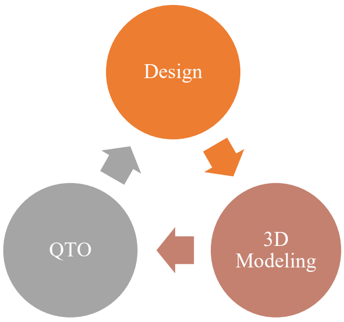


Fig. 2 2D-3D-QTO

III. Workflow of QTO and Cost Estimation

As developed from the traditional computer-aided design (CAD) system, BIM is a digital representation of a civil/ building 3D modeling technique with models generated to simulate the planning, design, construction and operation of projects and assets.

High-level measures are recommended for digitalization in construction to drive horizontal (across disciplines), vertical (across project and asset phases) and longitudinal (across projects and assets) integration in projects and organizations [5].

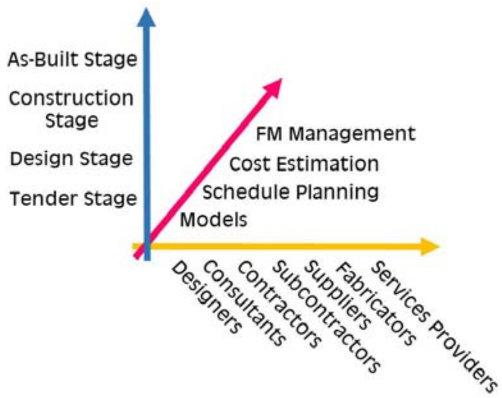


Fig. 3 Relationship of project participants and work stage to cost estimation [5]

Autodesk Revit with built-in Dynamo is the prevailing *de facto* BIM platform in compliance with Industry Foundation Class (IFC) in an openBIM process which can be defined as shareable project information that supports seamless collaboration for project participants including suppliers, fabricators, subcontractors, contractors, designers, consultants and services providers in the construction industry value chain, and facilitates interoperability to benefit projects and assets throughout their lifecycle [6].

openBIM enhances collaboration among different project parties for very effective communication throughout the project lifecycle in particular during pandemic by adhering to international standards [6], for example, ISO 19650 and commonly defined work processes [14]-[17]; facilitates a common data environment (CDE) that provides opportunities for users to develop new workflows, software applications and technology automation. It enables an accessible digital twin which provides the core foundation to a long-term data strategy for built assets [6].

Workflow from the scope including drawings of the pricing document in the Client's requirements to the Contractor's proposal for Revit setup, modeling and information output automation is illustrated in Fig. 4.

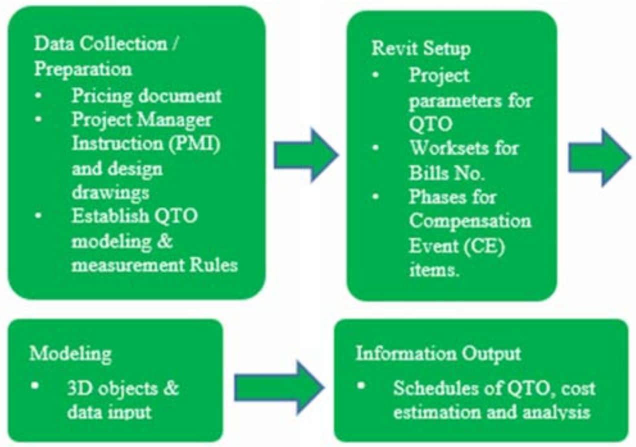


Fig. 4 Workflow of automatic QTO and cost estimation

IV. BIM Approach for QTO

In establishing the workflow of QTO model, a critical step is to create a guideline for 5D BIM model, which is 3D model plus time (4D) and cost (5D) information, determines the rules, modeling techniques and output on whether the data are sufficiently obtained, extracted and calculated. It affects the decision of choosing the best modification tool to create 3D elements concerning the upward application of planning, cost estimation, valuation, control, budgeting and advice.

The primary task is to create a framework of a 5D model, guidelines and rules from the standard method of measurement applied to tender pricing document. It is guided not only to determine and adjust the approaches modification of model setting, but also to ensure generating the correct information output.

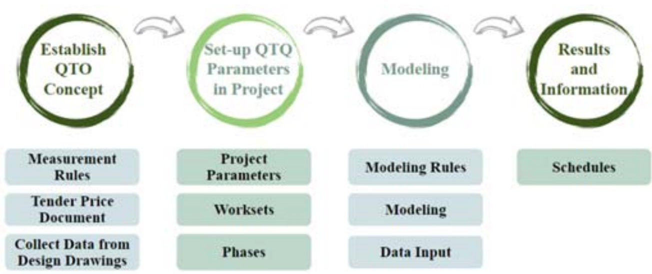


Fig. 5 Workflow of QTO model

For the traditional 5D model workflow: Design → BIM → QS, a lot of data cannot be suitably filtered for extraction from

BIM models because the QS concept of measurement has not been setup in the models. The usefulness of such BIM information is low and hence much time is required for amendments.

Apart from the traditional guides and standards of 3D models for revealing design problems and providing advice, 5D models require the information to meet the needs of QTO use. It is thus important for QS to use BIM QTO at the early stage of project for maximizing its benefit. The 5D model workflow should be Design → QS → BIM → QS.

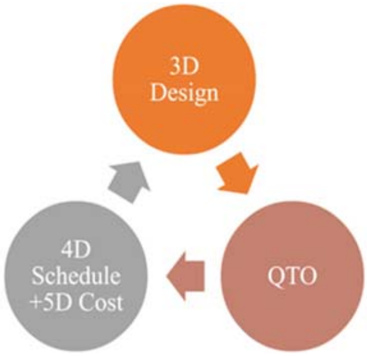


Fig. 6 Concept of QTO model

The concept of QTO should be familiar with creation of different elements as it will affect the units shown or not from the elements which can be read and extracted with output fit the needs to process further steps.

Modeling techniques are various among AECO disciplines and depend on the pricing items description for establishing modeling rules. Modeling should be prepared from design drawings together with tender pricing document. Its analysis helps creation of QTO model which has to be well understood for preparation in accordance with the standard method of measurement. QTO model with price would be automated upon design changes.

Modeling increases the speed of QTO/measurement process in particular design and build projects, for example, the same unit rate priced by the Contractor for different elements of column and corbel would simplify formwork cost estimation without adjustments at the interfaces. The Contractor may consider pricing same items differently at different zones or locations to suit subcontracting and/or timing of works. Location and zone ID would be added to model parameters. QTO models also help double-check drawings and bills and determine if there is allowance for provisional items.

In addition to the values generated from BIM-based software basic functions, the shared parameters listing the QTO main parameters and the unit format have to be setup precisely in projects.

The built-in 3D dimensions' values by Revit include length, area and volume. The QTO parameters need to be categorized and put into the model project properties.

Fig. 7 Essential QTO parameters setting

Using schedules and add-in programme software can filter, extract and record the information output from the model elements. General and costing information groups are essential QTO parameters for all models. The rest of other parameters should be filtered to suit different disciplines, and quantification including piling works is usually set out for site and underground utilities models.

The unit of the QTO parameters corresponds to the type of parameters in Revit. The unit format has to be set whether it is a digital, text, yes/no options, etc. for the parameters. For instance, it can be input $1000 as a text in unit price, however, the result in schedule cannot be calculated since it is not a countable number.

The sensitive pricing information of the models would be kept confidential. Workset is a work sharing concept among teams and the collection of elements in the project [7]. It is usually used as separating the functional zoning for collaboration and visibility while working for each system clearly.

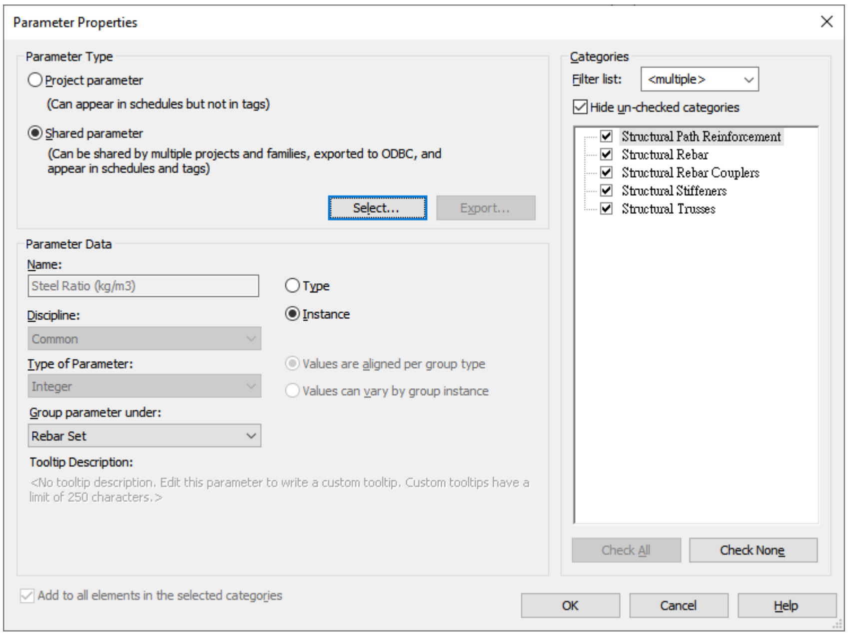


Fig. 8 Edit QTO parameter properties

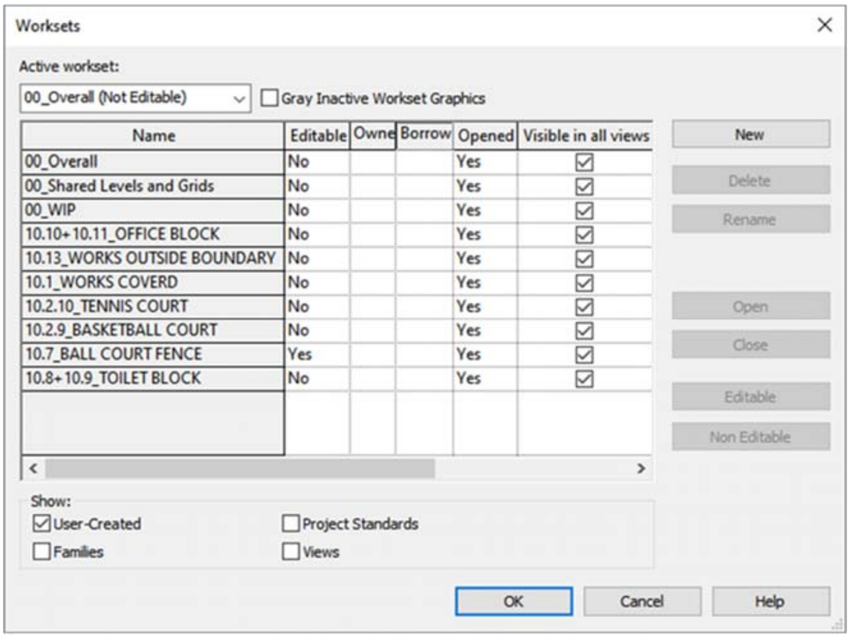


Fig. 9 Worksets for zones

In the QTO model, worksets are to apply the separate zones or areas by the clauses shown in the pricing document containing elements with multiple systems and different levels for cost estimation. The detailed levels and locations can be clearly filtered and shown in parameters at the schedule. It is also to create worksets if there are specific conditions needed to apply, for example, outside boundary elements, preliminaries items, provisional items, site clearance items, etc., and to ensure that the list of worksets is concise.

