

# Building Information Modelling (BIM)

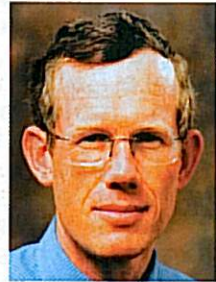
## Introduction

The concept of a Building Information Model (BIM) also known as a Building Product Model (BPM) is nothing new. A short article on BIM will never cover the entire field, because it is a particularly complex field that is recently beginning to receive a lot of attention. The idealistic goal of a BIM has been to provide a single building model capable of being used throughout the process (Howard *et al.*, 2007).

Architecture, civil engineering and building construction have relied on paper-based drawings for a very long period of time. This situation changed significantly with the introduction of CAD into South Africa in the early 1980's. It is not common knowledge that the South African built environment professionals were at one stage one of the highest per capita users of CAD in the world. At this time no fewer than 3 CAD systems were developed locally<sup>46</sup>. One of the first problems that built environment professions were confronted with was the exchange or translation of mostly graphical information from one CAD system to another. One of the most popular exchange formats are still the Autodesk (AutoCAD) dwg and dxf formats. Due to significant differences between the internal proprietary formats of the various CAD systems drawing translation and exchange was never entirely satisfactory.

In the mean time the world changed significantly. Building designs are now expected to be energy efficient and must conform to known or predictable performance levels. The designer must also be able to demonstrate the expected life cycle cost. Increasingly sophisticated buildings are currently locally being designed such as lecture buildings that rely almost entirely on renewable resources such as natural ventilation, solar and wind energy. Abovementioned factors both locally and abroad prompted a new generation of far more sophisticated CAD systems now generally known as a BIM.

3D, 4D and BIM technologies represent three separate, but synergistic, ways in which computer technologies can aid the management of facilities throughout a project's lifecycle. 3D geometric models are the geometric representation of building components and are typically used for photorealistic visualization, design and construction coordination. 4D models (3D + time) include information that can inform and analyze project phasing, tenant sequencing, and construction scheduling. BIMs include not only 3D geometric models, but also more specific information or attributes on a wide range of building elements and systems associated with a building such as wall types, spaces, air handling units, geospatial information and circulation zones. BIMs, being a specialized 3D model, are therefore capable of directly generating 2D and 3D working drawings from the detailed virtual model.



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<sup>46</sup> Caddie (1986), Genes1s (1987) and AllyCad (1985) were originally developed locally and are still being used.

## What is a BIM?

Many definitions of BIM's exist. According to the U.S. General Services Administration (GSA), Building Information Modelling is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility. From this views appropriate to various users' needs can be extracted and analyzed to generate feedback and improvement of the facility design.

Charles Eastman, the current Director of the Georgia Institute of Technology, AEC Integration Laboratory, originally used the name Building Product Model for BIM (Eastman 1999). According to him a BIM is a digital information structure of the objects making up a building, capturing the form, behaviour and relations of the parts and assemblies within the building. A BIM is potentially a richer representation than any set of drawings and could be implemented in multiple ways, including as an ASCII file or as a database.

Translation between different CAD systems is difficult because it must handle geometry and many other alphanumeric attributes. Soon after the invention of CAD systems it was realized that a single building information model would solve many problems. The goal of the single building information model has existed for at least 30 years and various standards have been published such as the International Association of Interoperability (IA) Industry Foundation Classes.

**FIGURE 14.1** A typical BIM produced with AutoDesk Revit



One of the early BIM systems is the OXSYS CAD system developed by Applied Research in Cambridge (ARC) and used in very large projects such as the Milton Keynes Hospital in 1981 (Figure 2). This system had all the essential characteristics of a modern BIM system. The OXSYS building system was based on a predefined set of building components. All building elements could be defined in a library, which ARC called a Codex. The Codex was extensive including structural elements, cladding components, partitions, slabs, ceiling elements as well as room types, interior fittings and fixtures and mechanical equipment. An

important capability was the fact that each element was described in terms of its dimensions, descriptive text giving its name and general use, weight, function-related properties, environmental characteristics and also the graphic codes required to draw the elements in different views. The set of working drawings including sections, elevations and plans could be directly produced from this model.

It is expected that BIM systems will eventually be used by most people associated with the building and real estate businesses. Although it was originally intended as a means to centralize and persist the building models, it is unlikely that translation would be entirely replaced. The reason for this is that there is large number of non BIM systems around that won't suddenly disappear. By persistence is understood the approach where the building model information exists in a neutral and completely open format and is not dependable on any CAD system to retrieve relevant information. Even though BIMs offer huge benefits the acquisition, conversion and training cost in the use of BIM systems is still quite high for the smaller architectural practice.

