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Allocating BIM Service Cost—A Taiwan Experience

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Abstract

Benefits of BIM application in building construction projects have been reported by many previous researchers, but very few works were done for the guideline of estimating and allocating of the costs of various BIM uses. Without such a guideline, it is difficult for the owner to determine and budget the selected BIM uses. To meet this need, this paper presents a case study on the estimating and allocating the costs of BIM service based on the 25 BIM Uses defined in the 'Taiwan BIM Guide' developed by the Architecture and Building Research Institute (ABRI), Ministry of the Interior (MOI), Taiwan, for implementation of BIM by local construction industry. Appropriate portfolio of BIM Uses should consider the limitation of available resources and specific project characteristics. Only the priority of the 25 BIM Uses need to be selected and budgeted. To estimate and allocate required costs for various BIM uses, the current study proposes a method to determine the relative requirements of costs for different BIM uses by surveying the BIM practitioners from the 10 public social housing projects owned by the Taoyuan City Government using an Analytic Hierarchy Process (AHP) method. A BIM use cost allocation guideline is provided as a reference to the BIM practitioners to determine the required costs for different BIM Uses.

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1. Introduction

In the past few years, many Building Information Modelling (BIM) implementation guides have been developed by the government agencies or professional associations in many countries, such as the 'BIM Project Execution Planning Guide (PEPG)' by CIC [1] and the 'National BIM Standard-United States' by NIBS [2] in the USA, the 'Publicly Available Specifications (PAS) 1192-2 [3] & 3[4]' by BSI in the UK, the 'Singapore BIM Guide' by BCA in Singapore, the 'Unified Standard for Building Information Model Application' by General Administration of Quality Supervision [6] and 'Shanghai BIM Guide' by Shanghai City Government [7] in China, and the 'Taiwan BIM Guide' by ABRI [8] of Ministry of the Interior in Taiwan. The BIM Guides of different countries are usually developed according to the specific construction characteristics and local industrial requirements. As a result, they provide specific purpose to fit the local construction environment and specify different requirements for BIM project delivery.

Although the BIM Guide provides the participants a clearer specification to deliver, review and accept the project deliverables, there are two problems remains to be resolved before the BIM Guide can assist the construction industry to implement BIM adoption: (1) How to select the most appropriate BIM uses for a specific project? —since the project

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characteristics, the project delivery method, and the owner's needs may differ from one project to the other, only the most appropriate BIM uses should be adopted; (2) How to budget the selected BIM uses?—different BIM uses will cost the efforts of the BIM service provider differently, it is desired to estimate the cost borne for the selected BIM use items. Although previous researchers have found that the adoption of BIM will reduce overall project cost [9] and thus most BIM service providers will bear the costs of BIM adoption [10], it is the common practice for the project owners (especially the public project owner) of the BIM developing countries to offer incentives or subsidy for BIM services in the early phase of BIM introduction in order to encourage the BIM adoption by the industry [11,12,13]. Moreover, the decision of the second problem may further affect the decision of the first problem, since the project owner usually allow limited budget for BIM services. As a result, the correct estimation of BIM service costs for various BIM use items is very desirable, not only for budgeting the costs but also for progress payment of BIM services.

In light of the abovementioned objectives, the current research aims at proposes a method to determine the relative requirements of costs for different BIM uses by surveying the BIM practitioners from the 10 public social housing projects owned by the Taoyuan City Government using an Analytic Hierarchy Process (AHP) method. A BIM use cost allocation guideline is provided as a reference to the BIM practitioners to determine the required costs for different BIM Uses.

2. Relevant Works

2.1. BIM Uses defined in this research

As addressed in the Introduction, the costs of BIM services specified by different BIM guide will bear different costs, it is necessary to define the BIM uses clearly before the BIM service costs can be correctly estimated. In this research, the BIM service costs for the 25 BIM uses defined in 'Taiwan BIM Guide' are selected for case study. The 25 BIM uses defined in 'Taiwan BIM Guide' are defined and described in this subsection. The BIM use items of Table 1 are the outcomes generated from the BIM model developed by project participants in the stage of the project. For example, '(8) Construction permit' means the use of Basic Design BIM Model to produce the drawings required for application of 'Construction permit'; similarly, '(15) Budgeting' means the use of Detail Design BIM Model to generate required bill of quantity (BOQ) for budgeting; and so forth.

