Compatibility Between BIM Software and Cost Estimate Tools: A Comparison between Two Directions of Solutions[1, 2]

Ying XU

ABSTRACT

Inaccuracy and redundant work are major issues in the cost estimating. The utilization of Building Information Model (BIM) can increase the efficiency and reduce some manmade errors. However, there are many BIM software, cost estimate software, as well as cost databases existing in different companies. All these platforms have different features from each other. It is still difficult to really realize the exchange of data. It is important to find out a solution to tackle this incompatibility.

This paper introduces the concept of two directions of solutions, "from BIM to cost estimating" and "from cost estimating to BIM". It explains in detail the pros and cons of these two directions. By using a Multi-Attribute Decision Making Method (MADM), the two directions are compared in both quantitative and qualitative analysis. The result of the analysis shows that "From BIM to cost estimation" is a better solution. The key to realizing compatibility with this solution is to have a universally adaptable coding system.

Keywords Compatibility, Building Information Modeling, Cost Estimation, Bill of Quantity, Material Take-off, Software

INTRODUCTION

1. The inaccuracy of cost estimation

Statistics show that in 2015, fewer than one-third of the projects managed to come within 10 percent of the planned budget Large percentage of projects are facing a problem of cost overrun. This shows that there is a large potentiality of improvement in terms of project cost estimation.

[1] Editor's note: This paper was prepared for the course "International Contract Management" facilitated by Dr Paul D. Giammalvo of PT Mitratata Citragraha, Jakarta, Indonesia as an Adjunct Professor under contract to SKEMA Business School for the program Master of Science in Project and Programme Management and Business Development. http://www.skema.edu/programmes/masters-of-science. For more information on this global program (Lille and Paris in France; Belo Horizonte in Brazil), contact Dr Paul Gardiner, Global Programme Director, at paul.gardiner@skema.edu.

[2] How to cite this paper: Xu, Y. (2019). Compatibility Between BIM Software and Cost Estimate Tools: A Comparison between Two Directions of Solutions, *PM World Journal*, Vol. VIII, Issue VIII, September.

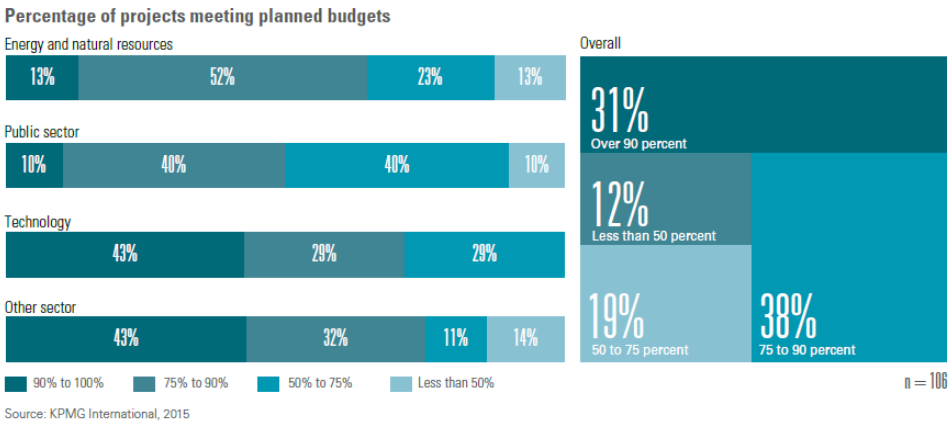

Table 1: Percentage of projects meeting budgets [3]

There are many factors that can lead to cost overrun. One of these is the inaccuracy of cost estimation.

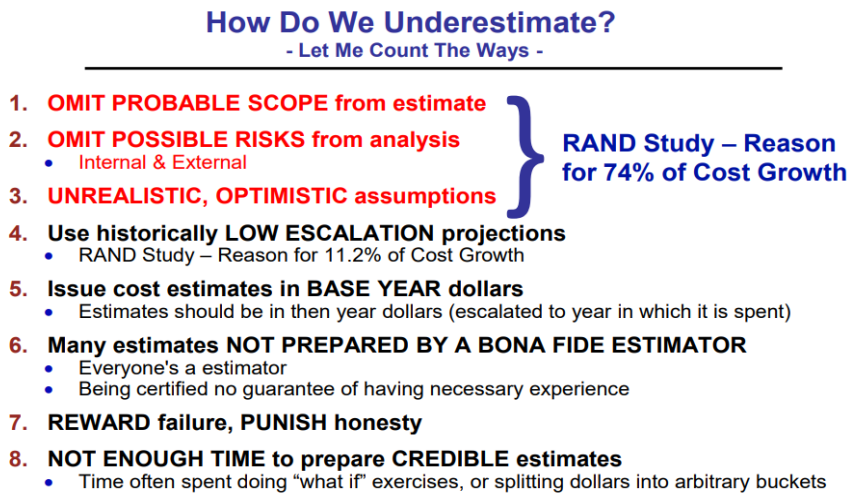

Table 2: How do We Underestimate[4]

Take process industry project, for example, depending on the technical and project deliverables (and other variables) and risks associated with each estimate, the accuracy range for any particular estimate is expected to fall into the ranges identified (although extreme risks can lead to wider ranges).[5]

[3] *Global Construction Survey 2015: Climbing the curve*. (2017, April 3). Retrieved from https://home.kpmg.com/xx/en/home/insights/2015/03/global-construction-survey.html
[4] Butts, G. (2010, February). *Mega Projects Estimates-A History of Denial*. Retrieved from http://www.build-project-management-competency.com/wp-content/uploads/2010/09/Glenn.Butts-Mega-Projects-Estimates.pdf
[5] *Cost estimate classification system - As applied in engineering, procurement, and construction for the process industry*. (2016, March 1). Retrieved from https://web.aacei.org/docs/default-source/toc/toc_18r-97.pdf?sfvrsn=4

