Building information modelling: Literature review on model to determine the level of uptake by the organisation

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Building Information Modelling: Literature Review on Model to Determine the Level of Uptake by Organisation

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Abstract

Building Information Modelling has been recognised as one of the Information Technology/Information Systems that could assist construction delivery in achieving Integrated Practice. However, the level of uptake currently varies between one organisation to another and has raised the need to determine whether the uptake is moving towards integrated practice or not. Through a literature review, this paper discussed a few models that that could be used to determine the level of uptake and they are CMMI, $(PM)^2$, SPICE, BEACON, VERDICT, i-CMM and BIMMi. This paper concludes that VERDICT, i-CMM and BIMMi can be used to determine the level of uptake. The selection of the model, however, depends on the purpose and area of evaluation.

Keywords : Building Information Modelling, Level of Uptake, Integrated Practice.

1. Introduction

It has been eleven years since the report of Rethinking Construction by Construction Task Force was released. The report which is also known as Egan Report (1998), was produced to initiate improvement in quality and efficiency in the U.K construction industry, citing that low profitability, low investment in research and development, inadequate training and low client satisfaction as particular area of concern. As a recommendation, the report also identifies five key drivers for change and they are committed leadership, a focus on the customer, integrated process and teams, a quality driven agenda and commitment to people. since then, much effort has been driven by the industry and academia to support the national agenda.

Recently, to review the progress of the construction industry, another report has been produced in 2009 by Constructing Excellence. The report, which was entitled Never Waste a Good Crisis: A Review of Progress since Rethinking Construction and Thought for Our Future, produced by several voluntary industrial player, has conducted a survey in 2008 to seek for validity of Egan's original drivers and also to track progress. The result shows that Egan's original drivers are still valid in today's market condition. The overall result however, shows that although there has been significant improvement, it has not been on the scale anticipated by the task force and according to Sir John Egan, on a scale of 10, only the score of 4 could be given since the expectation was that the industry could have had a revolution and a bit of improvement was achieved instead. On the other hand, Sir Michael Latham, also shared the same opinion by saying that, what has been achieved was more than expected but less than hoped.

As thoroughly discussed in the Egan Report, fragmentation was identified as one of the critical problem and many agree that by resolving the fragmentation issue, the industry could improve significantly. Consequently, many approaches and concepts have been identified, developed, introduced and tested to provide the solutions which lead to the term "integrated practice" in construction. Such of them are, to name a few, concurrent engineering (Anumba et al, 1998) , web based project management (Anumba et al, 2008; Alshawi and Ingirige, 2003), partnering (Bresnen and Marshall, 2000), Building Information Modelling (Eastman et al., 2008; Sacks et. al., 2005; Howard and Bjork, 2007), 4D modelling (Fischer, 2001; Heesom and Mahdjoubi, 2004), *n*D modelling (Aouad et al., 2007; Lee et al. 2003) and Integrated Project Delivery (AIA, 2007).

Among the solution, the used of BIM as the repository is identified as an important tool to achieve the collaboration required for integrated practice. One of them is Integrated Project Delivery (IPD) which has been introduced by the American Institute of Architects (AIA) where in the the guide to assist effective delivery of IPD, the utilisation of BIM is very important and the full potential benefits of both, BIM and IPD are achieved only when they are used together. On the other hand, a well known association, International Council for Research and Innovation in Building and Construction, CIB is also supporting integrated practice in the construction industry by launching Integrated Design Solution as a priority theme of CIB. The theme "Improving Construction and Use through Integrated Design Solutions" (IDS) has been under development since early 2006 and in June 2009 the CIB IDS 2009 First International Conference was held. The theme aims at speeding up the adaptation of techniques and practices that guide

the traditional document-based work methods towards the use of Integrated Building Information Modelling.

The use of BIM has also been extended by the work that has been carried out by the University of Salford's (UoS) From 3D to *n*D Modelling project which aimed to integrate an *n*th number of design dimensions into a holistic model which would enable users to portray and visually project the building design over its complete lifecycle. In the project, the model developed is based upon the Building Information Model where the BIM will be a repository that stores all the data objects with each object being described only once. In the project, the dimensions that have been incorporated into the model are whole-lifecycle costing, acoustic, environmental impact data, crime analysis and accessibility. The uniqueness of the work carried out by the university however, is that it could enable the what-if analysis to be carried out before the real construction takes place; for instance what are the knock-on effects for time, cost, maintainability, etc of widening a door to allow for wheelchair access (Marshall-Ponting and Aouad, 2005).

