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BIM Based on Structural Framework to Generate Quotation

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ABSTRACT : *It is very important to estimate accurate construction total cost needed early in the project. In the initial phase of the design, the project cost estimates are determined by total quantity from design documents and the variables that affect the calculation of the total cost of the project. In order to determine accurate total construction cost, the contractor has to produce detailed quantity information based on the drawings and specifications. The process of preparing quantification and cost estimation documents is still being worked out manually, and a lot of errors have been occurred in many cases. However, recent advances in information technology have led to the BIM based quantity takeoff and cost estimation. This paper aims to develop a BIM based structural framework to generate quotations that can calculate specific structural members' quantities based on Revit Families and custom-build database. The study defined ten levels of quantity category that could be produced by BIM.*
KEYWORDS: *3D, 5D, Shared Parameter, Families Template, Microsoft Database, BIM generate quotation.*

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I. INTRODUCTION

According to [6] The correctness of the information on quantities will immediately affect the cost's accuracy. Accurate cost information is vital to fending off-budget overrun, and using building information Modelling (BIM) in quantity calculations may be greener than the traditional approach. The 3D BIM intelligent object is combined with a specialized template with a custom-built database, ensuring ease of use while manually minimizing the re-entry cost adjustments. This algorithm generates a list of the specialized work breakdown structure (WBS) based on the business method, including construction requirements and unit costs. According to [7], The Level of Development (LOD) Specification is a guide that allows AEC industry practitioners to identify and communicate the content and reliability of the Building Information Model (BIM) with a high degree of clarity at various stages of the design and construction system.

II. LITERATURE REVIEW

Automating is one of the significant advantages of preparing the bill of quantities for the estimator [1]. This term describes the ability to accelerate to QTO for a construction project to increase the estimate [2]. BIM-Based quantity takeoffs don't give all the information to make the cost estimation and bill of quantities [3]. BIM-based quantity takeoffs do not provide all the necessary data to create the cost estimation and a Bill of Quantities (BOQ). The Construction information database system based on BIM technology allows the extensive management of site information generated during the construction stage [4]. It is vital to create a database containing details on the materials and components incorporated in a building to handle all construction processes effectively [5]. In order to handle all design processes efficiently, a database containing all sorts of information about the materials and components incorporated in a building needs to be maintained.

III. METHODOLOGY

The technique presented here is capable of evolving a BIM primarily based-on Structural Framework to generate a quotation for bidding documents based on a BIM tool that integrates with custom databases and specialized templates. The whole process of this method is shown in Fig.1.

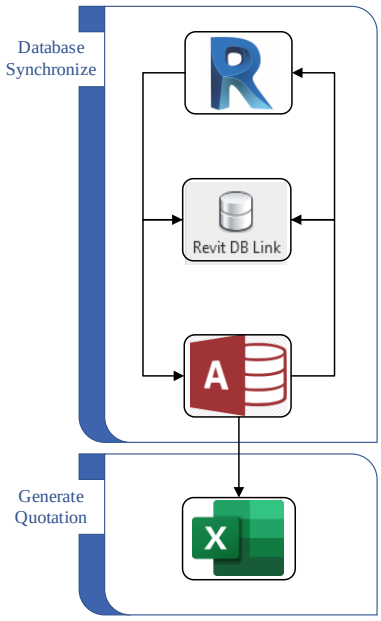

Fig.1. The Database Synchronize bill of quantities

The results from the above system are given in both tabulated and graphical forms. Daily, monthly, yearly and total plant production are the main output parameters from the system in addition to carbon dioxide (Co2) saving and system data. Some results are shown in Fig. 2.

