FOUR APPROACHES FOR INTEGRATION OF DIGITAL BIM PRACTICES IN AEC PROJECTS

GILLES HALIN[1], VERONIKA BOLSHAKOVA[2],
ELODIE HOCHSHEID[3], HENRI-JEAN GLESS[4] and SIALA AIDA[5]
[1]*UMR CNRS MAP. Lorraine University, France*
[1]*gilles.halin@univ-lorraine.fr*
[2]*UMR CNRS MAP*
[2]*bolshakova.veronika@gmail.com*
[3,4]*UMR CNRS MAP. School of Architecture of Nancy, France*
[3,4]*{elodie.3h|hj.gless}@gmail.com*
[5]*UMR CNRS MAP. Carthage University, Tunisia*
[5]*aida.saila@gmail.com*

Abstract. The newest information and communication technologies bring a major shift to the AEC sector and foster it towards the new digital globalized economy. The last decades witnessed many changes in the AEC industry brought in by digital tools and by the adoption of Building Information Modeling/Management (BIM). The changes had influenced the common practices of design, construction and management, they have also fostered new digital practices into AEC. Innovative digital project management becomes a base element of an effective BIM project management. The project teams' collective competencies and skills contribute to design development and value engineering of the project. In this context, four approaches: BIM adoption, agile BIM, 4D digital decision-making, qualitative requirements to BIM, which are resulting from the research are presented in this article whose objective is to assist and facilitate the integration of digital in AEC specific professional practices.

Keywords. Digital Practice; BIM Process; Adoption; 4D; Agility.

1. Introduction

The last decades witnessed many changes in the AEC industry brought in by digital tools and by the adoption of Building Information Modeling/Management (BIM). The changes had influenced the common practices of design, construction and management, they have also fostered new digital practices into AEC. Innovative digital project management becomes a base element of an effective BIM project management. In this context, four research approaches are presented in this article, with an objective is to assist and facilitate the integration of digital in AEC specific professional practices.

Since BIM is a collaborative innovation, the research has mainly focused on understanding implementation in project teams, neglecting that BIM has also a

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great impact on every firm of AEC project. The first approach, presented in part 2, focuses on the adoption steps and organizational changes that firms face when they are adopting BIM. It proposes an online tool to help architecture firms understand the steps in a process of BIM adoption and the stages of its implementation. In following part 3, the approach focuses on integration of the agile software engineering practices into design activities in French architecture firms to improve: communication, group cohesion, and client integration. Four agile practices have been identified and adapted for architecture project design. The next part presents the third approach, it describes a collaboration practice issue to the adoption of an nD BIM in a project: the collective decision-making with 4D BIM. This research explores the use of natural user interfaces (NUIs) and proposes touchable tool for the meetings (synchronous collaboration sessions). The tool improves interactions between the un-trained users and the 4D BIM. The last approach focuses on a new digital design practice that allows us to consider and implement the program spaces requirements in BIM process. The goal is to support the design of BIM models that meet better the project program requirements and optimize design time. This approach is based on a semantic model describing project spaces, it encomases: qualitative spatial requirements, a process and a tool.

These four approaches are the result of mutual thinking on the integration of digital practices into AEC projects. Approaches are based on different surveys, on different pedagogical or professional experiments, which are supporting and validating the proposed methods, and tools foster their integration into a collaborative BIM process.

2. BIM adoption and implementation in architecture firms

Architects are at the heart of design and construction process and are often at the origin of the first digital mock-up of the project. In France, architectural firms are generally very small and rarely ready to go through BIM implementation. While more and more companies are interested in BIM, many are afraid to adopt this innovation. Some firms found BIM avoidance strategies, despite the increasing demands from clients for BIM deliverables. Some firms do not want to implement BIM practices, others do not wish to do so but do not know how to operate. So it seems essential to carry out work on the adoption of BIM in architectural firms to respond two main objectives: (1) build a better understanding of the adoption of BIM in architectural firms and (2) provide tools, methods, and documentation that will help companies that want to implement BIM.

During an exploratory work in 2016, we identified that there was no BIM implementation guide adapted to SMEs. In these guides, implementation is very often understood as setting up BIM in a project team that is already operational on BIM processes. We studied BIM implementation as the first setting up of BIM in a firm, which refers to micro BIM adoption (Succar and Kassem 2015).