The aforementioned effort by CIB, UoS and AIA, perhaps could be the target of implementing BIM. Since BIM has many potential, which to some extent, influence the government policy of tendering (General Service Administration, 2010). Many companies are moving towards BIM and claims that they are BIM capable but the real question is, to what extent they are really capable since the applications of BIM itself are very wide. Is it enough to categorise a company as a BIM capable company if the implementation of BIM is in a small fracture of the process, for instance, drafting purpose. Or would it be equal to label a company implementing the BIM for the purpose of visualisation only as compared to the company which using it for the clash detection application where several models are needed to be developed and brought together. Clearly, the level of uptake of BIM plays an important assessment to understand the current position of the industry whether they are moving towards the achievement of integrated practice or simply satisfy the need to stay in an isolated application.

This paper tries to bring forward the assessment model that could be used to determine the level of BIM uptake. To start with, general discussion of BIM will be drawn followed by the general model for assessing performance of Information Technology/Information. After that, the models which related specifically to BIM, will be discussed in details and finally a recommendation will be drawn upon.

2. Definition of BIM

In the context of application within construction industry, it is really important to understand the definition of Building Information Model and Building Information Modelling. According to Kymmel (2008), by using software and hardware related to computer application, Building Information Model represent the building virtually where the physical characteristics of the project and all information are contained or attached to the component of the model. The model may include any or all of the 2D, 3D, 4D (time element-scheduling), 5D (cost information), or *n*D (energy, sustainability, facilities management, etc., information) representations of a project. While on the other hand, Building information Modelling is defined as the act of creating and/or using a Building Information Model. In this context, the Building Information Modelling is taken as a tool that may help in achieving the team's project goal.

Also, in defining Building Information Modelling as a tool, the concept is also supported by AIA where according to AIA (2007) BIM is defined as a digital, three-dimensional model linked to a database of project information. It is identified as one of the most powerful tools to support IPD. Because BIM can combine, among other things, the design, fabrication information, erection instructions, and project management logistics in one database, it provides a platform for collaboration throughout the project's design and construction.

In comparison Eastman et. al (2008) argued that BIM is just a software or tool. In their context BIM is defined as a modelling technology and associated set of processes to produce, communicate and analyse building models. Building information modelling is a verb to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation. Therefore BIM describes an activity, not an object. In this context, the building information model on the other hand, is the result of the modelling activity and further explained as a digital, machine-readable record of a building, its performance, its planning, its construction and later its operation.

According to Hardin (2009), Building Information Modelling is just not a tool but it is a process and software which agrees with Eastman et. al (2008). This is supported by the explanation that "many believe that once they have purchased a license for a particular piece of BIM software, they can sit someone in front of the computer and they are now doing BIM. What many do not realise though is that building information modelling means not only using three-dimensional

modelling software but also implementing a new way of thinking. In the authors' experience, as a company integrates this technology it begins to see other processes start to change. Certain processes that have made perfect sense for CAD-type technology now do not seem to be as efficient. As the technology changes, so do the practices and functions of the people using the technology."

3. Application of BIM

From inception through handover the project, BIM application could be applied for every single phase of the project. According to BIM Project Execution Planning Guide by The Pennsylvania State University, there are twenty-five uses of BIM for consideration on a project as can be seen in Figure 1. And as the guide suggest, it is not appropriate to implement all of the application of BIM. The most importantly is to understand the main reason why BIM is used in the project and to set objectives of adoption. Only then, the use of specific BIM application can be selected.

