BUILDING INFORMATION MODELS – EXPERTS' VIEWS ON BIM/IFC DEVELOPMENTS

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ABSTRACT: The goal of the single building information model has existed for at least thirty years and various standards have been published leading up to the ten-year development of the Industry Foundation Classes. These have been initiatives from researchers, software developers and standards committees. Now large property owners are becoming aware of the benefits of moving IT tools from specific applications towards more comprehensive solutions. This study addresses the state of Building Information Models and the conditions necessary for them to become more widely used. It is a qualitative study based on information from a number of international experts and has asked a series of questions about the feasibility of BIMs, the conditions necessary for success, and the role of standards with particular reference to the IFCs.

Some key statements were distilled from the diverse answers received and indicate that BIM solutions appear too complex for many and may need to be applied in limited areas initially. Standards are generally supported but not applied rigorously and a range of these are relevant to BIM. Benefits will depend upon the building procurement methods used and there should be special roles within the project team to manage information. Case studies are starting to appear and these could be used for publicity. The IFCs are rather oversold and their complexities should be hidden within simple-to-use software. Inevitably major questions remain and property owners may be the key to answering some of these. A framework for presenting standards, backed up by case studies of successful projects, is the solution proposed for better information on where particular BIM standards and solutions should be applied in building projects.

KEYWORDS: building information models, standards, IFC, CAD, cases, benefits.

1 INTRODUCTION

Representation of all the information needed to describe buildings throughout the whole design, construction and management process has long been an objective for those applying information technology in building (Eastman 1999). The use of computers to replicate traditional ways of representing building information: 2-dimensional drawings, perspectives, engineering calculations, quantities, management networks and costs, has been easier to achieve via separate applications, while it has long seemed that an integrated model should be possible. The object-oriented tools to build such a model have now been available for some time, but the need to integrate the many people involved in the process, and the ways in which their information is organised, have been a limitation on the widespread use of Building Information Models. Standards are critical when communication between different specialists, internationally and over long periods, takes place. The most ambitious programme for standardising object models of buildings, the Industry Foundation Classes (IAI 2007), has been developing for over ten years and the resulting protocols have still mainly been applied in test projects only. There is now an awareness of the cost of not having interoperability and some major building clients are starting to encourage their teams to use the standards compliant tools that are becoming available.

While CAD systems facilitating the production of 2-D drawings were being taken into widespread use some researchers and system developers started to envisage more advanced building representations, which could solve some of the more demanding data sharing functions that graphics-oriented CAD systems cannot. The software technology which seemed to offer the solution to this was object-orientation, where the information packets that the software manipulates are created based on predefined classes. This paradigm is currently in wide-spread use in the computing industry both in programming languages and also as an organising principle for systems development (Martin & Odell 1992), and is particularly successful in the creation of more complex applications.

Digital building descriptions using objects which belong to predefined classes have usually been called building product models (Björk 1989), although some software vendors have recently coined the new term building information model (BIM) for essentially the same thing. The research concerning such models was envisaged as early as in the late 1970's (Eastman 1978) but started to gain more momentum around 1985, when the ISO STEP standardisation project started. STEP stands for Standard for the Exchange of Product Data (STEP Tools 2007) and

tries to solve the data exchange needs of a large number of manufacturing industries. Early attempts at building standardisation within STEP included the global AEC reference model (Gielingh 1987) and the Building Systems Model (Turner 1988).

In the mid 1990s the product modelling standardisation for the building domain was taken over by an industry consortium called the International Alliance for Interoperability (IAI). The first version of the Industry Foundation Classes (IFC) was issued in 1997. Although there are some software applications which have been implemented based on the IFCs, and these have been tested in a number pilot projects (Fisher et al 2003), neither the standard nor product modelling are widely used in practice. There are also highly differing views among researchers as to the optimal structure of BIM-models (for one viewpoint cf. Amor and Faraj 2000).

A growing awareness of the importance of the management of the standardisation and adoption processes for the eventual success of BIM, has led us to initiate a study of a number of standardisation projects of central importance to the use of IT in construction. This work has first focussed on the basic level of standardising CAD drawings, ISO 13567 – Organisation and naming of layers for CAD (ISO 1998), and secondly on the more ambitious level of integrated modelling of construction information as objects, with particular reference to the IAI Industry Foundation Classes.

