FUTURE OF PRODUCT MODELING AND KNOWLEDGE SHARING IN THE FM/AEC INDUSTRY

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SUMMARY*: This paper describes a technology foresight study performed in co-operation with Stanford University (CIFE) and VTT Building and Transport. The main aim of the project is to provide information for decision-makers about the future of interoperability and product modeling. Information was collected about technologies and their use, conditions affecting the use of the technologies and development trends.*
The project had two main phases: state-of-the-art and scenario building. Different methods were used for collecting data for the state-of-the-art phase. A two-round Delphi survey complemented interviews and literary study. Scenario planning and technology roadmapping were used to formulate alternative pictures of how product modeling and use of interoperable software might affect the industry.
The scenarios are based on two main forces seen as the ones most likely to shape the business environment: the adoption non-proprietary approach in developing software and the adoption of value-adding approach in providing services during the life cycle of facilities. Based on the survey and data, the most wanted scenario is identified as well as different roadmaps toward most wanted scenario.

1. BACKGROUND

1.1 The rationale

The rationale of this paper is to describe the main findings of project called "Future of Product Modeling and Interoperability". The project aimed at finding out how the use of product models and relevant interoperable software can impact the facilities management, building and construction business. The deliverables are:

- scenarios of how business environments might look as a result of the developments referred above,
- roadmaps showing alternative ways from current state of use of technology toward preferred or undesired states, and
- knowledge of what areas of the business processes seem most likely to change,

The scope of the project is to focus on the facilities management and architectural, engineering and construction (FM/AEC) industries and in the use of product modeling technologies within it. This project focuses on the interdependencies of the business processes of the industry and product modeling technologies. Examples of efforts to produce similar roadmaps can be found, such as the

- Elsewise –project roadmap (Hannus, 1999)
- "The islands of automation" –roadmap (Hannus, 1998),
- Theoretical foundations of Engineering Frameworks Workshop roadmaps (Froese, 2001).

These examples focus on finding technological or research and development strategies and identifying topics for further investigations without linking them to possible or alternative scenarios of possible business environments.

1.2 Problem statement

The concept of interoperability of software has probably been used as long as two different software packages have been in the market. Interoperability in the FM/AEC industry has been seen as the most critical factor for re-engineering the business, which is said to (Young, 2001):

- focus is invariably on "the project", Organizes "virtually", players (service providers) coming together to form a team,
- consist of predominantly small businesses in local markets,
- use many intelligent applications, and have little interoperability across applications,
- operate with little efficiency, have very few standards, and
- not be ready for web future, have need to have computers first and need the bandwidth to support web information.

Internationally coordinated efforts to improve the interoperability of design and engineering tools used in the business have been since the 1980's. As object oriented programming tools evolved and three-dimensional tools for design became available, a need to define building and its components in a common, agreed format understandable to a number of different solutions emerged. Efforts such as the STEP (Standard for The Exchange of Product data) standardization work or the work done by the International Alliance of Interoperability have paved the way to such a common format. However, these efforts are still on-going and evolving. The promise of these efforts has not yet been realized due to alleged problems of being too rich in content to be manageable.

The shift to the information society reshapes conventional value chains in all areas of businesses. As an example, the Vision 2010 report states (Tekes, 2001) that the new generation of construction will see industrial fruition as a result of co-operation between customers, designers and the implementation chain and the rethinking of their processes. New information and communication technology will enable procedural simplification and integration based on real time, transparent information transfer, as well as management of costs over the lifecycle of buildings and infrastructure.

Stakeholders of the industry face the problem of finding the right areas of technology where to invest as well as areas of processes where to re-engineer. To succeed in this effort, decision-makers need to grasp a better understanding of the interdependencies of a number of uncertainties. The problem from the viewpoint of the decision makers is that they need to understand their business environment and changes within it better and that they need to be more ready to react to changes faster and more agile. Therefore, there is a need to create a methodology and information to ease the process of making decisions and formulating strategies.

2. APPROACH AND METHODOLOGY

2.1 Research approach

Different areas of science emphasize research by gathering data and drawing conclusions from random samples in very different manners [Olkkonen, 1993]. Depending on the point view, research approaches fall into two categories, either to positivistic (natural sciences, clarification), and hermeneutic (human sciences, understanding). This research work is based more on the hermeneutic approach, although not exclusively. The research relies on hermeneutic approach in developing comprehension of the problem and source material. Normative methods for obtaining knowledge and in processing it further into scenarios have been used as well. Based on the back up of the normative methodology, resulting framework of scenarios and consequent roadmaps to the most likely or desired states were drawn.

Basic information about the problem was gathered by performing a literature study and conducting interviews. This information was used for conducting a two-phase Delphi survey. The knowledge acquired from this survey laid the foundations for the formulation of the initiative scenarios. These were further processed and discussed in a workshop with experts of the field. According to the workshop findings the scenarios and roadmaps were refined.

2.2 Survey

Delphi survey was chosen as a methodology for gathering information. It attempts to obtain a consensus of opinion among experts in a certain field on the likely future. The Delphi method is based on two basic assumptions. First, that the experts working in a field of technology have a good feel of how the field might progress and when certain key results might be obtained. Second, that the consensus opinion of several experts is more reliable than the opinions of single experts. In the light of past experience, it seems that these two assumptions are of the, but by no means always, justified. As long as the time horizon is reasonable and no unforeseen events occur, experts do know what to expect within their field (Braun, 1998).

The survey was conducted by sending out two rounds of questionnaires. The first round of the survey was divided into three areas:

- scope and use of product models today, definition of interoperability, benefits of using interoperable software,
- possible needs and uses of product models and interoperable software in the future, new technologies and trends, and
- identifying new business processes and areas most likely to change within the industry.

The second round of the survey focused on refining the conclusions made based on the first round and tested the opinions on the direction of the future development work in regards to two major factors likely to influence the industry's approach. The panelists are the persons who have contributed to the survey. Out of the 192 questionnaires sent out on the first round, 46 answers were received. The majority of answers were received from various European countries (29 answers). 8 answers were received from North America and 8 from Asia and Australia. The majority of the panelists represent senior level experts or managers within their organizations. Most importantly, the expertise of the panelists with regards to the topic can be considered high. The average panelist has approximately 11 years of experience of tasks related to IT and its use. The panelists can be divided into categories according to the organization type. 21 of the panelists represent the FM/AEC industry itself (real estate owners, designers, contractors, construction managers, building system and installation companies). 12 of the panelists represent academia (universities or research organizations) and 12 represent software vendors. Out of the 45 panelists of the first round 30 panelists answered the second round as well. 19 panelists can be regarded as industry, 7 academics or researchers and 4 as software or information vendors. Out of the 30, 18 were from Europe, 6 from USA and 6 from Asia, Australia or New Zealand.

