Chapter 2
The Future of Building Information Modelling: BIM 2.0

Abstract The first evolution of BIM was from being a shared warehouse of information to an information management strategy. Now the BIM is evolving from being an information management strategy to being a construction management method. This change in interpretation of BIM is fast and noticeable. Four newly emerging dimensions in management of building information towards transforming BIM to BIM 2.0 focus on enabling an (i) integrated environment of (ii) distributed information which is always (iii) up to date and open for (iv) derivation of new information. The chapter starts with providing recent trends in building information modelling and then elaborates on technologies that will enable BIM 2.0. BIM-based management of the overall construction processes is becoming a major requirement of the construction industry, and the final part of this chapter provides matrices that can be used as a tool for facilitating BIM-based projects and process management.

2.1 Introduction

Over the last half-century ICT has evolved beyond the 'personal' computer to become a strategic asset for business in delivering productivity improvements, extending to provide socio-economic development and growth (European Commission 2006). From the personal computer we have witnessed the emergence of technological advancements such as business systems and applications, visualization, communications, the Internet, mobile/smart/android devices, social networking and most recently, virtualization and cloud computing as part of this revolution. There is no doubt that the effects of the digital age have facilitated considerable changes and improvements to the construction industry and in shaping and modernizing the industry as we currently see in the twenty-first century when compared to the 'traditional', 'archaic' and 'draconian' one from the dim and

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distant past. It is evident that construction organizations are already in the process of looking towards rapidly maturing technology approaches such as virtualization and cloud computing in the provision of cheaper, more flexible and commoditized ICT infrastructure services to directly drive business efficiencies (France et al. 2010). Other industries are demonstrating that combined cost savings up to 35 % can be achieved through a range of modernization measures, including the consolidation of data centres and full utilization of virtualization technologies. The advancements in information technologies have changed the way we interpret design, analysis and construction management and facilities management. As it has been discussed in the previous chapter, building information modelling has emerged as a cure to the illness of poor interoperability in the industry, but now the paradigm is accepted as a new method of information management, and a new method of construction management. The optimistic view on building information modelling argues that this methodology will be a "*sine qua non*" in the future of the construction industry. The first evolution of BIM was from being a shared warehouse of information to an information management strategy. Now BIM is evolving from being an information management strategy to being a construction management method. The evolution of BIM is fast and noticeable. Today, BIM-based management of daily processes in construction is becoming a de facto standard for large investments. Many projects in the US, Singapore, Dubai and the UK require the existence of BIM-based processes, and involvement of BIM managers (a profession emerged in the past 10 years).The evolution of BIM from BIM 1.0 to BIM 2.0 can be investigated in two dimensions. The first dimension is the changing role of information models (i.e. the shared information sources) from being a shared database to something more complicated. The second dimension is the emerging role of BIM as a new construction management method. We elaborate on these two dimensions in the remainder of this chapter, but it would be good to look at the research dimensions of BIM in the past 5 years as a starting point.

2.2 Research Dimensions of Building Information Modelling

In 2010, Underwood and Isikdag edited *The Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies*, which was the first collaborative academic book that involved authors from all over the globe.

The handbook (Underwood and Isikdag 2010a, b) contained 28 chapters, which had been the motivation behind defining a research compass for BIM (see Fig. 2.1). The research compass provides the current research directions for BIM. These directions were explained in detail in Isikdag and Underwood (2010), the following will summarize these directions.

