BIM VERSUS PLM: RISKS AND BENEFITS

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ABSTRACT

Applying Building Information Modeling (BIM) is a hot issue. The Building industry feels the urge to use it, but at the same time companies see huge risks, since the ownership and control of information becomes unclear when all building information is put together in one model. Also the cost and the benefits do not always land at the same place. To that account three Dutch firms operating in multi-disciplinary building & construction projects asked the authors to execute a research and design project how to solve this problem. As a result a framework for assessing risks was developed for setting up a successful BIM process. It seems the manufacturing industry is much ahead of the Building industry in using these concepts and technology, be it under the name of Product Lifecycle Management. However, comparing the approaches in the Building industry and manufacturing industry shows that, while construction is primarily interested in the risks, manufacturing is primarilyu focussed on the benefits. The paper tries to explain this difference and concludes with some suggestions to reduce risk and enhance the benefits of BIM for construction companies.

Keywords:, Data collection, Product Lifecycle management, Building Information Modeling and Data storage.

1. INTRODUCTION

BIM (Building information Modeling) is the most topical subject of the current practice in the building industry – in the Netherlands, and abroad. The Dutch government supplied in 2009 over 40M€ for subsidies for innovative services and processes within the building industry. A significant share of these subsidies is allocated to the implementation and use of BIM throughout all sectors of the building industry. These national strategies, combined with the technological advances made towards the facilitation of information exchange and gathering through building design and performance analysis software platforms, are generating a powerful industry trend predicted to change the face of the building industry as we know it.

BIM is "the process of creating and using digital models for design, construction and/or operations of projects" according to [Succar, 2009], and is centered around a Building Information Model, which is "the virtual representation of the physical characteristics of a facility from inception onwards. […] it serves as a shared information repository for collaboration throughout the facility's lifecycle" [Suermann, 2009].

BIM requires from its users an integral, collaborative work style for yielding maximum of results. The collaborative nature of a BIM-centric project enables two main shifts from the traditional AEC practice[Eastman e.a., 2008]: first is the linear increase of facility documentation value – uninterrupted or lessened due to handover from one phase to the next, or from one actor to the other, second is the reduced redundancy in the facility documentation production, which also influences the man/hour effort to produce and maintain the information for the facility documentation during the design and construction phases. The impact of BIM on these aspects becomes even more remarkable once in the

startup and operation phases. At this point in a traditional process, the facility documentation produced during the design and construction phases becomes rapidly outdated and loses a great deal of value. At the same time, the effort put into creating the facility management database process increases rapidly over a rather short period of time, as it is very loosely coupled with the documentation produced earlier in the process. This effort spikes to a height comparable to that required during the construction phase when the facility needs to be retrofitted, later in its lifecycle.

The added value of a BIM-based delivery and operation process is spread throughout all its phases and can, therefore bring benefits to all actors involved in each stage. A particular aspect of the added value a BIM product can bring to the project is enabling optimized activities of analyzing, testing and validating the design before the project execution, thus saving a significant share of failure costs later in the building lifecycle [Eastman e.a., 2008], [Kiker, 2009].

Figure 1-1 BIM process setup steps

The complexity of organizing a BIM process for a multi-disciplinary building & construction process has led to gaping differences of interpretation on how BIM ought to be implemented. It is in this context that three AEC companies (Wiegerinck architecture and urban planning practice, ABT, a building technical consulting firm, and Strukton Worksphere, an installation and facility management consulting firm initiated this research with the question:

> ***How do we adjust to the BIM way of doing projects?***

What this general inquiry aims at is the understanding of how the project team roles, process and project organization will be affected by the inherent risk/benefit distribution change in the (expected) new age of the building industry. To answer this question, we must first define the frame in which these changes will be considered – namely the type of client and contractual model that will support this new design process.

