Building Information Modelling: Point of Adoption

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Abstract

Building Information Modelling (BIM) is the current expression of construction industry innovation generating a wide range of augmented market deliverables, new requirements and emergent roles. For organizations to cross the innovation chasm, they need to progressively implement complementary tools, workflows and protocols. Such multifaceted implementation is not instantaneous but passes through recursive periods of implementation readiness, capability acquisition, and performance maturity. Similarly, BIM diffusion within organizations is not a frictionless derivative of BIM implementation, but a function of competition dynamics and institutional isomorphic pressures. While there are a number of academic studies and industry surveys covering organisational readiness, software implementation or innovation diffusion, there is no single conceptual model to describe, explain and test BIM adoption as a single construct connecting all these concepts. Based on published research and experiential knowledge, this paper introduces the Point of Adoption (PoA) model which integrates these concepts into a single visual model. The PoA model – not only clarifies the connection between these concepts but – facilitates the assessment of current organisational abilities, and clarifies a step-wise approach to BIM adoption and continuous performance improvement.

Keywords: BIM Implementation, Performance Assessment, Innovation Diffusion

1. Introduction

Building Information Modelling (BIM) is an expansive knowledge domain. Over the past few years, much research has been conducted into the connotations and impact of BIM tools and workflows on the construction industry. BIM has been repeatedly described as a 'disruptive technology' (Smith & Tardif, 2009, p. 32) instigating a 'process change' (Eastman, Teicholz, Sacks, & Liston, 2011, p. vii), or as an 'unbounded' and 'systemic' innovation (Harty, 2005, p. 51) (Taylor & Levitt, 2004, p. 84). These and other descriptions invariably position BIM as the *current* expression of innovation within the industry, and that BIM technologies, processes and policies are significantly impacting industry's deliverables, relationships and roles. While there are numerous studies relaying the many benefits of BIM, there are far fewer studies identifying the steps taken by organisations to realise these benefits. Also, the overlapping topics of organisational readiness, capability development and innovation diffusion have been typically approached as distinct areas of investigation rather than as a single performance improvement continuum. To remedy this shortfall, this article presents a unified performance model which overlays the concepts of BIM readiness, BIM implementation, and BIM diffusion. The model offers a simplified template for assessing organisational BIM performance as well as for planning structured BIM adoption activities.

2. Research Methodology

This section introduces the methodology used in developing the Point of Adoption model. The exercise builds upon and further extends the BIM Framework (Succar, 2009) by employing its existing conceptual constructs – terms, classifications, taxonomies, models and frameworks – to identify, explain and test new constructs. Through the 'BIM Framework's Conceptual Reactor' (Figure 1), a theory-building exercise is conducted using three iterative stages (J. R. Meredith, Raturi, Amoako-Gyampah, & Kaplan, 1989) (J. Meredith, 1993). The first stage develops a *description* of reality; identifies phenomena; explores events; and documents findings and behaviours. The second *explanation* stage builds upon descriptions to infer a concept, a conceptual relationship or a construct; and then, develops a framework or a theory to explain and/or predict behaviours or events. Finally, the third *testing* stage inspects explanations and propositions for validity; tests concepts or their relationships for accuracy; and tests predictions against new observables. The proposed Point of Adoption model follows a cyclical path as the one described by J. Meredith (1993) from describing; to explaining; to testing; and then back to describing. First, the model is generated through process of inductive inference (Michalski, 1987), conceptual clustering (Michalski & Stepp, 1987) and reflective learning (Van der Heijden & Eden, 1998) (Walker, Bourne, & Shelley, 2008). Second, conceptual models are developed to visually *explain* the knowledge structures. Third, each model is *tested* through either a focus group, peer-review questionnaire, or focus groups (Succar & Kassem, 2015).