	Deliverables from Each Phase				Ranges of Acceptable Accuracy for Schedule and Costs	
Guild of Project Controls Combined Asset and Project Phase Gate Names:	WBS	Schedule Level	Cost Estimate Level	Primary Responsibility	Time	Costs
Phase 1	Level 1	Level 1	Level 1	Owner	+100% to -20%	+100% to -20%
Phase 2	Level 2	Level 2	Level 2	Owner	+60% to -15%	+60% to -15%
Phase 3	Level 3	Level 3	Level 3	Owner	+30% to -10%	+30% to -10%
Phase 4	Level 4	Level 4	Level 4	Owner (Firm Fixed Price Contract) Owner & Contractor (Design-Build, EPC or IPD Contract)	+15% to -5%	+15% to -5%
Phase 5	Level 5/ Level 6	Level 5/ Level 6	Level 5/ Level 6	Contractor (Contract Work) Owner (Self Performed Work)	+3 to -3%	+5% to -5%
Phase 6	N/A	N/A	N/A	Owner	N/A	N/A
Phase 7	N/A	N/A	N/A	Owner	N/A	N/A

Table 3: WBS, Schedule, and Cost Estimate Level Taxonomy [6]

While the traditional way of manual quantity survey on 2D drawing, and cost estimating derived from this often lead to mistakes, the booming BIM concept seems to be a potential solution. "Building Information Modeling (BIM) is a new technology in the field of CAD, which contains not only geometric data but can accommodate a great amount of engineering data over the lifecycle of a building." [7] It simulates the construction of the building in a virtual environment.

2. The gap between current researches and reality

To realize a more accurate, faster cost estimation and reduce the cost overrun, BIM should be considered as the technical support of the cooperation cost estimation database. Using BIM can largely avoid the missing scope of work.

BIM has evolved through 3D (modeling), 4D (schedule) to 5D (cost) or even 6D (project lifecycle information).[8] Researches have studied the major benefits from BIM implementation in project cost estimation: accurate and precise takeoff that subcontractors can rely on confidently early in the design phase, reduction of change orders, reduction of requests for information,[9] accurate and precise take-off[10]. Despite the advantages of BIM, Krzysztof Zima and Agnieszka Lesniak

[6] *GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet)*. (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-cost-estimating-budgeting
[7] Elbeltagi, E., Hosny, O., Dawood, M., & Elhakeem, A. (2014). Bim based cost estimation/monitoring for building construction. *Int. Journal of Engineering Research and Applications*, *4*(7), 55-66. Retrieved from www.ijera.com
[8] *BIM dimensions - 3D, 4D, 5D, 6D BIM explained*. (2017, July 10). Retrieved from https://www.thenbs.com/knowledge/bim-dimensions-3d-4d-5d-6d-bim-explained
[9] Elbeltagi, E., Hosny, O., Dawood, M., & Elhakeem, A. (2014, July). Bim-based cost estimation monitoring for building construction. Retrieved from https://www.scribd.com/document/313569443/BIM-Based-Cost-Estimation-Monitoring-for-Building-Construction
10 Using Building Information Modeling (BIM) for Estimating and Scheduling, Adoption Barriers. (2015, March 9). Retrieved from http://www.hrpub.org/download/20150930/UJM5-12104533.pdf

point out that design errors that prevent or hinder takeoff automatic calculation based on BIM model.[11]

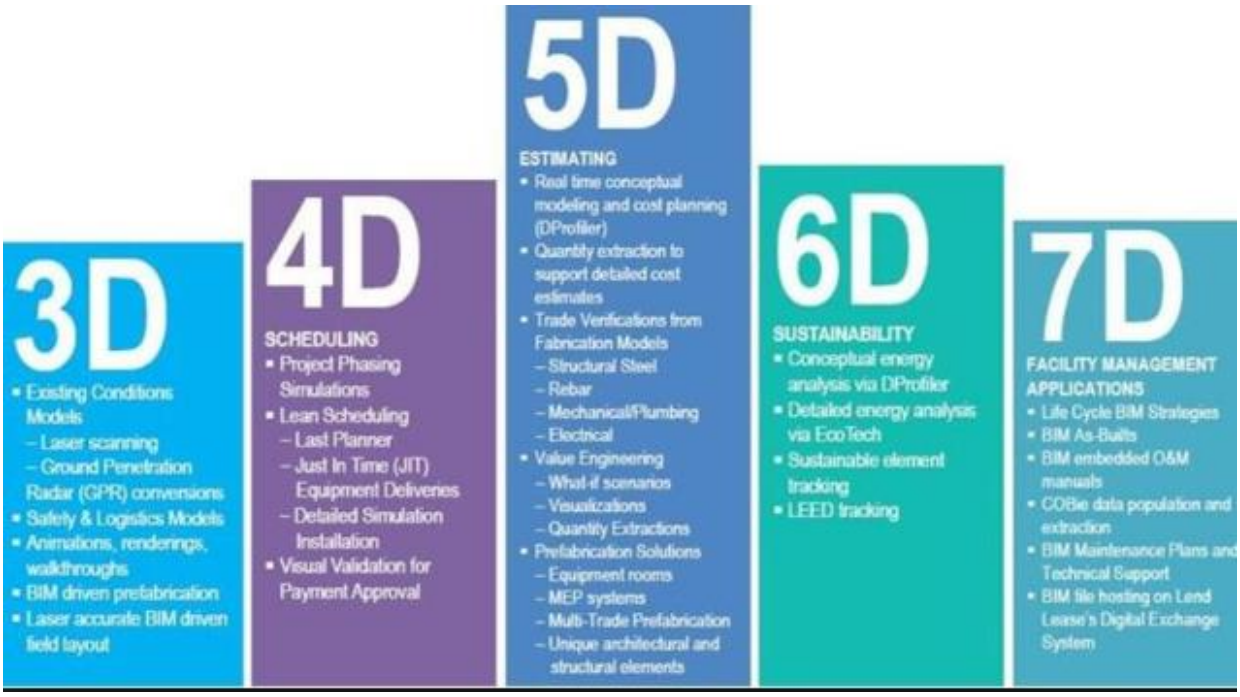

Table 4: BIM 3D, 4D, 5D. 6D and 7d [12]

