A Case Study on Assessing the Productivity of a BIM team in a Construction Company

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Abstract: Due to the labor-intensiveness, high investment cost, long execution time, frequent change orders, and many stakeholders in a BIM project, a BIM manager is bound to face a lot of risks to make decisions in cost managing process. Since the productivity of a BIM team will affect the execution cost, this study investigates a simple method of assessing the productivity of a BIM team using the working timesheet records of the team. In this research, the productivity of a BIM team is defined as the effective working floor area (in square meters) of BIM uses per labor-time (in man-months) spent by the team. After the applicability of this method is tested by regression analysis using data from 5 real BIM projects in the construction phase, it is found that the simple productivity definition adopted in the method, although easy-to-implement, does not produce a statistically constant productivity value. More research is therefore needed in the future to devise better indicator(s) for assessing the productivity of a BIM team.

Keywords: Building Information Modeling (BIM), productivity, cost management, decision-making, cost breakdown structure

I. INTRODUCTION

Although implementing BIM in a construction project can usually help decrease the construction costs and increase construction efficiency and quality, the costs of BIM implementation still need to be estimated in advance for the project manager to decide on whether it is cost worthy or not. Also, once BIM is implemented, the manager may need to figure out how much they need to charge for a construction project.

At present, most researchers, e.g. [1, 2, 3], focus more on the benefits BIM has brought. Nevertheless, the costs of BIM should not be overlooked if one plans to implement it. Therefore, both return on investment (ROI) or cost-benefit analysis (CBA) may be used to effectively assess not only benefits but also costs of BIM, and to provide an easy way for project managers to comprehend and evaluate the worthiness of implementing BIM. For example, some researchers [4, 5] evaluated ROI or CBA [6] on BIM implementation into construction projects. In some other studies [7, 8], ROI was also included in key performance index (KPIs). However, in practice, calculating the benefits of BIM is not an easy task for a manager. Instead, calculating the extra costs incurred due to BIM implementation and determining if the costs can be paid off by replacing some existing works are much easier.

Little research has discussed the costs of BIM implementation from the productivity point of view. However, in practice, the costs of BIM implementation may be estimated using the productivity information of the project BIM team. Therefore, this research investigates a simple method for calculating the productivity of a BIM team in a construction company and for estimating project BIM costs using the calculated productivity. The applicability of the method is tested using data from five real construction projects in Taiwan.

Some terms used in this research are discussed here first. A BIM project refers to the BIM execution in the construction project and serves as a subproject within the construction project. A BIM team here refers to a group of engineers who are mainly executing BIM related works. In addition, the timesheets software refers to the software developed by the Timesheet MTS software company for recording the tasks and corresponding time spent by members of a BIM team in a construction project.

II. THE STUDY CASE AND DATA COLLECTION

In this research, the study subject is one of the leading construction companies in Taiwan. The company has implemented BIM since 2008. In this case study, five of its building projects, as shown in Table I, which implemented BIM are selected for data collection and analysis.

In these projects, the BIM engineers were asked to record their project content and corresponding hours using the timesheets software. Before the engineers' working data were recorded, a cost breakdown structure (CBS) for data collection was established first. In this case, a CBS was built to serve as a tool for collecting and classifying cost data in these five projects.

The CBS has a 3-tier structure, in which the first tier is the company name or group name, the second tier is the cost category, and the third (base) tier hosts cost-based activities. The CBS of BIM cost at project level is shown in Figure I. During the period of case study, the CBS has been revised twice to solve the problem of mapping the cost-based activities with the timesheet activities.

