CLOUD BASED BIM SOLUTION FOR TENDER ESTIMATION REGARDING MECHANICAL, ELECTRICAL AND PLUMBING (MEP) Trades

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Abstract: Currently, Microsoft Excel is used in many leading construction companies to prepare tenders regarding Mechanical, Electrical and Plumbing (MEP) trades. Normally, 2D drawings with reference to MEP parts are read and the quantities of such articles are taken off manually. The reached quantities are imported into Excel sheets and following, the unit cost per each article is imported as well. Subsequently, the tender regarding MEP equipment is prepared. Obviously, this method is not accurate and transparent. Moreover, when a drawing is updated, the complete process should be repeated. Furthermore, there is a countless number of articles in MEP industry and without an integrated platform, it's not possible to manage them. Storing such amount of information (local storage) will lead to many operational problems for the used software solutions. So it's desirable to use cloud based BIM firstly to improve the transparency and accuracy within tender estimation phase and secondly to increase the operation speed of the related software solutions. For this study, a pilot project in cooperation with Max Boegl group, RIB and StabiPlan was implemented. StabiPlan provides a platform to create a 3D model with the exact properties information for most MEP articles. Then the created 3D-model is imported into RIB iTWO to prepare the tender. Moreover, a server is established to store properties information regarding each article. Following iTWO MM (material management) and iTWO TX (tender exchange) modules are going to come into account. They will create an e-platform to transfer sub-tenders between main contractor, subcontractors and wholesalers.

1 INTRODUCTION

At the moment, many leading construction companies are still using Microsoft Excel for cost estimation regarding MEP Trades, instead of software solutions for tender calls, allocation or accounting. This method cannot be the only possibility and does not cover the full potential for process management. Nowadays, usually there are a lot of changes during tendering/planning phases of a construction project. These changes lead to a lot of reworks regarding updating the Excel sheets (Rajabi & Bigga 2015). On other hand, implemention of BIM for coordination of MEP trades has saved a lot of time and decreased the cost for their installation (Khanzode, Fischer and Reed 2008) but unfortunately, currently BIM is not increasing the quality of estimates or decreasing the time required for cost estimating for large contractors and only a small number of contractors are using BIM to automate estimating processes. (Sattineni & Bradford 2014).

To find out how BIM can improve cord calculations, it's necessery to study the effect of BIM on accuracy and precision of estimates (Nassar 2008). Here, it is tries to increase the accuracy of estimates by using
BIM (not just 3D model) for quantities take off and it’s believed the precision of them can be increased by using specific information rather than general information in information part of BIM.

Within this study, a 3D model is created. The articles within this model have the same properties and article numbers which are published by manufactures (specific information). Following, the model is imported into RIB iTWO and the necessary search sets are created. These search sets are written based on imported properties and can be used for all incoming projects. Then a scenario is developed to create a master data platform. Considering the size of stored data, it’s desirable to keep them on cloud. The master data is created based on received Excel sheets from different wholesalers. These Excel sheets should be edited in such a way that a match key for each article can be created. Following, iTWO APIs (application performance interface) will come into account. By the help of APIs, a virtual version of commodity catalog and cost code catalog for each article will be created. As the result, there will be no issues regarding operation speed of the software since the data are stored in cloud.

Finally a content is going to be developed which automatically extracts data from a building model for later use in the cost calculation phase. The required data is collected from the CAD platform, and will be processed in iTWO. Moreover, the detailed level of the model, regarding articles and the level of content which should be developed in iTWO will be studied. In other words, the goal is to create a content which works smoothly with or without availability of the detailed building model (Rajabi & Bigga 2015). Following, the extracted quantities will be linked to the created database and the primary estimation will be created. Within the next step, the created bill of quantities (BOQ) will be sent to different wholesalers and their prices will be requested. This task is going to be done by iTWO MM (material management) module. Moreover, by the help of iTWO TX (Tender exchange) module, the BOQ will be sent to different subcontractors as well. Finally, according to the reached price information from Wholesalers and subcontractors, the tender is going to be estimated.

For this study, a pilot project in cooperation with Max Boegl group, RIB and StabiPlan is defined and according to the reached result, it will be tested in a real case study. Moreover, it should be mentioned that the reader would have basic knowledge regarding RIB iTWO since this software solution is used as the basis for this research work.

2 PREPARATION OF THE BUILDING MODEL

A virtual industrial building is chosen for this pilot project. As it’s shown in figure 1, this study is focused on South-west part of the building where MEP articles are modeled.