## The differences between 3D models and BIM

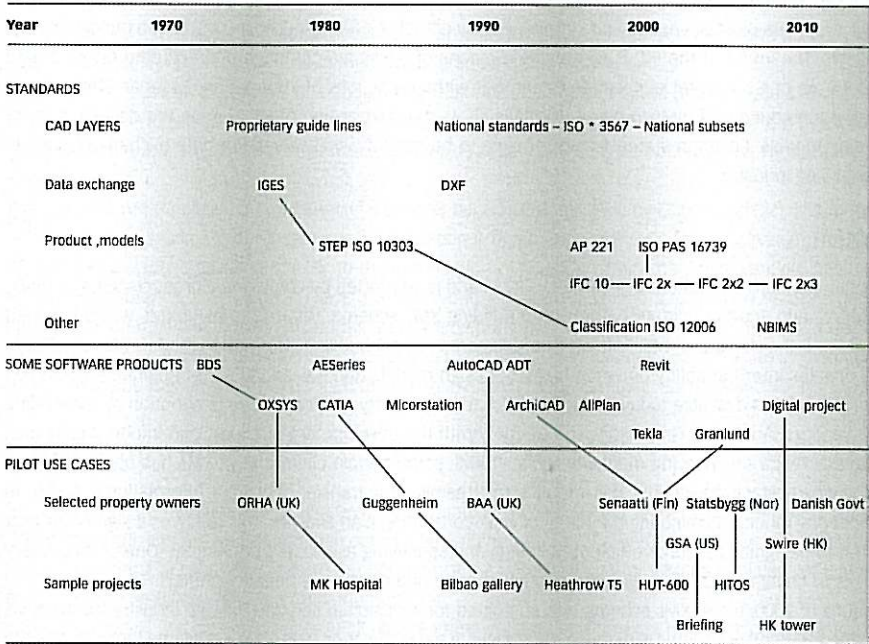
3D geometric models contain mostly geometric information making it especially suitable for very realistic visualization. BIM models contain a much higher level of intelligence. It must be noted that some pioneering object based 2D and 3D CAD systems such as GDS (MicroGDS) and CADDIE had some of the capabilities of a full BIM for many years. Full parametric capabilities, i.e. the capability to resize an entire building or component with the rest of the structure following suit is a more recent introduction. A BIM is a detailed virtual graphical and attribute prototype of the building. It contains all the elements of the building such as the building floors, spaces, walls, doors, windows and a large number of attribute information associated with each of these elements. A BIM can normally be viewed in 3D, but the model also includes information used by other building analysis applications, such as cost estimating, energy simulation, daylighting, computational fluid dynamics (CFD), space planning and building code checking.

Although 3D models make valuable contributions to communications, 3D models alone do not qualify as BIM models since a 3D geometric representation is only part of the BIM concept. The rest of the BIM concept is contained in the "I" of BIM, which stands for information. BIM is a data rich digital representation cataloging the physical and functional characteristics of design and construction. It can serve as a shared knowledge base that can be directly manipulated (computable) by any application that supports the supports the BIM standards. Its importance stems from having an open interchange of information across platforms and a transferable record of building information throughout a building lifecycle. BIM serves as a reliable foundation for decision making and provides a platform for automated analyses that can assist in planning, design, construction, operation, and maintenance activities.

## The potential of a BIM

The information in a BIM model catalogs the physical and functional characteristics of the design, construction, and operational status of the building. Multiple instances of these states can demonstrate the dimension of time and/or to capture a rich and searchable data set, which provides a record of design decisions, construction sequencing and operational events that is not possible using static representation alone. These models can even be used to test the constructability of a building. Although the latter is not yet mainstream examples of this is known in academic papers and a few case studies. This information may span a number of disciplines and application types. BIM integrates this information in one database in a consistent, structured, and accessible way. As a result, BIMs are multi-purpose and can be evaluated from many different points of view as required to optimize design, construction and operation of a building.

FIGURE 14.2 Proposed framework for documenting developments in BIM (Howard 2007)



## Standards

BIM systems eventually became due to the availability of high speed computer and display hardware that is now much more affordable than 10 years ago. Simultaneously generic and popular software standards emerged such as a XML and OpenGL discussed below.

### XML

eXtensible Markup Language (XML) was developed by an XML Working Group under the auspices of the World Wide Web Consortium (W3C) in 1996. One of the main reasons for this was that the further development of the web required a far more flexible approach where the presentation (layout) and data aspects be separated in web pages. Previously both aspects were handled only with the relatively inflexible Hyper-text Mark-up Language (HTML). Although XML was originally intended to be a web (Internet) standard, its impact is now much far wider than that. The flexible and hierarchical nature makes it a natural language for structured and hierarchically related knowledge that is prevalent in built environment related information. XML is a flexible set of rules for defining semantic tags that break a document or data model into parts and identify the different parts of the document (Harold 1999:3). At this stage XML is one of the most important formats for exchange of information between technical systems in the Internet, on the desktop and intranet environments. Many important commercial systems have XML export and import formats and it is now the most important standard used for the exchange of BIM information.