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TABLE I
DESCRIPTION OF THE FIVE PROJECTS

Project	Building Type	Construction Type	Level	Floor Area
A	Commercial building	RC	11+4	28760 (m^2)
B	Residential building	SRC	26+3	26105 (m^2)
C	Residential building	RC	18+3	18920 (m^2)
D	Academic building	RC	9+2	28235 (m^2)
E	Residential building	SS+RC	41+6	87909 (m^2)

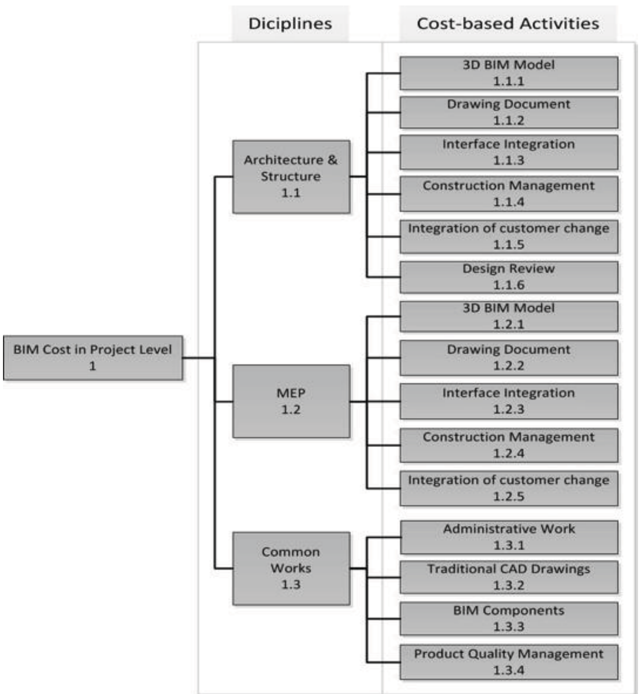

FIGURE I
THE CBS OF BIM COST AT PROJECT LEVEL

Figure II shows the three cases of mapping the cost-based activities with the timesheets activities. For the purpose of analyzing the productivity of different BIM uses, the cost-based activities are mapped with the timesheets BIM activities. The relationship between these two tables is an one-to-many relationship. Three different cases may occur when the two tables are mapped:

- Case 1: Cost-based activities with more than one timesheet activities.
- Case 2: Cost-based activities without timesheets activities.
- Case3: Cost-based activities with one timesheets activity.

The costs and productivity of these different activities should be analyzed respectively. Then, the analysis outcomes can serve as the basis for calculating productivity.

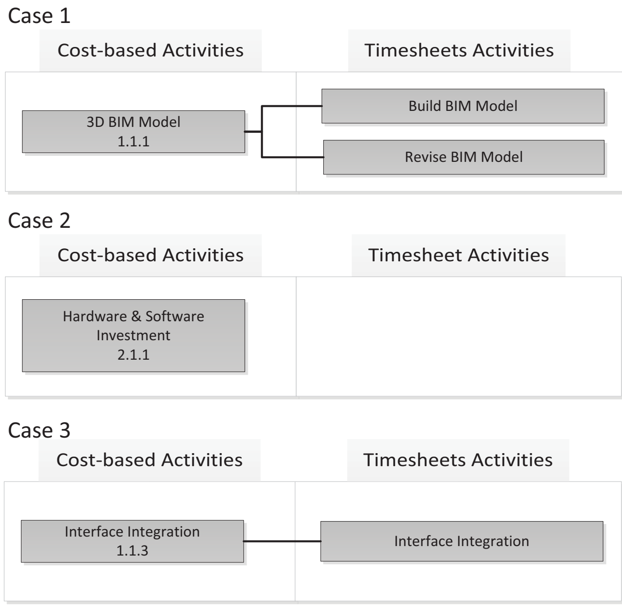

FIGURE II
3 CASES OF MAPPING THE COST-BASED ACTIVITIES WITH THE TIMESHEETS ACTIVITIES

III. PRODUCTIVITY DEFINITION AND CALCULATION

The costs of a BIM project mainly come from the investment on software, hardware and labor. Among these costs, the labor costs account for a large portion of the total expenditure. In this research, the productivity of a BIM team is defined as the working area (in square meters) per labor-time (in man-months):

$$Productivity(P) = \frac{Working\ area(A)}{Labor-time(T)} \quad (1)$$

in which the working area refers to the floor area built in either a BIM model or its corresponding building, and the labor-time is the time spent by a number of the team members to build the floor area. For example, if a BIM team spent 5 man-months to build a BIM model for a building with working floor area of 10,000 square meters, the productivity of the BIM team to build a BIM model in this project would be 2,000 square meter per man-month.