2.3 Scenarios

The technique for building scenarios was chosen as a basic framework for representation of the findings and in structuring of the main findings in an applicable format. Scenario formation is useful when

- macroscopic factors need to be included,
- long-term time frames are required,
- static descriptions of future environments are useful,
- great uncertainty surrounds the problem,
- data are scarce, unavailable or very expensive, and
- non-quantitative factors must be included.

The building of scenarios can be said to be "Painting concrete and vivid narratives of the future that hinge on key uncertainties whose outcomes will shape the future environment" or "Disciplined stories about the future". The main outcomes are alternatives of how various elements (technology, market demands, competition, and other relevant trends) might interact under different assumptions. This information can be used for better corporate planning and decision making. A methodology described in (Day & Schoemaker, 2000) was chosen as a basic guideline. The methodology divides the building of scenarios in ten steps that were executed parallel to the project research approach as follows:

- Define issues & scope (executed during the state-of-the-art phase)
- Identify stakeholders (executed during the state-of-the-art phase)
- Identify & study main forces (based on the findings of the state-of-the-art phase)
- Identify major trends affecting the major forces and issues (based on the findings of the state-of-the-art phase)
- Identify key uncertainties (based on the findings of the state-of-the-art phase)
- Select two most important key uncertainties -> 2x2 matrix -> 4 alternatives (based on the findings of the state-of-the-art phase)

- Assess the internal consistency and plausibility of the initial alternatives -> revised scenarios (based on the findings of the Delphi study and the workshop)
- Assess the revised scenarios (Based on the findings of the workshop),
- Re-examine internal consistencies (Tested in the workshop and executed during final reporting)
- Re-trace steps 1-9 (Executed during the final reporting).

2.4 Roadmaps

As an integral part of the scenarios, roadmaps defining the evolvement from present state to the state described in the scenarios were drawn. A roadmaps is defined as an "identification of elements, issues, & paths towards a defined goal" (Froese, 2001). Some sources and examples present roadmaps in a way that is very close or even identical to strategies or even action plans. This project, however, uses the term for a roadmap somewhat differently. The emphasis is on providing information to be used as background material when making decisions rather than providing a guideline or a definite route to be followed.

3. STATE-OF-THE-ART AND TRENDS

3.1 Defining interoperability

Two concepts crucial to this study are obviously product model and interoperability. With "building product model", one refers to the data used in a construction project or, to "a particular type of product model, a computer-interpretable description of a building, structured according to some building product data model. Some difficulties occurred in finding a definition for interoperability in conjunction with object-oriented software within the FM/AEC industry. The panelists were given a number of suggestions for a definition and a chance to give suggestions. The answers of the first round were divided between the choices indicating that a transferable building product model should be commonly used or shared by different applications or services throughout the life cycle of a facility or a building. Most of the answers emphasized the need of a common logical (standard geometric and semantic) structure.

Based on the revisions made by the panelists during the second round, the following definition of the term interoperability was defined: "Interoperability (as understood and used within the FM/AEC industry) means that *a building product model data can be transferred to or shared with* all of the relevant applications, throughout the life cycle of a facility or a building, *by using a common logical structure*."

3.2 Use and benefits of product models today

The panelists were asked about the use of interoperable software and product models as well. Most experts felt that the most advanced companies in the industry seem to have interoperable software partly in use for adequate communication with partners (e-mail, project web sites, etc.). As one of the experts put it: "The current status of interoperable software is low and patchy (as it is still in its early days), but it is crucial to truly enable and use web-based solutions (e.g. Project Websites) while allowing the various project partners to use software and processes which suit their particular needs. It also underpins the flexibility of project and the need for true value adding by all participants, as well as the ability to all work from the same model".

However, it was felt that there are not enough solutions available at the moment to turn interoperability to a competitive advantage. Most companies rely on the market to take its course in the development and adapt accordingly. Most companies are currently looking for solutions or piloting ones. When asked for the benefits of the use of interoperable software, the panelists gave some indication of evidence, such as:

- being able to record better productivity in projects through improved data flow (12 answers),
- being able to save money by having to make less paper copies, having fewer meetings and less rework (8 answers), and
- showing reductions in project lead times (5 answers).

Most of the comments given indicated that the first generation of interoperable software is just entering the market and that all results so far have been promising, but very little has truly been measured. According to one of the answers, evidence can be found in some pilot projects from as early as 1994 and from other industries, but research work on finding the impact interoperability are needed. One panelist stated that according to studies conducted in the UK, the investment in interoperability pays off with the factor of 4 to 10 in terms of avoided rework only.

The second round of the survey focused on refining the conclusion shown above. 25 of the panelists out of the 29 answers accepted the definition without or with minor comments. Three panelists disagreed with the statement. The comments pointed out that the statement is optimistic, the standards for interoperability are not yet robust enough, and that the pioneers now testing the concept are paving the way for the vast majority to follow. If the concept of interoperability is to prevail, the industry and its customer need to understand its added value. In this respect the concept and the industry is now in a turning point.

As a conclusion of the scope, definition and benefits, one could state that:
The industry as a whole is now on the threshold of adapting the actual concept of interoperability and slowly putting product models into use. The users now can be described as early adopters and the majority of the industry (estimated at over 90%) has not reacted yet. The potential in terms of concrete cost savings is visible, but the actual impact on the processes and the businesses is not known yet.

3.3 Emerging technologies and areas where they are most needed

The gathering of information concentrated on finding the emerging technologies and the areas where these technologies are most needed. The first round of the survey produced a preliminary list of the needs and this was refined into a list as shown in Table 1.

