Enterprise Architecture to Identify the Benefits of Enterprise Building Information Model Data: An Example from Healthcare Operations

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Keywords: Enterprise Architecture, Enterprise BIM, Dynamic Scheduling, Healthcare Operations, Value-added Services.

Abstract: This paper explores the concept of Enterprise Building Information Models in a hospital and how they could be used in combination with Enterprise Architecture to support innovation in healthcare operations. The motivation for this work has been to improve the use of easily available data for creating new value-added services that could make an enterprise more flexible and agile. Enterprise Architecture has been used as the approach for structuring and visualising how the data in the Building Information Models can be utilised in combination with other data and applications in a hospital to identify potential new services for the benefit of multiple stakeholders. In this paper, we have considered Enterprise Building Information Models as analogous to the concept of data exchanges identified in some Enterprise Architecture frameworks and use Enterprise Architecture models to describe a business case based on a dynamic scheduling algorithm for cleaning. The main contribution of this work is an Enterprise Architecture model of the hospital, which relates data in Building Information Models to strategic and operational processes.

1 INTRODUCTION

Building Information Models (BIM) have been identified as a transformational technology for buildings as well as for organisations (Forgues & Lejeune, 2015). The transformative value of BIM lies in the richness of the data in digitised models and their potential to add value and increase the benefits to the operation of the building, which in turn must support the organisational processes. For example, in a hospital, the services that are provided to support the healthcare personnel and the patients are of utmost importance to the hospital. In realising the true potential of BIM during the operations phase of the hospital, BIM data has been considered with other enterprise data, introducing the concept of Enterprise BIM (EBIM) (Evjen, 2019).

The success of many technologies such as BIM and EBIM, or indeed the value of data rely on how accessible the data is and the knowledge of the stakeholders. During the operations of any enterprise, the stakeholders are not only IT related but encompass many more, such as strategic decision makers, facility managers and procurers. It is often a challenge to relate technical components or single sources of data to high-level processes or strategic decision-making processes.

Enterprise Architecture (EA) is an area of study that has emerged as a means of relating the IT components in an enterprise to its business needs (Zachman, 1987). The abundance of EA frameworks and EA consultants highlight the popularity of EA in organisations. However, there are challenges in communicating the value of EA for an organisation. Nevertheless, several benefits of EA have been identified in the literature (Tamm et al., 2011). EA is seen to play an important role in supporting timely organisational decision making through access to relevant high quality information, and as a means of supporting service provision in organisations (Frampton et al., 2015). EA provides the ability to visualise and show potential services of specific technological components and data. EA is reported to increase agility and the value of organisations to its

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Petersen, S. and Evjen, T.
Enterprise Architecture to Identify the Benefits of Enterprise Building Information Model Data: An Example from Healthcare Operations.
DOI: 10.5220/0011084600003179
In *Proceedings of the 24th International Conference on Enterprise Information Systems (ICEIS 2022) - Volume 2*, pages 567-576
ISBN: 978-989-758-569-2; ISSN: 2184-4992

customers and employees and to improve the business potential of organisations (Shanks et al., 2018).

The main aim of this paper is to highlight the value of EBIM (BIM data together with other enterprise data) and visualise the potential benefits of EBIM for healthcare operations. A prototype of a mobile application that uses a dynamic scheduling algorithm for cleaning has been developed by a student group (Tenstad et al., 2018). The algorithm was designed using the idea of EBIM and using BIM data together with other sources of data. We have used EA as a means of describing and communicating two business cases for the dynamic cleaning algorithm and highlight the potential services and benefits that it could bring to several stakeholders of the hospital. The main aim of this paper is to illustrate the potential of EBIM, using the EA approach. Our contribution is a set of visual EA models that are developed to describe new services developed by using EBIM, and how they can benefit multiple stakeholders during the operations of the hospital. We have taken the EA approach and visualised the services as a part of the hospital EA, where EBIM is described as a set of data sources and ICT applications. The models describe a number of potential value-added services that could be of benefit for the various stakeholders. The strength of this work lies in the visualisation of the artefacts and the relationships among them, such as which data could be used by who to create value and which stakeholders or actors could or should collaborate to achieve this. The purpose of these models is primarily a means of supporting discussions among the stakeholders.

