COMPARATIVE ROLES OF MAJOR STAKEHOLDERS FOR THE IMPLEMENTATION OF BIM IN VARIOUS COUNTRIES

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Abstract
In this paper, the implementation of Building Information Modelling (BIM) systems in various selected countries is reviewed to highlight the successful practices in this field. In several situations, BIM was implemented in conjunction with Industry Foundation Classes (IFC) for better integration and interoperability of various components of BIM system. The roles of the public and private sectors as major stakeholders in promoting and providing support for the implementation, research and development of BIM systems is presented. The impact of such roles on the overall progress of BIM in a country is discussed. Different scenarios of the level of support from the public and private sectors are presented along with the identification of major areas of research in BIM. The findings show that the roles of both public and private sector in promoting BIM have peculiarities under the circumstances of the country and may depend on factors such as the size and nature of country's economic system.

Keywords: Building Information Modelling, Industry Foundation Classes, Interoperability, Stakeholders' Roles, Singapore, Scandinavian Countries, Hong Kong

INTRODUCTION

The function of Building Information Modelling (BIM) is to develop and use a computer model to simulate design, construction and operation of a facility. BIM has the attributes of both an approach and a process/action. It is an approach as it provides an alternative to the traditional paper based approach of project design and management. It is a process/action as it creates a product called Building Information Model, whose performance can be measured. In normal practice, the terms "Building Information Modelling" and "Building Information Model" are being used interchangeably. But to be precise, there is a difference between these two terms as one is a process, and the other is a product.

BIM is now being increasingly used as an emerging technology to assist in conceiving, designing, constructing and operating the buildings in many countries, notably in the United States. A comparative review of BIM initiatives in the USA and Hong Kong is underway by the authors and its implementation and development in Hong Kong has been presented in another paper (Wong et al. 2009) Other countries including Finland, Singapore, Denmark, and Norway have also adopted BIM at the public and private sectors which are studied in this paper. VTT in Finland, Rambøll in Denmark and SINTEF in Norway are the major research organizations in BIM in these countries. Various countries including the USA, Finland, Norway, Denmark, Germany, Singapore and Korea are currently in the process of or have released BIM guidelines. The involvement of companies in the BIM initiatives by International Alliance for Interoperability (IAI) and buildingSMART in European countries is on the rise. According to a survey in 2008, such involvement has been estimated to vary between 20 and 40% of the number of companies implementing BIM (Kiviniemi *et* el., 2008, p.20). Outside of the USA, the Scandinavian region is considered as the most active in BIM implementation whereas Singapore is one of the few countries in Asia who have implemented BIM at the public sector. Therefore, in this paper, a review of the initiatives taken in the selected Scandinavian Countries including Finland, Norway, Denmark and the Asian Country Singapore to implement BIM at the public and private sectors is presented to highlight the successful practices in this field. The findings from this study are based on this review of BIM initiatives and would relate to the roles of public and private sectors in these countries.

BIM IMPLEMENTATION IN VARIOUS COUNTRIES

BIM in Finland

In a survey conducted in 2007, the usage of BIM and IFC compliant BIM applications in Finland was estimated to be 33% (Kiviniemi, 2007). In the same survey it was observed that in Finland, 93% of the architect firms were using BIM for some parts in their projects whereas the engineer's usage was nearly 60%.

Public Sector and BIM Guidelines

Senate Properties is the public owner running pilot projects using BIM and IFC. There has been a growing interest by (Architectural Engineering and Construction/Facilities Management) AEC/FM companies in BIM and IFC compatibility. Their focus is to use product model technology in ordinary project work. Starting from 1st October 2007, Senate Properties has decided to require models meeting the IFC standard in their projects (Senate Properties, 2009). They have also drawn detailed modelling guidelines related to convey the data content requirements for models to the participants in the project at each stage of the design. The guidelines will be in compliance with the more general guidelines from ProIT project and would be useful for making decisions in Senate Properties' investment processes. For example, Senate Properties has mandated for all design software packages to pass 'IFC 2 x 3 Certification' in accordance with the requirement from their BIM guidelines. This shows the great commitment of the public sector in Finland toward wider BIM implementation.

In Finland, the BIM guidelines are being drafted as a result of the ProIT project which is an R&D project conducted with industry wide support. It developed a number of guidelines on product modelling. The guidelines are in Finnish language and cover general principles of product modelling in construction projects, product modelling in architectural design, product modelling in structural design and product modelling in building services design (Senate

Properties, 2009). These guidelines describe product modelling in details, however, these guidelines do not explain in details the data exchange specifications which could be the next step for further development in the guidelines.