CAD layering was the subject of the first part of this project. This study used a combination of literature review and survey with domain experts and has been reported elsewhere (Howard & Bjork 2007). The main results were that CAD layer standards based on ISO 13567 have been implemented, particularly in northern European countries, but are not very widely used. A major problem which was identified was the lack of resources for marketing and implementing the standard as national variations, once it had been formally accepted.

There are also other initiatives, particularly those associated with proprietary CAD systems, and the objective of the study reported in this paper was to identify the factors that make these initiatives more or less successful. Several case studies of trial BIM projects have been reported, for example from Finland (Kam 2003) and Hong Kong (Tse 2006), but, to get a broader view, we decided to carry out a qualitative study using experts from different countries to give their informed opinions on the state of BIM/IFC models and their usage. 18 experts from 7 different countries responded to structured email questions. In addition a workshop with six leading international BIM experts was arranged in August 2006 and one expert was interviewed in person, the interview being recorded. The comments have been analysed and a synthesis of the views is presented in this paper.

Recent experience of trial projects and a growing awareness of this technology by large client groups have led to some particularly influential papers being written about the state of BIM. These written sources have also been used as an input to this paper. A study by the US National Institute for Standards and Technology (NIST 2004) has estimated that the cost of not having interoperability in the US Capital Facilities industry is about $15.8 billion per year. This has stimulated new initiatives there to develop a National Building Information Modelling Standard, driven by large client bodies such as the GSA which commissions federal buildings. In Finland, there has been a major commitment by the public sector and large construction process stakeholders to IFC usage. One of the leaders of the Finnish initiative, Prof. Arto Kiviniemi, recently presented an informed and critical view of IFC developments at the Toronto CIB conference (Kiviniemi 2006). In the UK the fifth terminal at Heathrow Airport has been a target project for building modelling and a leading consultant to the project, Mervyn Richards, has summarised the need for changing business processes rather than just promoting superficial differences in technology (Richards 2006). These and other discussions have raised awareness of the need to apply appropriate technologies and standards that can be adopted easily by companies that already have most of the communications and computing facilities necessary.

In addition to case study reports, one important source of information is provided by a number of recent surveys of industry uptake and perceptions of BIM. A survey of Virtual Design and Construction and BIM in the US was being carried out at CIFE using a web survey (CIFE 2006) At 1st November 2006 it had 39 responses from AIA, CIFE and CURT members and had reviewed 32 projects. The analysis suggested that Virtual Design & Construction / BIM was being used in all phases of design and construction. It now addresses key process problems; most respondents perceive high value but cannot quantify benefits and there are established programs for future expansion but also impediments which should not stop progress. The IT Barometer surveys of three Nordic countries were carried out in 1998 and 2001 (Howard, Kiviniemi & Samuelson 2002) and showed low awareness of CAD standards and virtually no use of BIM. This is due to be repeated in 2007.

In January 2007 The Finnish Funding Agency for Technology and Innovation commissioned a web survey among persons listed on the mailing list of their construction industry R&D programme SARA. In total 86 company experts answered the survey (Kiviniemi 2007). From the viewpoint of this study the key question was: "Has your organization participated in projects where the participants utilized shared product models". Among the design companies a majority (76 %) had used products models (52 % in under 10% of projects, 22 % in 10-60 % of projects and 2 % in over 60 % of projects). The corresponding figures for other types of companies including contractors was 45 % overall YES with a detailed breakdown of 33 %, 9 % and 3 %. Interestingly Product modelling was the clear top priority for increasing ICT use in the next two years among designers (85%), whereas the other stakeholders had project extranets for document management as top priority (40%). The results from this study cannot be extrapolated directly to the industry as a whole, since companies (and experts) on this mailing list represent the most innovation-oriented in the Finnish construction industry. However, the results indicate clearly the current development trend in Finland.

2 METHODOLOGY

Broadly-based, quantitative surveys in the construction industry on IT-use have until recently showed widespread ignorance and little usage of the IFC standard. In order to find the critical success factors for implementation and use, it was decided to carry out a qualitative study based upon the views of a number of experts including those defining and implementing standards, end users and property owners wishing to enforce them. A small number of questions were asked by email on the potential for BIM generally and the specific contribution of the IFCs. Respondents were told that their views would be reported anonymously and that they could reference relevant papers or web sites. They were offered copies of the analysis when it was complete. The emails were collected during autumn 2006. The questions are shown in Table 1.

