EVALUATING VBE AND BIM-FRAMEWORKS:

A Cost Estimation Case Study and Reflections to Environmental Issues

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Abstract. This paper describes and evaluates two recently emerged concepts, Virtual Building Environment VBE and Building Information Modelling BIM, fitting them into the context of contemporary design and construction. Both are elementary concepts in modern digitally "reinforced" design and construction. A case study of cost estimation is presented to illustrate how discipline related issues are currently managed within VBE and BIM. An environmental aspect is presented as a corresponding domain to evaluate the other use cases of building related information. Other similar domains to be evaluated perhaps in further case studies could be the functional user aspect, the project management aspect and the regulating aspect by the society and authorities. A hypothetical assumption is, that methods and technologies which are currently used within VBE and BIM, mainly by designers, can well support various data extractions from BIM-models, but they may not serve all construction process participants in the most beneficial way. Also wider scale building portfolios are requested as conceptual extensions to VBE and BIM. This study is based on ongoing PhD studies on building information modelling and environmental life cycle assessment.

Keywords. VBE; virtual building environment; BIM; building information model; CAD; cost estimation; life cycle assessment; LCA

1. Background: CAD, VBE and BIM - State of the Art

Computer-aided design, CAD, spreaded to architectural and engineering building design practice as a digital working platform and tool in the 1990's. CAD-systems in the AEC-field (architecture, engineering & construction) have been developed to manage *building design* related information. Aside CAD, document and data management methods have been developed in order to manage also *building project* related information more comprehensively. The objective has mainly been to support the whole life-cycle of a building, not only design or construction phases.

An overall concept of VBE, virtual building environments, as described by Vladimir Bazjanac, describes a software-related true working framework where various building process stakeholders with the help of technical software experts can work integrated with building information (Bazjanac 2004).

The concepts related with building information, and modelling building information, have been under research discussion since the late 1980's (Eastman 2006) although the idea of component based, graphic oriented and parametric design systems was not new then either (Sutherland 1962). Building product models - as they were at that time called - started to gain more volume in construction field practice in the late 1990's (Penttil 2005) and currently, when the concept of BIM, building information model, is more or less admitted, it is one of the most prominent collaborative working platforms within building design and construction (figure 1).

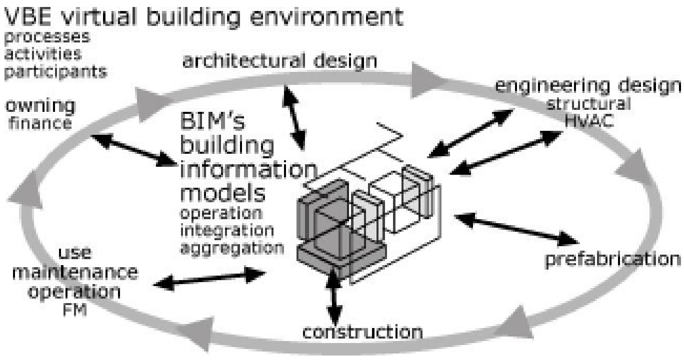

Figure 1. Virtual building environment VBE is a collaborative environment for model-based builing related information. One major objective VBE is to coordinate building data management and data-related processes within the context. Building information models are the actual core tools to manage all discipline related data.

One key issue in the evolution of AEC-field information technology, has been the change from document-oriented data management of design and construction process, towards model-based - or object-oriented, as it was described in the 1990's - information management of the buildings. Another trend in building related information management seems to extend the overall development objectives from design phases towards the whole life cycle of the building (Amor et al 2002).

An important objective of VBE is the intention to manage all building project information in centralized or at least well controlled way. VBE and BIM-methods are developed and used to reduce reproduction of building data, to enhance integration between the various project stakeholders and to enhance effectivity and quality within design-construction processes.

Collaterally the CAD-systems' technical evolution towards information modelling, major construction field organizations and companies have recently announced their visions and strategies towards "the BIM-future" (GSA 2007, Senate 2007). BIM does not only concern the technological data exchange aspects, but also how the various design-construction process actors use BIM. Even if model-based design and construction is currently represented by tools and data exchange technologies, such as IFC, the usability and applicability of these technologies to enhance processes are crucially important. IFC (industry foundation classes) is one central data exchange standard used in BIM-related data exchange (IFC 2007, Moum 2005).

