BIM-BASED GOVERNMENT PROCUREMENT SYSTEM- THE LIKELY DEVELOPMENT IN TAIWAN

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ABSTRACT: In Taiwan, government procurement still relies on the traditional "paper-based" approach. Much information is mis-carried and then mis-interpreted when procurement information is transferred from that of paper to digital form. This creates design negligence, conflicts, mis-calculations, and inconsistencies among drawings, specifications, etc, which often cause change orders and contract disputes. Government agencies, as the biggest procurer, are the most vulnerable to these problems. Considering the huge number of tenders every year, a sizable share of public resource is wasted to resolving the disputes caused by such information gap among owners, designers and contractors. Hence, the evolution of a true 3D digital approach hinges upon the government's will to adopting it. The aim of this research is to examine the feasibility and the means to launch a BIM-based procurement system for public works in Taiwan. If a BIM platform is adopted, the current procurement system in Taiwan would need significant adjustments, which require a thorough and comprehensive analysis. Through this work, it is expected that the BIM-based procurement system can save much of the government's trouble related to traditional paper-based approach, and the efficiency of government procurement will be enhanced.

Keywords: *Government Procurement System, BIM-based Approached, Paper-based Approach, BIM models, 2D Drawings, Project Delivery Method, Project Life Cycle*

1. INTRODUCTION

As computer-aided approach in expressing procurement requirements becomes common and well accepted, government procurement still relies heavily on the traditional "paper-based" approach. In fact, much information is mis-carried and then mis-interpreted when procurement information is transferred from one medium to another, in particular from that of paper to digitalization. This inevitable transfer of information creates design negligence, omissions, conflicts, mis-calculations, and inconsistencies among drawings, specifications, and other contract documentations. These problems cause frequent change orders and may contribute to disputes among owners, designers and contractors.

Government agencies, as the biggest procurer in the construction industry and also the most conservative users who rely on the paper-based approach, are perhaps the most vulnerable to the afore-mentioned problems. Considering the huge number of tender being brought to the attention of potential bidders every year, a sizable share of public resource is wasted to resolving the disputes caused by such information gap among owners, designers and contractors. In addition, the contracting industry, in reaction to government agency's conservative paper-based approach, is also sloth to embrace the true benefit which 3D based design can offer, as the ability to work on 2D drawings and concepts including quantity surveying, construction planning, system integration, etc., is still crucial. Hence, the evolution from 2D paper-based to a true 3D digital approach in the construction industry hinges upon the government's will to adopting a 3D procurement approach in the first place.

The aim of this research is to examine the feasibility as well the relevant means to launch a BIM-based procurement system for public works in Taiwan. If a BIM platform is adopted, rather than the traditional paper-based approach, the current government procurement system would need significant adjustments, and many other spin-off functions surrounding government procurement, which are not likely to be possible in the past, may also be contemplated. Through this work, it is expected that the BIM-based procurement system can significantly save the government's trouble in relying on traditional paper-based procurement approach, and the efficiency and effectiveness of government procurement will be further enhanced.

2. COMMON PROBLEMS OF PAPER-BASED PUBLIC WORK PROCUREMENTS IN TAIWAN

The construction phase involves a variety of organizations, persons, equipment, materials, etc. and thus only paper drawings served as the medium to link each other are not sufficient. As a result, such a procurement approach often faces many problems as follows and causes disputes among the owner, designer and contractor:

a. Objects Clash or Design Negligence: After the initial design of a building is finished, the engineers will do the MEP design. Although with frequent coordination and integration, only depending on paper drawings can not easily find objects clash or design negligence, especially in larger projects.
b. Bad Constructability: If considerations about construction details are not fully made in the design phase, it is likely to have difficulties in construction sequence, work space, equipment availability, etc.
c. Omissions or Mis-calculations: After the detail design is completed, the quantity surveyor will take off all work items of a project and calculate quantity of materials. The correctness of QTO is relies on both the accuracy and level of detail of drawings, and the careful review made by the surveyor. Recently the public works has grown larger and more complicated so it is more difficult to check if there are omissions or mis-calculations from 2D drawings.

