CHANGING ROLES OF ARCHITECTS, ENGINEERS AND BUILDERS THROUGH BIM APPLICATION IN HEALTHCARE BUILDING PROJECTS IN THE NETHERLANDS

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Abstract

The healthcare sector in the Netherlands is undergoing a significant change due to the new policy to increase the service and cost competitiveness. Much attention is given to the real estate, which contribute to the major expenditure of healthcare institutions. Healthcare building projects are very complex due to complicated functional and technical requirements, decision-makings involving a large number of stakeholders, and a long-term development process. Therefore, an integrated approach to design, construct and maintain sustainable buildings has become a necessity. In such approach, communication of information among different stakeholders becomes critical as each stakeholder possesses different set of skills. In this context, Building Information Model (BIM) is important to support the collaboration between many different disciplines working with an integrated approach.

A number of BIM pilot projects in the healthcare sector are being carried out. However, there are still knowledge gaps in the application of BIM. Its use as an ICT tool for collaboration is still limited and not fully explored. These ICT difficulties are closely linked with the difficulties of changing the way to organise building actors and processes to achieve the optimal benefit of BIM. The most notable aspect is the changing roles of architects, engineers and builders. These actors need to adapt to the reconfigured order of activities as they are asked to contribute to the design process rather simultaneously. They are also confronted with the amended tasks division as a new role (i.e. model manager) is introduced.

Refer to literature and previous research, this paper discusses the reasoning and approach of the changing roles of the building actors due to new collaborative processes and the use of BIM. It then presents some results of the observation of ongoing hospital building projects in the Netherlands where BIM is used. It analyses the discrepancies between the theoretical knowledge and the current practice of multidisciplinary collaboration with BIM support. Finally, recommendations are given on further applied research.

Keywords: BIM, ICT, process innovation, healthcare, collaboration

INTRODUCTION

Hospital building projects are of a key importance, involve significant investment, and take a long-term development period. Hospital building projects are also very complex due to the complicated requirements regarding hygiene, safety, special equipments, and handling of a large amount of data. The building process is very dynamic involving iterative phases and intermediate changes. Many actors with shifting agendas, roles and responsibilities are actively involved, such as: the healthcare organisations, facility managers, national and local governments, project developers, financial institutions, architects, contractors, advisors, and equipment manufacturers and suppliers. Such building projects are also much influenced by the healthcare policy which change rapidly in response to the medical, societal and technological developments, and vary greatly between countries (WHO, 2000). In the Netherlands, for example, the way a building project in the healthcare sector is organised is undergoing a major transformation. In 2008, a fundamental change in the Dutch health policy was introduced.

The rapidly changing context posts a need for more flexibility of the building in its life-cycle. In order to incorporate life-cycle considerations in the building design, construction technique, and facility management strategy, a multidisciplinary collaboration is required. Despite the attempt for collaboration, healthcare building projects in practice still faces serious problems, such as: budget overrun, delay, and sub-optimal quality in terms of flexibility, end-user's satisfaction, and energy efficiency. It is evident that the lack of communication and coordination between the actors involved in different phases of a building project is among the most important reasons behind these problems. Communication of information among different stakeholders becomes critical as each stakeholder possesses different set of skills. As a result, extraction, interpretation, and communication of complex design information from drawings and documents are time consuming and difficult processes. Advanced visualisation technologies, like 4D planning have tremendous potential to increase the communication efficiency and interpretation ability of the project team members. However, their use as an effective communication tool is still limited and not fully explored (Dawood et al, 2008). Besides, there are barriers in the information transfer and integration. Many existing ICT systems do not support the openness of the data and structure that is prerequisite for an effective collaboration between different building actors or disciplines.

A Building Information Model (BIM) offers an integrated solution to the abovementioned problems. Therefore, BIM is increasingly used as an ICT support in complex building projects. The multidisciplinary collaboration and the use of BIM require changes in the traditional roles, (contractual) relationships, and collaborative processes between the building actors, especially the architects, engineers and builders. However, at present there are knowledge gaps in managing the building actors to collaborate effectively in their changing roles, and in developing and utilising BIM as an optimal ICT support of the collaboration.

In the following sections of this paper, based on literature and previous research, the theoretical perspective of the changing roles of the building actors through integrated collaboration and the application of BIM is discussed. Subsequently, the observation results of ongoing pilot projects in the Netherlands are presented. The analysis that follows provides a more detailed insight into the actual practice and the existing knowledge gaps. This serves as a reference point to set up a plan for applied research to develop a process framework and an open BIM structure.