Semi-directive exploratory interviews were conducted with fifteen architects at the beginning of the project. These interviews allowed us to identify four BIM-reaction profiles within the architect's population : (1) firms who regularly use BIM on a large part of their project, (2) those who work with traditional processes and don't want to change to BIM (Succar and Kassem 2015), (3) those who work with traditional processes and want to implement BIM, and (4) firms that have several processes coexisting (Hochscheid and Halin 2019b). Situation 1 is quite rare in France, and Situation 2 allowed us to identify BIM avoidance strategies.

A BIM-specific literature review allowed us to identify a gap : the difference between diffusion, adoption and implementation was not explicit (Hochscheid and Halin 2019a). This distinction led us to focus on the five-stages BIM adoption process found in the diffusion of innovation theory (Rogers 2003). During the adoption process, a company goes through five main stages: awareness, intention, decision, and, once the adoption decision is taken, companies go through implementation and confirmation stages ((Hochscheid and Halin 2019a). Decision of adoption (DoA) seems to be a turning point in the adoption process. Before the DoA, companies focus on decision while after the DoA, they are concerned about the practical problems and the success of the implementation. The BIM adoption process model allowed us to distinguish the factors that influence the decision to adopt (decision factors) from the factors that influence implementation (implementation factors).

In BIM adoption scientific literature, factors that influence BIM adoption are rarely placed on the adoption process. It has led to a confusion: factors that intervene before and after DoA are not differentiated and are often reduced to factors that influence decision do adopt BIM. Implementation factors have been little studied, as if decision to adopt necessarily leads to the success of the implementation. We defined a framework for studying factors that influence the process of adopting BIM and specifically those on implementation to help the company understand how to avoid failure. It has been identified that implementation factors can be of four different types: internal context of the firm, external context, BIM and change characteristics (implementation strategies and change management) (Hochscheid and Halin 2019c).

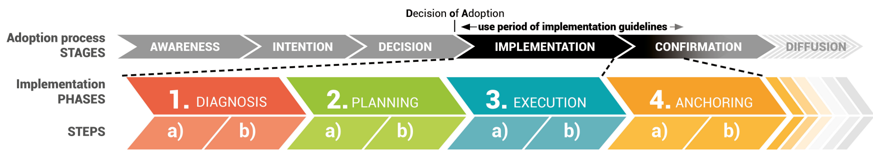


Figure 1. BIM adoption process with the four-phases guidelines for implementation.

Identification of adoption factors has been useful for the elaboration of a survey we diffused to 30,000 architects via the French Institute of Architects (CNOA) and we collected 892 valid responses. The results are not yet published but this survey will allow us to get to know the French architectural firms better, to identify their digital practices, their reaction to the BIM, factors that influenced them to decide to adopt the BIM and the BIM implementation practices that they put in place.

The final part of this work focuses on developing a method to assist firms to implement BIM. A action research based on the observation of four architecture firms during BIM implementation has been put in place. These experiences allowed us to test implementation strategies and to observe how firms react to BIM implementation. Based on an in-depth literature review, interview results, survey results, and action research, we proposed guidelines to help companies to develop their personalized implementation plan (Hochscheid et al. Halin 2019b). This method covers the last two steps of the adoption process (implementation and confirmation) and comprises four main phases: diagnosis, planning, implementation and anchoring (Figure 1). The first three phases refer to a disruptive change, whereas the anchoring phase refers to an incremental change. We developed a web application that tools this method and gives access to to architecture firms in an interactive and playful way.

3. A BIM-Agile method in Architectural design project

According to Patrick MacLeamy's curve, BIM technology increases design work, (Kensek 2014) and it also changes digital and collaborative practices. By emphasizing the design work, BIM technology brings more tasks and decision-making, its implementation obliges designers to early coordination. This creates mistrust among the project actors, and rigidifies collaboration. In software engineering and HCI design sectors, agile methods are being applied to answer similar challenges (Womack and Jones 2003).Thus, we have oriented our research towards collaborative practices to improve collaboration and consequently exchanges within a group in order to solve these problems.

