A Controlled Integral Product Model(IPM®) in Building and Construction

Rob J B Reefman, Sander van Nederveen
rob.reefman@productdatabank.com, g.a.vannederveen@tudelft.nl

AEGOR-ProductdataBank B.V.
PO Box 58
4273 ZH Hank
The Netherlands

Delft University of Technology
PO Box 5048
2600 GA Delft
The Netherlands

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Abstract

Significant improvements within Building and Construction projects are expected from the application of the Building Information Model, BIM. A major cause of failure costs is the use of invalid or wrong documents / models in the process. This means when BIM is the central data source in the project it should be up to date at any moment in time.

Today the BIM model is often one huge single file, usually a merger of two or more files created by different disciplines, for example the model of the architect and the model of HVAC project partner. A BIM file is very often released as one object which indicates a bad controlled process because the Building Information Model is a collection of many objects each having its own life cycle. The use of the building information model BIM is still restricted to a few areas. A major application of the BIM model today is the use of its geometry model. This is used as a verification tool, e.g. interference checking.

The Integrated Product Model (IPM®) concept places a well managed digital product model in the centre of the design and engineering process in which all engineers at different disciplines and locations are working together. Well managed means that there are appropriate release and change processes in place.

The paper discusses an integrated design and engineering environment using the IPM-concept and applying modern configuration management concepts to assure actual and good documents or models all the time.

An example is given how Product Lifecycle Management (PLM) systems are used to deliver good document / models to the BIM model. The paper concludes that BIM should be more integrated in the design and engineering process and eventually needs to be integrated in a PLM environment.

Introduction

Applying Building Information Models[1] based on IFC neutral format seems very promising for relevant improvements of Building and Construction processes. However the management of changes seems to be a real problem. Best practises from aerospace industry and modern PLM systems used in industry might give directions for further BIM developments and applications.

The article starts to study the current situation of using Building Information Models, e.g. BIM and searching for explicit stated needs for process management. It proceeds with the definition of an ideal Integral Product Model, its background and objective. The backbone of the IPM is the product structure. As in BIM, an important interface with the user is the 3D product geometry. Vital for a flawless product model is managing the processes to create and maintain this model and assure its integrity. These are processes over the borders of the different companies working together in a Building and Construction project. An organisation model is proposed to execute these processes, including roles and responsibilities.

Finally BIM is compared with the proposed integral product model.

Current situation

Introduction

In this chapter the current situation using building information models is studied, especially looking for publications concluding to a need for process management.

BIM

BIM is to offer the project one single database in a standard format from which all disciplines can obtain the information they need. It is expected that building and construction processes are much improved by using BIM. It means better communication, better collaboration and so less loss of information in the transfers between the different stages of the product life cycle (Wenfa Hu 2009[2]).

Following Singh 2007[3] BIM is a repository of all information, geometric and non-geometric, relevant for a building and construction project throughout all the phases of its lifecycle. The repository or BIM model is a collection of non-related entities in the neutral IFC format and is managed in a BIM Model server. Usually this BIM model server does not contain any other applications other than basic data management. The different disciplines and other stakeholders involved in a project import and export the information they create or need relevant to the project.

Beetz 2010[4] is discussing the IFC-based Open Source BIM server as an IT solution. In the chapter on user experience he discusses the use of subsets of IFC entities (subprojects) and expresses also the need for document management.

BIM applications in the Netherlands have their emphasis on 3D geometry. Different disciplines usually are creating their own models in a native format which are exchanged with the other disciplines involved in the project using the IFC format. Viewing and interference checking are major activities for the use of BIM models. BIM models are often informal released as one object. This is a signal of weak process management because the model exists of a lot of single objects with each its own lifecycle. This might be expected in an environment where release processes have to be improved anyhow (Reefman 2011[5]).

However the awareness about the issue of managing a BIM model is increasing in the Netherlands, let us see what happens outside the Netherlands.

London and others 2008[6] did a survey in Australia. Besides a slow adaption, the research showed a clear lists of management needs in a BIM environment concerning issues like:

- Data organisation;
- Version management;
- Validation (or release management);
- Roles and responsibilities.

These are typical Product Lifecycle Management[1] (PLM), e.g. Configuration Management[2] (CM) issues[7]. This relation with product lifecycle management is not explicitly mentioned by London.
Hao (2008 [8]) from Canadian NRC institute looks to the building and construction process with the view of managing changes. Within the focus of this article change management is vital for a flawless building information model like BIM. Hao sees it the other way around: BIM is important for change management. In his view BIM is mandatory for change management but not the core of change management.
Hao suggests a general and generic change process of:

- Identify;
- Propose;
- Approve;
- Implement;
- Review;

and compares this with the SAP PLM solution, which misses, according Hao, the link with manufacturing or in Building and Construction the realisation phase.
In the Netherlands the VISI[3] concept handles changes in Building and Construction, but only the ones which have a relevant impact on the project and therefore being managed on contract level. VISI manages the transactions between the contract partners. VISI has no typical PLM functionality and no explicit link to BIM.
Returning to the work of Singh one can find an implicit link between BIM and PLM. Singh presents a table with BIM tools including BIM model servers. One of this BIM model servers is from EDM, Jottne EDM a PLM company. It is expected that the mentioned data management at EDM as mentioned in this citation implies PLM functionality.

