Optimization of the quantity take-off (QTO) process for Mechanical, Electrical and plumbing (MEP) trades in tender estimation phase of the construction projects

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ABSTRACT

Nowadays, many leading construction companies are still using 2D drawings, Microsoft Excel or other spreadsheet programs to prepare tenders regarding MEP trades. 2D drawings are scanned and the quantities of commodities are extracted and imported into spreadsheet programs. This method is not accurate and transparent. In addition, too much time and effort is required to keep these files up to date. On the other hand, the variety of other solutions are developed to help estimators for a more accurate and transparent cord calculation. Building Information Modelling (BIM) is one of the solving methods. Nowadays, BIM is applied for many of the construction projects, and its usage is growing up worldwide. Truly BIM has been used for Visualization, Clash detection, building design and very more other tasks in building industry; however, its acceptance for quantity take off (QTO) and following, tender estimation is limited. Currently, not too many quantity surveyors (QS) are using BIM as normally a detailed building model is not available in the very early stage of a construction project. This research work is done to develop a new workflow to use BIM for QTO regardless the availability of a <u>detailed</u> Building model. It's tried to create some logics which simulate the required quantities of the commodities. These logics can be based on defined norms and standards or be created according to the reached experience of QS. Subsequently, they will be implemented in RIB iTWO to create the variable wizards. These wizards create a better user interface to be used by QS for QTO.

Keywords

MEP; RIB iTWO; QTO; Building Model; logics

1 Introduction

The National Building Information Model Standard (NBIMS) defines BIM as "a digital representation of physical and functional characteristics of a facility" [1]. In other words, BIM can be defined as the model of a facility which stores specific or generic information about its components as well as its whole lifecycle. Such information can be stored in Industry Foundation Classes (IFC) formats. IFC lets BIM models be transferred easily from one software solution to another one without any problem regarding their format limitations.

The benefits of using BIM and Virtual Design and Construction (VDC) technologies are listed out in many research works which are done within last decade. As example S.Azhar [2] indicates the benefits of BIM as:

- Faster and more effective processes,
- Better design,
- Controlled whole-life costs and environmental data,
- Better production quality,

In addition, A. Khanzode [3] did apply BIM/VDC technologies for the coordination of MEP systems on a $96.9 Million healthcare project in Northern California, USA. The result of this implementation is:

- Labor saving ranging from 20% to 30% for all the MEP subcontractors.
- 100% pre-fabrication for the plumbing contractor.
- Only one recorded injury throughout the installation of MEP systems over a 23,000 square meters project area.
- Less than 0.2% rework for the whole project for the mechanical subcontractor.

- Zero conflicts in the field installation of the systems.
- 6 months saving on the schedule.
- About $9 Million saving in cost for the overall project.

On the other hand, B. Becerik implemented an industry-wide online survey in 2009. According to this survey, mainly BIM is used for visualization, clash detection, building design and as-built model [4].

Figure **1** indicates the result of this survey. As it's shown, just for around 28% of the construction projects, model based estimation is implemented!
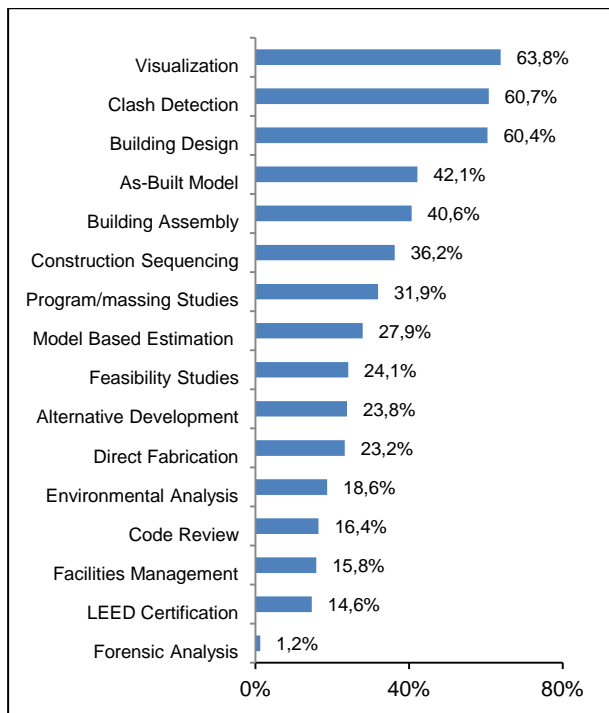