The overall volume of contemporary BIM is somewhat difficult to evaluate, but based of recent research in Scandinavia (Samuelson 2007) the volume of BIM of all design work may be somewhere between 5...10..20 %, depending very much of the project type and company size. Nevertheless, BIM-activities in various countries (Scandinavia, USA, Netherlands, Australia, and Germany) seem to have accelerated during the last few years.

The BIM-concept has been very much of a research issue for a long time, and also technology standards such as IFC and various software tools have been developed long, before the concept finally made its "breakthrough" in the early 2000's. Now construction field companies, first building owners and designers, are gaining experiences in BIM-pilot projects and it is also clearly seen, that companies are currently implementing BIM-related methods into pragmatic project work (figure 2).

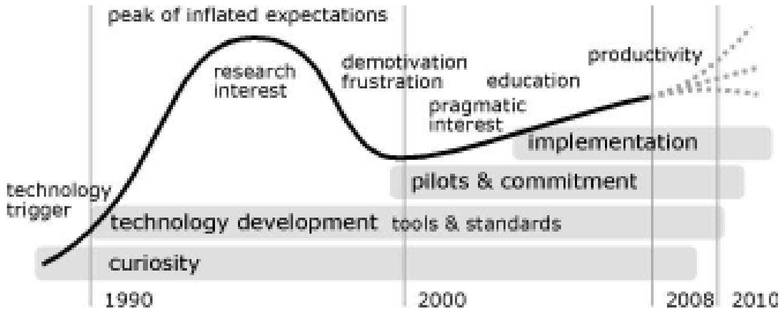

Figure 2. BIM - hype or reality ? The evolution of BIM-concept. Hype-curve of BIM was presented by Arto Kiviniemi to evaluate the status of the BIM-phenomena (Kiviniemi 2006). Gartner group has used the curve to assess technology maturity since the mid 1990's.

Contemporary BIM represents a rather technical and also highly structural aspect of building-related data. Even if the future of virtual buildings may become one major objective for the construction practice, the approach has also been criticized to be too unilateral and limited. Component based approach on building modelling is said to be inadequate to manage *all* building related information and knowledge, especially in the design phases (Kalay 2006). Pre-defined structures of BIM-models, which are currently used for instance in CAD-systems, are most appropriate for later design and construction phases, where project objectives are geared towards realism, buildability and construction practices. In earlier design phases, where design variations, creativity, flexibility, and sometimes even deliberated fuzziness are important values, component based BIM does not seem to supply the needs of the design discipline that well yet. Contemporary CAD, hence also BIM, is oriented towards very geometry-related building modelling, but more conceptual or abstract features of the building, such as user project requirements, alternative design options or user activities can not be supported with these technologies that well yet.

2. A Case Study of Building Costs

A case study of building cost estimation is presented to illustrate the pragmatic use and applicability of the BIM framework. Component based quantity take off and calculation and evaluation of building costs have been the earliest proven advantages of digital building models (Froese 2003).

The case study was done on a kindergarten project *"Toivo"* during the summer 2007 (figure 3). An architectural BIM-model from Autodesk/Revit was used to supply quantities and further constructional cost estimations in three project phases: early design sketches, mid-project decision making and later in detailled constructional production phase.

A decomposition-composition method was used. Quantity data was first extracted from the architectural design model. Data was then "itemized" to smallest manageable cost-related components, and finally "the data atoms" were reconstructed to describe all the concepts and elements needed in cost estimation. Revit Architectures' elements and components were exported first to MS/Excel tables, which were then imported to a cost estimation software Klara.biz. IFC data transfer was not used because Klara-software did not have the feature available.

Figure 3. Architects Revit-model of the Kindergarten project “Toivo”. Design elements and components were extracted from Revit and imported to Klara cost estimation software via Excel-files, where cost estimation data was first sorted and organized.

Main discovery from the case study was, that some 30...40% of elementary data for cost estimation can be extracted from the architectural design model. The architectural model can supply the bearing frame and other “visible” building components rather well, but there was also a clear lack of data for footings, bearings and quantities related with the site structures (table 1). Since the technical systems of the building (HVAC and electrical) were not available, their quantities could not be included either. Cost estimation process needs always data which is usually not included in the design models, namingly data about construction activities and resources and supplementary costs for on-site works.