BIM Process

Within projects using BIM there is usually a BIM manager who is importing and exporting BIM models or subprojects on request between Project level and the different project partners.

The project BIM model is the central product database for the project. Creation, release and change is performed in the native systems at each party or discipline. Thus the BIM model is a model outside the direct development process and for its integrity and consistency depending on local processes.

BIM and change management

Although there is not much literature about BIM and data management and certainly not about BIM and PLM, it can be concluded that the community of BIM users feels something has to be done about managing their BIM models. This can be concluded from public BIM discussions and presentations and can also be derived from IT publications about BIM, for example in the earlier citation of Beetz.

Triggered by experience in aerospace it will be discussed or some best practises from aerospace industries and modern PLM data management systems can be used to improve the management and use of BIM models in order to achieve up to date and valid documents.

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[1] Product lifecycle management (PLM) is the business strategy for managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal. PLM should integrate people, data, processes and business systems and provide a product information backbone for companies, their extended enterprise and for capital assets also the customer.

[2] Configuration Management is an important part of PLM. Configuration Management in industry is the process of managing an organisation's products, facilities and processes by managing their requirements, including changes and assuring that results conform in each case. (Guess 2002[10])

[3] VISI is an agreement accepted by the Dutch Building and Construction on digital exchange of formal communications.

Integral Product Model (IPM®[4])

Introduction

In the first paragraphs of the chapter on the integral product model is described what this model really is. In the last paragraph, entitled process, it is discussed how this integral product model is managed. The following processes will be discussed:

Creation process;
Release process;
Change process;
Verification process.

The focus is put on the change process and its organisation.

Definition

IPM® (Integral Product Model) is a well managed[5] digital product model in which all engineers of all disciplines and parties perform their design and engineering together, independently from their location.

The IPM® is situated in the middle of the primary process in an integrated design and engineering process.

Background

The IPM® is based on the best practises of Aeritalia[6] in the end of the 80ties developing the systems for the Eurofighter and of Roll Royce (aircraft engines) building digital mock-ups[7] (DMU) for their aircraft engines. Figure 1. Shows a picture of a DMU experiment in those years. In the corner, right under, one sees a simple presentation of the product structure.