Although creating workset is usually the first come-up suitable option to distinguish newly designed items from archived items, phasing in Revit is a preferred option to record the compensation events (CE)/variation elements.

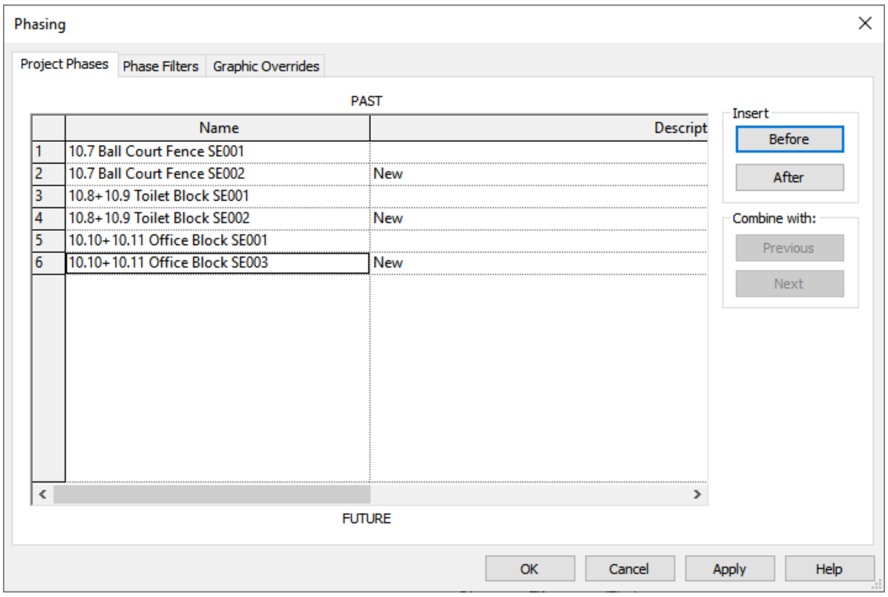


Fig. 10 Phasing

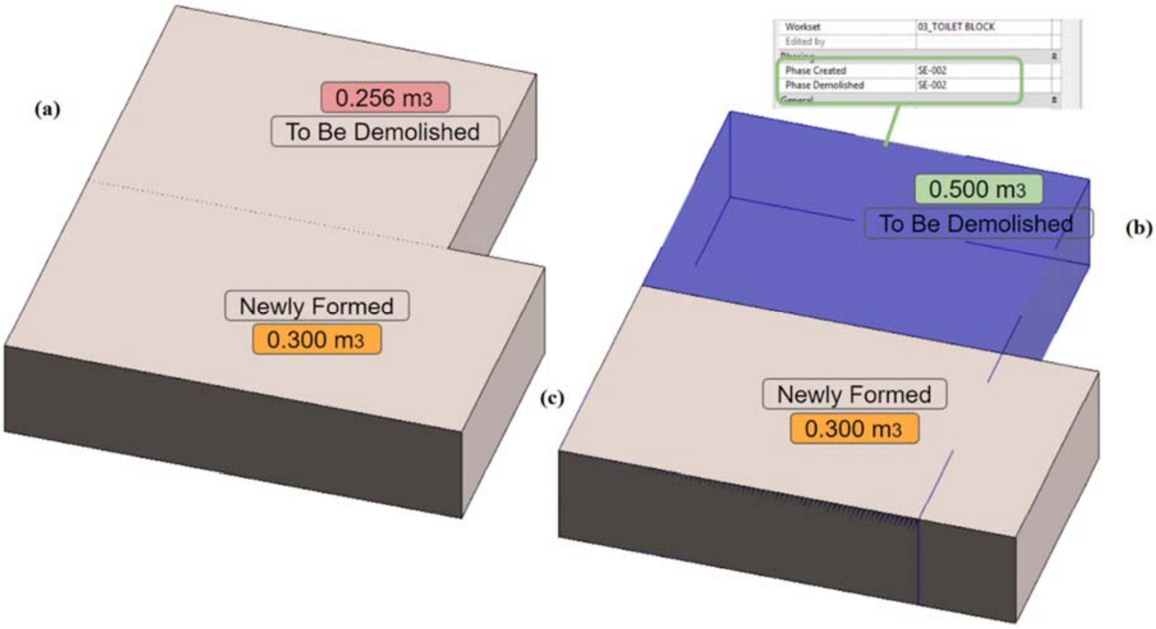


Fig. 11 Portions (a) and (c) applied elements in Workset while (b) and (c) applied in Phasing. Portion (a) demolished element would interfere with the newly designed items of which the volume was deducted from (b) 0.500 m3 to (a) 0.256 m3 resulting in false data in the schedule

Phasing in Revit is to determine the phases of work and show a specific period of work stage [8]. By applying the concept of workset to CE, it can only distinguish the new items from demolished items but cannot deal with the geometry interference issue, of which phasing can perfectly solve. While determining the demolished items as the previous Project Manager Instruction (PMI) design, the items are set as to be demolished, and its geometry will not interfere with the geometry of newly designed items.

It is more reliable than using a workset to unjoin the demolished items before creating new items noting that there is a high risk of false geometry information occurring in both CE calculations above.

Phasing includes timeline, visibility and the individual CE schedule for both newly designed items and demolished items. Taking these advantages, phasing is a desirable approach to modify the CE items changes.

Beware of the unit format set for the parameters, usually used three decimal places in Revit, and taken two decimal places in schedule for QTO, the three decimal places would result in a significant difference in the final calculation. Choosing instance parameter is preferable to type parameter since even the same types of Revit family would have different description or unit price while its location or level is different. There are two approaches mostly used to finish these settings, importing shared parameters with an edited Excel file and text file, or pouring all grouped parameters by Dynamo script into project parameters which is the fastest way.

V. Modeling

For the concept on Level of Information Need (LOIN) [9] at design stage and construction stage, the Level of Graphics (LOD-G) is usually higher than Level of Information (LOD-I).

In QTO model, LOD-I and LOD-G depend on the tender pricing document at all stages. It determines how detailed should the model element be created, any parts affected by the price, the description mentioned in the pricing document and the adjacent element geometry interference, models parameters' values should completely reflect the calculation and be editable to the quantities while the description of the items changed. The difference in quantity multiplying unit rates upon design changes would be automated accordingly. The QTO model is more efficient and flexible than the standard one. For some cases, LOD-G is less demanding than LOD-I in the QTO model, especially when it counts the items in numbers.

The joining elements sequence directly affects the values while modeling the elements with interface condition. Based on the standard method of measurement calculation method [10], it is the most considerable part in the QTO modeling method.

A. Precise QTO Information

Revit has built-in 3D dimensions creating irregular shapes of walls but there is no length and volume shown in properties. Schedule or Dynamo is used to get the data from the elements while the wall should be able to host the rebar, the option that selecting wall categories under generic model would be the preferred choice, it is still be categorized in wall category and can be calculated the volume at the same time. The units of the activity items are considered first followed by the appropriate modeling method chosen to obtain the information needed. The first priority is to follow the BIM standard modeling approach, and the second is to decide the categories which can help the function and generate the data it suits.

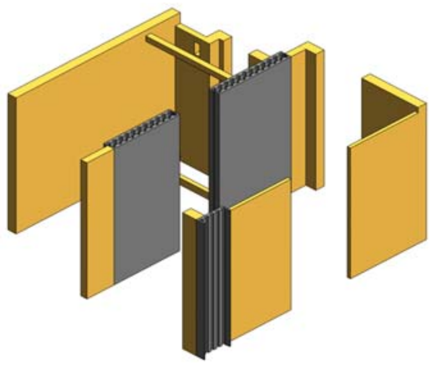


Fig. 12 Taking the irregular element volume in MiC composite concrete wall

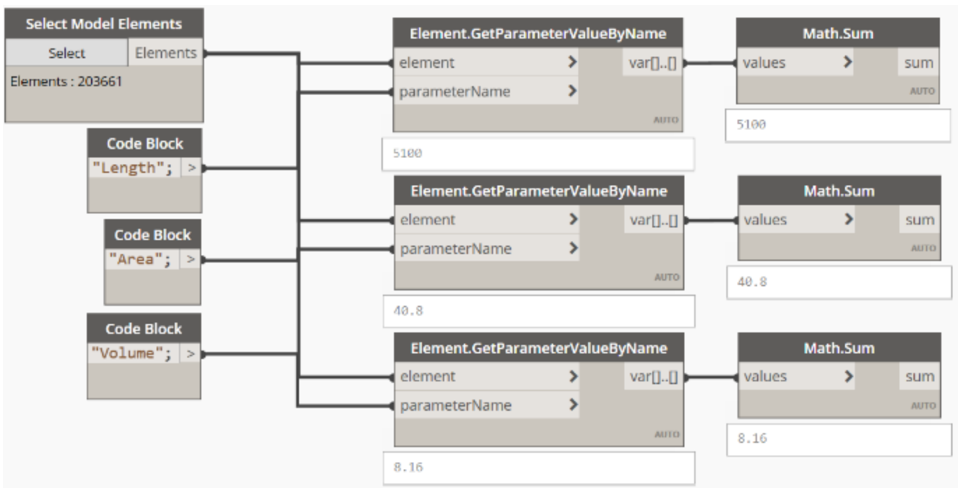


Fig. 13 Using Dynamo script to take the length, area and volume

B. Customizing and Enriching the Functions for QTO

Revit provides its own opening function but it just reveals the level. As for the tender price, the opening unit prices are different for different use as well as it divides to each activity code by its level and size. The function provided by Revit is far from enough for the QTO process. To create an opening by the Revit family by shared parameter, it not only provides the level but also the area, perimeter, volume and count numbers. All can be set inside the Revit family by simple mathematical calculation. Perimeters can be used to calculate formwork as well.