CHANGING ROLES IN BUILDING PROJECTS IN THE HEALTHCARE SECTOR

The building process is usually complex involving various disciplines and roles. In the Netherlands, the changing roles of building actors are part of a new strategy of many healthcare institutions. This new strategy is inevitable due the new healthcare policy.

Previously under the Healthcare Institutions Act (WTZi), healthcare institutions were required to obtain both a license and a building permit for new construction projects and major renovations. The permit was issued by the Dutch Ministry of Health. The healthcare institutions were then eligible to receive a financial support from the government. Since 2008, a new legislation on the management of hospital building projects and real estate has come into force. In this new legislation, a permit for hospital building project under the WTZi is no longer obligatory, nor obtainable (Dutch Ministry of Health, 2008).

This change allows more freedom from state-directed policy, and respectively, allocates more responsibilities to the healthcare organisations to deal with the financing and management of their real estate. The new policy implies that the healthcare institutions are fully responsible to manage and finance their building projects and real estate. The government's support for the costs of healthcare facilities will no longer be given exclusively, but will be included in the fee for the healthcare services. This means that healthcare institutions have to earn back their investment on real estate through their services. This new policy intends to stimulate sustainable innovations in the design, procurement and management of healthcare buildings, which will contribute to effective and efficient primary healthcare services.

The new strategy for building projects and real estate management endorses a life-cycle approach and an integrated procurement through which end users, building operators / facility managers, builders and specialist contractors can be involved in the planning and design processes. The implications of the new strategy are reflected in the changing roles of the building actors and in new methods of tendering and contracting.

In the traditional method, the design and its details are developed by the architect and advisors. Then, an application is sent for an approval on the building permit and financial contribution of the government. Following a tender process to select the builder, the construction would commence. Due to the high level of technical complexity, and moreover, decision-making complexity, the whole process from initiation until delivery can take up to 10 years. After the delivery, the healthcare institution is fully in charge of the operation of the facilities. Redesigns often take place during the construction period and the exploitation phase to cope with new functions and development in medical techniques.

The integrated procurement pictures a new contractual relationship between the parties involved in a building project. Instead of a relationship between the client and architect for design, and the client and builder for construction, in an integrated procurement the client only holds a contractual relationship with the main contractor which is responsible for both design and construction (Joint Contracts Tribunal, 2007). The traditional borders between tasks and occupational groups become blurred since architects, consulting firms, builders, subcontractors, and suppliers all stand on the supply side in the building process while the client on the demand side. Such configuration puts the architect, engineer and builder in a very different position that influences not only their roles, but also their responsibilities, tasks and communication with the client, the users, the team and other stakeholders.

A new challenge emerges in case of positioning an architect or en engineer in partnering with the builder or with the client. In one case, the architect can enter the partnering between the architect or the engineer and the builder. In this case, one of the most important issues is ensuring that architectural values as well as innovative engineering are realised through effective construction processes. In another case, the architect can stand at the client's side in a strategic advisory function. In this case, the architect's responsibility is translating client's requirements and wishes into architectural values in the design specification, and evaluating the builder's proposal against this. In any of this new role, the architect holds the responsibilities as stakeholder interest facilitator, custodian of customer value and custodian of design models. Furthermore, the transition from traditional to integrated procurement requires a shift of mindset of the parties on both the demand and supply sides. It is essential for the client and builder to have a fair and open collaboration in which both can optimally use their competencies. Besides, the success of the collaboration is determined by the client's capacity and strategy to organize innovative tendering procedures (Sebastian et al, 2009a).

Such a transition also brings consequences in the payment schemes. In the traditional building process, the honorarium for the architect is usually based on a percentage of the project costs; this may simply mean that the more expensive the building is, the higher the honorarium will be. The engineer receives the honorarium based on the complexity of the design and the intensity of the assignment. A highly complex building which takes a number of redesigns is usually favourable for the engineers in terms of honorarium. A traditional builder usually receives the commission based on the offer to construct the building at the lowest price by meeting the detailed specifications given by the client at the minimum level. Extra work due to modifications is charged separately to the client. After the delivery, the builder is no longer responsible for the long-term use of the building. In the traditional building process, all risks are placed at the client side.