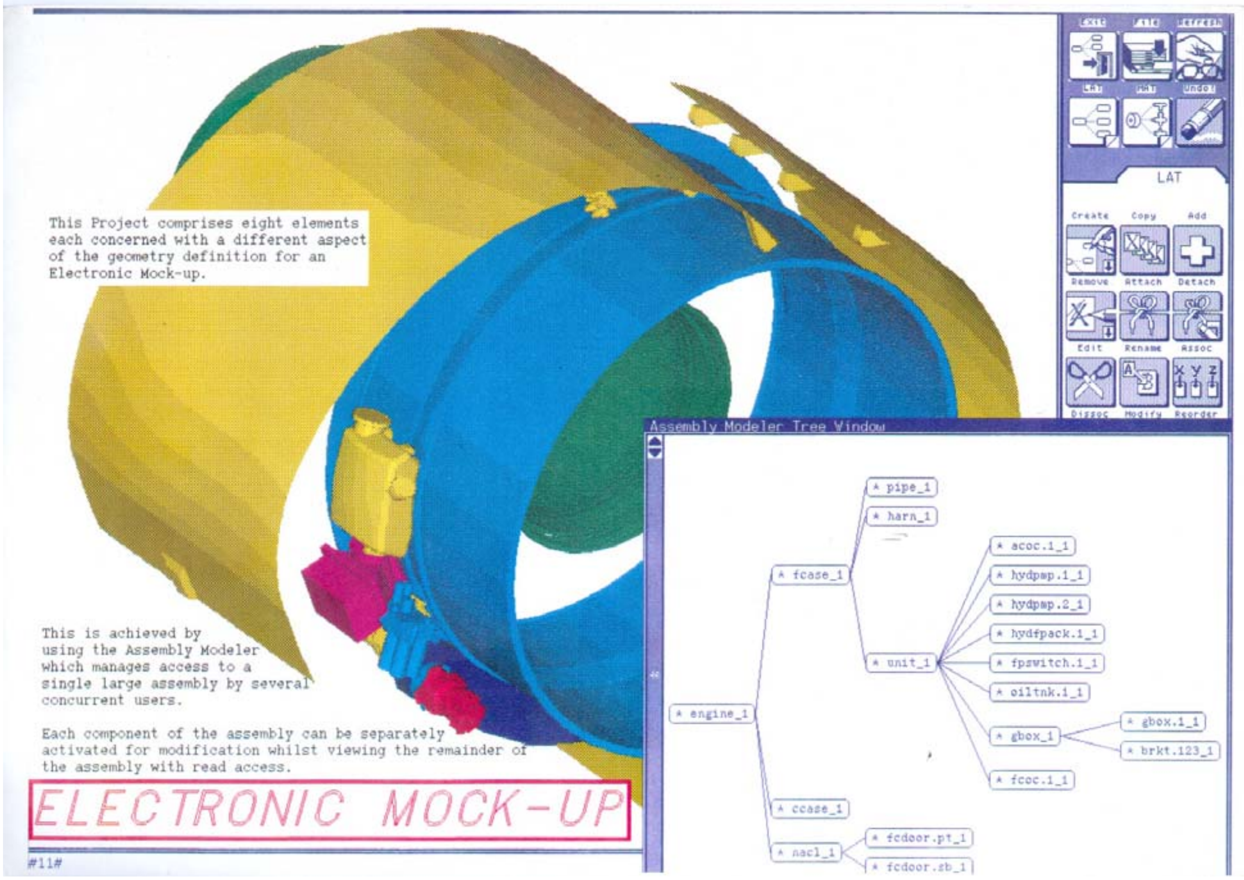

Fig. 1 DMU experiment of Rolls Royce in 1989

[4] IPM® is a registered trade mark by AEGOR (owned by author)
[5] PLM functionality
[6] Today it is Alenia
[7] A digital representation for a physical model, for example a prototype of an engine

Objective

The objective of working with an IPM® is creating an effective concurrent engineering environment[8] in which documents are created first time right. Due to the application of a well controlled digital mock up at Aeritalia, pipes and harnesses for the Eurofighter aircraft prototypes were 99% first time right (1989)! [9]

Product structure

Any form of product structure is needed to determine the complete set of documents that have to change to realise a change proposal. In the case of an unstructured set of entities, like in BIM, one is dependent on the skills, experience and overview of the engineer only. The product structure is also used as a navigation tool through the product. It is quite usual to model the project in a decomposition structure but also quite other structures are researched, for example to describe the structure in a formal generic artificial language. (Renssen 2005[10]). The product structure is created when the architecture of the product, building or construction is developed, see for example Blanchard 2008[11].

The decomposition of the product structure is a topic of ongoing discussion. Guess [12, 13] argues the product structure of the product should be the way the product is actually going to be built or assembled. Major arguments for this choice are:

1. It is easier to make impact analyses for change proposals;
2. It is easier to develop time and cost dimensions[9] for the project.

The backbone of IPM® is the product structure, a decomposition of the product in assemblies subassemblies and further down into parts. The structure is build of the digital representations of physical objects. They have attributes and are linked with their belonging documents. Two attributes of the physical object are especially important for the 3D model. These are the location in x,y,z Cartesian coordinates of the origin of the object and the angular position of its orientation axis expressed in the direction angles α,β,γ of this axis. For each user, depending on his access rights, the product structure is divide into two parts, a reference structure where the user has a right to read and view the object attributes and linked documents and a work structure were he or she has also the right to create and edit these.

The 3D Model

In large programmes or projects different parties are usually working with different CAD software. The different parties are creating parts of the 3D model of the product, building or construction. Within the PLM system[10] these parts are extended with a simple digital geometry description used for viewing only. The size of such a "viewing file" is just a fraction of the original CAD file. These viewing files are in a "standard" format and this viewing files only, are used to feed the overall 3D Model containing the objects of all parties and disciplines. This is done instantly when a part is saved in the PLM system. This means other project members with the appropriate access rights will see immediately (geometric) results of their colleagues in the programme or project. Form and fit requirements can be checked immediately during the time the design and engineering work is actually performed. The environment of the 3D model can be seen as an Assembly Modeller. The part models themselves cannot be changed but their positions and directions in space can. The changed position and angle attributes will be returned to the native CAD systems.

Not only the product structure can be used for navigational purposes also the 3D model can be used for this. The user can switch between the geometry model and the product structure.

The IPM® functions as a design and engineering tool in the middle of the primary process. The objects are practically designed in the 3D geometry model.

Not only the geometry model of BIM but many other digital mock up applications today are not directly used in the design and engineering process. They are used for posterior verification and review only, like for example the performance of a structural analyses is executed.

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[8] Containing an optimal engineering collaboration as would be said in today's engineering vocabulary
[9] In Building and Construction one speaks about the 4th and 5th dimension []
[10] For example Windchill and Teamcenter

Process

Introduction

A product development process is producing documents. And in respect to these documents one is dealing with the following processes:

- Creation process;
- Release process;
- Change process;
- Verification process.

