MODELING IN CIVIL ENGINEERING AND ARCHITECTURE

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Resumen
Se considera que el uso de Tecnologías de Comunicación e Información modernas (ICT) es una parte integrada de la construcción moderna e industria de la construcción. Building Information Modelling (BIM) gana cada vez más la importancia. Los modelos estan absolutamente esencial para la introducción, realización y aplicación de la nueva técnica y métodos para ingeniería asistida por ordenador (computer aided engineering) en el proceso de ingeniería civil. Hoy en el cambio de estructura en el edificio e industria de la construcción, que es un resultado de globalización económica y europeo que combina la información moderna y tecnología de comunicación atrajo la importancia extraordinaria. Las empresas medias y pequeñas prefieren la cooperación y trabajando juntos. Este puede ser realizada por la nuevas tecnologías de información y de comunicación. En este articulo hablan sobre la importancia y posibilidades de realizacion de Building Information Modeling.
Palabras Clave: Modelo, intercambio de datos, BIM, IFC

Abstracts
The use of modern Information and Communication Technologies (ICT) is considered to be an integrated part of the modern construction and building industry. Building Information Modeling (BIM) is gaining more and more importance. It is becoming essential for the introduction, implementation and integration of advanced Computer Aided Engineering techniques and methods in the processes of the Architecture, Engineering and Construction (AEC) domains. Today, due to the introduction of new procurement systems in the AEC industry responding to changes in the global economy and European merging, the modern ICT technologies have attracted extraordinary importance. Big building enterprises and construction firms co-operate with many suppliers. Middle and Small Enterprises (SMEs) prefer co-operation and working together. Therefore, such forms of cooperation need an infrastructure that can be achieved on the basis of the new ICT technologies. Thus, the importance and advantages of the BIM way of working are discussed in this paper.
Keywords: Modeling, Data Exchange, Building Information Modeling (BIM), IFC

1. INTRODUCTION

The effective application and the appropriate use of the modern information and communication technologies (ICT) have become an essential requirement for architecture, engineering and construction (AEC) practitioners to assert themselves in the market. Meanwhile, it plays no role whether it concerns big, small or middle size enterprises. The mastering and effective implementation of modern ICT developments is rather difficult to achieve due to the rapid development of these technologies which is quite difficult to catch up with. Furthermore, it is often difficult to formulate the exact demands of the technology users and their workflows. These demands can be only defined by reaching a detailed level of knowledge of the underlying AEC domains, internal organisational structure and workflow patterns. Therefore, the first step for an optimum use of these technologies is defining a clear description of the internal procedures or processes (i.e. Business Process Model). This is considered to be relatively difficult especially for small and middle AEC offices under everyday stress.

In AEC offices, it is assumed that the underlying construction project is the central focus point of all processes. The design process and its management are supported by a huge number of software applications all over its detail levels and iteration cycles. However, it is quite often that the various AEC designs are developed separately in parallel using several software applications.

Consequently the question of the data exchange or the interdisciplinary integration of data (i.e. interoperability) is in the foreground in the design process. Here, the main concern is not only about the interdisciplinary software exchange of data in the design phase, but also about the design process as a whole in addition to the life cycle of the building itself.

2. EXCHANGE OF INFORMATION IN BUILDING DESIGN PROCESS

The exchange of information in the building design process can be restrictively achieved despite proprietary nature of software applications. It should be mentioned that this more often than not results in information loss.

