

**ANALYSIS OF THE INFORMATION NEEDS FOR EXISTING BUILDINGS  
FOR INTEGRATION IN MODERN BIM-BASED BUILDING INFORMATION  
MANAGEMENT****Bjørn Godager***Geomatics Group, Gjøvik University College, Post Box 191, NO-2802 Gjøvik, Norway.  
E-mail: [bjoern.godager@hig.no](mailto:bjoern.godager@hig.no)*

**Abstract.** The challenge is to decide how to design a building information model (BIM) to support building maintenance and development for existing buildings. Until now the main BIM focus has been related to new projects, and this study focus on different challenges when deciding to use BIM for both new and existing buildings. This paper is based on studies together with regional and hospital authorities, but should be relevant for other types of existing buildings as well.

The primary objectives of these studies are to implement requirements for fire safety, universal design, environmental regulations, status of maintenances, occupancy, daily operations, rebuilding, mechanical, electrical, and plumbing installations (MEP) and effective use of energy and space within the BIM model. Additionally, these studies consider what BIM competence is required and by whom. It must also be decided which information is necessary for operating different types of building, and which information must be kept up to date.

Successful BIM adoption needs a good implementation strategy, professional guidelines and motivated people in the organisation.

This paper explains important options and decisions necessary to establish a BIM for management of existing buildings. Central questions concern the need for competence at different levels in the building owner organisations. At the same time the paper considers how the organisational structures may need to be adjusted.

**Keywords:** BIM, building management, building maintenance, building lifecycle, AEC (Architecture, Engineering and Construction), Geographical Information Systems (GIS), existing buildings.

**1. Introduction**

As the world's largest and most fragmented industrial activity, construction faces a huge challenge in pursuit of sustainability. It is estimated that 40% of all resource consumption are related to industry (European Construction Technology Platform 2004). As we all know, most buildings are already built and they meet more and more environmental requirements and other requirements from the authorities to meet the future in a sustainable way. To meet these challenges it seems very necessary to focus on the information needs for modelling and managing existing buildings during their lifetime. One of the questions or challenges is to decide how to design a BIM to support building maintenance and development for the whole life of the building (Chuck Eastman *et al.* 2008: 1-2).

The international open standards and neutral technology, collectively known as buildingSMART technology,

has the vision to enable efficient information flow during the complete lifecycle of the building and beyond.

BIM is beginning to change the way we build, the way the buildings look, the way they function and the way buildings are maintained and managed. Until now we have seen most focus on using BIM in quite new building projects. As we all know, existing buildings, roads and other constructions have a big need for efficient operations and maintenance.

Today, shareholders of the larger buildings and structures all over the world have to meet all those regulatory requirements for management and operations. The building's life cycle from planning and construction, through building use and management, maintenance and renovation and finally to the dismantling or demolition means more and more updated information. The resource consumption and waste production together also trigger a number of environmental problems. BIM seem to be a very important tool to handle all these challenges. European Union countries and many other countries now focus more and more on sustainable constructions. The construction materials industry is now looking at ways in

which to adopt a life cycle approach to improving the environmental performance of its products.

BuildingSMART International (buildingSMART) is a neutral, international and unique organisation supporting open BIM through the life cycle, and they have regional chapters in Europe, North America, Australia, Asia and Middle East. They have a special focus on improving business processes and to develop new business models, and this work will be of great value for organisations which want to implement BIM in their buildings life cycle.

## 2. This study

The project and the paper are based on literature studies combined with internal management, operation and maintenance studies made together with regional and hospital authorities in Inland Norway. These organisations together are responsible for managing some 600 000 square meters of existing buildings.

Additionally, these studies consider what kind of localized information and analyses are needed in larger buildings and what BIM competence is required and by whom in the organisation.

This paper explains important options and decisions necessary to establish a BIM for building management. Central questions concern the need for competence at different levels in the building owner organisations. At the same time the paper considers how the organisational structures may need to be adjusted.

The project is still going on, and the final report is planned to early 2012. An analysis of the ways the hospitals are facing their daily operations, their information need, their challenges and their requirements from the authorities is still going on.