Develop BIM Tools to generate the Quotation

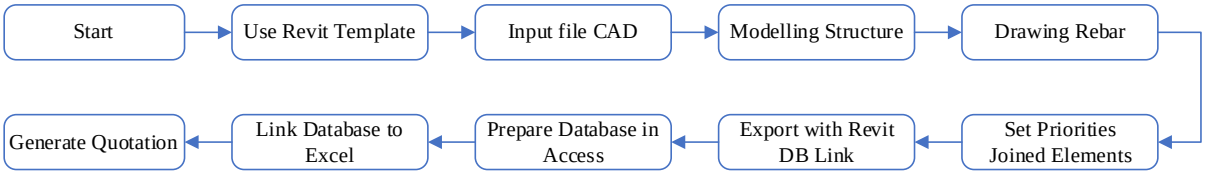

Fig. 2. The flow chart to generate Quotation

In this research, Autodesk Revit Structure 2020[8] is used as the BIM Tool for developing the object properties. As the Autodesk help [9] shared parameter is stored in an unbiased family document or Revit project, we can get entry to the file from exceptional families or projects. This BIM application provides "Shared Parameter and creates new families tool" within "Database Explorer" containing parts and components for users to develop object geometries based on their projects' requirements. The object's behavior within the model is described by parameters and a parametric relationship between objects [10]. Apart from the default parameters specified in the program, the user can also create a 'Shared Parameter' specified by the user and connect it with a particular collection of objects in the BIM model. The Shared Parameters can be defined either as “Instance Parameters” or as “Type Parameters”. If the shared parameter is created as an Instance Parameter, the information entered therein by the user will only be available at that particular instance of the beam system in the model. On the other hand, if it is defined as a Type Parameter, it will be available to every instance of the type which exists in the model. The first "Instance Parameter" strategy will require information to be vetted before it is released in the model, while the second strategy enables instantaneous dissemination throughout the model. Autodesk REVIT software allows the export of the BIM Model as a database in Microsoft Access. The Shared Parameters and the information added by the users can easily be extracted from this file. The information captured using BIM models must be maintained in a centralized archive that users can access the method mentioned above to yield advantages. A specific function should be allocated to each user to make it accessible to the user based on their function and duty in the project and the organization. The process of the objects properties developments as shown in Fig.3

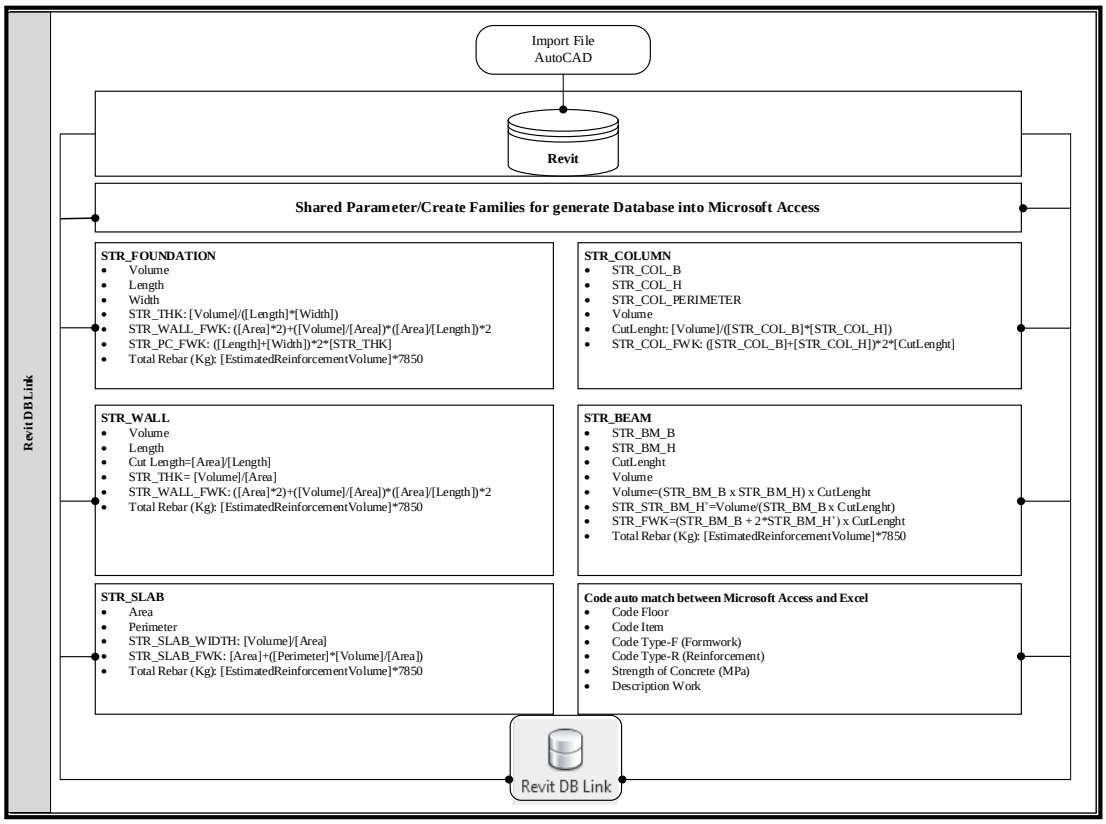

Fig. 3. The flowchart BIM Based-on Structural Framework to generate forbidding project

3.1 SET UP PRIORITIES

According to [11] Autodesk AutoCAD Structural Detailing, A priority is a value that lets you manage interpenetration (cutting to fit) of structural elements that overlap with each other. The priority determines the importance of an element in relation to other elements in a model as you create plans and sections. It also affects the calculation of volume and area of formworks of materials used in a structure. Use the Join Geometry [12] tool to create clean joins between 2 or more host elements that share a common face.