The benefit of creating Revit family instead of some Revit function is the data with customized parameters that can be extracted from Revit family and generated into schedule, of which structural opening function from Revit cannot achieve.

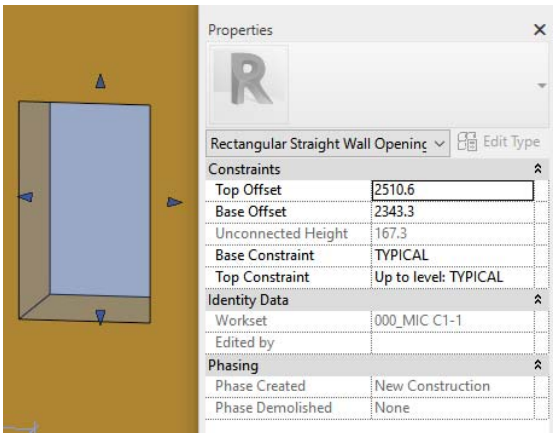


Fig. 14 Creating opening by structural opening

C. Multiple Use of the Similar Function

A material take-off schedule can be customized to list the information of materials quantities and cost. A good tool to measure the formwork area is as-painted material at walls including edges and breaks, surface items, formwork of columns and beams' side and soffit without generating thickness. Moreover, the paint material tool has its area and cost parameter, and creates a simple formula inside the schedule. It automatically calculates the total cost while adding the painted area as formwork area.

Fig. 15 Create opening by family

<00 _ WALL FORMWORK>

A	B	C	D	E	F	G
Mark	Material: Name	Material: Area	Material: Cost	BQ-SOR	Type	Material: As Paint
	TYPICAL FLOOR FINS FORMWORK (EDGES)	1.140 m²	216.00	5.3.1/4T	SUB.S-G45/20-R.C 160mm	Yes
5.3.1/14B	TYPICAL FLOOR LIFTS WALL FORMWORK (VERTICAL SURFACES)	351.186 m²	216.00			Yes
5.3.1/15+1B	TYPICAL FLOOR WALL FORMWORK (EDGE AND BREAKS)	204.453 m²	250.00			Yes
5.3.1/14B	TYPICAL FLOOR WALL FORMWORK (VERTICAL SURFACES)	2355.106 m²	216.00			Yes
Grand total: 389		2911.884 m²				

<01 _ STRUCTURAL FRAMING FORMWORK>

A	B	C	D	E
Material: Mark	Material: Name	Material: Area	Material: Cost	Reference Level
4.1.1/1A	GROUND BEAMS FORMWORK (G15/20)(50mm BLINDING LAYER)	111.723 m²	1161.00	
4.1.1/3C	GROUND BEAMS FORMWORK (SIDES)	196.162 m²	426.00	
5.3.1/14D	SUPERSTRUCTURE BEAMS FORMWORK (SIDES AND SOFFITS)	559.501 m²	216.00	
	Concrete, Cast-in-Place gray	566.392 m²	0.00	
Grand total: 649		1433.777 m²		

Fig. 16 Using material schedules to calculate the painted area as formwork area

The interfaced area should not be calculated. By splitting the face at walls and removing the area interfaced with slab and beams, those data will not be calculated on material take-off schedule.

D. Making the Data Import/Export More Efficient

Once each element has a unique activity code, all the descriptions, unit price, unit, etc. are inserted by Dynamo through an Excel list. This is the most efficient way to minimize the workload for more time to focus on optimizing the collected data.

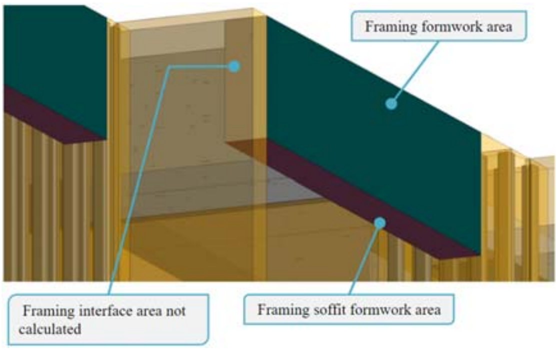


Fig. 17 Paint the formwork with side area and soffit area in the Revit family

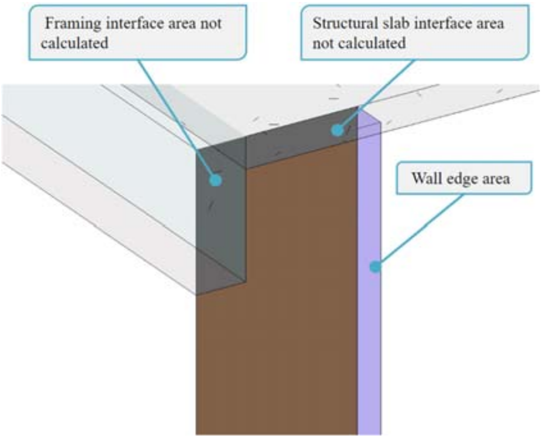


Fig. 18 Formwork modeling for calculation: spilt the face to avoid calculating the interfaced area between walls, beams and slab

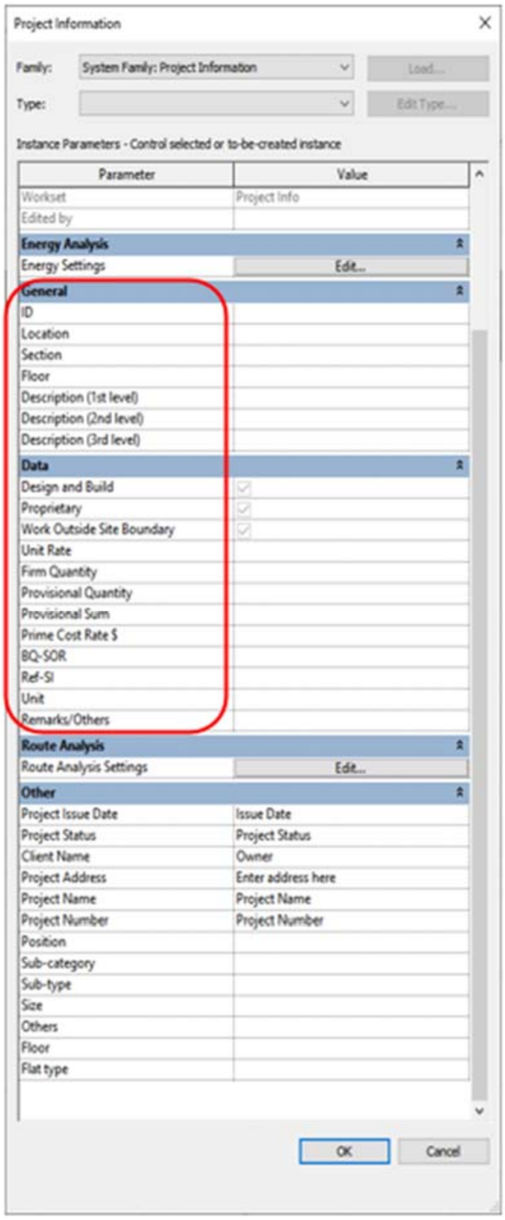


Fig. 19 Project information

After filtered the parameters, input is needed to project. In project information, the parameters are checked for ensuring input correctly, for example, whether the unit set for the parameter type is a text, digital or yes/no options etc., since it affects the data output to work and edit precisely.

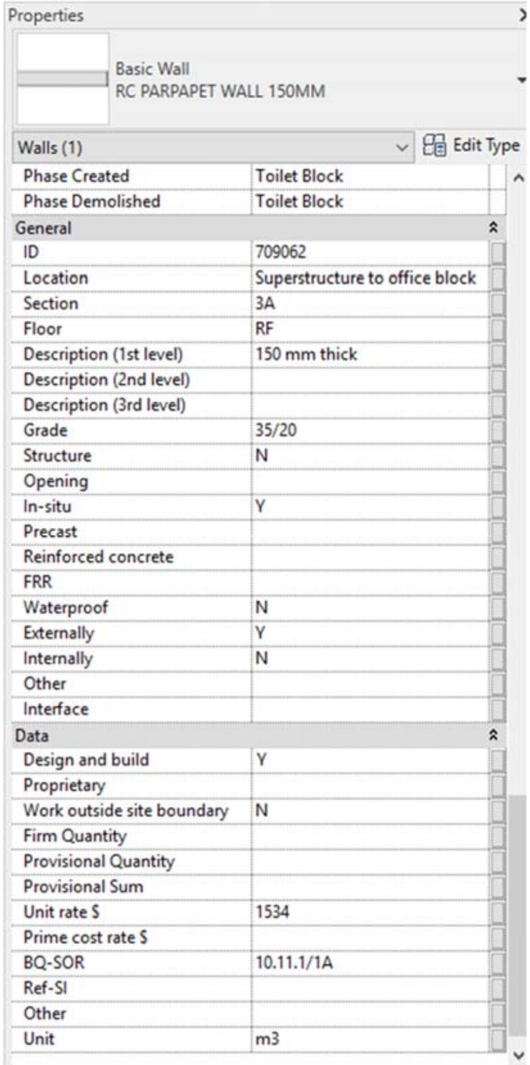


Fig. 20 Properties of elements

E. Results and Information

Mostly, the quantities taken from the model are close to the activity schedule (AS). Sometimes, there are discrepancies which have already eliminated the errors from modeling.