## The Industry Foundation Classes (IFC)

The International Alliance for Interoperability (IAI) Industry Foundation Classes standard (IFC) is at this stage by far the most advanced and simultaneously complex general-purpose XML based building model available. The intent of the IFC is to provide a means of passing a complete and accurate building data model from one computer application to another without any loss of information. Eastman (1999) documented the concept of BIMs in detail. The IAI's IFC is the culmination of 25 years in the development of building models. Eastman stated that it remains to be seen if it will solve the data exchange issues in the building industry.

## gbXML

Another standard that recently became available and is supported by commercial products such as Revit, ArchiCAD and EcoTect is gbXML. The Green Building XML schema, referred to as gbXML was developed to facilitate the transfer of building information stored in CAD building information models (Kenedy 2008). This enables interoperability between building design models and a wide variety of engineering analysis tools and models available today. Today, gbXML has the industry support and wide adoption by the leading CAD vendors, Autodesk, Graphisoft, and Bentley. With the development of export and import capabilities in several major engineering modeling tools, gbXML some people claim that gbXML has become the de facto industry standard schema. It is intended to streamline the transfer of building information to and from engineering models, eliminating the need for time consuming plan analysis. This removes a significant cost barrier to designing resource efficient buildings and specifying associated equipment. One of its primary aims is to enable building design teams to collaborate and realize the benefits of BIMs.

In June of 2000, the gbXML schema was submitted for inclusion in aecXML(TM), the industry-led initiative, launched by Bentley Systems with much excitement in the summer of 1999. gbXML became the draft schema for the International Alliance for Interoperability's Building Performance and Analysis working group.

The gbXML.org site was created in February of 2002 to host and further stimulate development of the schema.

## Google Earth Keyhole Markup Language (KML)

KML is another XML based file format used to display geographic data in an Earth browser, such as Google Earth, Google Maps, and Google Maps for mobile. You can create KML files to pinpoint locations, add image overlays, and expose rich data in new ways. KML is an international standard maintained by the Open Geospatial Consortium, inc. (OGC). OpenGIS® is a Registered Trademark of OGC and is the brand name associated with the Specifications and documents produced by the OGC. (OGC, 2008)

## OpenGL

FIGURE 14.3 The official OpenGL logo



Although OpenGL® is not directly related to BIM, it is a standard that played a significant role in making the hardware and software efficient enough to support BIM systems. It is essentially a software interface used

by CAD and BIM developers to the graphics display hardware. This interface makes the high speed display of interactive three-dimensional applications possible. OpenGL® doesn't provide high-level commands for describing models of three-dimensional objects such as relatively complicated shapes such as columns, doors and roofs. It concentrates on a small set of *geometric primitives* - points, lines, and polygons that can be very efficiently implemented in high speed graphic display cards.

OpenGL® is based on the original GL programming interface that has been used for many years on high performance Silicon Graphics machines. OpenGL® provides machine independence for 3D since it is available for various X platforms (SGI, Sun and Windows) and is included as a standard part of Microsoft Windows. (Myers 1994:10)

The OpenGL® API (Application Programming Interface) began as an initiative by Silicon Graphics Incorporated (SGI) to create a single, vendor-independent Application Program Interface (API) for the development of 2D, 3D and BIM graphics applications. Prior to the introduction of OpenGL®, many hardware vendors had different graphics libraries. This situation made it expensive for software developers to support versions of their applications on multiple hardware platforms and it made porting of applications from one hardware platform to another very time-consuming and difficult. SGI saw the lack of a standard graphics API as an inhibitor to the growth of the 3D marketplace and decided to lead an industry group in creating such a standard.

## Conclusions

Because BIMs are machine readable it becomes practical to use the data in many different ways such as bills of material, lighting and energy use not in a post facto mode at the end of the process, but rather as feedback during the process to inform the designer of the impact of changes. Many new uses of BIM data are waiting to be discovered and implemented.

Building models can potentially benefit all parties in the construction process by saving cost, construction time and the better support for building performance analyses that might be required.

Although the Industry Foundation Classes has been developed for over 11 years, the resulting protocols have been mainly applied in test projects (Howard *et al.*, 2007). Many studies indicated the benefits to users who applied BIM well. It is expected that it will eventually become the standard for the built environment.

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