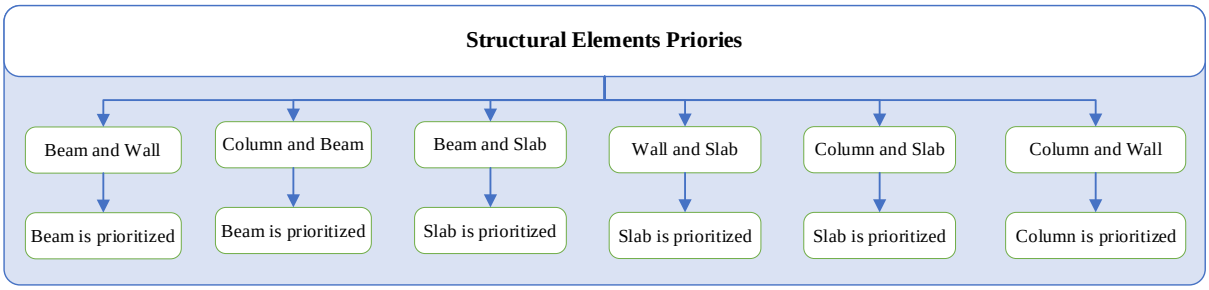

Fig. 4. The flow chart to generate Quotation

3.2. STRUCTURAL FOUNDATION

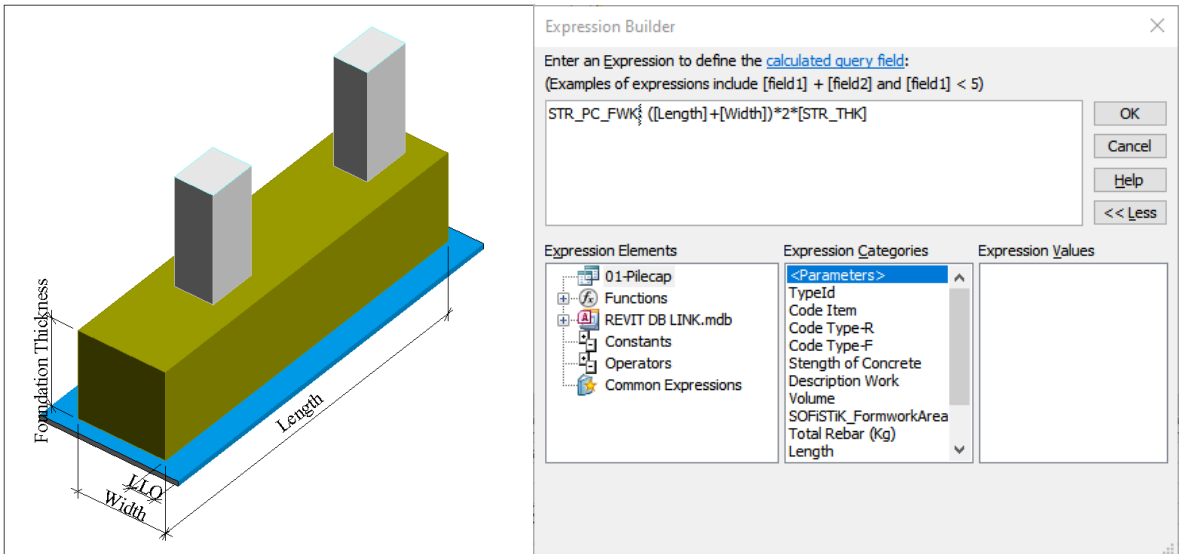

Fig. 5. Shared Parameter Structural Foundation in Revit for Database in Microsoft Access

$$STR\_FON\_THK = \frac{[Volume]}{([Length] \times [Width])}$$

$$STR\_PC\_FWK = ([Length] + [Width]) \times 2 \times [STR\_FON\_THK]$$

$$Total\ Rebar\ (Kg) = [EstimatedReinforcementVolume] \times 7850$$

LEAN CONCRETE

$$LLO\ (Lean\ Length\ Offset)$$

$$STR\_PC\_Lenght = Lenght + LLO$$

$$STR\_PC\_Width = Width + LLO$$

$$Lean\ Volume = [Lean\ Thk] \times [\ STR\_PC\_Lenght] \times [STR\_PC\_Width]$$

$$STR\_COL\_FWK = \bar{(}[ST\bar{R}\_COL\_B \bar{\times} ST\bar{R}\_COL\_H] \times 2 \times [CutLength]$$

