Empirical Research on BIM Application for Cost Estimation of HVAC System in Buildings

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Abstract— Building information modeling (BIM) is considered as a major trend of the construction industry in the future. In traditional way for estimating the cost of the HVAC system in buildings, a lump sum method is adopted as a rough approximation. Instead of detailed quantity calculation, the lump sum method often result in inaccurate total cost and quantities. The purposes of this study is to promote the BIM to the owners and MEP designers. This research found that the BIM software needs to be updated and revised. By building detailed HVAC system components of a completed public office building, the overestimation of HVAC budgets has been revealed in the case study. The contractor has earned an extra profit about 3.9% of the total project cost due to the overestimated quantity of HVAC components in the building.

Keywords—HVAC system; BIM; lump sum; quantity; cost estimation.

1. INTRODUCTION

The Heating, Ventilation and Air Conditioning (HVAC) system is an important link in the building electromechanical system. "Lump-sum" is one of the types of construction payments. BIM can calculate the quantity of materials, and also can improve the Lump sum of the defects of pricing. But for now, BIM for thequantity of mechanical and electrical engineering calculation and evaluation of capacity also need to beassessed. If BIM has this study attempts to construct a BIM model of HVAC system for case study. This study analyzes the accuracy of the BIM model output to the quantity and amount of the HVAC system, comparing the amount of Lump sum in the contract.

2. CASE STUDY

2.1 Case study introduction

The steel structure buildings project case study is "North Emergency Operation Center". This case was completed in January 2013, underground construction of two floors, one floor of the isolation layer, the ground to build nine floors, the total floor area of 18896m^2. The cost of the project is NT $ 1,156.55 million, including NT $ 126,250,000 for mechanical and electrical system. The NEOC building has public bath facilities, laundry facilities and staff restaurant facilities, the quantity of HVAC system needs higher,

Table 1. The amount of NEOC HVAC system (NT $)

	Budget	Completion Amount
(a) Total mechanical and electrical engineering costs	129,505,646	126,245,113
(b) HVAC system construction costs	33,302,968	33,022,647
[(b/a)*100%]	25.7%	26.2%

Table 2 HVAC equipment engineering amount

Item	Budget(A)	Completion Amount(B)	Tender discounts[(B-A)/A]
Machine	12,409,471	12,315,008	-0.8%
Foundation and shockproof	1,029,946	1,016,361	-1.3%
Wind pipe	5,346,294	5,262,478	-1.6%
Pumping	6,722,775	6,639,172	-1.2%
Electronic	1,654,860	1,655,900	0.1%
Automation control	3,277,648	3,271,754	-0.2%
Cooling water control	523,474	523,474	0.0%
Silencing Engineering	1,656,916	1,656,916	0.0%
Base isolation hose equipment	196,160	196,160	0.0%
Machine test	485,424	485,424	0.0%

million Taiwan so the HVAC system facilities project cost of 17.52 dollars. The amount of budgetreduction 40% in the case of the design of the tender phase. The budget gap is not large difference with completion phase and the tender phase of this case, therefore, the object of this study is the amount and quantity of project bidding stage.

Fig. 1. South Emergency Operation Center building appearance

The BIM software Revit outputs details in this case of the HVAC system engineering as shown in table 2, it is for the scope of this study. The table 1 total cost is 126,245,113 NT $, accounted for 26.2% of the HVAC system engineering. It is means that the BIM can be imported after a detailed estimate of HVAC system.

Fig. 2. Case building structure model

3. BIM MODEL BUILD AND QUANTITY OUTPUT

This study uses Autodesk Revit 2014 software. This version of Revit also includes the functionality of MEP, which means it can build mechatronic systems facility with the same software. In this study, the BIM model foundation is provided by the design unit to provide the building plans and HVAC system design. To build building Structure Model and HVAC system Model.