Agile methods are specific management methods that involve the client into the decision-making process and follow three fundamental rules: team collaboration, continuous improvement and change acceptance (Beck et al.2001). We hypothesize that the implementation of agile practices into design activities will improve project team communication and coordination and project quality. We identified four agile practices in software engineering and HCI design, and then experimented and adapted them to architecture design.

The **design matrix** is an collaborative online tool that obliges design team to complete a table which is linking the program (inputs) and the architecture designers intentions (outputs). The table of the design matrix contains in rows the program elements of the project (an entrance hall, a living room or a meeting room) and in columns the stakes (concept, keywords or materials). Collaboratively, the designers fill each cell and write their architecture intentions. The design matrix is thus positioned as an intermediate object, like a dashboard in which all design information is recorded. Also it is essentially a tool to assist designers therefore each cell does not need to be filled.

Micro poker is a card game inspired by poker planning (Kniberg 2015), an agile practice used in Scrum or XP methods in which designers will ask themselves questions about how to perform BIM tasks (complexity, duration, urgency or relevance) and then show the tasks estimates using game cards. To answer these questions, each player selects a card from a set of four cards, with several scales of estimates on every card: numerical, colour, magnitude, chance (see Fig. 3). We avoid the phenomenon of cognitive anchoring, known as the "first speaker". Thus, a player cannot influence others by showing his card first. First players choose their cards, next ones with the most extreme card values start a debate. The objective is to reach a consensus by allowing all players to express themselves and thus to develop collective group consciousness.

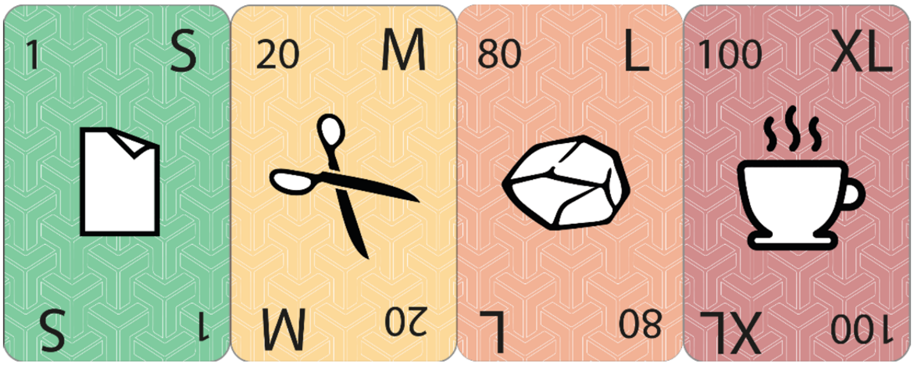


Figure 2. Set of a micro poker deck.

The **stand-up meeting** is a practice mainly used in the Scrum method (Kniberg2015). It involves regularly convening the design team and measuring the progress. Each person, answers three questions: what did I do yesterday, what will I do today, what problems am I facing? The meeting should be short and give the global vision of team's work while allowing mutual assistance and solutions. It is held standing to avoid comfort and shorten meeting duration.

The **BIM-agile coach** is a practice inspired by the agile coach (Kniberg 2015). This is a person outside the design team whose role is to ensure that the BIM collaboration is applied properly, and that the team has all the necessary to advance the project. His approach must resemble to a client representative, a person who envisions clients' needs to be responsive. Thus, the BIM-agile coach can be a person who will lead the stand-up meeting, play the role of the game leader at the micro poker or check the correct fill up of the design matrix. This person maybe the project manager of a project.

These four practices were tested at an architecture design workshop with multidisciplinary student teams. The workshop survey results show that BIM-agile practices improve communication and coordination among design actors (Gless et al.2019).

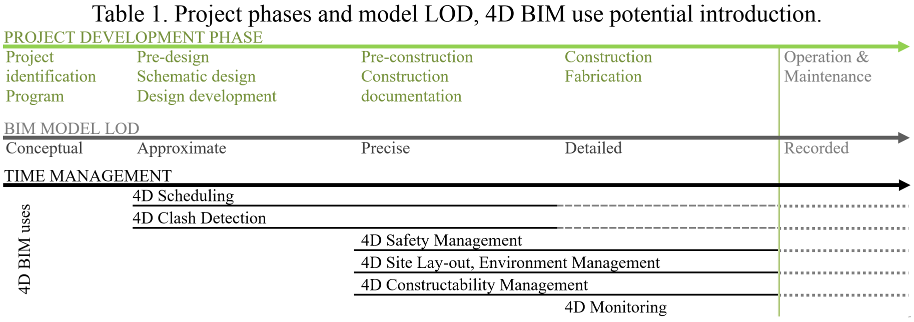
4. Digital tool support for a synchronous collaboration and decision-making with 4D BIM