The rest of this paper is structured as follows: Section 2 provides an overview of related work; Section 3 provides a brief description of the research gap and the research approach; Section 4 describes an example case and the value-added services visualised using EA models; Section 5 describes the main stakeholders and benefits of EBIM as described in the EA models, and Section 6 concludes the paper.

2 RELATED WORK

This section will provide a brief overview of the main concepts that are discussed in this paper: BIM, EBIM and EA and EA frameworks.

2.1 BIM

Building Information Models (BIM) have been identified as a transformational technology for buildings as well as for enterprises (Forgues & Lejeune, 2015). In addition to describing BIM as "a digital representation of the physical and functional characteristics of a facility", BIM is also described as a "shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward" [National Institute of Building Sciences, (2007), p.149]. BIM has played a role in the design and construction phases of buildings, and in supporting communication among the different stakeholder groups from the construction perspective (Ku & Taiebat, 2011).

A broad perspective of BIM have been described by some authors, such as a means of supporting the entire lifecycle of buildings and as a set of interacting policies, processes and technologies (Succar, 2009) generating a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle" (Penttilä, 2006). However, most of the research reported in the literature focus on the design and construction phases of a building (Pikas et al., 2011; van der Zwart & Evjen, 2018) and does not take into account the activities that take place in the building. The common uses of BIM beyond the construction phase are mostly in facility management (Lucas et al., 2013; Sabol, 2008; Wang et al., 2015) and assets management (Krugler et al., 2007; Miettinen et al., 2018). There are, but a few examples of the use of the data in BIMs during the operational phase of a building and in relation to specific activities of the enterprise that takes place within the building, e.g. (Petersen et al., 2019). Thus, there appears a research gap in the identifying the potential of BIM data for enterprises and their strategic and operational processes.

2.2 EBIM

The concept of Enterprise BIM, or EBIM, has been proposed, and is defined as a discrete information database aimed to support the whole building mass and several enterprise aspects, and enable the integration of the core business and the various processes of the hospital (Aksnes, 2016). The enterprise aspects represent the parts of an enterprise that are relevant for the different phases of its lifecycle. For example, during the operation phase, enterprise aspects of relevance would include the business and operational processes, patient related information, logistics, technical and digital infrastructure as well as assets and facility management, (Evjen et al., 2020; Petersen et al., 2019). Thus, EBIM can be considered as BIM data in combination with several other data that is available in any enterprise, that enhances the value of BIM for an enterprise during multiple phases of the lifecycle of the building. Furthermore, EBIM could identify the potential for new and innovative services that could add value and could potentially improve the use of the built environment and spaces for the benefit of the enterprise processes. For example, tracing the movement of assets within the space to identify spaces that are most in use (Jørstad, 2016), or to learn more about the use of specific rooms based on the assets or material (digital and physical) associated with the room (Hestman, 2015).

2.3 Enterprise Architecture Frameworks

The first EA framework, the Zachman Framework (Zachman, 2008) was proposed as a taxonomy of the different entities, emphasising the roles or stakeholders within an enterprise and the data and information elements and artefacts that are of interest to the different stakeholders. The scope of the stakeholders goes beyond those actively involved in the development of IT systems. The most popular EA framework and methodology today is The Open Group's EA framework (TOGAF) (The Open Group, 2011), which takes a layered approach to distinguish the business, data and information and the technology layers of an enterprise. TOGAF emphasises primarily on the business and IT stakeholders and how to engage these stakeholder groups to create a solution architecture.

