



HAL
open science

Leveraging on Enterprise Building Information Models in Health Care Services: The Case of St. Olav University Hospital

Sobah Abbas Petersen, Tor Åsmund Evjen, Seyed Reza Hosseini Raviz, John
Krogstie

► **To cite this version:**

Sobah Abbas Petersen, Tor Åsmund Evjen, Seyed Reza Hosseini Raviz, John Krogstie. Leveraging on Enterprise Building Information Models in Health Care Services: The Case of St. Olav University Hospital. 21th Working Conference on Virtual Enterprises (PRO-VE), Nov 2020, Valencia, Spain. pp.644-653, 10.1007/978-3-030-62412-5_53 . hal-03745791

HAL Id: hal-03745791

<https://inria.hal.science/hal-03745791>

Submitted on 5 Aug 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



This document is the original author manuscript of a paper submitted to an IFIP conference proceedings or other IFIP publication by Springer Nature. As such, there may be some differences in the official published version of the paper. Such differences, if any, are usually due to reformatting during preparation for publication or minor corrections made by the author(s) during final proofreading of the publication manuscript.

Leveraging on Enterprise Building Information Models in Health Care Services: The Case of St. Olav University Hospital

Sobah Abbas Petersen², Tor Åsmund Evjen¹, Seyed Reza Hosseini Raviz²,
John Krogstie²

¹ St Olavs University Hospital, Trondheim, Norway. Email: tor.asmund.evjen@icloud.com

²Dept. of Computer Science, Norwegian University of Science and Technology, Trondheim, Norway.

Email: {sap, seyed.r.h.raviz, krogstie}@ntnu.no

Abstract. Building Information Models (BIM) play a central role in the construction phase of buildings. At St. Olav University Hospital in Norway, the focus has been on generating value from BIM during the entire lifecycle of the many buildings that comprise the hospital and supporting the core business processes of the hospital during the operations phase. St. Olav University Hospital has been at the forefront of developing Enterprise BIM, where the information from BIM are utilized together with other data and information, such as availability, positioning and movements of equipment and use of the different physical spaces. In this paper, we focus on the use of EBIM and how they could support Collaborative Networks of different stakeholders and their interactions with one another, with the building facilities and the relevant equipment for supporting daily operations.

Keywords: Building Lifecycle, Enterprise BIM, Health care Services, Enterprise Processes, Indoor Positioning

1 Introduction

Hospitals are complex buildings that serve a variety of stakeholders and support a variety of direct and indirect complex relationships among them [1]. The ability of a hospital or any health care institution to provide the best care with the least resources have been one of the drivers. Similarly, the agility to rapidly reorganise resources and adapt to arising needs is of utmost importance to ensure the wellbeing of patients and health care personnel. Building Information Models (BIM) have received a lot of attention as a technology that could support efficient design and construction of hospitals; e.g. [1, 2]. More recently, BIM have been considered beyond the early life cycles of building, to support hospitals during their operations phases. Some of these areas of application include Facility Management (FM) [3], asset management and refurbishing of older buildings [4].

At St. Olav University Hospital in Trondheim, Norway (St. Olav hereafter), the concept of Enterprise BIM (EBIM) has been explored [5]. EBIM brings together information from BIM models and other enterprise information systems, to provide relevant information and data that could support the daily operations of the hospital and support effective collaboration among stakeholders. In this paper, we describe how St. Olav takes BIM beyond the design and construction phases and FM to support the operations phase of the lifecycle of the hospital buildings. St. Olav has developed an EBIM and utilises information from EBIM along with other relevant data and information to support enterprise processes. Information in BIM models contribute to the development of 3D visualisations of the physical context and layout of buildings. This can be leveraged to create value to a number of stakeholders in hospitals including the management and patients. The aim of this paper is to explore the benefits of EBIM to support a diverse set of stakeholders in hospitals. The main research focus is to investigate possible ways that EBIM could be used to support daily operations in the hospital. By using the Case Study research method [6], we describe some of the approaches taken by St. Olav to utilise information available in their BIM models to create more value for their enterprise processes. To achieve this, St. Olav has developed several prototype applications to explore the possibilities and demonstrate the value of EBIM.

