The State of the Art of Finnish Building Product Modelling Methodology

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Abstract: This paper describes and analyses the impacts of the current Finnish building product modelling methodology on the building process and on construction field organizations. The objective is also to recognize and monitor changes in the design and construction environments as well as in the software platforms. In Finland building product modelling has, after 10-15 years of preliminary research, evolved into a piloting phase where the developed modelling methods are currently tested in real-life projects. One quite possible – and even more desired – future scenario is that building product modelling will become an essential collaborative working platform for building projects within the next 10 years.

1 OBJECTIVES

The main objective of this paper is to describe, analyse and evaluate the impacts of the building product modelling methodology currently being applied to the building process, the construction field organizations and to the participants' activities in Finland. A building product model is a digital framework to manage all information within the disciplines of architecture, engineering, construction and facility management (AEC/FM), throughout the design and building process, also covering the use and maintenance of the building.

The objective is also to recognize and monitor the changes in the AEC working environments as well as in the available software platforms. The paper describes the state of the art of recent Finnish product modelling efforts.

2 INTRODUCTION: FINNISH CONSTRUCTION FIELD IT-RESEARCH

The results and case studies presented in this paper are based on several joint national ICT-oriented construction field research programmes, which have been carried out in Finland during the last 15-20 years (Table 1).

Table 1 Finnish research programmes and associations

Project / organization	Definition
RATAS	• A research programme financed by TEKES, 1983-95 • Created a profound research environment for the future co-operative joint work, and also crystallized and documented the problems of the research area • http://cic.vtt.fi/projects/ratasimp/
VERA	• A research programme financed by TEKES, 1997-02, volume approx 50 million Euros • Distributed construction field IT methods and processes widely and deeply into the Finnish construction field. • http://www.tekes.fi/english/vera/
SARA	• A research programme financed by TEKES, 2003-07, volume approx 33 million Euros • Will develop participant networking, the business methods and IT-based practices into the construction field. • http://www.tekes.fi/eng/
Pro IT	• A joint research effort by the Finnish construction industry, 2002-04, volume approx 1,5 million Euros • Based on realized pilot projects of building product modelling methods. • http://www.rakennusteollisuus.fi/proit/

A significant number of Finnish construction field organizations and companies have been participating in the projects of these programmes. All of the named programmes have been strongly supported by the National Technology Agency of Finland (TEKES), which is the main public funding organisation for research and development in Finland.Finland has acted as a ”laboratory” for contemporary IT-research within AEC/FM, due to these large national research efforts and perhaps due to extensive participant involvement and project sizes, where the projects have been manageable in size. One common feature for all these programmes has been ”a national desire” to develop an integrated digital working environment to collaboratively manage design and more widely construction field information within the process and time (Froese 2002). As an implication of the desire, Skanska, one of the biggest construction companies in Scandinavia has [unofficially] stated that more than half of their housing projects could be based on a product modelling methodology in the near future.

3 FROM DOCUMENTS TO PRODUCT MODELS

There seems to be an on-going trend towards more and more complicated software applications and work-tools in AEC. Despite the growing complexity towards heterogeneous environments, these tools also offer a better digital working environment to support more flexible collaboration and totally manageable building project data.

The environment’s key characteristics are described here briefly, to have a better understanding of our currently rather complicated digital working environments.

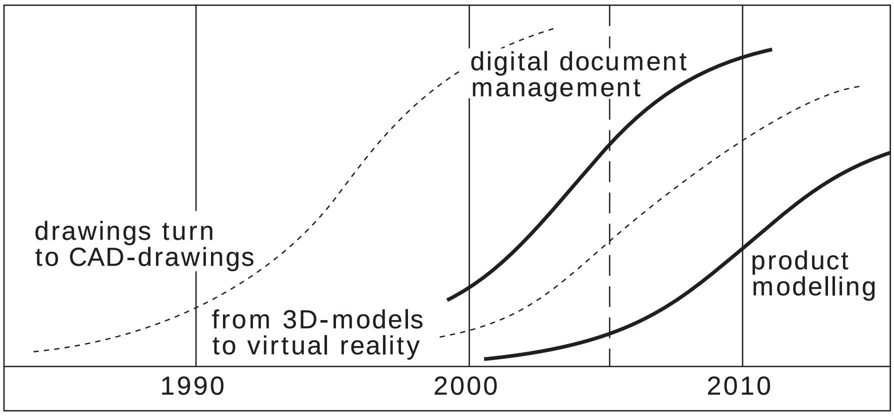

Figure 1 Some significant and recent features in building data management

3.1 Document-based Information

Drawings have been the representation of building-related information for centuries. Since the mid-1980s, paper drawings have been replaced by digital documents with advent of competent CAD-systems. Digital documents are currently the major method of storing building-related information in digital form (Howard, Kiviniemi and Samuelson 2002).