These processes take place in all project or programme organisations. In order to do things right the first time and make maximum use of available knowledge, special processes or best practises will be introduced and implemented in current organisation structures. A model of the current project organisation is given in figure 2. In this model a consortium member is modelled as a manager plus an engineer.

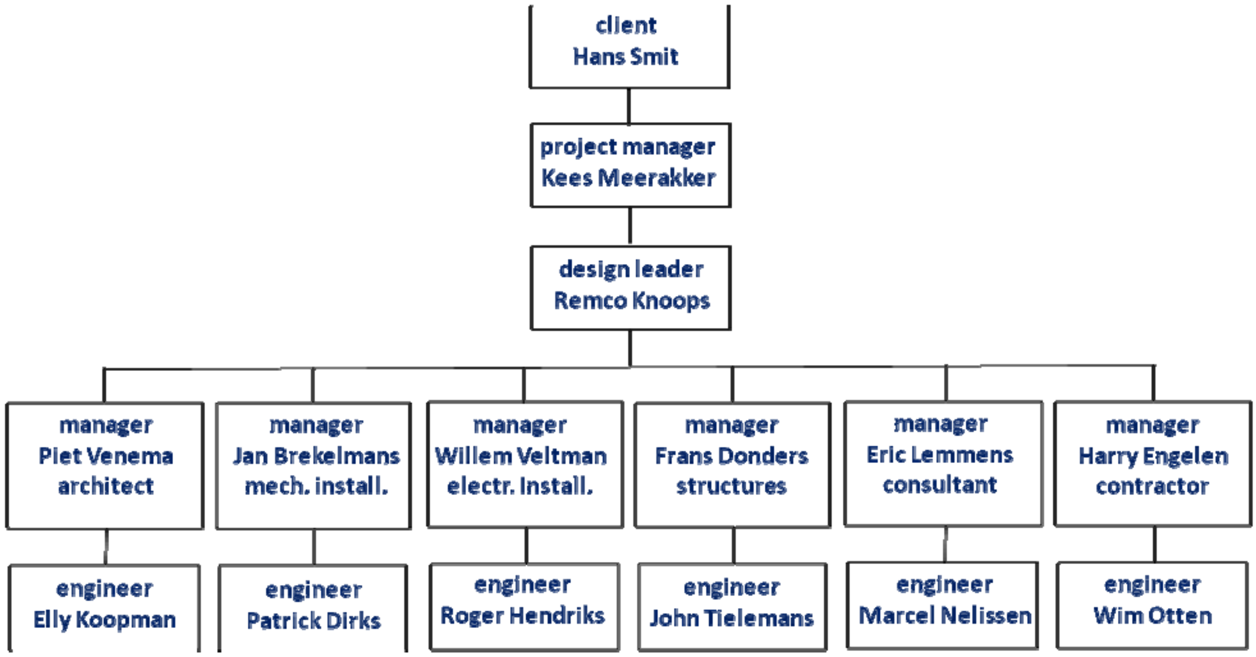

Fig.2 An organisation model for the current situation

Creation process

The application of IPM® will not cause much difference in the creation process except the engineers are directly working in an integrated design environment. And within the lifecycle of the documents that are created in the project or programme he or she will be involved in the work of his colleagues project members.

The engineer at the end of the line in the project or programme organisation has to do his job and create a document on the basis of input documents. For support he or she has available IT tools like CAD, libraries and procedures. He or she is working in an integrated design and engineering environment using the IPM® in his work. The only difference with the current situation might be the strict requirement about an order. There must be an order. No work will be done without an order. Furthermore the order has to refer to all needed documents to do the job and all these documents have to be good (Reefman 2011[5]). The creation schema is given in figure 3.

The creation of the product structure is done in the design phase of the project when the system is designed. A well implemented Systems Engineering approach would be helpful (Blanchard 2008[11]).

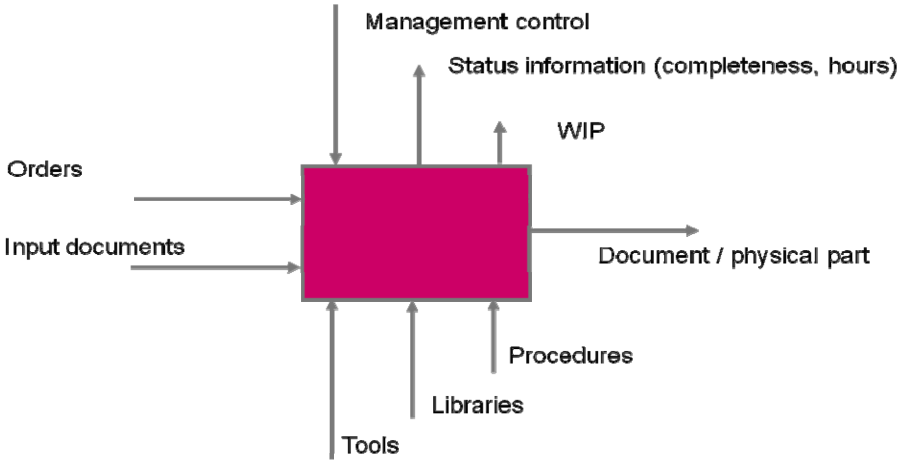

Fig. 3 A schema for the creation activity

Release process

The release process assures good documents. An effective release process as is used in an IPM® environment is described by Reefman 2011[5] and presented in figure 4.