In this paper, we describe briefly three prototype applications that have been developed and tested follows: Section 2 provides a brief overview of related work on BIM and EBIM; Section 3 describes the case of St. Olav and how EBIM is used to develop three prototype applications and Section 4 summarises the paper and outlines future plans.

2 BIM, EBIM and Collaborative Networks

BIM modeling was introduced in the early 2000s in pilot projects to support the building design in the architecture and engineering sectors. As a result, the main research trends focused on enhancing and development of pre-planning and design, visualization, collision detection, quantification, cost and data management [4]. Construction projects involve complex sets of linkages between stakeholders with different professional backgrounds [7]. Therefore it was necessary to change the emphasis from a fragmented approach to a concerted and collaborative effort to support the owner's goals [8]. More recently, the use of BIM has evolved to support the entire lifecycle of buildings or sets of buildings such as a hospital complex, and to support a variety of business and organizational processes such as facility management and asset management. The use of BIM has numerous benefits for a variety of stakeholders in hospitals [9]. Some of the advantages of BIM are the fact that they can represent the different mechanical systems in the buildings such as the ventilation system (HVAC); they enable the building to be considered as a system in itself [9], and they can contain data related to equipment. The possibility to represent the different systems and equipment within a physical and spatial context provides huge advantages in decision making during the entire lifecycle of a building.

BIM have been considered as a significant contribution for Facility Management (FM), where the BIM models were handed over from the entrepreneurs and other relevant actors in the construction phase to the owners and/or operators of the building; in the case of hospitals, the hospital facility managers. BIM models provide value to FM as they already contain relevant information and thus will reduce the cost and time required to collect and build FM systems [10]. This resulted in the continued use of information in BIM to support cleaning processes [11], proactive maintenance practices and tracking of equipment [12, 13], among others [14]. BIM are also recommended as a tool for supporting the refurbishment of existing buildings and the use of BIM in refurbishment are discussed in detail in [15].

More recently, building owners and operators have focused on leveraging value from the BIM models, or the virtual real estate they represent, by using the information available to support core organizational processes, reduce operating costs and management decision making. In fact, the operational phase of a building has been identified as the main contributor to the building lifecycle cost [10]. The concept EBIM is defined as “a virtual holistic representation of buildings adapted for optimized business management, knowledge sharing and collaboration” [5]. The use of EBIM can facilitate the integration of BIM and other relevant information, through the use of standardised IFC (ISO 16739) models and other information models, in a model server. This opens up for the use of EBIM in making decisions, supported by data and visual components, that are relevant for the operations of the enterprise. The main difference between BIM and EBIM is that EBIM considers the whole enterprise (e.g. the hospital) rather than just the building and puts the core business processes into focus (owner, director, personnel, patient, authorities, manager and builder). For example, such operations could be optimal asset management, efficient collaboration or indeed making critical decisions involving the use of assets and facilities during an unforeseen emergency situation [16].

A lot of the work has focused on BIM-based construction networks to support collaboration and to support collaboration during the design and construction phases; e.g. [17, 18]. Similar to the design and constructive phases, the benefits of information and experience sharing and collaboration among the different stakeholders are significant during the other phases of the lifecycle. In particular, supporting Collaborative Networks [19] outside the context of a project is challenging. Collaborative networks in the health care operations have been addressed by researchers; e.g. Noran analysed the collaborative networks in various tasks performed in hospital operations, where the focus was on the collaboration among different stakeholders [20]. Collaborative Networks in healthcare and interactions across different health care institutions in processes such as request for investigations and information and physical material (e.g. blood samples) flow were analysed in [21]. Challenges identified include locating physical material that should flow along with their information counterparts, within the IT systems.