Use of BIM in hospitals and larger existing buildings get more and more focus, but the knowledge about BIM seem to be on a lower level, and it is not understood through the whole organisation. From different pilot project we can find that use of BIM means a quite new way of thinking. To succeed people in the organisations need to act and do things quite different from before, and these knowledge aspects would be focused in the final project report.

BIM is associated with the whole building's design life (Penttilä 2006 and Succar 2009). The main difference between projects that use BIM is already in the planning and construction phase versus projects that wish to use BIM technology for existing buildings is that we get later into the project life cycle phases (Succar 2010, Fig 9). By adopting BIM for existing buildings arises a need to design a BIM that are adapted to needs in the operational phase. Design phase and construction phase are finished and in most cases for a long time ago, and available information is very variable and could stored in many different ways.

Because it usually will be most appropriate to create a simpler and customized BIM model for existing buildings, we choose to call it a slim BIM.

Our project experience that it is a great need to examine how a transition to BIM-based management and operation of large existing buildings should be carried out.

Various surveys show that there are challenges in implementing BIM (Arayici Y. *at al.* 2010). From this hospital study we experience much of the same challenges and needs. It is about to really understand the BIM concept, potential and value, and how to move to modern lean orientated work flow, how to train people, choice of software and how to optimize the use of software.

## 3. Which information is necessary for operating different types of existing buildings, and which information must be kept up to date?

It may be different information need for different types of buildings, but many things should also be the same. Some requirement will come from the management but other claims will come from further down in the organisation. And some requirements will come from the authorities through laws, requirements and regulations.

In our hospital related project we have focus on requirements and information need related to management, operation and maintenance and here the project will focus on how to use BIM in the condition assessment and the analysis process. The project will specially focus these areas although there may be others that are just as important:

1. Universal design
2. Fire safety
3. Environmental regulation and effective use of energy
4. Electricity network
5. Mechanical Electrical Plumbing installations (MEP)
6. Daily operations and effective use of spaces and areas
7. Organisation of the management, operation and maintenance processes and need for a modern and good Facility Management System software to solve the challenges. Here it is also included how to import or transform data from one system to another and how to organize this work.
8. Rebuilding

One main focus in the project is to find out how to integrate BIM into the management, operation and maintenance processes.

### 3.1. Universal design

The National Office of Building in Norway has made guidance and regulations on technical requirements for construction works in Norway (Norwegian building codes).

The regulation from the national authorities shall ensure that measures are planned, designed and constructed out of concern for good visual quality, universal design and

so that the measures meets the technical requirements for safety, environment, health and energy.

The requirements are given either as functions or services in all major areas such as aesthetics, universal design, health, environment, energy and security. According to the Planning and Building Law, the responsible designer must prepare the necessary documentation to ensure that all requirements made in or pursuant to the Planning and Building Law is taken care of in the finished building.

### 3.2. Requirements for universal design

There is a clearly defined ambition in laws and regulations that all products, buildings and surroundings shall be made to be used on equal terms by as many as possible. That means in other words universal design. The authorities have given the strongest requirements to new buildings and constructions, but also public existing building has got strong requirements.

Examples are parking areas, lighting and marking in entrances, step-free entrances, placement of a solution for any automatic door opener, requirements for elevators, rooms and the doors must be suitable only for all users included wheelchair users and people with reduced vision, important rooms should be available for all users. On top of this it should be easy to navigate with good signs and marking.

All these things could be a part of a modern BIM, and then it is possible to run analysis where the different requirements should be checked in the software.

### 3.3. Fire safety

Owners of buildings are required to provide the necessary security measures to prevent and mitigate fire, explosion or other accident. And to keep technical building construction, safety devices and other security measures to protect against fire, explosion or other accident in proper condition and ensure that at any given time appear as intended.

Other important fire safety information to be stored in a BIM could be:

- Exterior walls shall include doors and windows shown in the right size and shape. These items should also be applied to any fire and audio classes and show stroke direction.
- Interior doors and windows should also have marks of fire and sound classes, and also which way the doors are opening.
- The grip of fire and sound can be read by walls, doors and window.
- Technical rooms, main shafts, and electrical cabinets shall be located.
- Doors and windows are in place both in size, shape and location concerns. Classes and audio classes are also applied.

