

DIGITAL FM; BUILDING INFORMATION MODELLING USED TO IMPROVE THE PERFORMANCE OF BUILDINGS OVER THE LIFE-CYCLE

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ABSTRACT

Lack of efficient communication within the building industry leads to low end product quality and serious failures. Process integration has been identified as a key element for quality improvement and efficiency. This means restructuring and new ways to cooperate.

The industry can obviously take advantage of a more extensive use of digital tools, such as Building Information Modelling (BIM), from the beginning of the design process. BIM is based on Industry Foundation Classes (IFC), the new standard for interoperability between Computer Aided Design systems. A BIM can support creating and operating digital databases for collaboration, managing changes in projects and in reusing data. Professionals have, by using BIM, the possibility to achieve higher quality work, greater speed and productivity, and lower costs in the design, construction and operation of buildings. The FM-industry (Facility Management) has an important role to play as future principal supplier of experience data and feedback in a “new building process”.

INTRODUCTION

This paper focuses the Integrated Design Process (IDP) from the beginning of design processes linked to a virtual Building Information Model (BIM). BIM can support the design team and key actors to handle the design information arising and in supporting the decisions taken, from early phases of design throughout production, operation and management of buildings. The role of the architect, performance contracts and fees are focused.

In my opinion systematic re-use of data from one phase to the next by extracting them from the updated BIM, ought to be very effective. Research shows that 80% of the information input in building projects is identical (Egan, 1998). Time and again the same information is embedded into the building project from different actors - designers, consultants, constructors, contractors and facility managers - and this represents considerable portions of the fees (Sunesen, 2003). New IT-technologies including internet/intranet, global information networks, e-mail, mobile telephone, video conferencing, web publication and web databases give us incredible possibilities in supporting workgroup communications (Haugen, 2002, Palazzola et al. 2002). By integrating experience data from the operation/Facility Management-phase back in a new BIM, we can reduce the building damage, increase the level of quality and lower the building costs.

THE NEED FOR BETTER PERFORMANCE IN THE BUILDING INDUSTRY

Over the past years different sources have made comprehensive studies of the building industry in the UK and in the US, where The Egan Report - *Rethinking Construction. The Report of the Construction Task Force* - (Egan, 1998) is perhaps the most forward-looking. The Task Force was under the auspices by the British government with the purpose to assess the future and improve quality and efficiency of the UK construction industry. It identified

five key elements of change needed for the construction industry at large: committed leadership, a focus on the customer, integrated processes and teams, and a quality driven agenda and commitment to people.

Another fact is that the building industry is organized in a rather antiquated way, and with inappropriate division of roles where all the actors have their own economic agenda and role to play in protecting an old-fashioned and conservative structure (Egan, 1998). The products - *the buildings produced* - are generally high in cost, low in quality and characterized by many types of damage that influence indoor environment, health and safety. Contracts and fees are other areas to discuss related to building performance and organisation. The building industry itself, in cooperation with the national authorities, must devise some radical alterations to improve the performance in the industry (Egan, 1998). Increasing the level of industrialization is one obvious issue to bring into focus (Jensfelt, 2003). Using ready-made building elements produced in a controlled, indoor climate and with high objective settings and systematic quality control, is one possible way to process (Persson, 2003).

Statements from practitioners and researchers more than indicate that the industry can take advantage of a Building Information Model (BIM) developed from the very beginning of the project and updated throughout the building process to fit the production-phase, along with the operation and management phase (Khemlani, 2003).

THE INTEGRATED DESIGN PROCESS - IDP

There will be an increasing focus on developing building-integrated and user-friendly solutions and strategies that will reduce the demand for energy and power for heating, cooling and lighting. These matters are highly focused upon in the IEA Task 23 project - *Integrated Design Process(es) – IDP* (Larsson and Poel, 2003, Hestnes, 2002).

IDP involves a different approach to the design process. Introducing inter-disciplinary teamwork right from the beginning, it is distinct from the traditional design process where the technical consultants usually enter the design team later in the process, when the architect and the client have almost finished the design. IDP also requires a high level of skills and communication within the team and involves a synergy of skills and knowledge throughout the process using modern simulation tools. In addition IDP leads to a high level of synergy and integration of systems (Hestnes, 2002). The overall characteristic of an IDP is that it consists of a series of design loops per stage of the design process (iterations) separated by transitions with decisions about milestones. In each of the design loops the design team participants are those who are relevant for that stage in the process.