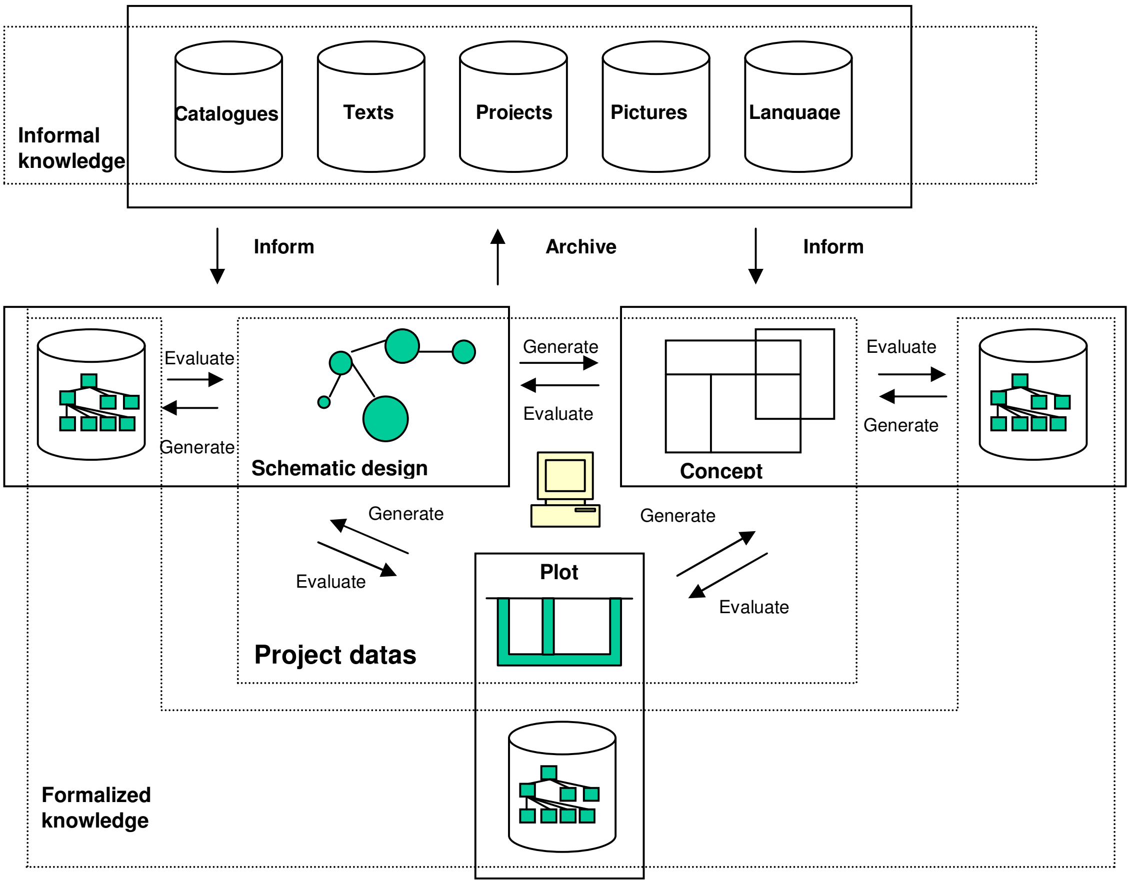

Fig. 1: Example of the flow of information in a knowledge-based system

This concerns, on the one hand, the ICT view and on the other hand the disciplines views. From ICT view it will always concern text including calculations, pictures and drawings (informal knowledge). This data is available of course in different forms to the designers and developers (owners). This data must be processed and worked upon across the several disciplines in the various iteration loops of the design process and finally has to be archived. This can happen across different actors regardless where they are located and regardless their own local time zones. Today in addition to the power of computers and design supporting software tool, linking (combination) pieces of information together is still vital for the effectiveness of any implemented ICT system. The relation between pieces of information can be shown after (Kretzschmar y Kirschke, 1994) in general for a planning segment like in fig. 1. From this approach, it could be concluded that the design process must be considered in its totality as a whole including its functions, constructs and representation. The correlation between different forms of knowledge -formal as well as informal- would ultimately support the evaluation process of design solutions.

A lot of discussions about computer-aided building design or even about computer integrated manufacturing (CIM) have taken place within the AEC domains since a long time. However, the results of such discussions could not be implemented like in the mechanical engineering or automotive industries up to now. In these industries the computer science tools are used generally from the production in the narrower sense (manufacturing, assembly) as well as in the ranges close to production (construction, job preparation, production control, quality assurance etc.) strictly. In the AEC domain only unique solutions as isolated islands of automation still exist. These islands are often described as bottle neck solutions. In the meantime, every project is different from the other, due to difference in location, timing, weather, supply chains, etc.