   On the other side, the bidders do not have enough time to carefully read paper construction documentations (drawings included) due to the short period of waiting bids. Some bidders submit their bids without thorough inspection and will find omissions or mis-calculations problems after the start of construction. According to the regulations, if the quantity difference between the actual and the number on the QTO is below 5% (originally 10%) the contractor has to afford by its own. As to the omissions of work items, the contractor may not get the claims because of its own negligence to find them and propose to the owner before bidding.
d. Many change orders: Paper-based procurements often have change order problems. While changing these drawings, the designer has to redraw them in a great effort. The inconvenience is originated from the limitation of a paper drawing itself. Besides, a change order may involve several trades within the same space so their shop drawings should be updated simultaneously. Another great effort is made to coordinate and integrate the change.
e. Inconvenient Keeping of As-built Drawings: To keep as-built paper drawings and records is not easy. After a period of time, these drawings may be lost, or just key pages lost, or not updated even if being found. It seems as-built drawings nearly valueless. Plus, the contractor may not be found some years later. To maintain the facility becomes a difficult task then.
f. Incomplete e-Procurement: The Public Construction Commission (PCC) is an official unit that responsible for managing all government procurements. PCC has established the Web-based "e-Tendering Systems" and the computer-aided "Public Construction Cost Evaluation Systems (PCCES)." The two systems make some processes electronic and some documents produced automatically. However, the procurement agencies still use paper drawings as bidding documentations, and the bidders have to take them back and check if the QTO is correct. In other words, the e-Procurement is not complete and has room for improvements. Besides, the PCCES relies on manpower to input project data instead of directly reading an IFC-based file.

3. VERSATILE FUNCTIONS AND APPLICATIONS OF BIM

An innovative Building Information Modeling (BIM) technique can successfully solve those problems mentioned in Section 2. The BIM technique was developed to aid planning and design activities but with the evolution of IT technique its functions and applications are being expanded. At least the BIM has the following functions and applications currently:

a. Object-oriented Design: BIM is an object-oriented technique and allows complicated curved design so the types and construction methods of an architecture are more peculiar and flexible.
b. Element with Information: The element of a BIM has the geometric information and can save kinds of physical information of project elements. The content of information can be editable in some BIM tools.
c. Auto-quantity Take-off: With geometric information in the BIM, certainly quantity can be auto-calculated.
d. Clash Detection: With tools, clash among objects in the BIM can be detected and shown in a different color.
e. 3D Simulations: Using BIM can do more thorough simulations, explore alternatives by Value Engineering study, and make visual construction plans to investigate constructability.
f. Construction Management: BIM can link time and cost information and can automatically produce (or update) schedule (4D) and cost table (5D).
g. Life Cycle Considerations: With software packages, building sustainability analyses (6D) of sunlight, energy-saving, carbon-reduction, or LEED can be done.
h. Coordination and Integration: A BIM master model may consist of several models such as architectural, structural, MEP, HVAC. Each model can be modeled in different places and then integrated into the master model by Web-meeting. This way can strengthen coordination among project team members.
i. Auto-producing Project Specs.: Using 3 built-in code systems, CSI UniFormat, MasterFormat and OmniClass, the construction and materials (products) specifications of the project are produced.
j. Operations and Maintenance Management: The as-built model can be adapted for facility management (FM), asset management, etc.
k. Information Keeping Value: Along with the progress of a project lifecycle, BIM can keep more value of knowledge as shown in Table 1. It can solve the problem that paper-based delivery process has information gaps among different phases.