Currently, there are no risk assessment/management tools available in the public domain, specifically designed or adapted to the complexities of the BIM process. Therefore, we consider that a risk assessment framework is necessary for the successful setup of the BIM process. More so, the approach to managing BIM-specific risk will have to take in consideration that the additional responsibilities defined for a BIM project are not yet explicitly defined and collectively accepted by the current practice. As such, the main research question was formulated as follows:

> ***How can companies manage risk distribution and transparency when entering a BIM-centric design process?***

The result of this research project [Iliescu, 2010] was a framework to identify the different roles with respect to BIM depending on the type of contract (traditional, management contract, PPS etc.) and a

plan of steps to assess the risks and to cover them in the necessary contracts. The steps, as illustrated in Figure 1-1 are:

1. Establishing the project's BIM scope,
2. BIM maturity and capability scan,
3. GO/NO GO verdict on the BIM process,
4. Establishing the project's BIM risks – inherent and perceived,
5. Establishing the project's BIM roles distribution,
6. Confirmation/rejection of assigned role,
7. Finalizing the project's BIM Organizational Breakdown Structure (OBS) and BIM Task Breakdown Structure (TBS),
8. Establishing the project's BIM Process Map,
9. Signing BIM service agreements.

It is interesting to notice that, although the participating companies were quite satisfied about the results, the original problem was uncertainty about risks and benefits, while the resulting steps the risks are explicitly identified, but benefits or specific BIM targets are not. This indicates that these companies, and probably many more in AEC industry, view BIM as a risk rather than an opportunity.

2. RESEARCH PROBLEM

BIM seems very similar with Product Lifecycle Management (PLM) as being developed and applied in manufacturing industry since about 1990. While the discussion on PLM has always been very much focused on the benefits, the attitude towards BIM is more directed towards the risks. Today for PLM it is generally accepted that large companies cannot survive without it. This difference in perception on BIM and PLM is the trigger for this paper: compare BIM with PLM to find reasons for the different appreciation. The research problem in this paper is therefore:

What are the differences in the approaches of BIM and PLM that can explain the different appreciation of risk and benefit?

Having answered this question we also investigate to what extend some recommendations to BIM can be given to enhance acceptation in AEC industry.

3. PRODUCT LIFECYCLE MANAGEMENT

1.1 PLM concept

Where the concept of BIM came up in the last decennium, PLM already goes back to before 1990, when several mechanical CAD vendors introduced Engineering Data Management (EDM) systems to help engineers in managing the growing number of CAD files [Saaksvuori, 2004]. Around 1995 a new generation of software products was introduced and called Product Data Management. The scope of these products was extended to making design documents available to all parties in a manufacturing company, and to support the design processes and projects. In 2000 a third generation was presented under the name of Product lifecycle management (PLM). This time the scope of the support was extended from company to supply chain and from product development to all product lifecycle phases from conception to demolition. Also, because of the more general introduction of 3D CAD, visualization of products and processes became an important feature. Products, product properties and possible clashes between components are much more easily detected in a 3D visualisation than on 2D drawings. The first goal of EDM was to save cost by elimination document search time and errors because of using out-dated versions. PDM added the goal of shorter time to market because of workflow support. PLM shifts the goal to developing and supporting products that better fit the actual needs of the customer and society [Silventoinen e.a, 2011].