Recent technological advances have transformed enterprises from generating and owning all their data and IT systems to leveraging on third party systems and Open Data. Thus, EA framework have evolved to support the dynamics of today's enterprises and one such EA framework that is of interest when we consider several data sources such as BIM and IoT data is IDS-RAM, which is a Reference Architecture Model for Data Spaces to support the current digitisation trend and the data-centric landscape (Otto et al., 2018).

The fundamental ideas of EA and the distinction of the business, data and information, technology and solution architectures, while bridging them, have been considered relevant in the area of smart and sustainable cities (Pourzolfaghar et al., 2016). Thus, several smart city architectures have adopted the layer-based approach of several EA framework. One such EA framework is the one developed in the European H2020 Smart Cities project Positive City Exchange, +CityxChange (Ahlers et al., 2019). The + CityxChange EA framework is layer-based and brings together the needs of a city or an enterprise such as a healthcare provider and the entities and layers that are included in a traditional EA framework such as TOGAF.

In the healthcare context, EA has been defined as a "plan (or set of plans) that guides healthcare management responsibilities and strategies, including the identification and use of IT resources" (Bradley, Pratt, Thrasher, et al., 2012). A few examples of EA in healthcare institutions have been reported in the literature; e.g. (Haghighathoseini et al., 2018). Most of these address the design and construction phases of buildings. The main limitation identified in studies in the application of the EA approach in hospitals is the lack of involvement of stakeholders other than those from the IT domain (Ajer et al., 2019; Bradley, Pratt, Byrd, et al., 2012).

2.3.1 + CityxChange EA Framework

The + CityxChange EA framework is designed to provide an overview of the ICT applications that are developed to meet the needs of the different stakeholders in a city. The services meeting the needs are often based on several ICT applications, often developed and/or owned by several organisations, thus resulting in a collaboration among several organisations to provide the services. An overview of the +CityxChange EA framework is shown in Figure 1.

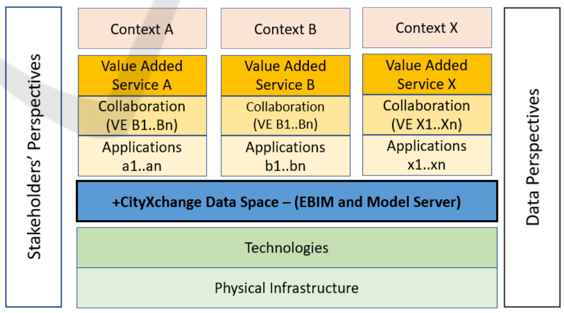

Figure 1: +CityxChange EA framework, adopted from (Petersen et al., 2019).

The bottom three layers focus on the technological aspects, e.g. the physical infrastructure layer serves as the sources of data, such as sensors on equipment or metering devices. The large amounts of data gathered from this layer is transferred to the technology layer, which includes the software and hardware infrastructures. The framework is centred around the Data Space, which provides an overview of all the data that is available to an enterprise for developing ICT applications and value-added services. This data space layer serves as the glue between the software and hardware infrastructures to support the data and the contexts in which the data could be leveraged to create value to several stakeholders. The application layer can be used to describe the ICT applications that could be developed by collaborations among one or many actors or organisations; described as a VE or a collaborative network. These applications or combinations of applications meet the needs of stakeholders; in the case of a hospital, they may include healthcare personnel, facility managers, logistics managers, patients and visitors to the hospital.

3 RESEARCH GAP AND RESEARCH APPROACH

The research gaps that have been identified include the lack of use of the data in BIM models in the operations phase of a building to support enterprise processes. The use of EBIM, BIM data together with other enterprise data, to create innovative value-added services to support the enterprise processes has not been explored. And finally, there are challenges in communicating the value of EBIM and available data to the different stakeholders in an enterprise.

In this regard, we have explored the use of EA in healthcare operations in hospitals and identified that while there are a few examples of the use of EA in the area of healthcare, it appears that there is a lack of involvement of stakeholders other than those working with IT. The benefits of using EA in enterprises have been described by several researchers (Frampton et al., 2015; Shanks et al., 2018; Tamm et al., 2011). Hence, we have chosen EA as our approach and used an EA framework for describing the value of BIM and EBIM, by visualising how they could be used to create several value-added services in an enterprise.