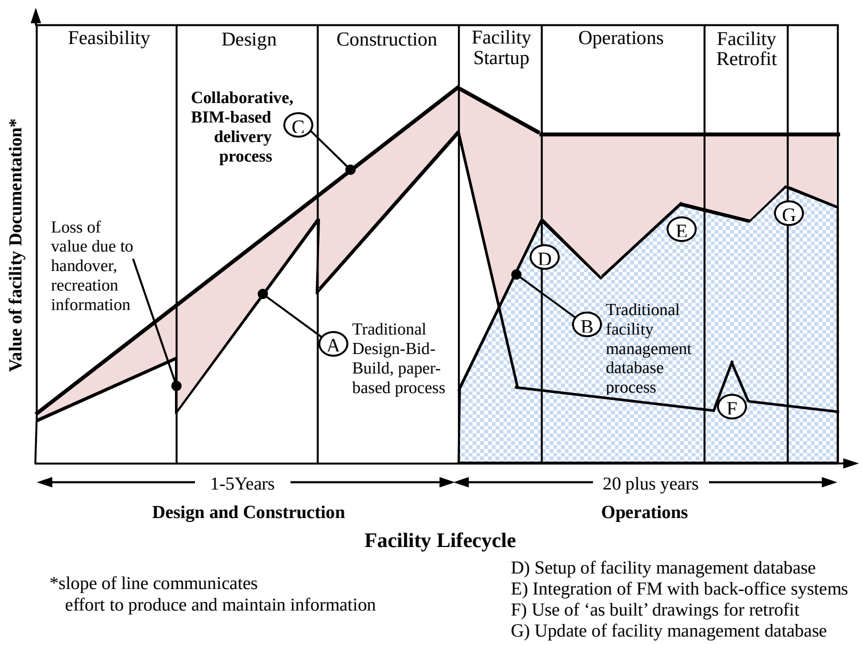


Fig. 1 Value of facility documentation: comparison of D-B-B process and BIM-based process [1]

4. REQUIREMENTS OF MODELING A BIM AND ITS MATURITY

A BIM is likely to consist of a variety of models. The models that may be part of the BIM are [2]：

a. Site model (context—land, buildings, landscape, etc.)
b. Architectural model (walls, floors, roof, etc.)
c. Structural model (structural systems)
d. MEP models (mechanical, electrical, plumbing)
e. FP model (fire protection)
f. Specialty models (equipment, finishes, temporary construction—scaffolding, formwork, trenching, etc.)

A BIM can be developed with the progress of a project. In different procurement phases, the model content may be different. The American Institute of Architects (AIA) published Document E202 in 2008, which describes 5 levels of development (LOD) and model content requirements as shown in Table 1. The document also includes a Model Element Table as Table 2, which the owner can write into the required LODs and model element authors (MEA) of every BIM elements. Some kinds of the BIM and responsible MEAs are illustrated as follows:

a. Design Models: produced generally by the architect and including components from structural and mechanical engineers.
b. Construction Model: assembled in most cases by the general contractor according to the construction documents prepared by the architect.
c. Shop Drawing Model: produced by manufacturers, and used in lieu of shop drawings to fabricate their components and study interference.
d. As-built Model: updated properly from an existing BIM by the time the project is finished.

The maturity of the BIM can be evaluated according to National BIM Standard (NBIMS) Capability Maturity Model (CMM) designed by National Institute of Building Science (NIBS). The 11 evaluation items are listed in Table 3. The credit score of every item is between 1 and 10 and given by an evaluation team according to the CMM Matrix. Finally, calculate the credit sum and decide the Maturity Level. An evaluation example is given in Table 3.

Table 1 Levels of development and model content requirements of AIA Document E202-2008 [3]

LOD	Model Content Requirements
LOD100 (Conceptual Design)	Overall building massing indicative of area, height, volume, location, and orientation may be modeled in three dimensions or represented by other data.
LOD200 (Schematic Design)	Model Elements are modeled as generalized systems or assemblies with approximate quantities, size, shape, location, and orientation.
LOD300 (Construction documentation/ Shop Drawings)	Model Elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location, and orientation. Non-geometric information may also be attached to Model Elements.
LOD400 (Fabrication & Assembly)	Model Elements are modeled as specific assemblies that are accurate in terms of size, shape, location, quantity, and orientation with complete fabrication, assembly, and detailing information.
LOD500 (As-built conditions)	Model Elements are modeled as constructed assemblies actual and accurate in terms of size, shape, location, quantity, and orientation.

Table 2 Model Element Table (CSI format) and an example of traditional delivery method [3]

§4.3 Model Element Table

Identify (1) the LOD required for each Model Element at the end of each phase, and (2) the Model Element Author (MEA) responsible for developing the Model Element to the LOD identified.

Insert abbreviations for each MEA identified in the table below, such as "A - Architect," or "C – Contractor."

NOTE: LODs must be adapted for the unique characteristics of each Project.