Therefore, the solution from an engineering-scientific point of view is to link up the software systems used in isolation up to now and to integrate them firmly into the design and building process. This could be achieved through three main tasks:

1) Construction of the necessary net structures,
2) solving the interface problems and
3) organisation of common databases.

Historically two integration draughts reveal themselves for the engineering domain, on the one hand, the product-related and on the other hand the job oriented integration. If this is applied on the AEC domain, the building project-related and the disciplinary oriented integration can be identified (Meißner et al., 1992). Moreover, a further major subject today is the interlinking and the integration of both the design and construction processes and their partners on the basis of a common database. In the meantime, the building industry is very different from the production industry: A building is created not as a standard article according to factory standards, but must be formed as a unique object that is individually designed and detailed, where many professional disciplines and trades are involved. The cooperation model consists of several logical workflow steps in which numerous independent legal entities are concerned with the planning, construction, facility management and exploitation of the building. In general a big variety of different orders and job assignments are allocated to the involved enterprises independently. Many components and working actions are not standardized yet. In the meantime, a huge number of codes and norms must still be considered. In different stages of the execution of the construction project, the need arises for changes, tuning, feedback and update of the design and consequently all related documents.

3. COMPUTER AIDED DESIGN

The concept CAD designates interactive sketching and drafting with computers. In AEC, it is understood as the elaboration of design documents for buildings and equipment. The development of CAD tools is closely coupled to the computers' technological development. In 1941 the first functional programmable arithmetic machine was built by the structural engineer Konrad Zuse. His target was man power intensive mechanical problems quicker and lighter to resolve. This is carried out now successfully since more than 6 decades. Even if the computer capacity was still enormously expensive at the beginning of the new era, computers asserted themselves in the area of the calculation very fast. In parallel with the development of the hardware an immense development of new analyses and their implementation using mathematical algorithms through programming tools took place.