Some of the operational activities in an enterprise often comprise of tasks that arise where communication and coordination among individuals or teams from different specialised areas are important; e.g. in a hospital, medical personnel may need to know the availability of specific medical equipment in a specific area of the hospital or about the availability of a medication. Such activities require collaboration among

some of the medical staff with FM or people interacting with procurement and logistics. They are strictly teams, but the need for communication (perhaps indirect) is essential. There have been a few attempts at addressing such challenges; e.g. by integrating a workflow engine and a multi-model BIM collaboration platform [22].

3 Example Case – St. Olav University Hospital

St. Olav, located in Trondheim, Norway, is made up of many buildings. Both old and new buildings have been incorporated in this complex, that have to be kept in proper or good condition in the course of the decades of lifetime. The hospital needs to identify a homogenized and standardized open platform with a view to develop and maintain their amenities. Today, all the buildings that constitute St. Olav, approximately 350000m² of building area, have been modelled according to the openBIM standards [23]. By considering BIM as a digital interaction paradigm for all types of properties through all lifecycle phases, where everyone can initially share and gain insight through different digital interfaces, the focus has shifted from the project-centric to see BIM in a business perspective. St. Olav and Central Norway's Health Authority set up a collaborative project called Lifecycle BIM in 2012, to build up a lifecycle BIM based on a FM platform. The result was to implement an EBIM philosophy, where information from BIM are considered in hospital operations.

The main research focus is to investigate possible ways that EBIM could be used to support daily operations in St. Olav. The Case Study research method [6] is used to identify and describe different approaches that could be used to create value from EBIM to support enterprise processes. The primary information sources are three ICT prototypes that have been developed by MSc students [24-26], and informal discussions with the staff in St Olav's Property Department. The prototypes were developed based on documentation available from the Property Department and semi-formal interviews with the staff, which helped identify the requirements. The evaluations were focused on the proof of concepts.

3.1 EBIM at St. Olav University Hospital

At St. Olav's, EBIM is defined as a discrete information database aimed to support the many enterprise aspects and enable the integration of the core business and the various processes of the hospital [27]. Traditionally, when the building construction phase is completed, the BIM models are made available to the FM activities. The EBIM concept at St Olav considers the BIM models to be available as a part of the EBIM, which brings together other ICT applications and data that support enterprise operations and strategic decision making, such as facility management, patient related activities, logistics, ERP systems and procurement. This is illustrated in Fig. 1, where EBIM relates the BIM models to the other operational activities.

The main objective of EBIM is to strive for a comprehensive and rational digital management of the building stock that reflects as best as possible the real building structures and functions. In order to meet this objective, a BIM server has been acquired for St. Olav, which is used as the main tool for validating, storing and

communicating all building technical information. The system has features that support operation and maintenance, rental agreements, retrieval and tracking of mobile equipment and people, as well as web-based real estate portal and wireless communications in the field. One of the main technical challenges in adopting BIM-based models and achieving EBIM is interoperability among different IT systems [28, 29]. At St. Olav, an application for visualizing and management of EBIM, called Model Server Manager (MSM) has been developed. The application is object-oriented and based on open standards such as IFC and EXPRESS data specification language, defined in ISO 10303-11 [30]. All of St. Olav's building models are stored in a database on a BIM server and the MSM can retrieve and update these models. The application allows a display of multiple models in the same view.

