Bringing the design team together: coordinating inter-organizational design work using an agile co-working method

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Abstract

Designing buildings requires efficient information exchange and knowledge co-creation between different disciplines to add value for the customer. The high of fragmentation of the AEC industry makes collaboration between disciplines difficult. New methods for increasing collaboration, knowledge co-creation, and customer involvement are needed. This paper presents a case study on developing and using an agile co-working method for coordinating inter-organizational BIM based design work during the conceptual design phase. Data was collected before, during and after the agile co-working sprint. The data includes discussions during four preparation meetings, the audio and video recordings of two-day co-working sprint, and nine interviews after the sprint. The co-working sprint necessitates planning: determining common ways of working, technology to be used, and the practicalities of the shared facility. Shared rules for conduct need to be agreed at the beginning of the sprint to ensure that members know how to exchange knowledge, what technology to use and in what way. The co-working sprint needs a team leader to facilitate the discussion and ensure coherent outcomes. Team members of the co-working sprint need to be motivated to work together. One of the most beneficial outcomes of the sprint was committing to goals that were defined together. The agile co-working sprint increased common understanding between team members about other disciplines' work tasks during conceptual design. The study sheds light on how to bring the design team together using an agile co-working method which enables the visualization of knowledge for customer's decision making.

Keywords: Coordination, knowledge integration, agile, co-working, BIM.

1. Introduction

The companies in the AEC (Architecture, Engineering, and Construction) industry are specialized into certain functional disciplines to design and build complex buildings. Due to this specialization, the industry is highly fragmented which challenges knowledge sharing and collaboration. (Brandon 2009, Dulaimi et al. 2002) Fragmentation can also be seen in

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the separation of design and construction, coordination issues between functional disciplines, and insufficient communication. Low productivity, cost and time overruns, and conflicts in the AEC industry are seen to be caused by this fragmentation. (Xue et al. 2005) New methods are required for collaborative and iterative development in the AEC industry. Owen et al. (2006, p. 63) discuss adopting agile management in the pre-design phases of construction.

The management of the design process is crucial because 80% of the costs of a construction project are determined in the front-end of the process (Tzortzopoulos 2006, p. 657). During the conceptual design of a new building, a number of issues are in constant flux and great uncertainty is involved which causes complexity (Owen et al. 2006, p. 61). For example, the structure, form and placement of the building affect the energy consumption and life-cycle costs. In practice, different disciplines', such as architectural, structural, and MEP (Mechanical, Electrical and Plumping), design decisions need to be made iteratively. Many design decisions produce requirements to other disciplines, affect design quality and investments, and pose requirements for the construction site planning. In addition, the customer is rarely able to specify all the requirements for a building during the conceptual design phase of a project. The designers of different disciplines can help the customer in the decision-making process by giving information and providing different solutions about what is possible and how it affects other design parameters such as energy consumption or building lifecycle costs. For this purpose, the different disciplines' knowledge needs to be integrated to achieve value to the customer within the constraints of time and cost. Value can be accomplished by first understanding customer's priorities and then by defining the requirements for the building through optimizing the different aspects of the building, e.g., life-cycle costs, energy usage, placement of the building on the site, to be designed by utilizing building information modelling (BIM). The customer needs to be involved in the value generating process to give priorities. BIM can help in simulating and visualising the alternative solutions to the customer.

The fragmentation of knowledge and high degree of specialization in the AEC industry creates "need for coordination between the various project participants." (Mitropoulos & Tatum 2000, p. 48) This paper studies the use of an agile co-working method for coordinating inter-organizational design work of a new school building during the conceptual design phase. The idea of an agile co-working method is to integrate the different disciplines' knowledge to provide the owner relevant information for the decision-making process. This study advances organization theory, specifically coordination theory, by understanding how the agile co-working method can act as a coordination method for managing collaborative design work between different organizations.