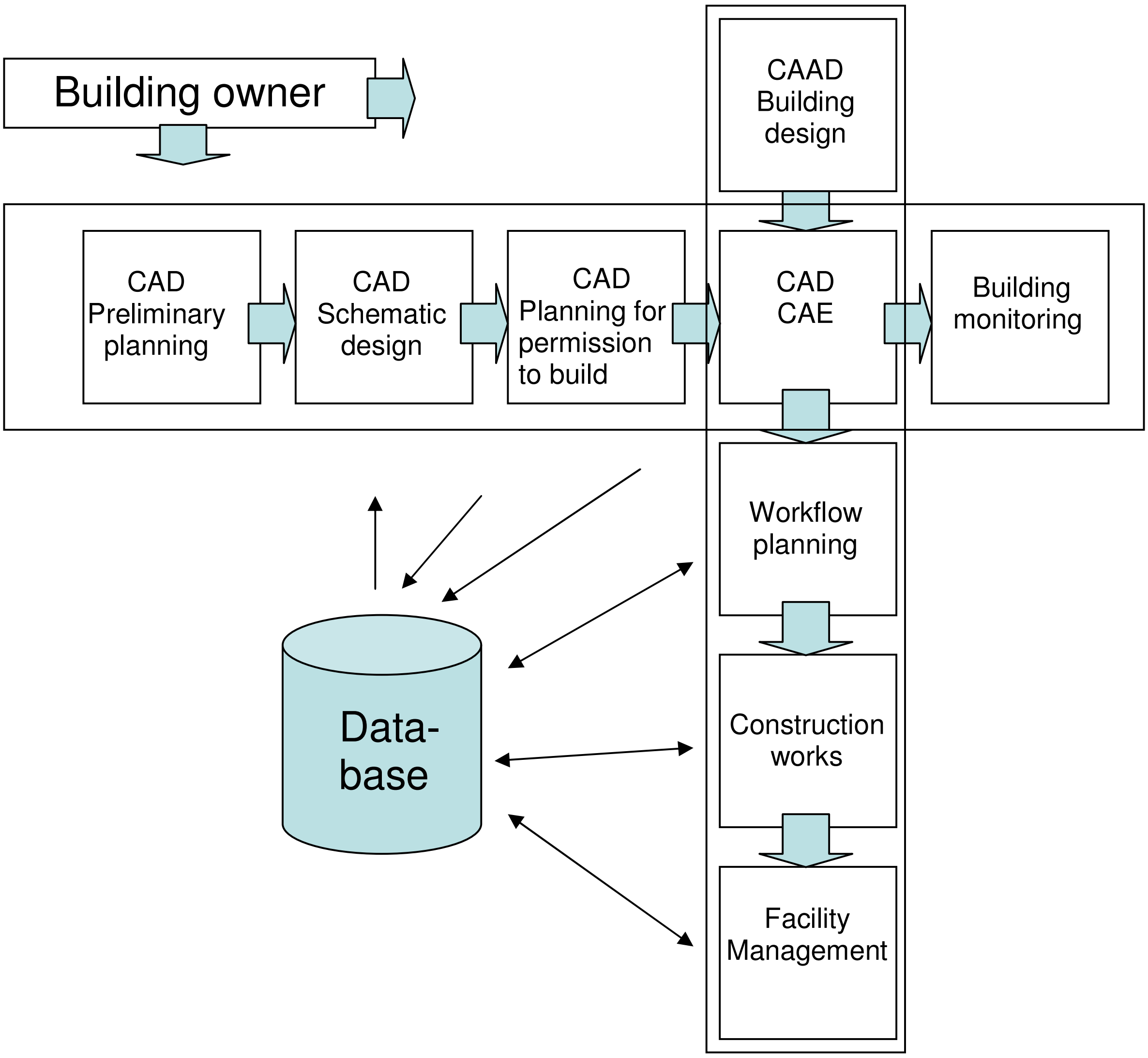

Fig. 2: Horizontal and vertical integration in the civil engineering

The Finite Elements Method (FEM), for example, and its mathematical-technical implementation has become the routine of nearly every structural engineer. Besides, the evaluation of the long printing lists was not always easy at the beginning. A relevant visual (graphical) interpretation was often absent. Here, the technical development of the hardware did not catch up with the development of the mathematical methods and models.

The origin of CAD goes back to the developments of the MIT (Massachusetts Institutes of Technology) in the 60s of the past century. With the help of new peripheral devices (light pen, display, switch) the man-machine-communication was introduced for the first time in an interactive way which enabled interactive sketching and drafting with the computer. Certainly for today's images it was very simply, however, for the past it was revolutionary.

The first practical use of CAD in construction started in Germany in the early 80s. The software products were often developed by the construction companies themselves. Because computer capacity was still very expensive at this time, several users often had to share a computer which was situated in specialized computer centres. The costs of hardware and software were enormously high for these developments. Accordingly, the use of computers was very limited and constrained to certain projects and certain problems. This could really be described as islands of automation.

In the design process, technical drawings are considered to be the formal medium to the representation and communication of design solutions. Drawings are considered to be the “language of the engineer“. Manual drawings have a major disadvantage that they are hardly changeable and are hard to evaluate. The main aim of CAD development since the 80s till the middle 90s was the support of engineers and professional designers by the production and evaluation of drawings. Working with CAD productions became a de facto standard in nearly all engineering disciplines due to the accuracy, amount of information content and complexity that it can represent. In Germany the DIN 1356-1 specifies the contents and basic rules of the representation of construction drawings.

At the Bauhaus university in Weimar the bases of the geometrical modelling with CAD are given for the students through the example of a church building.

4. MODELING IN CIVIL ENGINEERING

The word model has various meanings. In this context only some aspects with regards to the AEC domains model formation are discussed. Within computer science the models can be described as models coming from the professional sciences which can be described and edited with the help of a computer. The question of the model elaboration is now the question of the professional sciences which are simplistic or more or less complicated representation of the reality according to classical ideas. Nevertheless, this leads to a simplistic model concept, because there is no one model that can mimic the reality 100%, but contexts of experiments always specify the degree of abstraction for representing discipline and observation contexts.