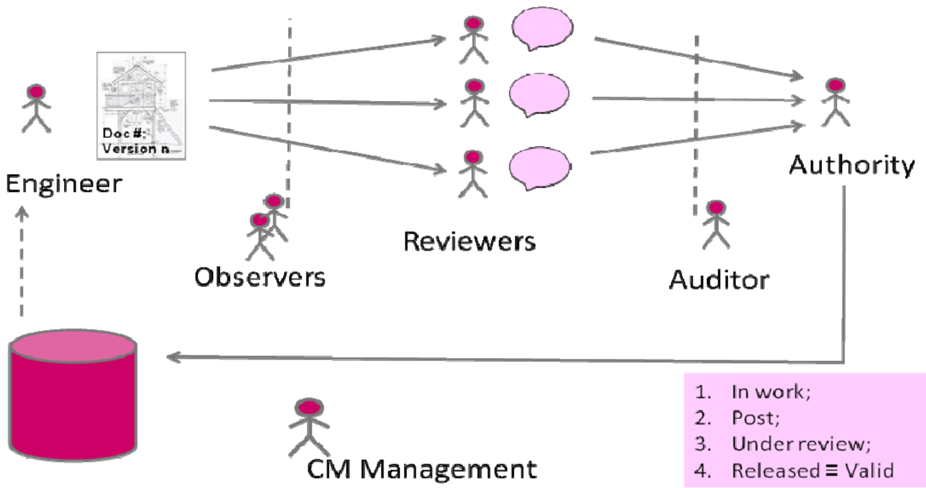

Fig. 4 IPM® Release process

The proposed document lifecycle for an IPM® work environment is:

- IN WORK (create);
- POST (observe);
- UNDER REVIEW (judge);
- RELEASED (authorised and valid)

For the discussion of IPM® and an integrated design and engineering environment the focus is on the second phase in the release process, the POST phase. In this state of the document lifecycle other engineers can observe the work of their colleagues and react. The application of this POST state can be realised and used in many organisations under many situations and it always has a positive impact on the project. But using the well managed 3D geometry model within an IPM® environment has a much larger effect due to the embedded concurrency and the fact that the results are shown immediately. This means that the individual engineer sees immediately the consequences of somebody's work for his or her job. The POST state in the document lifecycle means a maximum use of available project knowledge as early in the project as possible. This saves a lot of costs because early changes are cheap especially if they even happen before the document is released. It is also a good balance between formal and informal project information exchange. The POST state functions very well within an extended enterprise or any integrated design and engineering environment.

Change process

Hao 2008 [8] writes however Building and Construction projects are very different in size, scope and complexity, they share one common element and that element is change. Change Management is a critical problem for the Construction Industry. Changes are identified as the major cause of project delay, cost overruns, defects and even project failure. Hao concludes that in spite of the urgent need for change management in the construction industry there is very little research done addressing change management in Building and Construction. Hao is studying change management in industry and looking into PLM and ERP solutions, e.g. SAP and comes to the generic change process of:

1. Identify the change;
2. Make change proposal;
3. Approve the change proposal;
4. Implement change;
5. Review the result.

Building and Construction projects are based on contracts between many parties and change procedures should be part of the contract. Hao sees for Building and Construction projects three types of changes:

1. Changes generated by unanticipated causes;
2. Changes issued by the customer;
3. Jobs that have to be redone because they were implemented wrong the first time.

All changes are going through the change process that is leading to a change order which has to be implemented.

Best practises for industrial change processes can be found in Watts 2000[14] and Guess 2003[12]. The study of Hao is in line with the work of Watts and Guess.

There are differences however. A difference is that Guess has defined a closed loop change process starting with a released document from the product model and ending with the new version of the document. Also much of Hao's change management vocabulary can be recognised. Where Hao stops with a list of change management challenges Guess proceeds and shows how the process has to be implemented in the organisation including procedures, tasks, roles, responsibilities and change forms and documents. Guess implements one change process for all changes within the project.