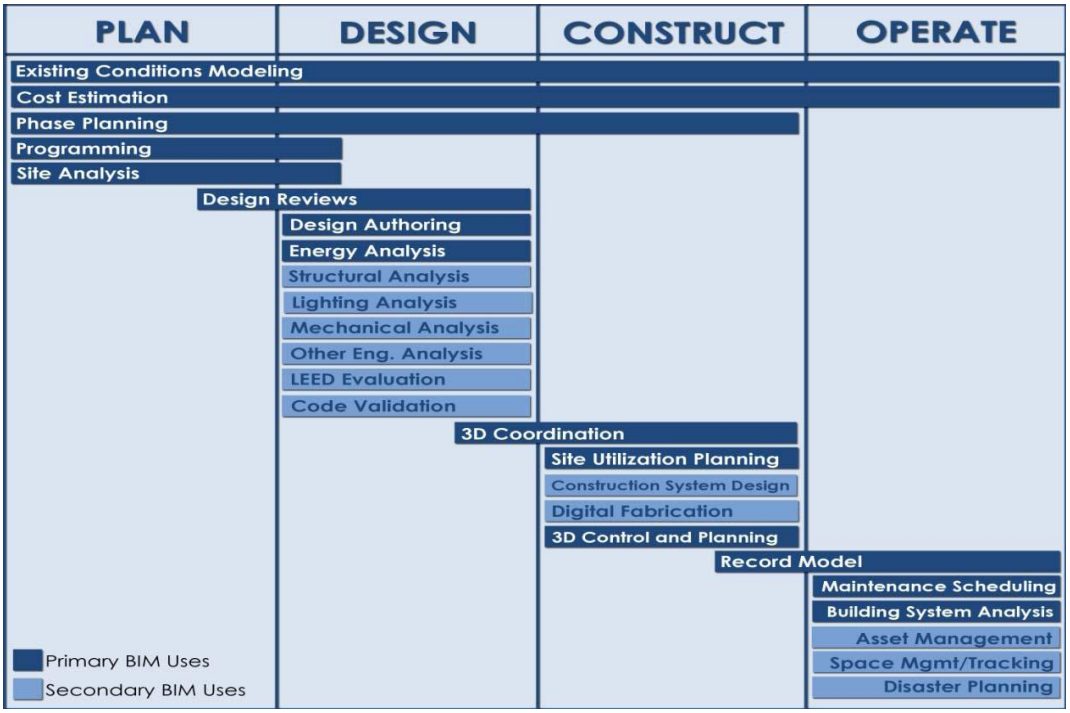

FIGURE 1: BIM application in project life-cycle (BIM Project Execution Guide, 2009)

4. IT/IS Performance Measurement

BIM is a part of Information Technology/Information System (IT/IS) and a lot of issue regarding to the uptake of BIM are overlapping with general IT/IS uptake. Therefore, the IT performance measurement model, especially those related to construction industry need to be reviewed. Since 1970, according to Alshawi (2007), high percentage of failure of IS/IT projects to meet their intended business objectives has been a major concern for many organisations. A lot of projects were either abandoned, significantly redirected or to the extend, kept alive in spite of the failure has lead to the need for the development of evaluation methods to measure the effectiveness of IS/IT.

In measuring the IS/IT success, Salah and Alshawi (2005) then classified the method into three categories depending to the focus of the evaluation. By referring to the table 2 below, the first category is concerned with those approaches that evaluates IS/IT as a product, followed by approaches that evaluate the process which underpin the development of IS/IT and lastly the category which assess the maturity of IS/IT within an organisation in terms of IS/IT planning, infrastructure, utilisation and management.

Table 1: Type of IT/IS Performance Measurement

Approach	*Type*	*Details/Example*
Product-based	*System quality*	*Focuses on performance characteristics such as resource utilisation and efficiency, reliability, and response time*
	System use	*Reflects the frequency of IS usage by users*
	User satisfaction	*Widely used approach which is based on the level of user satisfaction*
Process-based	*Goal centred*	*Measure the degree of attainment in relation to specified targets. Examples: GQM and ITIL*
	Comparative	*Benchmarking approach*
	Improvement	*Assesses the degree of adaptation of a process to the related changes in requirements and work environment*
	Normative: Compared to external standards : CMM, ISO standards	*Maturity-Based : Measures performance* *Non-maturity Based :*
Organisational maturity	*General Model*	*Example of such models are those by Nolen;Earl;Bhabuta;and Gallier and Sutherland*

In respond with the Table 2, generally in construction industry there are many models that could be applied to measure either the success and/or readiness towards certain concept. The purpose

of the model varies depending on the concepts that are going to be taken. Such models are summarised as follows:

CMMI : Capability Maturity Model Integrated is a normative model, consist of best practice which can be used by many industry to improve process within a project, a division, or an organisation. Succeeding from Capability Maturity Model (CMM), which initially developed specifically for software industry, the model was formed to sort out the problems of using multiple CMM. Basically the assessment is looking for the maturity of the process and it has 5 maturity levels which are Initial, Managed, Defined, Quantitatively Managed and Optimised. Depending on the areas of interest, there are three models available which concentrates on Product and service development, Service establishment, management, and delivery and Product and service acquisition. (Software Engineering Institute, 2009)