2. Literature study

2.1 Coordinating work between organizations

Poorly coordinated collaboration of different stakeholders results in decreased project quality, lower customer satisfaction, and information loss. In this study, coordination is defined as "the act of working together harmoniously" where the components of coordination are goals, activities, actors, and interdependencies. (Malone & Crowston 1990, p. 358) First, the goals need to be identified and mapped to predefined activities. Then, activities need to be assigned to actors. Finally, activities have goal-relevant relationships, i.e., interdependencies which must be managed. (ibid.) Reciprocally interdependent activities provide input for each other in a mutually interdependent way. Actors executing reciprocally interdependent tasks need to communicate frequently and adjust mutually, which usually happens in small organizations or in complex operational environments such as projects. (Thompson 1967) Unscheduled meetings, ad hoc communication, cross-functional teams, and physical proximity represent mutual adjustment. (Mintzberg 1979)

According to Malone and Crowston (1990, pp. 364-365), there are three processes underlying coordination: group decision making, communication, and the perception of common objects. Coordination necessitates that some decisions are made and accepted by the group executing the coordination. Group decisions require communication about the goals between the parties. Finally, communication necessitates that messages are transported between senders and receivers in a language that is understandable to both parties. According to Malone and Crowston (1990, pp. 364-365), common language means that the parties perceive common objects, such as physical objects or information in a shared database. (See Table 1)

Table 1: Processes underlying coordination, components of coordination, and examples of coordination (Malone & Crowston 1990, p. 365)

Process level	**Components of coordination**	**Examples of coordination**
Coordination	Goals, activities, actors, resources, interdependencies	Identifying goals, ordering activities, assigning activities to actors, allocating and synchronizing resources
Group decision making	Goals, actors, activities, evaluations, choices	Proposing and evaluating alternatives, making choices
Communication	Senders, receivers, messages, languages	Establishing common languages, selecting receivers, transporting messages
Perception of common objects	Actors, objects	Seeing same physical objects, accessing shared databases

In the AEC industry, the work is executed in projects with several different companies and disciplines having their own language and knowledge, which challenges the codification and transfer of knowledge. (Bresnen et al. 2003, p. 157) The AEC industry lacks ways of working together in a way that would allow creation of common language and knowledge to enable knowledge integration from the customer's point of view and not from a single stakeholder's point of view.

2.2 Knowledge management through agile methods in construction

Knowledge management in the AEC industry is needed for innovation and improved efficiency through the use of different tools, processes and methods (Kamara et al. 2002, pp. 54-57). The AEC industry is organized in projects and the practice is guided by project management (Ballard 2000). As the industry has become highly fragmented and organizationally complex, the traditional project management methods are not adequate to deal with challenges such as stakeholder management and iterative inter-organizational design. Mitropoulos and Tatum (2000, p. 52) discuss that integration during project's design phase is important for project performance and it requires the participation of contractor and customer in the design and joint decision making and "not only exchange of information and knowledge". In their study Mitropoulos and Tatum (2000) found three types of mechanisms to increase project integration: contractual (e.g., strategic alliances), organizational (e.g., cross-functional teams), and technological (e.g., electronic linkages between construction applications). The current focus in the AEC industry is on information and communication technology, although it should be more focused on finding "new ways of producing, collaborating, sharing knowledge and adding whole-life value." (Prins & Owen 2011, p. 231) Agile methods emphasizing lean thinking, flexibility and iterative development with the involvement of customers and end-users are one solution to these challenges. (Ribeiro & Fernandes 2010, p. 161)

Koskela (1992) started the discussion on applying lean to construction. According to Koskela, the construction industry was not paying enough attention to value creation but on transforming inputs to outputs which in the end leads to poor overall outcome and sub-optimization. (ibid.) Later Owen et al. (2006, p. 52) differentiate agile project management (APM) from lean methods such as lean construction or Ballard's (2000) 'Last Planner'. According to them, lean was developed "as a response to the competitive pressures with limited resources" while agile manufacturing is "a response to the complexity brought about by constant change". APM is based on "incremental and iterative development with continuous learning being essential to the evolution of the optimal value to the customer within the constraints of time and cost". (Owen et al. 2006, p. 57)

Ribeiro and Fernandes (2010, p. 162) state that "the number of scientific publications on the agile paradigm in construction is limited" which gives the authors of this paper a good reason to further study agile methods in construction. Owen et al. (2006, p. 63) conclude that adopting agile management in the pre-design and design phases of construction has considerable potential as the incremental and iterative development can "facilitate creative solutions, particularly to complex and uncertain requirements." Owen et al. (2006, p. 57) describe an agile project manager as "a facilitator who enables small, self-organizing multi-disciplinary teams to decide for themselves how they satisfy their value goals." This paper is studying agile methods as a way to manage knowledge of inter-organizational design work. We define the management of knowledge in inter-organizational work as the integration of different disciplines knowledge to add value for the customer.