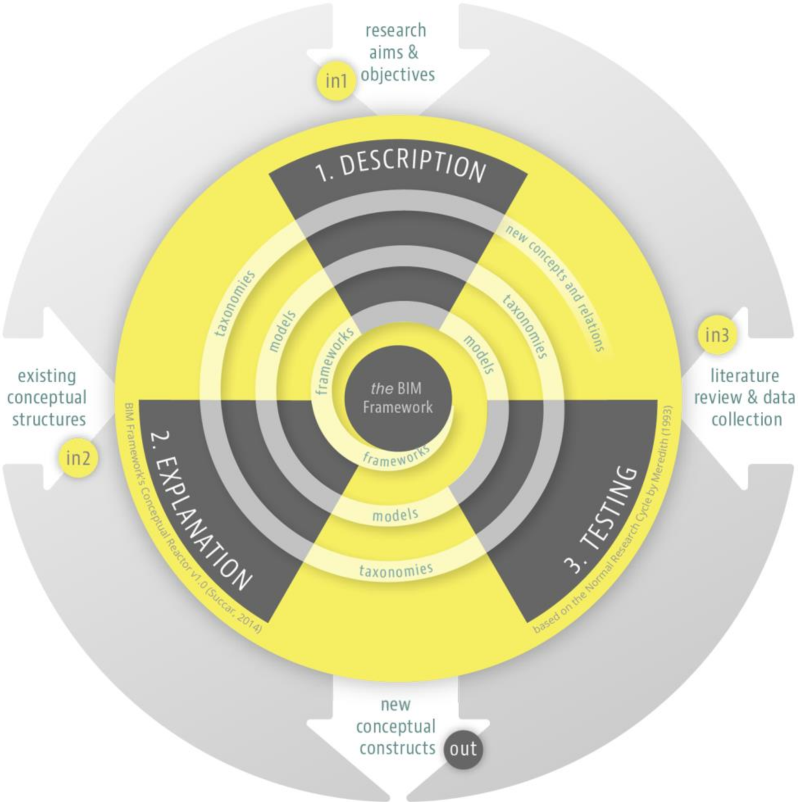


Figure 1. The BIM framework conceptual reactor

3. Terms, Concepts and their interaction

Before introducing the Point of Adoption (PoA) model, it is prudent to delimit a number of terms. The terms used to describe the act of implementing an innovative system/process are often confused with the terms used to describe the spread of this system/process within a *population* of adopters – be it within an organization or across a market. This delimitation is both artificial and necessary: it is *artificial* as other researchers can recalibrate the connotations of the same terms to fit their own unique purposes. It is *necessary* due to the availability of a large number of relevant diffusion models (Pierce & Delbecq, 1977) (Saga & Zmud, 1993) (Fadel, 2012) which do not differentiate between the stages of implementation - e.g. between acceptance and routinization as in Cooper and Zmud (1990) - the mechanics of diffusion, and the pressures causing the shift from one stage to another.

In introducing and delimiting these terms, we also limit ourselves to BIM as an innovative set of tools, processes and policies within the construction industry. This limitation is also both artificial and necessary: it is *artificial* as implementation/diffusion models introduced later are arguably applicable to other innovations within and outside the construction industry (e.g. to GIS and PLM). It is *necessary* due to the dearth of investigations covering innovation diffusion within the construction industry (Taylor & Levitt, 2004) thus warranting – as exemplified below - a focused attention on industry-specific and, by extension, BIM-specific terms.

3.1 BIM Implementation

Implementation refers to the wilful activities of an identifiable player[1] as it adopts a novel system/process to improve its current performance. More specifically, *BIM implementation* refers to the set of activities undertaken by an *organizational unit* to prepare for, deploy or improve its BIM deliverables (products) and their related workflows (processes). BIM implementation is introduced here as a three-phased approach separating an organization's *readiness* to adopt; *capability* to perform; and its performance *maturity*:

- BIM readiness is the *pre-implementation status* representing the propensity of an organization or organisational unit to adopt BIM tools, workflows and protocols. Readiness is expressed[2] as the *level of preparation*, the *potential to participate*, or the c*apacity to innovate*. Readiness can be measured using a variety of approaches – product-based, process-based, and overall maturity (Saleh & Alshawi, 2005) – and signifies the planning and preparation activities preceding implementation;
- BIM capability is the wilful *implementation* of BIM tools, workflows and protocols. BIM capability is achieved through well-defined *revolutionary stages* (object-based modelling, model-based collaboration, and network-based integration) separated by numerous *evolutionary steps* (Succar, 2009). BIM capability covers many technology, process and policy topics and is expressed as the *minimum ability* of an organization or team to deliver a measureable outcome; and
- BIM maturity (or *post-implementation*) is the *gradual and continual improvement* in quality, repeatability and predictability within available capabilities. BIM maturity is expressed as *maturity levels* (or performance improvement milestones) that organizations, teams and whole markets aspire to. There are five maturity levels: [a] Ad-hoc or *low maturity*; [b] Defined or *medium-low maturity*; [c] Managed or *medium maturity*; [d] Integrated or *medium-high maturity*; and [e] Optimised or *high maturity* (Succar, 2010).