This is a big and important field where it seem to be big opportunities to develop the integration between todays software and the requirements from the authorities. The project will continue to focus on what different software manufacturers can offer of BIM implementation.

### 3.4. Environmental regulation and effective use of energy

The modern society has more and more environmental requirements because of growing environmental challenges and lack of energy. This means that it is a need for focusing on building materials and for performance classification in the energy field.

We have got strong energy performance directives in buildings from the European Parliament and of the Council of 19 May 2010 (European Parliament 2010). Today we talk more and more about sustainability, but how should the owners and facility managers meet the future to handle these requirements? International studies show that energy efficiency is the easiest and cheapest climate measure. It really is great potential in existing buildings. The EU has a strong focus on this, and authorities in Europe must follow up in this area.

It seems to be a great need to have good models both for typical GIS and for BIM, and these days we can see an international focus and some very exciting research on the integration between GIS and BIM. To face environmental challenges in the future it seems to be necessary to have more intelligent information about all things related to the environment.

We have in 2010 got a new European energy labeling system with letters from A to G. A is the lowest class and G is the class with highest energy use.

If we really should analyze the energy use in buildings, we also need good and intelligent models, but today we are still far from that level.

### 3.5. Electricity network

The hospitals in Norway have like many other owners of buildings got requirements for electrical drawings from the authorities. Today they have no such drawings and no model. There is a need for electrical network and construction documentation and quality analysis. This area also seems to demand a model, and the answer seems to be let it be a part of BIM.

### 3.6. Mechanical Electrical Plumbing installations (MEP)

Large buildings also need to have good information about MEP installations. These are not focused yet in the project, but this information is related to the rest of the information. Also in this area new laws and strict regulations push the owners, and the need for a good model seems obvious also in this field.

### 3.7. Daily operations and effective use of spaces and areas

Many issues related to implementation of BIM are non technological. Project communication has been little studied from more than a technological standpoint (Cerovsek 2010). Newer research has addressed more non-technological issues (NIBS 2007, Succar 2009, Suermann 2009). Large buildings have different use and also over time different use inside the same building. Many people are working in these buildings. Hospital patients are changing quickly and move around inside the building. The mapping of different hospital equipment is important, and the possibility to find out where rooms, equipment and persons are very interesting information. To handle these things it is also interesting to focus on LEAN processes, which means how to streamline the way of working. New research shows that a combination of LEAN and BIM has big potential to get very good results (Arayici Y. *at al.*). Therefore it seems interesting to focus these things deeper in the project. These things are also related to the management part in next chapter.

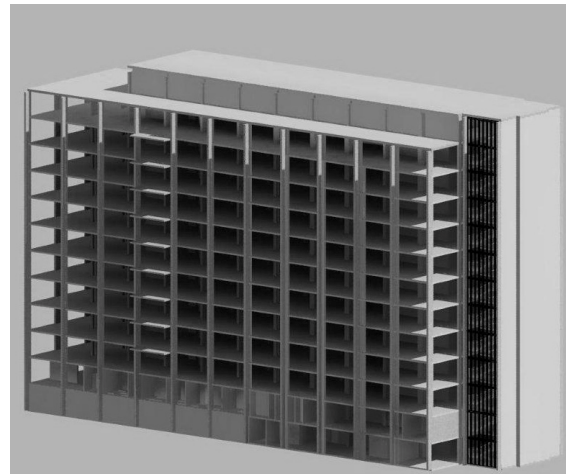
### 3.8. Organisation of the management, operation and maintenance processes

In existing buildings the owners see an increasing need for modern and good Facility Management System software to solve more and more of the challenges. The value of all buildings should be much higher with a complete model (Chuck Eastman *at al.* 2008: 93-146). In the project we are now focusing on existing buildings and then the reality is very often no model at all, and in this Norwegian hospital project we can find that all these 600 000 square meter hospitals are in a 2D Facility Management System, FMS. The hospitals in Norway are using two different facility management systems (Plania), (Lydia) at the moment. At best, we can call these systems “light” BIM. The software has possibilities to plan and to find the costs within maintenance, cleaning and rental. The programs have planning and reporting functions for the operation and maintenance activities in the enterprise.