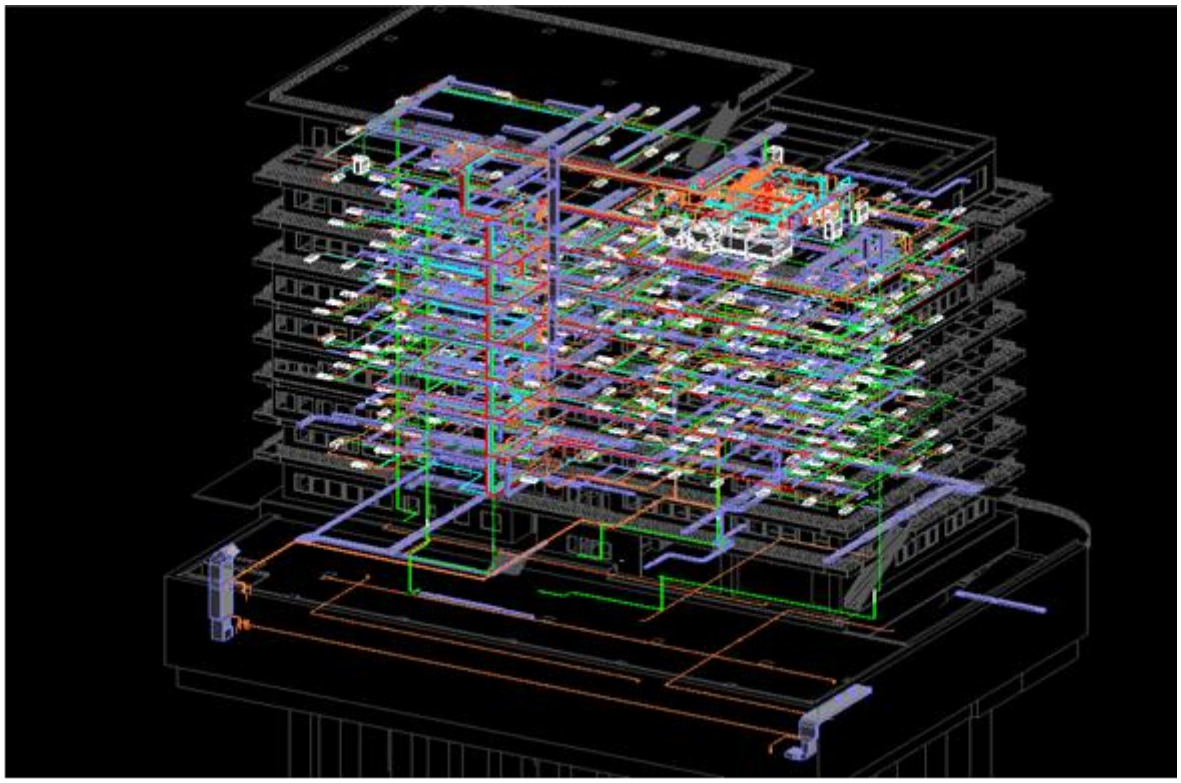

Fig. 3. BIM model of HVAC system

3.1 Quantity output of HVAC system components

In Revit, the general components such as faucets, toilet showers and other facilities are a single cost. It means that an components can only have one price. In the Revit software, it is not easily to enter different unit prices for different sizes, including Routing and Type parts such as HVAC and components. The main reason for the routing components is the family system. It is the same price with the same material in different sizes or length of the pipe in Revit.

3.2 Quantitative analysis of air conditioning system

There are two major projects included in the HVAC system plumbing engineering. The two items are the pipe fittings and the other parts, the table 3 shows the quantity of galvanized steel pipe and hot water stainless steel pipe, the quantity of PVC pipe drainage, the quantity of ice water and hot water pipes of the detailed list.

The main reasons for this study are summarized as follows:

1. The traditional calculation of the design unit is to enlarge the quantity and length of the pipe by the rule of thumb. The traditional way will cause a quantity of errors. And in order to reduce the risk, the design unit will try to avoid underestimating. Therefore, the results of traditional methods of valuation, the design unit is generally overestimated amount and quantity.
2. The results of this study shows that the output of the diameter 50mm of the drainage pipe is higher than that of the BIM output results by 167%. After comparing with the original design, it is found that the reason is that the design unit is seriously underestimated by the drainage pipe.
   In the HVAC drainage system, there are 5 50mm drainage pipe, the 50mm of the drainage pipe is through the whole building drainage pipe. The two layer underground extends to the ground floor of each 50mm drainage pipe, the total height is 47 meters.

Table 3 Comparison of the amount of material and parts for pipe.