Figure 1: Tasks BIM is used for [4]

So although, BIM has brought too many advantages for construction industry, it's usage for QTO and tender estimation is limited (28%). Moreover, A. Sattineni [5] has conducted a survey of construction practitioners to determine the extent to which estimating processes were automated in the conjunction industry, with the data from a BIM model. Figure 2 demonstrates a comparison of how often survey participants created and used the BIM models for QTO. As it's shown, only 13% of contractors are using BIM models for QTO regarding MEP trades; however, 46 % of them are using Architectural building model for QTO.
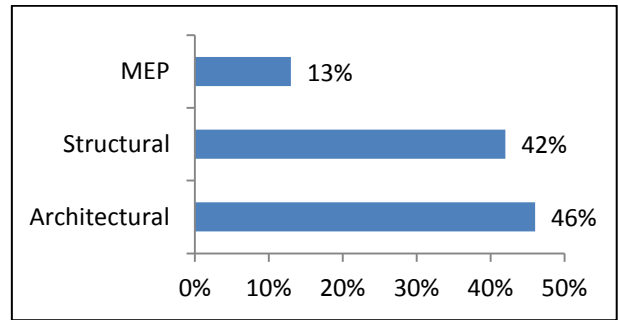

Figure 2: BIM models created by U.S contractors for QTO [5]

Interestingly, A. Sattineni has studied how often the models received from architect or engineer; contain all necessary information to perform a quantity take-off. The result is indicated in Figure 3. As it's shown, just 22% of received models are fully qualified to be used for QTO regarding MEP trades.
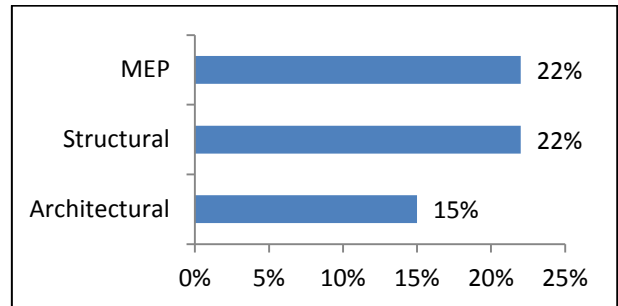

Figure 3: Completed received model from Architect or Engineer [5]

So obviously, mostly contractors are unable to use the models for estimating purposes, as provided by their design counterparts and QTO process cannot be limited to the 3D model.

Within this study, firstly some logics and relations are defined and developed to count the quantities of used commodities in a project when no building model is available. They can be created based on available norms and standards or according to the reached experience of QS. As much as these logics are accurate, the QTO and subsequently the estimation will be accurate. Following, these logics will be implemented in the available software solutions to have a better user interface. For this purposes, RIB iTWO is used and based on developed logics, some variable wizards are created. Basically, these wizards are same with the defined logics with this difference that they can have a better interaction with user. Shortly, theses wizards are created to request necessary information from the user, analyze them and finally print the best answer.

For this research work, a virtual industrial building is selected. Following, the above mentioned logics, for

the used lamps and radiators in this pilot project are defined and developed.

2   Preparation of the building model

As it's shown in Figure 4, this study is focused on South-west part of a virtual industrial building where MEP equipments are modelled.