3.2 BIM Diffusion

In contrast to *implementation* which represents the successful adoption of a system/process by an organization, diffusion represents the spread of the system/process across the organization. That is, the diffusion of a solution occurs after the solution has been adopted (Peansupap & Walker, 2005) or what we term as the *Point of Adoption* (PoA). However, the mere acquisition of an innovative solution (e.g. a software) "need not be followed by widespread deployment and use by acquiring organizations" (Fichman & Kemerer, 1999, p. 256).

Rogers (1995, p. 5) defines diffusion as the "process by which an innovation is communicated through certain channels over time among the members of a social system", a definition that

[1] Depending on the 'scoping lens' applied, BIM players are either individuals, groups, organizational units, or whole organizations. BIM players, deliverables and their requirements have been extensively covered in earlier works (Succar, 2009).
[2] Definitions adopted from the e-commerce context as used by the Asia-Pacific Economic Cooperation (APEC), Center for International Development (CID) at Harvard University (CID, 2014).

covers the increase in "number of firms using or owning a technology (inter-firm diffusion) [and the] more intensive use of the technology by the firm (intra firm diffusion)[3]" (Stoneman & Diederen, 1994, p. 919) (Mansfield, 1963). Diffusion is also identified as the third and final phase of the well-noted Schumpeterian Trilogy: "invention (the generation of new ideas), innovation (the development of those ideas through to the first marketing or use of a technology) and diffusion (the spread of new technology across its potential market)" (Stoneman & Diederen, 1994, p. 918).

There are numerous studies dedicated to innovation diffusion across a population of adopters (Bass, 2004; Kale & Arditi, 2010; Mansfield, Rapoport, Romeo, Wagner, & Beardsley, 1977; Rogers, 1995). These studies either explain and expand-upon the S-curve diffusion pattern (Cumulative Normal Distribution) (Rogers, Medina, Rivera, & Wiley, 2005) consistently encountered when analysing the spread of innovation; or introduce *diffusion models* that "depict the successive increases in the number of adopters and predict the continued development of a diffusion process already in progress" (Mahajan, Muller, & Bass, 1990, p. 2).

According to Geroski (2000), there are two main types of diffusion models providing insights into the manner and speed of technology adoption – the epidemic model and the probit model. The 'epidemic' diffusion model attributes the diffusion of technology (software in particular) to a given population's knowledge of its existence; its comparative benefits; and the spread of its use through word of mouth. As a result, in the epidemic model the spread of innovation is largely affected by the transfer of knowledge and information among the involved population. As it focuses on a whole population of adopters, the epidemic model is interested in the gradual, unfolding impact of a new system/process on a market through its aggregate use. This contrasts with the 'probit' and 'salience' diffusion models which focus on the effect of *individual decision-making* on the spread of innovation and account for the differences in adoption time between individuals due to their distinct goals, needs and abilities (Geroski, 2000, p. 614; Strang, 1991).

This individual decision-making affecting diffusion follows three identifiable patterns – contagion, social threshold and social learning (Young, 2006, p. 4):

- Contagion represents how an industry player (e.g. an engineer or an engineering company) adopts an innovative system/process upon *contact with another player* who has already adopted it;
- Social Threshold represents how an industry player adopts an innovative system/process when *enough similar players* have adopted it; and
- Social Learning represents how an industry player adopts an innovative system/process when *enough proof is available* of prior adopters finding it worth adopting.

These diffusion models and patterns have been shown to collectively describe and help predict the incremental diffusion of technological solutions across a population. However BIM is not solely an innovative technological solution proliferating incrementally across the construction

[3] To avoid conceptual overlap, the spread of a solution within an organizational unit will not be referred to as intra-diffusion but as improved implementation (or higher level of maturity) across the whole organization.

industry (Fox & Hietanen, 2007) (Mutai, 2009) (Gu & London, 2010) but a an organizational and *systemic* innovation (Taylor & Levitt, 2004) of complementary technologies, processes and policies. While BIM may be initially classified as a *technical innovation* (Murphy & Wardleworth, 2014), it will need to be urgently reclassified - upon its transformative adoption by organizations - as an *organizational innovation* characterised by the "generation, acceptance, and implementation of new ideas, processes, products or services" (OECD, 2005; Thompson, 1965, p. 2).