A schedule of quantities was developed from an Excavation and Lateral Support (ELS) model in Fig. 23.

Total amount calculated in AS and model quantities are slightly different (point **A**) due to the first layer of ELS covered, unless the survey points reveal the sag and swell topography, this results the situation (point **B**) a notable change in 1.50 - 3.00 m deep excavation.

In CE situation, design changes in foundation influence significantly the net cut of ELS (point **C**), the total amount of price varies greatly.

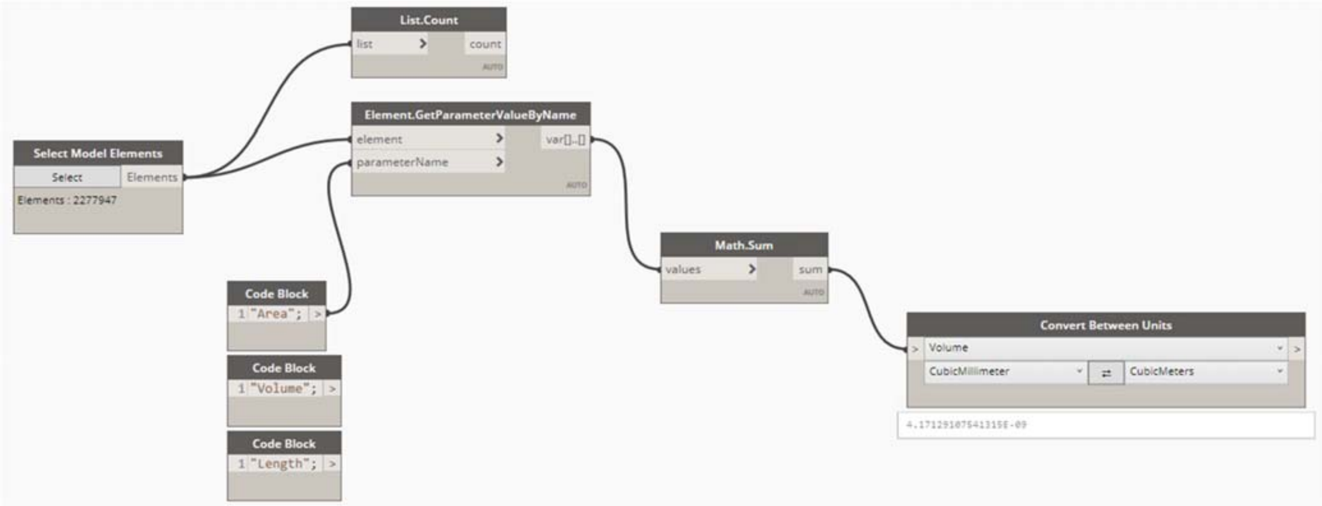


Fig. 21 Checking and taking the quantities and calculating the selected elements quickly for data/values import and export by Dynamo nodes

Wall Schedule										
BQ-SOR	Unit	Length	Volume	Volume	Data Needed	Type	Descriptio	Descriptio	Descriptio	Unit rate $
10.2 1/4B	m	120000	27.00 m³	27.00	120000	Approximate 295	Approxima	Hoarding v	Design, pr	$26,730.00
10.2 1/4D	m	120000	27.00 m³	27.00	120000	Approximate 492	Approxima	Design, provide erect		$12,825.00
10.2 1/6A	m	167000	37.58 m³	37.58	167000	Generic - 100	Approxima	Galvanizec	Design, pr	$3,173.00
10.2 2/1C	m3	107540	25.40 m³	25.40	25.40		Filling with decomposed granite:			$454.00
10.2 2/2B	m	111760	13.96 m³	13.96	111760		Filling with decomposed granite:			$454.00
10.2 6/3A	m	4000	0.05 m³	0.05	4000	Expansion Joints_	Forming e	Movement	Movement	$810.00
10.2 9/1+2A	m	24300	0.11 m³	0.11	24300	4500 mm (expose	4500 mm (	Basketball	Design su	$31,105.00
10.2 9/1+2B	m	56685	0.26 m³	0.26	56685	4500 mm (expose	4500 mm (	Basketball	Design su	$31,105.00
10.2 9/2C	m	292690	0.03 m³	0.03	292690	Line 50 mm wide	Lines; 50 n	Approved	Design su	$68.00
10.2 9/2D	m	118455	0.01 m³	0.01	118455	Line 50 mm wide	Lines; 50 n	Approved	Design su	$68.00
10.2 10/1+1D	m	62968	0.25 m³	0.25	62968	TENNIS COURT_	4000 mm (	STEEL AND METAL W		$27,648.00
10.2 10/1+1E	m	129167	0.52 m³	0.52	129167	TENNIS COURT_	4000 mm (	Design supply and ins		$27,648.00
10.2 10/2D	m	475859	0.05 m³	0.05	475859	Approved proprie	Lines: 50 n	Approved	Extra over	$68.00
10.2 11/1E	m3	6900	2.76 m³	2.76	2.76	Generic - 200mm	200 mm th	Walls		$1,534.00
10.2 11/2E	m2	1850	0.74 m³	0.74	0	ELECTRICAL MET	Walls	On fair-fac	One coat s	$57.00
10.2 12/1E	m3	5047	1.26 m³	1.26	1.26		Walls: 200 mm thick			$1,534.00
10.6/5+1B	m	112000	25.20 m³	25.20	112000	Approximate 711	Approxima	Galvanizec	Design, su	$37,237.00
10.7/1+1B	m3	64507	109.22 m³	109.2	109.2		Walls; 540 mm (average) thick			$2,187.00
10.7/2+1A	m	501	0.05 m³	0.05	501	Forming Moveme	Forming movementjoints; with A			$810.00
10.7/2+1B	m	5100	0.09 m³	0.09	5100	Forming Moveme	Forming movementjoints; with A			$810.00
10.7/2E	m	3005	0.30 m³	0.30	3005	Forming Contract	Forming contraction joints; with			$810.00
10.7/2F	m	32101	0.65 m³	0.65	32101	Forming Contract	Forming contraction joints; with			$810.00
10.7/2G	m	1002	0.10 m³	0.10	1002	Forming Expansio	Forming expansion joints: with A			$810.00
10.7/2H	m	10700	0.22 m³	0.22	10700	Forming Expansio	Forming expansion joints; with A			$810.00
10.8 2/1J	m3	44277	12.40 m³	12.40	12.40	250mm THK. R.C	250 mm th	walls		$1,534.00
10.8 2/2E	m	60542	0.02 m³	0.02	60542	Beds Toilet Edg	Beds	Edges and breaks; 10		$155.00
10.8 2/2G	m	28232	0.01 m³	0.01	28232	Beds_Edges and	Beds	Edges and breaks; 20		$155.00
10.9 1/1+1D	m3	51407	45.22 m³	45.22	45.22	Generic - 250	250 mm thick			$1,534.00
10.9 1/1C	m3	33548	7.77 m³	7.77	7.77		150 mm thick			$1,520.00
10.9 1/1D	m3	36045	11.50 m³	11.50	11.50	RC PARPAPET W	200 mm thick			$1,520.00
10.9 1/3B	m	90706	0.03 m³	0.03	90706	Slabs Toilet Edg	Slabs	Edges and breaks; 10		$181.00
10.9 1/3D	m	29045	0.01 m³	0.01	29045	Projections Offic	Projection:	Extra over formwork t		$181.00
10.10.2/1E	m3	27308	7.18 m³	7.18	7.18	Generic - 200mm	200 mm th	Walls		$1,366.00
10.10.2/2B	m	39241	0.01 m³	0.01	39241	Beds Office Edg	Beds	Edges and breaks; 10		$155.00
10.11.1/1A	m3	38019	9.09 m³	9.09	9.09	RC PARPAPET W	150 mm thick			$1,534.00
10.11.1/1F	m3	26171	17.14 m³	17.14	17.14	Generic - 200mm	200 mm thick			$1,534.00
10.11.1/2J	m	39266	0.01 m³	0.01	39266	Slabs_Office_Edg	Slabs	Edges and breaks; 10		$181.00
10.11.1/2L	m	21247	0.01 m³	0.01	21247	Projections_Toile	Projection:	Extra over formwork t		$181.00
Grand total: 316		2598193	383.18 m³	383.1						

Fig. 22 For massive output, use Revit schedule or Dynamo script to export the data from models

Provisional items and the model elements aligned in drawings but not shown in AS are marked with symbol '*' (point **D**) or parameter setting marked 'Provisional = Y' for ease of filter use and CE. Those elements are shown in drawings but not in AS items. For those items in AS marked 1 as quantity (point **E**), the QTO model generates the quantity which is checked close to the designed drawings.