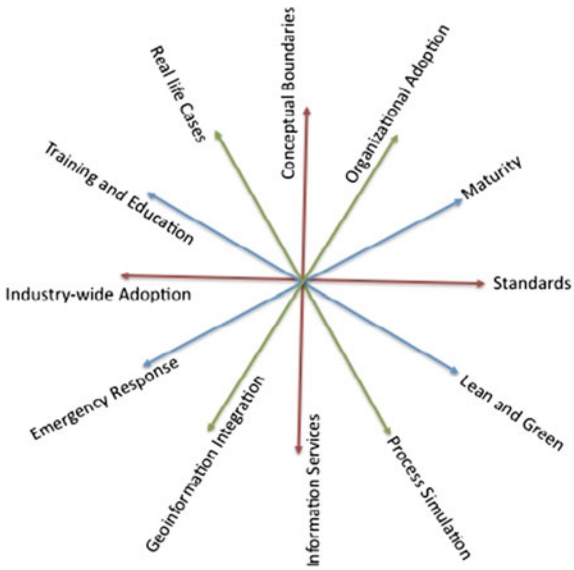

Fig. 2.1 BIM research compass

2.2.1 Information Model-Related Aspects

Conceptual Boundaries of the Information Model BIMs have mainly emerged in the form of schema standards for information exchange, i.e. as enablers of data level interoperability. Van Nederveen (Van Nederveen et al. 2010) indicated that a clarification between (a) what is being modelled and (b) how these can be modelled needs to be clearly identified. The research in the area focuses on enhancing the methods and languages for information modelling and reasoning-based approaches to BIM.

Standardization As standardization is a key enabler and facilitator of data level interoperability, this area will continue to be a focus of BIM research. For example, Dado et al. (2010) provide an overview of the characteristics of interesting conceptual product approaches such as standardization, minimal model, core model, NOT, vocabulary and ontology product modelling. In recent years, the US and UK have taken the initiative for developing nationwide BIM standards, which covers more than representation and exchange of information (Suermann and Issa 2010). Such approaches can help in formalizing the information exchanges, the processes and workflows, and will contribute to the evolution of BIM to a project management method.

2.2.2 *Organizational Aspects*

Adoption The move from CAD-based thinking to the vision of BIM is much more difficult as it involves a shift in fundamental data management philosophy. As indicated by Bew and Underwood (2010), in a similar manner to the move from old accounting packages to Enterprise Resource Planning (ERP), this transformation includes the formal management of processes on a consistent, repeatable basis. Like the ERP implementation, this too is a very difficult transition to make. The lack of mature process management tools and methodologies for the projects has made this transition more confusing. BIM adoption most likely occurs in phases (i.e. in an almost Darwinian evolutionary way), but serious effort should be taken to move from one phase into another.

Maturity A key area in BIM is organizational readiness. If BIM is considered as a set of new technology and methodologies supporting information management in the construction industry, then maturity in terms of implementing and using BIM (technology and methodologies) is critical to the success of BIM implementation. Frameworks for measuring BIM maturity can greatly facilitate organizations in positioning themselves against their competitors in terms of technological, methodological and process maturity. Such a maturity framework is explained in Succar (2010).

Education and Training Education and training is *sine qua non* for successful BIM implementation and adoption in addressing issues/barriers such as culture, etc. As mentioned in Tanyer (2010) and as appeared in the Integrated Project Delivery (IPD) efforts in the US, AEC professionals are beginning to move away from the traditional way of design and project delivery towards a more integrated one. Project-based collaborative learning environments such as in Stanford University (PBLLab 2007), and e-learning environments such as ITC-Euromaster (2009) will also facilitate (and be facilitated by) the use of BIM and collaborative design approaches.

Real-life Cases BIM is not a subject of pure (laboratory type) research any more. This has significantly evolved over the last few years with the implementation of BIM methods and shared digital models in real-life projects increasing exponentially (Lostuvali et al. 2010; Underwood and Isikdag 2010a, b; Riese 2010). The experience and lessons learned from real-life cases will contribute to the development of BIM as a data model or as a project management methodology.

Industry-wide Adoption Research towards the positioning of BIM adoption across disciplines in relation to their current status and future expectations and based on such factors as the tools, people and processes is viewed as a key requirement. For instance Gerrard et al. (2010) provided a bird's-eye view of the industrial adoption picture.