$$Total\ Rebar\ (Kg) = [EstimatedReinforcementVolume] \times 7850$$

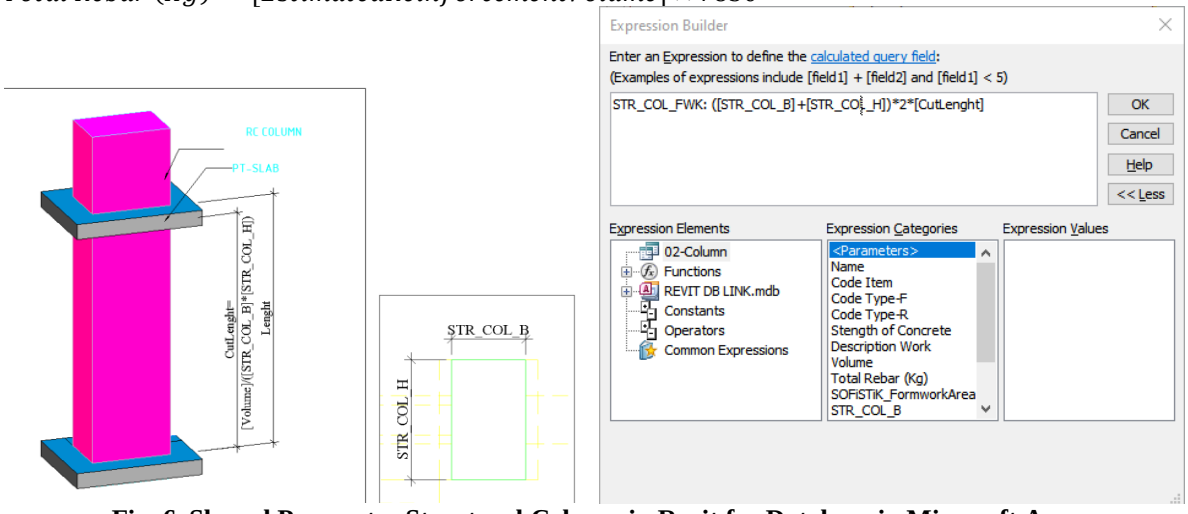

Fig. 6. Shared Parameter Structural Column in Revit for Database in Microsoft Access

3.4 STRUCTURAL WALL

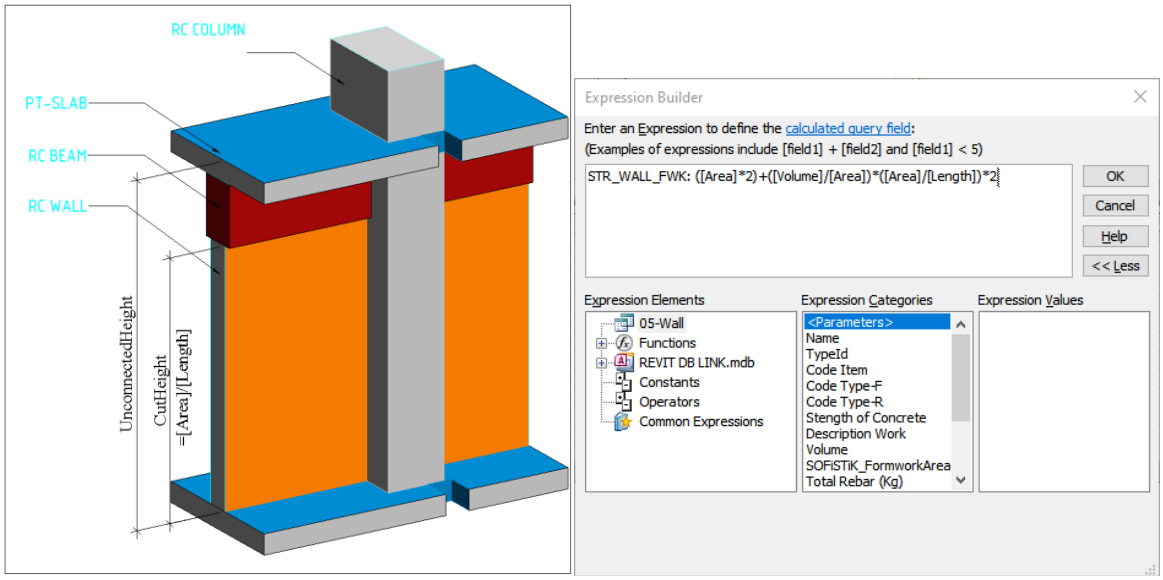

Fig. 7. Shared Parameter Wall in Revit for Database in Microsoft Access

The default height of [UnconnectedHeight] in Autodesk Revit, it considers from the base to the top level of the elevation. Wall Modelling extensively impacts the elements connected to the wall. The Modeling of the beam, slab, and column may also vary, relying on the definition of the height and length of the wall for accurate modeling. Therefore, it significantly impacts the automated quantity estimation. The modeling method is the height and length of a wall as the lower column's bottom dimension, slab, and beam. The wall volume calculates based on the wall's height and length in the lower column's the inside bottom, the slab, and the beam. The basic formula of the volume for concrete in the building structure $V = B \times H \times W$, gives the main concept to create Shared Parameter and Families Database in Revit.