$(PM)^2$: Project Management Process Maturity which is also a normative model where it is a collection of best practice by the industry and purposely developed to measure the maturity of project management process. The model follows a systematic and incremental approach that progresses from an unsophisticated level to a sophisticated PM maturity level. Each maturity level consists of major PM characteristics, factors, and processes and demonstrates sequential steps that outline an organization's improvement of its PM processes Basically, It has 5 maturity levels which are: Initial, Planned, Managed at Project Level, Managed at Corporate Level and Continuous Learning (Kwak and Ibbs, 2002)

SPICE: Standardised Process Improvement for Construction Enterprises which was developed by University of Salford is a framework for continuous process improvement specifically for construction industry. The scope of the model is to incorporate the process that directly related to the design, construction and maintenance procedures of a construction organisation. Adapting from CMM, it indicates the management processes in a step-wise framework and consists of 5 maturity stages which are Initial/Chaotic, Planned & Tracked, Well Defined, Quantitatively Controlled, and Continuously Improving. (Finnemore and Sarshar , 1999)

BEACON : Benchmarking and Readiness Assessment for Concurrent Engineering in Construction is a concurrent engineering readiness assessment model which is used assess the readiness of construction companies to improve their project delivery processes through the implementation of concurrent engineering. It is conducted before the introduction of CE within an organisation, and investigates the extent to which the

organisation is ready to adopt CE. Adapted from Readiness Assessment for Concurrent Engineering Model (RACE), which is used in manufacturing, the model has 5 level of maturity which are Ad-hoc, repeatable, characterized, managed and optimizing and consists of four elements of measurement which are People, Process, Technology and Project. (Khalfan, Anumba, & Carrillo, 2001)

VERDICT : Verify End-User e-Readiness using a Diagnostic Tool is an e-readiness model that assess the readiness of organisation to adopt e-commerce tools, such as web based collaboration tools. The model can be used to assess the e-readiness of construction companies, department (s) within a company or even individual work groups within a department. The model, identify four elements of measurement which are people, process, technology and management. The assessment is carried out using 6 value of Likert scale in which 5= strongly agree, 4= Agree, 3=Neutral, 2=Disagree and 1=Strongly Disagree and finally 0= Do not know. In classifying whether an organisation is ready or not to adopt e-commerce, there are 3 levels were identified which are Red Level: average score equal or greater than zero but less than 2.5, Amber : average score equal or greater than 2.5 but less than 3.5 and lastly Green: where average score greater than or equal to3.5. The Red value indicates that urgent attention needed to be e-ready, Amber indicates moderate attention needed to be e-ready and lastly Green indicates that the elements have adequate capability and maturity which equal to e-ready to adoption. (Ruikar, Anumba , and Carrillo, 2006)

The previous model, however, was not developed to specifically satisfy the need for BIM application within an organisation. Some of them are just concentrates on one aspect of measurement such as process improvement which could be seen in $(PM)^2$, SPICE and CMMI. Whereas, on the other hand, even though the models do measure the whole elements of an organisation, the application is specific to certain concept such as BEACON model where the model was built to measure the implementation of the concept of Concurrent Engineering Meanwhile, for the VERDICT model, the element of assessment could potentially be adjusted and adopted for the use of assessing BIM uptake since the model is generic enough for any ICT tool. For the record, in VERDICT, the e-readiness is defined as the ability of an organisation, department or workgroup to successfully adopt, use and benefit from information and communication technologies such as e-commerce.

5. BIM Performance Measurement

For performance measurement, specifically developed for BIM application within construction industry, there currently 2 models that are available which is the one developed by National Institute of Building Sciences under National Building Information Modelling Standard and another one is Building Information Modelling Maturity Index (BMMI) proposed by Succar (2010), which at the final stage of validating the model. The next section discuss in more detail regarding to these models.