2.2. Analytic Hierarchical Process (AHP) and Adaptive AHP Approach (A³)

The Analytic Hierarchy Process (AHP) method was originally proposed by Saaty [15], and it has been become a widely adopted tool for multi-criterion decision making nowadays [16]. The AHP procedure consists of six general phases or steps [15,17]: (1) Define the decision problem; (2) Construct the decision hierarchy; (3) Construct matrices to calculate a set of pairwise comparison; (4) Calculate the relative weight of the elements to each level; (5) Check and balance of decision; and (6) Decision documentation. It has been applied to multi-criterion decision making in many fields, including Information Technology [18], Public Administration [19], Manufacturing [20], Transportation Industry [21], Service Industry [22], etc.

Although AHP provides a useful method, there are several weaknesses of the traditional AHP in assessing the relative importance weights as pointed out by Triantaphyllou and Mann [23] and Lakoff [24] due to the use of Saaty's discrete 9-value scale to reflect the decision maker's preferences and the human's difficulty in identifying the in-between preference scales. These are sources of the high Consistency Ratio (CR) defined by Saaty [15], i.e. high inconsistency, while applying AHP method.

In order to improve these drawbacks, Yu [25] and Lin et al. [26] proposes an Adaptive AHP Approach (A³) using simple Genetic Algorithms (sGA) to recover the real number weightings of the various criteria in AHP and provide a function to improve the consistency ratio of the pairwise comparison automatically. The A³ also eliminates the tedious reassessment process when the consistency ratio is slightly unsatisfactory. It is very desirable for decision-making problems, as the interviewees of AHP are usually high-ranked manager or domain experts who are extremely busy and

are not available for iterative re-assessment of the pairwise comparison matrixes. Details of the A^3 can be found in Yu [25] and Lin et al. [26]. In this paper, the original A^3 program is adopted for fine-tuning the relative weightings of criteria in AHP.

Table 1. The 25 BIM uses defined in ‘Taiwan BIM Guide’ [14].

Stage	Objective	Description of objective	BIM Use Item
Planning	Mass planning of the building	Showing rough length, area, volume, position and orientation of building.	1.BIM execution plan (BEP) 2.Site analysis 3.Conceptual design 4.Final conceptual model
Basic design	Schematic building components and systems	Showing qualitative and quantitative schematic information of building.	5.Basic architectural design 6.Basic engineering design 7.Basic design estimate 8.Construction permit 9.Final basic design model
Detail design	Building component and system development	Showing accurate qualitative and quantitative information of building components and systems.	10.Detail arch. design 11.Detail structural design 12.Detail MEP design 13.Detail design estimate 14.Detail design integration 15.Budgeting 16.Final detail design model
Construction	Model to support construction management designs	Providing required information for construction, prefabrication and installation; 2D construction drawings.	17.Construction model 18.Pre-construction planning 19.Construction drawing 20.Change order 21.Occupation permit 22.Final construction model
Completion	As-built model	Ensuring correct and accurate qualitative and quantitative information in the as-built BIM model.	23.As-built model 24.Construction acceptance
Facility management	Model for facility management	Adding qualitative and quantitative model information for facility management.	25.Facility management model

2.3. Cost of BIM Use Services

As addressed in Introduction, there not many works reported on the cost of BIM use services due to the diversity of project characteristics and the different levels of BIM implementation in project. According to the survey of Becerik-Gerber and Rice [9], 59% practitioners of BIM considered no extra space requirement, while 41% believed no extra labors required, 21% believed labor requirement decreases and 13% believed more labors are required to implement BIM.