Another difference is the characterisation of changes. Guess distinguishes only two types of changes:

1. Major changes with a high impact[11];
2. Minor changes with a low impact.

The boundary for the two types is obviously rather subjective but organisations with a mature implementation of the CMII concept[12] show a characteristic ratio of 15:85 for high and low impact changes. (Guess 2006 [13]) Major changes follow the complete change procedure, minor changes will go through the same process but will have a so called fast track through the change organisation. And a change approval according Guess is split up in two parts, the technical proposal including financial consequences, made under direction of the Configuration Manager (CM specialist I in fig. 5) and the management decision made by the Change Review Board (CRB). For changes needing customer approval the board (CRB) has to include a customer representative.

After the Change Proposal has been approved by the board (CRB) a plan will be made by the CM planner or CM specialist II in fig.5) to implement the change. The Change Implementation Board (CIB) has to approve the plan. The first action is to determine the list of documents which have to be changed and to decide when these changes should and can become effective. This information is put in a change order and from there individual orders are prepared for those designers and engineers who have to change the documents. After release the new documents versions will return into the database.

Guess has developed his Configuration Management Model for one (industrial) organisation. In this article his CMII concept will be implemented in an extended enterprise.

The change process of Guess is given figure 5.

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[11] Impact on HSE (health, safety and environment), costs, quality and or schedule

[12] CMII is a configuration management concept going further than the ISO guidelines

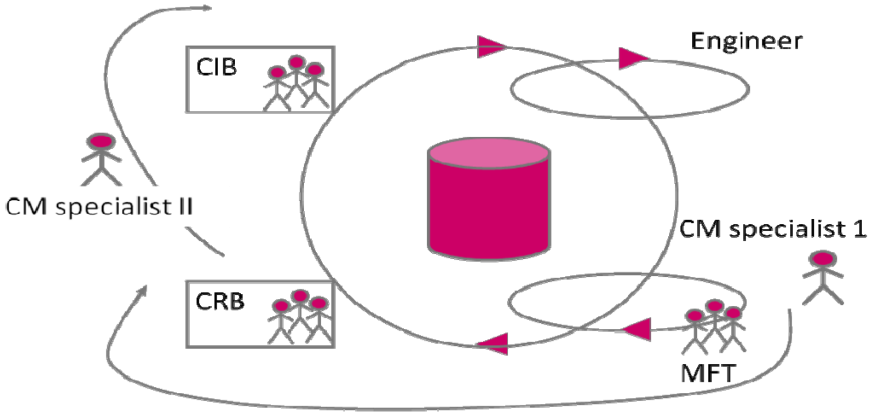

Fig.5 The change process according CMII

Change management and organisation

Organisation of Guess

An implementation of CMII roles in a building and construction organisation

The classical project organisation is modelled with a project line directing a number of independent parties and or disciplines. Each party or discipline is modelled as a manager and an engineer. All members of the modelled organisations in this chapter have dummy names in order to model the organisation in a PLM demonstrator as has been build on the University of Delft.

The classical project organisation model is presented in figure 2.

For the IPM® environment the organisation will be extended with a Configuration Manager, a Volume (or Area Manager), a Design Team and an information distributor.

The Configuration Manager is responsible for:

1. The integrity of the project database;
2. Quality and execution of release process; change process and verification process;
3. Appropriate IT support for Configuration Management.

The Configuration Manager has also the following tasks:

1. Receiving, assessing and guiding change requests and the corresponding amendments to the administrative review by the CRB, the Change Review Board;
2. Providing leadership to assess the impact of a change request or proposal, as well technical as well financial;
3. Assign a person or composing a multi-functional team (MFT) for making a change proposal;
4. Leading the department for Configuration Management.

The volume manager is a project line manager under the design leader (see fig.6) and is responsible for the placing and fitting of all physical objects in the volume assigned to him. For simple projects this function can be performed by the design leader or his delegate and in very complex projects one might have more than one person performing this function. The volume manager is a central figure in the design and engineering process. He or she is directing and directly interfering in the design and engineering process. He or she is the officer to solve interdisciplinary design and engineering problems. In the release process the volume manager is a reviewer. The function of Volume Manager is useful in a classical situation as well but in this situation his or her tasks will be constricted to the function of a reviewer. In case of an IPM® environment he or she is involved in the design and engineering on a continues basis and sees the results when they are being created, which means short throughput times and less mistakes.

Design teams become more and more common practise. By choosing the right members the design team has access to all knowledge and experience within the project regarding the complete lifecycle of the Building or Construction. The design team has the following tasks:

1. Leading the design and control of system architecture and product structure;
2. Advising the project management and line managers on design and engineering issues.

The information distributor is also a new role. He or she will deliver on demand of the user the product information requested in the format wanted by the user, e.g. drawings, pictures and other classical media outside the computer. Within the IT System the information is good. But outside the IT system there is always the risk that documents are becoming their own uncontrolled life. To avoid uncontrolled document versions within an IPM® integrated design and engineering environment the validity for any document outside the IT system is very restricted. Documents outside the IT systems are valid for one event only, the event for which the document was requested. For example a document requested for an identified meeting with the customer. For a next meeting one has to go back to the system or distributor to request the latest document version.