In integrated procurement, the payment is based on the resulted building performance and it is non-adversarial. Since the architect, engineer and builder have a wider responsibility on the quality of the design and the building, the payment is linked to a measurement system of the functional and technical performance of the building over a certain period of time. The honorarium or payment becomes an incentive to achieve the optimal quality. If the building actors succeed to deliver a higher added-value exceeding the minimum client requirements, they will receive a bonus in accordance to the client's extra gain. Furthermore, the level of transparency is improved. Open book accounting is an excellent instrument provided that the stakeholders agree on the information to be shared and to its level of detail (InPro, 2009a).

Next to innovative building process through integrated procurement, the new strategy for hospital building project and real estate management focuses on innovative product development through life-cycle management. A sustainable business case for the investment and exploitation of hospital buildings relies on dynamic life-cycle management, which takes into account the market development in short and long terms together with the building costs (investment / initial cost, operational cost, and logistic cost). Compared to the conventional life-cycle costing method, dynamic life-cycle management encompasses a shift from focusing only on minimizing the costs to focusing on maximizing the total benefit that can be gained from the project. One of the determining factors for a successful implementation of dynamic life-cycle management is that of the sustainable design of the building and building components, which means that the design has the required degree of flexibility to accommodate possible changes in the long term (Prins, 1992).

Designing based on the principles of life-cycle management affects the role of the architect, as he needs to be well-informed about the usage scenarios and related financial arrangements, the changing social and physical environments, and new technologies. Design needs to integrate people activities and business strategies over time. In this context, the architect is required to align the design strategies with the organisational, local and global policies on finance, business operations, health and safety, environment, etc. (Sebastian et al, 2009a).

The combination of process and product innovation, and the changing roles of the building actors can be accommodated by Integrated Project Delivery (IPD). IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction. IPD principles can be applied to a variety of contractual arrangements. IPD teams will usually include members well beyond the basic triad of owner, architect, and builder. At a minimum, though, an Integrated Project includes tight collaboration between the client, the architect, and the main contractor ultimately responsible for construction of the project, from early design through project handover. The key to a successful IPD is assembling a team that is committed to collaborative processes and is capable of working together effectively. IPD is built on collaboration. As a result, it can only be successful if the participants share and apply common values and goals (AIA California Council, 2007).

CHANGING ROLES THROUGH BIM APPLICATION

Building Information Model (BIM) is considered as a comprehensive and sustainable ICT support that is necessary in integrated procurement and life-cycle management. BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward (NIBS, 2007). BIM facilitates time and place independent collaborative working. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. BIM in its ultimate form, as a shared digital representation founded on open standards for interoperability, can become a virtual information model to be handed from the design team to the builder and subcontractors and then to the client (Sebastian et al, 2009b).

BIM is not the same as the earlier known Computer Aided Design (CAD). BIM goes further than a digital (2D or 3D) drawing or a centralised database (Bratton, 2009). BIM is an integrated model in which all process and product information is combined, stored, elaborated, and interactively distributed to all relevant building actors. As a central model for all actors in all building phases, BIM develops and evolves as the project progresses. Using BIM, the proposed design and engineering solutions can be measured against the client's requirements and expected building performance. The functionalities of BIM to support the design process extend to multidimensional (nD), including: three-dimensional visualisation and detailing, clash detection, material schedule, planning, cost estimate, production and logistic information, and as-built documents. During the construction process, BIM can support the communication between the building site, the factory and the design office – which is crucial for an effective and efficient prefabrication and assembly processes, as well as to prevent or solve problems related to unforeseen errors or modifications. When the building is operational, BIM can be used in combination with the intelligent building systems to provide and maintain up-to-date information of the building performance, including the life-cycle cost.

The application of BIM to support an optimal cross-disciplinary and cross-phase collaboration opens a new dimension in the roles and relationships between the building actors. Several most relevant issues are: the new role of a model manager; the agreement on the access right and Intellectual Property Right (IPR); the liability and payment arrangement according to the type of contract and in relation to the integrated procurement; and the use of open international standards.