This building model is created by StabiCAD which is run on Revit MEP platform. By StabiCAD, there is this possibility to select the exact production lines from its database to draw MEP equipments. As the result, the exact geometry and properties (the ones that are published by manufactures) of the drawn equipments are available in the created BIM model.
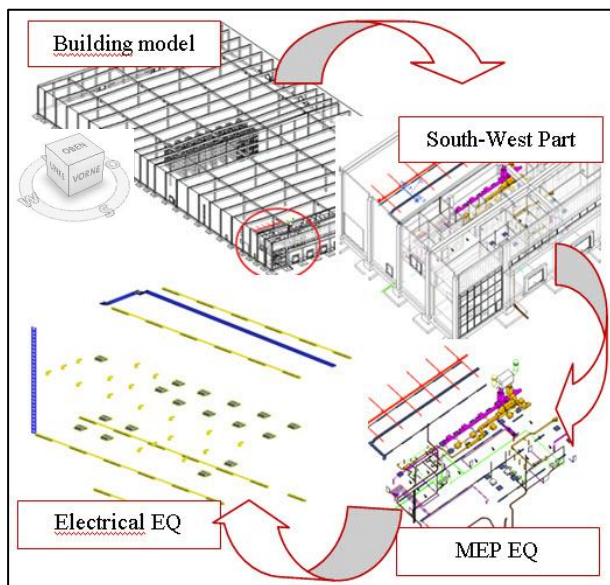

Figure 4: Building Model [6]

"The length of the bidding period (time between the invitation to tender and the closing date) typically varies from four to eight weeks"[7]. In this short period, it's not possible to create a detailed model. Obviously by increasing the available time, more detailed building model can be created. So in the first step, it's necessary to define the detailed level of the tender models. According to figure 2, less amount of logics and content should be developed in accounting software solutions, if more detailed tender model be available. On the other hand, much more work is needed to be done in accounting software solutions, when less detailed building model is available. Considering the developed contents and logics can be used for all following projects, it will be more efficient to develop once these contents and use them for all on coming projects. In this case there is no essential need to have detailed building

model for MEP trades in tender estimation phase, although a detailed model always help to have a more transparent and accurate result in tendering and all other oncoming phases of a construction project.
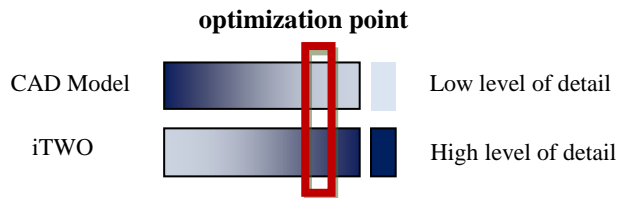

Figure 2 - optimization point [6]

3   Quantity take-off for the modelled lamps

One of the Prerequisite steps before preparing tenders is to take off the quantities of all equipments and materials which will be used in the construction project. Within this research work, it's tried to take off all required information from the building model regardless its detailed level!

To start this process, the created building model is imported into RIB iTWO. Figure 5 indicates the imported electrical commodities.
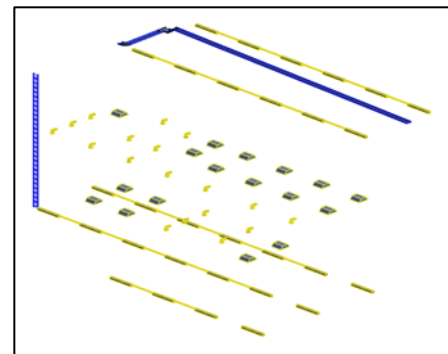

Figure 5: Electrical Equipments

As the created BIM model contains the exact properties information of drawn articles, these properties information are available in RIB iTWO as well. Three different production lines for lamps are available within the BIM model. They are defined in Table 1 and shown in Figure 5.

Table 1: Production lines

Lamps	Production line	Manufacture
Down light	Panos	Zumtobel
LED Fluorescent	E-Line T-5	Trilux
General	GentleSpace gen2	Philips

Following, these three production lines are categories in three different groups since they have different unit costs. In general, all equipments with same unit price and same unit of measurements will be placed in one category. This task is done by the help of search sets in RIB iTWO. They are written based on imported properties. Figure 6 indicates a sample search set. With defining a standard template, these search sets can be exported as an .xml file and used for all other oncoming projects.