Though IDP is a new concept, it contains no elements that are radically new, but integrates well-proven approaches into a systematic total process. From an engineering perspective, the skills and experience of mechanical and electrical engineers, and those of more specialised consultants, can be integrated at the concept design level from the very beginning of the design process. When carried out in a spirit of co-operation amongst key actors, this results in a design that is highly efficient with minimal, and sometimes zero, incremental capital costs, along with reduced long-term operating and maintenance costs. The benefits of the IDP are not limited to the improvement of environmental performance. The experience of IEA Task 23 members is that the open inter-disciplinary discussion and synergistic approach will often

lead to improvements in the functional program, in the selection of structural systems and in architectural expression (Hestnes, 2002).

THE ROLE OF THE ARCHITECT, 3D CAD AND PERFORMANCE BASED FEES

Development of new IT-technology will implement major changes in the way architects work. A study published last year by ACADIA - *The Association for Computer-Aided Design in Architecture* - found that the labour expenses of architectural practices using no CAD-software or 2D drafting software followed roughly the same work pattern as the traditional fee structure. Practices using 3D based systems, however, showed a very different pattern. They spent more time early in the design phase, but, because of that invested time, they saved time in the documentation phase. They were able to level out their work loads and labour expenses, and avoid the all-out efforts of hiring people for short term contracts that is common in traditional practices. A closer look reveals that architects using 3D based software spent their time in the early phases where it was cheapest, most fun and where they were most free to explore design alternatives (Fig. 1). They could produce working drawings in less time because they were starting with a well-developed 3D model. Also, because they had more information up front, these architects could make better design decisions with greater confidence and avoid costly and risky changes later in the process (Marlatt, 2003).

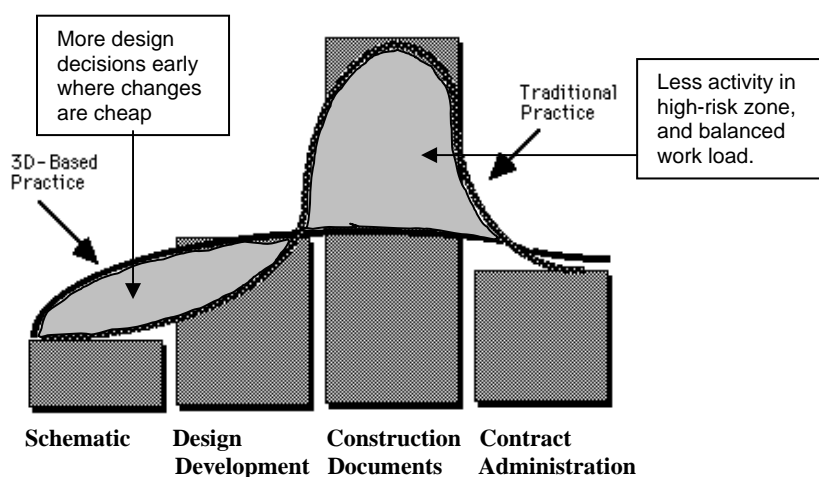


Fig. 1. 3D CAD. More time spent early means saved time in documentation. (Ill. David Marlatt, 2003)

The architect is the creative driving force of the built environment. This crucial role involves balancing aesthetics with the suitability of materials, systems, types of construction and budget, and has a significant long-term effect on the life and operation of the facility. In connection with IDP, introducing inter-disciplinary team-work from the beginning, this team effort also involves coordination of other consultants and updated client requirements in order to achieve time, cost and quality results. Indeed, this points out interesting directions that successful design firms will have to manage in the future. The architects will more than likely become more closely associated with their client base than with their buildings as they work continuously to construct, maintain, upgrade, and sell the buildings of their clients using computer-based models in their offices. Implying vast changes in their professional education and culture, the architects (and engineers) will adopt a more project-oriented approach by

exercising *extreme* collaboration using virtual design and construction (Garcia, 2003, Meniru et al., 2003). At Stanford University, California; research is being conducted on high performance project-teams (Lambert et al., 2002) and the use of virtual building tools in designing and construction, among them 4D research where *time* is the fourth dimension (Fischer, 2003, Garcia et al., 2003, Kunz et al., 2002, Koivu, 2001). Associate Professor Martin Fischer, a pioneer and leading force in the epoch-making research on virtual building tools, has illustrated (Fischer, 2003) by means of several short case studies how virtual building tools enable designers, builders and owners to test any aspect of a project's design, organisation and schedule before committing significant resources to the project. The Norwegian University of Science and Technology, NTNU is also involved in 4D research (www.metamorfose.ntnu.no) (The Integrated Building Process, 2000).