It seem to be problems or challenges with facing requirements related to universal designs, energy analyses, fire safety electricity system in their current system. The hospitals have dwg-drawings, but until now they have no 3D models of their old existing building. Until recently they had focus on CAD (Computer Aided Design) and not BIM. They also have made a CAD manual and have one dedicated person to handle all drawings. This person has the title “CAD responsible” today. BIM offers wider range of applications than CAD. The learning needs in BIM are quite different and bigger than the learning needs of CAD (Wong K.A. 2011).

It is an ongoing student project at the moment to make a 3D hospital model from existing drawings which can be used as a reference model for further BIM development. In these processes it is necessary to choose which information you will put into the model. In all

cases it seems to be most realistic and also reasonable to talk about “slim-BIM”. That means you take the most important information first. In other words you build up the skeleton first, and then afterwards you can enrich the model over time after which information you want to put into the model. So far the student projects had to inspect the building many times to supplement important things into the model.



**Fig 1.** Early stage of making a “slim-BIM” for Lillehammer hospital in Revit Architecture

If you for instance want to analyze all the electricity system or fire safety the different blocks or building parts have to be linked together in a common model. Today they are in fact in separate 2D models, and it is not possible to do analysis for the whole hospital. On top of this there is no unique numbering of the different room.

The challenges we can see here are rather typical in organisation like this. Systems are built up before newer technology was available. It seems to be a great need to make a common model and to establish good understanding and procedures among employees who should maintain and use the system.

To handle orders, the running time, periodic delivery and billing, and making work orders, it is needed to have a good quality system.

The new Pad technology seem to be a very interesting method both to do necessary data capture and for daily use and model maintenance, and the hospital organisation already have plans to buy some of these. In all cases it is really a need to build up a “slim- BIM” if there are no models from before.

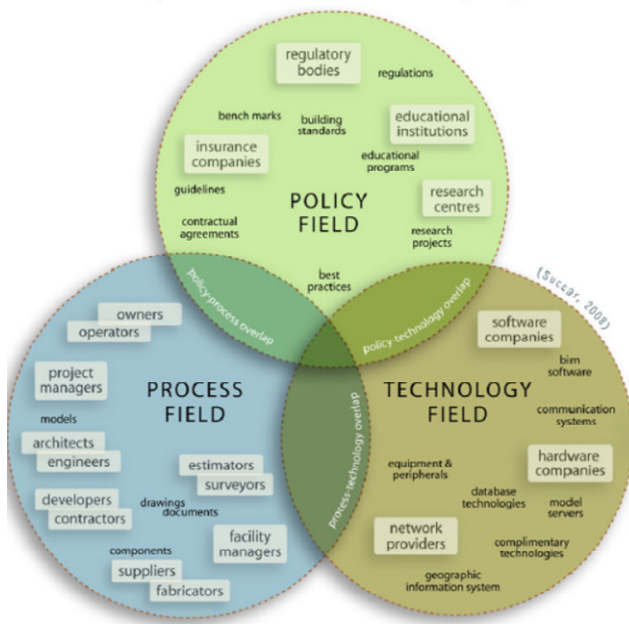
The next years we can see new techniques for early detection, analysis, or monitoring natural hazards. So we need a quite new life-cycle design way and thinking.

The figure 2 (Succar B. 2009) shows important key processes or clusters and interaction between policy, process and technology field. The different fields will have overlaps. There is still also a need for a framework that positions BIM as an “integration of product and process modelling” (Succar B. 2009, Kimmance A. 2002) and not just as a disparate set of technologies and

processes. Our ongoing hospital project needs to make their own diagrams and their own BIM manual.