Figure 6: Written query for a search set

This query first picks up all equipments which are modelled in Electrical layer (358 = electrical). Then it searches for all equipments which their Revit category name is "light". In the next step, all articles which their Revit family name is "general light" are selected. It should be mentioned, within this query,"and" condition is written. It means the selected articles have all the written conditions.

Figure 7 shows the result of each search set for available lamps in the model. They are down light lamps, General lamps and LED Fluorescent lamps as mentioned in Table 1.
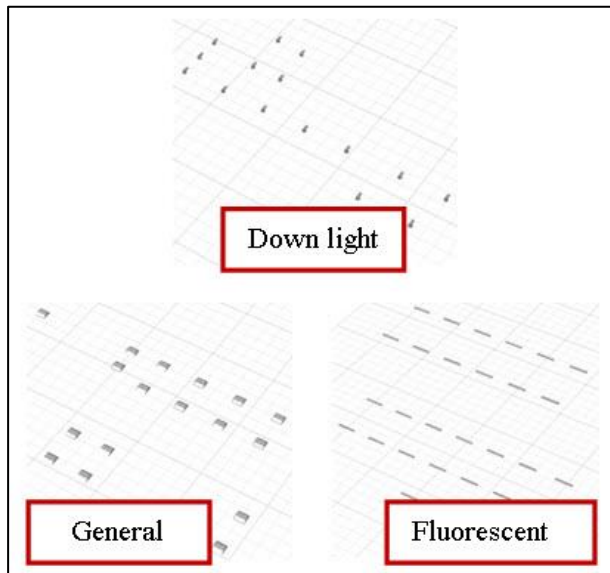

Figure 7: The Lamps

After categorizing the commodities, it's turn to create work items. Each category of commodities has to be assigned to a work item. Work items can be created in one project (master project) and be saved in iTWO database. In this way, they can be used for all oncoming projects. It should be mentioned, work items can be defined for all equipments regardless being available in the 3D model or not. When a work item is created, its relative search set will be assigned to it. As the result, the work item perceives its assigned articles. Then a question query should be written. This query will ask about the quantities of the equipments which are assigned to the work item. Figure 8 indicates a question quarry which is written to take off the number of lamps within each search set.

Figure 8 : A sample question query

Within this question query, QTO refers to quantity take-off. This query counts the number of equipments which are assigned to a work item and its unit is stuck. If it be necessary, other queries can be written to take of the length, area or volume of their assigned commodities. As the result, the quantities of commodities (Stuck, Length or volume) in each search set are counted automatically. In other words, the quantities of the articles are extracted from the model and by linking the unit price, cost can be calculated.

4 Quantity take-off for not modelled lamps

Now it's desirable to find out the quantities of lamps which are not modelled. It can be done by the help of variable wizards in RIB iTWO. Figure 9 shows the logic which is defined to calculate the quantities of such lamps. In the defined variable wizard, the first question is if a building model is available or not. If the answer be "no", the user is requested to select the type of room or area. The available options to be selected and their standard illumination level (Lux) are shown in Table 2[8].

Table 2: Light level [8]

Activity	Illumination (lux)
Public areas with dark surroundings	20 - 50
Working areas where visual tasks are only occasionally performed	100 - 150
Homes, Theatres	150
Easy Office Work	250
Normal Office Work, PC Work,	500
Supermarkets	750