Table 1: Refined ranking of the functions most urgently in the need of interoperability

Area	N:o of 1^{s} priority	N:o of 2nd priority	N:o of 3rd priorities	N:o of 4th priority	N:o of 5th priority
Quantity take-off and cost est.	9	3	2	0	1
Use of product libraries	4	9	1	1	2
Architectural design	2	5	3	0	1
Other design functions	1	2	3	5	0
Facilities Management	1	2	4	2	4
Life Cycle Cost estimating	1	0	2	2	2
Structural engineering	1	1	1	2	0
Code checking	0	0	2	3	2
Visualization	0	1	1	2	2

The experts commented that all some of the design disciplines are already well on their way in deploying new tools. The technology seems to be available for quantity take-off and other disciplines, but not really deployed. Some of the answers on the five most important areas suggested, that the design disciplines should be integrated as one entity with architects in the lead. At the same time or after this, the contractors and project management professionals should integrate their tools, such as scheduling with the designers. The use of 4D CAD was seen as a good step forward.

Based on the results of the both rounds, areas where product models and interoperability should be put into use to have the best possible impact on the industry are rather easily identified. As a conclusion, the suggestion of this study is to give priority to:

- use of interoperable quantity take-off and cost estimating,
- integrating architectural design to other design disciplines and analysis functions,
- development of open, object based product libraries,
- the use of model data by Facilities Managers (in activities such as occupancy and move management, and
- development of life cycle cost estimation tools.

The panelists gave justifications on why they see these areas as priorities. For example, improving the interoperability of quantity take-off and cost estimating will result in immediate business benefits due to decrease in resources, increased accuracy and the possibility to test alternatives with less effort. Better

interoperability for architects or architectural design and planning processes was seen as one of the most important areas, since this is the main source of information for the following activities.

The development of product libraries was prioritized high. It is seen as one of the key elements enabling better use of life cycle information. The manufacturers can be active in providing this information and thus add value to the models. Building information vendors may have a role in this respect as well, since they are in a key position to change information exchange from paper based to digital format. However, also skeptic comments regarding the product libraries were expressed. It was pointed out by one panelist that technically this is not a major issue, but the agreements ensuring interoperability between those who provide the information may prove to be very difficult to make.

The panelists regarded facility management functions to be of particular interest. However, it is evident that the majority of the panelists does not represent or have a very wide experience of the FM sector. Some of the comments emphasized the need to use product model data in space management, security, different types of services, sales, etc.

The panelists were asked to prioritize emerging technologies on the basis of which ones need to be developed first in order to gain the potential benefits of interoperability. The comments pointed out that the FM/AEC industry is not in the position to solve problems such as high-speed data transfer or data transfer security. However, these technologies have will have an effect on interoperability and use of product models. Some of the comments pointed out critical relations between technologies. For example, the use of data exchange protocols, such as XML, will not be very useful without developments in common product model schemas. Based on the comments, this study ranks the technologies most important for interoperability as follows:

- common, standardized product model schemata,
- new internet data exchange or access protocols,
- model server technology,
- intelligent agent technology and
- user interfaces.

3.4 Two key uncertainties

In addition to gathering data on technologies and their use, it is of vital importance to distinguish key uncertainties that are independent of each other and have the most dramatic effect on the issue in question. Based on the information collected by the survey, interviews of industry and other experts, as well as data collection performed in this project, the following two major axis guiding the trends were recognized by the researcher:

1. The distinction between proprietary or non-proprietary approach:

A major influence on the future will be the approach taken by software developers on a data structure for the product models. The vendors might adapt a proprietary approach, count on their own, protected code to be adopted by the industry as a de facto standard. The vendors would thus count on the customers to base their integration on this proprietary software. The other end of this axis is that vendors agree more on a common, open standard data structure as basis for development.

2. The emergence of a demand for life cycle oriented, value adding services in the FM/AEC industry:

The other major axis for the development work is the question of whether the industry will be able to add value to the end-customer that finally picks up the bill. This development might emerge if the FM and AEC industries actually start to merge into one industrial cluster. Thus, interoperability and product models might have the chance to add value to new services. Instead of focusing on the cost reductions in the existing process, the industry might start to see a potential to new, value business opportunities and decisions will be based on the life cycle economy.

3.5 The desired trend

The two key uncertainties were tested during the second round of the survey. The expert panelist were asked to give their opinion on the likelihood of how the uncertainties will actually develop in the next 3, 5 and 10 years. The experts were asked to place numbers into one or more of the cells in the following table depending on what

the most likely direction of development will be. Figure 1 was drawn to illustrate the opinions of the panelists. The majority of the answers see the development towards non-proprietary, value-adding area as the major trend.