Collaborative working using BIM demands a new expert role of a model manager that possesses ICT as well as construction process competencies (InPro, 2009b). The model manager deals with the system as well as with the actors. He provides and maintains technological solutions required for BIM functionalities, manages the information flow, and improves the ICT skills of the stakeholders. The model manager does not take decisions on design and engineering solutions, nor the organisational processes, but his roles in the chain of decision-making are focused on:

- the development of BIM and relevant tools, in terms of defining the structure and detail level of the model, models checking and merging, and clash detections;
- the contribution to collaboration methods, in terms of facilitating decision-making and communication protocols, and integration of task planning and risk management;
- the management of information, in terms of data flow and storage, identification of communication errors, and decision or process (re-)tracking.

Regarding the legal and organisational issues, one of the actual questions is: 'In what way does the Intellectual Property Right (IPR) in collaborative working using BIM differ from the IPR in a traditional teamwork?' In terms of combined work, the IPR of each element is attached to its creator. Although it seems to be a fully-integrated design, BIM is actually resulted from a combination of works/elements; for instance: the outline of the building design is created by the architect, the design for the electrical system is created by the electrical contractor, etc. Thus, in case of BIM as a combined work, the IPR is similar to the traditional teamwork. Working with BIM with authorship registration functionalities may actually make it easier to keep track of the IPR (Chao-Duivis, 2009).

How does collaborative working using BIM effect the contractual relationship? On the one hand, collaborative working using BIM does not change the liability position in the contract nor does it obligate an alliance contract. The General Principles of BIM Addendum confirms: 'This does not effectuate or require a restructuring of contractual relationships or shifting of risks between or among the Project Participants other than as specifically required per the Protocol Addendum and its Attachments' (ConsensusDOCS, 2008). On the other hand, a change of payment schemes can be anticipated. Collaborative processes using BIM will lead to the shifting of activities from to the early design phase. Much, if not all, activities in the detailed engineering and specification phase will be done in the earlier phases. It means that the payment for the engineering phase, which may count up to 40% of the design cost, can no longer be expected. As engineering work is done concurrently with the design, a new proportion of the payment in the early design phase is necessary (Chao-Duivis, 2009).

To unleash the full potential of more efficient information exchange in the AEC/FM Industry in collaborative working using BIM, both high quality open international standards and high quality implementations of these standards must be in place. The IFC open standard is generally agreed to be of high quality and is widely implemented in software. However, the certification process allows poor quality implementations to be certified and essentially renders the certified software useless for any practical usage with IFC. IFC compliant BIM is actually used less than manual drafting for architects and contractors, and show about the same usage for engineers. A recent survey shows that CAD (as a closed-system) is still the major form of technique used in design work (over 60%) while BIM is used in around 20%

of projects for architects and in around 10% of projects for engineers and contractors (Kiviniemi et al., 2008).

OBSERVATION OF ONGOING BIM PILOT PROJECTS IN THE NETHERLANDS

In the Netherlands, the changing roles of the actors in healthcare building projects are part of the strategy which aims at achieving a sustainable real estate in response to the changing healthcare policy. Refer to literature and previous research, the main factors that influence the success of the changing roles can be concluded as: an integrated procurement method and a life-cycle design approach for a sustainable collaborative process; and an agreement on the structure and intellectual property right of BIM and the role of a model manager for an effective use of BIM as an ICT support. The preceding sections have discussed how to deal with these factors effectively in theory. This section observes two actual projects and compares the current practice with the theoretical view respectively.

The main issues which are observed in the case studies are:

- the selected procurement method and the roles of the involved parties within this method;
- the implementation of the life-cycle design approach;
- the type, structure, and functionalities of BIM used in the project;
- the openness, arrangement for transfer of model and information, and intended use of BIM in the future;
- the roles and tasks of the model manager.

The pilot experience of collaborative processes supported by BIM can be observed in the hospital building projects at University Medical Centre St Radboud (further referred as UMC) and Maxima Medical Centre (further referred as MMC). At UMC, the new building project for the Faculty of Dentistry in the city of Nijmegen has been dedicated as a BIM pilot project. At MMC, BIM is used in designing new buildings for Medical Simulation and Mother-and-Child Centre in the city of Veldhoven.

The University Medical Centre (UMC) St Radboud is more than just a hospital. UMC combines medical services, education and research. More than 8500 staff and 3000 students work at UMC. As a part of the innovative real estate strategy, UMC has recently decided to use BIM for its building projects. The new development of the Faculty of Dentistry and the surrounding buildings on the Kapittelweg in Nijmegen has been chosen as a pilot project to gather practical knowledge and experience on collaborative processes with BIM support.

