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10 Questions

Ten questions concerning building information modelling

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ABSTRACT

Building information modelling (BIM) has been a dominant topic in information technology in construction research since this memorable acronym replaced the boring "product modelling in construction" and the academic "conceptual modelling of buildings". The ideal of having a complete, coherent, true digital representation of buildings has become a goal of scientific research, software development and industrial application. In this paper, the author asks and answers ten key questions about BIM, including what it is, how it will develop, how real are the promises and fears of BIM and what is its impact. The arguments in the answers are based on an understanding of BIM that considers BIM in the frame of structure-function-behavior paradigm. As a structure, BIM is a database with many remaining database challenges. The function of BIM is building information management. Building information was managed before the invention of digital computers and is managed today with computers. The goal is efficient support of business processes, such as with database-management systems. BIM behaves as a socio-technical system; it changes institutions, businesses, business models, education, workplaces and careers and is also changed by the environment in which it operates. Game theory and institutional theory provide a good framework to study its adoption. The most important contribution of BIM is not that it is a tool of automation or integration but a tool of further specialization. Specialization is a key to the division of labor, which results in using more knowledge, in higher productivity and in greater creativity.

1. Introduction

Humans do many things without planning or thinking, such as when someone throws us a pen we asked for, we catch it without consciously calculating the curve-of-flight and planning the catch. However, when humans do something rationally, we first imagine doing it. We act it out in our heads before actually taking action. When hanging a painting on a wall, for example, we imagine where it should hang, how it should be aligned with existing paintings, where we need to drive the nail into the wall, considering the location of the hanger and the offset to the edge of the frame.

As Aristotle put it [1] "First, have a definite, clear practical ideal; a goal, an objective. Second, have the necessary means to achieve your ends; wisdom, money, materials, and methods. Third, adjust all your means to that end." In a similar fashion, Shakespeare [2] described the process of construction: "When we mean to build, We first survey the plot, then draw the model; And when we see the figure of the house, Then must we rate the cost of the erection; Which if we find outweighs ability, What do we then but draw anew the model, In fewer offices, or at last desist To build at all?"

Information models of buildings have been represented as drawings since paper became inexpensive and available for tasks such as building design. As the Shakespeare citation demonstrates, drawing was called modelling well before modelling is replacing drawing. Paper enabled fairly reliable communication among the designers of buildings and bridged distances in time, space and profession [3].

The latter is particularly important because it enabled specialization of professions. Earlier, master builders—with all the relevant general knowledge and all the specific plans – were, due to the lack of communication, mostly confined to themselves. Later they could be replaced by teams of specialists. Teams could collaborate because paper-based communication offered a reliable way to communicate [4]. They were able to share an information model of a building. On one hand, this enabled the specialization in the professions designing, constructing and managing buildings. It enabled the specialization of businesses involved with these processes. However, it also resulted in fragmentation and disintegration of professions, knowledge, processes and businesses. The

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process accelerated with the introduction of digital technology. A research topic called computer-integrated construction [5–7] set out to develop solutions that would counter the fragmentational effect of digital technology.

The main topic in computer-integrated construction research was the development of methods to describe buildings using a common language and methods to collaborate in that language. In the late 1980s, the solution was called "Conceptual Modelling of Buildings" [8]. Later, the community borrowed the term "Product Modelling" [9], which was used in mechanical engineering to describe design and manufacturing information about future products [10–12]. The ISO-STEP standard first appeared in mechanical engineering [13]. There were several attempts to use it in construction [14,15] but without much direct practical impact on the industry.

In the meantime, the construction software industry was creating various tools to support engineering activities during designing and planning. Most of that software was concerned with the analysis and simulation required by various specialists. They operated on mechanical, physical or mathematical models of phenomena, such as finite element models of beams, energy models of walls, and process models of work. These models became increasingly accurate, and the simulations, due to the increasing speed of computers, became more reliable.