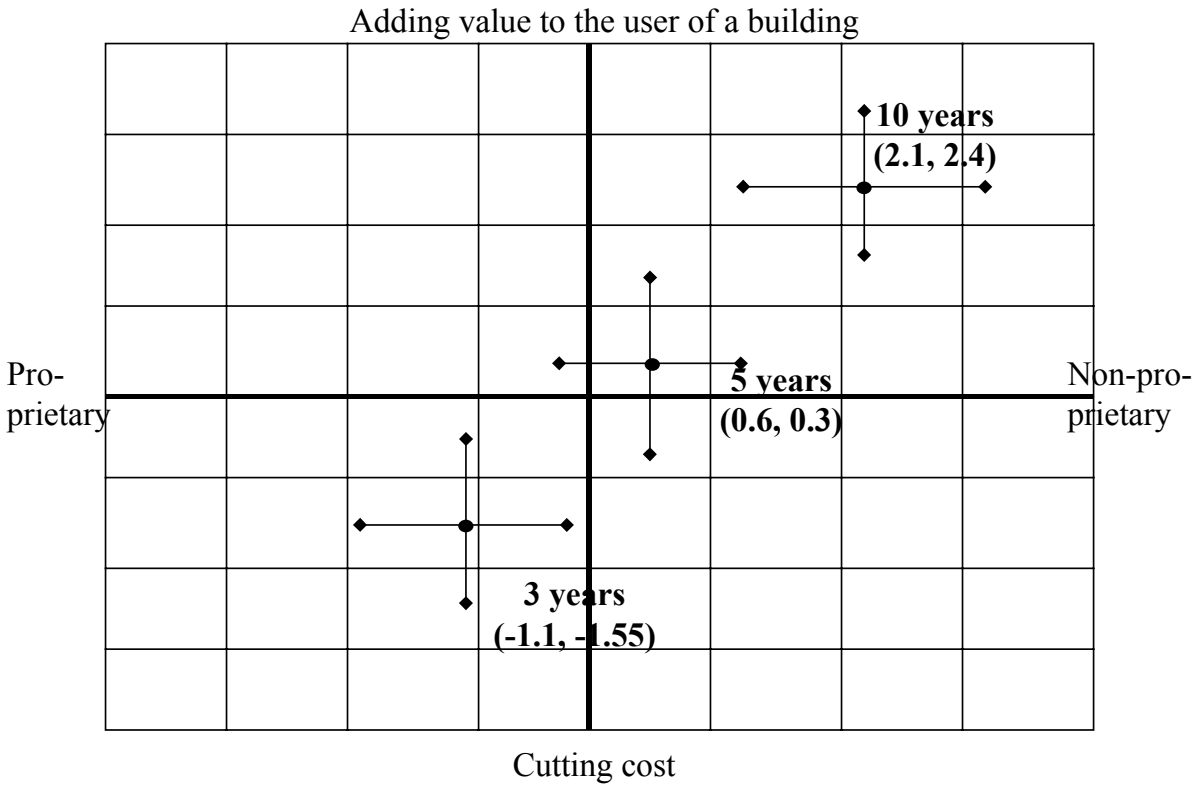

FIG. 1: Averages (points in a scale from –4 to + 4 and lines representing standard deviation) of expert opinions of where the industry might advance in 3, 5 and 10 years from now calculated from the survey answers.

Most of the panelists placed the industry to the lower left-hand corner for the duration of the next three years. The majority of answers gave an indication, that the situation will have shifted just over the side to the upper right hand corner, i.e. non-proprietary, value-adding approaches would be slowly prevailing within 5 years. Most of the answers gave indication that within ten years, development will clearly have lead us to the upper right hand corner, i.e. towards more value adding – non-proprietary approach.

Some of the comments pointed out that the migration might not be very simple. As one panelist commented: “A near term proprietary approach is needed because standards don’t exist. The most likely scenario is that standards around E-business will be adopted by the FM/AEC industry. Proprietary standards are usually required early, however they should evolve to a non-proprietary status. Non-proprietary status is essential to enable rapid adoption and development”.

The value-adding approach was very much wanted by the panelists. However, many of the comments regarded the time frame for this trend to happen as very long. The industry’s ability to adopt tools for the analysis of life cycle economy is one of the key factors needed to speed up this trend.

4. THE “OPEN FM/AEC” SCENARIO

4.1 “Open and value-adding” prevailing

On the basis of the data collected from the experts, the researcher developed scenarios according to the method laid out in section 2. The consequent framework; alternative scenarios, factors and possible roadmaps were tested and further discussed in a seminar with 25 experts. This paper focuses on two of the scenarios that are based on the two by two matrix shown above. The scenarios are called "Open FM/AEC" and "The cost effective divide the market".

Both of them are presented to give a narrative picture of how the future might look. Therefore, it is not the nature nor purpose of the scenarios to find out what is the most probable future, but to help in structuring different alternatives should one or the other direction of either key uncertainty prevail. It should be noted that there is no statistical, direct positivistic connection between the data collected by the Delphi survey. The information gathered is used by the researcher as the main input for intuitive reasoning in making the scenarios.

Two scenarios were described in further speculated detail. They represent ultimate opposites of the 2 by 2 matrix shown in Fig. 1. The upper-right hand corner (value-adding and open approach prevailing) and lower-left hand corner (cost minimizing and propriety approach prevailing) were chosen. The reason for choosing extreme opposites was to highlight the differences in approaches and in evolving circumstances. Furthermore, both scenarios are complemented by roadmaps that illustrate possible paths in technology development work leading to respective circumstances. The roadmaps are presented to give idea of when different breakthroughs might be possible along the way from present situation to the likely scenario in 5 – 8 years from now.

Based on the results of the survey and the seminar, it is evident that there is a strong desire for non-proprietary (or open source) and value-adding approaches in the development efforts of vendors and industry professionals. Should the development work take a favorable course in the terms of these to uncertainties, the scenario for this situation can be characterized as:

- having much more integrated delivery chains (different modes for projects do exist, but they are characterized by having far better integration in terms of data transfer and collaboration, even having minimized transaction costs),
- having richer product models available that covers information about the properties of the building, its parts, their functionality, cost, etc. over the life cycle of the facility,
- having an integrated, version manageable model data available that can be handled by different, more intelligent tools,
- having a wide and easy access to the product model data with mobile and ubiquitous computing devices and advanced user interfaces and working environments,
- having the availability of tools for "virtual construction", i.e. tools for designing, constructing and simulating use before actual construction activities begin, and
- having decisions made from the life cycle economy and user perspective.

Furthermore, this scenario makes the assumption that development work of software will be based on the user needs, i.e. the industry. The industry has become a more active and demanding in the development work itself as industry sees new opportunities in new, value adding services as the business environment and the FM/AEC structure evolves. Especially the new roles of facilities managers and building owners will have contributed to this change. The industry operates more dynamically in terms of project modes and is able to take more risks. The simplified characteristics of this scenario can be laid out as in Table 2.

Table 2. Characteristics of "Open FM/AEC" -scenario approximate time horizon of 5-8 years.

Area	Characteristics, features
FM/AEC Market	New, emerging markets for different expert services based on the value of knowledge. Competition is also based on best value during the life cycle and not only the price of initial investment. Competitive advantage in this case is based on the ability to show to end-users virtually and in advance how value is added. Part of the industry is taking risk in market creation and has developed different business models. Competition has become more global, also among medium size companies and between their networks, although projects are set up locally. Owners and facility management professionals have a strong role as service providers and being