Private Sector and BIM Research
In Finland's private sector, several companies are performing R&D in BIM. For example, Skanska Oy is investigating the integration of project specific Building Information Model into industrialised building process and adopting 3D modelling in practice (Kiviniemi, 2009). Another company, 'Tekes' promotes the potential of BIM in Finland due to which a higher utilization of BIM in Finland has been achieved in Finland than in the other Scandinavian countries. The Association of Finnish Contractors is also active in promoting implementation of BIM in the industry, along with the state client (Senate Properties) whose path is similar with the addition of the need for open standards.

Research organizations and universities in Finland are running several programmes involving the implementation of BIM. For example, Helsinki University of Technology and VTT's Engineering and Construction Project Information Platform (ECPIP) integrates BIM into actual construction and building management (Leicht et al. 2007). VTT and Tampere University of Technology's Virtual Building Environments (VBE) and Tampere University of Technology's project investigates industrial processes with the support of an Open Virtual Building Environment incorporating IFC based BIM (VTT, 2007).

Another important organization in Finland is VTT which is in the research of building product models, or building information models since the late 1980s. Finland and especially VTT actively took part in the international development and standardization of integrated BIM when the International Alliance for Interoperability (IAI) was formed in 1996. VTT is focusing on technical issues related to the downstream applications – tools that utilize the information in the models – such as different analysis, simulation and process management applications. In those tools, energy and environmental analysis tools are given more attention because these tools can reliably evaluate the environmental impacts or lifecycle costs of buildings by robust analyses and simulations.

VTT intends to apply BIM for the evaluation of environmental impacts of the built environment or the sustainability of the built environment in general. It would make it possible to use the information generated in the design phase to be used during the building operation phase. Researchers from VTT used Building Information Models and web service integration technology to enable real-time information sharing for addressing the problem of information transparency in the construction supply chain (Permala et al. 2008). BIM and web service applications were used as information sources to construction supply chain. The end product developed was a prototype and a small scale test for web services, called CS Collaborator. The CS Collaborator program was one of the first attempts to build a BIM-based Web service for the construction industry.

BIM technologies including IFC standards were used for integrating performance based building standards and business processes. It helped to enhance innovation and sustainable development (Huovila, 2008). The potential for value creation during the whole life of buildings by the use of BIM was identified in a number of areas including customer and end-user requirements, sustainability within the building process and life cycle phases, decision-making, building process re-engineering, etc.

Mäkeläinen et al. (2008) reported the Engineering and Construction Project Information Platform (ECPIP) project in which BIM was utilized. The objective in this project was to improve the quality and productivity of the Real Estate and Construction Cluster (RECC) through customer driven development and implementation of new processes utilizing an integrated information platform. This helped bringing RECC processes and BIM into an innovative dialogue by using process simulation. In another project Hakkinen and Kiviniemi (2008) investigated the potential of BIM for seeking solutions for the problems of sustainable building processes.

BIM in Norway

In Norway, the civil state client Statsbygg has promoted the use of BIM in the last few years. The Norwegian Homebuilders Association has encouraged the industry to adopt BIM and IFC. A number of Norwegian contractors have spent in and implemented BIM systems for integrating ICT support for their production of apartments and houses.

Public Sector & BIM Guidelines

Norway's BIM guidelines are called BIM manual. These guidelines are based on the experiences from the Statsbygg's HIBO project. Statsbygg have produced up to now 0.9 alpha version of the guidelines. The BIM manual is delimited to the Norwegian standard NS8353 CAD manual, and it is prepared in coordination with the NBIMS standard in the USA. This manual was actually for Statsbygg's use however it is now also being used by other parties in Norway as well (Le et al. 2006). Moreover, Statsbygg has decided to use BIM for the whole lifecycle of their buildings. In 2007, 5 projects had used BIM. By 2010, all the projects will use IFC/IFD based BIM.

Private Sector & BIM Research

In private sector Selvaag-Bluethink is developing BIM and ICT solutions based on BIM. SINTEF in Norway is the leading organization conducting research in BIM. It is a part of Erabuild which is a network of national R&D programmes, focussing on sustainable tools to improve construction and operation of buildings. Erabuild includes funding organisations from Austria, Denmark, Finland, France, Germany, the Netherlands, Sweden, Norway and the United Kingdom. From Norway, the Research Council is the funding organization for Erabuild. Norway is among the first few countries to develop IFD (International Framework for Dictionaries) standard (IFD) in the building construction regime (i.e. ISO 12006-3) which is an initiative for global application. About 22% of the AEC/FM companies in Norway have used or implemented BIM or IFC enabled BIM.