The case study approach (Yin, 2014) is the overall approach that we have used, particularly to understand the environment and the needs. We have chosen a prototype ICT application which uses a dynamic scheduling algorithm for cleaning, which has been developed as a part of a student group project (Tenstad et al., 2018). The student thesis has been the main data source for our work. In addition, informal conversations with people from the property department at the hospital have provided us insights. We have used the information available to create an EA model to identify potential value-added services and their benefits for stakeholders that make strategic and operational decisions in healthcare operations. The visual models are the artefacts that have been developed and described in this paper.

4 VALUE-ADDED SERVICES – AN EXAMPLE CASE

In a hospital in Norway, a prototype of a dynamic scheduling algorithm for cleaning has been developed, which utilises data from EBIM. This application creates dynamic cleaning plans based on the use of equipment and spaces within the hospital. Information such as mobile phone traffic within a specific physical space, (respecting privacy compliance) and BIM data were used. A prototype was designed after conducting surveys among several Norwegian hospitals to identify limitations and challenges related to the current cleaning services. Some of the challenges of the current cleaning services that were identified were the lack of connection with the BIM models (e.g. spatial data) resulting in a separate service that was required to transfer the relevant data to the cleaning systems, which included an additional cost, and manual updates of the maps of the physical space. Thus, a prototype, a mobile solution available on an iPad using 3D visualisations, was developed to explore possibilities for dynamic cleaning routines based on the actual usage of the rooms and spaces (Tenstad et al., 2018). Such an application could make cleaning routines more effective while reducing the overall cost of cleaning.

We have used the +CityxChange EA framework, described in Section 2.3.1, and EA Modelling to visualise the dynamic cleaning scheduling algorithm in the context of the EBIM and other relevant applications and data in the hospital and this is shown in Figure 2. The EA models have been created using Troux Architect, which is an Enterprise Modelling tool, supporting several EA approaches. Note that the aim is not to describe the entire EA for the hospital, but the applications that are relevant to illustrate the new value-added services that could be created by using EBIM.

The contents of the layers are described below:

- Context/Needs layer describe the needs of the stakeholders and the context in which the needs arise. In the case of a hospital, there is a need for clean rooms and equipment, the satisfaction of the patients and the management would like to optimise their costs of operating the hospital.