Models are the result of a process of development whose aim is the endeavour for a better understanding about the behaviour of buildings. In the course of the time new knowledge has led to the advancement of theories and, finally, to a high specialisation degree. The experiments about static behaviour have led to the development of construction statics that represents our experiences from experiments or from real buildings exactly through manageable mathematical descriptions.

The model development has led to a big variety of models and above all to a clear increase of the design data. The adjustment of data has thereby become substantially more extensive and can be hardly managed according to the former traditional or classical ways. For such needs, the developments have contributed to the creation of technical drawings as a language for the engineers. From the tendency of the present developments, it is recognizable that this will lead on the one hand to a further increase in specialisation and, on the other hand, to more extensive dependencies between the professional models.

The aim of the mapping process is the formalization of an understandable description of the professional models by means of computer software. Limitations arise for the description of the professional models according to the ability to formalise and define the professional models into their corresponding computer models. These limitations are derived to a high degree from the expenditure for the description of the professional models in a computer-compatible form. Other restrictions originate from the algorithm implementation which is determined basically by the complexity of a problem and the computing power. From these compulsions there originates the question up to which degree the work of the designer can be made easier through the use of computers. According to this objective certain elements of the professional model are to be mapped. Besides, the quality of the mapping is measured by the ability to be reused and applied for the same types of problems.

The knowledge which a designer needs for the use of his professional model can be divided in three groups (Weise, 2006):

1. The model state or the design data of the professional model.
2. The behaviour of the professional model, so the reactions to changes of the model state.
3. The linking with an integrating model, so the interrelations between the design data of the professional model and the design data of the integrating model.

If the communication is limited to the exchange of a model state that corresponds to the understanding about the information exchange between designers, then information about the behaviour or other implementing details is necessary. It is rather enough to know the meaning of the design data. If the communicating-partners refer to the same professional model, the meaning of the planning data can be derived from her allocation to this common professional model. Nevertheless, the interpretation is still up to the programmes, as the data is interpreted and is transferred in own data structure.

With the concentration on the model state, the formalisation processes focuses on the data models which are used for the data exchange and increasingly on data management. In this connection, it seems reasonable to derive the data models from the programmes. This is quite interesting when they are conceived with modelling tools and are described formally, for example, when using the Unified Modelling Language (UML).

For the formalisation of data models independent of programming concepts whose origins are in the knowledge representation and the database design are used. Network-like and schema-based representation formats have achieved the best results in this field. In this context, the entity-relation-ship model that comes from the database design is often used.

In the meantime, in engineering applications the description language EXPRESS (ISO 10303-11) is considered as an accepted standard to the description of data models and finds wide support. EXPRESS is based on the entity-relation-ship model that was extended around object-oriented concepts as well as the possibility for formulating consistency conditions. We provide these concepts for the students at the Bauhaus university in a lecture in the second semester. Here aspects of the model description and its formal representation in addition to the computer-supported implementation are in the foreground. Furthermore, a small structural engineering problem is usually modeled and solutions are partly implemented through programming with the help of current database systems. (Kirschke, 2007)

5. DATA INTEGRATION

A building project is totally described using the design data. Due to the existence of several models, the same information exists in different forms and in several technical contexts several times. Redundancies often appear due to contradictions between the various models. These redundancies should be avoided with the help of data integration processes. For example, if the architect changed the size of a space, accordingly the width of the supports must also be updated in the static model. However, the redundancy which appears between or also within models is not always as evident as in this example and often leads to complicated dependencies relations.

The main aim of data integration is to get free from problems due to communicating the common design objects which are shared between models, as for example in the technical drawing. This working mode was achieved at the beginning of the computer usage with data formats specific for products like the drawing exchange format (DXF).

For long time the so-called product models were considered as a solution to the data integration problems. Product modeling is generally concerned with the development of logical models for product data, where here data about construction objects that is needed all over the life cycle starting from the design, installation/ construction and use are meant. The product data includes the description of the geometry, the functional description as well as the description of technical properties and other characteristics. The product data is usually in the focus of computer-aided design. Therefore data integration on the basis of the product data would be possible. With the definition of a product data model the objective is to reach a standard representation of the product information. A product data model is thereby considered a neutral and a general interpretable form which can be used for the exchange and the management (administration) of the product information. Moreover, two aspects are to be considered: the content aspect (application layer) and the aspect of the computer implementation (physical layer). With the modeling it has turned out suitable to introduce an interlayer (logical layer). This layer has the independent application specification of the product models to the object. To create obligations for the interfaces between the content modeling and the tool development unification and standardization at the level of the logical layer is necessary.

