Building Information Modelling: improving facility project delivery

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ABSTRACT

Building Information Modelling (BIM) is an approach that is fast gaining traction in the architect, engineer and construction (AEC) industries. BIM combines the construction of a virtual model with all aspects of a facility, from design (space planning) to construction (cost and scheduling), and from operations to maintenance (planning and asset management). BIM is also a process as well as a project. Even though the technology for implementation of BIM will change, and probably change rapidly, the process and underlying concepts will likely change very little. This paper outlines the guiding principles of BIM and its ability to enhance the project delivery process of the AEC industries.

Introduction

BIM directly relates to a project team's ability for visualization, understanding, communication and collaboration [1]: visualization to see the project; understanding to know the project elements, communications to ensure the understanding, and collaboration to receive all the necessary input at the proper time. The benefit of collaboration and working together will likely pose the greatest challenge. BIM requires openness amongst the team players for sharing information that supports the goals of the project.

With the definition of BIM as a process, a product, and a lifecycle management tool come a variety of additional properties. As a process, BIM covers business drivers, automated process capabilities, and open information standards for information sustainability and reliability; as a product, it is a digital representation of physical and functional characteristics of a facility, serving as a shared knowledge resource for information about a facility forming a reliable basis for decisions during the facility lifecycle from inception onward; as a lifecycle management tool, it provides important information exchanges, workflows, and procedures which teams can use as a repeatable, verifiable, transparent, and sustainable information-based environment throughout the building lifecycle [2].

BIM has become a valuable tool in many sectors of the capital facilities industry. The fundamental characteristic of BIM is its development through an information feedback loop. The development of the visual model and the relevant project information is iterative in nature as different project team members develop the project. During the course of a project, the information gradually increases in scope, depth and relationship to the project. A coordinated and intelligent project will grow out of the building and project information that is continually cycled through the BIM as more and more detailed information is added and coordinated [1].

Many of the benefits of BIM can be viewed as direct benefits, although the greatest benefits are actually indirect benefits. Direct benefits include such items as improved visualization and the centralization of project and building information. The indirect benefits include the necessity of collaboration and the resulting better project understanding and reduction of project risk, which is brought about by improved understanding, coordination, and material use in the management of the project as well as reduced construction conflicts, construction waste, and project cost.

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Aspects of Building Information Modelling

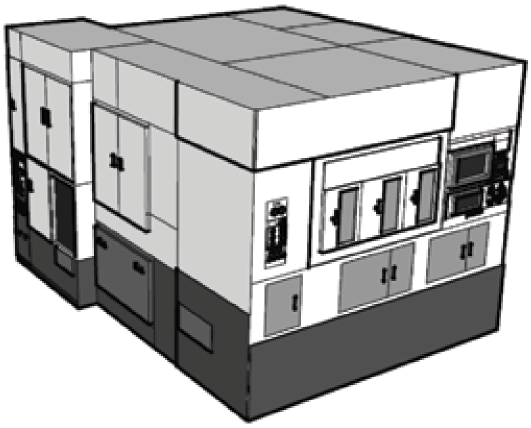
As noted, BIM is a process as well as a project. As a process that continues through the facility's lifecycle, aspects of the model and process are developed for additional uses and process. For example, most construction is still accomplished utilizing the conventional two-dimensional (2D) drawings. With the visualization aspect of the project becoming more intuitive through the use of software, the third dimension (3D) is added to allow a virtual facility to be constructed and modelled for understanding the facility/project composition.

With an added dimension of time, the fourth dimension (4D), a sequence of activities can be determined that will allow the visualization of a facility/project in time, i.e. build the facility on 'paper' before commitments are made in the field. This allows the investigation of system and structure interference (clash detection) and development of effective construction sequencing. With the development of project models, quantities take-off become easier and more accurate due to the dimensional accuracy of the virtual model and estimating can be accomplished with greater accuracy and with less time.