A wide survey to more than 2,000 industrial BIM practitioners by McGraw Hill Construction [27] showed that most respondents believe that the BIM implementation cost is less than 0.5% of total net revenue of the firm; where 39% respondents consider hardware cost increases by 0.5~1.49%, while 34% believed software cost increases the most.

Olatunji [28] found that 55% of BIM implementation cost is attributed to software, while 22% attributed to hardware cost and 18.2% attributed to training cost.

According to the statistics of the Construction and Planning Agency (CPA), Ministry of Interior, Taiwan in performing 9 public construction projects, the BIM implementation cost was ranging from 0.09~0.43%, and the average cost is 0.19% of overall construction cost.

A more definite reference for the BIM implementation cost suggested by the Public Construction Commission (PCC) of Taiwan was 0.4~0.5% of overall construction cost both for design and construction phases. Such a reference is similar to that suggested by ‘Taiwan BIM Guide’ [14], which is 1% of overall construction cost for the whole

construction project lifecycle including facility operation and maintenance phase. In this paper, the 1% overall BIM implementation cost is also considered as a standard reference for all 25 BIM uses defined by ‘Taiwan BIM Guide’.

3. Research Methodology

The research aims at allocating the BIM cost required for the 25 BIM uses of ‘Taiwan BIM Guide’ defined by the ABRI shown in Table 1. An Analytic Hierarchy Process (AHP) method is employed to determine the relative requirements of costs for the 25 different BIM uses by surveying the BIM practitioners from the 10 selected public social housing projects owned by the Taoyuan City Government. Basic information of the 10 selected public social housing projects is shown in Table 2.

Table 2. Basic information of the 10 selected public social housing projects.

No.	Project ID	Building Description	Floor (m ²)	Construction budget (NT\$)	BIM cost (NT\$)
1	CL-1	Twin towers: 14-F+Sub-3F.	21,104	754,112,852	3,914,734
2	CL-2	Triple towers: A-17F, B-16F, C5F+Sub-3F.	33,917	1,118,310,000	3,267,567
3	CL-3	Triple towers: 20-F+Sub-3F.	49,233	1,710,879,886	8,886,179
4	CL-4	Triple towers: 20-F+Sub-3F.	49,309	1,736,701,047	9,031,131
5	BD-1	Triple towers: 18-F+Sub-3F.	52,807	1,603,520,000	4,682,491
6	BD-2	Twin towers: 19-F+Sub-3F.	35,623	1,092,876,556	3,000,000
7	BD-3	Four towers: 21~22-F+ Sub-2F.	75,696	2,441,000,000	12,440,000
8	LJ-1	Triple towers: 11-F+Sub-3F.	14,231	514,765,288	2,619,246
9	LJ-2	Four towers: 14-F+ Sub-2F.	49,372	1,472,820,731	3,796,387
10	JL-1	11 towers: 11~13-F+ Sub-2F.	138,608	4,838,626,974	24,462,651

An AHP questionnaire is designed to compare the relative importance on cost requirements among the 25 BIM uses based on the hierarchy of Taiwan BIM Guide, i.e., 6 phases · 25 BIM uses as shown in Fig. 1. The questionnaire was prepared and provided to the project owner, the Office of Housing Development of Taoyuan City Government.

In order to make sure all BIM practitioners of the projects fully understand the definition of the 25 BIM uses and the process of relative preference comparisons of BIM, presentations were held to those practitioners by the research team. Then the project owner helped distribute the questionnaire to all participants of the 10 public social housing projects and collect the responses. The responses were collected twice: first collection was at the end of 2017 with 26 responses. It was figured out that most of the responses were from the designers or engineering consultants, since the projects were in their early stages. As a result, the second survey were conducted and collected in May of 2018. Finally, 50 valid responses were collected and analysed.

