**BIM in Literature**

Building Information Modeling (BIM) has developed into the most important tool for managing construction projects today. Its value is not just in the ability to visualize and organize a project across many disciplines but also as a method of improving building life cycles and operations. The improvements make BIM an indispensible tool in AEC today, but the changes in organization have made its implementation slow and uneven throughout the industry.

In *Knowledge Management as a Catalyst for Innovation within Organizations: A Qualitative Study*, (2000) R. McAdam demonstrates that innovation within an organization is a function of how information is both disseminated and embodied – that is, made tangible to the team. Before knowledge becomes useful as a new product an important step is realizing its potential as much as it is disseminated. Knowledge management is thus described as the process of transmitting and embodying goals and new learning. This is the real power of BIM in a building project. Modeling embodies the information into a more physical presence that can then be realized in physical form.

This approach is brought directly to BIM by B. Succar in *A Proposed Framework to Investigate Building information Modeling Through Knowledge Dissemination and Visual Models* (2007). In this paper the need for visual models to embody knowledge is highlighted. The knowledge necessary is described as belonging to three categories, namely policy, process, and technology. Six stages of organizing the material that goes into an effective BIM process are identified as preparation, identification, acquisition, organization, review and recommendation. Through these stages the model becomes complete and the information is both disseminated and embodied.

A rigorous process is not always accessible to any given team, however, given different levels of familiarity and practice with BIM methodology. A method of assessing the maturity of a team to perform appropriate BIM is given by B. Succar in the 2009 work Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies. In this, the three stages of BIM modeling performance are outlined as Stage 1: object-based modeling, Stage 2: model-based collaboration, and Stage 3: network-based integration. Before an appropriate model can be developed for the team the appropriate system has to be outlined and agreed by the members and the appropriate software tools have to be present. It is also proposed that this evaluation be used as a tool for continuous improvement and development of more advanced BIM development.

Variations in BIM Maturity naturally occur regionally, given different rates of experience by the participants. The paper *A Proposed Approach to Comparing the BIM Maturity of Countries* (2013) by K. Mohamad outlines how to compare these different stages of implementation and readiness by evaluating key metrics in the field of BIM. These are the availability of noteworthy BIM publications, their distribution, and their relevance to the local industry. Such an evaluation gave high marks to the US, UK, and Australia for BIM maturity but found that is was lacking in most European nations.

A somewhat different approach is taken by HS Jayasena in *Assessing the BIM Maturity in a BIM Infant Industry* (2013). The Bew-Richards BIM Maturity Model (2008) is considered to compare the readiness of teams generally through an IPD framework along with work by B Succar. The synthesis of these is presented as Integrated Design and Delivery Systems (IDDS), characterized by an assessment of four components: collaborative process, enhanced skill, integrated information and automated systems, and knowledge management. These four components are proposed as a way for an organization to break down its own personal assessment of BIM maturity to enhance internal development.

Beyond assessment and preparation for BIM enhancement within an organization is a deep need for practical guides to begin the process. A publication by the Construction User’s Roundtable, *BIM Implementation: An Owner’s Guide to Getting* *Started* (2010) offers just this. It offers practical advice including management systems, software recommendations, and assessment tools for three distinct stages of BIM implantation in an organization. These are pre-planning, design and construction, and operations and maintenance. This paper presumes, without defining, an IPD structure within the team that can implement BIM in any manner that is deemed appropriate at any given stage of the building life cycle.

A more regulatory and specific approach to BIM implementation is taken by the Port Authority of New York and New Jersey (2012). Without specifically requiring BIM as a pre-requisite for their projects, the scope of their specifications essentially mandate a consistent representation of BIM across all projects that they are to undertake. It mandates AutoCAD systems and is entirely prescriptive of every step along the way. This is typical of agencies of their type and scope and represents the direction that the AEC industry is moving towards in very specific terms.

A more academic approach to BIM Implementation is taken by Messner, J et al in *Building Information Modeling Project Execution Planning Guide* (2010), a guide published by the Computer Integrated Construction Research Group at Pennsylvania State University. The information and structure of a BIM system is outlined along with a comprehensive list of components that must be present without presuming IPD or any other management structure. An example of proper implementation is given and sections are devoted to sustainable (LEED) development.

The value of BIM implementation for design and construction firms is made in very stark terms by M LeFevre in the Spring 2011 Journal of Building Information Modeling (JBIM). In his article *Leverage Points, Reframing and Key Decision Factors in BIM Transformation* the costs of being “left behind” by not implementing BIM are broken down for each player in the AEC industry. In the hypothetical project outlined nearly $10M in waste and inefficiency is presented as the cost of not being BIM ready.

Implementation of BIM invariably leads to the choice of software and hardware platforms, which can result in confusion – especially with international projects operating in different BIM regimes. The case for an open platform, called BIMStorm, was made by the Kirmon Onuma firm in the Spring 2011 JBIM. The development of a truly open standard for collaboration internationally was made and tested with a generally good reception.

Montiero, et al (2014) found that the separation of design documents and written specifications is a significant source of problems in the usefulness of most BIM applications. The integration of these two is demonstrated in a specific case study in an IPD environment, where such integration is even more crucial. A pre-modeling step is described in great detail, where the information used to build both the models and the specifications is laid out and agreed to by all parties on the management team. The development of appropriate cross-checks as a part of the modeling management process is shown and the potential development of new software is described.