SINTEF is also working on several internal and cross-department projects under buildingSMART initiative besides developing BIM Guidelines. They are converting over 800 design sheets to format recommended under buildingSMART guidelines. BuildingSMART is a national coordinating effort to focus and collaborate on all building development and implementation projects. Under Norwegian University of Science and Technology (NTNU), several student projects and thesis proposals are focused on buildingSMART technology and are being conducted in collaboration with industry and research organizations to develop student courses.

Norwegian IAI Forum is developing the definitions of the requirements on the information exchange under IDM (Information Delivery Manual) (IAI Forum Norway, 2007). The aim of the IDM is to support the information exchange requirements for business processes within

the building construction industry. Through IDM, the parts of the IFC model that is necessary for information exchange between identified processes can be specified.

BIM in Denmark

The overall usage of BIM in Denmark is promising. According to a survey which was carried out in 2006 (cited in Kiviniemi et al., 2008), the most commonly used BIM application among architects was Architectural Desktop with approximately 35% of the firms using it. It was followed by Archicad, Revit and Bentley Architecture. The survey also showed that about 50% of the architects, 29% of clients and 40% of engineers in Denmark were using BIM for some parts of their projects in 2006.

Denmark has slight edge on other Scandinavian countries in prescribing by specific modelling standards/guidelines in their construction works by the clients. These requirements have already been stated by the government and some of them are part of the law. In Denmark, 'bips' which is a user driven organisation has a strong influence in the use of IT in the Danish construction industry. The mandatory demands on BIM from the Danish state clients in 2007 have moved the use of BIM to a higher level in Denmark.

Public Sector and BIM Guidelines

In Demark, there are at least three public owners who have initiated the work on BIM. These include The Palaces and Properties Agency, The Danish University and Property Agency and Defence Construction Service. In Denmark, although the governmental projects do not represent a large part of the total property area, their impact on the market created by the IFC requirements is big. The Palaces and Properties Agency is responsible for providing the Danish state with office buildings in the order of 550,000 m^2 floor area, which is worth a total of DKK4.3 billion (US$0.72 billion). In addition, approximately 450,000 m^2 are leased and administered by the agency on behalf of the state. Another governmental agency, The Danish University and Property Agency had a portfolio of 1,640,773 m^2 buildings in 2006. The third governmental agency, Defence Construction Service's portfolio consisted of 2,900,000 m^2 of buildings in 2007. Other government agencies like Gentofte Municipality and KLP Ejendommehave have also adopted the requirements from the Digital Construction project in Denmark.

Denmark has actively put forth its requirements for using BIM in the governmental projects. Such requirements from the government are known as Byggherrekravene (Det Digitale Byggeri, 2007). The architects, designers and contractors participating in governmental construction projects have to utilize a number of new digital routines, methods and tools starting from January 2007. The initiative is called 'Det Digitale Byggeri' in Danish which means 'the Digital Construction'. Since the initiative is still under experimentation, the governmental clients have exercised flexibility in its use. For example, the adoption of a new common classification system is recommended in the system, but it is normally up to the clients to decide whether the system should be used or not. The adoption of Digital Construction Program has been facilitated with the development of a number of reports and guidelines.

The use of 3D models in the projects has been related with the price of the project. For projects above 5.5 million Euros, 3D models in the design have to fulfil a number of requirements regarding content, information levels for the various phases, which are to be defined by the client for individual project. The models are recommended to be exchanged

using the IFC format. Also there are a few municipalities and private clients in Denmark who demand for object based modelling.

In Denmark, the guidelines for working with 3D CAD applications have been prepared. This was accomplished under the Digital Construction program initiated by the Danish Enterprise and Construction Authority. A package of guidelines regarding 3D was developed. The guidelines concerned both the setting up and fulfilling requirements in file and database based CAD/BIM applications. These guidelines are also available in English which include: 3D CAD Manual 2006, 3D Working Method, 3D Working Methods and Layer and Object Structures 2006.

