Automation in Construction 43 (2014) 84–91

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Beyond the BIM utopia: Approaches to the development and implementation of building information modeling

Reijo Miettinen *, Sami Paavola [1]

Center for Research on Activity, Development, and Learning (CRADLE), Institute of Behavioural Sciences, University of Helsinki, P.O. Box 9 (Siltavuorenpenger 3 A), Fin-00014, Finland

ARTICLE INFO

Article history:
Received 13 August 2013
Received in revised form 3 February 2014
Accepted 8 March 2014
Available online 28 March 2014

Keywords:
Building information modeling
BIM promises
BIM implementation
Experimentation
Cultural historical activity theory
Evolutionary theory of innovation

ABSTRACT

Building information modeling (BIM) refers to a combination or a set of technologies and organizational solutions that are expected to increase interorganizational and disciplinary collaboration in the construction industry and to improve the productivity and quality of the design, construction, and maintenance of buildings. In this paper we analyze first the rhetorical–promotional dimension of the BIM implementation sometimes characterized as a "BIM utopia." Second, we analyze the views of the enhancement of BIM implementation. Although BIM visions and promises are needed for BIM implementation, they need to be complemented with a more realistic view of conditions of the implementation. For this we outline an activity–theoretical and evolutionary view by drawing conceptual tools from science and technology studies and other relevant social scientific literature. According to this view, in addition to standards and guidelines underlined by normative approaches, local experimentation and continuous learning play a central role in the implementation of BIM.

1. Introduction

There is no single satisfactory definition of what building information modeling (BIM) is. Rather, it needs to be analyzed as a multidimensional, historically evolving, complex phenomenon. BIM can first be defined as a digital representation of a building, an object-oriented three-dimensional model, or a repository of project information to facilitate interoperability and exchange of information with related software applications. BIM tools support parametric modeling and allow new levels of spatial visualization, simulation of the behavior of the building, as well as more efficient project management. BIM is also emphatically a tool of collaboration. When BIM is extended from design to construction, and facility management and maintenance of the building, new levels of interoperability and collaboration can be achieved. The collaborative use of BIM reduces design mistakes and increases the productivity of the construction industry. BIM therefore, provides an emerging new paradigm for construction management or "an emerging technological and procedural shift in the Architecture, Engineering and Construction industry" (Succar [1], p. 357).

The high expectations of the increased productivity and a new level of collaboration express the rhetorical dimension of BIM development and implementation. As a matter of fact the term BIM, introduced in 2002 by Jerry Laiserin, may be regarded as a new promotional umbrella concept [2]. Historically, the need and possibility for developing more integrated or interoperable software was recognized already in the 1970s by researchers of construction projects developing "integrated design databases" [3] or "integrated design systems" [4] (see also Björk [5], p. 12). BIM can be seen as an evolution of CAD systems but providing more "intelligence" and interoperable information. These systems were named with terms like Virtual Building, Project Modeling, Virtual Design and Construction, and nD Modeling (see Aranda-Mena et al. [6], p. 420-1, Succar [1], p. 359). One central background for BIM was product data models concerning the information of buildings [5].

The literature is growing on how technological visions and promises are used for finding support and funding for the development of new technologies [7–10]. The promises are an essential part of legitimating the development of technology and getting the funders and future users convinced of the importance of investing in its development (Brown et al. [11], p. 881): "Initial promises are set high in order to attract attention from (financial) sponsors, to stimulate agenda setting (both technical and political) and to build 'protected spaces'." In its analysis of the European innovation policy, an expert group of the European Commission on science policy (Felt & Wynne [9], p. 24) found what is called a "regime of technoscientific promise." According to the group (Felt & Wynne [9], p. 25), the first principle or rhetorical move operative in this regime is: "the creation of a fiction in order to

* Corresponding author. Fax: +358 9 191 44579.
E-mail addresses: reijo.miettinen@helsinki.fi (R. Miettinen), sami.paavola@helsinki.fi (S. Paavola).
[1] Fax: +358 9 191 44579.

http://dx.doi.org/10.1016/j.autcon.2014.03.009
0926-5805/

attract resources (…) that the emerging technology (biotechnology in the 1980s, nanotechnology now) will solve human problems (health, sustainability, etc.) through a wide range of applications."

These technical visions have been characterized in terms of "generalized technological promise" [8] "or a guiding vision" [12] or a "promotional metaphor" [13] by the science and technology studies. New technologies are naturally future-oriented and try to change reality, improve technology-mediated practices, and create new opportunities. These visions are generative and guide activities. The BIM can also be characterized as a *transdiscursive term* [14] that develops and operates simultaneously in research, policy making, and industry. Such a term must be loose and abstract enough in order to function as an interdisciplinary organizer enabling different groups to articulate a roughly shared direction of interests and moral commitments and still maintain their own identity and goals [15]. Because of its fuzziness organizing visions can constantly be complemented with new promises that reflect the development of the technology itself and react to the problems and challenges that emerge in the construction industry. This paper will focus on the rhetorical–promotional viewpoint of the BIM development and on the views of the enhancement of BIM implementation.