Another interesting discovery was that even if the elementary data could be extracted from BIM-models, the end user of that data - in this case the quantity surveyor - should also be able to rely on the data. Very essential question is, how to ensure the comprehensive coverage of BIM-based quantities and how to confirm the reliability of the data. Even if the BIM-model supplies quantities, say, for internal wall surfaces, do the quantities still include *all* wall surfaces? In the case project the architect supplied also a dwf-model to ensure the quantities, but checking of all details from the model was simply too tedious and technically too complicated for the quantity surveyors and specialists.

TABLE 1. Cost estimation results of kindergarten project Toivo in three project phases. Model-based quantities (15...39 %) were extracted from the architect’s model. Non-model-based costs were estimated based on traditional volume (brutto-area) based estimations.

		sketch phase		**mid-project phase**		**final construction**	
			3,25 mill. eur		**3,07 mill. eur**		**3,28 mill. eur**
		model	non	model	non	model	non
		15%	85%	**35%**	63%	**39%**	61%
B	Project management		350 000		400 000		400 000
C	Site costs & works		280 000		280 000		280 000
D	Regional (external)		283 000		192 000	5 000	202 000
E..F11	Footings & soil-related		388 000		429 000		429 000
F13..27	Bearing frame	145 000	70 000	273 000	22 000	265 000	22 000
F31..34	External walls & openings	332 000	67 000	274 000		412 000	7 000
F41..43	Roof structures		204 000	197 000	21 000	191 000	21 000
F51..57	Internal non-bearing		25 000	164 000	9 000	198 000	10 000
F61..63	Internal surfaces		495 000	178 000		206 000	
F71	Furnifure (fixed)		95 000		117 000		120 000
G	HVAC-systems		308 000		313 000		313 000
H	Electrical systems		210 000		204 000		204 000

3. Reflections to Environmental Issues

3.1 AN ENVIRONMENTAL BRIEF

The environmental awareness and complexity of the western construction field is constantly growing. In the future building design and construction activities, as well as the use, maintenance and renovation have to meet even more and more detailed environmental requirements to foresee, measure and simulate the buildings' comprehensive environmental performance. Environmental evaluations and simulations will be required by the society already today to analyze buildings' environmental behaviour, energy consumption, and various impacts of building materials to the environment as well as waste-related issues within the built environment. Examples of life cycle long environmental issues are:

- Physical flows,
- Material (building material, water),
- Energy (embodied and operation energy),
- Waste (building materials and waste from use),
- Emission (waste released directly to the atmosphere or to the water),
- Information flows and
- Financial flows.

Life cycle analysis (LCA) is an evaluation method of resource consumption and the impacts on the environment of a product, a system or a service during the life cycle - starting from the extraction of the raw materials and lasting up to the elimination of waste. It is basically an accounting method of mass and energy flows using system ecological methods (Odum, E.P., 1971).

3.2 ENVIRONMENTAL DATA AND BIM

Energy related simulation and analysis tools can usually use the basic building geometry which is created by the designers. Energy simulation software then combines HVAC-system specific data, weather data and other needed simulation parameters to building geometry and allows performing various simulations. Current energy simulation software is documented for instance in one of Stanfords CIFE's recent reports (Maile et al 2007).

Despite the energy related simulations, such as committed energy or energy consumption, there are also other important environmental needs to assess: needs to evaluate alternative material use, needs to assess building related waste - sometimes hazardous - and needs to assess other environmental impacts, such as CO2-emissions. In practice, there is no sense in making isolated LCA for materials of single building components, only buildings provide the least coherent functional unit. Buildings in turn have to be decomposed in a systematic way and using the same functional units throughout the life cycle (Peuportier et al 1997). Current LCA-methods try to adopt the information of systematical description of buildings more and more from the earliest design stages (Chouquet et al 2003).

6. Conclusions

One main conclusion of this study is, that even if BIM-methods can be used in domain specific tasks such as cost estimation or environmental evaluation, the VBE and BIM-frameworks still always need extensions and further elaboration to fully support whatever domain specific use is.