Table 1. The study questions.

General BIM questions	IFC specific areas
	6. The timing and duration of the standardisation effort in relation to the general technical development of BIM technology
1. Is it possible to create Building Information Models which can contain and coordinate most of the data needed for design, construction and management of buildings?	7. The resourcing and management of the technical IFC definition work
2. What should be the role of standards, both formal and de facto, in the definition of BIMs, that can be used nationally and internationally?	8. The simplicity versus complexity of the standard
3. Do these standards already exist or are new ones needed, and who should develop, implement and promote them?	9. The question of freezing versions of the standard for longer periods
4. What benefits will result from applying standardised BIMs, and to which members of the building team, including owners and facility managers, will most benefit accrue?	10. The resourcing and management of information about the standard
5. What changes are needed to the building design, construction and management processes to ensure that BIMs provide the greatest benefits?	11. The development of IFC compliant software by vendors and related quality issues
	12. The commitment of major client organisations and construction companies to the standard

By the end of 2006 18 responses had been received from experts in 7 different countries: Denmark, Hong Kong, Holland, Norway, Sweden, UK and USA. The greatest number was from Sweden and UK. Professional backgrounds were approximately divided equally between architects, engineers, contractors and IT specialists, with about half of these having academic posts. Their responses were grouped according to the questions posed and common elements or differences noted and particular insights or recommendations recorded.

Analysis of the responses

1. Is it possible to create comprehensive BIMs?

Predictably all the responses were qualified, and about equal numbers fell into the 'Yes, but …' and 'No. but…' categories. Other responses were that it is theoretically possible or that information modelling is nothing new. The reservations were mostly about the lack of definitions, which the IFD library project aims to solve, and the lack of good software, with CAD vendors using the term in their own ways. BIM has become an important topic in the US and some managers are said to be 'going for glory' by attending meetings of the NBIMS. Most uses of BIMs are in specific areas with contractors using it for spatial coordination of projects and briefing trade contractors. The single building model is seen as cumbersome by some and will need to be used in conjunction with other forms of data. The Information Delivery Manual being developed in Norway should help implementation. It may be easier to coordinate through a single database and to keep the geometrical model simple. The single BIM has been a holy grail but it is doubtful whether there is the will to achieve it.

Key statement: The Building Information Model may be have to be used first in specific areas.

Key question: Which areas of BIM will current interest by property owners ensure become used?

2. The role of standards, both formal and de facto, in the definition of BIMs

When Alvar Aalto, the famous Finnish architect, was asked about dimensional standards he said that his office module was 'about a millimetre or less'. Predictably the respondents to this question all believed in standards but differed as to what should be standardised, how formal standards should be and whether they were likely to be observed. The ability to transfer information digitally throughout the building process has emphasised the need for standards. For wide recognition it was felt that they should be formalised internationally by ISO, but that de facto standards which were widely used should be capable of formalisation. The European approach was said to be irrelevant to the US where the industry is more disorganised and only procurement standards have any legal status. Diverse and changing project teams depend upon standards. Common libraries should be usable by different BIMs. Proprietary standards are suspect and de facto ones, while faster to produce, often leave out essential elements. Standards should not be a barrier to creativity and innovation. They may apply to: language, products, elements or processes. Those relevant to construction mentioned include: IFC, IFL ISO 12006-3 (Barbi/Lexicon), IDM, CIS/2 steelwork, GML city models, UN/CEFACT business, Process Protocol, Uniclass and Avanti. On the question of timescales most were pessimistic about widespread usage, even nationally, and questioned whether the lead was coming from the US or Europe. The critical factor was whether the intended beneficiaries of BIM standards appreciate the commercial need.

Key statement: Standards are nominally supported, are most effective nationally, but need ISO endorsement.

Key question: Are property owners aware of how suitable BIM standards could benefit them?