Other software was concerned with replacing paper-and-ink drawing boards, and drawing software evolved. The key evolution was in the elements that the drafter could place (draw) on the canvas (drawing). The simplest drawing elements are pixels, followed by lines and other 2D geometric shapes, followed by 3D geometric objects. In some fields—for example for organizational diagrams, software engineering and industrial process maps—2D geometry was replaced by symbols that stand for something in the problem domain – such as sectors and their bosses, machines on the assembly lines, their inputs and outputs, or steps in a computer algorithm.

Finally, 3D CAD software evolved from allowing the modelers to place 3D geometric objects into 3D model space, to placing engineering or architectural elements into the digital representation of the landscape. In a geometric CAD system, it was the human who had to interpret, for example, a cylinder as a structural column. In BIM software, this is explicitly stated in the resulting database. The software industry began to transition from CAD to BIM.

While the acronym BIM is attributed to Jerry Lassarin [16], the concept was a result of a long series of research under the topic of conceptual modelling of buildings and product modelling of buildings since the 1970s [17,18].

Conceptual modelling, product modelling and BIM have traditionally been subject more to research push than industry pull [19]. The first attempts to standardize data structures needed to describe the built environment came from the top-down within ISO-STEP, followed by a more bottom-up approach in the International Alliance of Interoperability (IAI) with Industry Foundation Classes (IFC) [20,21].

In summary, designers of buildings have always used information models of buildings. In fact, the design process was all about information modelling of buildings. With information technology, the information models first became digital and have since become increasingly well structured. CAD evolved naturally from 2D geometry via 3D geometry towards 3D professional objects with the 4th dimension added for time. The amount of data that we have on buildings is growing exponentially, much like Moore's law and IT capacity allow. Specialized engineering software (such as finite elements software) was based on engineering objects—not lines or pixels—from the very beginning.

2. Ten questions

BIM is an exhaustive research topic in the field of construction informatics [22] or computing in building engineering. Selecting ten questions is not easy. The author chose questions that may generally be overlooked in the ongoing quest for "better" models and more "efficient" collaboration. The questions can be grouped into three categories:

1. What BIM is and what are its future directions?
2. What are the fears and promises related to it?
3. How it is affecting selected areas related to construction?

The author is aware that each of these questions deserves a separate in-depth study and hopes they would follow and complement the problem solving type of research that dominates the BIM research community.

2.1. *What is BIM?*

The acronym stands both for building information modelling (the process) and building information model (the artefact), and the attention of the research community and software developers alternates between the two. Initially, the challenge was the representation of buildings. As the representation matured, the attention shifted towards the processes in which these representations can be created, developed and used.

BIM can also stand for building information management—the control of the processes in which models are built and used [23]—and for building information marketing [24]. The latter is a cynical observation of the exploitation of the acronym, both in the industry and in the academia.

BIM initially represented the new, structured ways to represent buildings that went beyond lines and "implicit meaning" towards objects and "explicit meaning". The issue of meaning will be revisited in Section 2.6.

One could argue that building information modelling—the process of creating information about (future) buildings—has existed for centuries. This is even acknowledged in the BIM maturity levels [25,26], where BIM level 0 corresponds to information modelling of buildings using paper drawings, BIM level 1 to 2D and 3D CAD and only BIM level 2 and above to object-oriented (see Section 2.2.1) representations of buildings and corresponding processes.

The US National Building Information Modelling Standard defines BIM as "A digital representation of physical and functional characteristics of a facility … and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition" [27]. In this definition, the M clearly stands for model. The definition is broad, and many legacy technologies and techniques could fit into the definition.

Some define BIM in broader terms—as an approach to engineering collaboration rather than specific technical solutions [28]: "Building information modelling (BIM) refers to a combination or a set of technologies and organizational solutions that are expected to increase inter-organizational and disciplinary collaboration in the construction industry and to improve the productivity and quality of the design, construction, and maintenance of buildings."

The two ways of defining BIM can be reconciled using an approach engineers and architects have been using for a long time. When describing things, they often resort to a paradigm known as structure-function-behavior [29,30]. Using this paradigm, the definition of BIM has three facets: structural, functional and behavioral.