	closest to the end-users of facilities. Information content will form a significant factor in the competitiveness of manufacturing of materials and products
Software market & use of data models	▪ Open and common data structure has contributed to creating a larger market; richer variety of services and tools is available for less cost for the buyer. ▪ Market entry for new software products and service is easy and especially new start-ups are formed more often, but also have a shorter life span. ▪ The competitiveness of a software as a product is based on other features and functions than file formats or a proprietary data structure of a facility.
Technology policies and options	Technology is seen as the means for solving business problems or as a platform for new business models. Research funding is directed towards open data standards or applications supporting openness. International co-ordination efforts helping in creating a common data standard platform are backed up. More shared or collaborative risk to develop tools or new business aiming for added value is rewarded. Emphasis on solving possible contractual conflicts due to the use of models has been paid.
Areas of process engineering	Design process revolutionized from two-dimensional drafting to object oriented three-dimensional design. Models are used during maintenance and operations phase for various tasks such as workspace management, quantity take-off for maintenance/refurbishment contracts, simulation of different operations such as fire or other emergencies, actual performance data is analyzed, etc. Construction project management and especially procurement has partly been able to diminish unwanted transaction costs. Projects are done virtually before actual site opens, i.e. the model is designed and project scheduled virtually on the computer. This involves re-engineering of the construction management processes as well as design. Processes interacting with the end user of a facility are re-created. Product manufacturing involves a component of producing model information and making used intelligently during design and procurement.
New emerging technologies	Advanced user interfaces, for example stereoscopic simulation or visualization Mining or knowledge re-use of project data, comparison of actual versus planned performance New building automation or construction automation applications using model data
New key technologies	Model server technology ("full" model in one logical location enabling manageable access of different applications without having to worry about changes). Use of wireless technologies to improve access to remote locations, deliveries and sites. Parametric model or product data libraries. Extended project collaboration tools enabling teamwork (visualization, simulation, "what-if" analysis) with the model
New applications	Intelligent uses of models, software analyzing models, for example against codes. Life cycle economy analysis tools, simulation of value-cost relationship "always on". New types of product catalogues. 4D (3D + scheduling) software in use in most large projects, aspects of operations simulations included.

4.2 Towards the "open FM/AEC" scenario

The path from the current situation to the wanted one can be drawn in various ways and there is no single answer to the problem of mapping the path from here to year 2010 – or any other year for that matter. However, trying to identify possible breakthroughs and making alternatives helps in structuring the problem and gives better insight and is more likely to result in more successful action. The roadmaps shown can represent only examples of the large number or alternatives that should be collected to an atlas to give thoroughly complete and covering tool for making decisions.

The first roadmap tries to identify major breakthroughs probable to happen or needed on the way towards "open FM/AEC", see Fig. 2. This path can be called the "all encompassing model" –path. This roadmap builds on an approach by Charles Han (Han, 2002) as well as on information gathered in this study. This approach is chosen by the researcher since it relies on the "top-down" approach in managing the standardization process and relies on the coordination of the implementation of the standards to be successful throughout the industry in much the same way that happened in mobile telecommunication standardization in Europe. The GSM standard (Global Standard for Mobile Telecommunication) was used by all operators, which provided a platform for growth. In the USA, the same approach has not really worked in any industry.

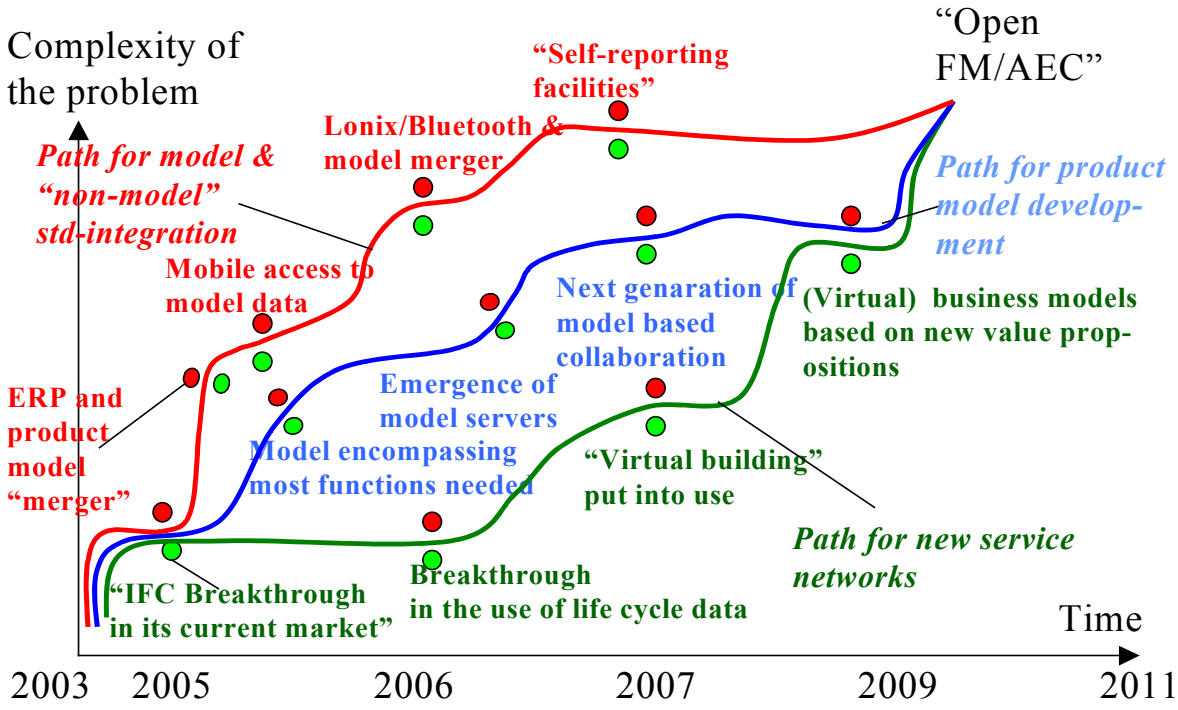

FIG.2: The "all-encompassing data model" –path towards "open FM/AEC".

This alternative displays three complementing paths towards the "open FM/AEC" scenario. These paths pass different gates representing breakthroughs on three areas: formation of new types of business and service networks, product model technology itself and in merging of model approach to other areas of information and building automation technologies. This roadmaps assumes that the major breakthrough in forming a common base standard for building product model has taken place, for example by the vendors and industry widely adopting the Industry Foundation Classes standard (IFC). The basic assumption in drafting this path is that the common model can be very rich but still functional and manageable by for example, model server technology.

The model and its definitions can serve all needs of the life cycle of a facility and the vendors are able to comply with these standards. This will also result in the further usability and merger of the all-encompassing model to cover more and more areas of use outside design and production planning, such as building automation or enterprise resource planning. Also, the "all-encompassing" approach is applied also to the formation of new types of business networks or processes since a network is expected to use a model in its full capacity. The benefit of this approach is that the common standard will enable very wide scope of interoperation. The downside is that the process of creating an "all encompassing" standard is practically impossible or too slow to succeed.