Rebuilding processes could be very different. If you have a model from before it should be much easier. But if you do not have any model from before our own project and other projects show possibilities for winning if you choose to make a BIM model. The BIM certified software has object functionality and can rather easily give you a BIM today.

*B. Succar / Automation in Construction 18 (2009) 357-375*



**Fig 2.** Three interlocking Fields of BIM activity — venn diagram (Succar B. 2009)

Our ongoing project is also linked and involved into a rebuilding project where the old building shall be stripped before reconstruction. But it is not results from this part yet, because the practical work has just started.

As a part of the research it is planned to use laser scanning after the building are stripped. These data are planned to model up a slim-BIM and to compare this with a model made from old drawings (as built).

#### 4. Need of competence needs in the organisation

The analyses for needed BIM competence can be different from organisation to organisation. It will of course depend on the organisation plan and what kind of functions each employee is intended to have. But it is mostly good to have a deeper knowledge than just exact connected to the job description – just to understand bigger processes. So, this also need some research to find a more optimized level.

In all cases many different BIM projects until now show that it is very important that foundation and understanding in the organisation is very important. That means that all workers need some knowledge about BIM

and need act to the fact that the organisation is based on BIM.

Most users only need to read the model and need of course less information. Those people who are going to manage or to build up the models need a lot more competence. In this hospital organisation this part of the project has just started, but it seems to be a great need to change the way of thinking and the way of organizing. All authority requirements, environment, quality assurance and economy/ efficiency need are all examples which seem to lead many owners of existing buildings against thinking BIM modelling.

There is also a need to make requirement for different types of employees who are involved in construction projects in their direction.

Further in the study it must together with the hospital authorities be assessed and described how the overall BIM expertise can be optimised, and recommendation of which projects should be BIM pilot projects.

What should be the basis for the services, with its associated resources that it is appropriate to have in your own organisation. What services should be purchased externally? This should be considered in relation to competency and utilization of resources.

#### 5. What should be modelled?

It may be a risk that the use of BIM can result in too much focus on material and quantifiable properties can get too much attention. Thus, we believe that things are built "good enough" when it undergoes a streamlined model system and meet all requirements. For example, the requirements in the universal architectural design, aesthetics and site design suffer BIM world opportunities for standardization, efficiency and rule checking. Aesthetic objects and personal wishes and views are subjective and therefore very difficult to model.

Requirements in the mobility part of universal design maybe easier to check in a model than the demands for sight and hearing. This suggests that BIM alone can't answer all questions.

Various internal and external studies in recent years shows that the degree of available information and how it is stored is important for the choice of method and choice of modeling completeness.

The Construction-Operations Building Information Exchange (COBie) format facilitates the delivery of building information during planning, design, construction, and commissioning for delivery to facility owners and operators (buildingSMART Alliance).The hospitals authorities in Norway will use COBie in some new building projects in 2011. All big owner of building projects need tools to lead and standardise the different types of object orientated 3D information into their Facility Management Systems, and further best practice studies seem to be welcome.

Some rebuilding projects will have special focus related to implementing BIM, and the organization will make a plan for incremental implementation of BIM.

## 6. Do every owner of big existing buildings need a BIM manual?

Today the hospitals only have a CAD manual, and there is still no BIM manual. The project has to find out if it is necessary to change the focus and also the name to BIM manuals. In the same operation it seems natural to consider whether there is a need to have their own BIM manuals for various purposes (operation and maintenance, rebuilding, new buildings). At the moment it still is a need for further standardization of the different libraries and processes based on the open, international building smart standard, Industry Foundation Classes, IFC (buildingSMART). This process is running in good progress and development. In any case it should not be wrong to start the process of restructuring the way of thinking and working, while the standardization work will constantly be in a development adapted constantly to new demands and needs.

## 7. Summary and conclusions

To work with BIM has to change our traditional way of thinking, because using BIM requires looking into things in a quite new manner, and it also needs new knowledge.

The BIM development seems to run faster and faster and seems to be very important to meet many types of challenges. This paper shows that most of the areas mentioned are strongly linked together and they seem to be very depending to have a model - a BIM model. For existing buildings and constructions we often have to start with either paper drawings or digital drawing to make a 3D model. Only for newer buildings we have a 3D model and sometimes a BIM model as well. To succeed in making good analysis of existing buildings, we must therefore try to establish models adapted to the amount of information and with the precision that is desirable.