Model Elements Utilizing CSI UniFormat™				Preliminary Design LOD	Preliminary Design MEA	Schematic Design LOD	Schematic Design MEA	Design Development LOD	Design Development MEA	Construction Documents LOD	Construction Documents MEA	Construction LOD	Construction MEA	LOD	MEA	Note Number (See 4.4)
A SUBSTRUCTURE	A10 Foundations	A1010	Standard Foundations							300						
		A1020	Special Foundations							300						
		A1030	Slab on Grade							300						
	A20 Basement Construction	A2010	Basement Excavation							NA						
		A2020	Basement Walls							300						
B SHELL	B10 Superstructure	B1010	Floor Construction							300						
		B1020	Roof Construction							300						
	B20 Exterior Enclosure	B2010	Exterior Walls							300						
		B2020	Exterior Windows							300						
		B2030	Exterior Doors							300						
	B30 Roofing	B3010	Roof Coverings							300						
		B3020	Roof Openings							300						

Table 3 NBIMS Interactive Capability Maturity Model and an evaluation example [4]

Area of Interest	Weighted Importance	Perceived Maturity Level	Credit
Data Richness	84%	Completely Authoritative Information	6.7
Life-cycle Views	84%	Includes Operations & Warranty	5.9
Roles or Disciplines	90%	Limited Control	4.5
Business Process	90%	Operations & Sustainment Supported	7.2
Change Management	91%	All BP Collect & Maintain Info	7.3
Delivery Method	91%	Real-time Access w/Live Feeds	9.1
Timeliness/Response	92%	Web Enabled Services – Secure	7.4
Graphical Information	93%	4D - Add Time	8.4
Spatial Capability	94%	Integrated into a complete GIS	8.5
Information Accuracy	95%	Computed Ground Truth w/Full Metrics	9.5
Interoperability/IFC Support	96%	Full Info Transfers Between COTS	5.8
		Credit Sum	80.1
		Maturity Level	Gold

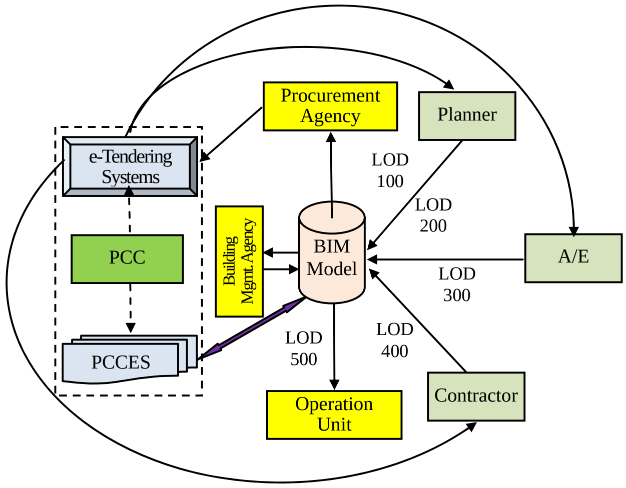
5. INTERNATIONAL TREND OF BIM-BASED GOVERNMENT PROCUREMENT

In view of BIM functions and applications, and many successful private projects using BIM, several countries started to investigate the BIM-based approach to project procurement and asset management around 2000. In 2007 the U.S. Government Services Administration (GSA) publicized BIM Guide Series (01-Overview and 02-Spatial Program Validation). At the same time, GSA required all new projects adopt BIM to plan and build office buildings, and to manage assets. The Singapore government has developed the Construction and Real Estate Network (CORENET) Systems. The users can e-submit IFC-based drawings and the drawings can be reviewed by e-Plan Checking Systems. The UK government had prepared a route map to use of BIM in government projects. A trial team was set to make recommendations about procurement best-practice in March 2011.

Taiwan started such studies of BIM later but was making great effort to catch up to the trend. Actually some private, large consulting companies have introduced BIM to aid their planning and design activities. However, the deliverables to the owner are still 2D drawings as normal. Until 2010 the National Science Council officially constituted an integrated team to study a development strategy for use of BIM in AEC industry. The Taipei Building Management Agency also began to investigate the feasibility of developing a computer-aided checking of design plans. In March 2011 the Taipei MRT Construction Agency publicized the "Requirements of Modeling the BIM" and chose two projects to test its effectiveness.