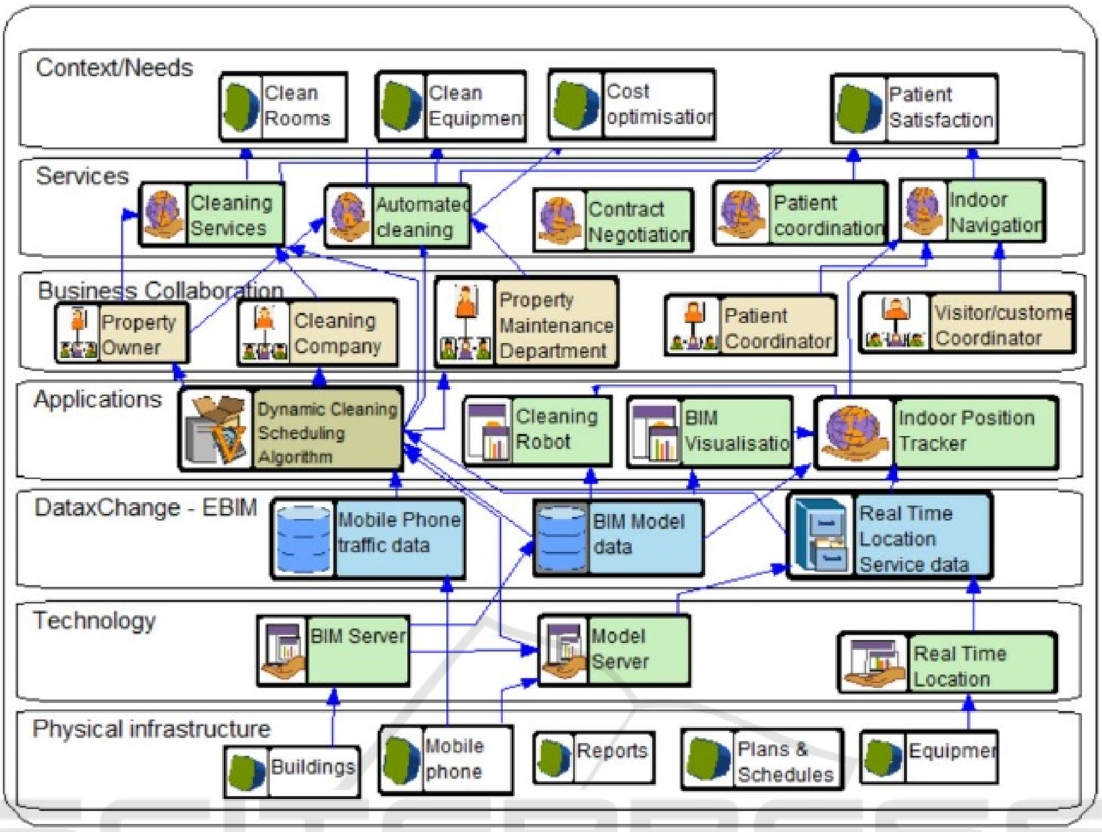

Figure 2: EA model of EBIM and example business cases.

- Services layer describes the services that could be developed to meet the needs of the stakeholders. In hospitals, some of the services that could meet the needs identified in the Context/needs layer include cleaning services, contract negotiations, patient coordination activities and indoor navigation support services.
- Business Collaboration layer describes the partnerships or collaborations that may need to be formed to provide the services. For example, the property owner (of the hospital) would need to collaborate with the property maintenance department and the cleaning company for the cleaning services. Similarly, the patient coordinator may need to collaborate with the visitor coordinator or the property maintenance department.
- Applications layer describes the various ICT applications that could be used to develop and support the services, such as the dynamic scheduling algorithm for cleaning, application to visualise BIM data and indoor positioning applications.
- DataxChange layer describes what could be considered as an EBIM and describes the data that is available to create the applications and the services to meet the needs of the stakeholders. In this case, some of the relevant data are the data in the BIM models, mobile phone traffic data, real time location service data and other enterprise data.
- Technology layer describes the different technologies that provide the data and the underlying software and hardware technologies that support the data and the applications described in the higher layers of the EA model. In this case, some of the technological components include the BIM server, a model server that was implemented to provide access to multiple data services using the IFC data format and real time location data.
- Physical Infrastructure layer describes the sources of the data, which are not the same as the technological components or the hardware. They include the physical buildings, mobile phones, equipment. Some of the components in this layer could also include other sources of data such as from social media or documents.