The organisation has to find their information and analyze need to solve the management. To reach these goals it is also necessary with good knowledge both about the BIM technology, but also knowledge about the working field.

In the real world owners of big buildings will have a mix of quite new buildings in BIM, reconstruction – maybe with BIM and older existing building - where we start with different kinds of drawings. Sometimes the owners are missing some drawings too, so it could be hard work to make a model.

The hospital authorities also need to make an evaluation of what should be done with existing buildings with regard to 3D modeling. The ongoing project modeling existing building is a pilot project, and decisions about other buildings would be taken after the pilot project is finished.

Traditionally we have used GIS at the beginning of the facility lifecycle process, before BIM was needed. In the future we will see a much better interoperability between BIM and GIS and greatly increased value of GIS to

support the needs of facility owners and operators. The GIS field have used advanced systems for many years (for more than 20 years), and also offshore and industry have used advanced models for years. Now there are also finally some BIM-GIS interoperability best practices studies to build this bridge between these fields. There is an obvious need for standards to integrate indoor and outdoor locations and to integrate the technologies of design (AEC, CAD and BIM) with the technologies of observation and measurement (surveying, GIS, remote sensing, LIDAR, navigation, location services), (Hecht Jr. L. 2010 and Open GIS Standards).

The facilities owners and operators maybe feel a big pressure to jump into BIM, but in all cases they need to have sustainable buildings for optimal occupancy and use. Smart buildings will be able to support planners and operators.

BIM implemented for existing buildings has to be more focused in systematic research. This case study and paper has identified some challenges and some unanswered questions. Some questions are technological, other questions are more non-technological and are related to how an organisation works and how people behave.

The focus and use of BIM around the world appears to be accelerating, but it is a great need for best practice studies. From such studies we would have better guidelines to help establishing effective strategy and methodology of implementing BIM at the organisational level (Arayici Y. *at al.* 2010).

The buildingSMART alliance, a council of the National Institute of Building Sciences (NIBS) and the North American Chapter of buildingSMART International has been coordinating the efforts of the facilities industry to implement open BIM standards for the industry over the past several years. The "United States National BIM Standard Version 1, Part 1: Overview, Principles, and Methodologies" was released in December 2007 and laid the foundation and provided templates for our future open BIM standards efforts.

The final goal of all these technologies, processes and policies will eventually facilitate an Integrated Project Delivery (IDP).

## References

- Arayici, Y.; Coates P.; Koskela, L.; Kagioglou, M.; Usher, C.; O'Reilly, K. 2010. Technology adoption in the BIM implementation for lean architectural practice. *Automation in Construction* 20: 189-195.
- buildingSMART. Available on the Internet: <<http://www.buildingsmart.com>>
- buildingSMART Alliance. A Council of the National Institute of Building Sciences. Developing Open BIM Standards for Communication Throughout the Facilities Industry. Available on the Internet: <<http://www.buildingsmartalliance.com>>
- Cerovsek, T. 2010. A review and outlook for a 'Building Information Model' (BIM): A multi-standpoint framework for technological development. *Adv. Eng. Informat.* doi:10.1016/j.aei.2010.06.003.