6. PROTOTYPE OF TAIWAN'S BIM-BASED GOVERNMENT PROCUREMENT SYSTEM AND ITS IMPLEMENTATION STRATEGY

The paper proposes a prototype of BIM-based government procurement system fit for Taiwan's conditions. Although the prototype shown in Fig. 2 is presented for the D-B-B delivery method, it is also useful for the other two methods. For instance, the prototype can be adapted for the DB method by incorporation of both the A/E and contractor into a team.



[Remarks: 1.Line--electronic delivery; 2.Dummy--administrative management,; 3.Double-arrows--data link]

Fig. 2 Prototype of Taiwan's BIM-based Government Procurement System for D-B-B method

As described in the end of Section 2, PCC has established the e-Tendering Systems. In the future the procurement agencies can electronically deliver bidding documents with the BIM to bidders, in replace of using manpower to deliver 2D paper drawings. The bidders are able to use the BIM to link the PCCES systems through the Internet, to input pricing data and auto-produce bid sheets, and to e-submit their bids by e-Tendering. In all project procurement phases, the planner, A/E and contractor are required to submit deliverables by electronic tools so the procurer can use the deliverables directly for the next tendering processes, or can handover to the operator.

Besides, if all building management agencies establish the e-Plan Checking Systems, both design and as-built models can be reviewed automatically.

In order to implement the BIM-based government procurement system, PCC may take the NBIMS as reference to make native BIM technical specifications. Next, the implementation regulations can be written according to GSA BIM Guide, and the Public Works Procurement Contract should be revised to incorporate use of BIM. Furthermore, PCC may follow the AIA Document E202-2008 and AGC ConsensusDOCS 301-2008 in order to make an exemplified BIM Agreements as reference. The BIM Agreements shall have requirements of information management, BIM execution plan, deliverables, LODs and MEA, etc. Also included is the evaluation rule of a BIM's maturity, which states the composition of an evaluation panel and evaluation items. Kuo and Hsieh [5] suggested using 11 items of the NBIMS CMM Matrix plus a new item of "Regulation Checking Support."

As to the implementation strategy for the BIM-based government procurement system, three proposed steps are:

a. The key to introduce BIM into the AEC industry is the methodology of "Top-down" such as those experiences in the U.S., Singapore, and the U.K.
b. The implementation plan should set several phases rather than "one stop". For example, the first priority is the Design Phase. The deliverables that the A/E should submit is BIM-based. Secondly, construction project is not obligatory of using BIM at the beginning. However, the owner may award the project to the bidder who uses BIM while other bidders with similar conditions.
c. Implementing the BIM-based procurement can promote DB or Turnkey delivery processes, and can accelerate introducing BIM into the Construction Phase. Hence choosing medium-large construction projects to use BIM is recommended. If so, the efficiency and quality of government procurements can be enhanced.

7. CONCLUSIONS

The government procurements in Taiwan are paper-based but there are many common problems originated from 2D drawings. Although the Government has established e-Tendering and PCCES systems, the electronic procurement is not completely automatic and allows more improvements. Fortunately, an innovative BIM technique can assist to conquer these problems. Several countries have implemented the BIM-based approach to government procurement in recent years. In response of the international trend, the Taiwan government is making great effort to catch up.

The paper proposes a prototype of BIM-based government procurement system fit for Taiwan's conditions. The prototype is that using BIM with the already existing e-Tendering systems to deliver bidding information, and the planner, A/E and contractor should submit deliverables to the procurer. If so, the goal of e-procurement is achieved. To implement the BIM-based system, the Government shall publish the national BIM technical specifications, BIM Agreements, and Requirements of Modeling the BIM. Also, the Procurement Contract should be revised. As to the BIM implementation strategy is Top-down, phased, propriety for the Design Phase and large DB projects.

The prototype proposed is not through empirical study, and some key issues such as property rights of special elements, BIM storage method (central or not), e-BIM delivery tools, BIM modeler certifications, etc. are not discussed in the paper. These will be further studied afterwards.

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