Very few researches have been done on the problems tackled in the process of utilizing the BIM system for cost estimation. E.Elbeltagi, O.Hosny, M.Dawood, A.Elhakeem studied activity-based cost variance.[13] Dr. Paul D.Giammalvo studied the Using of Omniclass Coding Structures and Activity Based Costing.[14] Sigma Estimates has worked out a 5D Cost Estimation Integration for BIM 360.[15]

11 Limitations of Cost Estimation Using Building Information Modeling in Poland. (2013, May). Retrieved from https://www.researchgate.net/publication/268978758_Limitations_of_Cost_Estimation_Using_Building_Information_Modeling_in_Poland
12 BIM 3D,4D, 5D, 6D & 7D. (n.d.). Retrieved from http://www.bimpanzee.com/bim-3d-4d--5d--6d---7d.html
13 XU, S., Liu, K., & Tang, L. (2013, October). Cost estimation in building information model. Retrieved from https://www.researchgate.net/publication/264195542_Cost_Estimation_in_Building_Information_Model
14 Mapping ERP 'Chart of Accounts? to Building Information Modeling Software - Project Management World Journal. (n.d.). Retrieved from https://pmworldjournal.net/article/mapping-erp-chart-of-accounts-to-building-information-modeling-software/
15 Sigma Estimates 5D Cost Estimation Integration for BIM 360. (n.d.). Retrieved from http://revitaddons.blogspot.com/2017/11/sigma-estimates-5d-cost-estimation.html

3. The causes of incompatibility

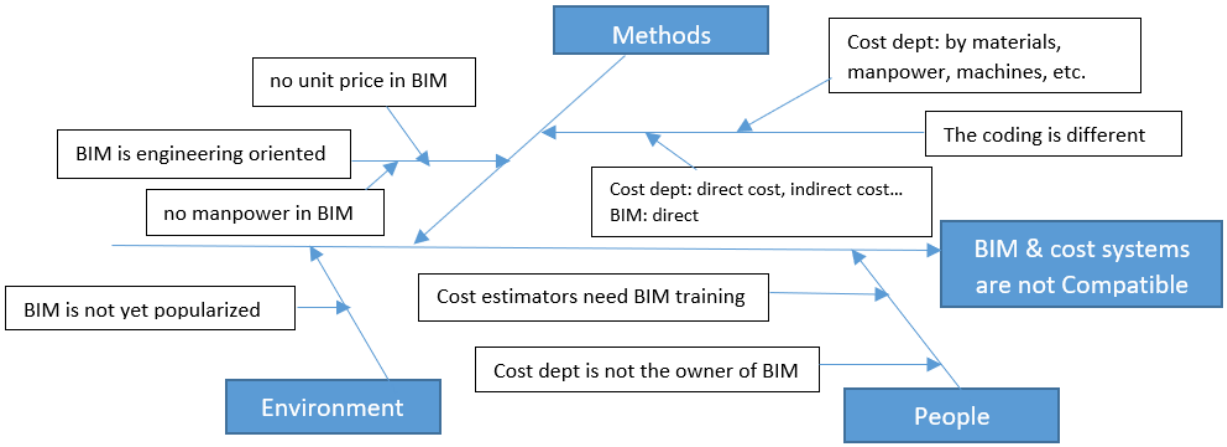

Table 5: Root Cause Analysis[16]

There are some subjective causes of the incompatibility such as: BIM is not largely popularized in the industry, cost estimators/cost controllers are not yet familiar with this tool, etc. These environmental and people aspects will not be further discussed in this paper.

Suppose that the company already applied BIM. BIM software is mainly design oriented. It is possible to generate the bill of quantity or material take-off from BIM software, but there is not a ready for use module of cost estimating. Main elements, such as unit price, manhours are still missing.

It is relatively easy to correspond each item in BIM with a direct cost. But how to reflect the indirect cost in the BIM is another issue that needs to be addressed.

While in BIM, OmniClass coding system can be considered as a common language, each company has its unique coding system for cost estimation. Matured engineering companies already have their own database of cost. Built over the years on the previous projects, these data are read in the categories of material cost, manpower cost, machine cost, etc.

METHODOLOGY

Step 1 Problem Statement

As shown in the previous pages, there are gaps laying between BIM and cost estimating. This paper is going to discuss from comprehensive aspects on:

- What are the possible solutions to realize the compatibility between the BIM software and the cost estimation database?
- What are the advantages and disadvantages of these solutions?

16 By Author

Step 2 Feasible Alternative Solutions

To connect BIM and cost estimating together, there are basically two directions. We can build the cost modules in BIM or we can extract the quantity from BIM and import it into cost estimating.

Step 3 Development of outcomes

3.1 From cost estimating to BIM

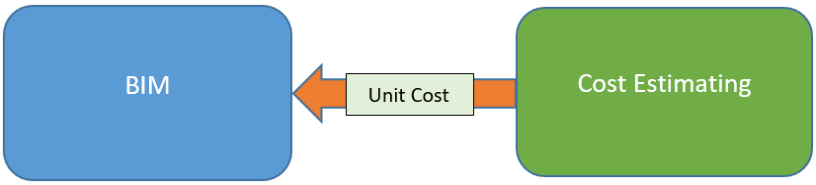

Table 6: Solution 1 From Cost Estimating to BIM [17]

BIM is no longer a simple engineering tool. When 5D BIM concept is introduced, it is possible to add cost elements into the BIM software.

Take Revit for example, in the function of "schedule/Quantities", a table with both quantities and cost can be generated.