1.2   PLM basis architecture

From the beginning the PLM vendors have recognized that many different software tools, like CAD, CAE and ERP system, were in use and that PLM should not try to replace them, but interface with them. Therefore PLM makes a clear distinction between creating or editing documents at one side, and managing documents at the other. Creating and editing is left to the existing editors like CAD and office programs. PLM concentrates on storing the output, making it accessible and easily retrievable to all authorised parties and to support the processes in which the documents are created and used. PLM regards the managed files as 'buckets of bits', meaning that it does not use any knowledge about the internal structure of the documents. Therefore it is no problem if e.g. models from different CAD systems are to be managed.
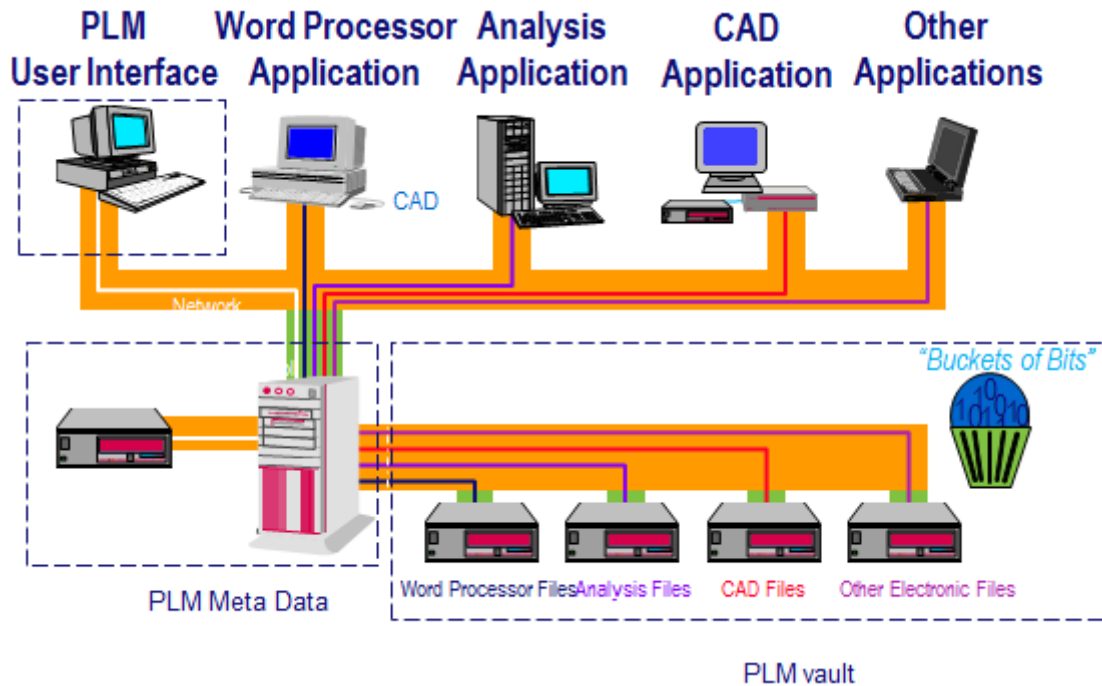

Figure 3-1 PLM Basic Architecture

Figure 3-1 shows the basic architecture of a PLM system. The PLM system, indicated by the framed parts, is clearly separated from the different document editors. The core functions of the PLM system is the PLM-vault, where all document contents are stored in a safe way. The PLM Meta Data contains all information about the document like author, title, version, status etc. Note that CAD systems and analysis functions (like for strength analysis, heat transfer, em-radiation, electronic circuits, etc.) are independent from the PLM system. The functions perform the actual analysis, but the input data is retrieved from CAD models in the vault and the results are stored as documents in the vault again.

1.3   PLM and visiualisation

Above, it was stated that visualisation of products and processes is an valuable function of PLM. Visualisation of the whole product, or arbitrary parts of it, requires that the CAD models from different editors are combined into on integrated view. These models may originate from different CAD systems and thus may have different file formats. Sharing CAD files is a troublesome issue already, because, even when two designers use CAD systems of the same version from the same vendor, the way they get the model presented on their screen may differ because of different local settings in the CAD system. The same problem occurs when a text document is viewed. If e.g. the paper format setting is different between two users, they get different views on the document and may have the same sections at different page numbers. To prevent these problems text documents are often

distributed in pdf format, with the advantage that the presentation does not depend on local system settings and that the contents cannot be edited anymore. In the mechanical engineering world similar viewing formats have been developed, like e.g. 3D-pdf. An additional advantaged is that the file size is an order of magnitude smaller, such that downloading files and building integrated views is much faster. However an important requirement for a viewing format is that is contains all relevant information as required in the deliverable. For a mechanical design this means that all details needed to produce the part must be presented, like dimensions, tolerances, roughness etc. For this purpose the JT standard [ISO 2009] has been introduced. Using this standard the PLM system will automatically create a JT-file when a CAD file is checked-in into the PLM system. The JT file is regarded as the actual result to be presented to the intended readers of the document. The native CAD file regarded as an intermediate result, that is returned to the author when he checks-out the document for making a change. The JT-files are used to build assembly models and to do clash detection. Further the visual product model is very useful as searching mechanism. By simply clicking on a component, the associated documents can be retrieved, as well as interfacing parts, subparts and other assemblies where it is used as a part.