Location	BQ-SOR	Description (1st level)	Description (2nd level)	Description (3rd level)	Cut	Net cut/fill	AS	Model Qty	Unit rate $	AS	Model Total	Mark	Unit	Projected Area
											Total			
Tennis Court - Retaining Wall	10.7/1A	Retaining Wall; Area A	EXCAVATION AND LATEI	Allow for design, provisio	0.00 m³	1306.59 m³	-	-	$1,201,500.00					423 m²
Tennis Court - Retaining Wall	10.7/1B	Not exceeding 1.50 m de	EXCAVATION AND LATEI	Allow for design, provisio	634.72 m³	-634.72 m³	660	634	$243.00	$160,380.00	$154,062.00	A	m3	423 m²
Tennis Court - Retaining Wall	10.7/1C	1.50 - 3.00 m deep	EXCAVATION AND LATEI	Allow for design, provisio	1245.83 m³	-1245.83 m³	407	611.83	$378.00	$153,846.00	$231,271.74		m3	423 m²
Tennis Court - Retaining Wall	10.7/1D	3.00 - 4.50 m deep	EXCAVATION AND LATEI	Allow for design, provisio	1616.85 m³	-1616.85 m³	209	371.02	$608.00	$127,072.00	$225,580.16		m3	423 m²
Tennis Court - Retaining Wall	10.7/1E	Filling inside retaining wa	EXCAVATION AND LATEI	Filling with Grade 200 rock fill			1500	896.689	$344.00	$516,000.00	$30[illegible]117.02	B 10.7/1D - 10.7/1+1A - 10.7/1+1B - 10.7/1F 10.7/1G - 10.7/1H	m3	
		30' Open Cut					*	1653.422	$344.00	*	$568,777.17	10.7-1E (2)		
Tennis Court - Footing	10.2.10/1A		Not exceeding 1.50 m dee	Excavating for footings and the like		-229.20 m³	232	229.2	$513.00	$119,016.00	$117,579.60		m3	334 m²
Tennis Court - Footing	10.2.10/1A		Not exceeding 1.50 m dee	Excavating for footings and the like		-16.28 m³	*	16.28	$513.00	*	$8,351.64		m3	9 m²
Toilet Block	10.8.1/1A		Not exceeding 1.50 m dee	Excavating for footings and the like		-266.96 m³	337	266.96	$351.00	$118,287.00	$93,702.96		m3	192 m²
Toilet Block	10.8.1/1B		1.50 - 3.00 m deep	Excavating for footings and the like		-373.89 m³	117	373	$1,620.00	$189,540.00	$604,260.00	C	m3	192 m²
Office Block	10.10.1/1A		Not exceeding 1.50 m dee	Excavating for footings and the like		-124.15 m³	159	124.15	$351.00	$55,809.00	$43,576.65		m3	83 m²
Office Block	10.10.1/1B		1.50 - 3.00 m deep	Excavating for footings and the like		-161.09 m³	44	161.09	$1,620.00	$71,280.00	$260,965.80		m3	83 m²
ELECTRICAL METER CABINET	10.2.11/1A		Not exceeding 1.50 m dee	Excavating for footings and the like		-18.32 m³	15	18.32	$513.00	$7,695.00	$9,398.16		m3	
Basketball Court	10.2.9/1A	Not exceeding 1.50 m de	Excavating for footings and the like		192.17 m³	-161.27 m³	203	161.27	$513.00	$104,139.00	$82,731.51		m3	
Basketball Court - Fence Footing	*	Not exceeding 1.50 m de	Excavating for footings and the like		145.57 m³	-145.50 m³	*	145.5	$513.00	*	$74,641.50	D	m3	
Basketball Court - Planter Excavation	*	1.50 - 3.00 m deep	Excavating for footings and the like		60.85 m³	-60.85 m³	*	60.85	$513.00	*	$31,216.05		m3	
10m Height Fence Footing	10.6/5D	Not exceeding 1.50 m deep					545	648.275	$513.00	$279,585.00	$332,565.08		m3	
10m Height Fence Footing	10.6/5E	Backfilling to excavation					468	390.491	$371.00	$173,628.00	$144,872.16	10.6/5D - 10.6/5+1A		
Water Meter Cabinet	10.2.12/1A	Not exceeding 1.50 m deep					1	12.241	$513.00	$513.00	$6,279.63	E	m3	
Water Meter Cabinet	10.2.12/1B	Filling to make up level					1	1.922	$371.00	$371.00	$713.06		m3	

Fig. 23 Types of QTO results found between AS and BIM model

VI. MIC UNIT IN PRACTICE

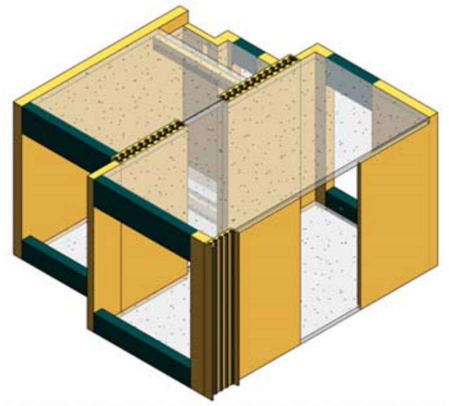


Fig. 24 Typical MiC unit structural model for the quantities of framing, walls, slab and formwork

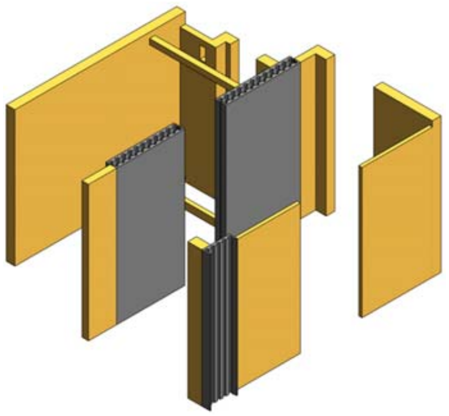
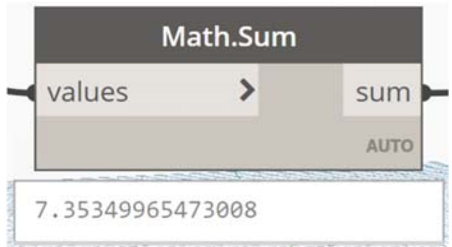


Fig. 25 Typical MiC unit walls

Although the volume is not shown in the properties of walls in irregular shape, the volume can be calculated by using Dynamo or wall schedule.



<Wall Schedule>

A	B	C
Family and Type	Mark	Volume
Walls 4: Walls 2	C	0.766 m³
Walls 1: Walls 1	C	0.632 m³
Basic Wall: PTS-STW-RC200	C	0.183 m³
Basic Wall: PTS-STW-RC200	C	0.143 m³
Basic Wall: PTS-STW-RC200	C	0.851 m³
Basic Wall: PTS-STW-RC200	C	2.474 m³
Basic Wall: PTS-STW-RC200	C	0.245 m³
Basic Wall: PTS-STW-RC200	C	0.204 m³
Basic Wall: PTS-STW-RC200	C	0.329 m³
Basic Wall: PTS-STW-RC200	C	0.015 m³
Basic Wall: PTS-STW-RC200	C	0.001 m³
Basic Wall: PTS-STW-RC200	C	0.002 m³
Basic Wall: PTS-STW-RC150	C	0.165 m³
Basic Wall: PTS-STW-RC150	C	0.306 m³
Basic Wall: PTS-STW-RC125	C	0.033 m³
Basic Wall: PTS-STW-RC125	C	0.010 m³
Basic Wall: PTS-STW-RC125	C	0.221 m³
Basic Wall: PTS-STW-RC125	C	0.001 m³
Basic Wall: PTS-STW-RC90	C	0.030 m³
Basic Wall: PTS-STW-RC90	C	0.008 m³
Basic Wall: PTS-STW-RC90	C	0.013 m³
Basic Wall: PTS-STW-RC75(NON)	C	0.354 m³
Basic Wall: PTS-STW-RC75(NON)	C	0.367 m³
Grand total: 23		7.353 m³

Fig. 26 Typical MiC walls volume

The opening family should be able to deduct the wall volume and countable as well. Usually, the countable Revit function Structure > Opening is used; however, the size cannot be shown.

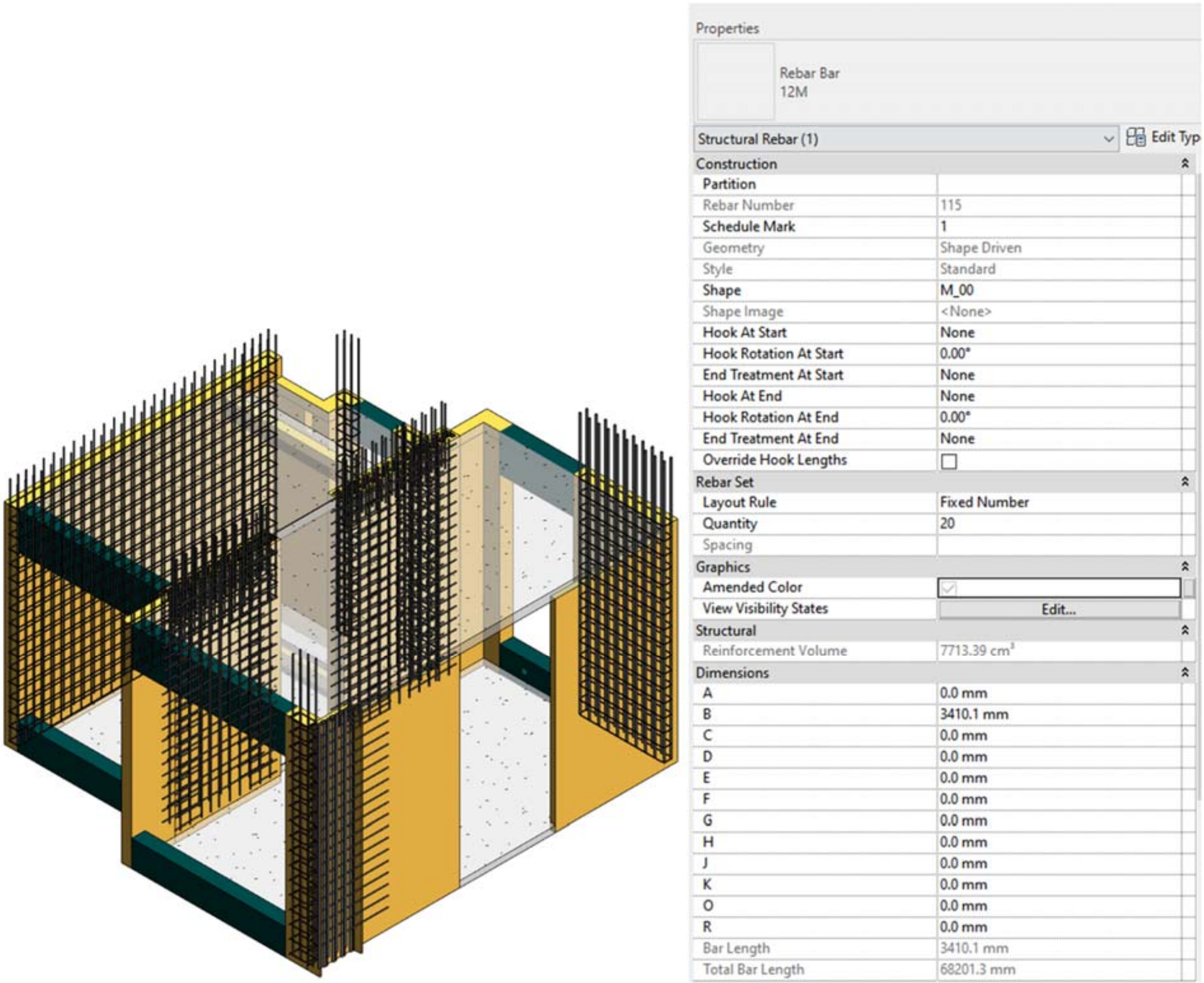


Fig. 27 Typical MiC unit rebar in walls

As for price and creating the family factors, level of opening and the size of parameters should be considered for QTO.