$H = \frac{V}{B \times H}$, $B \times H = Area = \frac{V}{W}$

The default height of [UnconnectedHeight] in Autodesk Revit, it considers from the base to the top level of elevation. To calculation the formwork area of the wall structure, we need to find the [CutHeight] by [Area] over [Length].

$$[CutHeight] = \frac{[Area]}{[Lenght]}$$

$$[STR\_THK] = \frac{[Volume]}{[Area]}$$

$$STR\_WALL\_SEC\_AREA = [STR\_THK \times [Lenght]$$

$$STR\_WALL\_FWK = ([Area] \times 2) + (\frac{[Volume]}{[Area]} \times 2 \times [STR\_THK] \times [CutHeight]$$

$$Total\ Rebar\ (Kg) = [EstimatedReinforcementVolume] \times 7850$$

3.5 STRUCTURAL FLOOR

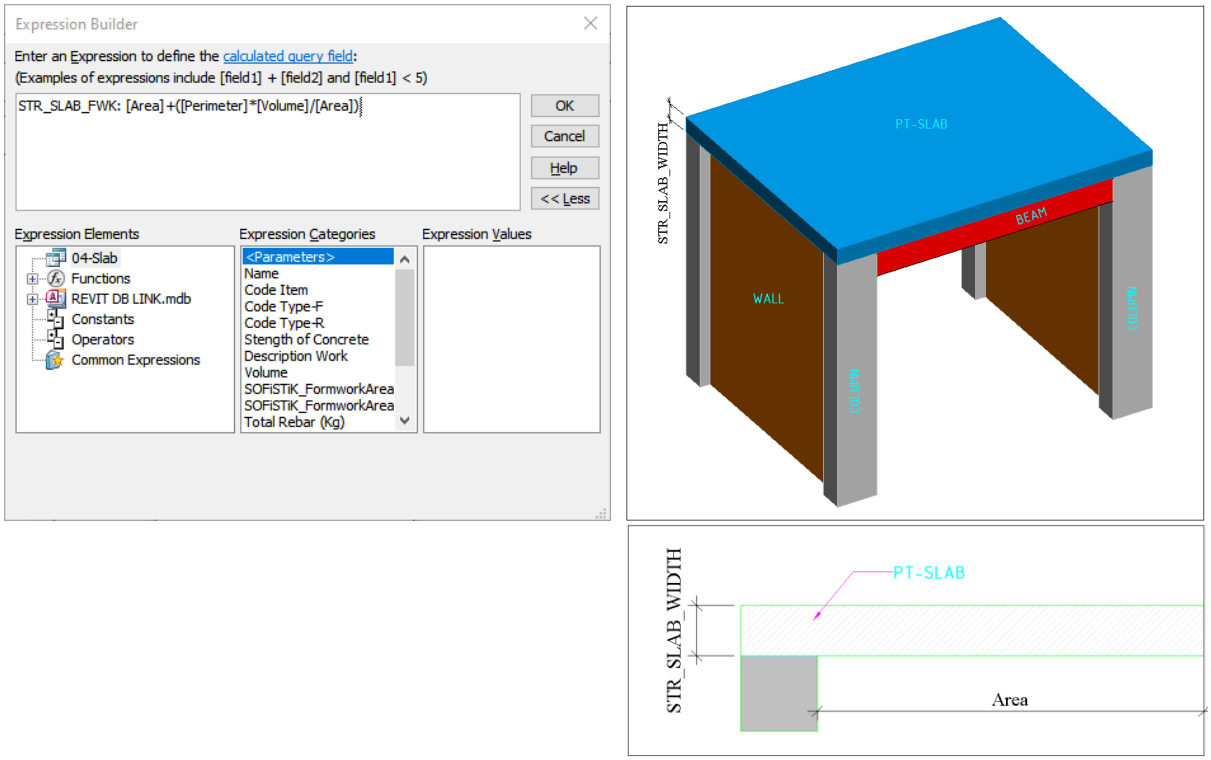

Fig. 8. Shared Parameter Floor in Revit for Database in Microsoft Access

The [CutLenght], the distance from the upper slab of the corresponding floor to the lower slab of the next floor, is modeled. The [Length] is the distance from the corresponding floor's upper slab to the next floor's upper slab.