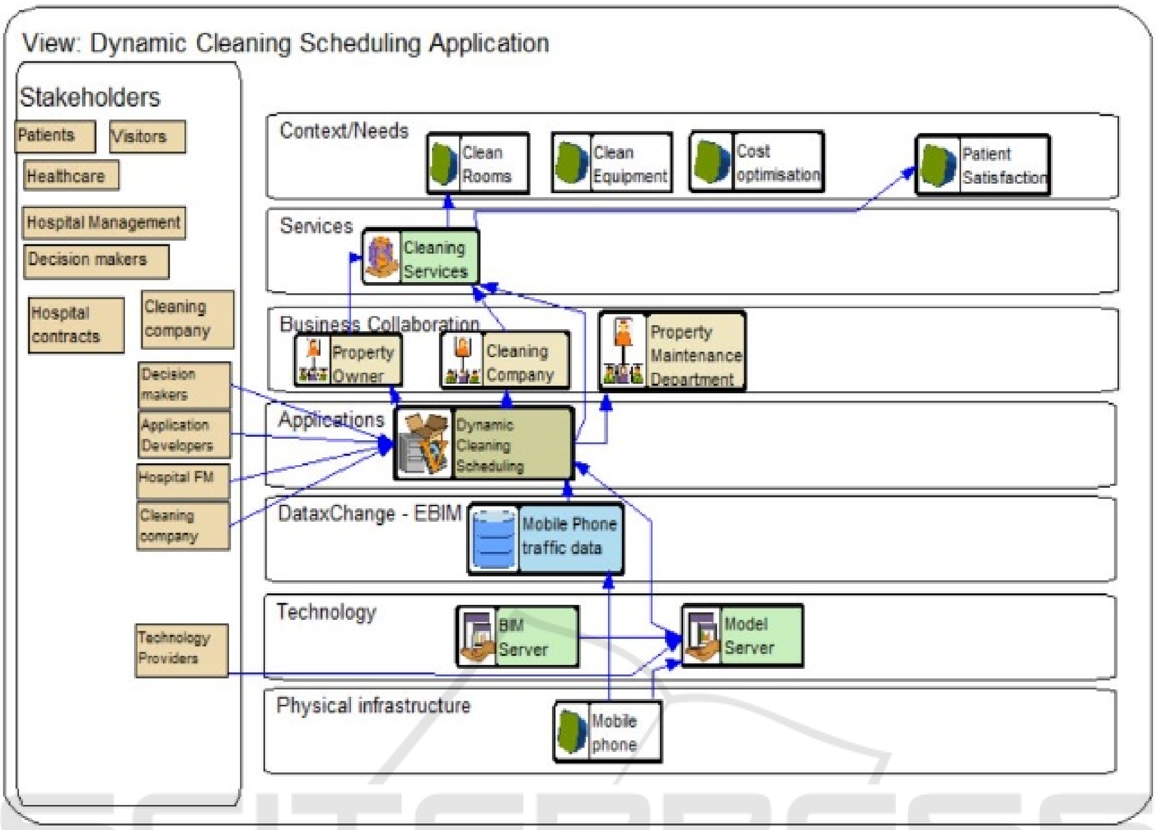

Figure 3: Business case A - dynamic and flexible cleaning services.

A dynamic scheduling algorithm for cleaning based on the actual usage of space could be of benefit to several stakeholders associated with the hospital. The model in Figure 2 shows the elements that are related to the ICT application “Dynamic Scheduling Algorithm” for cleaning. It uses BIM data, mobile phone data and data related to cleaning history and schedules (the latter two are not shown in the model). Note that mobile phone data is one of many sources of non-intrusive data that could indicate if a physical space had been occupied. Other sources of data that could be used, if available, include footfall counters or other sensor data that note people entering or leaving rooms.

In the following sub-sections, we describe two new services that could be developed using the dynamic scheduling algorithm for cleaning and how it could be of benefit for several stakeholders involved in the operations of the hospital.

4.1 Business Case A – Cleaning Services

The main stakeholders related to the ICT application, the dynamic scheduling algorithm for cleaning include the cleaning company, the facility manager, the application developer and the hospital management; see Figure 3. Thus, in the Business layer of the EA model, some of the actors are central stakeholders, e.g. in negotiating the cleaning contract which could be of mutual benefit to the cleaning company and the hospital management. The hospital could optimise their costs while being ensured a cleaning service based on the actual usage and demand, and the cleaning company optimises their resources by avoiding unnecessary cleaning effort while delivering an efficient service. Such a possibility could be of utmost value, particularly in situations such as the COVID-19 pandemic, when new and more vigilant cleaning routines had to be adopted overnight to minimise the risk of infection. Furthermore, such a dynamic and flexible cleaning service based on demand and usage could potentially contribute to reducing the amount of cleaning chemicals that are used, which is also favourable to the environment.