3. Do the standards already exist, and who should develop, implement and promote them?

Many standards relevant to BIM exist but there is a lack of a framework into which they fit. The IFCs are the ones to be encouraged but could be improved. If all software were compatible with these might there be no need for any more? BIM standards are poorly marketed and incomplete. They need to be seen to be used by the top firms and should have support from clients, industry bodies and governments. Development should be by experts from the construction industry with implementation by software companies. Some believe that useful standards do not exist and any new development should start from an unchanging metaphysical structure and ideas. More work is required in classification and data definition. Object libraries, according to ISO 12006-3, are being developed in the Netherlands and their standard, NTA 8611, is being proposed to ISO TC59/SC13 as an international standard. There is no standard for modelling structures. In Hong Kong the architects lead the BIM process but engineers have little incentive to follow. There is a lack of modelling standards for facility management.

Key statement: A framework is needed into which all BIM standards can fit, including data definition.

Key question: How should such a framework be defined to include all phases of construction and the future?

4. What benefits will result to whom from applying standardised BIMs

Almost no one questioned that benefits from BIMs were achievable and to all involved in the process. There were a few examples of savings achieved on individual projects and the NIST report (NIST 2004) was often quoted, and suggests that 2% greater efficiency could be achieved immediately and 10% after a few cycles. The main beneficiary would be the client followed by the facility managers, but all in the supply chain could benefit. One problem is that work by one member of the project team might benefit another and benefits ought to be shared by all. The greatest benefit from BIM would accrue over the lifetime of the building hence Private Finance Initiative projects, tendered for construction and operation over many years, might gain most.

All these potential benefits depend upon the people and software being used. In the US 4D software combining 3D models and project management was having an immediate impact, and combinations such as Google Earth and SketchUp were successful in visualising buildings on their sites. The type of procurement is a factor, with fixed price contracts using BIM benefiting the contractor but design and build less likely to do so. In the UK the Heathrow Terminal 5 and Stansted Endeavour House projects showed benefits to the whole supply chain, but this only applies to single solution projects with interoperability and use of standards. Some other projects have shown a 100% increase in profits. Manufacturing industry has achieved over 30% savings from integrated IT but this is unlikely to be achieved in construction. In Europe productivity in construction is rising at only 10% of that in manufacturing. No one provided information on the cost of setting up, training staff and applying BIM systems, and this is an area that should be explored further.

Key statement: Distribution of any benefits from BIM will depend upon type of procurement and responsibility for operation of facilities.

Key question: What have been the costs and benefits of the projects already applying BIM?

5. What changes to the process are needed to ensure BIMs provide the greatest benefits?

It was generally agreed that major changes were necessary but perhaps the BIMs and standards currently available needed to match industry procedures better. Institutions should recognise the need for a new specialism in applying technology, standards and modelling, and being responsible for spatial coordination. Decisions need to be made earlier in an integrated process and time can be saved by parallel working. Technically BIM solutions are almost fully available but the commercial drive to apply them has hardly started. Education, from site operatives learning to read, write and handle numbers, to students getting more information on BIM, is essential for eventual success. If the pressure comes up from new graduates and down from commercial management, BIM systems will eventually come into general use. There is a need to integrate project teams through giving responsibility for the whole process and partnering (Lessing). Information needs to be recognised as a strategic asset and paid for. It also needs to be constantly updated.

There are benefits from applying BIMs to industrialised building. Some changes proposed are: integrating design and specification, automating regulations and creating a collaborative umbrella. Some of these changes are starting to happen but BIM does not appear to be driving them yet.

Key statement: Changes to the process are already starting but there may need to be a special role to manage BIM, and special education.

Key question: How should a BIM specialist and training be built into the construction process?

The following questions relate to the particular development of the Industry Foundations Classes

6. The timing and duration of the IFC standardisation effort

IFC development has taken about 10 years so far. Some feel that this was too slow and that resources were inadequate. Others feel that the timing is about right now that BIMs can be run on desktop computers. However general deployment of BIMs and IFCs could take 10-20 years. Standards development has been by interested and qualified people but management in the US do not understand their significance. They only pay lip service to BIM. In smaller countries like Finland, Norway and Singapore there has been more success. For instance the R&D funding agency TEKES in Finland has been quite instrumental in promoting IFCs and is concerned with doing the right thing whereas stakeholders in the US are only concerned with the lowest price. Comprehensive standards such as the IFCs are not generally understood and are not being adopted. The IAI has been around so long that people

have forgotten it or become bored. Some software products based on it are available but the scope was too broad. The move to include specific formats, like CIS2, is good. IFC development started at the right time but with little knowledge of existing standards and has delayed the deployment of BIM. STEP AP221 might have been a better starting point. There is a need to support specifications and costs. A user friendly interface is essential. There is a need for a technical audit of IFCs and an enquiry into what support vendors are giving.