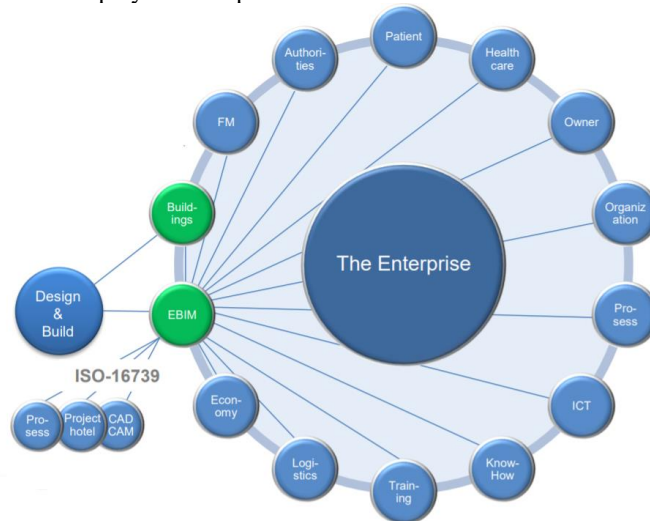


Fig. 1. EBIM and Enterprise Processes

Information from the EBIM models have been used to develop data driven models and simulations [1]. Furthermore, several prototype implementations to explore the value of EBIM for enterprise processes have been developed. They are also aimed at supporting interaction among the stakeholders and between the building and objects within it, and users of the hospital facilities and services. In the following subsections, we describe briefly some of the ways in which St. Olav uses EBIM and other information in the model server to support enterprise operations and decision making. The technical details for the prototypes are beyond the scope of this paper.

3.2 3D Visualisation of Buildings and Objects

A web-based prototype, using the WebGL API and BIM models has been developed as the foundation for a 3D scene, to explore the possibilities that 3D WebGL applications can offer in a virtual hospital context. It includes objects to interact with, which could likely feature in the virtual hospital arena, and in various enterprise

processes such as logistics, optimization, training or simulations [26]. Information from EBIM models were used to create a 3D visualisation of one of the hospital buildings from 1930. The types of models used were architectural models (ARK) which included elements such as walls, windows, doors, ceiling, roof, beams, benches; and electrical models (RIE), which included lamps, emergency door openers, sockets, card readers, elbow switches, emergency exit signs and more. An additional layer of information was added to include objects placed in the building.

The main aim of the implementation was for users; e.g. facility managers or patients, to walk around in the virtual building and interact with the building and various objects within the building. St. Olav owns a large collection of art. Thus, the prototype chose presentation of the artwork and paintings in the virtual hospital building, where the user could identify their locations and interact with the paintings to learn about them and update information about them as relevant; see Fig. 2. Users could also select a room in the building and access presentations and videos that have been presented in the room. Such a functionality is aimed at enhancing implicit collaboration, communication and knowledge sharing among different stakeholders of the hospital.



Fig. 2. Interaction with a painting, in a 3D visualisation of a BIM model [26]

The benefits of such a functionality include the possibilities to use information from EBIM for creating a sense of the physical space in a virtual environment. A game to support navigation was created using the 3D visualisation. The main advantage of using BIM information as the basis for modelling the physical environment in the game was the level of detail of the building that was available; a digital twin of the hospital buildings. A usability test was conducted with 17 users from the hospital. A short questionnaire indicated positive responses and over 85% of the respondents saw a value in these types of applications for familiarizing themselves in real buildings, while 69 % thought that web-based 3D applications have a potential in educational scenarios. The value of such applications can be for facility managers, health care personnel as well as patients and visitors.

3.3 Asset Management

Asset management involves the balancing of costs, opportunities and risks against the desired performance of assets, to support decision making, planning and execution of activities and tasks of assets as desired by building owners and operators [13]. Hospitals have a need to locate medical equipment as equipment, such as robots and Automated Guided Vehicles (AGV), hospital beds and wheelchairs tend to move relatively frequently. Smaller medical apparatus (e.g. insulin pumps, nebulisers) and other equipment are often borrowed from one section within the hospital to another and in some cases they are never returned. The possibility to efficiently locate such equipment would save time and thus effort and costs to the hospital staff including the health care personnel.