Then the used up production lines are going to be queried. Some limited production lines (the ones which were mostly used in previous projects) are defined in the database of each variable wizard. One of these products can be selected for estimation.
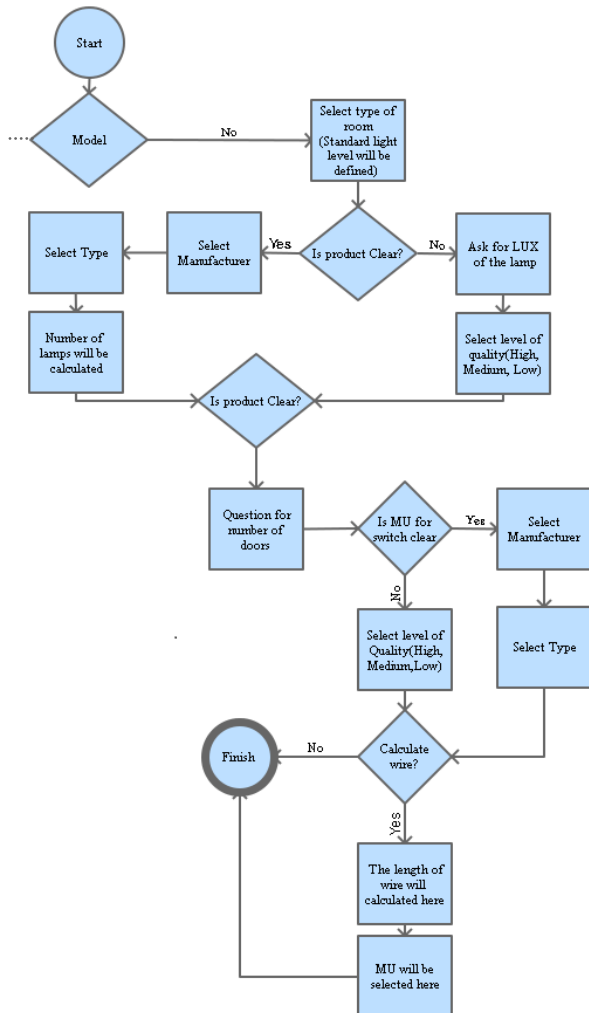

Figure 9: Quantity takes off for lamps (without model)

Within the next step, according to the standard illumination level of the area and the standard Lux for each lamp, the quantities of the required lamps will be calculated. Figure 10 indicates a part of the variable wizard for this pilot project. This wizard can be assigned to different work items. By selecting one work item, the wizard will be opened automatically.

As it's shown in Figure 10, there is no geometry data for this work item (lamp) in the model. So the "model available" option is not selected. Following, the type of area is selected as "supermarket" which should have 750 lux (*lumen/m²*) light level according to Table 2.

Moreover, the Lux level of each lamp is available in their commodity catalogs in iTWO. With assumption of 30 Lux for this downlight lamp, 25 lamps of this specific type will be required for the mentioned supermarket.

Figure 10: Quantities of lamps

Moreover, according to each production line, more necessary options can be presented. Such as example, within Figure 11, E-Line T-5 from Trilux is selected as the used lamp in our construction project. It's known, when E-Line t-5 is going to be applied, DIN rails should be used between the lamps as well. This logic is defined within the database of the wizard. So another filed will appear and user will be requested to select the type of DIN rail. Then the image of selected DIN rail will be shown.

Figure 11: Available options in the variable wizard

On the other hand, in the very early stage of a construction project, usually user has no information regarding the type of lamps which will be implemented in the project. So a variable wizard can be developed to help users in this case. This is indicated in Figure 12.

As it's shown, a drop-down list can be appeared and user be requested to select a category of lamps. For example, for this study, there categories are defined.

They are:

- Expensive or high quality lamps
- Middle quality lamps
- Cheap or low quality lamps.

Then the unit price can be assigned to each category and later on, the cord calculation be generated.
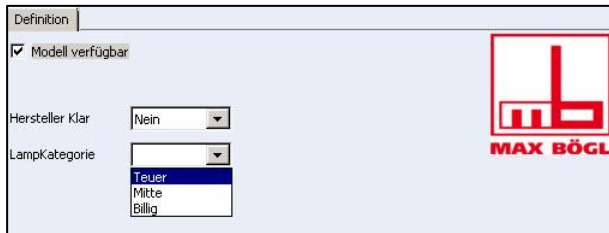

Figure 12: Categories of the lamps

So shortly as it was discussed, variable wizards can be used, firstly to take off the quantities of the required lamps when no building model is available and then assign a production line or a category of lamps to each work item.