$$STR\_SLAB\_WIDTH = \frac{[Volume]}{[Area]}$$

$$STR\_SLAB\_FWK' = [Area] + \left([Perimeter] \times \frac{[Volume]}{[Area]}\right)$$

$$STR\_SLAB\_FWK = [STR\_SLAB\_FWK'] - ([STR\_COL\_SEC\_AREA] + [STR\_WALL\_SEC\_AREA] + [STR\_BM\_SEC\_AREA])$$

$$Total\ Rebar\ (Kg) = [EstimatedReinforcementVolume] \times 7850$$

The custom-built Microsoft database represents from Access link to an Excel list of unique work breakdown structure (WBS) specialized that is created primarily based on the combination of labor and material unit cost lists. The method attempts to solve the problem following the custom-built database that allows you to transfer the labor and material unit costs into the estimating template for mechanically producing a total price. The Revit DB Link is significant and efficient for the BIM-Based on Structural Framework to generate bidding project quotations. Revit DB Link permits a connection between a Revit project and a Microsoft database and Access. It gives a manner to keep Revit model information in a database in which it can be modified, after which returned to the Revit model [10]. The relational database structure is adopted to integrate data of the proposed system systematically. Microsoft Access is chosen for developing the relational database module of the BIM-integrated Quotation. Advanced models (data synchronization and estimation) are generated in the various Excel sheets to connect the allocated formulas and functions. The data template obtained includes the same heading columns as those of the standard BOQ that can facilitate exporting data. The database template (Microsoft Access database) generates a database from Autodesk Revit DB link to Microsoft Access with different tables. Then we create new queries with different sheets to link each other by the assigned formulas and functions. The received data template contains the [Code Floor], [Code Item], [Code Type], [Code SOC], description, quantities, units. The estimating template (Microsoft Excel) links all queries database from Microsoft Access with a special detailing sheet that "if function" and "v-lookup" are assigned into every cell for linking with the received data template and custom-built database. Once the received data template got the data such as WBS codes, descriptions, quantities, and units from the typical BOQ, that information will be automatically transferred into the estimating template. Significantly, based on the WBS codes, this estimating template is capable of automatically searching for unit costs from the custom-built database and generating a completed BOQ and total costs.