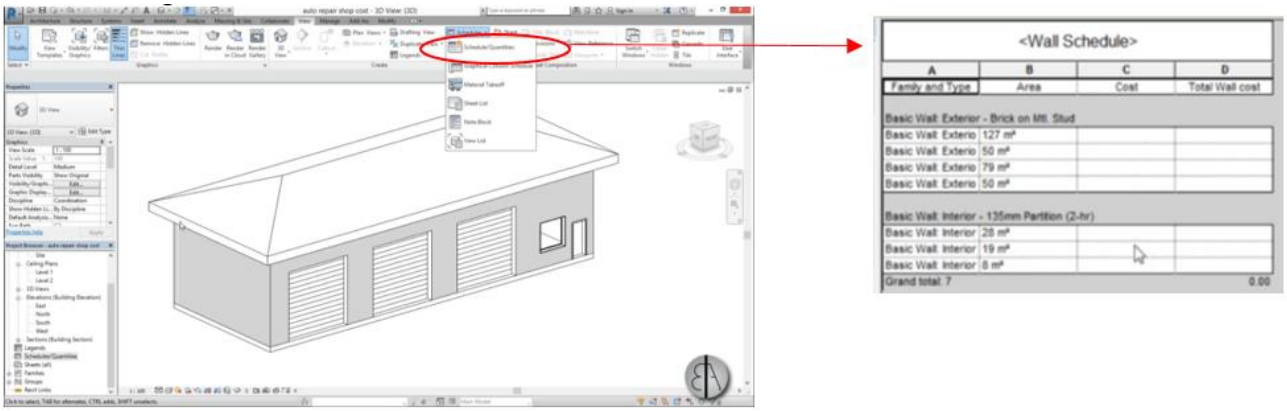

Table 7: Schedule Function in Revit[18]

3.1.1 Advantages

Cost estimator can directly involve in the progress of 3D module development, follow up the design change and get alerted by relevant cost change instantly.

Although it requires pre-fill of the "cost" column (the unit cost), this practice can largely save the time which traditionally spent on the later calculation.

[17] By Author
[18] *Cost Estimation (calculation) in Revit Tutorial* [Video file]. (2018, April 15). Retrieved from https://www.youtube.com/watch?v=YAb4O8DSDSM

3.1.2 Disadvantages

The cost estimation normally includes project direct costs, project indirect costs, contingency, escalation, overhead & profit, management reserves.[19] An example of the construction cost estimate is showed in table 8 and table 9. An example of BIM cost estimate is showed in table 10.

Project Direct Costs are the money spent directly to complete the work, such as material, labor, equipment.
Project Indirect Costs are the money spent to support the completion of the work, such as personal safety devices, QA/QC, environmental protection, etc.
Home Office Indirect Costs are what are known as "General, Sales, and Administrative (GS&A) costs" or "below the line" costs.
Contingency is intended to mitigate or offset the impacts of "known-unknown" risks, such as the deductible amount for an insurance policy, price increases in labor, equipment or materials.
Escalation is an amount of money, usually expressed as a percentage of the labor and/or material portion of a contract, designed to offset or mitigate inflation, currency fluctuations or unanticipated labor cost increases.
Overhead profit is a percentage that indicates the profit margin.
Management reserves is an amount of money used to offset, mitigate or otherwise cover "Unknown-Unknowns".

United States Department of the Interior
National Park Service
Class A Construction Cost Estimate
PROJECT COST SUMMARY

Project: Oso Comida Trailhead Improvements:
Park: Bear Arbor NRA
Park Alpha: BEAR
Estimate By: YtB
Date: 01/12/11
Reviewed By: BBB

Bid Item No.		Bid Item Description	Total Material Cost	Total Labor Cost	Total Equipment Cost	Total Direct Construction Costs	Design Contingency	General Conditions	General Contractor Overhead	General Contractor Profit	Contracting Method Adjustment	Inflation Escalation APR	Inflation Escalation Month	Bid Item Total
							2.00%	3.00%	8.50%	10.00%	15.00%	3.60%	32	
Bid Item:	1	Replace Pit Toilets with New Comfort Station					TOTAL VALUE OF GOVERNMENT FURNISHED PROPERTY (if any):							$ 46,000.00
	A10	Foundations	$ 30,028	$ 33,082	$ 7,293	$ 70,403								
	A20	Basement Construction	$ -	$ -	$ -	$ -								
	B10	Superstructure	$ 15,622	$ 13,198	$ 460	$ 29,280								
	B20	Exterior Enclosure	$ 35,992	$ 29,477	$ -	$ 65,469								
	B30	Roofing	$ 18,471	$ 8,706	$ -	$ 27,177								
	C10	Interior Construction	$ 25,573	$ 9,308	$ -	$ 34,881								
	C30	Interior Finishes	$ 4,476	$ 13,424	$ -	$ 17,900								
	D20	Plumbing Systems	$ 26,655	$ 16,121	$ -	$ 42,776								
	D30	HVAC	$ 1,269	$ 1,170	$ -	$ 2,439								
	D50	Electrical	$ 8,753	$ 9,366	$ -	$ 18,119								
	F20	Selective Building Demolition	$ 463	$ 1,990	$ 3,862	$ 6,315								
	G10	Site Preparation	$ 2,188	$ 4,362	$ 6,952	$ 13,502								
	G20	Site Improvements	$ 8,900	$ 7,300	$ -	$ 16,200								
	G30	Site Mechanical	$ 86,213	$ 32,582	$ 44,542	$ 163,337								
	G40	Site Electrical	$ 5,000	$ -	$ -	$ 5,000								
	XX	Standard General Conditions	$ 31,900	$ 101,200	$ 18,610	$ 151,710								
Total - Bid Item	1	Replace Pit Toilets with New Comfort Station	$ 301,503	$ 281,286	$ 81,719	$ 664,508	$ 12,370	$ 18,926	$ 55,233	$ 64,980	$ 122,403	$ 92,813		$ 1,031,234

Table 8: Example of Project Cost Summary[20]

[19] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-cost-estimating-budgeting
[20] Cost Estimating Requirements Handbook. (2011, February). Retrieved from https://www.nps.gov/dscw/upload/costestimatinghandbook_2-3-11_111417_AF.pdf

		Direct Cost				Indirect Cost							
Bid Item No.	Bid Item Description	Total Material Cost	Total Labor Cost	Total Equipment Cost	Total Direct Construction Costs	Design Contingency	General Conditions	General Contractor Overhead	General Contractor Profit	Contracting Method Adjustment	Inflation Escalation		Bid Item Total
											APR	Month	
						2.00%	3.00%	8.50%	10.00%	15.00%	3.60%	32	

Table 9: Split of direct cost and indirect cost[21]Some items, such as contingency, overhead & profit, management reserves, etc, can be allocated on every single activity or work package and expressed as a percentage during the calculation. Some other items are difficult to be allocated, such as the equipment purchase fee, software license fee, etc. The better practice is to list them aside.