5. "THE COST EFFECTIVE DIVIDE THE MARKET" -SCENARIO

5.1 Cost minimizing and proprietary approaches prevailing

The extreme alternative for the previous one is dealt with in this paper. It assumes that development is based on non-proprietary approach and that the industry still makes decisions on initial price only. This alternative was chosen to highlight the differences between the previous scenario.

This scenario is based on the assumption that software development is based on proprietary data structures of building product models. It also assumes that competitive advantage is based solely on cost leadership. Market will be polarized: Large companies try to rely on economics of scale and small ones specialize and focus on specific market segments. Interoperability is based on "point-to-point" approach, i.e. if two parties agree to share the means of data exchange. Typical of the scenario is that:

- There is very little variance in the business processes or project modes. Building owners and professional clients rely on a few standardized modes.
- Product modeling technologies are in use in companies that can justify long-term investment by clear cost savings.
- Product models can be managed by different software packages as long as the packages belong to a certain vendor's product portfolio.
- Access to the model data is easier and more versatile; for example, mobile devices can access data.

More characteristics are shown in Table 3.

Table 3. Characteristics of "The cost effective divide the market" -scenario, approximate time horizon of 5-8 years.

FM/AEC Market	Very little market pull, end-users of facilities have very little power or influence. Owners look at return on investment on a time horizon extending to the end of the first or second user's needs ▪ Industry is polarized; largest companies can operate worldwide or form alliances with, for example, vendors, otherwise there are lots of smaller companies acting locally in very fragmented markets. Industry is very risk averse and looks for cost savings in its development efforts.
Software Market & use of data models	▪ 2 – 3 very dominant software vendors divide the market for modeling as well as other software. ▪ Vendors react to emerging but very fragmented needs by adding on features to their existing software packages. ▪ Regional differences in packages are great (US, Japan, Europe each are dominated by different vendors with very different approaches). ▪ Small vendors depend on the set "de-facto" standards of larger vendors, and need to partner accordingly.
Technology policies and options	There are no coordinated efforts or common, global policies. Collaboration occurs in focused areas. Technological advances are expected to take place in individual organizations, joint ventures are not supported. Bodies such as the International Alliance for Interoperability does not exist Governmental or other public support is not directed in this area. Sponsors leave it up to the markets to take its course in standardization. The strongest players might be supported in their most advanced development efforts.
Areas of	No major changes in the construction processes, as we know it except for design becoming more

process engineering	object-oriented. Bidding and procuring is streamlined and becomes more effective, but the process remains basically the same. Facility management function uses as-built data to a limited number of tasks depending on whether vendors have developed tools for the purpose or not.
New emerging technologies	Tools enhancing trust building within project teams. On-line sub-contractor evaluation. Full service software packages providing solutions for the life cycle of a project. Tools helping in re-using the knowledge.
New key technologies	Model or schema translation technologies. New types of project collaboration tools enhancing work of the design teams. Automatic quantity take-off and cost estimation from certain available models to certain estimating packages. Electronic billing
New applications	"Full service" CAD packages, intelligent project extranets able to manage model data – as long as the software is by the same vendor or vendor family. Intelligent portals or e-commerce sites able to transfer product model data according to a specific vendor's schemas or data standards.

5.2 A possible path towards "cost effective divide the market", point-to-point -approach

The vendor driven future laid out in scenario "cost effective divide the market" is likely to result in a very different roadmap. Fig. 3 shows a roadmap that can be called "interoperability based on point-to-point approach". This alternative bases on the assumption that different software vendors try to serve their customers as well as possible by extending their packages towards more comprehensive package. Adding on new application areas can also be done by mutual, bilateral agreements between vendors. This is how a specific schema of vendor 1 can become interoperable through with vendor 2's software and or schema. Also, it is possible that specific model translating software is produced to address the problem. In the Figure below, tentatively three paths are sketched, two for competing hypothetical CAD vendors and one for their smaller affiliates. Typical of this roadmap is that interoperability relies on domain specific "point-to-point" approach, richness of the model is seen as a distraction and small subsets of data are more likely to be exchanged in standard formats. Translations between applications are more likely to be in use than models according to one standard schema. The benefit of this basic approach is that applications are likely to emerge very fast and according to the presumed need. The downside is that this approach does not give any guarantees on reaching a situation feasible for the fragmented industry.