1.4   Consistency Management in PLM

A product design evolves along a number of phases from the contributions of a number of different designers. In both manufacturing and construction industry the use of Systems Engineering [Dod, 2001] is widely accepted as basis for project phasing. In this approach (see Figure 3-2) the design process is split into:

1. Requirements Analysis to specify what the customer expects,
2. Functional Analysis, to define the functions the product should perform and
3. Design Synthesis to specify all physical details as needed to manufacture the product.

In each phase mechanical, electrical and software engineers work together. Often the requirements analysis, functional analysis and design synthesis require different skills and are assigned to different engineers. Also it is common use to phase the project according to the Systems Engineering processes, resulting in e.g. (1) a Requirements Phase, closed with a milestone where the requirements specification is delivered and frozen, (2) a Conceptual Phase where solutions for functions are chosen and validated, resulting in a design review where the functional specification is accepted and frozen, and (3) a Design Phase where all construction details are engineered, resulting in all necessary documentation for production to be delivered at the final design milestone.
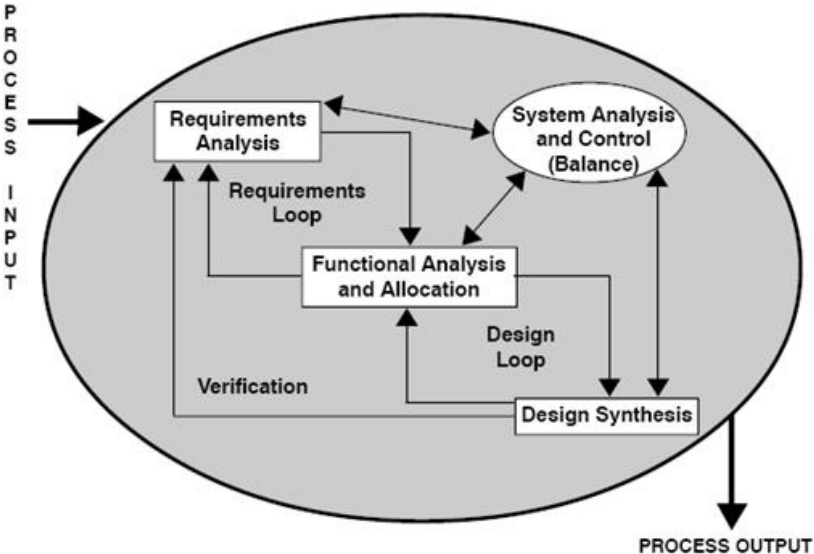

Figure 3-2 Systems Engineering

Systems Engineering stresses the importance of consistency between the results of the subsequent phases in designing a product, as indicated by the three loops in figure 2-2. Consistency means that

every function must be based upon a requirement and it must be proven that the specification of this function satisfies the requirement [Pels e.a, 2010]. In addition every requirement must find implementation in either a function or a design component. The same consistency is required between functional and design specification. A milestone cannot be passed if for any deliverable consistency has not sufficiently been checked. During each of the three phases there is communication between the disciplines resulting in many iterations in the design process in order to achieve consistency between all deliverables of that phase. However, although the deliverables of a phase are frozen at the concluding milestone, it often happens that new requirements emerge during functional analysis or even design synthesis, or that tests of physical components show that certain functional specifications cannot be met at reasonable cost. Systems Engineering requires that, if requirements have changed during the conceptual phase, the functional deliverables may not be approved unless there are new, approved versions of the corresponding requirements. Likewise the final design may not be approved unless all deliverables have been proven consistent with the current versions of all related requirements and functions. Only in this way it can be managed that the final product is according to the requirements as agreed with the customer.

Because of the iterative nature of the design process, many versions of many different documents emerge during the project. Assuring that in every situation the proper versions are used, requires very strict document management. A PLM system supports and partly automates this process [Reefman, 2011] and thus reduces very much the cost of quality of documentation. In addition the ease of sharing information improves very much the communication between the different designers and thus very much improves the quality of the design.