2.2.3 Domain-Specific Aspects

Lean Construction and Green BIM The aim of lean construction is to enable continuous improvement of all construction processes in the building life cycle (starting from design through the demolition of the building) (Solis and Mutis 2010). On the other hand, to address global concerns on environmental issues, the construction industry now takes the initiative to build more 'environment-friendly' buildings, along with reducing its own carbon footprint such as during the construction stage. BIM emerges here as a strong tool where green design, green construction and lean construction can be enabled by the utilization of BIM-based design, simulation and information management tools and methods.

Building and Geo-information Integration As mentioned by Peters (2010), Van Oosterom et al. (2006) and Isikdag and Zlatanova (2008) there is an apparent need for integrated geometric models and harmonized semantics between BIM and geo-information modes for efficient city management.

Emergency Response Emergency response operations indoors require a high amount of geometric, semantic and state information related to the building elements. Until very recently egress models used in building evacuation have mainly been based on 2D floor plans. Today BIM is capable of providing detailed geometric and semantic information related to the buildings, where floor plans, navigation graphs and indoor positioning methods are developed using this information.

2.2.4 Project Management Aspects

Process Simulation and Monitoring The efforts in the area of 4D CAD are making much use of 3D CAD models, but in recent years BIMs have superseded 3D CAD models in the visual simulation of construction processes. Analysis such as clash detection can now be completed using BIM software. BIMs are also used in monitoring the construction progress and as Rebolj et al. (2010) describes, activity progress can be monitored directly by using a combination of data collection methods which are based on the BIM, especially on the 4D model of the building.

2.2.5 Integration and Interoperability Aspects

Building Information Services (BIS) A current trend in the software industry is towards enabling interoperability over Web services. In fact the AEC industry is still not fully benefiting from the service-oriented approaches as the focus of our industry is still quite data integration-oriented. The use of BIM servers is now increasing with open-source implementations such as BIMServer (2010). As explained by London et al. (2010), future BIM approaches would require the shared models in model servers to be linked with external systems in a heterogeneous environment.

2.3 BIM-M: Utilization of BIM in Construction Management

Building Information Modelling and Management (BIM-M) can be defined as the information management process and strategy which covers the whole life cycle of a building (from conception to demolition) and mainly focuses on enabling and facilitating the integrated way of project flow and delivery through the collaborative use of semantically rich 3D digital building models in all stages of the project and building life cycle (Underwood and Isikdag 2010a, b). BIM-M is a model-oriented information management strategy that benefits from the use of building information models. BIM-M is offering significant opportunities in revolutionizing the sector by enabling seamless processes that support the complete life cycle of the facility, embedding a model-based approach and by supporting full information coordination and management. While BIM-M has been in existence in one carnation or another for over 30 years, it is only within the last decade that BIM-M has really begun to receive serious attention particularly from industry and also at a governmental level, which is continuing to gather momentum. BIM-M is currently being employed across the globe on a variety of projects from housing to the prestige, at varied levels of adoption, and within various types of organizations from prime contracting and large consulting organizations to small architectural practices. Clients are now also becoming aware of the potential for BIM-M at the pre- and post-occupancy stage in delivering real value. More recently, government clients across the globe including the US, Denmark, Finland and the UK have begun to implement national initiatives/strategies as a statement of intent in driving BIM-M forward through the procurement of public projects towards establishing industry-wide adoption, which is further contributing to progressing the modernization of the industry (Bew and Underwood 2010). The philosophy that lies behind BIM-M stemmed from four dimensions in relation to the management of building information and these have been agreed by the industry over the last two decades. These dimensions can be summarized as enabling (i) model-based management of (ii) shared building information, which provides (iii) meaningful data about a building/facility in a (iv) standardized way. The first dimension is related to representation of the information within an information model schema which will help the representation of the information in a structured manner. The building information model represents the building elements within an agreed spatial hierarchy and well-defined semantics. The second dimension is related with utilizing the shared way of information management instead of simple exchange of files which causes consistency problems due to versioning. The third dimension is related with utilization of a data model that is based on agreed taxonomies. The final dimension deals with providing the data model as an internationally agreed standard, for which many types of software would be able to develop input and output plug-ins to generate and read the contents of the exchanged model file; in addition this enables databases to provide application programming interfaces for interacting with the standard information model.