For Configuration Management the organisation is further extended with an Auditor and a CM planner.

The integrity of the information in the database is of extreme importance (Guess 2002[12])To assure maximum integrity a permanent auditor is added to the change process. He or she only checks or all agreed procedures have been followed before new document versions are added to the database. If not, the document versions are returned to the responsible officers to correct their actions.

The CM planner prepares the change order and presents it to the Change Implementation Board (CIB) which has to approve the proposed change order. There will be a CIB on project level as well on the local level by parties and or disciplines. The CM planner has to do all the co-ordinating work.

The new organisation applying IPM® and using the CMII concept of Guess to configure its PLM system is given in figure 6.

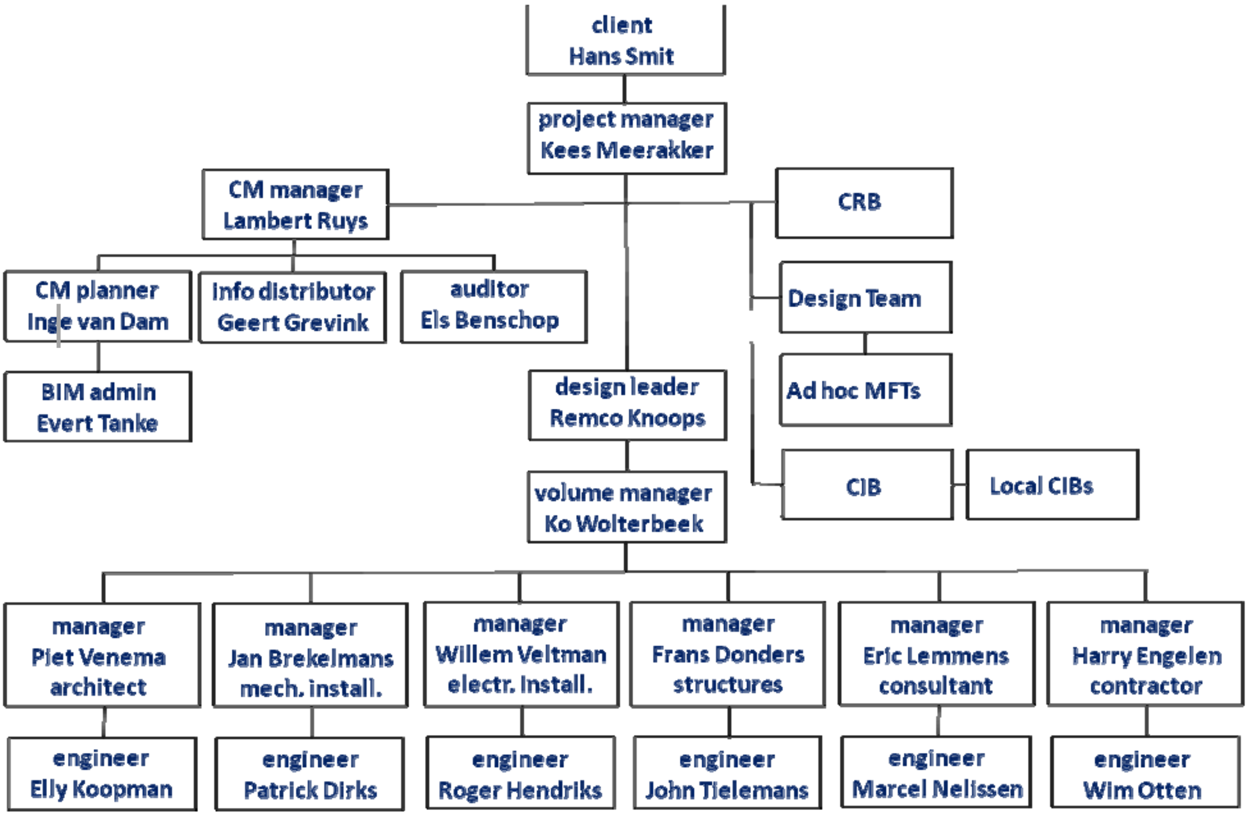

Fig. 6 New organisation applying IPM® and CMII to control BIM

Fast track

Where such a heavy committee as the CRB typically comes together ones a month the project would come to a standstill if every change should pass this committee. Therefore only changes with a high impact would go through the CRB. Small changes are going to pass the CRB. The approval and planning tasks are delegated to the author of the changed document and the most important user of it. While the first category of changes usually have throughput times of weeks, fast track changes might be executed in hours. Both with the same quality and both under responsibility of the CRB.