Due to the business schedule of the project participants, the iterative surveys of the traditional AHP were not possible. As a result, the Adaptive AHP Approach (A³) [25,26] was adopted to analyse the 50 valid responses from the surveys. In performing A³ processing, the CR was relaxed step wisely from 0.1 to 0.2, to 0.3, in order to obtain sufficient samples (default No. of sufficient samples was set to be 33 to meet the requirement of Central Limit Theory of Statistics). After analysing the 50 valid questionnaire responses, relative weightings in each level of the hierarchy of Fig. 1 were calculated to yield the final criterion weightings for all 25 BIM uses.

Fig. 1. Hierarchy of the 25 BIM uses of Taiwan BIM Guide.

4. Result Analysis

The analysis results of AHP via A^3 process are presented in this section.

4.1. Profile of participants

The profile information of the respondents of the two AHP questionnaire surveys help in Dec. of 2017 (1st survey) and May of 2018 (2nd survey) are shown in Table 3. It is noted that the No. of the General and DB contractors were increased in the 2nd survey due to the project execution phase. Other profile information of the respondents is shown in Fig. 2.

Table 3. Profile information of the 50 respondents.

Project participants	No. of respondents		
	1 st survey	2 nd survey	Sum
Owner/CM	5	7	12
Consultant	10	2	12
Architect	7	1	8
Contractor/DB	4	14	18
Total respondents	26	24	50

4.2. Results of A^3 processing

After AHP questionnaire survey, 7 pairwise weighting matrixes (PWMs) are obtained from each respondent: (1) Phases—6 criteria; (2) Planning—4 criteria; (3) Basic design—5 criteria; (4) Detail design—7 criteria; (5) Construction—6 criteria; (6) Completion—2 criteria; and (7) Facility management—1 criterion. As the No. of criteria is < 3 in AHP, there is no inconsistency ($CR=0$) for the PWMs; thus, there is no need to reprocess the PWMs of (6) and (7). However, A^3 reprocessing is required for the rest 5 PWMs when the CR of the PWM is > 0.1 [26]. The No. of acceptable returns ($CR<0.1$) in the original questionnaire responses for the 7 PWMs are: (1) Phases—12; (2)

Planning—15; (3) Basic design—17; (4) Detail design—16; and (5) Construction—14. Using the stepwise relaxation of CR in the A³ process, all PWMs of the AHP meet the requirement of 33 acceptable responses with adapted CR < 0.1. The No. of acceptable responses for each PWM is follows: (1) Phases—35; (2) Planning—36; (3) Basic design—41; (4) Detail design—33; and (5) Construction—37. As a result, the relaxation of CR stops at CR = 0.3. An example of A³ adaptation for a PWM is shown in Table, where DI is defined in Eq. (1). In Table 4, the adaptation stops at Generation 3 as CR has decreased to 0.0989 < 0.1.

Fig. 2. Profile information of the 50 respondents.

Table 4. Example of A³ adaptation

No. of generation	CR	$\lambda_{\max}$	Difference Index (DI)
-	0.2040	4.5507	1.0000
1	0.1759	4.4749	1.0047
2	0.1653	4.4464	1.0050
3	0.0989	4.2670	1.0481

$$DI = \frac{|G./G^*| + |G^*./G|}{n^2 - n} \quad (1)$$

Where 'G' is the value of an element in the PWM before adaptation; 'G*' is the value of an element in the PWM after adaptation; 'n' is the number of criteria in the PWM; './' is the element-wise division operator.

4.3. Relative weightings of cost requirements for the 25 BIM uses

The resulted cost requirement weightings for the 25 BIM uses after A³ adaptation are shown in Fig. 3 as grouped by phases.

Fig. 3. Relative weightings of cost requirements for the 25 BIM uses (grouped by phases).

The cost requirement weightings for the 25 BIM uses in decreasing order are shown in Fig. 4. It is noted that the most significant cost demanding BIM use has been '25-Facility management.

Fig. 4. Relative weightings of cost requirements for the 25 BIM uses in decreasing order.

5. Application Demonstration

In this section, how the obtained relative cost requirement weightings for the 25 BIM uses can be employed to plan a BIM project is demonstrated. The selected case project is a high-rise residential construction project. Total floor area of the project is 34,860 m², with construction budget of USD\$37.77 million. Assuming that the BIM service cost is 1% of the construction budget, the allocated required costs for all 25 BIM uses are shown in Table 5.