As covered in depth in earlier research (Succar, Sher, & Williams, 2012) and briefly explored in Figure 1, BIM adoption by an organization passes through three adoption points pertaining to three capability stages. Even if multiple organizations pass through the first Point of Adoption (PoA) separating pre-BIM status from minimum BIM capability (Stage 1), the spread of *modelling* practices among this population does not necessarily or automatically translate into a diffusion of multidisciplinary *collaboration* or interdisciplinary *integration* practices (Stages 2 and 3 respectively). Similarly, BIM is not a mere technological solution but reflects a combinatory and mutational diffusion of technologies, workflows and protocols (Merschbrock & Munkvold, 2014) (Yoo, Richard J. Boland, Lyytinen, & Majchrzak, 2012). This multi-stage, multi-faceted, and multi-component nature of BIM – resembling a *complex adaptive system* (Johnson, 2002) - prevents the effortless application of technology-centric diffusion modelling and invites the development of more representative BIM adoption models.

4. Point of Adoption Model

The Point of Adoption (PoA) model combines many of the concepts introduced earlier (Figure 2). In addition to distinguishing between invention, innovation and diffusion (Stoneman & Diederen, 1994), the three implementation phases – readiness, capability, and maturity - are also depicted). As explained further below, PoA is a term that identifies the juncture(s) where organizational readiness transforms into organizational capability:

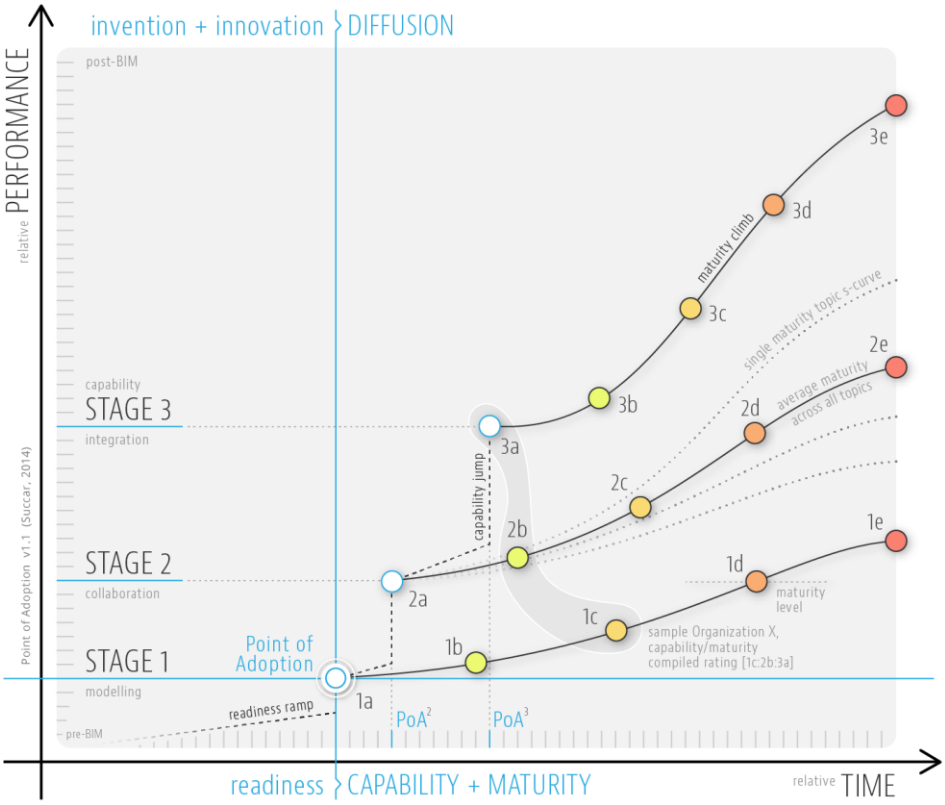
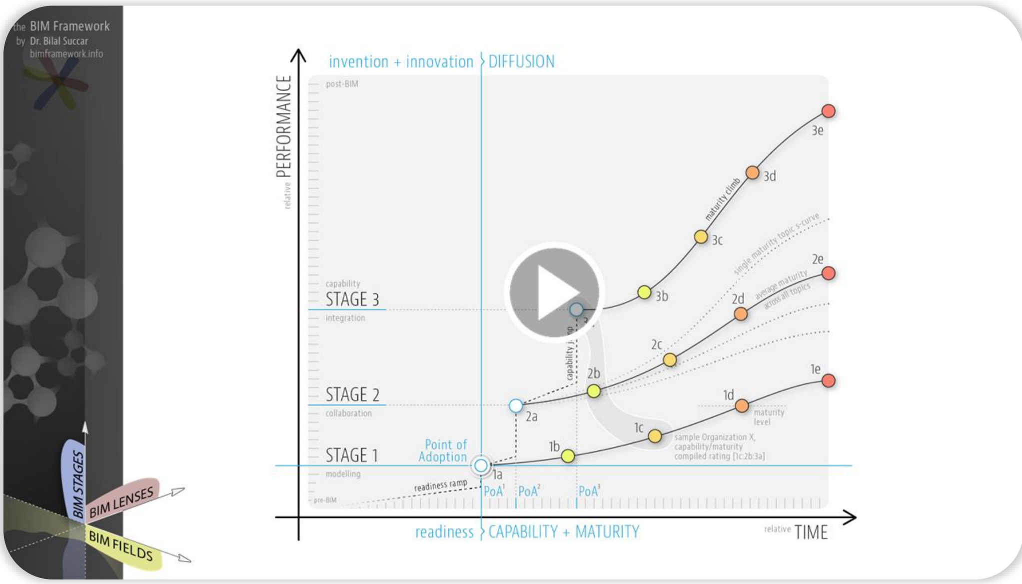