Key statement: The IFCs have a new stimulus through US property interest in BIM and the IAI re-branding as BuildSMART, but easy to use software implementations are still needed.

Key question: What is the real commitment of CAD vendors to implementing IFCs and other standards?

7. The resourcing and management of the IFC work

Almost all said that resources and coordination were inadequate. Is this the fault of the IAI? The best people need to be paid to work full time on the IFCs and vendors should contribute. More companies are beginning to invest in BIM. Pioneers have to take the first steps before commercial companies join in. Development of IFCs has been confined to a small circle of enthusiasts. Development of OGC has achieved more but with greater resources. IAI resources and membership may now be decreasing owing to development and adoption taking too long. If CAD vendors really want interoperability they can provide it but it may limit sales of their software. Users do not see that they have a problem.

Key statement: If benefits to property owners can be quantified from case studies, resources could be generated for raising awareness of BIM/IFC.

Key question: How can potential changes in the process through BIM/IFC be presented in economic terms?

8. The simplicity versus complexity of the IFC standard

The IFCs are complex but this need not be apparent to the user. Less complexity means less functionality. Mobile phone standards are easy to use because they are built into the phones. W3C OWL could supersede some aspects of IFCs. Simplicity could be introduced through subsets eg: views, a stable core (ISO PAS) and ifcXML. Models need the elegant simplicity of some drawings with less explicit information and more tacit knowledge. There is a need to test translators. Simplicity is paramount and leads to easier understanding and implementation.

Key statement: IFCs should be presented in the simplest possible terms using any relevant techniques.

Key question: How could IFCs be built into widely used software applications?

9. Should versions of the IFC standard be frozen for longer periods?

The general feeling was that IFC versions should be frozen for longer periods to encourage development of software. Individual suggestions were for 2 or 4 years. If not it will be impossible for all implementations in the world to be in step. An upward migration path between versions is essential. There should be an advised method for managing versions. Segmentation into application domains might meet development requirements without having to revise the whole standard. Some outsiders exaggerate the difference between versions. There has been a stable core to IFCs for some time. This has been added to but not changed.

Key statement: A framework for BIM standards could include timescales planned for IFC versions.

Key question: What management advice is needed to help users to choose appropriate standards from such a framework?

10. The resourcing and management of information about the IFCs

Promotion of IFCs is critical to their success. Organisations like ISO can help this. The EU does nothing although IFCs are used in their research projects. Technical presentations tend to put off the people who should be supporting them. Awareness of IFCs appears to be improving via semi open source publication. The latest BuildSMART initiative and web tools are improving marketing and dissemination.

Key statement: As stated previously owners expecting savings should support promotion of BIM/IFC and publicise their effect on their projects.

Key question: Could case studies from all parts of the world be collected and presented together with economic analysis?

11. The development of IFC compliant software by vendors

Development and quality testing should become self regulating eventually. Poor software will be superseded. The construction industry is too big a market to accept sloppy software. The better products may become de facto solutions. Some vendors are implementing IFCs because they have to rather than because it is the right thing for them. ArchiCAD and Allplan were pioneers in BIM support. ADT and now Revit 9.9 have import and export facilities. IFC Models have been passed between ArchiCAD and Revit with some objects not defined in IFC 2X2 missing. Some vendors are actually obstructive. Testing of exchanges has been discouraged. Quality testing levels have now been raised from lax to stringent. There needs to be a reality check on the IAI who claim that IFCs are used across the world when they are mainly used by academics.

Key statement: Related to a framework of BIM standards there should be information on vendors' commitment and testing of their products.

Key question: Would realistic assessments of IFC use, linked to leading owners and projects, be more effective in promoting BIM/IFCs?