5.1 The Interactive Capability Maturity Model.

The Interactive capability Maturity Model has been released in year 2007 by National Institute of Building Sciences. Under the U.S National Building Information Modeling Standard (NBIMS), the model was developed to be applied as according to McCuen and Suermann (2007):

a) to serve as a tool for the user to evaluate the practice and process regarding to the BIM implementation
b) portfolio-wide analysis to establish an organization's current strategic or operational BIM implementation
c) to set goals for achieving greater information maturity on future BIM projects

The models however, developed to be used internally within an organization to provide information about the level of BIM information management and the level of maturity of individual BIM as measured against a set of weighted criteria and is not intended to be a tool to compare BIM implementation as further explained by McCuen and Suerman(2007). There are two versions that has been released where the first version is the tabular CMM, which is a static Microsoft Excel workbook consisting of three worksheets and the second version which has the same content with the first one, but be presented more interactively where the worksheets are interactively and actively update the BIM's maturity level as the user enters information. (laman web nBIMS). As to validate the model, according to smith and tardiff (2009), in late year 2007, the model was tested by NBIMS testing team, led by Professor Tammy McCuen and Air force Major Patrick Suerman by evaluating the BIM maturity of the 2007 American Institute of

Architects (AIA) Technology in Architectural Practice (TAP) BIM Award. Although some refinements were made, the testing result showed that the variance in score did not exceed 5% in any instance and frequently varied by no more than 1 or 2 percent.

Generally, the assessment of the I-CMM is focused on the maturity of building information model and the process used to create it (Smith and Tardiff, 2009). As can be seen in Table 2, the model consist of 10 level of maturity which assess 11 areas of BIM which is A data richness, life cycle review, change management, business process, timeliness/response, delivery method, graphical information, spatial capability, information accuracy and interoperability/IFC support.

Table 2: Index for Interactive Capability Maturity Model (National Institute of Building Science, 2007)

Maturity Level	***A Data Richness***	***B Life-cycle Views***	***C Roles Or Disciplines***	***G Change Management***	***D Business process***	***F Timeliness/ Response***	***E Delivery Method***	***H Graphical Information***	***I Spatial Capability***	***J Information Accuracy***	***K Interoperability/ IFC Support***
1	Basic Core Data	No Complete Project Phase	No Single Role Fully Supported	No CM Capability	Separate Processes Not Integrated	Most Response Info manually re-collected - Slow	Single Point Access No IA	Primarily Text - No Technical Graphics	Not Spatially Located	No Ground Truth	No Interoperability
2	Expanded Data Set	Planning & Design	Only One Role Supported	Aware of CM	Few Bus Processes Collect Info	Most Response Info manually re-collected	Single Point Access w/ Limited IA	2D Non-Intelligent As Designed	Basic Spatial Location	Initial Ground Truth	Forced Interoperability
3	Enhanced Data Set	Add Construction/ Supply	Two Roles Partially Supported	Aware of CM and Root Cause Analysis	Some Bus Process Collect Info	Data Calls Not In BIM But Most Other Data Is	Network Access w/ Basic IA	NCS 2D Non-Intelligent As Designed	Spatially Located	Limited Ground Truth - Int Spaces	Limited Interoperability
4	Data Plus Some Information	Includes Construction/ Supply	Two Roles Fully Supported	Aware CM, RCA and Feedback	Most Bus Processes Collect Info	Limited Response Info Available In BIM	Network Access w/ Full IA	NCS 2D Intelligent As Designed	Located w/ Limited Info Sharing	Full Ground Truth - Int Spaces	Limited Info Transfers Between COTS
5	Data Plus Expanded Information	Includes Constr/Supply & Fabrication	Partial Plan, Design&Constr Supported	Implementing CM	All Business Process(BP) Collect Info	Most Response Info Available In BIM	Limited Web Enabled Services	NCS 2D Intelligent As-Builts	Spatially located w/Metadata	Limited Ground Truth - Int & Ext	Most Info Transfers Between COTS
6	Data w/Limited Authoritative Information	Add Limited Operations & Warranty	Plan, Design & Construction Supported	Initial CM process implemented	Few BP Collect & Maintain Info	All Response Info Available In BIM	Full Web Enabled Services	NCS 2D Intelligent And Current	Spatially located w/Full Info Share	Full Ground Truth - Int And Ext	Full Info Transfers Between COTS
7	Data w/ Mostly Authoritative Information	Includes Operations & Warranty	Partial Ops & Sustainment Supported	CM process in place and early implementation of root cause analysis	Some BP Collect & Maintain Info	All Response Info From BIM & Timely	Full Web Enabled Services w/IA	3D - Intelligent Graphics	Part of a limited GIS	Limited Comp Areas & Ground Truth	Limited Info Uses IFC's For Interoperability
8	Completely Authoritative Information	Add Financial	Operations & Sustainment Supported	CM and RCA capability implemented and being used	All BP Collect & Maintain Info	Limited Real Time Access From BIM	Web Enabled Services - Secure	3D - Current And Intelligent	Part of a more complete GIS	Full Computed Areas & Ground Truth	Expanded Info Uses IFC's For Interoperability
9	Limited Knowledge Mngmt	Full Facility Life-cycle Collection	All Facility Life-Cycle Roles Supported	Business processes are sustained by CM using RCA and Feedback loops	Some BP Collect&Maint In Real Time	Full Real Time Access From BIM	Netcentric SOA Based CAC Access	4D - Add Time	Integrated into a complete GIS	Comp GT w/Limited Metrics	Most Info Uses IFC's For Interoperability
10	Full Knowledge Mngmt	Supports External Efforts	Internal and External Roles Supported	Business processes are routinely sustained by CM, RCA & Feedback loops	All BP Collect&Maint In Real Time	Real Time Access w/ Live Feeds	Netcentric SOA Role Based CAC	nD - Time & Cost	Integrated into GIS w/ Full Info Flow	Computed Ground Truth w/Full Metrics	All Info Uses IFC's For Interoperability