Figure 2. Point of Adoption model v1.1 ([full size, current version]())



Video 1 . Point of Adoption Video (YouTube Link: http://bit.ly/Video-PoA - 17 mins)

As explored in Figure 2 and clarified in Video 1, transformative BIM adoption starts at the Point of Adoption (PoA) when an organization, after a period of planning and preparation (readiness), successfully adopts *object-based modelling* tools and workflows. The PoA[4] thus marks the initial *capability jump* from no BIM abilities (pre-BIM status) to minimum BIM capability (Stage 1). As the adopter interacts with other adopters, a second capability jump (Stage 2) marks the organization's ability to successfully engage in model-based collaboration. Also, as the organisation starts to engage with multiple stakeholders across the supply chain, a third capability jump (Stage 3) is necessary to benefit from integrated, network-based tools, processes and protocols. Each of these capability jumps is preceded with considerable investment in human and physical resources, and each stage signals new organizational abilities and deliverables not available before the jump. However, the deliverables of different organizations at the same stage may vary in quality, repeatability and predictability. This variance in performance excellence occurs as organizations climb their respective BIM *maturity curve*, experience their internal BIM diffusion, and gradually improve their performance over time[5].

The multiple maturity curves depicted in Figure 2 reflect the heterogeneous nature of BIM adoption even within the same organization (e.g. sample Organization X in Figure 2 has a compiled rating of 1c, 2b and 3a). This is due to the phased nature of BIM with each revolutionary stage requiring its own readiness ramp, capability jump, maturity climb, and point of adoption. This is also due to varied abilities across organizational sub-units and project teams: while organizational unit A1 (within organization A) may have elevated *model-based collaboration* capabilities, unit A2 may have basic modelling capabilities, and unit A3 may still be at the readiness stage preparing to implement BIM software tools. This variance in ability necessitates a compiled rating for organization A as it simultaneously prepares for an innovative solution, implements a system/process, and continually improves its performance.

5. Conclusions

The Point of Adoption (PoA) model represents the sequence and relationship between multiple performance assessment concepts. By overlaying the readiness, implementation, invention, innovation and diffusion concepts into a single term, and into a single visual representation, the PoA model clarifies the progression of BIM adoption within and across organisations. Also, through well-defined BIM Capability Stages and BIM Maturity Levels, the PoA model offers a simplified template for measuring BIM performance as well as for planning structured BIM adoption activities.

[4] The Point of Adoption (PoA) is not to be confused with the critical mass 'inflection point' on the S-curve (Rogers, 1995) (Rogers et al., 2005); or with the 'tipping pint', the critical threshold introduced by Gladwell (2001).
[5] The X-axis in Figure 2 represents time relative to each PoA, not as an absolute scale. That is, this version of the chart does not represent a snapshot view of compiled capability/maturity at a specific point in (absolute) time.

The PoA model has several theoretical and practical implications. At the theoretical level, it demonstrates how (a) BIM is a multifaceted innovation; (b) current theories of innovation diffusion may be inadequate for studying BIM diffusion; (c) it is possible to overlay the concepts of readiness, implementation and diffusion into a single adoption model; and (d) the need for a more in-depth theoretical study to underpin BIM adoption and multifaceted innovation diffusion.

At the practical level, the PoA model highlights (e) the simultaneous coexistence of varying BIM abilities within the same organisation; (f) the need to account for these variances when certifying organisations or pre-qualifying tender participants; and (g) the need to revise or discard the prevailing market maturity assessment methods which do not account for such variances.

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