Private Sector and BIM Research
In the private sector 'bips' is developing BIM guidelines and Rambøll is working for collaboration between Rambyg and IFC. 'bips' has adopted the results from the Digital Construction project and are promoting the new working methods to all companies in the Danish Construction Industry. Rambøll is the main organization in Denmark performing research in BIM. Danish Enterprise and Construction Authority is an organization supporting the research in BIM in Denmark. Other organizations and universities are also performing R&D work in BIM. For example, the work in Aalborg University is focussed on IFC model servers and 3D Models. Aarhus School of Architecture is focussing on product configuration, design intent and IFC model server whereas Technical University of Denmark's work is on interoperability.

BIM in Singapore
Public Sector
In Singapore, Construction and Real Estate Network (CORENET) is the main organization involved in the development and implementation of BIM for government projects. It is a major IT initiative that was launched in 1995 by Singapore's Ministry of National Development. CORENET provides information services which includes e-Information System such as eNPQS and e-Catalog to its clients. It also offers integrated submission system in the form of e-Submission and Integrated Plan Checking System. IT Standards are being adopted in the Construction Industry of Singapore which has been followed from the guidelines of International Alliance for Interoperability.

Guidelines
Singapore has since 1997 been promoting and later on also requiring the use of BIM for various kinds of approvals like building plan approvals and fire safety certifications (Khemlani, 2005). The CORENET e-PlanCheck defines Singapore's Automated Code Checking System and several authorities in Singapore are participating in the e-submission system, which requires the use of BIM and IFC. The BIM Guideline called "Integrated plan checking" has now been completed.

DISCUSSION OF BIM IMPLEMENTATIONS

Role of Public Sector
A few areas of comparison related to the public sector support for BIM are summarised in Table 1. It is observed that the support of the central government towards BIM implementation can be regarded as the driving force towards higher utilization of BIM in those countries. If the support is strong it would create a uniform environment for nation-

wide acceptance of BIM. BIM requirement would then come under legal jurisdictions. It would provide users from all sectors an official approval of their BIM implementation. In the education sector, the programmes which have incorporated BIM would be in coordination with each other. A strong government support would also create an active environment for research and development in BIM. Situations to this scenario can be observed from the implementation of BIM in Finland, Denmark, and Norway and to certain extent in Singapore where the support of public sector is significant. These countries are medium to small size in terms of population and area. The policies of the governments in these countries are easier to implement nation-wide than in big countries. Further to this, all these countries have an industrial base and have rich experience of automation from the manufacturing sector which is adopted in the construction and real estate sector as facilitated by BIM.

On the other hand if the government support for BIM implementation in a country is not strong then market forces could be dominant in BIM implementation. However, this scenario could result in uncertain outcomes. Even if the market conditions depict a booming economy especially in the building sector, there would be non-uniformities in the nationwide implementation of BIM as each market stakeholder would implement its own BIM system. There would be non-uniformities in the stages of deployment of BIM by each market sector and it would be difficult to predict the overall level of implementation of BIM in that country. Similarly BIM education would be based on the effort of the individuals from educational institutions. Research and development would also be limited in this case as there would be no dedicated support for BIM by the government. The condition of implementation of BIM in Hong Kong is more likely to resemble this scenario which has been presented by authors in another publication (Wong et al. 2009). It is more likely because of the local market conditions, as the economy of Hong Kong is significantly dependent on trade and services sector. The role of the public sector in Hong Kong is conservative in this respect. The government could get a benchmark for the implementation of BIM in Hong Kong from that in the Scandinavian countries and the USA due to which the implementation of BIM could be expected to gradually increase in the public sector of Hong Kong in near future.

Table 1: *BIM Implementation in Public Sectors of the Scandinavian Countries*

Country	Finland	Denmark	Norway
Organization	Senate Properties	The Palaces and Properties Agency The Danish University and Property Agency Defence Construction Service	Statsbygg
Projects	Pilot projects	To implement BIM and IFC in public works	Pilot projects
BIM adoption Policy	To adopt BIM in all projects from 1st Oct 2007	Since January 2007, the architects, designers and contractors would follow the format set by"Det Digitale Byggeri" (the digital construction).	BIM to be used for whole life-cycle of buildings. Complete implementation by 2010
Information exchange policy	IFC is desired	IFC is recommended	