VII. Integration

The International Cost Management Standard (ICMS) provides global consistency in presenting entire construction lifecycle costs and carbon emissions (CO_2) at a project [18]. ICMS coding, cost and CO_2 values from the link between BIM and ICMS at a digitalized platform can be used as additional fields in the CDE to support information of asset information model and project information model (ISO 19650 Parts 1 and 2) [14], [15], [19].

ICMS assists and standardizes the project attributes and codes for different stages of construction lifecycle costs. Construction cost, renewal cost, management cost and end of life cost including NEC4 ECC X21 Whole-life cost [3] can be applied in BIM to control cost. Using this integration system to manage 5D BIM model bills can optimize the items of tender pricing documents by the standardized codes. The project attributes as the project parameters follow the format of appropriate values, with the delineation and calculation standard rules, the framework optimizing the QTO BIM model not only for completion of cost control, but also the design and construction drawings production.

<REBAR SCHEDULE>

A	B	C	D	E	F	G	H	I	J	K	L
Family and Type	Bar Diameter	Bar Length	A	B	C	D	E	Quantity	Total Bar Length	Unit Weight	Total Weight
Rebar Bar: 10M	10 mm	4117 mm	150 mm	3866 mm	150 mm	0 mm	0 mm	17	69992 mm	0.62 kg/m	43.12 kg
Rebar Bar: 10M	10 mm	4117 mm	150 mm	3866 mm	150 mm	0 mm	0 mm	17	69992 mm	0.62 kg/m	43.12 kg
Rebar Bar: 16M	16 mm	3806 mm	0 mm	3806 mm	0 mm	0 mm	0 mm	3	11418 mm	1.56 kg/m	17.81 kg
Rebar Bar: 25M	25 mm	2976 mm	0 mm	2976 mm	0 mm	0 mm	0 mm	1	2976 mm	3.85 kg/m	11.47 kg
Rebar Bar: 16M	16 mm	3806 mm	0 mm	3806 mm	0 mm	0 mm	0 mm	3	11418 mm	1.56 kg/m	17.81 kg
Rebar Bar: 10M	10 mm	392 mm	87 mm	267 mm	87 mm	0 mm	0 mm	16	6272 mm	0.62 kg/m	3.86 kg
Rebar Bar: 10M	10 mm	390 mm	87 mm	265 mm	87 mm	0 mm	0 mm	16	6247 mm	0.62 kg/m	3.85 kg
Rebar Bar: 16M	16 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	4	15584 mm	1.56 kg/m	24.31 kg
Rebar Bar: 16M	16 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	4	15584 mm	1.56 kg/m	24.31 kg
Rebar Bar: 10M	10 mm	499 mm	87 mm	373 mm	87 mm	0 mm	0 mm	15	7478 mm	0.62 kg/m	4.61 kg
Rebar Bar: 10M	10 mm	499 mm	87 mm	373 mm	87 mm	0 mm	0 mm	15	7478 mm	0.62 kg/m	4.61 kg
Rebar Bar: 16M	16 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	14	54544 mm	1.56 kg/m	85.09 kg
Rebar Bar: 16M	16 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	14	54544 mm	1.56 kg/m	85.09 kg
Rebar Bar: 25M	25 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	10	38960 mm	3.85 kg/m	150.15 kg
Rebar Bar: 25M	25 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	10	38960 mm	3.85 kg/m	150.15 kg
Rebar Bar: 16M	16 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	3	11688 mm	1.56 kg/m	18.23 kg
Rebar Bar: 16M	16 mm	3896 mm	0 mm	3896 mm	0 mm	0 mm	0 mm	3	11688 mm	1.56 kg/m	18.23 kg
Rebar Bar: 10M	10 mm	4078 mm	110 mm	1809 mm	150 mm	1810 mm	149 mm	10	40775 mm	0.62 kg/m	25.12 kg
Rebar Bar: 10M	10 mm	1406 mm	87 mm	1281 mm	87 mm	0 mm	0 mm	17	23905 mm	0.62 kg/m	14.73 kg
Rebar Bar: 10M	10 mm	1406 mm	87 mm	1281 mm	87 mm	0 mm	0 mm	17	23905 mm	0.62 kg/m	14.73 kg
Rebar Bar: 10M	10 mm	548 mm	150 mm	297 mm	150 mm	0 mm	0 mm	17	9316 mm	0.62 kg/m	5.74 kg
Rebar Bar: 10M	10 mm	502 mm	150 mm	251 mm	150 mm	0 mm	0 mm	17	8537 mm	0.62 kg/m	5.26 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 16M	16 mm	3050 mm	0 mm	3050 mm	0 mm	0 mm	0 mm	1	3050 mm	1.56 kg/m	4.76 kg
Rebar Bar: 12M	12 mm	700 mm	668 mm	33 mm	0 mm	0 mm		1	700 mm	0.88 kg/m	0.62 kg
Rebar Bar: 12M	12 mm	700 mm	668 mm	33 mm	0 mm	0 mm		1	700 mm	0.88 kg/m	0.62 kg
Rebar Bar: 12M	12 mm	700 mm	668 mm	33 mm	0 mm	0 mm		1	700 mm	0.88 kg/m	0.62 kg
Rebar Bar: 12M	12 mm	700 mm	668 mm	33 mm	0 mm	0 mm		1	700 mm	0.88 kg/m	0.62 kg

<REBAR SCHEDULE>

A	B	C	D	E	F	G	H	I	J	K	L
Family and Type	Bar Diameter	Bar Length	A	B	C	D	E	Quantity	Total Bar Length	Unit Weight	Total Weight
Rebar Bar: 10M	10 mm									0.62 kg/m	868.94 kg
Rebar Bar: 12M	12 mm									0.88 kg/m	712.77 kg
Rebar Bar: 16M	16 mm		0 mm		0 mm	0 mm	0 mm			1.56 kg/m	1164.53 kg
Rebar Bar: 20M	20 mm	3066 mm	0 mm	3066 mm	0 mm	0 mm	0 mm	1	3066 mm	2.47 kg/m	75.61 kg
Rebar Bar: 25M	25 mm		0 mm		0 mm	0 mm	0 mm			3.85 kg/m	311.77 kg
Rebar Bar: 32M	32 mm		0 mm		0 mm	0 mm	0 mm	1		6.31 kg/m	311.81 kg
Grand total: 693											3445.43 kg

Fig. 28 Typical MiC unit rebar in walls with total weight calculated

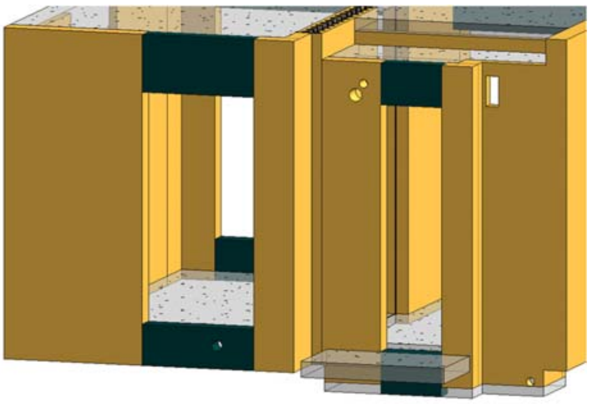


Fig. 29 Typical MiC unit opening including counting circular opening and rectangular opening

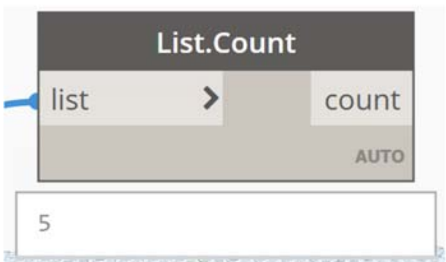


Fig. 30 Typical MiC walls opening countable and marked (created by family)

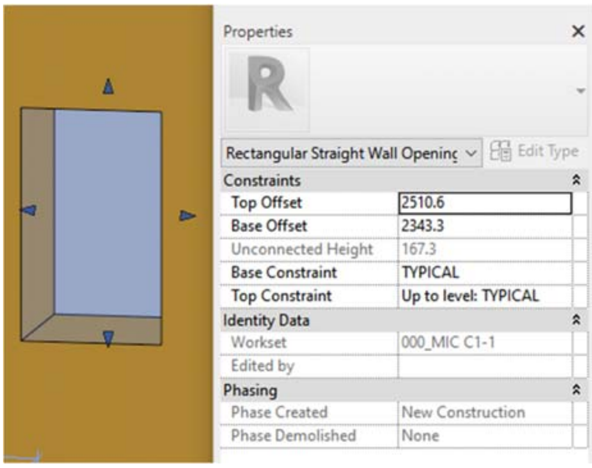


Fig. 31 Typical MiC walls opening (created by Structure > Opening)