Usually there are no incentives for energy efficient design or installation when Architects/Engineers (A/E) are contracting a new project. Design fees are usually either a percentage of the total construction budget or a flat rate. This has the effect of emphasizing speed and discouraging additional work such as improvements to overall building performance. A/E's often fear fault from non-standard or under-sized design. Since there is no incentive for saving equipment or energy costs, the mechanical engineer for example, often protects himself and his liability insurance by grossly over-sizing his design. Contractors have little incentive to insure that building systems are installed to operate efficiently.

There are possibilities and well-known solutions for developing incentives to save energy from Energy Services Companies (ESCO's) in the US, who have successfully implemented performance contracts on thousands of existing buildings. It is natural that professionals will be cautious about implementing these "new" ways of entering performance contracts, often based on a common team performance contract. This means that the whole design team, the architect, HVAC-engineer, structural engineer and electrical/day-lighting designer work together on bringing the actual themes into the process, developing the project until it satisfies all the goals and demands given. This group approach encourages creativity and varying degrees of experience of the design team and invigorates, educates and challenges those involved. Architects and engineers will need to work together to show building owners that any increase in design fees are a small investment toward decreased operational costs, improved occupant satisfaction and performance, and conservation of materials and natural resources.

INDUSTRY FOUNDATION CLASSES – IFC

There has been a clear tendency that standards for exchanging file formats in Computer Aided Design (CAD) have been established by dominant firms, not by cooperation in the line of business (Nygaard, 1997). Thus, it is more satisfying to follow The International Alliance for Interoperability (IAI) in their efforts to develop Industry Foundation Classes (IFC). The development of IFC is the basic turning-point when it comes to interoperability. The exchange of object-oriented building data between the different CAD-systems after the same IFC-structure totally removes the former discussions about which specific CAD-platform makes interoperability possible.

IFC are developed to provide for data exchange and sharing capabilities in the building and construction industry. IFC were developed in 1995, to establish a world-wide standard to exchange intelligent information between different CAD-systems. Since the foundation, three

releases of IFC have already been published. Many prototype implementations by leading software companies proved the IFC specifications and commercial products to satisfy the end user demands can be expected. The IFC, often referred to as a product-model or a digital building model, are divided into four main areas: design, production, operation and facility management (Bakkmoen, 2003). IFC make possible the exchange of information between all involved in the building process, all the phases of the building process and in the full lifetime of the building. IFC are not limited to frontiers, special IT-systems or any technical applications. The adoption of the IFC exchange protocol as an ISO-standard has been a major milestone (Graphisoft White Paper, 2003). With the publication of the latest release of the IFC model (IFC2.x), it is now the definitive global construction exchange protocol. New functionality is available for structural analysis, structural engineering (for concrete and steel structures), HVAC-design and performance simulation, electrical design, facilities and property management, visualization (rendering and lighting). Interoperability improves coordination, allows simulations of design, geometry, performance and costing scenarios, and enables sustainable design. Immediate productivity gains of up to 30% have been predicted with more integrated use of information and communication technologies in the building industry. Interoperability based on open, global standards makes all this possible.

BUILDING INFORMATION MODELLING – BIM

Building Information Modeling (BIM) is a way of representing buildings on the computer very different from traditional Computer Aided Design (CAD) technologies, which could have a revolutionary impact on how buildings are designed, constructed, and operated. The fundamental problem with CAD, whether two-dimensional (2D) or three-dimensional (3D), is that it uses generic geometric entities to represent objects. While this makes it flexible enough to be used across various domains, it does not add much intelligence to the manual drafting processes we used in the design process before CAD. As a result, CAD has all the problems associated with drawings. It is tedious and time-consuming to create separate plans, sections, elevations and details of the same building. Any change made has to be manually updated in all drawings and reports. There is no guarantee of accuracy, consistency or completeness, and coordinating work based on these drawings between the different professionals is extremely difficult. The biggest impact, no doubt, is seen at the construction site, where conflicts and errors are discovered that are very expensive to fix (Khemlani, 2003). All the principal CAD-developers have a lot to gain in developing competitive customer directed BIM software based on the IFC2.x protocol.