5 Quantity take-off for not modelled radiators

The QTO for radiators which are modelled are quite similar to QTO for modelled lamps. In this section, it's explained how variable wizards can be used to count the required number of radiators when no building model is available. So a variable wizard is created and shown in Figure 13.
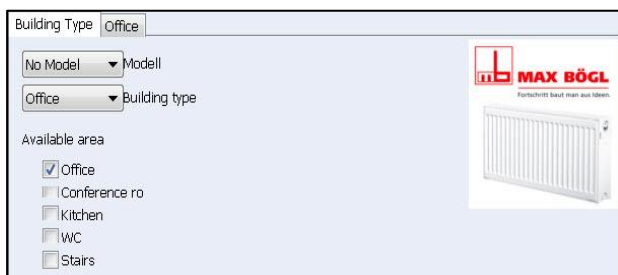

Figure 13 : Variable wizard for radiators

As it's indicated in Figure 13, firstly the user is asked if a model is available. For this case, no geometry model is available so "no model" is selected from drop-down box. Following, user is able to select a building type. The possible selections are Offices, Supermarkets, schools and houses which can be selected from drop-down box. When office building is selected, variable wizard suggests different available areas within an office building. They are office rooms, conference

rooms, Kitchen, WC and stairs. These areas are sub-divided since their standard thermal level can be different!

Once user does select office areas (selecting the check-box), a new tab will be shown. It's called"office" and the required number of radiators for all office areas will be calculated there. The view of this tab is shown in Figure 14.
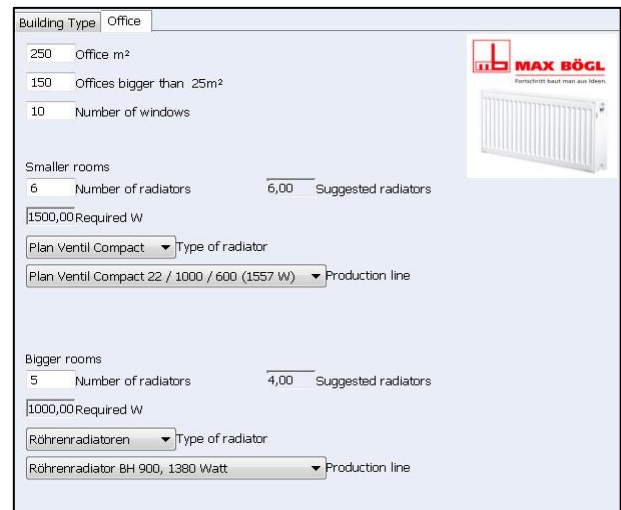

Figure 14: Number of radiators for offices

As it's indicated, firstly the user is requested about the total size of the office areas. Since a building model is not available, user has to import such information manually. Here, in Figure 14, 250 m^2 is imported as the total size of office areas. For the case if a building model be available, the size of office areas will be requested directly from the model and pasted in the variable wizard. It can be done by available question queries in RIB iTWO. These queries are written once and will be used for all oncoming projects.

Since the standard thermal level of bigger office rooms is smaller than the standard thermal level of smaller ones, two different categories of offices are defined. They are:

- Offices which are bigger than 25 m^2
- Offices which are smaller than 25 m^2

It's assumed the standard thermal level for small office rooms is 60 W/m^2 and for bigger ones is 50 W/m^2. Following, the total size of big offices are imported. For this example, 150 m^2 of all office areas are belonging to offices which are bigger than 25 m^2.