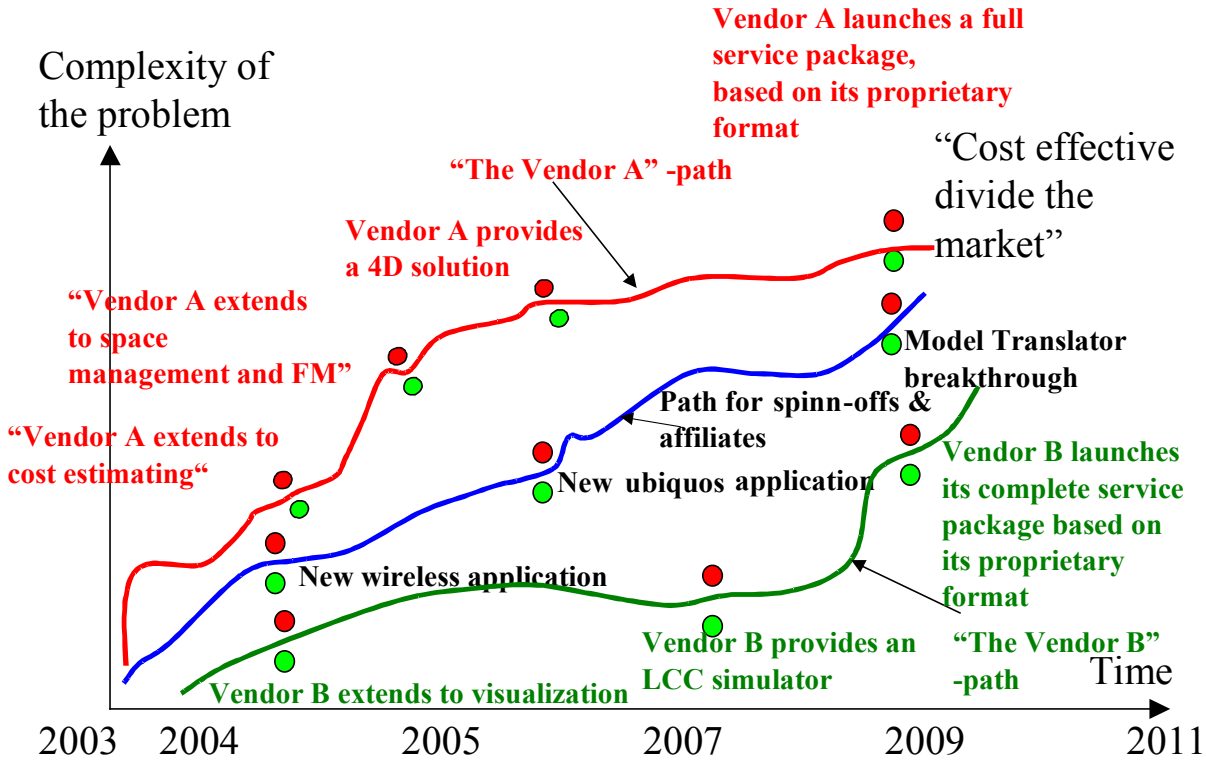

FIG.3: Possible paths and imaginable breakthroughs towards the cost effective divide the market scenario.

6. IMPACTS ON PROCESSES AND ROLES IN FM/AEC INDUSTRY

It is evident that processes within the FM/AEC industry need to be re-engineered if object oriented, intelligent and interoperable modeling tools are to be used to their fullest capacity. Re-engineering needs to take place both on the level of the whole life cycle from project initiation to recycling of building parts or demolishing of the whole building.

Areas where technologies have a profound effect are:

- Processes having to do with end-user interaction. End-users or customers can influence the setting of design criteria, making of selections and see the impact of these to the operations and maintenance as well as to the whole life cycle economy.
- Design will change from drawing to modeling. This applies to all design disciplines. Different designers are required to work as a tighter team. This also allows the designers to find new ways of pricing their work – instead of putting a price tag on a drawing; the pricing can be based on the value of the information.
- Before the actual construction, the building can be constructed virtually, i.e. on the computer screen. This means generating alternative schedules and simulating the actual erection or construction event. This helps in optimizing the process and can be also applied to the operations and maintenance.
- Quality assurance processes can truly focus on analyzing risks and creating procedures for avoiding unwanted events. Different control and checking procedures can be tailored as the virtual planning proceeds.

One example of what kind of re-engineering on the whole life cycle might mean is shown in Fig. 4. The process shown on top is based on (Karhu & Lahdenperä, 1999) and the revision of that on discussions and outcomes of this project.

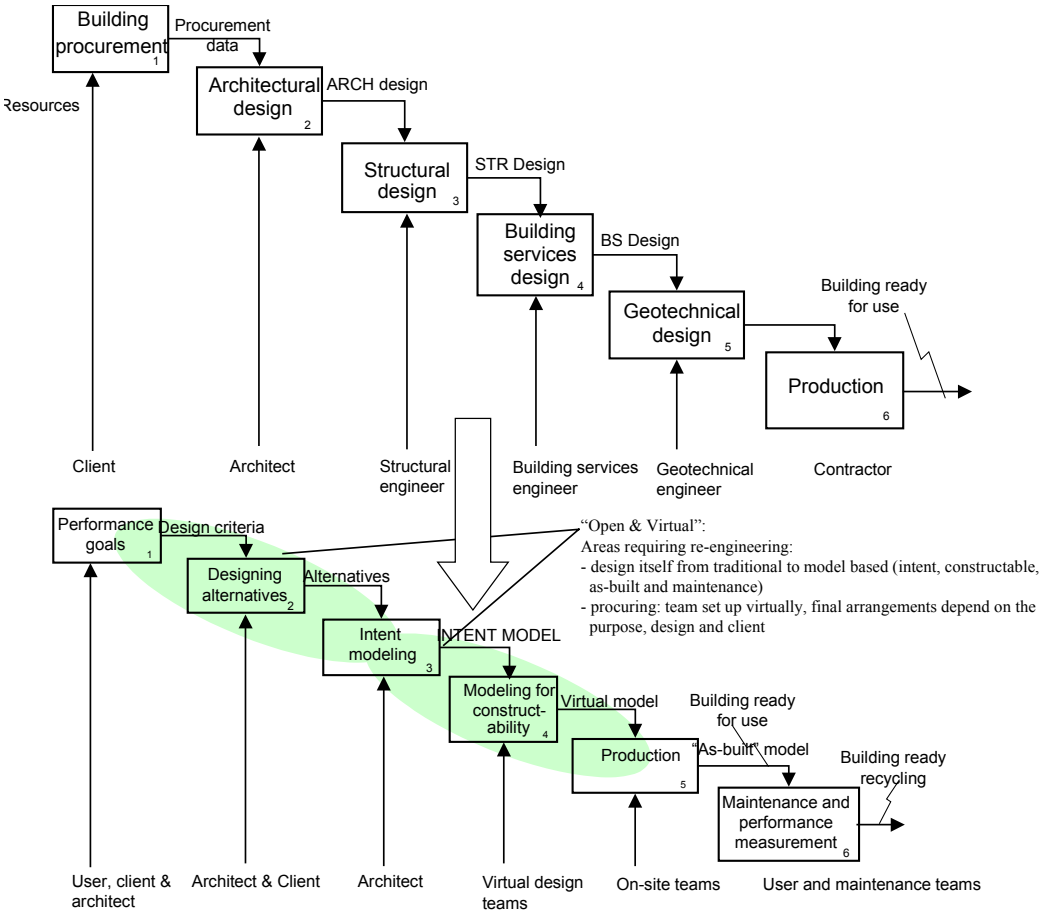

FIG.4: Some probable areas of the process requiring re-engineering.

The roles, processes and strategies of different players of the FM/AEC industry are likely face changes as well. Impacts of the technologies can be structured by looking at alternative scenarios and how advanced, innovative organizations are likely to react. For example, if innovative owners are more inclined to adopt the "open FM/AEC" scenario, they are likely taking risks to create new services, they interact with the end users and simulating the use of a facility together with their customers, they can configure a project modes according to the market situation and project features, they use models and model based tools during maintenance and they have modeled their entire building stock. Should the owners rely on the "cost effective" –scenario, they are inclined to use sophisticated asset management tools for controlling the costs and cyclic nature of the market, life cycle costs are under control, investing is mainly based on attractive location, marketing uses sophisticated visualization tools, and operations and maintenance uses the tools of one particular vendor for numerous functions.