Item	BIM output price A	Contract price B	Difference amount (A-B)/B
Duct sheet	753,098	476,414	-37%
Water pipe	1,366,726	1,081,782	-21%
Tube and cable	239,163	139,535	-42%
Pipe fittings	411,095	136,917	200%

Table 4 chilled and hot water pipe quantity list

Size	Unit	Quantity	Unit price	Total price	Revit output quantity	Revit output total price	Completion Amount
Galvanized steel pipe SCH40(Cold water pipe)							
200mm ∮	M	122	1,017	124,074	138	140,346	**14%**
150mm ∮	M	139	665	92,435	179	119,035	**29%**
125mm ∮	M	41	514	21,074	36	18,504	**-10%**
100mm ∮	M	454	373	169,342	346	129,058	**-24%**
80mm ∮	M	742	267	198,114	520	138,840	**-30%**
65mm ∮	M	552	209	115,368	341	71,269	**-38%**
50mm ∮	M	1,297	126	163,422	817	102,942	**-37%**
40mm ∮	M	320	95	30,400	250	23,750	**-22%**
32mm ∮	M	917	81	74,277	811	65,691	**-11%**
25mm ∮	M	133	60	7,980	70	4,200	**-47%**
20mm ∮	M	2,446	42	102,732	1672	70,224	**-32%**
Stainless steel pipe 20S(Hot water pipe)							
125 mm ∮	M	77	980	75,460	34	33,320	**-55%**
100 mm ∮	M	34	620	21,080	18	11,160	**-44%**

3. In practice, the design unit often to the proportion of the total amount of straight pipe to estimate the amount of another pipe. The coefficient of initial estimation is often influenced by personal experience and habits. However, the same material will have a close proportionality factor. This study estimates that human error may occur. An error in the estimation of the material scale factor, leading to erroneous estimates.
   In this study, for example, there are two other parts of the total amount of 0.1 as a coefficient calculation, but in accordance with previous engineering experience, it should be use 0.3~0.35 as a coefficient calculation.
4. In the air conditioning system engineering, the power distribution engineering and the automatic control engineering is the branch or continuation of power system engineering. The source of the system must be connected to the power system equipment to operate properly. HVAC system and power system are air conditioning engineering and power engineering, therefore, when the designer estimates the amount, the fuzzy classification is easy to confuse. In this study, the quantity of the electric pipe is different from the amount of the designer, which leads to a huge quantity difference.

4. Conclusion and discussion

In this study, through the establishment of BIM model of the case study, the establishment of a clear quantity and amount of pipe in the HVAC system,

Based on the results of Revit2014 software, this paper proposes the evaluation process, and compares the output of BIM model with the quantity and amount of raw materials in the original contract:

1 This study established a case BIM model, the case contract amount is NT$ 10439618, accounting for 31% of the contract amount of air conditioning system. The output value of the BIM model established in this study is NT$ 10036565, NT$ 403053 less than the original contract amount, the gap is -3.9%. In the case of the original quantity, and the amount of project valuation is 10459712 NT$, accounting for 32% of the amount of the system. The deletion of the NT$2541768 (24%) of the total amount of valuation item, and found that the electromechanical design unit quantity and cost higher.

2 The Revit software can use the function of the list to calculate the quantity of model components, but the software for the cost of the electrical and mechanical components of the air-conditioning system is limited. Due to the unit price cannot change the length of the pipe, the fixed price characteristics cannot meet the practical needs. In this study, we propose a method of calculating software aided pricing with Excel.

3 After the expert interviews found that, when the amount of the completion of the adjustment, it is not to calculate the amount of the completion of the construction site, and the amount of change to adjust the design. Therefore, the accuracy of the contract quantity and amount will directly affect the interests of the construction company. Through expert interviews, this study summarizes the following reasons for the differences:

   3.1. The mentality of the design unit to overestimate the quantity and amount. The design unit in the calculation of pipe length, the use of too high correction factor, resulting in excessive amount and amount of material. And the calculation of the amount of parts, may also use the error of the scale factor error.

   3.2. Due to the lack of elevation, the riser pipe parts may be underestimated, so that the quantity of estimates and graphic design is clearly inconsistent.

   3.3. If the system is not clearly defined, the design of the project is not consistent with the quantity and quantity of the project.

   3.4. In this study, a pipeline routing model is established, which considers only the collision of the air conditioning system. Therefore, it is a relatively economical path, which may produce additional length during actual construction.

The quantity of output function of the BIM model, this study to enhance the accuracy of calculation program. This study found that the design unit is often overestimated in valuation. This study is assist the owner to obtain a more detailed basis for the cost of the source, reduce the information generated by the lack of trust.

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