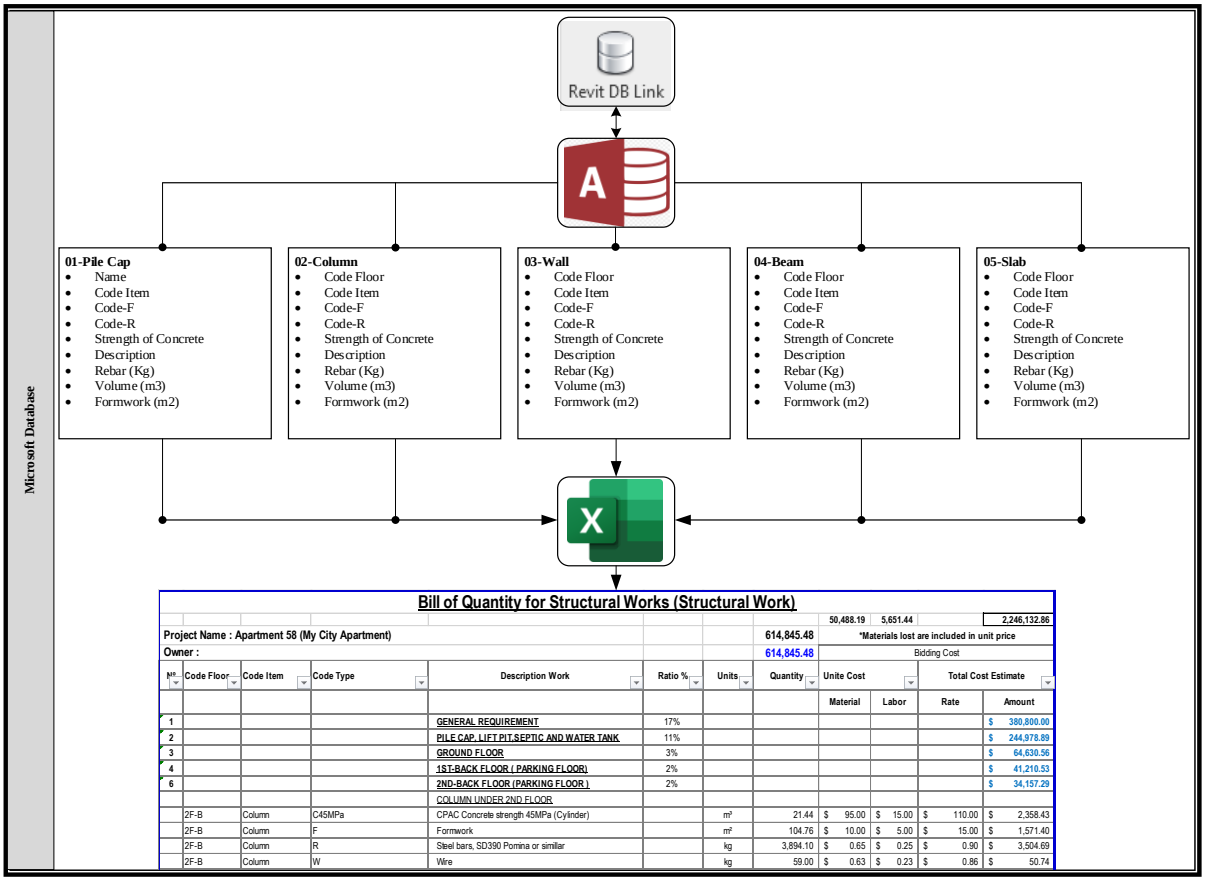

FIG. 9. THE FLOWCHART BIM BASED-ON STRUCTURAL FRAMEWORK TO GENERATE QUANTITIES TAKEOFF

IV. CASE STUDY

As mentioned above, BIM-based Quotation generating on a structural framework is developed in this study. With a ground area of 500 m^2, a case study of a 31-story residential building is built. This building is proposed in Sihanoukville, Cambodia, as a structural drawing, shop drawing, BOQ generation, cost control, and scheduling project. The construction of this building is built as a Post-Tension (PT) structure.

Fig. 10. The Modeling Realistic in Revit with real Construction Site

This method is an integral part of the object's property developers to create the completed smart element that can affect the quantity takeoff process. The WBS represents object definitions, and the material properties represent object specification. If both are not combined, the software will not recognize the materials to be taken off, and errors will happen during the takeoff process.

They are three steps to generate Quotation in Autodesk Revit,

1.Input file AutoCAD (structural design) in Revit Structure with 3D modeling and rebar.
2.Export database from Autodesk Revit into the Microsoft Access database.
3.Link queries from Microsoft Access to Excel to generate a quotation.

The code must be an auto-match between Autodesk Revit, Microsoft Access, and Excel to avoid errors during synchronize databases. The quantities of the real case-study solution's structural materials are calculated automatically in Revit, collaborating with Microsoft Access and Excel to generate a quotation. This is an important part of the objects' properties development to create the completed smart elements that can affect the quantity takeoff process. The WBS represents objects definitions, and the material properties represent objects specifications. If both are not combined, the software will not recognize the materials to be taken off, and errors will happen during the takeoff process. According to the existing objects, the BIM tool's properties are not sufficient for construction projects in Cambodia, as well as the formulas assigned, are not suitable for

Cambodia's material specifications. The present mechanism creates the building WBS with material properties based on the Cambodia standard system and combines them with the data information and formulas assigned are correct as well as adequate due to the Cambodia construction requirements. This is an integral part of the objects' properties creation to build the completed smart elements that will impact the quantity takeoff process. The WBS represents objects' descriptions, and the material properties represent specifications of objects. If these are not integrated, the program will not understand the extracted materials, and errors will occur during the takeoff process.

The new process produces the WBS building with material properties based on the Khmer norm framework. It blends them with the right as well as relevant data details and formulas allocated because of the Khmer construction specifications. The mechanism to combine is to select for "Report component" at "Part view" then open property for one of sub-activity at "Parts groups" that need to be combined. Next, click on "New report component" to show columns of Family, Name, and formula that users can select respectively for "Component families" and "Components" then assign formula based on the object specifications.

This research creates a schematic database in the BIM tool to support the 3D building models and quantity takeoff process with higher accuracy, thereby providing adequate intelligent objects based on the Cambodia material specification. This database is a requirement and sufficient for utilization to estimate their building projects in Cambodia. BIM tool is capable of extracting material takeoffs from the 3D models and export that data information in the form of spreadsheets, databases. The reported BOQ is based on settings completed using the "Quantify" tool and component definitions defined by the "Families" and "Parts" in the "Dataset explorer" that the level of accurate results is positively affected by the intelligent 3D objects. This present approach modeled a completed 3D building using intelligent objects, which contains specific codes associated with the Cambodia material specifications. This completed 3D model is then extracted due to a BIM-based QTO process to produce the typical BOQ, which has only building WBS specifications and quantities. So, this algorithm requires linking the typical BOQ with specialized templates capable of deriving labor and material unit price and generating a completed BOQ.

4.1. TYPICAL BOQ RELATION WITH ADVANCED TEMPLATES

The typical BOQ is a summary of data information in an excel sheet extracted from the completed BIM-based intelligent 3D models. Specialized templates are also the excel sheets that created for linking with the typical BOQ. The received data template contained the same columns heading to those of the typical BOQ to facilitate the linking process. All data information in the received data template will be automatically reflected in the estimating template capable of deriving unit costs from the custom-built database due to the WBS codes. Automatically generates for the completed BOQ as well as total costs. Linking between two excel workbooks is a simple process, and it is sufficient for the estimators to implement in their building construction project to get accurate results and time-saving, as shown in table 1.