The continuous and interdisciplinary cooperation requires a product data exchange, i.e. the transportation of data of a technical object from one into another system, so that continuous processing takes place. Considering the huge number of existing and used systems and their different functionalities and characteristics, it is necessary to provide suitable services and efficient solutions for the data communication and product data exchange. Here, the concept of the neutral exchange models has nearly asserted itself.

To support this approach of the data integration, STEP (standard for exchange of product model data) was developed. The original concern of STEP was the development of an interface for exchanging data between CAD systems. Nevertheless, it soon showed that the interface problems are embedded in the superior problem of the product modeling and product processing. Thus, STEP has been developed to a technological basis for the product modeling.

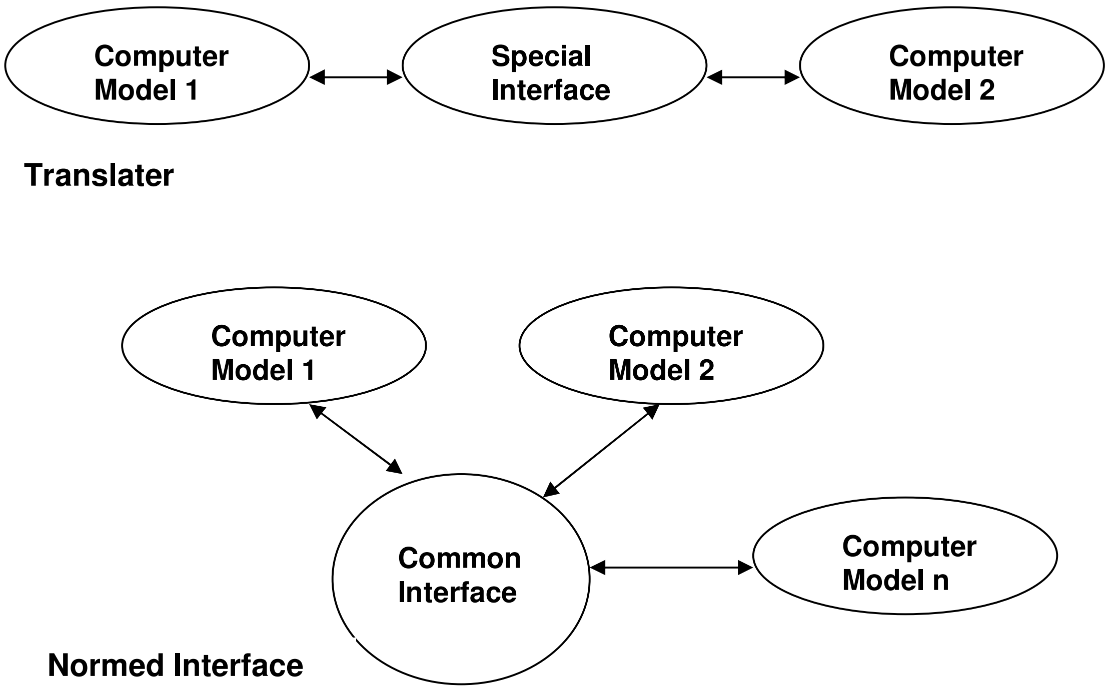

Fig. 3: Use different software

6. BUILDING INFORMATION MODEL

The efforts done regarding data exchange or data integration to be made easier or to be allowed, as already mentioned, exist in various ways. If the designer or engineer uses the same software system, the data exchange or the distributed work today is no more a problem. Nevertheless, if the work is distributed and worked upon by heterogeneous systems, then the situation is very different. There the complicated information exchange comes in the building design process and in the next step to the building use. The traditional and conventional exchange patterns are shown in fig. 4.