- 4D BIM uses and project development phases

4D BIM binds a virtual 3D model of the project with time and resources related information, and it occurs mostly at a pre-construction phase of project progress. Projects with 4D BIM use usually offer an improved cost and error control, whilst making scheduling and coordination more efficient during the digital project management. During the last two decades, various studies have been conducted and often concluded that the 4D BIM adoption rate stays relatively low (Gledson and Greenwood, 2017). Often, the main use of 4D BIM is for visualization of a construction project, however, the other uses have not been fully integrated into common practices for now (Guerriero et al., 2017).

To ample the general study of BIM uses, (Guerriero et al. 2017) propose the 4D BIM uses: Scheduling, Clash Detection, Safety Management, Site Layout & Environment Management, Constructability Management, Monitoring, and Visual communication as a core use. We propose the 4D BIM uses potential introduction and implementation by project development phases in correlation with the project LOD. Table 1 below presents a scheme for the proposal.

Table 1. Project phases and model LOD, 4D BIM use potential introduction.



Naturally, through project progress, the project information and task complexity augments as well as augments a number of professionals involved in the project development.

- 4DCollab research project and a new digital tool support for a collective decision-making

Digital nD information and tools form the core of a sociotechnical system. The core is encompassed by cooperation, collaboration and professional culture established by project stakeholders A continuity of digital information flow is important for efficient exchanges and collaboration. To maintain the digital continuum at the meetings (synchronous collaboration sessions SCS), a research team of 4DCollab (www.4dcollab-project.eu) project aims to design a new collaborative 4D-based decision-making tool. Where the 4D represents more complex information than a 3D, thus, it provides a perspective on questions of an efficient and adapted to the 4D BIM uses visualization of the nD project information. We propose to implement a digital synchronous collaboration tool (a multi-touch table and software) at the meetings. The tool unites the stakeholders' attention to the same documents, and also offers democratic interactions with the interface through natural user interactions (NUI). In addition, NUI offers the ease of access and low appropriation time with a tool. It fosters collaboration and the 4D BIM uses convergence with the ease of interactions. The research project team chose a user-centred approach to adapt the future prototype to AEC needs and to different types of meetings.

- Groundwork steps to the prototyping of 4D-based decision-making support tool

4DCollab team has run a series of experiments with AEC professionals, who have used a multi-touch table and 4D simulation for SCS on a task proposed by the experiment. Also, the pedagogic experiments complete the SCS observations (Bolshakova et al., 2019). These let to better understand and identify the specific needs of the users. In addition, we have assembled relevant to 4D BIM uses the stakeholders' roles and documents in correlation to a decision-making type. These concepts are united in an SCS model where a Collaboration Group Persona concept becomes a base of the multi-user cantered approach for the prototyping (Bolshakova et al., 2019), it helps to adapt the user interactions and visualization to the use cases, and completes the social part of sociotechnical system. On a technical side, a semantics for linking data from 4D BIM to digital collaborative tool fulfils the digital continuity of the documents flow (Boje et al., 2019).

5. Integration of qualitative spatial requirements in BIM process practices

Architecture design is based on spatial requirements determined at an early stage of design process. The requirements are either quantitative geometrical constraints (e.g. length, width, ceiling height, etc.), either qualitative constraints (e.g. accessibility, relation between spaces, relative disposition to each other, visibility, communication, etc.). These qualitative spatial requirements (QLSR) are fundamental to guide the designer on project shaping, and they are useful to evaluate a conformity of designed BIM models to a requested program. However, current BIM practices do not consider the QLSR, since they are based on standards, which transform all building information into mainly quantitative data. Currently, only constructive information is taken into account during design (Siala and al. 2016) and the QLSR are still partially known by design teams who have to check the program many times to retrieve the necessary information to verify their model conformity through project evolution. This activity is a significant time-waste, especially in highly collaborative projects where a data absence causes errors.