12. The commitment of major stakeholders to the IFCs

This is critical to the success of BIM and IFCs. IFCs are not yet used and most industry is unaware of them. Development has been top down. The people who produce drawings do not care about IFCs but if there are products to help them they would make use of them. Why should construction industry firms commit to something irrelevant to their practice? There are few committed individual users and if they move the initiative is lost. Some major government clients in Norway (Statsbygg), the US (GSA) and Finland (Senaatti) are beginning to take IFCs very

seriously. The Digital Construction project in Denmark (Det Digitale Byggeri 2006) and HITOS in Norway are examples of BIM initiatives. There is also growing commitment in China but the UK government does not seem to be aware. There is a lack of investment here both when the industry is busy and when there is little work. In Hong Kong a few cases show that architects lead the BIM process but other consultants have little incentive to follow. Clients who claim to be using IFCs should be surveyed to find out their real level of commitment.

Key statement: Perhaps IFCs should be presented as a little known secret that can give a competitive edge rather than as an obvious solution that all should be applying.

Key question: If clients were given a BIM standards framework, and simply presented statements of their real capabilities, would they indicate their current and future levels of commitment?

3 CONCLUSIONS

The information collected is very diverse and contains contradictory statements but is based on much experience of introducing new technology to the construction industry. It raises as many questions as it answers but there has been no time to follow these up except by reference to some recent surveys and reports. The time seems promising for a renewed drive towards moving at least some leading property owners and their consultants and contractors into greater use of BIM and the standards that support it. The object of this paper has been to distil from the experience of a few international experts some suggestions for better information, guidance and education in the economically viable means of using the tools and standards that exist and making further developments where necessary.

The key statements following each question were an attempt to express the most common and constructive thoughts of those responding to it. Inevitably common themes occur that link the different questions and start to form a conclusion to this paper, while the key questions suggest further work related to these statements.

1. The idealistic goal of BIM has been to provide a single building model capable of being used throughout the process. This requires a huge leap which has, so far, mainly been applied on trial projects. There is some evidence that BIMs may have to be applied to particular processes first, the example being the NBIMS in the US which uses simple .pdf files that can be checked automatically at the briefing and early design stages. Successful implementation of standards or models at an early process stage can lead on to reuse later in the process but the question arises of who benefits from the extra work done by lead designers.
2. Standards are like mother's milk; no one is against them but few apply them comprehensively. National groups have often been successful in implementing modest standards such as those for CAD layers, but international implementations need to be tailored for local cultures and conditions. Official endorsement, preferably by ISO, can give wide recognition but is no substitute for promotion and implementation in software.
3. There are many standards relevant to BIM, not just those that aim to address the single building model. A framework of relevant standards, showing their capabilities, stage of implementation and potential benefits, would help users to assess the appropriate level for them. The ability to move from the more basic standards towards those offering a comprehensive solution might then become more feasible.