The formula will appear like this:

Project Total Cost= Quantity x Direct Unit Cost x (1+ α % + β % + ….) + Others

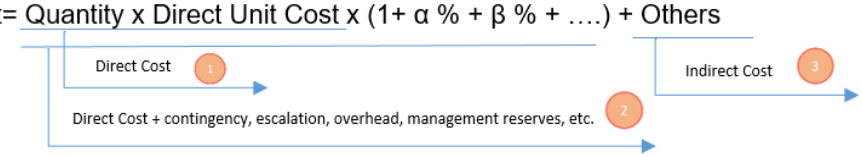

Table 10: The formula of project total cost[22]

03 30 Cast in Place Concrete										
03 30 53 Miscellaneous Cast in Place Concrete										
03 30 53.40 Concrete in Place										
0.0010 0.0020 0.0050	Including Forms (4 uses), reinforcing steel, concrete placement and finishing, unless otherwise indicated.	Crew Type	Daily Output per Unit	Labor Hours per Unit	Unit of Measure	Material Costs	Labor Costs	Equip-ment Costs	Total Costs per Unit	Total Price/Unit Including OH&P
0.0300	Beams- 5 kip per lineal foot, 10' long spans	C14-A	15.62	12.8	Cubic Yard (CY)	$315.00	$490.00	$48.50	$853.50	$1,225.00
0.0350	Beams- 5 kip per lineal foot, 25' long spans	"	18.55	10.78	CY	$325.00	$415.00	$40.50	$780.50	$1.100.00

Table 11: Illustrating an example of a commercial database[23]

Cost estimation in BIM can realize until step 2 as displayed in table 11 above. There is still a part of the cost that is difficult to be included.

[21] By Author
[22] By Author
[23] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-cost-estimating-budgeting

3.2 From BIM to Cost Estimating

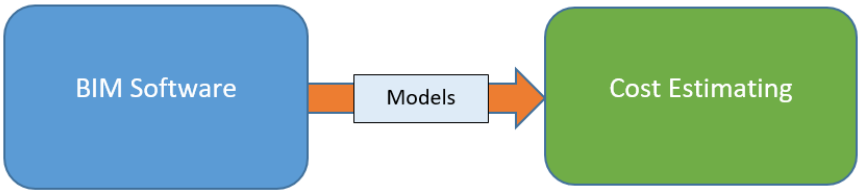

Table 12: Solution 2 From BIM to Cost Estimating[24]

The main output from BIM that cost estimating need is the quantities. In some research, this approach is also called an Application Programming Interface (API). From the BIM software, "a user exports the building model using the costing program's data format and sends it to the estimator, who then opens it with the costing solution to begin the costing process." [25]

For example, Sage Estimating has realized an integrate with Autodesk Navisworks by using an eTake-off bridge.

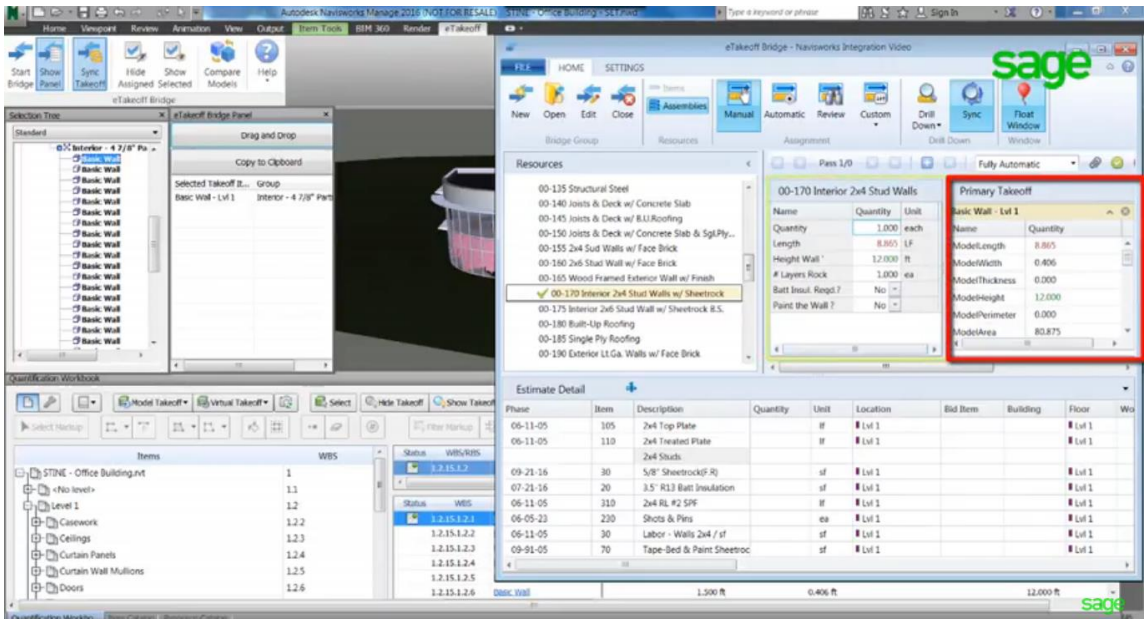

Table 13: Example of Sage Estimating[26]

3.2.1 Advantages

This solution does not require cost estimation personnel to obtain the skills of how to operate the BIM, especially how to input the unit cost. Once the models are extracted from BIM, cost estimator can load them into cost estimating software or use VLOOKUP in the Excel to finish the calculation.