This research focuses on integration of QLSR into current BIM practices to allow designers to consult and check compliance of BIM-based models throughout the design process. First a content analysis work on architecture program documents corpus identified the most relevant QLSR. The corpus encompasses a selection of program studies of various public building projects (e.g. a school group, a media library, etc.) and programming guides (e.g. a hospital, a museum, etc.), in order to collect the types of qualitative requirements. This allowed to identify five types of QLSR including: accessibility requirements (e.g. access type, characteristic and constraints), topology requirements (e.g. space arrangement constraints, type of the relationship between spaces, type of distribution) and comfort requirements (e.g. lighting type, ventilation type, acoustic, thermal and safety constraints). These are not taken into account by current BIM tools and formats (Siala and al. 2017). Also the analysis identified the most frequently used qualifiers of spatial requirements.

Based on this work, we have developed a new approach to integrate QLSR into BIM practice. It is built on a new process and a new space model. The space model considers and organises information on the identified QLSR. It includes the latest IFC specifications and represents a possible evolution of the standard. It contains information about the project spaces in both design and programming phase. Figure 5 shows this new model of QLSR. The process is based on the programming and the design phases. It involves two actors, the architect and the programmist (actor in charge of architecture programming) and adopts Autodesk Revit as a BIM tool and its visual programming plug-in Dynamo. This process has three steps; QLSR digital input in a Revit relevant format, their integration into Revit, and the checking of models' compliance.

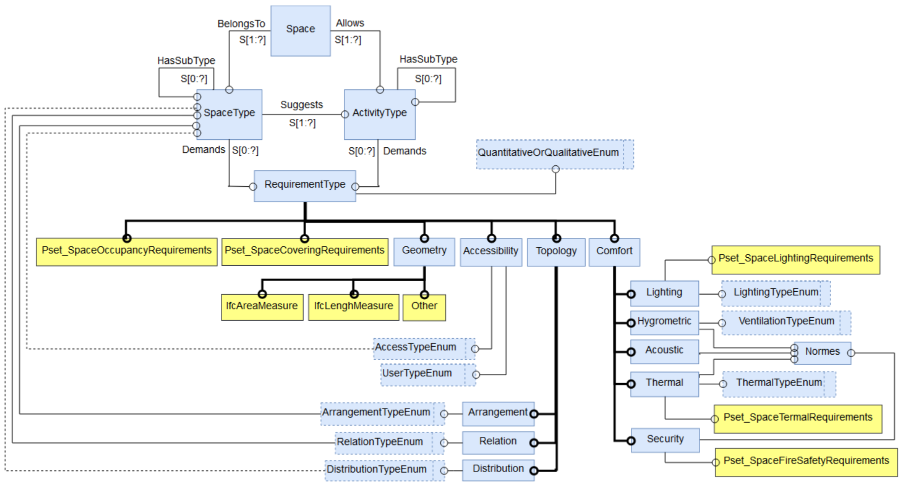


Figure 3. Extract from the proposed space model: the requirements model.

In the input step, a pre-filled spreadsheet has been prepared to allow a programmist to link the requirements with the requested rooms by selecting them from predefined values lists (according to the specified space model). Thus, the programmist provides the designer a programming study and a qualitative requirements spreadsheet file. In the integration step, before starting the designer adds those requirements to Revit by an execution of the spreadsheet exploit script.

When having all the QLSR on Revit, the designer does the design respecting the requirements visible in the rooms' constraint list. For the checking step, the designer can verify his model compliance to the required program, through the rooms' visualization according to each requirement parameter using a colour code (green: compliant/red: non-compliant) ensured through a set of scripts defined on a set of checking rules to verify: proximity of rooms, contiguity, distribution (vertical and horizontal), relation between rooms, accessibility, natural lighting, natural ventilation, etc. In this approach, the designer works only with the BIM design tool.

This approach was tested at a pedagogical experimented in real design situations and it was confronted with the usual design approach. The experiment shows that the approach not only allows to produce BIM models more in line with the program requirements but also to optimize the design time. This approach must now be experimented on a larger scale to determine how this new BIM practice should be improved for adoption by AEC professionals.