It should be noted that only quantities can be extracted from the model, which means that the productivity (labour hours, equipment, etc.) will still need to be determined by an individual company based on their resources. Sustainability ideas can be researched using a model to investigate shading, acoustics, daylight and energy usage. Much of the desired resource conservation can be investigated during the preconstruction period saving more than just energy, but materials, labour, and time. The virtual model can then become the basis for operations and maintenance information to track installed equipment, maintenance schedules, maintenance and operating information. Extending a virtual as-built model to the next step as an intelligent facility model would allow integration of the facility operations with manufacturing operations. This incorporation of an intelligent facility model would provide decision support tools that could reduce lifecycle cost and increase manufacturing effectiveness, provide real time O&M information exchange, automate critical performance factors, simulate facility performance and develop predictive maintenance/performance models.

Challenges of Building Information Modelling

Improvements fostered by the introduction of BIM technology into the work process will also bring several challenges as well as changes in practices and relationships. While BIM offers new methods of collaboration, it will introduce other issues with respect to the



Data Sheet Number	Data Sheet Title
100	Equipment Identification
200	Environmental Conditions
300	Physical Characteristics
400	Electrical Power
500	Water
600	Bulk Chemicals
700	Drains
800	Gases
900	Vacuum
1000	Exhaust

Figure 1. Building Element Model – Intelligent Tool Model.

development of effective teams. Today, project teams are engaging in information handovers on a daily basis. Many are even exchanging BIM data. However, this process is neither automated nor seamless. It works if a motivated team devotes several weeks to defining the information to be exchanged and the protocols for doing so. Often, the BIM is incomplete for its intended downstream use and must be augmented by verbal or text explanations and information [3].

Contractual arrangements will also require and facilitate increased collaboration between the designers and constructors, providing greater advantages to owners when BIM is used. The project delivery methodology most supportive to BIM and collaboration is the Design-Build and Integrated Project Delivery (IPD) process. The most difficult challenge that will be faced is the implementation of a shared model as the basis for all work processes, and collaboration as the question of who owns the model will arise.

Developing BIM data

BIM involves the definition of a facility as a composed set of objects. The BIM will be a project simulation consisting of 3D models of the facility components or objects, which links all the required information to the project's planning, construction or operation. These objects can be pre-defined by the BIM modelling tools due to their fixed geometries and defined parameters. As a design is developed, object definitions become more specific according to the project use or expectations. With the BIM modelling tools, it is possible to define an object once and use it for multiple purposes. The challenge is to develop an easy-to-use and consistent means of defining objects and instances appropriate for the current use and for later use.

The objects developed are Building Element Models (BEMs) that are 2D and 3D geometric representations of physical products, usually doors, windows, equipment, furniture and/or high-level assemblies such as walls, roofs, ceilings and floors (see Fig. 1). This also could apply to manufacturing equipment and over time, the knowledge encoded into these model libraries will become a strategic asset for an owner. They will represent the knowledge available as they incrementally improve and encompass information based on project use and experience. The risk of errors and omissions will decrease as higher quality models are developed and utilized.

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The complexity and investment that will be needed to develop Building or Tool Element Models (Intelligent Tool Blocks) and content will require a tool for management and distribution that allows users the ability to find, visualize, and use the model content. Model Intelligence means that information is contained in the 3D virtual model. According to Eastman [4], the new Omniclass classifications being developed by the Construction Specifications Institute (CSI) will provide a more detailed object-specific classification and access mechanism. It will then be possible to organize Intelligent Tool Blocks for access by any number of classification schemes such as products, materials, form, function, phases, or process. A well-designed library management system could then support the flexibility needed to navigate a classification scheme of Intelligent Tool Models.

As BIM becomes more standard in the construction industry, building products (fabrication tools) can be inserted directly into a model in electronic form, including hyperlinked references for parts lists, operating and maintenance manuals, and vendor information. Contractor- or subcontractor-developed components can be incorporated into the model to ensure more accurate quantities and cost estimates and analysis. Because the BIM includes comprehensive 3D geometric definitions, it allows visualization of facility appearance, function and context. This visualization capability is extremely powerful in expediting design decisions and communicating with all stakeholders [3].