Additional to line drawings, the data in a digital document can also be, in alphanumeric- (text & numbers) or pixel-based form (digital images). In document-based digital communication some file formats have become the ruling de-facto standards for storing and exchanging document data:

- Adobe’s PDF file format in software independent document management in general;
- Microsoft Words' .doc -file format in alphanumeric data;
- Autodesk's DXF/DWG file format in line based building drawings (i.e. vector or geometry-defined graphics);
- JPG -file format in digital image manipulation (i.e. pixel graphics).

Essential is that the content of document data is always interpreted by human beings. The traditional building representation in paper drawings is currently simulated with drawings in digital form.

The vast majority of AEC/FM information management and activities within it, has been done with document-based efforts during the era of construction field digitalization, in the 1990s. Document management systems and document banks for building projects have been introduced and widely accepted during the late 1990s .

3.2 Product Model-based Information

While a remarkable share of building-related information was transferred into digital documents during the 1990s, it was realized that line drawings with textual descriptions cannot handle all building data in a flexible and useful digital way.

The common understanding that CAD-drawings are not an ideal method for storing all building-related information was stated a lot earlier (Eastman 1999), and the limitations had been noticed already in the 1960s during the early days of computing.

The concept of the building product model was effectively defined during the 1980s to be an ideal method for managing building-related data in the digital form. Since then the associated product modelling methodology has been discussed and developed in several international projects and development programmes, such as IGES, STEP and lately IAI/IFC. The concepts and methods have been developed also in local national forums, such as the Finnish projects, to meet and fulfil the local requirements and customs. The historical development of product model related issues has been recorded by Eastman (1999) and Lieblich (2002).

An essential quality is that the content of product model-based data can be interpreted – both by human beings, and also by software applications: hence it can be used and analyzed in building product model databases.

It is also remarkable that while the data in drawing documents covers mainly the design & construction phase of the building process, the product model-based data covers the whole life-span of the building data from the design, through to the construction plus also the use and maintenance phases. Product model-based methods have been developing together with the evolution of AEC-software applications towards "more intelligent" object-oriented features, such as design entities (objects, components, elements), their properties and features and the interaction between these entities.

A wide range of construction-related activities, in the broadest sense of the words, can be managed with a product model methodology. But this would require that the methodology becomes the major information management standard in the near future, as is hoped.

3.2.1 The Phasing of Building Product Data

The idea of the rough phasing of the development and accumulation of building product model data over time is an old one, but is remarkable in understanding the design process evolution and the multitude of different requirements in the process (Eastman 1999).

Table 2 The Phasing of Building Product Data (Eastman 1999, Niemioja 2004)

Phase	Description
Requirement model	• Covers the user requirements for a building.
Spatial model	• Covers the spatial entities (rooms) of a building in an early design phase.
Draft building element model	• Covers the space bounding building elements, but without a defined detailed product structure, or construction type.
Building element model	• Covers all building elements and their product structure, i.e. construction type.
Construction element model	• Covers the actual commercial products to implement the corresponding building elements.
Design model	• Covers the design solutions developed by designers (architectural, structural, building services).
As-planned model (planning model)	• Covers the construction planning information, i.e. how the designs are planned to be implemented as construction work.
As-built model	• Covers product model information about how the designs and plans were actually implemented in construction.
Maintenance model	• Covers information about the maintenance of the building.
Process model	• A model that represents the relevant characteristics of a process for a defined purpose.

The models represented in Table 2 each cover a subset of building product data. Although these sub-models seem to describe a linear process, it is also recognized that design and construction work and activities have evolved towards an overlapping and simultaneous design and construction process, where the requirements between phases are not always well defined (Kiviniemi and Fischer 2004).