The effective communication for the purposes of efficient data exchange between all project partners is becoming increasingly more important. Partner (actors) from different domains like architecture (CAD), construction execution, quantity surveying (calculation program) and Facility management (CAFM) must be enabled to work on the same data basis.

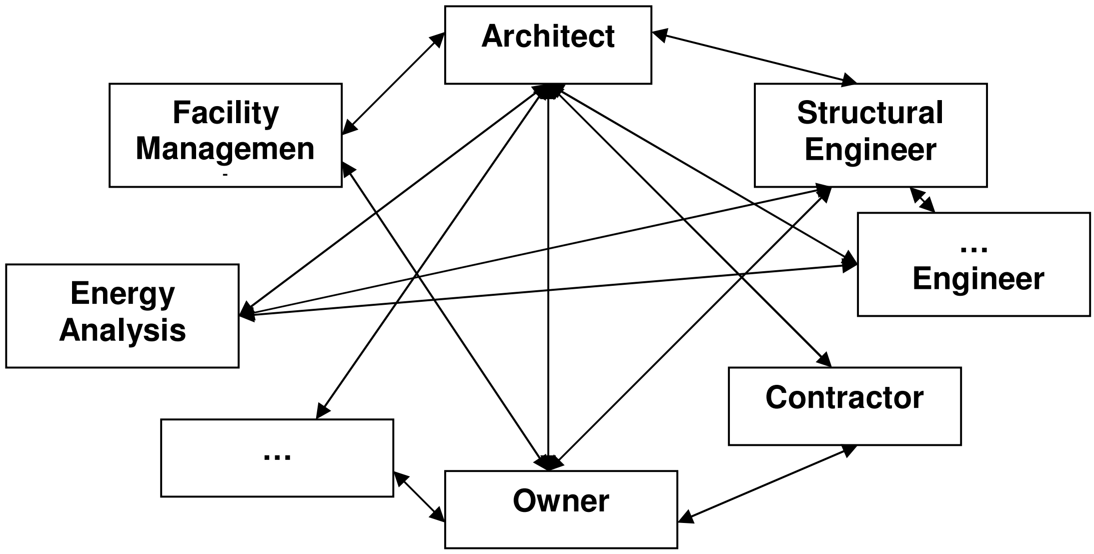

Fig. 4: Communication structure traditional

On the basis of the experiences collected in the STEP initiative and the results of the worldwide research in addition to the urging of the industry, the IAI (Internationally Alliance for Interoperability) now known as "building smart" was first established in the USA. Through the years several international companies from all construction areas came to investigate the potential of different software applications and to develop a standard for Software- Interoperability. There was a need for a concept to save AEC-FM data in Industry Foundation Classes (IFC). Therefore, there has been a need to develop an optimum data structure which contains all necessary components. To avoid big data amounts, only really required facts should be exchanged. It was consequently necessary to limit the exchange to the information relevant for the exchange objectives. Thus, it was necessary to develop model view definitions (MVD) that represent the relevance to certain information exchange needs.

The IFC specification is becoming an international standard that is being defined by an industrial committee of the IAI which is registered since 2005 in the ISO standard 16739. The specification, documentation and implementing directives are freely available, hence, they show a system-neutral model format and exchange file format. The IFC are developed to define a schema for the data exchange of building models between different applications and different AEC domains, especially the communication of different software of the building and construction industry. (Ester, 2008)

Within the scope of the IFC, all components that exist in the building are defined as objects and are interpreted in programmes which support the standard. The IFC are therefore an object-oriented standard which describes all information of design objects (construction elements, rooms, equipment, housing technology, etc.). In comparison to proprietary CAD formats, IFC objects with their properties can be extended with additional necessary information in the fields of management, technical and infrastructural building management. Therefore it becomes possible to encapsulate not only the geometry of the objects but also other types of alphanumeric information like costs, heating loads or referenced documents like drawing data or pictures within the different software programmes, implementation and building use. The data can be exchanged without geometry and with or without alphanumeric properties. Moreover, partial models representing a certain part of the building or data relevant to a certain domain can be exchanged.