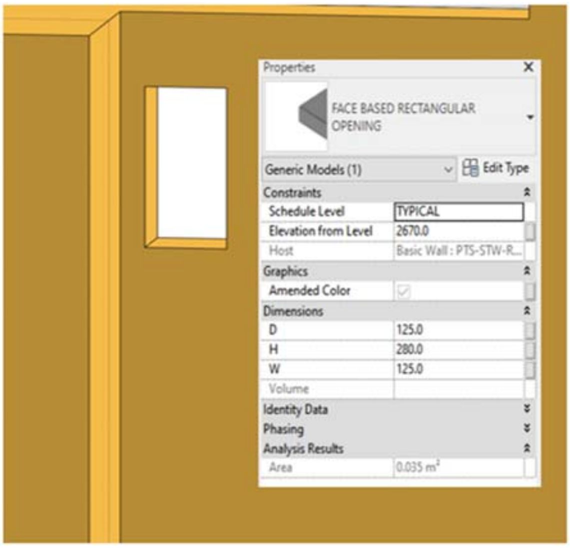
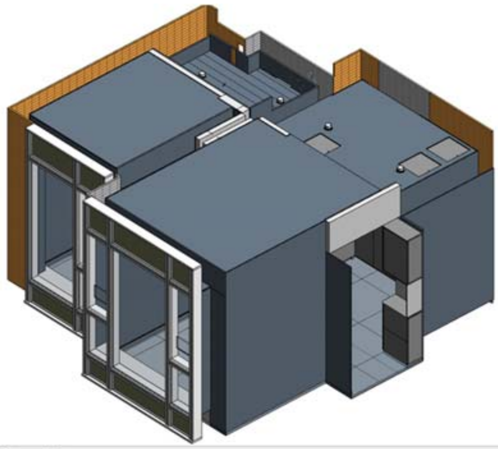


Fig. 32 Typical MiC walls opening (created by family)

<STRUCTURAL OPENING>

A	B	C	D	E	F	G	H
Type	Mark	OPENING TYPE	DES.	DIA.	W	H	Elevation from Level
FACE BASED CIRCULAR OPENING		WO	AC	100			2600
FACE BASED CIRCULAR OPENING		BO	AC	125			2775
FACE BASED CIRCULAR OPENING		BO	AC	125			2775
FACE BASED CIRCULAR OPENING		WO	AC	125			2485
FACE BASED CIRCULAR OPENING		WO	AC	125			2620
FACE BASED CIRCULAR OPENING		WO	AC	125			2620
FACE BASED CIRCULAR OPENING		WO	AC	100			2484
FACE BASED CIRCULAR OPENING		WO	AC	125			2571
FACE BASED CIRCULAR OPENING		WO	AC	125			2600
FACE BASED CIRCULAR OPENING		WO	AC	100			209
FACE BASED CIRCULAR OPENING		WO	AC	125			2600
FACE BASED CIRCULAR OPENING		WO	AC	125			2600
FACE BASED CIRCULAR OPENING		WO	AC	100			-92
FACE BASED CIRCULAR OPENING		WO	AC	125			2485
FACE BASED CIRCULAR OPENING		WO	AC	125			2620
FACE BASED CIRCULAR OPENING		WO	AC	125			2620
FACE BASED CIRCULAR OPENING		WO	AC	100			2484
FACE BASED CIRCULAR OPENING		WO	DR	100			120
FACE BASED CIRCULAR OPENING		WO	DR	100			-200
FACE BASED CIRCULAR OPENING		BO	DR	150			207
FACE BASED CIRCULAR OPENING		BO	DR	80			331
FACE BASED CIRCULAR OPENING		WO	DR	100			-200
FACE BASED CIRCULAR OPENING		WO	DR	100			120
FACE BASED CIRCULAR OPENING		BO	FS	80			2825
FACE BASED CIRCULAR OPENING		BO	FS	80			2825
FACE BASED CIRCULAR OPENING		BO	FS	80			2825
FACE BASED CIRCULAR OPENING		BO	FS	80			2825
FACE BASED CIRCULAR OPENING		WO	FS	100			2353
FACE BASED CIRCULAR OPENING		WO	FS	100			2353
FACE BASED CIRCULAR OPENING		WO	FS	100			2353
FACE BASED CIRCULAR OPENING		WO	FS	150			2353
FACE BASED CIRCULAR OPENING		WO	FS	80			2825
FACE BASED CIRCULAR OPENING		BO	FS	100			2353
FACE BASED CIRCULAR OPENING		BO	FS	100			2353
FACE BASED CIRCULAR OPENING		BO	FS	100			2353
FACE BASED CIRCULAR OPENING		WO	PL	50			2765
FACE BASED CIRCULAR OPENING		WO	PL	50			2593
FACE BASED CIRCULAR OPENING		BO	PL	50			75
FACE BASED CIRCULAR OPENING		WO	PL	150			2845
FACE BASED CIRCULAR OPENING		WO	PL	150			2845
FACE BASED CIRCULAR OPENING		WO	PL	100			2850
FACE BASED CIRCULAR OPENING		WO	PL	150			2605
FACE BASED CIRCULAR OPENING		WO	PL	150			2605
FACE BASED CIRCULAR OPENING		WO	PL	50			2593

Fig. 33 Typical MiC unit opening schedule: Openings are countable, size filtered, level marked



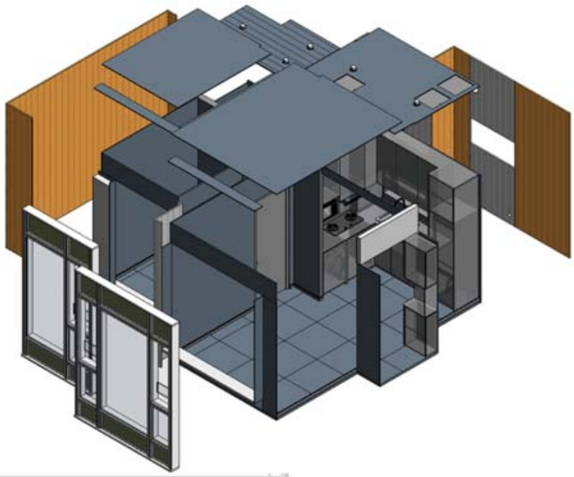
Properties

Basic Wall
RC PARPAPET WALL 150MM

Walls (1) | Edit Type

Phase Created	Toilet Block
Phase Demolished	Toilet Block
General	
ID	709062
Location	Superstructure to office block
Section	3A
Floor	RF
Description (1st level)	150 mm thick
Description (2nd level)	
Description (3rd level)	
Grade	35/20
Structure	N
Opening	
In-situ	Y
Precast	
Reinforced concrete	
FRR	
Waterproof	N
Externally	Y
Internally	N
Other	
Interface	
Data	
Design and build	Y
Proprietary	
Work outside site boundary	N
Firm Quantity	
Provisional Quantity	
Provisional Sum	
Unit rate $	1534
Prime cost rate $	
BQ-SOR	10.11.1/1A
Ref-SI	
Other	
Unit	m3

Fig. 34 Typical MiC unit structural model for the quantities of framing, walls, slab and formwork



General	
ID	
Location	
Section	
Floor	
Description (1st level)	Type MW—X1 or MW—X1R; 505 x 1375 mm overa...
Description (2nd level)	
Description (3rd level)	
Data	
Design and Build	✓
Proprietary	✓
Work Outside Site Boundary	✓
Unit Rate	1313
Firm Quantity	
Provisional Quantity	
Provisional Sum	
Prime Cost Rate $	
BQ-SOR	5.3.6/6G
Ref-SI	
Unit	No.
Remarks/Others	
Other	
Head Height	2315.0
System	
Sub-category	
Position	
Others	
Flat type	

General	
ID	
Location	
Section	
Floor	
Description (1st level)	Ceilings and beams
Description (2nd level)	Que thinned seale: coat; two Ell coats of anti-mou...
Description (3rd level)	One coat of alkali resistant primer, two full coats o...
Data	
Design and Build	✓
Proprietary	✓
Work Outside Site Boundary	✓
Unit Rate	38
Firm Quantity	
Provisional Quantity	
Provisional Sum	
Prime Cost Rate $	
BQ-SOR	5.3.10/1D
Ref-SI	
Unit	m2
Remarks/Others	

Fig. 35 Typical MiC unit architectural model for quantities

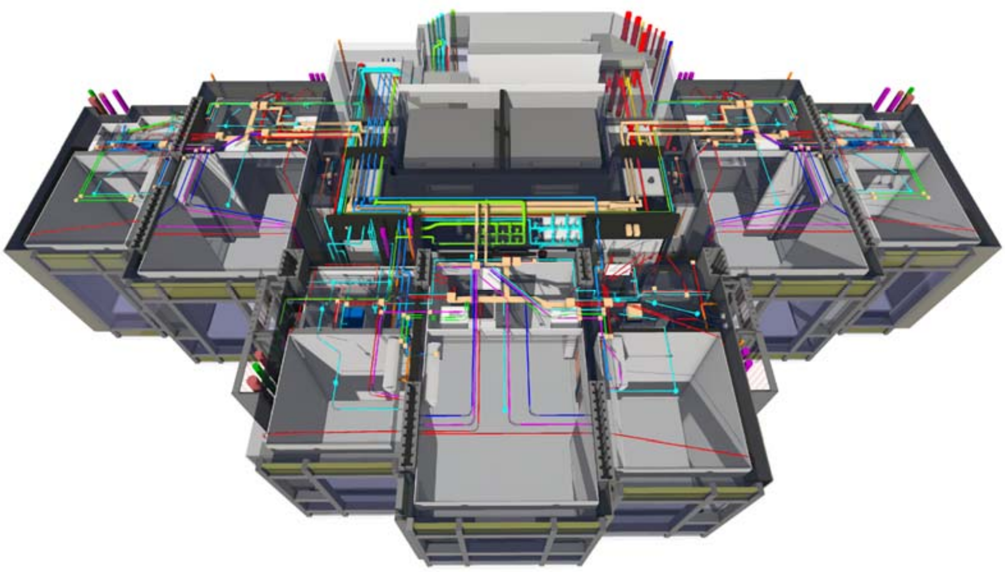
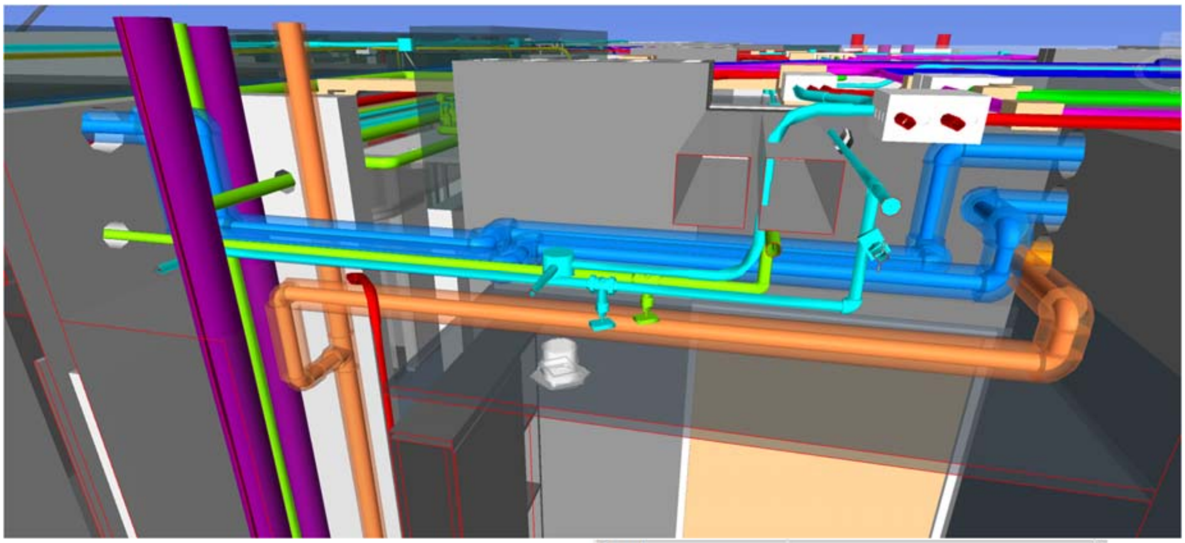