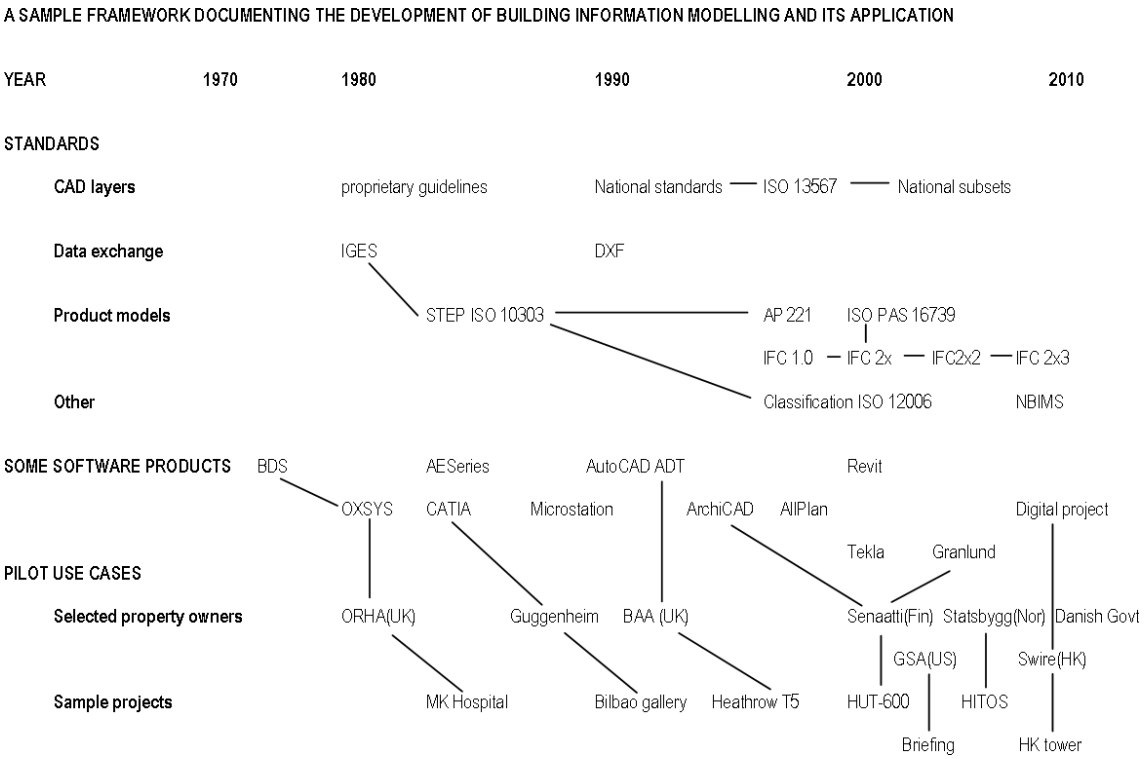

Table 2. An example of the framework proposed for documenting developments in BIM.

4. The process in which BIMs can provide most benefit implies that there are long term relationships between those involved. These can be achieved by partnering so that consultants and contractors are appointed early in the process, by framework agreements allowing teams to work together on a series of projects, and by Design Build and Operate contracts where the benefits of using BIMs can be obtained over the lifetime of the building.
5. It was suggested that, in order to develop more advanced use of BIMs, there should be a special role in the project team for an information manager who could coordinate use of models throughout the project. This role coupled with better student education on the techniques of BIM would eventually drive firms towards a greater commitment.
6. The IFCs have now received ten years of development, but with insufficient resources and dependence on a small number of experts. The signs are that some property owners are becoming aware of the benefits of BIM and that, coupled with the new image of the IAI as BuildSMART, there could be a new surge of enthusiasm. However there are complexities that need to be hidden within good software implementations.
7. There are now several case studies of the use of IFCs and the benefits obtained, both in quantity and quality, could be presented in a common format. This would help property owners to see the potential and might generate resources from them to provide the wider promotion necessary.
8. The IFCs could be presented in simpler terms. Sometimes the technical expertise of those producing them has deterred potential users. The concepts are simple and, if they can link directly to usable software, any relevant techniques should be used for this. There is much work on data dictionaries and these are essential to common terminology particularly internationally.
9. Concern was expressed about the timescales of different releases of the IFCs. Although there has been a stable core for some time, a framework for BIM standards could indicate likely release times looking forward several years.
10. Publicity is essential if particular standards are to be more widely used. Property owners should use successful case studies for promotion and identify the benefits they have obtained.
11. Software vendors are a key element in BIM and, where they have implemented IFCs, they should state to what level these have been tested, and what their real commitment is.
12. The IFCs have been presented as the ideal solution to the inefficiencies of the whole construction industry. In the long term, and with continuing development, this may be possible but the key to use of many innovations is the pioneer users who achieve significant success. To promote BIM and the leading IFC standard as a secret route to competitive advantage could be a more successful approach.

This may seem to be contradictory in that wider promotion of BIM requires publicity for successful projects, but there may be very effective uses of BIMs that are unknown and quietly benefiting their users. What this study points toward as the main aid to progress in the wider usage of BIMs and the standards that underpin them, is the development of an authoritative source of information on all relevant standards and tools, case studies of their use, preferably with some economic analysis of benefits, and hard information on the level of conformance of software products. This is something that could be built from existing information, supplemented by further discussion with property owners who have used the tools that exist, and maintained by an international body such as CIB W78.

The framework that is proposed would relate the use of BIM standards and tools to the stages of a building project, would include information from case studies and CAD vendors, and cover as many countries as possible. The questions that arose from the work in this study could be answered by some further research and presented within an agreed framework that allowed for a range of levels of solution, presented with evidence of their benefits and looking towards future developments. Any new project should ideally start by a consideration of the relevant standards to be applied and the software tools available to the project team. The client organisation, and initially this would be the large property owner who is already aware of potential benefits, would impose the agreed standards, provide any special resources necessary, and allow publication of the results as a case study. Their commitment to applying the standards would need to be stated and the procurement path to obtain maximum benefits is an essential element in achieving the objectives towards which so many academics, standards and software developers have been working for over thirty years.