As identified by Succar (2009), the i-CMM suffer several limitation which could restrict its application. Some of the limitations are listed as follows:

a) The model employs 10 maturity levels with slender division between respective level which and slightly different with most capability maturity models where the maturity level normally in the range 4 to 6.

b) The variability of scoring-weights assigned to Areas of Interest in accordance to organisational preference (or the elusive 'national consensus') – as encouraged within the NBIM Standard - will minimise the usefulness of the I-CMM tool and neutralise the 'certification' process

c) The variability of the 'minimum score for the Minimum BIM' will cause scoring inconsistencies. Pre-assigning the minimum score according to calendar year and allowing it to be changed 'according to demands by owners' are in sharp contrast. Also, it is difficult to imagine that industry's BIM maturity will increase (or can be encouraged to increase) in a pre-defined linear fashion or that owners' BIM requirements can be established/ represented through a generic minimum score

d) The NBIM's CMM Areas of Interest are only useful in assessing Models and not the teams, organisations or project-teams which generate them

e) The NBIM's CMM in both its static and dynamic versions can only be applied 'internally' through self-assessment or peer-revision.

f) Most importantly, the inability of the NBIM's CMM – in its current form - to assess any BIM metric beyond 'information management' (NIST, 2007) severely limits its applicability and usefulness.

g) The current configuration of the I-CMM tool allows organisations/projects to accumulate high total scores even if they achieved very low scores on a number of Areas of Interest ('platinum' certification can be achieved even when a project has no Change Management or Spatial Capability)

5.2 Building Information Modelling Maturity Index

Succar (2009) proposed a comprehensive model which covers the whole aspect of an organisation to uptake the BIM process and technology. The model Building Information Modelling Maturity Index (BMMI) has been developed by analyzing and integrating several models from different industries and tailored to reflect the specifics of BIM capability, implementation requirements, performance targets and quality management. It consists of 5 level of maturity (Initial, Defined, Managed, Integrated, Optimised) and 3 categories of key maturity area which are Technology, Process and Policy. The technology area then consist of 3 sub item for assessment which are Software: which focus on applications, deliverables and data, Hardware: which focus on equipment, deliverables and location and Networks: which focus on solutions, deliverables and security/access control. Meanwhile, in Process area it consists of Leadership: which focus on organizational, strategic, managerial and communicative attributes and innovation and renewal, Infrastructure: focus on physical and knowledge-related, Human Resources: focus on competencies, roles and dynamics. Products & Services: focus on specification, differentiation and R&D, Subsequently, in Policy key maturity area, it consists of Contractual: focus on responsibilities, rewards and risk allocations, Regulatory: focus on codes, regulations, standards, classifications, guidelines and benchmarks and Preparatory: focus on research, educational / training programme and deliverables

In the model, the author also makes a clear distinction between the term Capability and Maturity which contradict with most of the models mentioned in previous section where most of them simply assess the capability and maturity by using the same index of assessment where as in the BMMI model, since the terms are clearly defined, the index of assessment also varies significantly. In the model, maturity is defined as the quality, repeatability and degrees of excellence of BIM services. In other words, BIM Maturity is the more advanced ability to excel in performing a task or delivering a BIM service/ product.