![Building model](image)

Figure 1- Building Model

This building model is created by StabiCAD which is run on the Revit MEP platform. There is a possibility to select the exact production lines regarding MEP parts which are going to be used within this pilot project. So as the result, the exact properties are imported into iTWO. That’s important, since the search sets within iTWO are going to be written based on these imported properties.
Moreover, the length of the bidding period (time between the invitation to tender and the closing date) typically varies from four to eight weeks (world health organization 2015). In this short period, it’s not possible to create a detailed building 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 iTWO, if more detailed tender model is available. On the other hand, much more work is needed to be done in iTWO when a less detailed building model is available. Considering, developed contents and logics in iTWO can be used for all incoming projects, it will be more efficient to develop once these contents and use them later on for all incoming projects. In this case there is no essential need to have detailed building model for MEP trades in tender estimation phase (Rajabi & Bigga 2015), although a detailed model always help to have more transparent and accurate results in tendering and all other phases for a construction project. (Suermann and Issa 2007)

**optimization point**

<table>
<thead>
<tr>
<th>CAD Model</th>
<th>Low level of detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>iTWO</td>
<td>High level of detail</td>
</tr>
</tbody>
</table>

![Figure 2 - optimization point (Rajabi and Bigga 2015)](image)

## 3 DEVELOPING THE CONTENT IN iTWO

One of the Prerequisite steps before preparing tenders is to take off the quantities for all articles and materials which will be used in the building project. Within this study, it’s tried to take off all required information from the building model regardless its detailed level. Following, two different situations are taken into account. Within the first one, MEP commodities such as example radiators, are modeled and their quantities can be taken off directly from the building model. The second Scenario is applied when no radiator is available within the model. Within this situation, a logic is going to be developed to estimate the required number of radiators.

### 3.1 Quantity take off for modeled Radiators

To start this process, the created building model is imported into iTWO. Figure 3 indicates the imported heating articles.

![Figure 3: heating articles](image)

As it’s visible in figure 3, the radiators and their pipes are modeled. So their quantities are available within the building model. To take of these quantities, first of all a search set is defined to pick up all similar articles. Figure 4 indicates the defined search set for a group of radiators. As it’s shown in figure 4, this search set is going to pick up all elements which are modeled in heating layer (359 indicates heating layer
within our internal standard), their Revit category is radiator and are made by one specific manufacture with the same size (405 mm).

![Image of radiators]

Figure 4: a sample search set for a group of radiators

As a result, all radiators with the mentioned properties will be selected and assigned to a work item. It should be mentioned that the search sets can be saved as an .xml file and used within all other incoming projects.

Then a quantity query will be written for each work item. Figure 5 indicates a written quantity query. These queries will count the quantity of the assigned articles to a work item. As example, the written query within figure 5 is going to take off the number of assigned radiators to its work item.

![Image of quantity query]

Figure 5: Quantity Query

3.2 Quantity takes off for radiators which are not modeled

A logic should be developed to estimate the number of required radiators for a room. It will be discussed in figure 6. Other logics can be defined and implemented within iTWO database as well. These logics can be reached from defined Norms and standards or can be written according to the internal reached experience of contractors. Once the logic is defined, there will be no problem to implement them within variable Wizards in RIB iTWO. Variable wizards are a kind of assistance which can be used in complex situation to take off the used quantities of an article. Within this research work, variable wizards are used to find out the quantities of articles which are not modeled. As it's shown in figure 6, if radiators are not modeled, the user will be asked to define the type of area. Three different room types are defined within this variable wizard. They are offices, supermarkets and living rooms. Table 1 indicates the standard thermal level for each of these room types. It should be mentioned, according to the isolation level, these variables can be changed. These conditions will come into account when the basics of the defined scenario are checked and their performance is proofed.
Subsequently, the size of area will be requested. This information can be extracted directly from the architectural model and pasted into the variable wizard. This task is done by writing a quantity query to calculate the area of the room.

![Diagram](image)

**Figure 6: Developed logic**

<table>
<thead>
<tr>
<th>Type of Area</th>
<th>Standard thermal level (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>X1</td>
</tr>
<tr>
<td>Supermarket</td>
<td>X2</td>
</tr>
<tr>
<td>Living room</td>
<td>X3</td>
</tr>
</tbody>
</table>

Table 1: Standard thermal level

The calculated area will be assigned to a key and the amount of this key will be shown within created wizard. Following, according to the size of area and its standard thermal level, the required amount of heat will be calculated. As an experimental experience, usually, radiators are installed under the available windows within the room. So it can be assumed, the number of radiators could be the same with the number of available windows. So by counting the number of windows, the quantity of the required radiators can be calculated. When an architect model is imported into iTWO, all doors and windows are known as an open area. So it’s enough to search for open areas within a room. By defining some limitation about the size of the open area, doors can be put out from the search set. Then by dividing the required amount of heat by number of radiators, the capacity of each radiator will be subtracted. Moreover, it’s possible to define the most important production lines within the database of the assistance. So according to the required amount of heat, the correct radiator will be suggested to the user. In addition, one check condition can be defined as well. It’s clear the length of installed radiators should be shorter than the length of their relevant windows. So the length of the window can be asked from the building model and be shown within the defined wizard. As the result, user will be warned about the maximum length of selected radiator. Figure 7 shows the created variable wizard for radiators within this study.