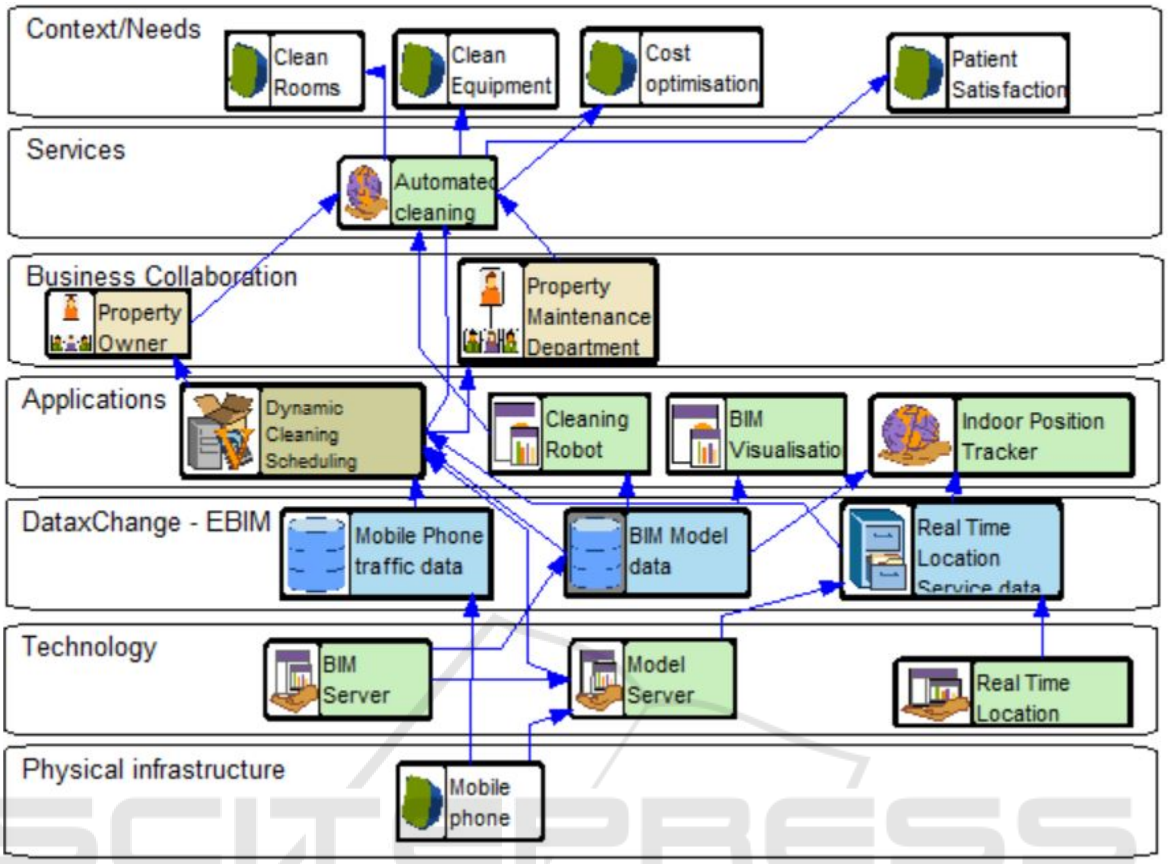

Figure 4: Business Case B: automated cleaning using autonomous robot.

4.2 Business Case B – Autonomous Cleaning Robots

The development of a dynamic scheduling algorithm for cleaning, using data from EBIM, not only provides direct benefit to the hospital and the cleaning service provider, but it could stimulate a number of potential business processes or opportunities for innovative value-added services within the hospital. The dynamic scheduling cleaning, using autonomous robots; see Figure 4. The possibility to combine BIM data and visualisations of it and the results from the dynamic scheduling algorithm for cleaning could accelerate the move to automated services within the hospital. In addition to cost savings and resource efficiency, such a service could be a life-saver in highly infectious areas in hospitals, and could contribute to reduced infections. This could have been a valuable service during the COVID-19 pandemic or similar crises. In addition to cleaning rooms and spaces, such a service could be combined with the indoor positioning service to trace and/or and track equipment, to support medical personnel, patients and others find relevant medical and/or other equipment which are clean and infection free, quickly and easily.