On the other hand, BIM Capability is defined as basic ability to perform a task or deliver a BIM service/product. The author then, introduce BIM Capability Stages to define the minimum BIM requirement, the major milestones that need to be reached by a team or an organization as it implements BIM technologies and concepts towards the achievement of Integrated Project Delivery or even a target beyond that. According to Bilal (2008), generally, BIM Stages are defined by their minimum requirements. As an example, for an organisation to be considered at

BIM Capability Stage 1, it needs to have deployed an object-based modelling software tool and the application of BIM takes place in an isolated condition within the organisation. Similarly for BIM Capability Stage 2, an organisation needs to be part of a multidisciplinary model-based collaborative project. While, to be considered at BIM Capability Stage 3, an organisation must be using a network-based solution like a model server to share object-based models with at least two other disciplines. Figure 2 and 3, summerised the BIM capability model and process to deliver BIMMI assessment, respectively

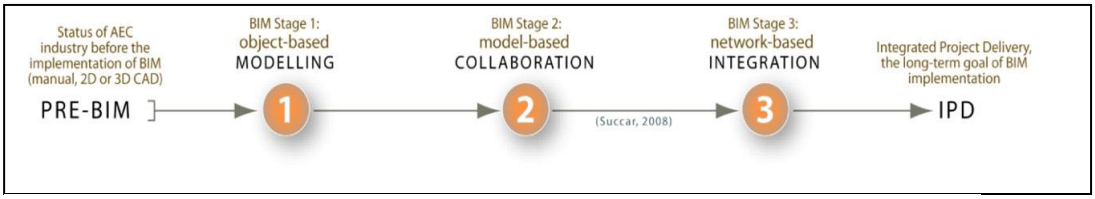

Figure 2: BIM Capability Model (Succar 2009)

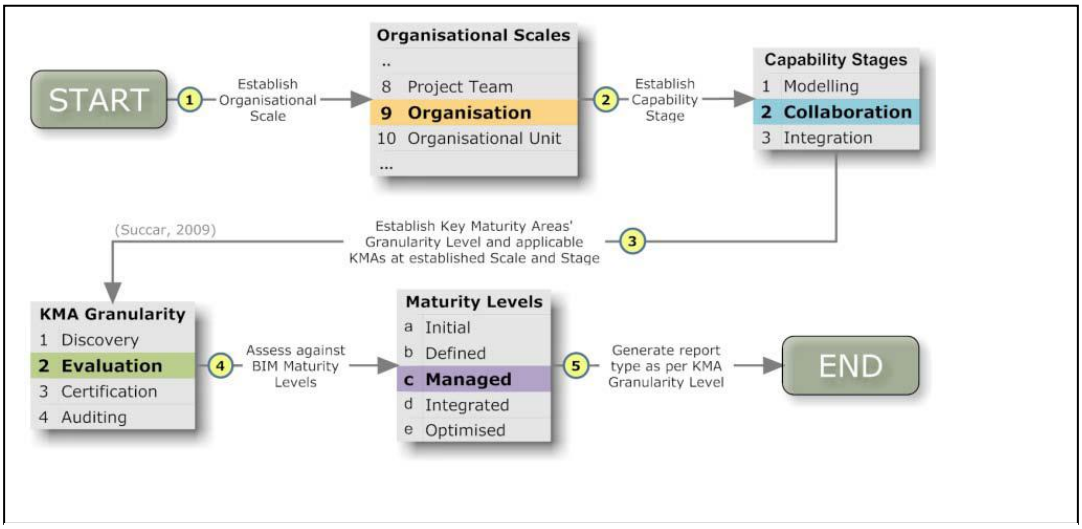

Figure 2: Flow of process to evaluate BIM Capability and Maturity (Succar 2009)

7.0 Conclusion

Application of Building Information Modelling in construction industry could provide many advantages to the construction industry. The uptake, however, varies from one organisation to another. Through literature review, in order to determine the level of BIM uptake, it is concluded that the model that can be used are VERDICT, CMMi and i-CMM. The measurement could be a basis for the organisation to monitor their progress towards the higher level of uptake and notifying them any area that need serious attention. Also, it could help in choosing the right team

in delivering a construction project. This papers it a part of the author's PhD work at University of Salford. At the time the paper was written, the element for measuring the level of uptake have been identified and the next stage of the research is to explore the current BIM level of uptake and also determine what are the minimum requirement needed to achieve the level.

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