The main ambition to be achieved through the use of BIM in the building projects of UMC can be summarised as follows.

- Using 3D visualisation to enhance the coordination and communication among the building actors, and the user participation in design
- Facilitating optimal information accessibility and exchange for a high consistency of the drawings and documents across disciplines and phases
- Integrating the architectural design with structural analysis, energy analysis, cost estimation, and planning
- Interactively evaluating the design solutions against the programme of requirements and specifications
- Reducing redesign/remake costs through clash detection during the design process

- Optimising the management of the facility through the registration of medical installations and equipments, fixed and flexible furniture, product and output specifications, and operational data

The Maxima Medical Centre (MMC) is a large hospital resulted from a merger between the Diaconessenhuis in Eindhoven and St Joseph Hospital in Veldhoven. Annually the 3400 staff of MMC provides medical services to more than 450000 visitors and patients. A large-scaled extension project of the hospital in Veldhoven is a part of its real estate strategy. A medical simulation centre and a women-and-children medical centre are among the most important new facilities within this extension project. The design has been developed using 3D-modelling with several functionalities of BIM.

Both UMC and MMC opt for a traditional procurement method in which the client directly contracted an architect, a structural engineer, and a mechanical, electrical and plumbing (MEP) consultant in the design team. Once the design and detailed specifications are finished, a tender procedure will follow to select a contractor. Despite the choice for this traditional method, many attempts have been made for a closer and more effective multidisciplinary collaboration. UMC dedicated a relatively long preparation phase before the design commenced. This preparation phase was aimed at creating a common vision on the optimal way for collaboration using BIM as an ICT support. Some results of this preparation phase are: a document that defines the common ambition for the project and the collaborative working process; and a document –which is a semi-formal agreement– that states the commitment of the building actors for collaboration. Different from UMC, MMC selected an architecture firm which had its own structural design department. Thus, the collaboration between the architect and structural engineer takes place within one firm and using the same drawing/ICT techniques.

Regarding the life-cycle design approach, the main attention is given on life-cycle costs, maintenance needs, and facility management method. Using BIM, the hospitals intend to get an insight in these aspects for a long-term. The life-cycle sustainability criteria are included in the assignments to the design and engineering teams. The different disciplines are asked to collaborate more closely and to interact with the end-users to address life-cycle requirements. However, ensuring the building actors to generate design solutions that can achieve the expected life-cycle performance is still difficult to so since their liability is limited and usually of a short-term, conformable to the traditional contract.

From the current progress of both projects, it can be observed that the type and structure of BIM relies heavily on the choice for a common software package. Revit Architecture and Revit Structure by Autodesk are selected mainly based on the argument that it has been widely used internationally and it is compatible with AutoCAD, also by Autodesk. The later argument is leading in the MMC project since the drawings of the existing buildings were created with AutoCAD. These 2D drawings were then used as the basis to generate a 3D model with Revit. The architectural model generated with Revit Architecture and the structural model generated by Revit Structure can be linked directly. In case of a change in the architectural model, a signal will be sent to the structural engineer. He can then adjust the structural model, or propose change in return to the architect, so that the structural model is always consistent with the architectural one.

Despite the attempt made within the design team to agree on using the same software, the mechanical, electrical and plumbing consultant is still not capable to use Revit; and therefore, a conversion of the model from and to Revit is still required. Another weakness of this 'closed approach' relying on the same software package may appear when the building process further progress into construction phase. If the builder uses another software package, extra work has to be done to make BIM from the design phase compatible for use in the construction phase. With regards to the traditional procurement method, a problem may appear since after tender, there is not much time and resource to re-create/re-build BIM; but, before the tender, the builder has not yet been involved in the project. In hospital building projects, a particular attention is given on the object library. Since a very large number of complex objects are typical to hospital buildings (e.g. installations, equipments, operation rooms, special facilities), the effective handling of the object library determines the efficiency of the design process. If it relies on a specific software package, the openness, accessibility, and extension possibility of the object library will be too limited.

Although some links to cost calculation and planning tools have been made, these have not yet worked optimally in practice. The full array of BIM functionalities have not yet been utilised as BIM in both projects focuses mostly on 3D-model for visualisation and clash detection. It is, however, considered as a significant improvement from working based on individual and two-dimensional CAD drawings. With a 3D model, all buildings in the whole complex can be visualised as a whole. This dynamic and three-dimensional masterplan model is useful for the hospital to organise the building and logistic processes for the whole development, and to communicate this to its staff and visitors. Furthermore, the hospital as the client can control the design progress more easily and, if necessary, it can propose design changes based on a clear 3D visualisation. The design decisions and their consequences can be made visual almost immediately.