Fig. 36 Typical MiC unit Electrical & Mechanical (E&M) service



General	
ID	1391715
Location	
Section	
Floor	
Description (1st level)	Drain pipes; suspended below soffits of ground sla...
Description (2nd level)	Coated cast iron pipes and fittings; rigid—joints
Description (3rd level)	
Grade	
Structure	
Opening	
In-situ	
Precast	
Reinforced concrete	
FRR	
Waterproof	
Externally	
Internally	
Data	
Design and build	
Proprietary	
Work outside site boundary	
Firm Quantity	
Provisional Quantity	
Provisional Sum	
Unit rate $	1829
Prime cost rate $	
BQ-SOR	10.12/4K
Ref-SI	
Unit	
Insulation	
Overall Size	100 mmø
Insulation Thickness	0.0 mm

General	
ID	
Location	
Section	
Floor	
Description (1st level)	
Description (2nd level)	Ball valves
Description (3rd level)	Valves and taps
Grade	
Structure	
Opening	
In-situ	
Precast	
Reinforced concrete	
FRR	
Waterproof	
Externally	
Internally	
Data	
Design and build	
Proprietary	
Work outside site boundary	
Firm Quantity	
Provisional Quantity	
Provisional Sum	
Unit rate $	540
Prime cost rate $	
BQ-SOR	10.9.8/11P
Ref-SI	
Unit	
Insulation	
Overall Size	20 mmø-20 mmø
Insulation Thickness	0.0 mm
Insulation Type	

Fig. 37 Typical MiC unit E&M data input

VIII. Conclusion

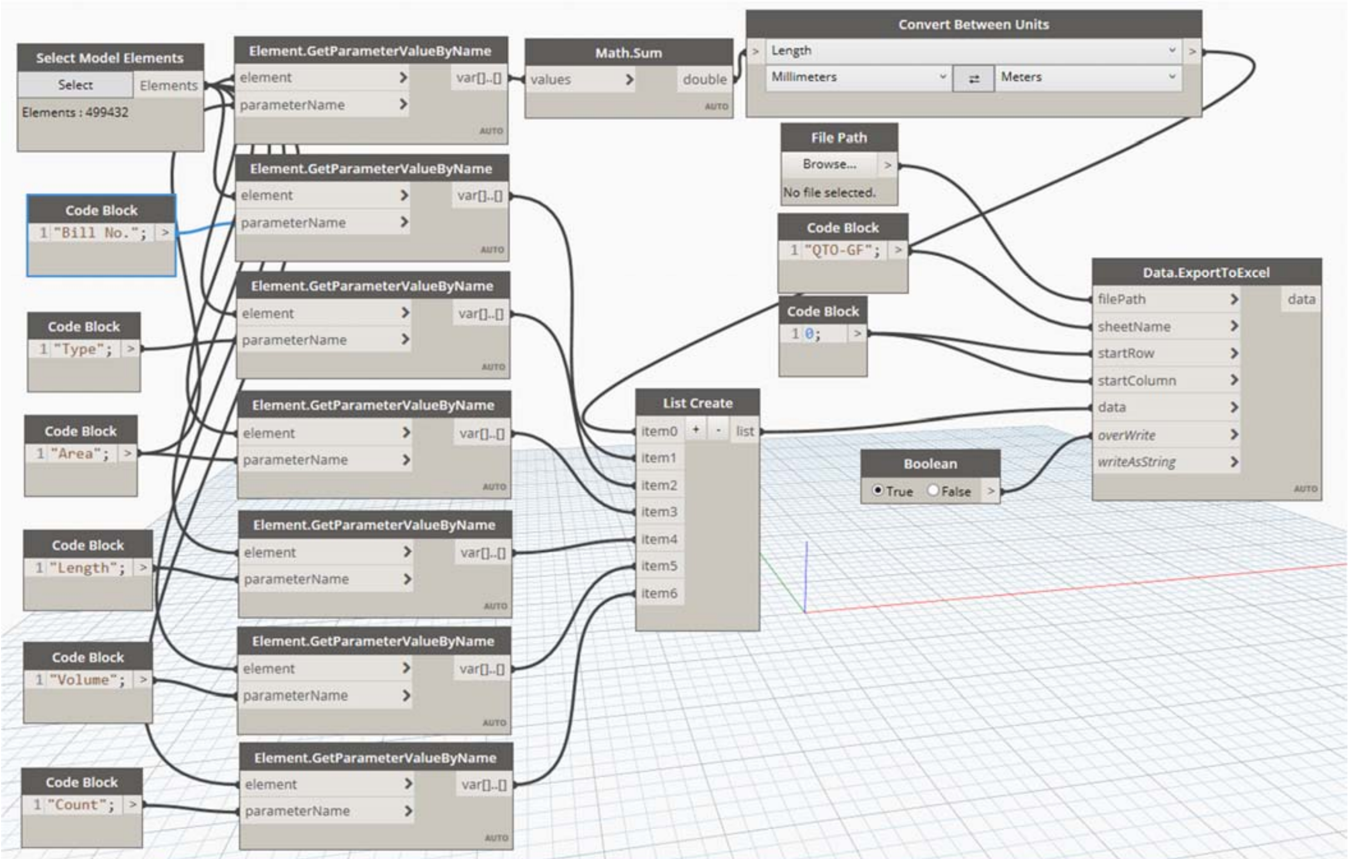
With domain knowledge, skill set and experience, technology, policies and transformation, the above BIM-based approach is set out for automatic QTO and cost estimation to enhance efficiency and effectiveness of project collaboration including global remote work.

In addition to using the BIM model to carry out more detailed and accurate calculations at whole-life stage for cost control, it greatly helps on generating bills in tender pricing documents for consultants, services providers, contractors and subcontractors.

Designers should be involved in the loop of QTO model as an important role. True 5D BIM would be BIM tender pricing documents produced by all sets of costs presented through BIM throughout project lifecycle. It also centralizes the design changes, cost estimation, calculations, project and asset data and information in a single source with all types of models in BIM.

The BIM-based protocol could thus be developed for seamless collaboration among AECO stakeholders by inserting information including proactive sharing via openBIM, cost and time estimate of construction as digital twin and blockchain [11].

With a range of cost and price, budget can be estimated upon instant design changes and report analysis automatically into BIM model according to specific codes together with construction stages simulation. It is best used for design and build projects with modular standardization, integration and project team in particular QS' early engagement.



Diameter	System Type	Pipe segment (Material)	Length (m)	Top Elevation	Bottom Elevation	Slope(1:X)
100	DR-Stormwater/RWP	Iron, Ductile - Cast Iron Pipe - BS.437	6.98	31159.88204	30870.47321	40.00
100	DR-SSD	Iron, Ductile - Cast Iron Pipe - BS.437	12.64931953	31888.07078	31589.7113	68.97
100	DR-SSD	Iron, Ductile - Cast Iron Pipe - BS.437	3.899418437	31677.97355	31485.02376	50.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	5.88001043	32167.08205	31905.86341	40.00
100	DR-SWP (BLD)	Polyvinyl Chloride - Rigid - VC	3.646921131	31766.39715	31063.60285	6.10
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	2.459927089	32057.13215	31881.38888	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	2.592849122	32045.08776	31866.02248	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	6.028523779	32013.23598	31748.28992	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	2.055	32062.05465	31896.4314	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	5.320673676	32020.16515	31773.19031	40.08
100	DR-RWP (BLD)	Polyvinyl Chloride - Rigid - VC	3.182771069	32389.57657	32195.76785	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	1.827694175	31704.57561	31332.9494	7.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	5.296388854	32195.44818	31948.81552	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	2.858101537	32181.70662	31996.0121	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	2.34	32261.46338	32088.7271	40.01
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	2.89	32274.85556	32088.36383	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	2.95256942	32344.46982	32156.41436	40.00
100	DR-SWP (BLD)	Polyvinyl Chloride - Rigid - VC	1.999573057	31932.11367	31767.87566	40.00
100	DR-SWP (BLD)	Polyvinyl Chloride - Rigid - VC	2.163893031	32400.8244	31716.56381	3.63
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	6.74280632	31866.34412	31583.56232	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	4.187428838	31917.73215	31698.81483	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	0.97484241	32187.18387	32048.55612	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	1.289399516	32230.10403	32083.61481	40.00
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	5.82	32020.77937	31761.48695	40.12
100	DR-WP (BLD)	Polyvinyl Chloride - Rigid - VC	1.884371416	31554.10215	31392.74328	40.00
100	DR-Stormwater/RWP	Iron, Ductile - Cast Iron Pipe - BS.437	5.475016495	31956.22971	30699.29707	4.68
100	DR-Stormwater/RWP	Polyvinyl Chloride - Rigid - Schedule 40	0.82025621	31707.93215	31573.16785	40.00

Fig. 38 Typical MiC unit E&M data output as a list by Dynamo, slope and length calculated

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