In the study case, the man-months data are converted from the man-hours records already stored in the timesheet software. Also, the actual working area for the BIM tasks can be smaller than the total floor area of the building because, for example, the MEP modeling is not done for every floor in this case study. Tables II and III show the actual working area of BIM uses (including modeling) in the architecture and MEP parts of these 5 projects, respectively.

TABLE II
THE ACTUAL WORKING AREA OF BIM USES (ARCHITECTURE)

Case	Working Area for Architecture (m^2)	BIM Uses
A	33,721	1. Structural BIM model 2. Clash detection 3. Working Drawings
B	30,151	
C	22,949	
D	34,689	
E	44,656	

TABLE III
THE ACTUAL WORKING AREA OF BIM USES (MEP)

Case	Working Area for MEP (m^2)	BIM Uses
A	16,945	1. MEP BIM model 2. Clash detection 3. Working Drawings
B	17,867	
C	9,654	
D	24,207	1. MEP BIM model 2. Clash detection
E	-	None

The productivities of the BIM team for the architecture and MEP parts are shown in Table IV and Table V, respectively, based on three different BIM uses. Because of confidentiality reasons, only normalized productivity values are shown. In this research, Project C is chosen as the base for normalization, so all its productivity values become 1.00.

IV. DISCUSSION

In this study, it is hoped that the productivity definition under investigation can provide a good and stable estimation for a BIM team's productivity. If the productivity value of a BIM team can be a constant with reasonable variation at a given period of time, the needing man-months and therefore the costs of BIM application can be well estimated by knowing the required working floor area.

TABLE IV
THE PRODUCTIVITY OF BIM ON ARCHITECTURE

Productivity on the basis of project C ($10000\ m^2$/man-month)			
Case	Structural BIM model	Working Drawing	Clash Detection
A	2.54	0.67	1.93
B	2.43	3.39	1.91
C	1.00	1.00	1.00
D	2.00	1.18	2.08
E	4.45	1.95	9.24

TABLE V
THE PRODUCTIVITY OF BIM ON MEP

Productivity on the basis of project C ($10000\ m^2$/man-month)			
Case	MEP BIM model	Working Drawing	Clash Detection
A	0.97	3.07	1.13
B	1.23	1.47	1.16
C	1.00	1.00	1.00
D	2.51	-	4.27

Figure III shows the production curves of different BIM uses on architecture using linear regression. The slopes of the regression lines with zero intercept can be regarded the productivity of the BIM team based on Equation (1). However, because all the R square values are negative, the productivity values of all the BIM uses cannot be regarded constant. This result may be largely due to that most buildings, especially residential buildings, have different number of typical floor plans and BIM modeling of the first typical floor usually takes much more man-months than the rest, leading to inconsistent calculation of productivity for typical floor plans. When two projects with the same total floor area are compared, if the proportion of the typical floor area over the total floor area is higher, the required man-months could be predictably fewer and a higher productivity value would be obtained.

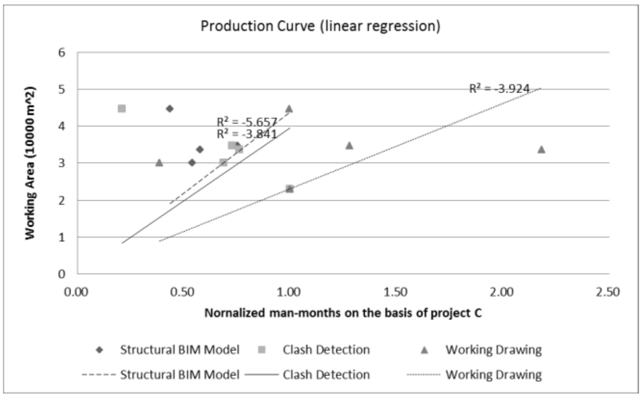

FIGURE III
THE PRODUCTION CURVES FOR DIFFERENT BIM USES ON ARCHITECTURE

Table V shows the actual working area of BIM uses on architecture that already excludes typical floor plans. The re-calculated production curves are shown in Figure IV. According to the R square values, the productivity value for the working drawing task can be considered as a constant value, but the values are still not constant for the structural BIM model and clash detection tasks. These results indicate that the calculation of the working floor area should take into account different complexity of BIM uses associated with different spaces on the working area. More detailed data analyses are currently underway to devise weighting factors for different spaces that involve different complexity of BIM uses. Also, the calculation of the working area in the productivity definition should be modified to become calculation of weighted working area.