3. Methodology

3.1 Case study on developing an agile co-working method

We examined a case study on the development and use of an agile co-working method that took place in spring 2012. The case study strategy allows studying a contemporary phenomenon which is difficult to separate from its context (Yin 1989). The development and use of the method is part of Model Nova (New Business Model based on Process Network and Building Information Modeling) work package of Built Environment Process Reengineering research program which is coordinated by the Strategic Centre for Science, Technology and Innovation of the built environment (RYM Ltd) in Finland. The idea behind the co-working method was that it would allow different disciplines to work intensively for a day or two in the same location, using BIM to integrate different participants' knowledge and thus create better design solutions for the customer, i.e., the owner and end-users. Mark (2002, p. 89) describes this type of design activity as extreme collaboration during which participants work in an electronic and social environment "to maximize communication and information flow".

The idea of testing an agile co-working method in the early stages, i.e., conceptual design, of a construction project arose in a workshop for Model Nova work package in January 2012. In another workshop in March 2012, a possible case including the object of co-design for testing the method was introduced and the interested companies and research institutes of the project to participate were identified. CRADLE (Center for Research on Activity, Development and Learning) research group within the University of Helsinki was named responsible for the practical arrangements of the development, such as organizing meetings to develop the concept of the agile co-working method. The authors of this paper from SimLab (Enterprise Simulation Laboratory) Aalto University and professionals from different disciplines and organizations participated in those concept development meetings.

The object of co-design was decided to be the planning of the conceptual design of a school and a day care building in a village next to the city of Kuopio, Finland. The building and design process had not been started, but the preliminary decisions of executing the project had been made. The spatial program had already been decided. The approximated number of students and children at the day care was about two hundred. The city of Kuopio represented the owner. The building to be built was to serve the inhabitants of an active village community, and the building itself should also provide possibilities for organizing events and past-time activities for the villagers. The inhabitants of the village, which were also the future users of the school, were eager to participate in the design process and share their ideas.

Two possible site locations were specified for the new building. In one location, the building would be a new building and in the other location, it would be renovated inside an old barn which at the time served as a summer theatre. The barn was considered as a historically relevant building and therefore the renovation should strive to preserve the old building and its style as much as possible. Model Nova work package agreed to provide the customer the conceptual design solutions for the building. The idea was that the customer could use them in decision making when choosing between the two site locations. The conceptual design was decided to be co-designed during a two-day agile co-working sprint where all the needed actors from different disciplines would work together in the same location. An important part of the sprint would be to hear the opinions of the customer as well as the end-users of the building and to pursue to fulfil these wishes in the conceptual design.

The development of the agile co-working method consisted of three steps: 1) preparation meetings together with different companies' individuals who attended the two-day sprint in the city of Kuopio, 2) the two-day agile co-working sprint in the city of Kuopio, 3) reflection part that consisted of analysing the co-working together with participants. CRADLE organized four preparation meetings to determine the practicalities of the co-working sprint. In the meetings, the interested participants were divided into two teams, each of which independently planned the principles of their co-working sprint. We will refer to the two teams with names team New and team Reno. Team New focused on creating solutions for the new building on an empty site whereas the team Reno concentrated on creating solutions for renovating the old barn. The objectives and desirable outcomes of both teams were discussed together. After the teams had been decided, they were left to decide how they would proceed with preliminary tasks before the co-working sprint. Both teams comprised of two architects, a structural designer, a MEP designer, a life-cycle designer, a construction management consultant, and a cost accountant. In addition, in team New there were two participants, whose main focus was on creating a visual representation of the data collected that would help with communicating the results to the customer and end-users. In team Reno a person representing construction management consultant filled information in the forms (that would visually represent the information) created by the other team.