7. RECOMMENDATIONS AND FURTHER RESEARCH

7.1 Recommendations

As a recommendation of a study of this nature, it is nearly dangerous to give direct advice other than to take the structured information under consideration when formulating strategies. This research and its results act as an example of how to structure information on alternative future scenarios. The result is a foresight that is meant lead to insight and onto action by the user of this information. The same basic approach and framework for

structuring possible future scenarios can actually be copied to give alternatives for companies formulating their strategies.

However, the "Open FM/AEC" seemed as the most desired alternative to most of the experts interviewed, answering the survey and participating the seminar arranged by the project, some general recommendations regarding this particular alternative can be outlined as examples of further action, such as:

- Building owners and professional clients (public and private) should consider revising their procurement policies to take into account the added value of the use of information and its benefits to the life cycle of a facility. Although the jump directly from the "lowest bidder" policy to evaluating bidders' abilities to add value to the use and life cycle of the facility is seemingly very drastic, incremental and coordinated steps towards a total revision are crucial. The first step could be to look how to use the information generated during the use of a facility to make better decisions earlier in the programming phase.
- The business cases and added value should be made visible to a wider audience through awareness campaigns. Healthy greed should be made to work in favor of adoption of the object oriented, interoperable product modeling technologies. Forums where business managers discuss competitiveness should be duly informed. Research organizations and organizations such as the International Alliance for Interoperability could have an active role in this respect.
- Contractors might expand their services to the use phase of the facility with the help of the product model data. This could mean, for example, giving guarantees on the energy consumption or other performance criteria of the facility. The contractors have a possibility to streamline their process and save money considerably and this should be exploited.
- The vendors of software as well as information of data should consider developing new services that actually facilitate new types of business processes as these new processes emerge. Joining the alliances respectively is recommended. New software products, such as product model servers, new CAD tools, sketching, workflow, life cycle analysis, visualization and simulation tools are needed. The vendors should consider deliberately loosing control over their file format and create the "GSM-standard" –effect (i.e. opening up the standard will expand the market).
- The industry should consider forming vertical networks of companies that are able to utilize the technology in more than just one pilot project but on a more permanent basis.
- The design professionals, especially architects, have the business opportunity to provide the rest of the process with model information that will be worth much more than the 2D drawings they provide today. Designers should exploit this opportunity.
- Standardizing bodies or organizations should consider expanding the common data structures (such as IFC) to facilitate the parametric and dynamic nature of the product models.
- The impact of 3D model-based design (instead of 2D drawing) should be taken into account in most widely accepted standard contracts. The trade associations and unions should be active in this respect.
- Public funding organizations of research and development work should consider rewarding the collaboration to adopt product modeling technology and forming of more permanent business alliances. Especially international collaboration in this area should be a high priority.
- Regulatory authorities should consider demanding for product model data for making approval decisions and in the context of large scale city models, governmental agencies and policies can in some regions even demand for the use of common data formats.
- Education and training programs need to be developed to cover both the uses of technologies but also the evident impacts on the businesses. Special programs to educate subcontractors should be implemented.

Naturally, should one trust more any of the other directions or alternative scenarios, the recommendations are likely to look different. Similarly, actions based on the scenarios are very speculative as well. An example of how a research program or projects might be structured is given in Fig. 5. It is based on the most wanted scenario and the relevant roadmaps. The time frame for the suggested research can be from 5 to 8 years and it should guide the selection of research topics on very generic level, for example, national technology programs.

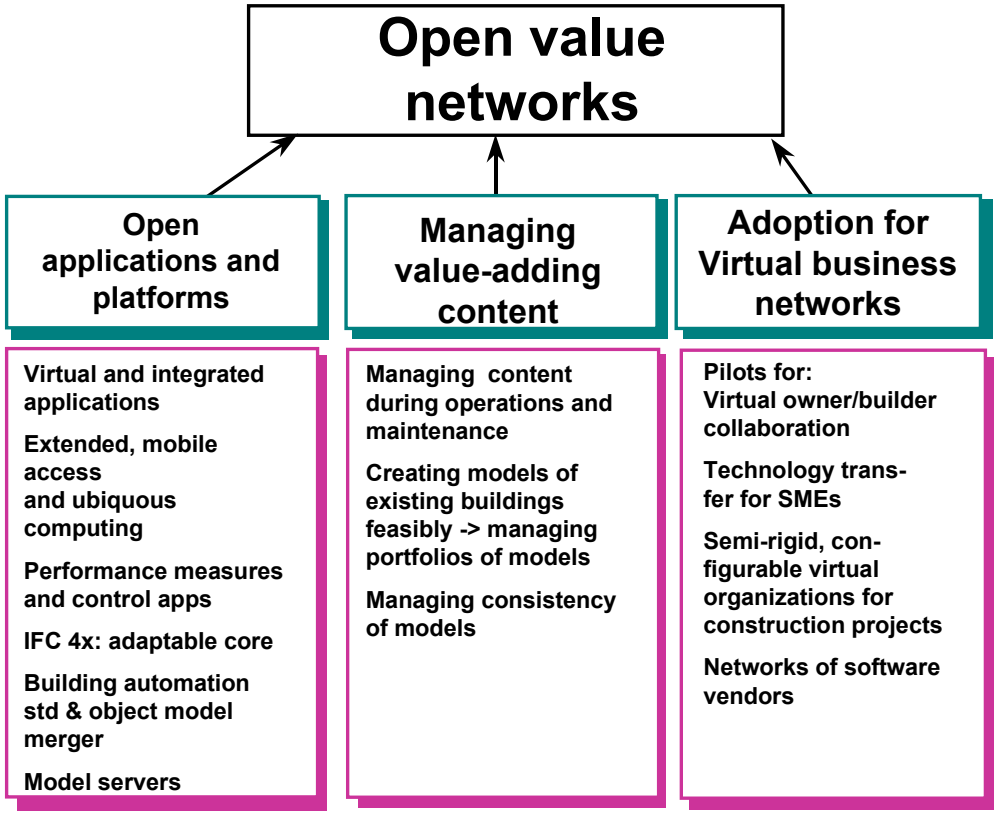

FIG.7: The suggested structure of further research

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