In general, one variable wizard can be assigned to different work items and help them to estimate the quantities more efficient, especially when no geometry data in available. In other words, variable wizards can be used for light calculation and help user to find out the required quantity of a target article. Moreover, they can be used to simulate a complex situation as well. The geometry of such conditions can be shown within a created variable wizard and user can be asked to import necessary parameters. Then, the used articles and their quantities can be gathered within assembly module in iTWO. Finally, the
created assemblies will be sent to the calculation module and the cost for such condition will be calculated.

Figure 7: Variable wizard

4 DATA MANAGEMENT PLATFORM

Usually, within MEP industry, the announcement regarding available articles in the market is done by publishing different Excel sheets. Table 2 shows a sample Excel sheet is published by one of the biggest wholesalers in Germany.

<table>
<thead>
<tr>
<th>Article number</th>
<th>Part</th>
<th>Manufacture</th>
<th>Type</th>
<th>Name</th>
<th>Discount code (%)</th>
<th>Price (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article 1</td>
<td>Electricity</td>
<td>Philips</td>
<td>Lamp</td>
<td>Panos</td>
<td>R5CJ</td>
<td>X</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Article n</td>
<td>Heating</td>
<td>Kermi</td>
<td>Radiator</td>
<td>Therm-X2 Plan-V</td>
<td>N3DC</td>
<td>X</td>
</tr>
</tbody>
</table>

As it's shown in Table 2, these Excel files are organized by different columns. For example, the first column indicates the global article number. It's a code which is specific for each article. In other words, commodities can be recognized by their article number. The second column indicates the category of the articles. Within this Excel file, commodities are grouped into four categories. They are electricity, air conditioning, sanitary and heating. Moreover, the manufacture is indicated in the third column. Then within other columns, type, name, discount code and the price of articles are indicated.

Considering the variety of MEP articles on the market, most probably more than 500000, it's suggested to categorize them in a sufficient way. This will lead to call them later on easier. To do that, one internal standard can be defined. Such as example, the articles can firstly be subdivided according to their main group. Main groups are introduced as: Electro, Sanitary, Heating, Air conditioning and Sprinkler. Next sub group can be manufacturers. Following the type and the name of production lines will come into account. As the result, an internal standard is defined to categorize MEP articles. Following this standard is going to be used to develop a content in iTWO. So a match key should be defined as well. Figure 8 indicates a sample match key.
All information regarding category, manufacturer, type and name of articles are available within the received Excel sheets. So a column can be added into the Excel file and such match key be generated automatically. This work can be done by available functions in Microsoft Excel so no more effort is required to create such match keys. As it’s shown in figure 8, the first part of the key indicates the first two letters of its category. Then the first two letters of its manufacture and its type are written. Finally, the full name of its production line is pasted at the end of the key. Within the next steps, this key will be used to create the virtual commodity catalogs in iTWO and following, their cost codes will be attached to them. Subsequently, these commodities will be linked to a master BOQ and an intelligent platform will be created to estimate the tenders.

4.1 Creating Virtual commodities

Following, a cloud or server will come into account. This cloud will act as a database and all Excel files are sent by wholesalers will be uploaded there. It should be mentioned, uploaded Excel sheets are prepared in the same format as was discussed above (Table 2) with added one more column which indicates the match key for each article. On other hand, RTB is requested for iTWO APIs. These APIs are going to be used to create virtual commodity catalogs within commodity module in iTWO. Figure 9 indicate its developed scenario.