The two-day agile co-working sprint was conducted in the city of Kuopio and it started with a joint meeting where teams, researchers, owner representatives and end-users participated. During the meeting, the objectives of the sprint were discussed, as well as the hopes of both the owner and the end-users. The sprint continued with one and a half day of co-located work by each team. At the end of the second day, the results achieved were presented to the owner, end-users, other team, and the researchers. The results were discussed together. The success of the sprint itself was later analysed with both teams and researchers in a separate conclusion meeting a few weeks later.

3.2 Data collection and analysis

The empirical data was collected before, during and after the co-working sprint. The first and the second author of this paper participated in all the four preparation meetings before the co-working sprint. During the meetings participants from different companies planned on how to work together during the co-working sprint, e.g., which tools to use. During the two-day co-working sprint the authors observed and made field notes on the co-working and discussions that were also audio and video recorded. CRADLE researchers acted as action researchers, whereas SimLab researchers were mainly observers and had minor impact on the development and use of the agile co-working method.

After the sprint, the authors interviewed nine participants from different disciplines to understand how the co-working sprint could be developed and how the working methods during the sprint functioned. The interviewees represented an architect developing the information visualization, two architects, two MEP designers, two life-cycle consultants, a contractor and a construction management consultant. The interviews were semi-structured but open questions to get rich and detailed real-life descriptions from the interviewees. The interviews lasted from thirty minutes to an hour and were held either face to face or via Skype. Two researchers were present at each interview, one interviewing and the other taking notes. The interviews were also audio-recorded.

The analysis process of the interview data followed the analysis recommendations of Miles and Hubermann (1994). First, the interviews were transcribed word for word. Then they were read through to get a preliminary understanding of the data collected. After that, codes for interview data analysis were determined based on interview themes and raw interview data. Six codes were determined: preparation before agile co-working, customer involvement, IT and BIM software usage, working methods, management of co-working, and co-created results. These codes were used to analyse the interview transcriptions using a qualitative data analysis software Atlas.ti. Video data was once analysed and used to verify the notes made by the researchers on how participants communicated with each other and how they used information technology in their collaborative work.

4. Findings

Based on the analysis of the interview data, researchers' notes and discussions during the co-working sprint, three themes which were important to every participant were selected. These were preparing for the agile co-working sprint, customer involvement during and after the co-working sprint, and management and working methods during the co-working sprint.

4.1 Preparation for agile co-working sprint

The teams had prepared for the co-working sprint very differently. Team New held three meetings and planned their working routines, discussed their objectives, and started to develop a visual representation of the data to be produced for the customers before the two-day co-working sprint. Most of the members of team New knew each other because they had worked together before. According to interviews, team New was quite satisfied with the preparation before the sprint and they started working efficiently from the beginning. However, more preparation would still have been needed. Everyone knew their responsibilities and they worked towards them. Though, there was not much discussion during the first day as everyone was concentrating on their own tasks, which means that knowledge integration was minimal. During the second day, team members started to share their work with each other, integrated knowledge and learn from each other's work.

Team Reno had no preparation and consisted of members that had not been collaborating before the co-working sprint. At the beginning of the sprint team Reno used almost two hours for general discussion and decision making about the courses of action, how to work together and the goals of the co-working sprint. During the first day the architects had a lot of work to do with BIM modelling but some other disciplines such as structural engineer did not have lot to do. During the second day, team members started sharing their work more and discuss different design solutions and cost calculations.

4.2 Customer involvement during and after agile co-working sprint

Communication towards the owner and the end-users was different between the teams. Team New had no communication with the customers during their individual work. During the interviews, the members of team New expressed that the contact with the customers would have been helpful in deciding what design issues to concentrate on. Team Reno made phone calls and exchanged emails with the representative of the owner. Team Reno requested information on details of the building to be renovated from the customer representative. However, neither team discussed their design solutions and the course of action to be taken in the design with the customers, even though the team members would have seen this useful afterwards. According to the interviews, the representative of the customer should be available, e.g. through phone or Skype, during the future co-working sprints to give comments and make decisions regarding financing and design solutions.

Both teams' design solutions and life-cycle cost analysis were presented to the customer in the end of the second day. The numbers in excel were visualized in order the customer to get a better understanding of different solutions. However, the design solutions of different teams were not comparable as the other team worked on the design for a new school building whereas the other focused on renovating an old building. If the case had been a competitive bidding, the results could not have been compared. However, if the purpose of the sprint would have been just to explore all possible solutions, this type of sprint would have pursued its case. The owner and end users were satisfied with the visual presentation of design solution information and encouraged to continue its development.