Structurally similar than BIM, and very often hierarchical approaches to describe buildings, are the various building classification systems which are used in design and construction practices. Research of these various classification systems and their conceptual backgrounds is presented for instance in Ekholm 1999.

Well structured BIM-models can supply basic data for various purposes. On the other hand, even if contemporary BIM-models are integrative and they can cumulatively gather data from design for construction processes, the models will not be able to include all necessary building related data which is needed in various project phases and for various purposes by all the project stakeholders throughout the whole building lifecycle. Various disciplines will always need and deal with discipline specific data which has to be connected with the designer created BIM-models.

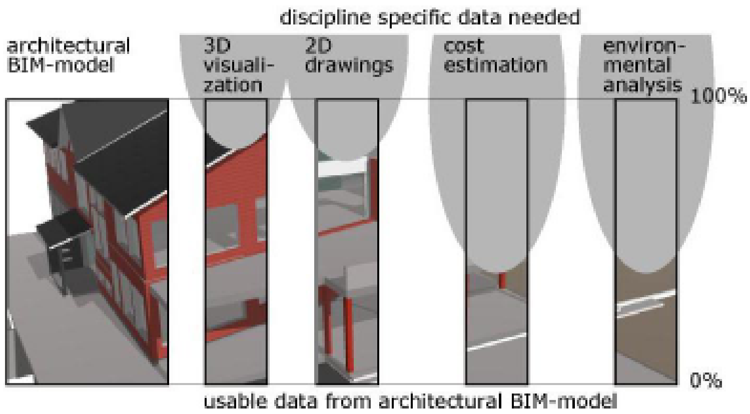

Figure 4. The usability of elementary architectural model. BIM-models always need additional domain specific data when they are used for various purposes.

To widely utilize building information in large scale cost estimation or environmental evaluation, digital building concepts need to be extended to manage multiple buildings and projects better than now. A building portfolio or building stock model connected with contemporary VBE and BIM would be a desirable extension (figure 5). One recent concept, VDC virtual design and construction, has extended BIM and VBE-concepts towards business, finance and project contexts (Kunz & Fischer 2008). The viewpoint of important AEC-field stakeholders, such as building owners, construction companies or building materials fabrication could perhaps be described and included in this kind of comprehensive construction field data model.

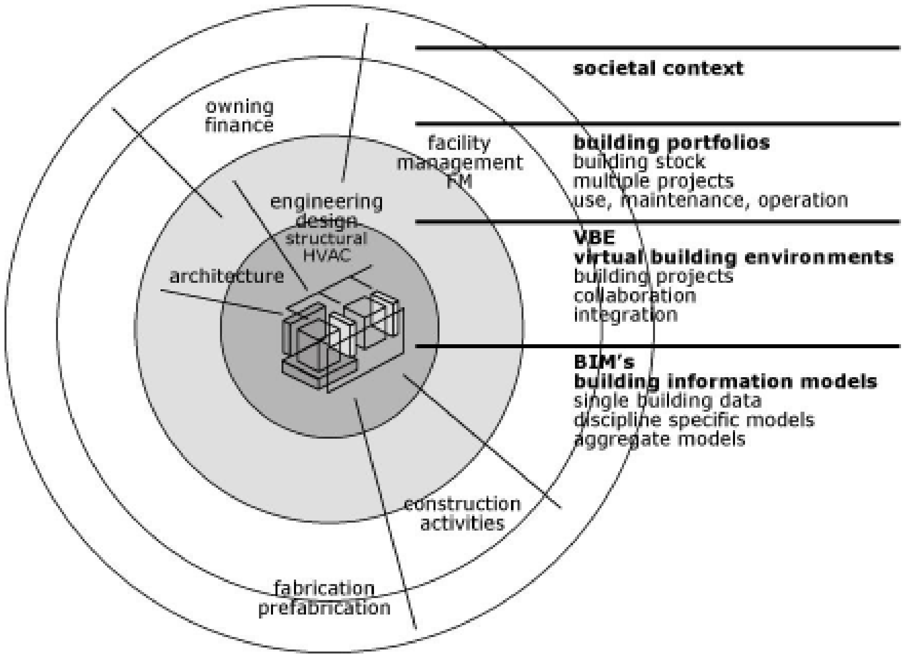

Figure 5. From single building data management towards large scale building portfolio or building stock data management.

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