This paper is a position paper. We analyze how the development and future of BIM has been represented in BIM literature. We complement the existing literature by introducing theoretical concepts of technology development and implementation which are not yet widely used. They originate from cultural historical activity theory, science and technology studies, as well as from information systems and innovation studies. This allows us to construct two alternative frameworks of understanding and analyzing the BIM implementation, which we respectively call the *normative* and the *activity–theoretical/evolutionary* frameworks. These are theoretical constructs that help to make sense of the ways in which BIM implementation can be understood and how the implementation can be enhanced. We are not arguing that either of these frameworks is true, but rather that they emerge from different theoretical traditions, complement each other and suggest different ideas and means for the enhancement of the BIM implementation. Since the latter framework is less known in BIM research, it may serve to enrich the discussion and to provide new ideas and means for BIM implementation.

We proceed in the paper as follows. First, we characterize four key promises of the BIM rhetoric that can, in a full-blown form, be called a "BIM Utopia." These promises are integral means of promoting awareness of the usefulness of BIM, and can be found in many of the BIM definitions. On the other hand, these promises have also been criticized and questioned in BIM literature. Second, we analyze the ways in which BIM development and implementation have been discussed in BIM literature and their connection to guidelines and capability maturity models developed in information systems theory. Thirdly, we briefly characterize how technology implementation has been discussed in activity theory, science and technology studies as well as information science and innovation studies during the last decades. The theories that will be reviewed find the mediating tools, local learning and collaboration with users essential for the implementation of new technologies. We present three constitutive features of an activity theoretical and evolutionary view. Finally, we compare it with the normative framework and discuss the recommendations for enhancing the BIM implementation they suggest.

We analyze promises of BIM and how the problem of implementation has been dealt with in the BIM literature resorting to systematic reviews of the field (e.g. [1,16,17]), the recognized handbook of the field [18], as well as a set of papers which deals with the development and implementation of BIM (see the list of references). We have selected concepts from science and technology-, information system and innovation studies that deal with the problem of implementing new technologies and specifically information systems. Although the paper is mainly theoretical, we also refer to our own empirical studies on uses of BIM in Finland which provide a local perspective on the BIM implementation. Our research group [19,20] has followed consecutive life-cycle projects of four public schools in Eastern Finland. In addition, we have followed several projects in different phases of the construction process as well as the uses of information technology in facility management and maintenance [21].

2. Four elements of the BIM utopia

All new technologies include potential to improve productive activities. These potentials are expressed in future-oriented visions of the advantages that will be achieved when the new technology is fully implemented. Such visions have also been called BIM "utopias" [22] or "idealistic goals" of BIM (Howard & Björk [23], p. 277). A central concern in the building industry is to increase productivity and efficiency of the business, and BIM is seen as a central vehicle here. BIM promises take many other forms: to eliminate design errors and quality of design, to help management of processes in construction, to deepen collaboration and communication between partners in the construction process, and to provide new forms of collaboration with clients. The influential *BIM Handbook* [18] lists several benefits of BIM in relation to preconstruction, design, construction and fabrication, and post construction phases (Eastman et al. [18], p. 19–25). The handbook also points out that BIM is a buzzword used by the software vendors: "The term BIM is a popular buzzword used by software developers to describe the capabilities that their products offer" (ibid. 19). That is why the definitions of BIM are "subject to variation and confusion."

Borup et al. [12] point out that the technological visions are future-oriented abstractions. They tend to transform the technological potentiality into a picture of future reality simultaneously disregarding many of the conditions and constrains that in reality will complicate and retard the realization of the vision. The technological visions particularly tend not to take fully into account the social and human conditions of the implementation of a technology.

In the following we discern four key elements of the BIM rhetoric or promises often included in the BIM definitions and accounts of the BIM implementation. They are characterizations that concurrently are included in the visions of BIM. These four elements are: 1) all relevant data needed in the design and construction of a building will be included in a single BIM model or is easily available with BIM tools, through common repositories or distributed database systems. 2) In allowing interoperability between data (shared with open standards like IFC) from several native design models, BIM becomes a tool of collaboration allowing new integrated ways of working. 3) BIM will be maintained and used throughout the lifecycle of the building. 4) BIM is expected to increase considerably the efficiency and productivity of the building industry. As the following examples show, many definitions in the literature reproduce and combine these elements:

> "Building information modeling (BIM) is an IR-based approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository." (Gu & London [24], p. 988)

> "BIM refers to a set of interacting policies, processes and technologies that generate a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle." (Succar et al. [25], p. 120)

Shen et al. ([26], p. 197) characterize FIATECH's roadmap for systems integration:

> "Information is available on demand, wherever and whenever it is needed to all interested stakeholders. (…) Interconnected automated systems, processes and equipment will drastically reduce the time and cost of planning, design and construction. (…) With a common data model, it is possible for building information to be created once, re-used and enriched in the rest building lifecycle."