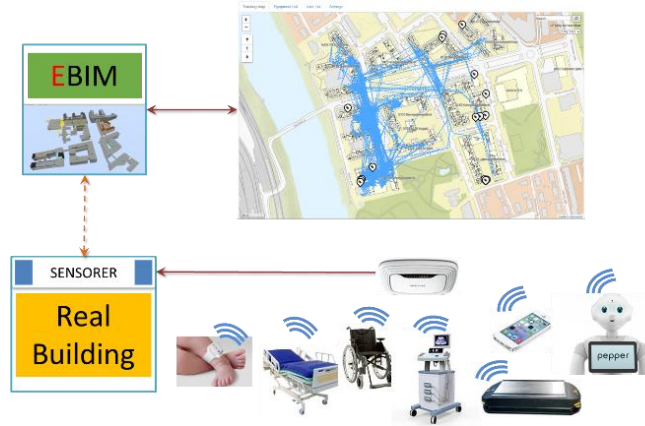


Fig. 3. EBIM and Indoor Positioning System for assets management

A prototype has been developed, using the information in the BIM models and the MSM together with Indoor Positioning data. The requirements for the prototype application were identified through informal interviews with hospital staff and by creating scenarios of how various types of personnel would use such a system; e.g. a maintenance staff, a porter and a project manager for remodelling. Smart asset tags on hospital equipment and wireless technologies were used to trace the movements of equipment and they were located using the CISCO location server. The position and time related data was then saved in an xml file, and visualized in the spatial context with the virtual hospital environment [25]. The movements of an electrical scooter through the hospital buildings within a 3 month period is visualised in Fig. 3.

One very important aspect of being able to track the location of an equipment and trace their movements is also safety and security; e.g. w.r.t. to the possibility of contamination and the reduction of the risk of infections. The movement and usage of equipment can also be used to manage the “fleet of equipment”, e.g. the no. of wheelchairs or AGVs, to an optimal amount, thereby reducing the costs and the effective management and maintenance of the assets.

3.4 Dynamic Cleaning

One of the beneficiaries of BIM are facility managers and examples of benefits include efficient cleaning of equipment and physical spaces. At St. Oav's, EBIM models have been used by the property owners to calculate the area for cleaning so that this information could be used to negotiate the price with the cleaning company [11]. Traditionally, cleaning is a routine process that is conducted at regular intervals, or at hospitals, related to specific activities in specific rooms such as operation theatres. At St. Olav's, an explorative study has been conducted to use information from EBIM and the Model Server to create dynamic cleaning plans based on the use of equipment and spaces. Information such as mobile phone traffic within a specific physical space, (respecting privacy compliance), could be made available on the model server. A prototype, a mobile solution available on an iPad using 3D visualizations, has been developed to explore possibilities for dynamic cleaning routines rather than fixed routines [24].

The requirement for the application were developed by interviewing employees from the cleaning company, who provides the service in several Norwegian hospitals. In addition, staff in the property department were included in the discussions. The prototype was evaluated by employees from the hospital's cleaning department, working with coordination and administrative tasks. The overall response was very positive and they could appreciate the benefits of such an application. Such an application could make cleaning routines more effective while reducing the overall cost of cleaning.

5 Summary and Future Work

In this paper, we have described the concept of EBIM and how St. Olav could create value to its stakeholders through utilising information from EBIM models along with other relevant data and information to support enterprise processes. The main contribution of this work is a demonstration of how BIM data could be operationalised during the operations phase of a hospital. Three prototype applications have been developed to support the operations phase of the lifecycle of the hospital buildings, using information from BIM models. In the first prototype, a 3D virtual hospital arena has been developed, where users could view and interact with objects such as artworks and paintings within the building as well as navigate through a virtual hospital. In the second prototype, indoor positioning data was collected for equipment within the hospital, and their movements were visualised using information in the BIM models. In the third prototype, EBIM information was used with other data to support dynamic cleaning routines, based on the actual use of rooms. The prototypes were based on the use of the IFC standard and a model server to overcome interoperability challenges.