ACKNOWLEDGEMENTS

This study has been made possible through a Senior Fellowship grant for Rob Howard from Stiftelsen Svenska Handelshögskolan and a Senior Scientist grant for Bo-Christer Björk from the Academy of Finland. The research is also closely related to that carried out in the FoundIT project funded by the Finnish Funding Agency for Technology and Innovation (TEKES).

REFERENCES

AEC (UK) CAD standard Version 2.0. www.aec-uk.org

Amor, R. and Faraj, I. (2000) Misconceptions of an IPDB, Proceedings of the UK National Conference on Objects and Integration, Watford, UK, 13-14 March, pp. 124-135.

Avanti – ICT enabled collaborative working. http://www.avanti-construction.org/

Bjork, B-C (1989) Basic Structure of a Building Product Model, Computer-aided Design, 21(2) (1989) 71-78

Building Smart wiki. SINTEF Byggforsk http://buildingsmart.byggforsk.no/index.php/Main_Page

CIFE (2006) Kunz,J & Gilligan, B. CIFE/CURT survey of VDC/BIM use.

Eastman, C. (1999) Building Product Models: Computer Environments Supporting Design and Construction, CRC Press, Boca Raton FL, (1999).

Eastman, C (1978) The representation of design problems and maintenance of their structure. Latcombe (ed.), Application

of AI and PR to CAD, IFIPS Working Conference, Grenoble, France, March 1978. Amsterdam, North-Holland. S. 335 - 337

Gielingh, W (1988) General AEC reference model. ISO TC 184/SC4/WG1 doc. 3.2.2.1, TNO report BI-88-150. Delft, the Netherlands

Howard, R and Bjork, B-C. (2007) Use of Standards for CAD layers in building. Accepted for publication, Automation in Construction.

Howard, R, Kiviniemi, A, and Samuelson, O.(2002) The latest developments in communications and e-commerce – IT Barometer in 3 Nordic countries. 2002. In Distributing knowledge of building, the proceedings of the CIB W78 conference Aarhus School of Architecture, Denmark.

IAI International Alliance for Interoperability, homepage http://www.iai-international.com

ISO 13567 (1998). Technical product documentation – organisation and naming of layers for CAD.

Kam C, Fischer M, Hänninen R, Karjalainen A and Laitinen J (2003) The product model and Fourth Dimension project, (2003) ITcon Vol. 8, Special Issue IFC - Product models for the AEC arena , pg. 137-166, http://www.itcon.org/2003/12

Kiviniemi, A. (2006) Ten years of IFC development. Why are we not there yet? Keynote presentation, Joint international conference on computing and decision-making in civil and building engineering, 14-16.6.2006, Montreal, Canada

Kiviniemi, A. (2007) Email communication

Lessing, J. "Industrialised House-Building - Concept and Processes", Design Methodology, LTH, Lund University.

Martin & Odell (1992)

Mohus, F. Slide set for HITOS project – a full scale IFC test. Statsbygg, Norway

NAEC. Danish National Agency for Enterprise and Construction. (2006) Det Digitale Byggeri. www.detdigitalebyggeri.dk

National Building Information Model Standard http://www.facilityinformationcouncil.org/bim/

NIST (2004) Gallaher, O'Connor, Dettbarn & Gilday. Cost analysis of inadequate interoperability in the US capital facilities industry. August 2004. National Institute of Standards & Technology. GCR 04-867

Richards, M. (2006) BIM, BIMS or SBIM? CAD User. November/December 2006. P11.

Tse, K, Wong, A, Wong, F, Leung, Y and Riese, M. (2006) Building Information Modelling – a case study of building design and management. 31st AUBEA Conference, Univ. of Technology Sydney, 11-14 July 2006

STEP Tools (2007) STEP ISO10303, STEP Tools Inc, http://www.steptools.com/library/standard/

Turner (1990) AEC Building Systems Model, ISO TC184/SC4/WG1, Doc. N363. Working paper, University of Michigan.

VTT Technical Research Centre for Finland. Pro-IT. http://virtual.vtt.fi/proit-eng/