[24] By Author
[25] Bim and cost estimating. (n.d.). Retrieved from http://images.autodesk.com/apac_grtrchina_main/files/aec_customer_story_en_v9.pdf
[26] *Sage Estimating integration with Autodesk Navisworks* [Video file]. (2017, March 1). Retrieved from https://www.youtube.com/watch?v=aVhEUeYAodg

Some unit prices are variable due to the quantity. For example, for one same subcontractor for passive fire protection (PFP), the quotation to execute 500 m^2 will be higher than execute 5000 m^2. In the cost estimating platform, this unit price change can be more flexibly adjusted.

3.2.2 Disadvantages

As cost estimator is neither the owner nor the user of BIM, it means that whenever there is an engineering update, the engineering department needs to inform the cost control department by an updated quantity report. This might increase the complexity. Sometimes, a neglection from engineering update can lead to big cost estimation mistake.

Another major issue is that to realize the integration, BIM software must have the same coding system than the cost estimating software or company cost database, such as omniclass.

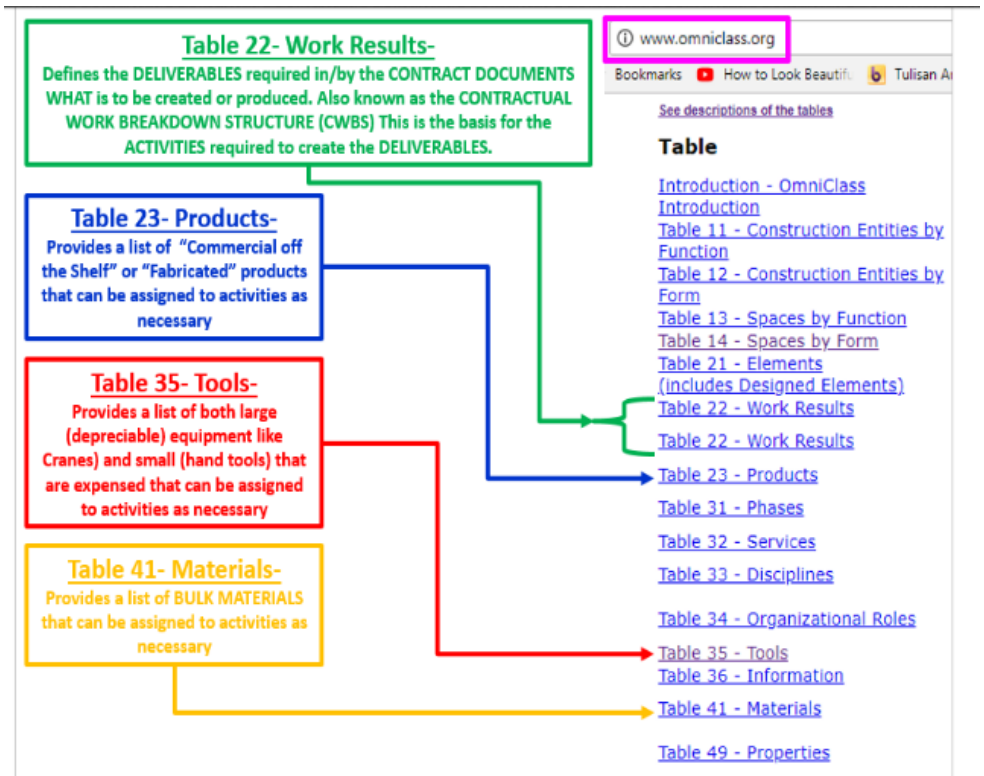

Table 14: Showing the 15 Omniclass Tables and the 4 Used by Contractors and SubContractors[27]

[27] Mapping ERP 'Chart of Accounts? to Building Information Modeling Software - Project Management World Journal. (n.d.). Retrieved from https://pmworldjournal.net/article/mapping-erp-chart-of-accounts-to-building-information-modeling-software/

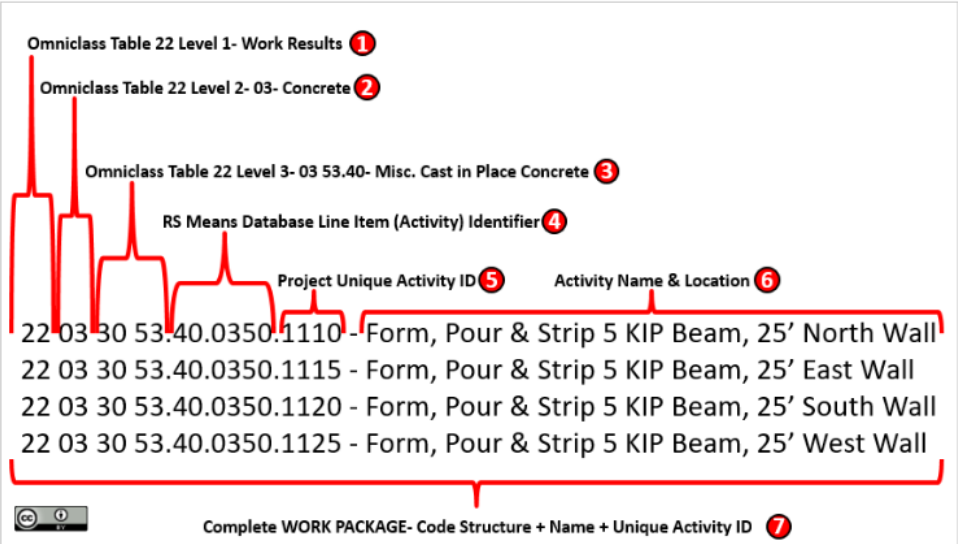

Table 15: Explanation of the Combined/Integrated Omniclass Table 22 with the RS Means Database Codes[28]

Step 4 Selection of criteria

Given that the budget in a project is limited, it is important to consider in the welfare of project beneficiaries. "It is best undertaken at the early stages of the project cycle to enable decision makers to make an informed decision on whether to undertake a particular investment given various alternatives and their corresponding costs."[29]

Cost estimators are not thinking machines, processing information in a computer-like manner.[30] Whether a cost estimation method is simple, user-friendly, can to some extent help to improve the results of cost estimation.