3.2.2 IFC-specification (Industry Foundation Classes)

Data exchange standards for product model-based environments have been developed in an international IFC-initiative. The IFC-development has been managed by the IAI-forum, the International Alliance for Interoperability. Prior to IFC, there were also earlier international efforts to develop similar kinds of software independent product data exchange standards, such as IGES and STEP-initiatives in the late 1980s and early 1990s. Industry foundation class definitions are published to provide a universal basis for the standardized use and sharing of building-related information (Lieblich 2002). Technically speaking the IFCs are implemented in software applications to create a common data exchange platform. From a pragmatic viewpoint, the end user of the applications sees IFC as a new feature to save and retrieve data in a form that is understandable also to other software applications.

3.2.3 Product Library-based Information

One recently recognized trend in managing building data in the near future is to structure sub-sections of building information into well-defined data libraries. Typical examples are building components, such as windows, doors, structural elements, pieces of furniture, and technical system components, such as electrical and HVAC-components. Structural type libraries of vertical and horizontal component types (external walls, internal walls, horizontal slabs, roof structures, etc.) are also currently under development for all Finnish AEC in ProIT-project. Product libraries can also be seen as the contemporary stage of building classification work and classification standards.

While IFC is a unifying standard on the software level, the product libraries act first as guidelines for end users (human beings using software). When carefully followed, the use of product libraries leads towards better-structured building data in the limited and well-described areas of AEC information space.

4 FINNISH PROJECTS

The first product model pilot projects in Finland were undertaken in the late 1990s. Since then piloting has been one of the key interest areas of the recent ProIT-project, and some of them are also documented (Sulankivi 2004). Three recent construction pilot projects and information sharing efforts are described here briefly.

4.1 An Auditorium Extension – HUT 600 – Project

The construction of the 600-seat auditorium extension at Helsinki University of Technology (HUT) started in April 2001 and was completed in February 2002.

HUT 600 was the first comprehensive Finnish product modelling pilot project where actual product model-based methods (not only in data exchange) were tested. The project is well documented by Fischer and Kam (2002). The main interest areas in the HUT 600 -project were:

- To test open IFC-standard (version 1.5.1 at that time) in data exchange;
- To test the design of complex spaces, visualization, simulation and analysis tools in a product model based environment.

As reported by Fischer and Kam, the main benefits of the pilot were:

- Object-oriented software and IFC shortened the design iteration time, expedited design in time, and helped in developing and keeping a reliable budget;
- Less redundant design data (less needs to re-enter geometric, thermal and material property data);
- The models supported early design phase visualization for project participants and improved collaboration between participants.

The project evaluation recognized technological, cultural and business barriers which limited the expected benefits. IFC was reported to be not yet as mature and widespread as needed in practice, especially in later project phases. Some shortcomings found in the pilot project, though, have been used in enhancing the newer IFC-versions (2.0 and 2x) and its software applications.

Some future recommendations were also presented in the evaluation, namely:

- Focusing on partial modelling techniques. Emphasizing the general and common core of the model data versus discipline-specific model data;
- Developing product model servers and more reliable application tools.