Role of Private Sector

A few areas of comparison related to the private sector support for BIM are summarised in Table 2. From the review of private sector initiatives in Denmark, Finland and Norway, the effect of the support of private sector on BIM implementation in a country is evaluated. For the case of a strong involvement of private sector in BIM initiatives in a country, it would help create new business processes, partnerships and collaborations. This may or may not

include the government sector. Although, the efforts over the country may not be uniform, strong inter-agency collaborations would exist in the private sector. The involvement of private sector would influence strong commercial incentives for developing new software or increasing the capabilities of existing software or hardware used for BIM. However, the effect of these efforts would be difficult to propagate nationwide without the support of the government. One may find the excellence in BIM applications on individual or in limited scenario; however, the overall development of BIM in a country would not be smooth enough without the government support. The conditions of BIM in the USA may be similar to this scenario. There is a strong support from the government agency in the USA. However, since the USA is a big country, the effort of government alone may not be enough for an effective implementation of BIM. Therefore, there are a number of non-government agencies involved in the deployment of BIM across the USA, which includes the software developers, research and development organizations, educational institutes as well as real estate and construction companies.

On the other hand, a weak support from private sector for BIM would not give companies the added advantage for inter-organizational collaboration. The companies in this scenario would focus more on their internal business processes which may not be well compatible with other companies and thus the fragmentation of the real estate and construction companies would increase. It would also affect the software and hardware development in BIM. The public sector in this case would not have enough feedback or push for development of BIM in a country. This scenario is reminiscent of many developing and under-developed countries where implementation of BIM at both the public and private sector is at the initial stage or is non-existent.

Table 2: *BIM Implementation in Private Sector of the Scandinavian Countries*

Country	Finland	Denmark	Norway
Organization	Skanska Oy	bips Rambøll	Selvaag – Bluethink
Projects and main function	Integration of Project Specific Building Information Model into Industrialised Building Process	BIM Guidelines Rambyg - IFC collaboration	ICT solutions based on BIM

Focus of BIM Research

A number of areas for comparison under this category are summarised in Table 3. From the review of the areas of research and development, it is observed that R&D in the selected Scandinavian countries (Finland, Denmark and Norway) is being conducted in two broad areas. These areas include the management aspects and the technical aspects. One such area is the investigation of the transformational effect of BIM on the overall business processes of a real estate and construction company starting from automation of the process and passing through informational effect. In another management research area, the business drivers for the implementation of BIM are being investigated which is divided into various areas concerning each stakeholder involved in the whole building lifecycle.

In the technical research, the interoperability issues have been given a good attention by researchers. IFC specifications are also being investigated to make them cater for the needs of the construction and real estate industry. The major issue in the use of IFC specifications is the complexity for its use by the industrial partners and efforts are being made to make the

specifications clearly modularized and categorized to better suit the needs of the construction industry users.

Table 3: *BIM Research Initiatives of the Scandinavian Countries*

Country	Finland	Denmark	Norway
Organization and projects	Helsinki University of Technology and VTT ECPIP, Engineering and Construction Project Information Platform	Aalborg University IFC Model Servers 3D Models – B3D	SINTEF Several projects under buildingSMART initiative BIM Guidelines development
	VTT and Tampere University of Technology VBE, Virtual Building Environments	Aarhus School of Architecture Product configuration Design intent IFC model server	buildingSMART A national coordinating effort to focus and collaborate on all buildingSMART development and implementation projects
	Tampere University of Technology IFC based BIM Industrial Processes Supported for Open Virtual Building Environment	Technical university of Denmark Interoperability	NTNU Student projects and thesis proposals focused on buildingSMART technology Collaboration with industry and research organizations to develop student courses
BIM Guidelines	ProIT Product modelling in construction projects General principles, architectural design, structural design and building services design	Digital Construction Program Guidelines for Working with 3D CAD Applications	BIM manual with experiences from the HIBO Statsbygg project

CONCLUSIONS

A review of BIM initiatives in selected Scandinavian countries (Denmark, Norway and Finland) and Singapore is presented in this paper. From the integrative analysis of the BIM initiatives in these countries, scenarios related to the roles of major stakeholders, the public and private sectors, for BIM and their BIM research initiatives have been presented. It is found that the level of support provided for BIM implementation in a country from both the public and private sector has its peculiarities. Generally, a more uniform and better coordinated mechanism of BIM development spreads across the country in the case of a strong public sector support. However, a strong public sector support would still be required even in the case of a strong private sector interest in the nation-wide implementation of BIM which follows that a weak public and private support is not an ideal scenario for effective BIM implementation in a country. The study also reviewed the salient BIM research initiatives in these countries and found that the sustainability, interoperability, informational and transformational issues are being given profound attention.

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