Verification process

Within an ideal situation and obligatory if one wants to manage the building and construction over its lifetime with minimum costs and effort one has to assure that logistics or the material flow always is a projection of the intellectual flow. In order words the document comes first and the physical object follows.

After physical objects are realised, of course based on orders, it has to be checked or these objects are in conformance with the describing requirements or document versions. The result of this check will be archived in the project database.

If there is a non conformance one has to adapt either the document or the physical object. If one doesn't do this, which is today the normal situation, one will never solve the terrible problem of unreliable information sources during the long time of the operational phase of the building or construction. Besides failure costs this is another source of unnecessary costs (Smit 2010[15])

The closed loop verification process is given in figure 7

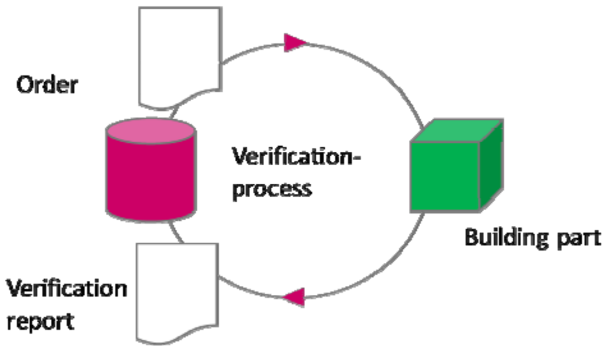

Fig 7. Verification process

BIM versus IPM®

Introduction

In a few lines common and different characteristics of the current building information model and the integral product model are mentioned. In the last paragraph an outline of an pragmatic solution is given how a product lifecycle management system today can assure an up to date building information model that might be stored in a so called BIM-Server.

Common characteristics

BIM and IPM® have one important common property. They both are the one source of project information including 3D Geometry and all other product information;

Different characteristics

There are a number of characteristics in which BIM and IPM® are different. BIM is a collection of single objects in a neutral IFC format while IPM® is using a product structure of representations of physical objects with links to documents in their native format controlled by a PLM system. BIM has no management system, e.g. no change management and does not include any processes or procedures. Unlike BIM, IPM® is completely defined including processes, procedures, organisation, roles, tasks and responsibilities. IPM® is a design tool where BIM is more used as a review tool, for example for interference checking.

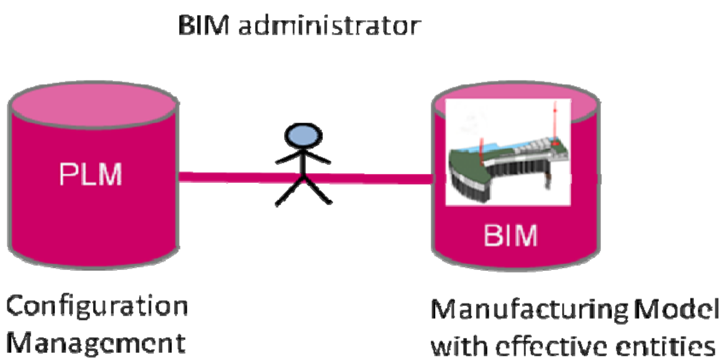

Fig. 8 Temporary technical solution for controlling BIM

BIM and IPM®

As a demonstrator at Delft University shows, one can use a PLM system to manage BIM. One can assure its integrity, validity and keep it up to date. The technical solution is given in figure 8. All objects are created in their local systems and managed with a PLM system in processes as described in this article. Ones the objects are released in an appropriate release process the BIM administrator gets the order to add and delete certain objects from BIM in conformance with the effectivities[13] given on the change orders. The BIM administrator functions under the CM planner in the CM department as is given in fig.6.

Conclusions and recommendations

It is possible to find in literature and in discussions in the field an awareness for the need to manage change in a BIM environment but this is certainly not in general. BIM is meant as an integrated design and engineering environment but is usually applied in a check and review environment. The discussed IPM® environment extended with CMII change management concepts might give directions for further BIM research and developments in order to achieve a better integration in the Building and Construction process. IPM® shows an example how a BIM model could be integrated in the design and engineering process. It has been shown how an approach like CMII, as a de facto standard for change processes, can be implemented in a Building and Construction project organisation.

Due to the need for change management BIM Model Servers have to get PLM functionality or have to be integrated in a PLM environment. It has been shown that the application of CMII and using a PLM system can offer a solution to create a proper change management in a BIM environment. But it is still recommended to do more research on change processes in Building and Construction and study more deeply what the practical industrial standard CMII can contribute to the Building and Construction process. It is recommended to define design and engineering processes in a BIM environment and study how a BIM model should be used within these processes.

It is also of extreme importance to find project or programme management willing to implement a well managed BIM/PLM environment, for example as discussed in this article. Measurement methods should be developed to quantify the differences between projects in Building and Construction executed with and without BIM/PLM.

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