The IFC serve as a neutral non-proprietary standard for data exchange in the AEC domains. They offer to all project partners the possibility to derive the biggest benefit during the life cycle of the project or the communication within multidisciplinary design teams. The definition of the IFC covers the whole life cycle of a building construction together with all its phases (e.g. design, planning, construction, tendering, etc.). Therefore, it covers the construction of the building, the facility management up to the demolition. A main objective of the IFC is to minimise data loss within the life cycle of a building and reach a lossless information exchange of design data between heterogeneous software platforms and multidisciplinary design team actors.

The BIM (building information model) is a 3D-building model in which multidisciplinary AEC-FM data can be exchanged. The idea lies in the construction of the data model by the architect and the advanced use by structural engineer, other building engineer and the facility management. Therefore the development of the model is initiated by the start of the preliminary design process that is later distributed among the various AEC design professions. Contractors have the possibility to access the IFC data and query it when required. Finally, it can be used by the owner for the real estate management.

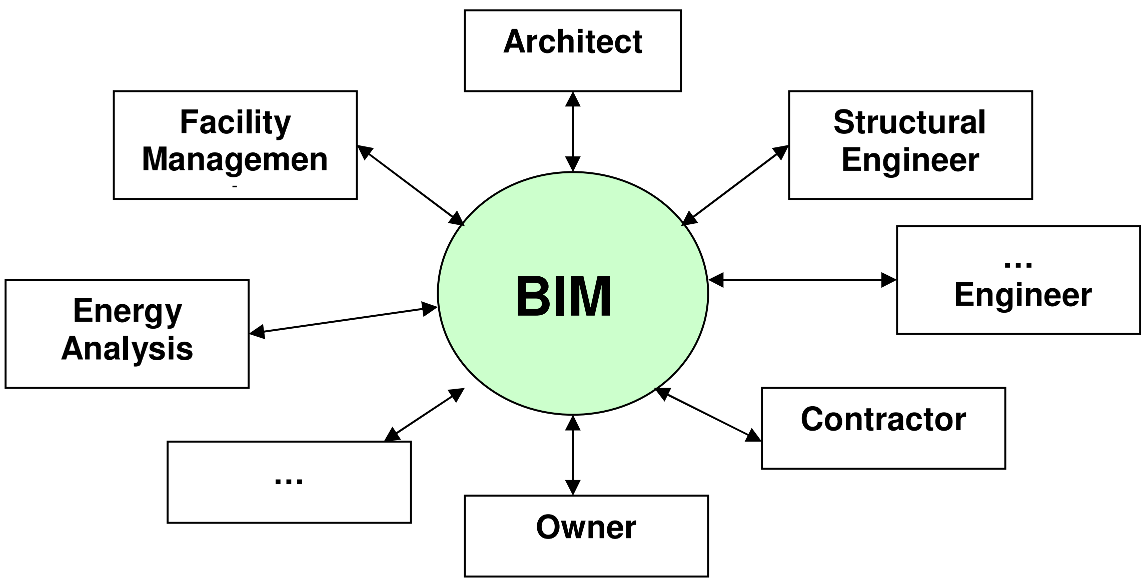

Fig. 5 Communication structure of BIM

7. CONCLUSION

The IFC are currently immerging as an efficient standard for the exchange of object-oriented model data in the construction industry. This development can revolutionise the workflow in the AEC-FM domains in future. Moreover, they allow the interoperability between ICT technologies that can have common access to the information of the building-models. Hence a consistent way of collaborative working across multidisciplinary AEC-FM domains based on sharing information rather than duplication is enabled. A lossless information exchange can be almost achieved by improving workflow aspects and using the appropriate ICT technologies. Furthermore a lifecycle approach to the construction projects is enabled, where information about construction elements and design components are available all over the lifecycle of the building from the first strategic briefing activity till demolition. Aspects of current and future research are the partial model exchange, model view definitions, object versioning and central BIM model server applications.

ACKNOWLEDGEMENT

"The result presented in this paper is part of InPro (http://www.inpro-project.eu) - an integrated project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)."

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