Model manager is a newly introduced role within a project with BIM support. The necessity of a model manager is still a highly debated issue. The two hospitals discussed in this paper differ in their strategy as UMC appoints a model manager, but MMC does not assign any. In the building project at UMC, the model manager plays a role as catalyst and facilitator of BIM. The main task of the model manager is to integrate the information supplied by different building actors into BIM. In the building project at MMC, this task is carried out by the architect. At UMC, the model manager continuously monitors the development of BIM and sends update reports. In terms of information management, each building actor remains fully responsible of the content and quality of the information. The model manager can further assist the project manager in the communication with the building actors and the clients by preparing 3D visualisations and maintaining clear protocols for information exchange. Beyond the design phase, the model manager will deliver the BIM and additional documents (drawings, specifications; if needed) to the builder. After the construction phase, the model manager will prepare as-built BIM to be used for facility management.

Another task of the model manager is to develop the standard modelling structure of the object library. The objects used in the project are then composed in accordance to this structure. Sometimes, the building actors deliver the objects to the model manager, who will then convert these based on the standard structure. This task is not typical for the architect or other building actors since the task requires the specific IT knowledge and systems to handle information and objects of different sorts.

In the future, there is an intention to assign the model manager to monitor the progress of the design in terms of the extent how design solutions meet the client's requirements. However, this has raised a new discussion on the division of role between the architect, project manager, and model manager. The project manager questions about the scope of the mandate of the model manager, as the model manager is contracted directly by the client. The architect wants to remain in charge of the design performance. He is also anxious that his design creativity would be reduced or limited if detailed information is required since the early design phase. Looking from another viewpoint, this discussion leads to a new awareness among the architects of the urgency to cope with the BIM knowledge in order to keep their role both as the creative brain as well as the conductor of the design processes.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

In the midst of the changing real estate strategy and changing roles in the healthcare sector, collaboration is the 'POWER' that comprises the main aspects of: product information sharing (P), organisational roles synergy (O), work processes coordination (W), environment for teamwork (E), and reference data consolidation (R). There is much research on how to release the power of collaboration through the changing roles of the client, architect, engineer, and builder within a collaborative process using BIM. This theoretical knowledge has been discussed in the second and third sections of this paper. However, based on the observation of the current practice in two hospital building projects in the Netherlands, as described in the fourth section of this paper, it is apparent that the management of the process and the implementation of BIM as ICT support are suboptimal and deviate from the theory.

The main findings of the case studies can be concluded as follows. In contrary to the ambition to endorse a life-cycle strategy to manage healthcare real estate effectively and efficiently, traditional procurement method is still largely used in hospital building projects. Although many attempts are made to realise an integrated collaboration, the contractual limitations of the roles and responsibilities of the building parties in the traditional procurement method hinder the optimal implementation of a performance-based honorarium system (a system which may stimulate the building actors to evaluate the life-cycle consequences of their design, engineering, and construction solutions). The decisions on ICT solutions for BIM are often not adequately grounded on the business and real estate strategies. In the current situation, much time is needed to define the structure of object and data modelling at the initiation of the project while changes must be enforced in a later phase as new actors with different ICT systems work with the model.

The healthcare sector serves as an appropriate case, but in terms of the development and practice of collaborative processes with BIM support, it is not unique compared to other construction sectors. Collaboration processes in a building project cannot be standardised. BIM is not a ready-made solution; it has to be tailored for each project. If the implementation of the theoretical knowledge is to measure up to what is expected of an effective collaboration, new practical approach and instruments are needed. Therefore, further applied research is needed to develop a practical method for a sustainable multidisciplinary collaboration using BIM as well as to utilise open standards for the purposes of content definition and data structure for BIM and object libraries.

An important success factor for the further knowledge development in this field is the cooperation between universities, research institutes, and the building actors. While the ICT developments –like open standards IFC and open-source BIM server– are ongoing, inputs from the real project experience is highly required to close the gap between technological invention and building practice. This is crucial to break through the mental barrier for an open collaboration, e.g. 'What's in it for me?', 'Is there any evidence of success?'

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