2.4 Technologies for BIM 2.0

In last 5 years, development of new technologies and approaches in information management provides interesting opportunities for BIM-based information management. Underwood and Isikdag (2011) stated that four newly emerging dimensions in management of building information towards transforming from BIM to BIM 2.0 focus on enabling an (i) integrated environment of (ii) distributed information which is always (iii) up to date and open for (iv) derivation of new information. Various information technologies can facilitate this new focus such as cloud computing, sensor networks, stateless Web services and semantic Web. The following elaborates on the role of these technologies in making BIM 2.0 a reality.

Cloud Computing The term cloud computing indicates the use of Internet (i.e. the cloud) for managing highly scalable and customizable virtual hardware and software resources (which are provided as services). Cloud computing today is broken down into three segments as providing “Software as a Service (SaaS)”, “Platform as a Service (PaaS)” and “Infrastructure as a Service (IaaS)”. Cloud computing also involves the virtualization of storage environments to form a virtual data centre which is available over the Internet. The construction industry will benefit from cloud computing mostly by making use of SaaS approach and data centre virtualization. Applications used in various stages of the building’s life cycle will work within a distributed environment (i.e. offered as software services), and the information backbone of the construction project or building (i.e. BIMs) will reside in a virtual data centre (and offered as a data service).

Sensor Networks Recent developments in the field of BIM-M have shown that BIMs are very successful in presenting sematic information about building elements along with their geometric representation. Although the information in BIMs is meaningful, it in fact becomes stateless after the construction of the building is completed. In other words, a BIM user can find out whether a door in a building is constructed of timber, or the door has been constructed (or not) on a given date, but it is not possible to get informed on whether that door is open or closed at a certain point in time only by using BIMs or BIM-based information infrastructures. In this situation, up-to-date building information will be provided by sensors, or by a network of sensors which are monitoring the building. In the context of BIM-M, the distributed sensors and sensor networks, Internet of Things (IoT) nodes will monitor conditions such as temperature, gas levels, pollutants, humidity, state of doors and windows (i.e. being open/closed and so on), occupancies in rooms and conditions of different systems working within a building/facility. These issues will be elaborated in more detail in the following chapters of this book, in the context of IoT.

RESTful Web Services Service-oriented architectures and RESTful Web services offer opportunities for making building information stateful (i.e. real time, accurate and up to date). Vast amounts of residing in BIMs, and micro (atomic) feeds from sensor networks can be exposed as loosely coupled Web services, where generating data mashups from these resources would be very straightforward.

Semantic Web If this mass of new information (derived from multiple resources) can be restructured in compliance with semantic Web Standards and supported by well-built ontologies, i.e. formal specifications of conceptualizations which consist of finite list of terms and the relationships between these terms (Antoniou and van Harmelen 2008), semantic queries such as “Would you provide me the number of working elevators and escalators in the Empire State Building between 12:00 and 14:00?”, “Would you provide me the average CO_2 level in top 20 floors of 5 of the highest buildings in London?” or “Please provide me the difference between temperatures in my hotel room in Singapore Marina Bay, and my office in Sydney” can be responded. The success rate in responses to the (presented) semantic queries will depend on, (i) the level of integration of distributed building information, (ii) the level of success in derivation of information mass from multiple loosely coupled resources (which are exposed as Web services), and finally (iii) how well the query can be interpreted and, reasoning/search and retrieval can be accomplished upon the interpreted query.