For business case B, we have not shown the stakeholders explicitly in the EA model. Here, most of the stakeholders from business case A, at least from the hospital, are still relevant. Additional stakeholders may be policy makers at the hospital and health authorities, concerning regulations and guidelines for autonomous robots and other equipment. The actors involved in the business collaboration layer may also differ, e.g. the cleaning company may be replaced by a robot technology provider or there may be collaborations between the cleaning company and the robot company.

5 STAKEHOLDERS AND BENEFITS

A structured approach offered through an EA framework allows attention to the different types of stakeholders that participate in different ways and are also impacted through EBIM. The EA models try to identify what may be considered a part of the EBIM, within the DataxChange layer of the EA framework and the business cases show how EBIM could be utilised to benefit a number of stakeholders. The purpose of these models is primarily as a means of supporting discussions among the stakeholders. As with many visual models (e.g. 2D or 3D models of BIM), they also convey the value of the services and the relationships from the elements in the EBIM and how they can be used to support new and innovative collaborative services.

Identifying the relationships among the different entities help to clarify the relevance and dependencies among the different entities. In this case, the models presented in Section 4 describe how the different data components in EBIM and the data contributed to the development of the dynamic scheduling algorithm. Similarly, they also help to visualise the stakeholders that could be impacted and are involved in such an application to create potentially multiple services that could be of benefit to the hospital and its many stakeholders. A brief overview of the main stakeholders and the main benefits for them are provided below:

- Medical staff (nurses, doctors, technicians, etc.), Patients, caregivers and visitors - improved health, sanitation, and safety; reduced risk of infection, more pleasant working spaces, a good impression of the hospital.
- Hospital Management - strategic decision making and contract negotiations, based on actual values, cost savings on cleaning, optimised contracts with third party service providers.
- ICT and operational services staff - potential to develop new and novel technological support (e.g. cleaning robots and other autonomous services); Minimise data format conversions, temporary storage, thus reducing costs and avoid duplication of data and inconsistency by information access to the source.
- Maintenance staff and Facility management- better resource utilisation and better overview of cleaning, e.g. through logs and automatically generated reports.
- Sub-contractors (e.g. cleaning services) - dynamic cleaning routines, on a real time needs basis, efficient work plan creation, cost savings by avoiding data conversions and additional data storage, (through direct access to EBIM using IFC standard), a product that they could commercialise and use elsewhere.

6 CONCLUSION

This paper explored the concept of EBIM in a hospital and how EBIM could be used in combination with EA to identify and communicate the benefits of EBIM to the multiple stakeholders in a healthcare institution. The motivation for this work arose from the challenges in communicating the potential benefits of EBIM in a business context. The example business is based on the work of group of students that had developed a dynamic scheduling algorithm for cleaning. The main contribution of this work is an EA model of a hospital, describing several business cases, the technological and the business contexts of those, visualisation of available data and applications that could be reused and the relevant stakeholders.

The main source of data for this work is the thesis from the students, which report a positive response from the stakeholders involved in the cleaning and maintenance departments. Although the ideas and information for the business cases have been partly obtained from reports, discussions and work conducted within the hospital, the models have not been discussed with all relevant stakeholders. Therefore, how well the model would serve as a means of communicating the value of EBIM and the EA approach to all stakeholders remains to be seen. However, based on the discussions of the benefits of EA in service provision and our own experience from using EA, we have used EA as an approach for communicating the value of EBIM.

The next step in our research would be the further validation of these models as a facilitator for communication among the stakeholders and for identifying business value.

ACKNOWLEDGEMENTS

The authors would like to thank the people in the Property Department at St. Olav Hospital for their collaboration and the group of students that implemented the prototype.

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