Table 5. BIM cost allocation for six phases.

Phase	Weightings (%)	Cost (USD\$)	BIM service provider
Planning	12.83%	48,453	Owner/Consultant
Basic design	11.21%	42,335	Architect
Detail design	22.59%	85,311	Architect/DB
Construction	27.17%	102,608	GC/DB
Completion	16.30%	61,557	GC/DB
Facility management	9.90%	37,387	FM firm

Table 5 demonstrates an example of planning BIM service cost for different project phases (by different BIM service providers). When different project delivery models were used for the same project, the BIM service budget should be planned differently: (1) for D/B/B project delivery model—the Architect (Designer) should be provided with USD\$127,646 for basic and detail designs and the general contractor (GC) should be provided with USD\$164,165 for construction and completion BIM works; (2) for Design/Build (D/B) model—the D/B contractor (including design and contractor) should be provided with USD\$249,476 for detail design, construction and completion BIM works, while the planning consultant should be provided with USD\$ 90,788 for planning and basic design BIM works.

6. Discussion

An interesting observation was found while analysing the different relative weightings in AHP questionnaire surveys. As shown in Table 6, the relative weightings by different project participants depicts some profound implications in BIM practice discussed in the following:

- The Owner emphasizes more on Completion and FM phases, while less on BIM uses in Planning phase;
- The Architect considers that Basic design deserves more BIM budget and less on BIM uses in FM phase, which is completely opposite to the Owner's opinion;
- Interestingly that the engineering consultant emphasizes more on BIM uses in Construction phase as he/she need to supervise that, while also give less concerns on FM BIM use that is similar to the Architect.;
- On the contrast to the Owner, the Contractor/DB emphasizes more on Planning phase, although it is irrelevant to Contractor/DB's responsibility. He/she gives less concerns to Detail design, which may be due to that the Contractor usually rebuilds the BIM model in practice.

Table 6. Relative weightings by different project participants

Party	Planning	Basic design	Detail design	Construction	Completion	FM
All	12.83%	11.21%	22.59%	27.17%	16.30%	9.90%
GC/DB	16.16%	11.30%	20.88%	25.25%	15.98%	10.47%
Owner (CM)	4.24%	9.91%	24.30%	26.74%	21.60%	13.21%
Architect	11.66%	13.63%	24.31%	26.54%	16.23%	7.61%
Consultant	14.50%	9.94%	24.26%	33.51%	11.74%	6.06%

7. Conclusion and Recommendation

This paper presents a case study on the estimating and allocating the costs required for BIM services based on the 25 BIM Uses defined by the 'Taiwan BIM Guide' developed by the Architecture and Building Research Institute (ABRI), Ministry of the Interior (MOI), Taiwan, for implementation of BIM by local construction industry. To estimate and allocate required costs for various BIM uses, the current study proposes a method integrating traditional AHP and A³ approaches to determine the relative requirements of costs for different BIM uses by surveying the BIM practitioners from the 10 public social housing projects owned by the Taoyuan City Government using an Analytic Hierarchy Process (AHP) method. A BIM use cost allocation guideline is provided as a reference to the BIM practitioners to determine the required costs for different BIM Uses. Finally, the relative weightings of cost requirements for the 25 BIM uses are identified. Such a method to determine the relative BIM service cost requirements were not found in any literature. The results can be applied to plan the BIM service costs for different project delivery models of a building construction project. Demonstrated case studies are also presented to show the feasibility of their applications.

Although a method for BIM service cost allocation has been developed, the exact BIM cost requirements for different project types have not yet been defined. In the demonstrated case, 1% of total construction budget was assumed for BIM service cost. This is also suggested by the ABRI and PCC of Taiwan government. However, different BIM guides will result in different BIM service cost requirements. It implies more research efforts should be spent in this topic.

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