4.3 Management and working methods of the agile co-working sprint

Both teams had a team leader whose task was to make sure that the team delivers what is agreed with the customers. Both team leaders had their own work tasks to be completed during the sprint and thus they could not much focus on leading their team's work. During the first day, the team leaders made sure that everybody knew what to focus on but more guidance would have been needed especially during the second day to encourage communication and knowledge sharing.

The purpose of the sprint was to help the owner set the design requirements, e.g., design layout and life-cycle costs, for the school and day care project. However, some of the participants of the teams thought that they would have needed more information, in addition to the spatial program, from the owner to achieve that result. For example, the target price for the building was not set which challenged defining the life-cycle costs of the building.

Both teams faced some technical difficulties during the sprint. Neither team had agreed on a joint project database to save documents and such needed to be created during the co-working sprint. Both teams could also have benefited from larger or multiple screens, where information could have been shared between participants more efficiently. Team Reno had only two Internet cables to use during the sprint, which slowed information sharing significantly. In addition, BIM software used by different disciplines had interoperability issues to overcome. The software used by the architect used different kind of classification for spaces than the software used by the other designers. Therefore the information created by the architect could not be directly transferred to other software. Some of the data was transferred via excel, other needed to be manually entered. The cost calculator could not directly use any type of data created by others, but needed to manually enter all information received. Additionally, the cost calculator was last one in the information chain which in practice meant that during the first day she did not have much to do but during the second day she had to work under constant time pressure.

5. Conclusion

The agile co-working sprint increased common understanding between team members about other disciplines' work tasks during conceptual design. For example, many participants reported having learned how cost calculations are done during the conceptual design and which software other participants use in their specific work tasks. The shared screens helped in integrating knowledge of different participants and focus on same issues. The exchange of information between team members was easy as people were co-located and focused on the same issue at the same time. Though, some reported that they were not sure when it was appropriate to interrupt others for information exchange as people were focusing on their individual work tasks. Bresnen and Marshall (2002, p. 500) found in their study that co-location of the design team permitted greater accessibility of participants and allowed timely and informal communications. In this study, participants focused mainly on formal communication as the co-location only happened for two days during the co-working sprint but still the informal communication may be an important ingredient for building trust between participants. Direct personal contact during co-working sprint and the socialization processes are ways of transferring knowledge (Nonaka & Takeuchi 1995).

A team facilitator's role is to ensure that different team members are motivated and know how to work together. In addition, the facilitator should aid in group decisions during the sprint. However, we argue that the success of the co-working method depends, among others, on the participants' capability and willingness to work together. Common rules for conduct need to be agreed at the beginning of the co-working sprint to ensure that members know how to exchange knowledge.

Most interviewed stakeholders thought that one of the most beneficial outcomes of the sprint was committing to goals that were defined together. All the big design decisions made during the sprint were based on the work of all stakeholders. Thus, the teams could choose an 'optimal' solution for the customer from all the stakeholders' points of view. Committing to these design decisions is believed to result in more compatible design solutions, which can also ease the workload during clash detection of BIM models. To add, since the decisions are made both on the basis of the different designers' as well as the customer's points of view, the end results are more likely to please the customer as well. These findings are in line with Mitropoulos and Tatum's (2000, p. 53) research results on interviews with managers: "Developing common norms, and understanding each other's culture and way of working enables better cooperation during projects." In addition to exchanging information and creating common understanding within the teams, one of the objectives of the sprint was also to communicate the results achieved to the customer. The visualization method created in team New was considered informative and useful for the customer's decision-making process. The visualization method was created during the sprint, and the participants believed that it could be used even more efficiently in a new sprint.