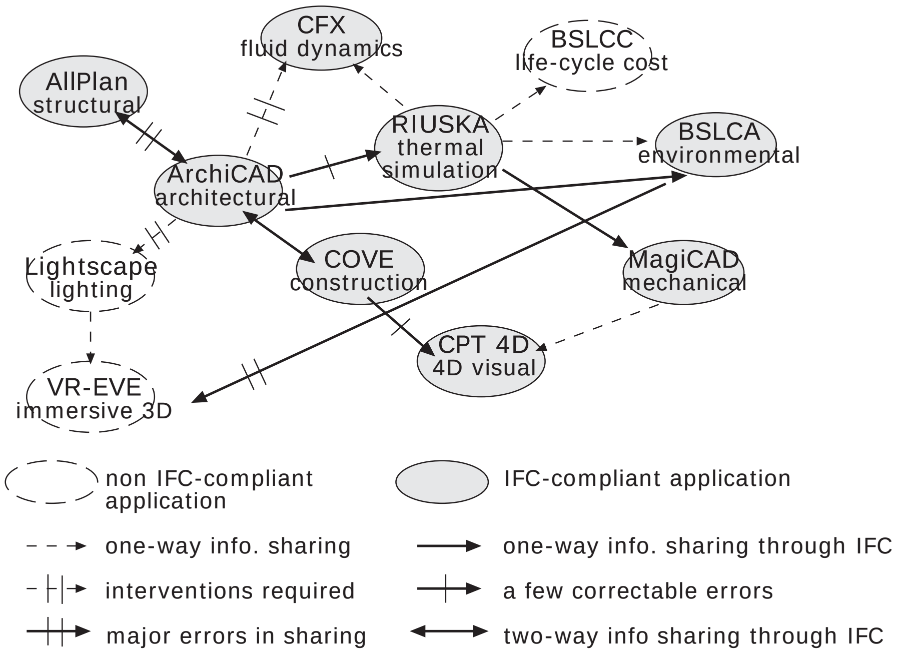

Figure 2 Software applications and data exchange in the HUT 600 –project (Fischer and Kam 2002)

4.2 A Housing Project – Mamselli (1550 m^2)

The design phase of Mamselli was undertaken between February and September 2004, and site activities started in September. As reported by Sulankivi (2004), the main interest areas in the project have been:

- To develop and test a product model guidelines for architectural design (Niemioja, 2004) and for structural design;
- To test product model-based data libraries for window-components;
- To test how quantity data was transferred from design to construction company cost calculations with IFC.

Software applications used in the project have been:

- Architectural design ArchiCAD
- Structural engineering Tekla Structures and ScaleCAD
- HVAC-engineering MagiCAD
- Project coordination NavisWorks and Solibri Model Checker
- Project documentation Raksanet-project bank

When product modelling was used heavily in architectural workflow, the majority of architectural drawings were reported to be produced from the product model:

- 70% of the main drawings (1:100) were produced from the model;
- 85% of the working drawings (1:50) were produced from the model;
- The architect's estimation of the overall work gain in producing detailed drawings (1:20 - 1:1) from the model was approximately 40%.

95% of window diagram document data, 70% of furniture diagram data and some 10% of door diagram document data was produced from the product model.

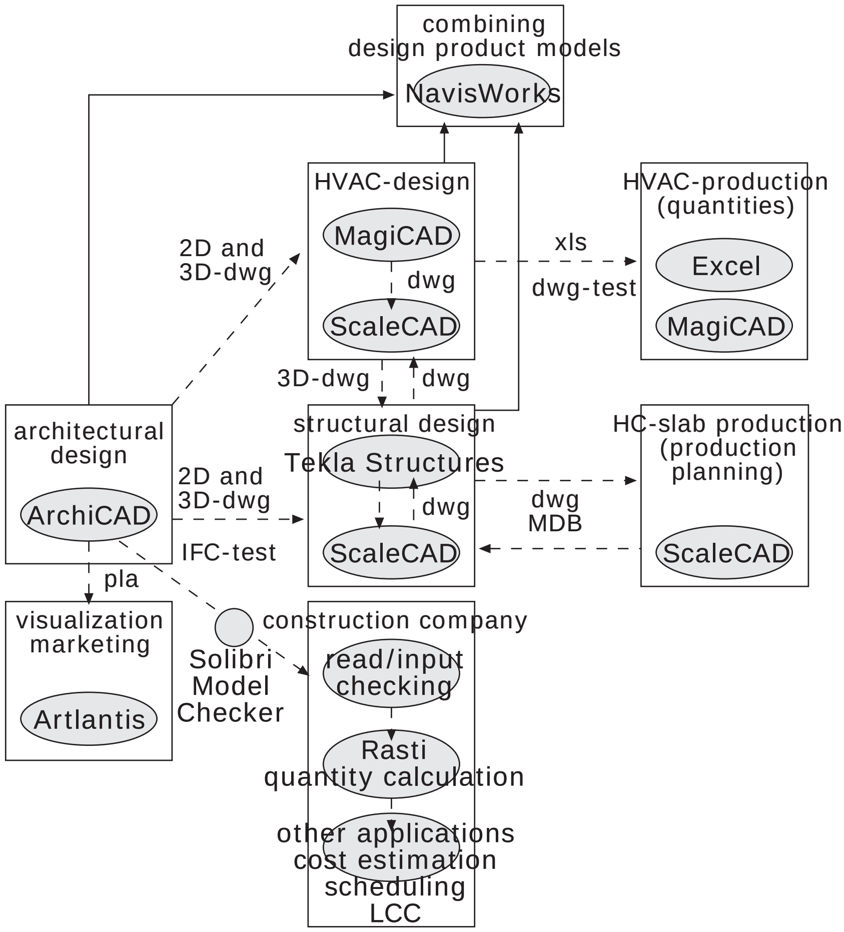

Figure 3 Data exchange used in the Mamselli pilot project

4.3 Extension of a Shopping Centre – Jumbo 2 (72 000 m^2)

Site activity for a concrete and steel framed shopping centre extension started in March 2004. In the Jumbo 2 project, a particular feature was that 4D-applications were piloted in the construction company's site activity planning and project guidance. In the report of the project experiences (Sulankivi, 2004) the tested topics have been:

- How the design phase overlaps the construction phase activities;
- How to combine the concrete and steel frames with a product model;
- How to assist site activity scheduling with a product model.

The software application used was mainly a product model-based Tekla Structures, which was used by all participants. AutoCAD was also used in some tasks.

Since the project is still in progress (November 2004), the reported pre-results have so far been:

- Product modelling seems to support construction companies' site planning and scheduling and also the production of bills of quantities;
- Product modelling seems to reduce errors in design, and it also increases the accuracy of measurements for building frame elements;
- Product modelling seems to have potential in saving time and shortening the total schedule of the project.

4.4 Product Modelling Guidelines

One of the most important conclusions of the Pro IT -project has been the underlining of the importance of education and training, which will obviously extend widely in the Finnish AEC-community in the near future.

The ProIT-project produced the first versions of working guidelines, which documented proper product model-based design activities, and they will have updated revisions:

- Product model-based architectural design guidelines (Niemioja 2004);
- Product model-based structural design guidelines (Finnmap 2004).

The architectural discipline is regarded as an important key producer of product model-based information (Fisher and Kam, 2002). The proper model data should be effectively in use throughout the building process. The future architectural education could also include product data management issues and understanding, and offer skills for a "new kind of professionalism":

- Skills and ability to work in a networked society;
- Skills to manage the design and building project issues throughout the whole life-span of a building;
- Technical skills to manage product model data with applications and tools.

4.5 The Evolution of Information Management

While the majority of building information (in volume) will be in the form of digital data in the near future, a growing volume of the data will also be structured following the [product] model-based guidelines. Document-based and product model-based concepts are not mutually exclusive but overlapping concepts.

A lot of human interpretation and analysis will still be needed in transferring the digital documents between project participants. While data exchange methods and tools develop, the human interaction will naturally never be excluded from the building process.

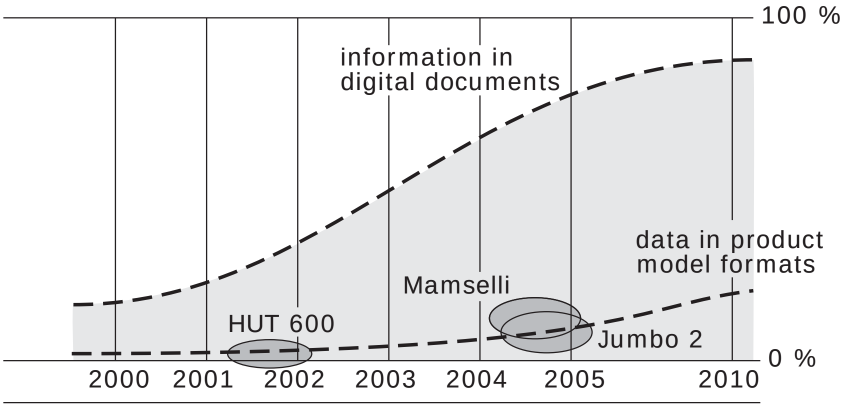

Figure 4 Finnish pilot projects within the framework of building information management

5 RESULTS AND CONCLUSIONS

Building product modelling is currently still in the phase of research and development, testing and piloting for wider real world construction utilization. Despite the complex technical character, the first results from the pilot projects are promising, and the companies involved seem to have a very positive attitude and future expectations of the methodology.

5.1 Comparison of Finland with other Countries

The development of building product model standards would not have been possible without the support of many EU-funded R&D efforts, clusters and networks. Remarkable national research programmes have also been carried out mainly in Finland, Germany and UK (Lieblich 2002). The research work has been supported by national industry associations. Commercial product model-based developments by several software retailers have been reported by Lieblich.