K Barlish (2012) uses a literature review of case studies to quantify the typical net benefit of BIM. This review of 21 sources found 4 complete cases that could be evaluated to determine actual savings through BIM implementation. All of the examples were construction projects and not building life cycle, however. A 42% reduction in change orders was found on average, but a net increase of 34% in design costs offset this improvement. Overall, a savings of 2% of the total project cost could be attributed to BIM.

A framework for understanding the stages of BIM implementation is critical to guiding development of a company or team’s progress. In *Building information modelling framework: A research and delivery foundation for industry stakeholders* (2009) B Succar presents an understanding of the three stages of BIM implementation in a construction project and how to realize them. Stage 1 is described as when BIM is fully implemented in the Design Phase of a project. In Stage 2, the Construction Phase is brought back to overlap with Design using BIM as a guide. Stage 3 describes bringing Building Operation into the earliest stages of the process, completing the integration of all Building Life Cycles and realizing the full potential of BIM.

Similarly, D Bryde et al found a high degree of benefit to project management with BIM in *The project beneﬁts of Building Information Modeling (BIM)* (2013). A survey of 33 case studies pulled from international literature found there were multiple benefits throughout the design and construction phases in most of the cases. Two cases noted negative effects, found largely because of improper or disorganized implementation of BIM. Confusion among players and inadequate attention to the management of the project through BIM is listed as the most significant risk to a BIM implementation.

Quality improvement and improved accuracy were the most important reasons cited to implement BIM in a survey of 66 AEC industry companies conducted in Liu, R et al *Factors influencing the adoption of building information modeling in the AEC* *Industry* (2010). 72% of the respondents also ranked BIM as important or very important in order to remain competitive, showing that BIM is already an industry standard practice in the US. However, 25% of respondents said they had no BIM training to date. The study concludes by noting the need for more rapid implementation as an imperative in many companies.

A detailed review of literature shows a lack of a consistent model to calculate the value of BIM implementation, however. A potential model to calculate the Return on Investment (ROI) is proposed in *Benefits and ROI of BIM for Multi-Disciplinary Project Management* (2012) by Qian. This model separates out the design and build savings as an up-front investment reduction and the savings from building life cycle management brought forward at an appropriate rate. Less tangible benefits were also taken from the literature, most notably: better company image, fewer mistakes, and strategic competitive advantage.

While there are clear benefits to BIM, there are risks involved with implementation, especially if it is not done properly. In *Building Information Modeling (BIM): Benefits, Risks and* Challenges (2008) S Azha examines in great detail a single case study, the Hilton Aquarium in Atlanta, Georgia. In this $45M project the benefits found were a very accurate estimation of costs, within 3%, and a net savings overall of $600k. The author was careful to highlight specific risks in the process, however, including compatibility issues in software and inadequate integration. The potential loss of checks and balances between traditional functions was also cited as a potential risk with BIM, due largely to tendency to turn decisions and cross-checks over to the software and thus out of some human intervention.

This sentiment is echoed by Arayici, Y et al in *Technology adoption in the BIM implementation for lean architectural practice* (2011). The paper examines BIM adoption and implementation through a two year project between the University of Salford and the John McCall Architects in Liverpool. Although the paper had a focus on the BIM technology adoption, it is actually as much about people and processes. It concludes that BIM implementation should have a bottom-up approach rather than top-down approach in order to: engage people in the adoption, ensure that people's skills and understanding increase and companies build up their capacities, apply successful change management strategies, and diminish any potential resistance to change.

Changes in project management are also cited as the key issue in BIM implementation in R Sebastian, *Changing roles of the clients, architects and contractors through BIM* (2010). This paper presents a general review BIM from literature case studies for hospitals. These projects are complex due to complicated functional and technical requirements, decision making involving a large number of stakeholders, and long-term development processes. A successful implementation cited involves product information sharing, organizational roles synergy, work processes coordination, environment for teamwork, and reference data consolidation.

The real benefits of BIM are systemic and the transition to an office that runs on BIM is essential to realizing its full potential, according to R Yori in the class materials for *Transitioning an Office to Mainstream BIM* (2010). This work focuses on crossing the “chasm” towards a full office integration by using BIM as a primary method of dissemination information in all aspects of work life. The process is described as essential to remaining competitive, however. The knowledge sharing is listed as the primary benefit to a design firm with respect to BIM.

BIM has been demonstrated in literature to be a critical tool for embodying and disseminating information through the entire life cycle of a building. As an information management system it naturally points to changes in project management, realized most fully as IPD. But BIM is also useful on its own as a tool for managing projects and an entire office. The net benefits are tangible in terms of the money save but they are also increasingly a fundamental requirement for design and construction firms to remain competitive in the AEC industry. There are risks associated with BIM implementation, but these have been shown in literature to be related to faulty implementation and inadequate integration. The full benefits are realized when integration is fully completed in Stage 3 BIM implementation, when the entire building life cycle is brought into the design and construction process and a fully realized IPD team is tasked with the development.

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