During the life-cycle of a project, the level of design evolves. Changes such as engineering modification, will affect the project scope and furthermore, the cost estimation. Successful estimating requires that estimate reviews be conducted to confirm that the estimate fully reflects the project scope.[31] Producing fast, competitive estimates is how a contractor wins contracts. In fact, an estimator's ability to create reliable, accurate estimates greatly impacts a company's overall success.[32]

[28] Mapping ERP 'Chart of Accounts? to Building Information Modeling Software - Project Management World Journal. (n.d.). Retrieved from https://pmworldjournal.net/article/mapping-erp-chart-of-accounts-to-building-information-modeling-software/
[29] Economic Analysis of a Project. (2017, December 12). Retrieved from https://morpheusland.wordpress.com/2017/12/12/economic-analysis-of-a-project/
[30] Prince, A. (n.d.). The Psychology of Cost Estimating. Retrieved from http://www.iceaaonline.com/ready/wp-content/uploads/2015/06/PM07-Paper-Prince-Psychology-Cost-Estimating.pdf
[31] Cost estimate quality control and quality assurance checks using formal review tools. (2009). Retrieved from https://trid.trb.org/view/881070
[32] Construction estimating guide - An overview of estimating tools and software. (n.d.). Retrieved from https://www.saimgs.com/imglib/lightbox-download-assets/construction-estimating-software-guide.pdf

There are some tools and techniques to develop cost estimates, such as Analogous estimating, Parametric estimating, Bottom-up estimating, Three-point estimates, etc.[33] "There is no single way to construct a cost estimate" [34] We are dealing with more and more complex projects. Each project has different circumstances. One cost estimating method cannot apply to all the projects.

The Guild of Project Controls believes the phased gate approach to be a "best tested and proven" practice. One of the objectives in using the phased gate approach is to VALIDATE that the cost estimate as produced by the owner's cost estimators meets three quality control metrics, that are accuracy, precision, reliability.[35]

Therefore, a good cost estimation is determined by many factors. To compare the two solutions side-by-side, the following eight criterions are selected:

- Economic

  Whether it is costly for a company or project to apply the alternative solution

- Simplicity

  Whether specific skills are required to cost estimators to apply the alternative solution, whether it is user-friendly?

- Efficiency

  Which alternative solution is more time-saving or otherwise more time-consuming?

- Timeliness

  Whether the alternative solution can enable the cost estimator to follow up the engineering updates?

- Accuracy

  Whether the alternative solution provides accurate data for cost estimator?

- Precision

  The spread or dispersion measured in standard deviation.

- Reliability

  Whether the alternative solution is sensible to the influence of outlying values

- Adaptability

[33] Project Cost Estimating Tools and Techniques. (n.d.). Retrieved from https://www.project-management-skills.com/project-cost-estimating.html
[34] Life-Cycle Cost Estimation. (2017, August 17). Retrieved from https://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/acquisition-program-planning/lifecycle-cost-estimation
[35] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-cost-estimating-budgeting

Whether the alternative solution is adaptable to different cost estimation methods in different projects?

To rank these criteria, they are assessed using a disjunctive reasoning method in table 12.

	Economic	Simplicity	Efficiency	Timeliness	Accuracy	Precision	Reliability	Adaptability	Ordinal Ranking
Economic	x	1	0	0	0	1	0	0	3
Simplicity	0	x	0	0	0	0	0	0	1
Efficiency	1	1	x	1	0	1	1	1	7
Timeliness	1	1	0	x	0	1	1	1	6
Accuracy	1	1	1	1	x	1	1	1	8
Precision	0	1	0	0	0	x	0	0	2
Reliability	1	1	0	0	0	1	x	0	4
Adaptability	1	1	0	0	0	1	1	x	5

Table 16: Ranking of the criteria[36]

In table 12, accuracy ranks the top, then it is the efficiency, timeliness that are following. While simplicity, precision, economic factors are relatively less critical than the others.

FINDINGS

Step 5 Comparison of the alternatives

This paper uses Multi-Attribute Decision Making, which is also called MADM, as a decision analysis tool. Both attributes weights and the performances are taken into consideration. How MUCH better or worse any solution is when compared to the other.

[36] By Author

Attributes	Ordinal Ranking	Weight (A)	From Cost Estimating to BIM		From BIM to Cost Estimating	
			(B)	(A)*(B)	(C)	(A)*(C)
Economic	3	0.083	1	0.08	3	0.25
Simplicity	1	0.028	1	0.03	3	0.08
Efficiency	7	0.194	2	0.39	2	0.39
Timeliness	6	0.167	3	0.50	2	0.33
Accuracy	8	0.222	2	0.44	3	0.67
Precision	2	0.056	2	0.11	3	0.17
Reliability	4	0.111	2	0.22	3	0.33
Adaptability	5	0.139	1	0.14	3	0.42
Sum	36	1.000		1.92		2.64

Table 17: Comparison of two alternative solutions[37]

To explain this table, in column (B) and column (C)
1=not good, 2=good, 3=very good

From the analysis above, the alternative solution which is from BIM to cost estimation has a total score of 2.64, which is much higher than the other (1.92). Although this solution is less timeliness than the other. In other areas, such as accuracy and adaptability, it has excellent advantages.

Both solutions are equally good in terms of efficiency.

Step 6 Selection of the preferred alternative

The previous part of this paper has explained the concept of the two feasible alternative solutions, their respective advantages, and disadvantages. A comprehensive comparison has also been conducted to analyze their performance in terms of eight factors.

Now it is apparent that "From BIM to cost estimation" is a better solution, it scores higher in six out of eight criterions, and it has a much higher total score.

Step 7 Performance monitoring and post evaluation of the result

Once the "From BIM to cost estimation" method is chosen, we can use a distribution chart to monitor and evaluate the result.