The prototypes demonstrated the benefits for hospital operations in efficient and optimum assets management, updating of information related to equipment and buildings, reduced effort in locating and ensuring the safety of equipment reduction in costs in routine processes such as cleaning. In addition, the possibility to interact with

objects in a virtual 3D hospital environment supported efficient update of information in the models as well the value of the models for supporting people to find their way around the buildings efficiently.

The prototype applications that were described in this paper focussed mainly on the technological solutions and little emphasis was given to supporting Collaborative Networks. Our next step will be to consider these within the contexts of workflow and collaborative tasks and how they can benefit collaborative tasks within the healthcare operations. Work also continues in the design and development of new applications that could be built upon the rich data that is available from the EBIM and to explore the value for specific organisational processes and stakeholders.

Acknowledgements. The co-author Raviz has been supported by ERCIM. The authors would like to thank St. Olav University Hospital for letting us use their EBIM applications as a part of the case study and the students that have developed the prototype applications.

References

- 1 Zwart, J.V.d., Evjen, T.Å.: Data Driven Simulation Model for Hospital Architecture: Modelling and Simulating Clinical Process, Architectural Layout and Patient Logistics in a Hospital's Building Information Model. In: Viana, D.L., Morais, F., Vaz, J.V. (eds.) *Formal Methods in Architecture and Urbanism*, pp. 223-236. Cambridge Scholars Publishing (2018)
- 2 Sanchez, A., Hampson, K., Vaux, S.: *Delivering Value with BIM – A Whole-of-life Approach*. Routledge (2016)
- 3 Soliman, A.A., Khodeir, L.M.: *Efficient Stakeholders Management: The Impact of Applying the Integrated Building Information Modeling/Facility Management Approach*, A Literature Review. *Sustainable Mega Projects*, Egypt (2016)
- 4 Volk, R., Stengel, J., Schultmann, F.: *Building Information Modeling (BIM) for Existing Buildings – Literature Review and Future Needs*. *Automation in Construction* 38, 109–127 (2014)
- 5 Evjen, T.Å.: *Smart Hospital and Enterprise BIM*. 7th International Megaprojects Workshop. University of Quebec, Montreal, Canada (2019)
- 6 Yin, R.K.: *Case Study Research: Design and Methods*. SAGE Publications (2014)
- 7 Latiffi, A.A., Brahim, J., Fathi, M.S.: *The Development of Building Information Modeling (BIM) Definition*. *Applied Mechanics and Materials* 567, 625–630. (2014)
- 8 Allen, C., Shakantu, W.: *The BIM Revolution: A Literature Review on Rethinking the Business of Construction*. In: Galiano-Garrigos, A. (ed.) *The Sustainable City XI*, vol. WIT Transactions on Ecology and the Environment, pp. 919 - 930 (2016)
- 9 Sanchez, A., Hampson, K., Mohamed, S.: *Perth Children's Hospital Case Study Report*. Sustainable Built Environment National Research Centre
- 10 Kelly, G., Serginson, M., Lockley, S., Dawood, N., Kassem, M.: *BIM for Facility Management and a Review and a Case Study investigating the Value and Challenges*. 13th Int. Conference on Construction Applications of Virtual Reality, London, UK (2013)
- 11 Reehaug, B.: *BIM – Et Hjelpemiddel for renholdskontrakter?*, Høgskolen i Gjøvik (2015)