As the intelligent models evolve, more sophisticated, even intelligent product specifications will provide information for such areas as structural analysis, LEED compliance or installation specifications. Intelligent Tool Blocks can become the core information source for quantities of work, material, construction methods and resource utilization. They can even play an important role in collecting data for construction control as well as manufacturing process and layout planning and control.

Intelligent Project Modelling

Pervasive computer use is inevitable; consequently, most AEC companies will use an intelligent 3D software model for the design process. Whether the approach used is BIM, single building modelling, parametric modelling, or any other type of computer modelling, it comes down to using data-rich 3D models in an intelligent fashion. This data may be physical (dimensions, location) or parametric (distinguishing one object from another similar object). Because these intelligent or smart models are solid models, they allow the incorporation of more information

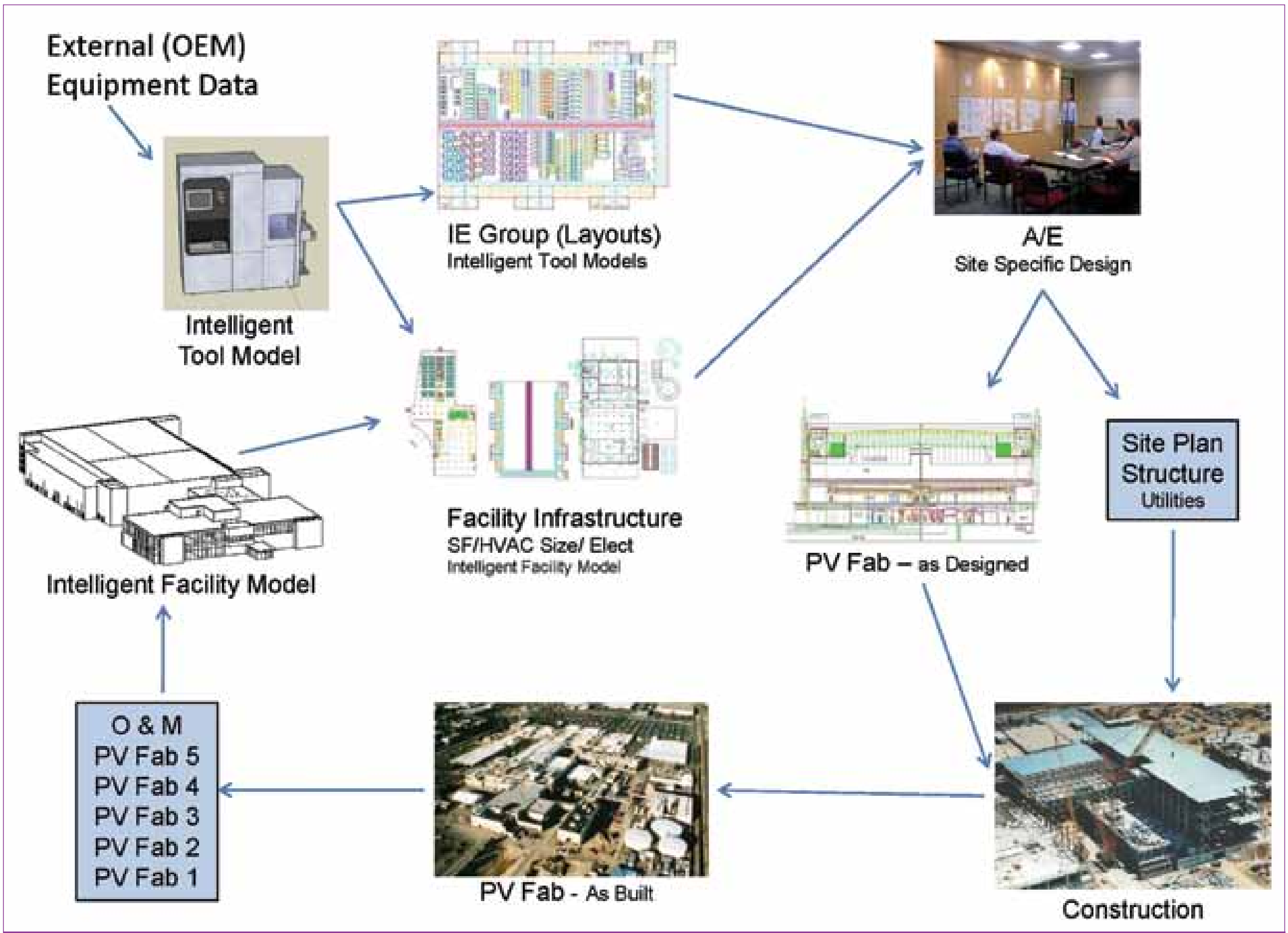

Figure 2. Intelligent Facility Design and construction process schematic.

than merely the visual aspects of an object through surface models. With the available technology, solid models can also generate 2D views that can be used for conventional construction documents.

The activities conducted throughout the lifecycle of any facility generate an enormous quantity of data that needs to be stored, retrieved, communicated, and used by all parties involved. Advances in technology have increased the opportunities for gathering, providing access to, exchanging, and achieving all of this information for future reference. These advances have also raised users' expectations about the ways this information ought to be made available and how quickly that access should be provided.

Continuing advances in Smart Building Technologies, BIM technologies and construction practices have not only increased the amount and detail of data generated and exchanged, but have also further raised expectations about its use and value as an asset. This increase in the amount and types of information generated – and the AEC industry's subsequent reliance on it – requires an organizational standard that will enable and add certainty to information communicated between parties separated by miles, countries or continents.

The AEC Industry has begun to realize that a greater degree of harmonization in classifying information is now necessary – and possible. This harmonization and reuse of information for multiple purposes is at the heart of value and cost savings presented by the BIM approach.

"The BIM will allow clash detection models to be run and the potential conflicts to be fixed before construction begins."