V. RESULTS AND DISCUSSIONS

This study presents a BIM algorithm that is the method of QTO to export the quantities of the building part from the BIM application to Microsoft Excel for the standard BOQ output. This BOQ provide unit price, so it requires a custom-built database and specialized templates to fulfill these gaps. These data then will be transferred to the estimating template that automatically generates a completed BOQ and total costs. The created mechanism provides a simplified, fast and accurate process because it need only a BIM application, Microsoft Access and Microsoft Excel, not requires for interoperating with estimating software.

Table 1: the results of estimating costs produced by BIM Based Quotation Generating on Structural Framework

Descriptions	Area (m^2)	Formwork Area (m^2)	Volume (m^3)	Reinforement (Ton)	Cost Per Square Meter (USD/m^2)	Amount (USD)
SUPPER-STRUCTURE						
3th Floor	432.18	1366.32	166.38	29.27	*118.43*	$ 51,184.30
5th Floor	432.18	1366.32	166.38	29.27	*118.43*	$ 51,184.30
6th Floor	436.40	1370.14	165.07	24.45	*107.20*	$ 46,781.80
7th Floor	432.17	1379.54	188.01	27.96	*116.74*	$ 50,451.40
8th Floor	436.40	1370.14	165.07	24.45	*107.20*	$ 46,781.80
9th Floor	432.18	1361.20	164.18	24.38	*107.66*	$ 46,527.30
10th Floor	432.18	1379.56	188.01	27.22	*115.02*	$ 49,707.40
11th Floor	435.90	1369.14	164.97	23.70	*105.57*	$ 46,019.50
12th Floor	432.18	1348.35	158.44	20.99	*99.74*	$ 43,106.70
13th Floor	435.90	1356.29	159.23	21.05	*99.43*	$ 43,342.90
15th Floor	432.18	1366.71	182.27	24.57	*108.82*	$ 47,030.80
16th Floor	432.18	1348.35	158.44	20.99	*99.74*	$ 43,106.70
17th Floor	436.50	1360.09	161.33	21.06	*99.49*	$ 43,428.30
18th Floor	412.50	1324.87	155.38	22.49	*106.70*	$ 44,014.20
19th Floor	436.60	1352.00	154.05	18.38	*93.45*	$ 40,800.00
20th Floor	432.18	1360.92	176.95	21.89	*102.88*	$ 44,461.40
21st Floor	432.18	1342.56	153.12	18.31	*93.80*	$ 40,537.30
22nd Floor	432.18	1342.56	153.12	18.31	*93.80*	$ 40,537.30
23Ard Floor	430.50	1606.81	237.37	30.40	*132.14*	$ 56,885.10
23Ard Swimming Pool Deck Floor	96.26	129.45	19.97	3.30	*56.22*	$ 5,411.30
23Brd Floor	250.10	1058.27	182.11	17.79	*141.50*	$ 35,388.10
25th Floor	430.40	1437.68	186.49	23.58	*109.52*	$ 47,138.40
26th Floor	429.90	1350.25	150.03	17.78	*93.12*	$ 40,031.70
27th Floor	434.40	1398.17	178.60	21.77	*104.21*	$ 45,270.40
28th Floor	311.36	1240.78	154.84	20.13	*129.14*	$ 40,210.10
29th Floor	398.00	1742.56	266.57	30.85	*150.57*	$ 59,927.80
29th Floor Swimming Pool Deck Floor	94.60	125.53	18.93	3.14	*52.74*	$ 4,989.20
Terrace	213.00	696.94	82.49	10.54	*104.09*	$ 22,171.60
Stair Cover Slab Floor	25.50	53.15	4.28	0.68	*60.73*	$ 1,548.60
SUB-TOTAL: D =	**10898.19**	**35304.64**	**4462.06**	**598.68**	***108.09 $/m²***	**$ 1,177,975.70**

Grand Total Complete Structural Work Cost =	**$ 1,397,100.00**
Total All Area=	**10898.19 m²**
COST PER M² =	**128.20 $/m²**

VI. CONCLUSION

Through theoretical research and case study with the real construction project, BIM based on simplified approach for automatically estimating building costs based on BIM 3D intelligent objects that integrates with Shared Parameter, Revit Families, Revit DB Link, custom built data and specialized template. This method created a custom-built database on that contains WBS specifications and unit costs. The developed objects that are created in a BIM tool is the schematic database, which will support the 3D building models in order to produce a typical BOQ with a higher accuracy. The process is completed by creating the specialized template to link with the typical BOQ and search for the labor and material unit cost from the custom-built database that automatically generates the completed estimating BOQ as well as total costs. Resulting from this research, a simplified but essential cost estimating algorithm is created for bill of quantities to implement and prepare estimating cost on their building construction projects.

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