- 12 Love, P., Zhou, J., Matthews, J., Sing, C., Carey, B.: A systems information model for managing electrical, control, and instrumentation assets. *Built Environment Project and Asset Management* 5, 278-289 (2015)
- 13 Love, P.E.D., Matthews, J., Lockley, S.: BIM for Built Asset Management. *Built Environment Project and Asset Management* 5, (2015)
- 14 Galliano-Garrigós, A., Andújar-Montoya, M.D.: Building Information Modelling in Operations of Maintenance at the University of Alicante. *Int. J. Sus. Dev. Plann.* 13, 1-11 (2018)
- 15 Sheth, A.Z., Price, A.D.F., Glass, J.: BIM and refurbishment of existing healthcare facilities. In: Egbu, C. (ed.) *Proceedings of the 26th Annual ARCOM Conference*, vol. 2, pp. 1497-1506, Leeds, United Kingdom (2010)
- 16 Krugler, P., Chang-Albitres, C.M., Pickett, K.W., Smith, R.E., Hicks, I.V., Feldman, R., Butenko, S., Hun, D.K., Guikema, S.: *Asset Management Literature Review And Potential Applications of Simulation, Optimization, And Decision Analysis Techniques for Right-Of-Way And Transportation Planning and Programming*. Texas Transportation Institute The Texas A&M University System (2007)
- 17 Oraee, M., Hosseini, M.R., Edwards, D.J., Li, H., Papadonikolaki, E., Cao, D.: Collaboration barriers in BIM-based construction networks: A conceptual model. *International Journal of Project Management* 37, (2019)
- 18 Merschbrock, C., Munkvold, B.E.: Succeeding with Building Information Modeling: A Case Study of BIM Diffusion in a Healthcare Construction Project. 47th Hawaii International Conference on System Science, Hawaii (2014)
- 19 Camarinha-Matos, L., Afsarmanesh, H.: Collaborative networks: a new scientific discipline. *Journal of Intelligent Manufacturing* 16, 439-452 (2005)
- 20 Noran, O.: Enhancing Collaborative Healthcare Synergy In: L.M., C.-M., R.J., S. (eds.) *Collaborative Systems for Reindustrialization. PRO-VE 2013*, vol. 408. Springer, Berlin, Heidelberg (2013)
- 21 Petersen, S.A., Bach, G., Svarlien, A.B.: *Patient Care Across Health Care Institutions: An Enterprise Modelling Approach. PoEM 2010*. Springer (2010)
- 22 Gürtler, M., Baumgärtel, K., Scherer, R.J.: Towards a Workflow-Driven Multi-model BIM Collaboration Platform. In: Camarinha-Matos, L., Bénaben, F., Picard, W. (eds.) *Risks and Resilience of Collaborative Networks. PRO-VE 2015*, vol. 463. Springer, Cham (2015)
- 23 <http://open.bimreal.com/bim/index.php/>
- 24 Tenstad, A., Halvor, B.M., Thorkildsen, M.K., Eidem, M.R., Ødegaard, O.K., Latif, S.M.: *Smart Cleaning. Dept. of Computer Science*, vol. MSc. Norwegian University of Science and Technology (2018)
- 25 Jørstad, F.K.: *Smart Hospital: Indoor positioning with BIM. Dept. of Computer Science*, vol. Specialisation Project. Norwegian University of Science and Technology, Trondheim, Norway (2016)
- 26 Hestman, L.M.: *The Potential of Utilizing BIM Models With the WebGL Technology for Building Virtual Environments: A Web-Based Prototype Within the Virtual Hospital Field. Dept. of Computer Science. Norwegian University of Science and Technology, Trondheim, Norway* (2015)
- 27 Aksnes, E.Ø.: *Indoor Positioning Integrated in EBIM. Norwegian University of Science and Technology, Trondheim, Norway* (2016)
- 28 Azhar, S., Hein, M.F., Blake, S.: *Building Information Modeling (BIM): Benefits, Risks and Challenges*. (2008)
- 29 Criminale, A., Langar, S.: *Challenges with BIM Implementation: A Review of Literature. 53rd ASC Annual International Conference Proceedings* (2017)
- 30 Huse, P.: *FDVU/FM med EDMmodelserver. BuildingSMART members' meeting. Jotne EPM Technology AS* (2015)