Despite the recent 10-15 years of developments, so far only a small number of actual construction projects have been carried out using building product models (Lieblich 2002). Commercial construction projects of this kind have been carried out mainly in Scandinavia (Finland and Denmark), in Germany and in UK.

5.2 First Application Areas and Technical Aspects

Product models have first been used in data exchange between software applications, first bi-directionally between two applications. Recently the IFC-standard has also been used as a software-independent, neutral data exchange format in the pilot projects.

Calculation tasks and counting performed to produce bills of quantities and further cost estimations have been the first applicable construction field topics. Product models have also been used for various visualization needs for project participants. 3D-views and animations have been produced from the models.

Product models have been used on a file basis (all product model data in a file), but also on a model-server basis, where the participants' applications manage just their own share of the model data (Lieblich 2002). The questions of version handling and design change management have so far been the most critical areas in the first product model server pilot projects.

Technically speaking, a product model is usually not a single database: it is merely a collection of loosely linked databases, where the linking has been done with clear rules. This was also suggested to be one of the future development areas by Fischer and Kam (2002).

A somewhat more technically sophisticated product model application area has been the design phase consistency checking, where design elements' collisions and overlaps have been analyzed with product model checkers such as Navis Works and Solibri-model checker application (Fischer and Kam 2002).

5.3 Benefits of Building Product Modelling

One early recognized benefit of building product modelling-based activity is the gained data consistency.

- Product modelling reduces overlapping data throughout the process, and it decreases multiple work and data redundancy;
- Product modelling also decreases the mistakes in the design information;
- Better management of changes during the process is also a realized benefit.

Product modelling extends the digital data management to the whole life span of a building process. Once stored correctly, product model-based information is usable also in the later process phases. Using product models unifies and simplifies the data exchange methods between project participants' numerous software applications during the process. Precisely defined modelling also clearly adds defined meaning to building data; hence it increases the information intelligence. Product modelling is also thought to give better cost and risk control and higher flexibility in client /participant requirements in a project.

In Pro IT pilot projects the participants have clearly recognized some business-oriented organizational benefits (Sulankivi 2004) such as:

- Product modelling gives a positive image reflecting contemporary technology;
- Product modeling increases a company's internal IT-skills and makes it easier to launch new [IT-based] products;
- Product modelling can lead to remarkable time savings, due to shorter project schedules.

5.4 Recognized Problems

Building seems to be a difficult object to describe, and a construction process is difficult to manage due to several heterogeneous participants with their own needs. Despite that, less than 10% of final building costs is used in design. In comparison, designing an airplane or a micro-chip may cost hundreds of millions of Euros (Eastman 1999). Construction and building design is in fact currently regarded as a low-tech field and a not too research-supportive discipline.

Some of the problems are clearly of a technical nature. Correct and clearly defined building modelling has to be used when the model is supposed to be used effectively later by other project participants. To avoid later re-modelling needs, all modelling activities during the process have to follow the given instructions. Nevertheless, it was recently stated in a product model pilot project, that ”it is better to have a poorly constructed product model to start with, than no model at all.”

The experiences in utilizing IFC in the earlier pilot projects raised criticisms about the technical inaccuracy of the IFC-standard (version 1.5.1) and its implementation on design applications. (Fischer and Kam 2002). The currently available IFC-version 2x is not yet fully implemented by the software retailers.

Despite the positive Finnish attitude towards building product modelling, which might even be a strength in developing efforts (Froese 2002), critical analysis and also some skepticism has been addressed when evaluating the product modelling technology and its usability in the field.

5.5 Expected Changes Ahead

It is hoped that product modelling will lead towards simultaneous design and construction, though it is currently still more at the phase of companies' expectations, hopes and guidelines for near future activities (Froese 2002).

The design phase seems to overlap the construction planning and actual construction phases. Since product modelling seems to shorten the project time span, it saves the contractor money. The shortened design phase and pressure to produce everything quicker could also lead towards over-heated design and engineering activity, unless these changes are not noticed in the agreements between the project participants.

Technical issues are not the only problems to be solved in product modelling in the future. There are also organizational, educational and legal aspects to be changed:

- A true and real desire to do things better with product models;
- The use of effective modelling methods in practice is promoted by publishing modelling guidelines (ProIT);
- Also the common policies within design and building practice and written contracts and agreements between project participants should be involved in the development efforts of the AEC community.

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