The process of consistency management is based on the principle of document lifecycles [Pels, 2008]. A document starts its life with status (1) In-Work, indicating that the document is not complete and only intended for commenting, (2) For-Review, indicating that the document is complete, but still has to be checked for consistency with all its inputs and (3) Released, indicating that all checks have been properly executed such that consistency can be concluded, and that the organisation that delivered the document takes full responsibility and accountability for its contents. The consistency check is performed in a review process, where a specific set of specialists is asked to review the document by checking it for inconsistencies wit constraints from their expertise. It is clear that in any case the requirements engineers must review all functional documents with elements based on their requirements. The released status is assigned by an engineer with sufficiently high rank to assume responsibility for the organisation. In many cases this is a project or engineering manager. It is his duty to verify that all necessary reviews have been properly executed with positive result.

Managing document lifecycle processes in the PLM system means that the system registers the creation and finishing of each individual task. This creates a real time and detailed overview of the status and the progress of the project. Not only this gives project transparency to the management, but also it enables to control the process with much more precision such that activities can be better coordinated. As a result the process will become more flexible, resulting in design that better responds to actual customer needs.

4. COMPARING BIM WITH PLM

Now looking at the BIM practice, we see that the BIM tool concentrates on the functions of visualising the product, calculating relevant properties (like stability, energy consumption and sound isolation) from physical dimensions and checking on clashes between different elements. Compared to PLM this represents the CAD and the Analysis applications. There is no vault, no document management, no version and status control, nor metadata management. Even if it would be used in combination with a project website, than the BIM is just one of the documents in the website, and there is no management of the consistency with other documents.

A very important difference is that in a PLM system each document is linked to responsible persons like IP owner, author, reviewers and releaser. In a BIM process organisation the model is maintained

by a separate officer who builds the model by interpreting the deliverables of the different project partners. As long as there is no formal review and approval process where the partners validate the information in the BIM system, the BIM model has no formal value in the process. Even then the BIM is a redundant copy of the real specifications and the effort to maintain it is in fact wasted. In addition this way of working introduces risks for the partners when this information is used for any purpose later in the buildings life. This might explain why partners are reluctant to pay for the cost of building the model.

Another difference is that BIM does not distinguish between requirements, functional and physical documents. In many countries there are standards or even legal requirements for the documents to be produced. A typical phasing in construction industry is (1) requirements, (2) global design, (3) construction and (4) realisation. This phasing resembles that of Systems Engineering, in the sense that the global design specifies functional elements of the building like its look, the positioning in its environment, its spatial decomposition, the styling of spaces, volumes and surfaces etc. Much of this information is represented in drawing or, increasingly in 3D sketches. Since a BIM recognizes only one integral model of the building, it cannot distinguish between the global design model and the construction model, nor can it check consistency between them or maintain separate versions. PLM systems do provide tools to make this distinction.

The function of the BIM fully concentrates on visualisation, and internal consistency checking, thus helping to detect errors during the design process. However, since there is no formal check of consistency with the actual deliverables, there is no guarantee that detected clashes are properly solved.

Concerning the benefits, PLM claims to (1) reduce design cost, (2) to reduce development lead time and (3) to increase customer value. For BIM this means that as well the architect as the construction engineers will save hours for designing the same building. The building company will save on failure cost. Reducing development lead time means that the building will be available earlier, or that the project can start later. More customer value means that that a more optimized building results that better servers its purpose. This means that the benefits for all parties are clear.

5. LESSONS FOR EFFECTIVE BIM

In the previous section we showed that a BIM performs two functions: visualisation and analysis. Only visualisation is a PLM function. Analysis is an engineering application, to be used by a properly skilled engineer. Therefore a BIM should be combined with a proper PLM system and a proper set of rules to play the game. Let us call this combined system a Building Information Lifecycle Management (BILM) system. Deploying such a system incurs the following rules upon the partners in the project:

1. Every deliverable should be delivered in the BILM. All documents should be delivered in such a format that the BIM function can visualize the contents as component of the integral visualisation of the product. The information readable from the visualisation is the single source of truth for this information. A task can only be accepted as completed if its deliverables are in the BILM with proper status.