As it’s shown in figure 9, firstly the received Excel files are uploaded into cloud. Different property information regarding articles could be available within these sheets; however, information regarding name, price, category, manufacturer, type and match key should be included. According to the match keys, a structure will be created in commodity module. This is done by iTWO APIs. Such as example, as it’s visible in figure 9, within commodity module, a folder for category of electricity is created. Then within this folder, a subfolder for all Philips products are made. Following a subfolder for lamps is created and a virtual commodity catalog is pasted there. It should be mentioned, whole of this process is done automatically and if one folder or subfolder is available already, it will not be duplicated. Finally, name, Price, discount rate and match key are linked from uploaded excel file into the created virtual commodity catalog. Considering the number of created commodity catalogs, it’s suggested to keep the source information in cloud and copy just a virtual version of them into the software. It lets to increase to operation speed of the program.
4.2 Cost codes

Usually each construction company has its own price information regarding installing MEP equipments. Such information can be added to the received Excel file from wholesalers. As the result, within these Excel files, price information for each article as well as their installation cost will be available. Similar with commodity catalog, such virtual cost code catalogs will be created based on defined match key. Following, by using iTWO remote control (API), each cost code catalog will be attached to its relative commodity catalog. As the result, price information for installation of each equipment will be available within its commodity catalog (Rajabi 2015).

4.3 Master bill of quantity

Subsequently, within “work item” module in iTWO, a master BOQ will be created. The same structure like commodity catalogs and cost code catalogs will be used to establish the mentioned master BOQ. As the result, per each available commodity, one work item will be available. Figure 10 indicates the defined scenario to create such master database.

Within the next step, the commodity catalogs will be attached to their relevant work item. It will be done by iTWO APIs. The defined match key is going to be used to create such links and all process will be done automatically. As the result, a master bill of quantity is created and the unit cost per each article and its installation cost are attached to its relevant work item.

The created mater BOQ will be copied for all incoming projects. For work items which are used within the project, their quantities will be taken off. Quantity takes off can be done directly by counting the articles within building model (if they are modeled) or using developed variable wizards if the articles are not modeled. After assigning the quantities to relevant work items, the project specific BOQ will be created. Within this bill of quantity, the only work items which have been used within the project are listed. Considering the related commodity catalog has been attached to each work item, easily the primary cost regarding MEP trade will be estimated. Following, MM and TX module in iTWO will come into account and more accurate price is going to be calculated.

4.4 TX and MM modules in iTWO

Figure 11 indicates the general overview of tender estimation process in iTWO. In the first step, the building model is imported and the quantities of articles are found out. Moreover, by developing variable wizards, the quantities of articles which are not modeled, can be found out as well.
Then the quantities are copied into created BOQ and will transfer into calculation phase. Within TX module, according to the reached BOQ, subcontractors will submit their prices for equipment's installation. These prices can be just the installation rate, or it can include the cost of articles as well. In the other hand, by the help of MM module, the list of needed articles will send to different wholesalers and the cost of them will be asked. One of the main benefits of this method is to have more discounts since more quantities of articles are bought directly by main contractor. In addition, MM and TX are run on e-platform so all process is done electronically. This leads to save time which is an important factor within tender phase of a construction project. Then other kind of cost such as cost for devices, salaries and etc. will come into account. With considering all different kind of costs, the tender will be estimated and sent to client. (Rajabi & Bigga 2015).

5 CONCLUSION

Within this study, a platform is developed to take off the quantities of the used articles from a building model. Two different scenarios were studied. Within the first one, the target articles are drawn and they are available within the building model. In this case, by writing quantity queries, their quantities will be abstracted directly from the building model. The second scenario is applied when no geometry data regarding the target article, is available within the building model. In this case, a variable wizard is developed to estimate the required quantity of the used article within the construction project. In addition, a platform is developed to prepare tenders regarding MEP trades. Considering the format of received Excel sheets from wholesalers, table 2, a match key can be created. This key is generated according to the category, manufacturer, type and name of each article and is passed within a new column in the Excel sheet. Creation of such keys is done by available functions in Microsoft Excel. Following, the edited Excel sheets are uploaded into a cloud or server. This cloud acts as a database to store information regarding all MEP articles. Considering the number of available MEP articles in the market, it’s recommended to store such information within a cloud. Then, the virtual commodity catalogs within the commodity module in iTWO are built and the created cost codes within the cost code module are copied into these catalogs. Following a master BOQ is generated and the commodity catalogs are assigned to their relevant work items within the above mentioned BOQ. This master BOQ is copied for all incoming projects to estimate the primary cost regarding MEP equipment. Within next step, iTWO MM and iTWO TX come into account. They create a platform to share the created BOQ with subcontractors and wholesalers to request their prices. According to the received prices from sub-contractor and wholesalers, the tender is estimated and then sent to the client.
The above mentioned platform can be operated very fast and prepare the tenders within a very short timeframe. Moreover, its transparency and accuracy is quite high. In addition, it’s done fully automatically and human errors are eliminated. Furthermore, it can manage probable changes within the design phase and new price estimations can be regenerated very fast.

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