TABLE V
THE ACTUAL WORKING AREA OF BIM USES WITHOUT THE TYPICAL FLOOR PLAN (ARCHITECTURE)

Case	Working Area for Architecture (m^2)	BIM Uses
A	30,854	1. Structural BIM model 2. Clash detection 3. Working Drawing
B	12,606	
C	11,943	
D	26,647	
E	30,889	

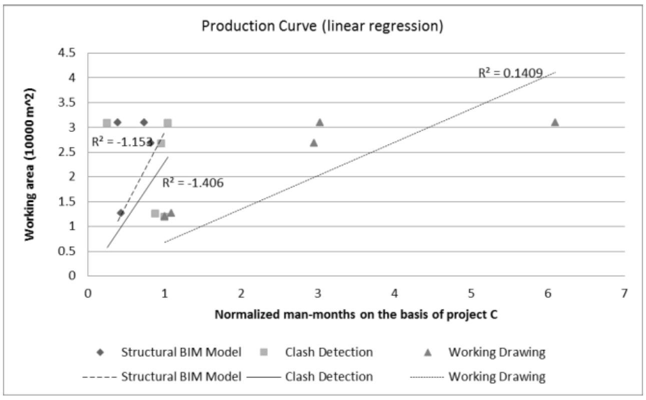

FIGURE IV
THE PRODUCTION CURVES FOR DIFFERENT BIM USES ON ARCHITECTURE WITHOUT THE TYPICAL FLOOR PLANS

Figure V shows the production curves for different BIM uses on MEP where the effect of typical floor plans has already been excluded. It can be seen that the productivity values for all three BIM uses are not constant. Again, weighting factors for different working area with different BIM uses should be further studied.

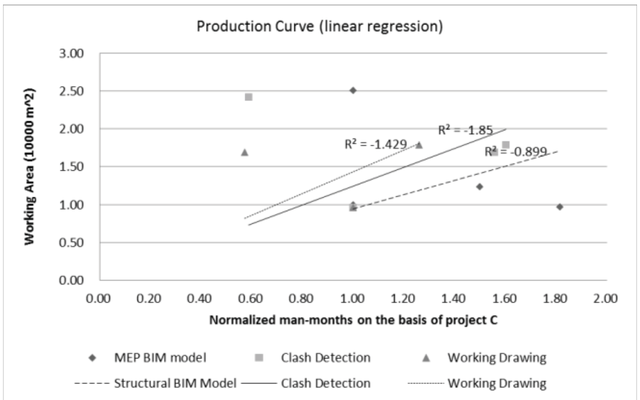

FIGURE V
THE PRODUCTION CURVES FOR DIFFERENT BIM USES ON MEP

V. CONCLUSION

The method investigated in this research for calculating the productivity of a BIM team is simple and easy-to-implement without much additional cost. It only requires a BIM team to record the working timesheets of its members based on the cost-based activities in the proposed CBS. However, in this preliminary study, after the simple definition for the productivity of a BIM team is tested using data from five real construction projects with regression analysis, it is found that some improvement is still needed in the current method before it can be used to estimate the BIM costs or become one of team KPIs. Work is currently underway by the authors to investigate a modified definition of productivity:

$$Productivity(P) = \frac{Weighted\ Working\ area(A)}{Labor-time(T)} \qquad (2)$$

and to devise weighting factors for accounting for various complexity of BIM uses (e.g. building type, levels of buildings, complexity of drawings, quality of drawings and construction type, etc.) involved in building spaces when the weighted working floor area is computed. Furthermore, more BIM projects and their data are being collected for better validation of the modified method.

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