As shown in Fig. 2, data is required throughout the design and construction process. For a new manufacturing facility implementation, the process would begin with the request for data regarding manufacturing tools or tool set from a manufacturer's database. This data (in the form of a tool database) would be downloaded from the manufacturer's web site as generic data in an intelligent tool block. This intelligent tool block would contain all the information regarding the tool (physical characteristics, utility requirements, tool specifications, etc.) that could be used by an Industrial Engineering Department to develop a tool layout concept to review for supporting the process requirements.

The tool utility requirements would also be available to a Facility Engineering Department to determine infrastructure requirements based on the tool data and the process tool layout. Iterations of the process layout and facility layout could produce a locally specific design package that would be placed in a data repository. Once in the data repository, the models could be available to the A/E for a site-specific facility model based on the data model provided. The intelligent tool blocks form the basis for tool installation design packages that would be embedded in the final facility BIM.

The A/E would generate a BIM for the facility project. For this process to be most effective, the entire design and construction team should be involved in the model development. During design, the construction manager should be developing cost and schedule models and major subcontractors can begin developing shop drawings for the major mechanical systems such as HVAC, plumbing and process piping. The BIM will allow clash detection models to be run and the potential conflicts to be fixed before construction begins.

From the construction model, a final as-built model is provided for use by the Operations and Maintenance Department and for development of an Intelligent Facility Model that is used for ongoing energy analysis, trend modelling, maintenance simulation, and future modification analysis. For future facilities, the intelligent facility model would form the basis for the next generation fab and is integrated with the process layout for concept and specific design package development.

Conclusion

Productivity increases for the construction industry will be needed to ensure that capital projects are continued to be provided in a cost-effective manner to meet the needs of owners. Building Information Modelling is proving to be a promising technology that will have an impact on the project delivery process of the architectural, engineering and construction community. It is a significant improvement in the way architects, engineers and contractors have traditionally worked. BIM allows visualization of a building design along with implementation of a methodology to determine conflicts and develop clash-free installations. Scheduling and estimating data can also be added to make a complete facility model providing important information attached to each building element. With this model, the goals of a better, faster, and more cost-effective building can be achieved, making BIM a key tool for the future of construction.

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