2.5 BIM-Based Management of Construction Processes

The developments in the field of building information modelling have led the stakeholders in the construction projects to re-engineer their traditional construction management processes to BIM-based design and construction processes. Although there does not exist an ISO standard for management of BIM-based processes, a joint effort (known as BIM Project Execution Planning) in the last 5 years has produced noticeable scientific outputs. As stated in the project website (BPEPG 2015) the planning guide which is produced as a result of this research aimed to provide a practical manual that can be used by project teams for designing their BIM strategy and developing a BIM Project Execution Plan. This guide provides a structured procedure for creating a BIM Project Execution Plan. The four steps within the procedure include:

1. Defining high-value BIM uses during project planning, design, construction and operational phases
2. Using process maps to design BIM execution
3. Defining the BIM deliverables in the form of information exchanges

4. Developing a detailed plan to support the execution process

The project is started by defining BIM uses, defined as "a method of applying Building Information Modelling during a facility's life cycle to achieve one or more specific objectives". The uses can be interpreted as use cases that cover multiple processes of BIM-based information management. As explained in PSU (2013), the defined BIM uses covered the overall life cycle of the project from inception to finalization. The project also elaborated on the concept of level of development (LOD) stating that for each of the BIM uses, the LOD should be identified in order to maximize the benefit from the BIM use. The LOD describes the level of detail/granularity to which a model element is developed. The LOD specification for BIM is originally developed by BIM Forum (2013) and presents six levels of development (Table 2.1).

The project presented 25 BIM uses as:

1. Existing conditions modelling
2. Cost estimation
3. Phase planning
4. Programming
5. Site analysis
6. Design reviews
7. Design authoring
8. Structural analysis
9. Lighting analysis
10. Energy analysis

Table 2.1 BIM levels of development (BIM Forum 2013)

LOD 100	The model element may be graphically represented in the model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the model element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other model elements
LOD 200	The model element is graphically represented within the model as a generic system, object or assembly with approximate quantities, size, shape, location and orientation. Non-graphic information may also be attached to the model element
LOD 300	The model element is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, shape, location and orientation. Non-graphic information may also be attached to the model element
LOD 350	The model element is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, shape, orientation and interfaces with other building systems. Non-graphic information may also be attached to the model element
LOD 400	The model element is graphically represented within the model as a specific system, object or assembly in terms of size, shape, location, quantity and orientation with detailing, fabrication, assembly and installation information. Non-graphic information may also be attached to the model element
LOD 500	The model element is a field-verified representation in terms of size, shape, location, quantity and orientation. Non-graphic information may also be attached to the model elements

11. Mechanical analysis
12. Other engineering analysis
13. LEED evaluation
14. Code validation
15. 3D coordination
16. Site utilization planning
17. Construction system design
18. Digital fabrication
19. 3D control and planning
20. Record model
21. Maintenance scheduling
22. Building system analysis
23. Asset management
24. Space management/tracking
25. Disaster planning

Based on the BIM uses and BIM LODs, BIM-based processes can be managed. Once the BIM uses for the projects and BIM LODs that will be used in each BIM Use are determined, the BIM Execution Planning Matrices need to be developed in order to manage the BIM-based processes. Examples of such matrices are developed by the author, and provided below.

BIM based process management matrix

Activity	Actors/role	Model/view owner	Software in use	Inputs	Outputs	BIM use	BIM LOD	BIM objects required	Exchange formats

Actor/Role matrix

Activity	Actor	Role	Sub-role	Eligibility of model ownership

Phase/Activity/LOD matrix

Project phase	Activity	BIM LOD	BIM objects required

BIM USE/LOD matrix

BIM use	BIM LOD	BIM objects required

As also stated in PSU (2013) there is no single best method for BIM implementation on every project, each team must effectively design a tailored execution strategy by understanding the project goals, project characteristics and the capabilities of the team members. For the construction industry, there is still a long way to go and much to do in terms of realizing the full potential of these emerging technologies in line with the efficiencies and performance improvement that are being witnessed in other sectors. However, as both the technologies along with the industry (in their capability to embrace them) further mature, and as BIM-based process and information management techniques get more advanced, progressive improvements towards BIM 2.0 will continue to be made, enabled through emerging technologies.

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