BIM can potentially avoid all the problems of CAD because it uses intelligent objects for representing the building; objects that are aware of themselves and their relationship with other objects. Compared to a CAD-application, it is faster and easier to create and edit a building model in a BIM-application since it is customized for building design. Once the model is created, all other requirements including 2D documentation, schedules, reports, 3D renderings, animations can be derived from it. Also, if a change is made, it is automatically reflected in all individual views and documents, eliminating inconsistencies. In fact, a parametric building model can take this change management even further. If we change one element, the corresponding changes are made to all the elements associated with that element. A major impediment in current BIM technology is the lack of ability in supporting conceptual design tasks such as programming, space planning, conceptual sketching and massing. BIM has implemented new solutions that enable the architect, design manager, contractor or owner to manage a master model, composed of multi-disciplinary data, shared through the IFC

protocol. This new functionality is web-enabled and based on technology already established in the advanced manufacturing sector. It will allow the storage and selection of multiple design concepts, separating versions, auditing and, of course, the management of each specific discipline or consultant's data. Complementing this commitment is an invitation to work with other application vendors, government agencies and companies to implement IFC based collaboration and to assist them in their implementation efforts. *“Faster, cheaper, and better may sound like suspicious marketing spiel but the use of BIM can really achieve these benefits.”* (Khemlani, 2003).

By using the IFC-protocol, it is possible to build high quality, accurate models to support the whole lifecycle development of facilities. The rich model now becomes an indispensable asset for contractors for estimation, procurement and construction management and, once updated, a fundamental resource for owners and clients to plan and manage their assets. The availability of appropriate digital building product data coming from the building product manufacturers to give input to the BIM, is still far from satisfactory. Internet has become a key resource for finding professional information about building products, materials and construction methods, but provides it in a unstructured and therefore unmanageable manner (van Leeuwen et al., 2002). BYGGFORSK is working with a Construction reference structure library (BARBI) on a global standard to allow trans-national and multiple language compatibility (Bjørkhaug, 2003).

BIM AND FACILITY MANAGEMENT (FM) – THE NEW BUILDING PROCESS

How can the design team by using appropriate organisation models, guidelines, contracts, fees, authority demands, building codes and supporting CAD-systems develop a base both for their own work and at the same time be useful to the building industry as an *experience-bank* in influencing a total iterative building process?

In what Hegge (The Integrated Building Process, 2000) has called the “New Building Process”, we look at the whole iteration in the building process, by this keep the experiences throughout the process, systematizing them in an “experience-bank” in the Operation- and Facility Management phases, and reintegrating them back into any new appropriate building process in a new conceptual building design.

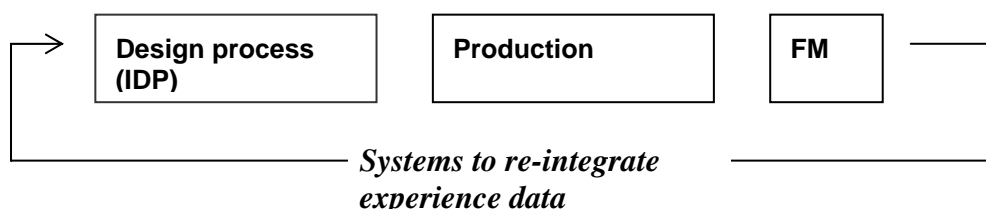


Fig. 2. Re-integrating experience data from the FM-phase. Ill. K. Hegge, 2000.

In my opinion, the ability to make “just-in-time” decisions doesn't stop with the design phase, but continues through construction and into operations and maintenance/Facility Management (FM) because a BIM eliminates the need to recreate data at each phase of the facility lifecycle. It is no longer necessary to wait until the end of Design Development to understand the

budget impacts of the design approach. The rich and numerous set of building data that is created during the design and documentation phase of the building remains relevant even after the building is built. It is not necessary to start over at the end of construction with only “redlined” drawings and operating and manufacturing manuals. It is possible to extract data directly from the virtual design model, so that the data matches the reality. Because the data already are contained in the BIM, the revision process is more efficient, resulting in little worry about losing documents or incorrect data. Even though it is difficult to predict exactly how a building will be altered over time, it is certain that plans and building data will be available when it comes time to renovate. In this context the FM-industry will have an important role to play as principal supplier of experience feedback in the building process, and in this way reduce the occurrence of damages, mistakes and defects, thereby increasing the level of quality and at the same time lowering the building costs. As an example, US-based Design Atlantic Inc. has developed a digital tool named 4SiteSystems (www.4sitesystems.org) based on Graphisoft’s ArchiCAD and ArchiFM. They use this in a collaborative process that identifies costs and success strategies early in the design process and documents decisions and the design at the outset. This project information is organized in a way that allows them to work with contractors to get the project built on schedule and under budget. This gives everyone immediate computer access to facility information that would take hours or days to *dig out* of the conventional process.

Virtual building models are here to stay. If applied by professionals who know how to design, build, and manage projects and facilities in the real world, they can be very effective in managing risk and improving communication. They have already proved their worth on projects both large and small (Fischer, 2003).

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