Malone and Crowston (1990) described the three processes underlying coordination: group decision making, communication, and the perception of common objects. The agile (i.e., iterative development) co-working method entails the three processes and thus can be described as a method for coordinating collaborative design work between different organizations. The agile co-working method allows group decision making and communication as participants are co-located. The participants should have the authority to make decisions and the customer should be available for timely decision making to advance group work. In addition, the facilitator ensures that every participant has the opportunity to express his/her ideas and encourages "goodwill" between the group members. The perception of common objects can be acquired through projecting the BIM models on a screen that every participant can see at the same time. The visualization of the object of common work on a screen helps participants to concentrate on the current collaborative work. Based on this study, the agile co-working method can be separated into three phases: before the sprint, during the sprint and after the sprint. The co-working method can be described as a process of following steps (See Figure 1):

Before the sprint:

1. Define together the **goals** for the sprint.
2. Determine the **common ways of working**, **technology** to be used, and the **practicalities of the common facility**.

During the sprint:

3. Make sure that **technology** and technical surrounding is working and supporting the sprint.
4. Choose a **team leader to facilitate** the discussion and ensure the outcomes.
5. Ensure team members are **motivated** to work together.

After the sprint:

6. **Communicate the visualized results** of the sprint to the owner and/or end-users.

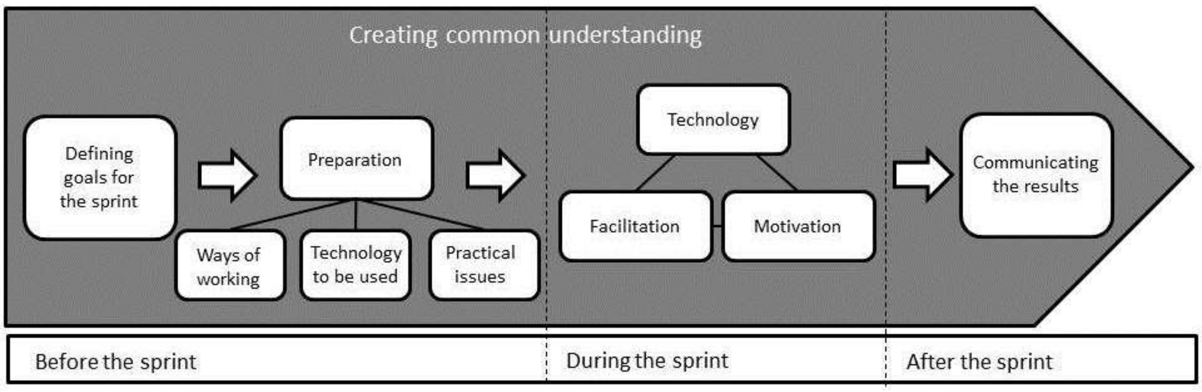

Figure 1: The process of the agile co-working method

6. Discussion

This paper presented a case study on developing and using an agile co-working method for coordinating inter-organizational BIM based design work during the conceptual design phase. The results show that the co-working sprint eases the exchange of information and learning between different disciplines during the conceptual design. The common working methods need to be specified in advance and a team leader appointed to make sure inter-organizational collaboration reaches its intended goals. The method seems to work as a coordination method to manage the inter-organizational design work during the conceptual design. The method should also be tested in other phases of design and construction process to understand how it could be improved. In addition, the agile co-working method should be designed to allow both face-to-face and virtual collaboration optimally from the project's perspective. The next step could be to develop the co-working sprint to also include partial co-location, e.g., by using virtual collaboration tools such as GoToMeeting or Skype.

The study also sheds light on how to increase customer involvement during the conceptual design by integrating and visualizing knowledge for customer's decision making. The participants of different disciplines would have wanted the customer to be available during the co-working sprint to guide the decision making of different design solutions. The visualization of knowledge needs to be improved in order it to function also during the co-working sprint in communication between different disciplines and the customer.

We recommend the co-working sprint to be used during such design phases where the knowledge of different disciplines needs to be combined and thus availability of many disciplines is crucial. When important design solutions that affect many stakeholders are made, a co-working sprint can be a very effective coordination method for creating different design solutions and encouraging joint decision making. The sprints can either be planned well in advance or used as a problem solving tool when sudden difficulties arise. In the studied case, all the participants in the sprint were somehow involved in the Model Nova work package and therefore interested in developing and trying out new design and co-working methods. In reality, most participants in a traditional project may be more inclined to keep things the way they have always been. The co-working sprint method needs to be tested in a project where the participants are not motivated through previous commitments in participating in such methods in order to determinate how well it works in a traditional project.

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