In the Guild of Project Controls, the model which has been used for illustration purposes is an adaptation of the model used by Chevron, (which is also based on AACE's RP 18-R-97 and RP

[37] By Author

17R-97)), to VALIDATE that the cost estimate as produced by the owner's cost estimators meets three quality control metrics, accuracy, precision, reliability, when benchmarked against the target value.[38]

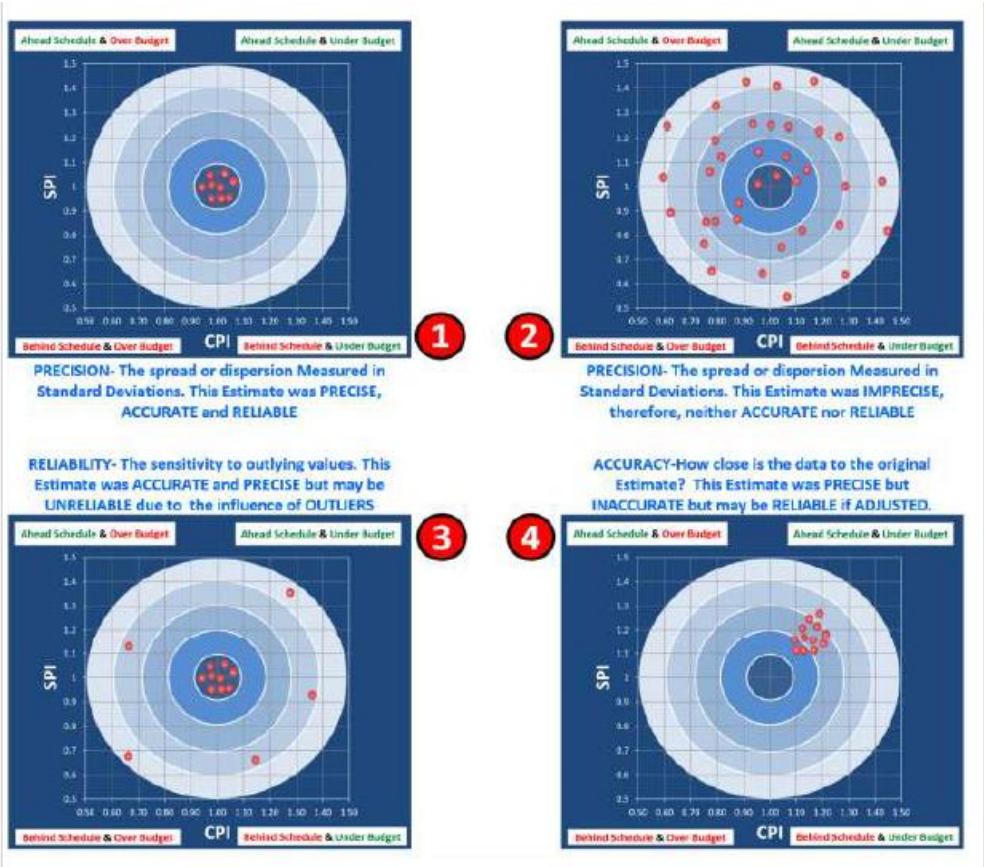

Table 18: Illustrating the Concepts of Precision vs Accuracy vs Reliability[39]

The 4 scenarios explained[37]:

(1) Scenario 1, the efficiency, as measured by the SPI and CPI are consistently falling within the acceptable target ranges. This means our original baseline estimate was precise, accurate and therefore, is reliable to use for future projections in terms of both time and cost.
(2) Scenario 2, the periodic readings are all over the place. This means our baseline estimate was imprecise, therefore it was neither accurate nor reliable to use to predict into the future.
(3) Scenario 3, while most of our periodic SPI and CPI report readings have been precise, accurate and therefore reliable, we have to assess the impact of the outliers.

[38] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-cost-estimating-budgeting
[39] GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (n.d.). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-cost-estimating-budgeting

(4) Scenario 4, we are getting SPI and CPI readings which are both PRECISE and RELIABLE but because they are missing the target the only way to use them would be if we adjusted the time and cost estimates to bring them back closer to the target which is one.

CONCLUSIONS / RECOMMENDATIONS

The aim of the paper was to explore the possible solutions to realize the compatibility between BIM technology and cost estimation. To fulfil the aim of this research, a literature review of the current research on BIM and cost estimation has been conducted. From the gap observed in the literature review, two research questions have been raised and answered by the analysis in this paper.

There are basically two solutions, one is "From cost estimation to BIM", the other is vice versa. These two solutions are totally in different directions. Each of them has advantages and disadvantages.

This paper has chosen eight criterions which are important to the quality of cost estimation. By ordinal ranking, each of the criteria is given a weight in the process of MADM decision analysis. The result of comparison shows that "From BIM to cost estimation" is a better solution. With the bill of quantity extracted from the BIM, cost estimators will have more accurate quantity, which can largely reduce the mistakes and time consummation comparing to manual quantity survey. Meanwhile, it allows flexibility in different cost estimation in different situations. However, a unified coding system is the key to success in the implementation of this method otherwise, the data from BIM cannot be used in a cost estimation tool.

However, examples are chosen from Revit, Autodesk Navisworks, the top two BIM software of 2018 [40] and Sega software, one of the best cost estimating software of 2018 [41]. Further study can be made on a wider range of software.

It is also noticed during the writing of this paper that a universally adaptable coding system is still not yet in place. Research needs to expand in this topic as it is foreseeable that in the trend of digitalization this problem will have to be solved in the near future.

[40] Best 20 Building Information Modeling (BIM) Software in 2018 - Financesonline.com. (n.d.). Retrieved from https://financesonline.com/building-information-modeling/
[41] The Best Construction Estimating Software of 2018. (2018, June 5). Retrieved from https://www.business.com/categories/best-construction-estimating-software/

About the Author

Ying XU

Shanghai, China
Paris, France

Ying XU is a Master of Science student in SKEMA Business School, major in Project and Programme Management & Business Development (PPMBD). She graduated from Shanghai Maritime University and holds a bachelor's diploma in Transportation Management. She has over 9 years working experience of which 7 years in a leading international engineering company in Oil and Gas industry, 18 months assignment on fabrication site of a mega LNG project. She has background knowledge about subcontract/contract management, proposal, and procurement. She lives in Paris, France now and can be contacted at ying.xu@skema.edu.