- Eastman, C.; Teicholz, P.; Sacks, R. and Liston, K. 2008. BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors. 490 p. ISBN 978-0-470-18528-5.
- European Construction Technology Platform. 2004. Working Paper. 38 p. Available on the Internet: <[http://www.e-core.org/ETPconstruction/Vision\\_2030.pdf](http://www.e-core.org/ETPconstruction/Vision_2030.pdf)>. Proceedings of the B4E conference, Maastricht, 14th of October, 2004
- European Commission Energy. Energy labelling. Available on the Internet: <[http://ec.europa.eu/energy/efficiency/labelling/energy\\_labelling\\_en.htm](http://ec.europa.eu/energy/efficiency/labelling/energy_labelling_en.htm)>
- European Parliament. 2010. Directive 2010/30/EU on the indication by labeling and standard product information of the consumption of energy and other resources by energy-related products. Available on the Internet: <<http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2010:153:SOM:EN:HTML>>
- Green Building XML (gbXML). A Building Information Modeling Solution for Our Green World. Available on the Internet: <<http://www.gbxml.org/>>
- Gu, N.; London, K. 2010. Understanding and facilitating BIM adoption in the AEC industry. *Automation in construction* vol. 19, no8. 988-999.
- Hecht, Jr. L. 2010. Laying the Foundation for BIM Interoperability Journal of Building Information Modeling. The National Institute of Building Sciences buildingSMART alliance, Washington. *An official publication of the National Institute of Building Sciences buildingSMART alliance*. 19-20. Available on the Internet: <[http://www.wbdg.org/pdfs/jbim\\_fall10.pdf](http://www.wbdg.org/pdfs/jbim_fall10.pdf)>
- Open GIS Standards. Available on the Internet: <<http://www.opengeospatial.org/standards/is>>
- ISO 29481-1. 2010. Building information modelling -- Information delivery manual -- Part 1: Methodology and format. *International organization for standardization*. Available on the Internet: <[http://www.iso.org/iso/catalogue\\_detail.htm?csnumber=45501](http://www.iso.org/iso/catalogue_detail.htm?csnumber=45501)>
- Kimmanca, A. 2002. An integrated Product and Process Information Modelling System for On-Site Construction, Thesis (Ph. D.). University of Loughborough, UK, 2002.
- Lydia. A Facility Management System in Norway. Available on the Internet: <[www.lydia.no](http://www.lydia.no)>
- NIBS, National BIM Standard, Part 1 2007. Overview, Principles, and Methodologies, *National Institute for Building Sciences* (NIBS), Washington, DC, USA. 182 p.
- Przybyla, J. 2010. Journal of Building Information Modeling, The National Institute of Building Sciences buildingSMART alliance, Washington. *An official publication of the National Institute of Building Sciences buildingSMART alliance*. 14-18. Available on the Internet: <[http://www.wbdg.org/pdfs/jbim\\_fall10.pdf](http://www.wbdg.org/pdfs/jbim_fall10.pdf)>
- Mihindu, S.; Arayici, Y.; Digital construction through BIM systems will drive the re-engineering of construction business practices: *12th international conference of Information Visualisation, IEEE Computer Society*, London, UK, 2008. 29-36.
- Norwegian building codes. Available on the Internet: <<http://byggeregler.be.no>>
- Penttilä, H.; 2006. Describing the changes in architectural information technology to understand design complexity and free-form architectural expression, *ITCON 11(Special Issue The Effects of CAD on Building Form and Design Quality)*: 395-408. <<http://www.itcon.org/2006/29>>
- Plania. A Facility Management System in Norway. Available on the Internet: <[www.plania.no](http://www.plania.no)>
- Sacks, R.; Koskela, L.; Dave, B. and Owen, R. 2010. *Journal of Construction Engineering and Management* 136, 968 (2010 ); doi:10.1061/(ASCE)CO.1943-7862.0000203. 13 p.
- Suermann, P. 2009. Evaluating industry perceptions of building information modelling (BIM) impact on construction, *International Journal of IT in Construction* 14. 574-594.
- Succar, B. 2009. Building information modelling framework: a research and delivery foundation for industry stakeholders, *Automation in Construction* 18 (3): 357-375.
- Universal Design. Available on the Internet: <<http://www.universal-design.environment.no/>>
- Yan, W.; Culp, C.; Graf, R. 2010. Integrating BIM and gaming for real-time interactive architectural visualization, *Automation in Construction*, doi:10.1016/j.autcon.2010.11.013
- Wong, K. A.; Wong, K. F, Nadeem, A. 2011. Building information modelling for tertiary construction education in Hong Kong, *Journal of Information Technology in Construction (ITcon)*, Vol. 16: 467-476. Available on the Internet: <<http://www.itcon.org/2011/27>>