6. Conclusion

Each of these four approaches contributes to the integration of BIM technology into AEC specific professional practices. The first one reveals that taking the adoption decision of BIM technology in a firm is not sufficient to succeed a real integration. The implementation factors must be taken into account. The second approach, on the other hand, shows that the use of agile practices in project management can facilitate the integration of new tasks resulting from the integration of BIM. The last two approaches identify new practices that has emerged with the integration of BIM. The collective decision-making with 4D requires relevant and AEC adapted digital tools and supports, which allow project actors: to access and manipulate all the digital information from a BIM model; to integrate the results of decision-making into the same BIM model. The last approach proposes a collaborative BIM practice that improves programmer and architect interactions by integrating qualitative requirements into the BIM model through the use of relevant processes and tools. The integration of BIM technology and, more generally, emerging digital technologies, into existing or new AEC practices still require more studies and research, which will be defining appropriate methods (models, tools and processes) and will be validated by experimental approaches for more efficient adaptation and adoption.

References

Beck et al., K.: 2001, “Manifesto for Agile Software Development” . Available from <http://agilemanifesto.org> (accessed december 2019).

Boje, C., Bolshakova, V., Guerriero, A., Kubicki, S. and Halin, G.: 2019, Semantics for linking data from 4D BIM to digital collaborative tool, *Frontiers of Engineering Management*, **on line**, nn.

Bolshakova, V., Guerriero, A., Carvalho, H. and Halin, G. 2019, Collective Decision-Making with 4D BIM: Collaboration Group Persona Study, *in* I. Mutis and T. Hartmann (eds.), *Advances in Informatics and Computing in Civil and Construction Engineering*, Springer International Publishing, Cham, 455-462.

Bolshakova, V., Halin, G., Guerriero, A. and Besançon, F.: 2019, Collaboration tool for 3D and 4D models: A pedagogical experiment applied to wooden construction, *Proceedings of CIBw78 2019*, Newcastle, University of Northumbria, 21-31.

Gledson, B. J. and Greenwood, D.: 2017, The adoption of 4D BIM in the UK construction industry: an innovation diffusion approach, *Engineering, Construction and Architectural Management*, **24**(6), 950-967.

Gless, H.J., Halin, G. and Hanser, D. 2019, Towards a BIM-Agile Method in Architecture Design Assessment of a Pedagogical Experiment, *in* I. Mutis and T. Hartmann (eds.), *Advances in Informatics and Computing in Civil and Construction Engineering*, Springer, Cham, 397-404.

Guerriero, A., Kubicki, S., Berroir, F. and Lemaire, C.: 2017, BIM-enhanced collaborative smart technologies for LEAN construction processes, *International Conference on Engineering, Technology and Innovation (ICE/ITMC), IEEE*, 1023-1030.

Hochscheid, E. and Halin, G.: 2019a, Generic and SME-specific factors that influence the BIM adoption process: an overview that highlights gaps in the literature., *Frontiers of Engineering Management*, **On line**, 1-12.

Hochscheid, E. and Halin, G.: 2019b, Micro BIM adoption in design firms: Guidelines for doing a BIM implementation plan, *Proceedings of Creative Construction Conference 2019 (CCC2019)*, Budapest, Hungary.

Hochscheid, E. and Halin, G.: 2019c, A framework for studying the factors that influence the BIM adoption process, *Proceedings of CIBw78 2019*, Newcastle, England, UK.

Kensek, K.: 2014, *Building Information Modeling*, Routledge.

Kniberg, H.: 2015, *Scrum and Xp from the Trenches: How We Do Scrum*, Lulu Press, Morrisville.

Rogers, E. M.: 2003, *Diffusion of Innovations*, Simon and Schuster.

Siala, A., Halin, G., Allani-Bouhoula, N. and Bouattour, M.: 2016, Toward Space Oriented BIM Practices, *Proceedings of eCAADe 2016*, Oulu, Finland.

Siala, A., Halin, G. and Bouattour, M.: 2017, Architecture space quality, from virtual to physical, *Proceedings of 5th eCAADe Regional International Symposium*, Cardiff, Wales, UK.

Succar, B. and Kassem, M.: 2015, Macro-BIM adoption: Conceptual structures., *Automation in Construction*, **57**, 64-79.

Womack, J. and Jones, D.: 2003, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Free Press, New York.