Moreover, normally, radiators are installed under the available windows within a room or area. So it can be assumed, the total number of required radiators are the same with total number of available windows in a room. As the result, subsequently, the user is requested to

import the total number of windows. It should be mentioned, if a building model be available, these number can be requested directly from the model and pasted within variable wizard. For this example, 10 windows are available in all office areas. So according to the ratio of the office sizes, variable wizard has suggested six radiators for smaller offices (smaller than 25 m^2) and 4 radiators for bigger ones. User can decide to accept the suggested numbers or not. In Figure 14, the user has accepted the suggested number of radiators for small offices; however he has chosen five radiators for bigger offices.

Subsequently, according to the number of radiators, the standard thermal level of the area and the size of each category of offices, the minimum required amount of watt (W) for each radiator is calculated and shown. Following, the user is requested to select the production line of radiators which is going to be used in the implementation phase of the project. Firstly, a category of radiators should be selected. It can be chosen from drop-down box. According to the German market, following categories are defined in the database of the variable wizard.

- Convectors radiators
- Plan Valve Compact
- Profile Valve compact
- Column radiators

Subsequently, a production line should be selected. For each category of radiators, around 10-15 different production lines are defined and user will be request to select one of them. Interestingly, the production lines which produce less amount of calculated watt will not be shown to be chosen.

Following, when a production line is selected, automatically it will be shown in the bill of quantities. Such as example, in Figure 15 two production lines of radiators from plan valve compact and column radiators are activated since they are selected from variable wizard. The production lines from other categories of radiators are inactivated since they are not selected from variable wizard.

	60		Radiators
	60.10		Unterflurkonvektoren
	60.20		Plan Ventil Compact
	60.20.40		Plan Ventil Compact 11 / 1000 / 600 (882 W)
	60.30		Profil Ventil Compact
	60.40		Röhrenradiatoren
	60.40.20		Röhrenradiator BH 1800, 2595 Watt
	60.50		Konvektoren

Figure 15: Bill of quantity for radiators

This variable wizard is developed to help estimators when no building model is available or when it's not clear which production line will be used. By selecting one of the most common production lines, more accurate result can be achieved.

6   Conclusion

Nowadays, BIM has applied for many of the construction projects and its advantages are seen. For example, A. Khanzode did implement BIM and VDC technologies for coordination of MEP systems on a $96.9 Million healthcare project and the final result was saving $9 Million for the overall project [3]. Moreover, B. Becerik has found, BIM is used mainly for visualisation, clash detection, building design and as-build model; however its usage for model based estimation is limited [4]. On the other hand, A. Sattineni did indicate that only 13% of the US contractors do create a BIM model for QTO regarding MEP trades and interestingly, just 22% of the received models from architects or engineers are qualified to be used for QTO [5]. To sum up with it, it will be true to state, unfortunately, the usage of BIM between quantity surveyors is limited; however very research work about the effect of BIM on construction industry have done and its benefits ,somehow, are discovered. One of the main reasons for the mentioned problem is, normally in the very early stage of a construction project no detailed 3D model is available. With considering BIM is not limited to a detailed 3D model, this research work has tried to develop a workflow to use BIM regardless the availability of a detailed building model. A scenario is developed to use logical relations between MEP systems for QTO regarding used commodities within a construction projects. These logics are developed once and will be used for all oncoming projects. As accurate these relations and logics are, the accurate will be the final reached quantities. Following, when a logic is developed, it will be applied in the available software solutions, and a better user interface will be created. For this research work, RIB iTWO is used and based on developed logics and relations, some variable wizards are created. These variable wizards are used by quantity surveyors when no detailed building model is available. In addition, some of the most common production lines of commodities which were used in the previous construction projects can be added to the databank of the variable wizard. It helps quantity surveyors to pick up the most common production lines which will be used later on in the implementation of the construction project. In other words, by using variable wizards, information phase of B*I*M can become specific. Moreover, different versions of tender based on different used commodities, can be prepared and sent to client. As the result, in a very shorter time frame more accurate estimations can be generated.

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