2. For each (type of) deliverable a proper release process with sufficient review tasks and the proper release authority must be defined. A deliverable only counts as delivered if it is in the BILM with the proper status (e.g. Released). These rules should be agreed in the project contracts. The company that released the document is accountable for cost incurred by errors.

3. A deliverable may only be released if it has been proven consistent with its inputs and with its intended purpose, by a proper review process. This means that after changing requirements or functional specifications, the requirements and functional documents must be updated and released before the design document can be released.

4. Each partner in a project is responsible for producing deliverables in the proper format and to perform proper analysis and validation of the contents, before releasing them. The cost of the editor an analysis tools are in principle for the responsible partner. When certain design or analysis tasks are outsourced, then this does not change the responsibilities of the out-sourcing partner. The partner pays for the required number of use licences on the BILM system,
5. Ownership if information remains with the responsible partner,
6. Also preliminary (non-released) information may, or even should, be made available in the BILM system, be it with the proper status indication, in order to invoke proper communication on the design
7. Distinct document sets for deliverables of different project phases should be maintained.

The required PLM functionality for a BILM system can be acquired from commercially available project website software or PLM software. The BIM functionality can be used from existing BIM software as provided by CAD vendors specialized on architectural design. Proper integration requires that a document retrieved from the data vault can be presented by the viewer. In addition the viewer should be able to present assemblies, by retrieving the models of the components in the vault and presenting them in the proper geometrical configuration. Standardization of the viewable file format would be very helpful.

6. DISCUSSION

The main argument for using BIM in literature is to reduce the risks concerning the information consistency and in that way decrease failure costs. The problem in the Netherlands, and a number of other European countries, is that failure cost only hit the construction company because of their product responsibility. Although they are investing in use and implementation of BIM, it depends on the contract if they are involved in the design process. This is only the case in Design & Built contracts and equivalents and not in traditional contracts. Due to this, product specification easily is limited and use and implementation of BIM and methods like SE will be limited too. This differs with countries like Belgium and Austria in which the architect has the final product responsibility. Architects in these countries have much more power to implement and use BIM technology (Emmitt e.a. 2009). . On the project level the client might not be interested to invest in the technology, especially since project development clients are only interested in the real estate value, not in the value of use. Substantial reduction of cost for new projects, might endanger the value of their existing real estate portfolio. For the companies involved still the question remains how to equally invest in such a system. Architectural firms often need to take the lead because their drawings and information is leading for the other involved firms. However, the information and knowledge embedded in their drawings often is re-used by the other firms involved Therefore it is important that the ultimate building is consistent with the final version of the architectural design. In manufacturing industry suppliers are simply forced by contract to deliver their work in the PLM system of the so called Original Equipment Manufacturer (OEM) who sells the end product to the customer. In the contract the risks are balanced with the benefits. So if architectural firms sometimes think it is reasonable that other parties in the design process pay for the additional value because of the better quality of the drawings and documents they receive from the architect. On the other hand, in the PLM approach each partner pays for the number licences he needs to do his job and makes the effort to maintain his part of the total model, meaning that he has the effort and the direct benefits in his own hand. That may help the other partners to easily put in additional information and knowledge. For the authors this problem is not solved in the research project and will need additional investigations how to deal with such matters in a proper and adequate way.

Another issue concerns the approval procedures concerning drawings, because these procedures are not standardized and sometimes lead to arguments between firms in a building & construction project. This is because documents need to be approved on the organizational level in a firm as well as on the project level by another firm who is only partly responsible for the building; for instance: the design

and technical specifications (architect) the construction (framework designer) or the installations (advisor building services). Approval procedures therefore can be time consuming and be a cause for failures because of the technical building complexity. Also this problem needs additional research.

7. CONCLUSIONS

BIM can learn a lot from PLM. Most important is to build the integral product model from separate deliverables from individual partners. This is essential to maintain data ownership and responsibility. Second is to keep deliverables from earlier project phases consistent with deliverables from later phases, when changes occur. This is essential for proving that the product matches the customer requirements. Third is to define and control document lifecycle processes. This is essential to enforce quality of documentation and to create project transparency. It enables shorter lead times and better response customer requirements.

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