IN TIME AT LAST–ADAPTION OF LAST PLANNER TOOLS FOR THE DESIGN PHASE OF A BUILDING PROJECT

Hannele Kerosuo[1], Tarja Mäki[2], Ricardo Codinhoto[3], Lauri Koskela[4] and Reijo Miettinen[5]

ABSTRACT

This study focuses on identifying how implementing the Last Planner System (LPS) tools can mitigate collaboration-related problems in design. The theoretical approach of the study is based on the cultural-historical activity theory (CHAT) and the data collection involved the observation of collaboration between designers in traditional design meetings and LPS meetings. How does the implementation of the Last Planner (LP) tools change the collaboration of designers? How does the temporal orientation change during LPS meetings?

The implementation of the LP tools brought about positive results in our case organization. The changes in collaboration involved transitions from formal to emerging agenda, from the use of rule-based tools to the use of new tools, from reactive to proactive temporal orientation, and towards better completion of the design tasks in the design meetings. Communication between different design disciplines increased during the LPS meetings. Especially, the main designer was able to take an active role in the LPS meetings with the help of new tools. During the process, the concerns to interdependency between design disciplines increased.

KEYWORDS

Last Planner, Building Information Modeling, collaboration, implementation process, cultural-historical activity theory, construction design, design management.

INTRODUCTION

Modern construction projects are often challenged by delays and other time-related uncertainties. Delays are often caused by poor communication, ambiguous requirements, and regular misunderstandings in the industry (Forbes and Ahmed 2011, Cremona 2011). Collaboration problems are commonly identified as one of the main factors affecting the low productivity and ineffectiveness in construction industry. Due to an increasing complexity of the projects,

[1] Docent, PhD, Institute of Behavioral Sciences, Center for Research on Activity, Development and Learning, University of Helsinki, P.O. Box 9 (Siltavuorenpenger 3A), 00014 University of Helsinki, Finland, Phone +358 50 415 6629, hannele.kerosuo@helsinki.fi

[2] Project Manager, Institute of Behavioral Sciences, Center for Research on Activity, Development and Learning, University of Helsinki, , Finland, Phone +358 40 755 2319, tarja.maki@helsinki.fi

[3] Lecturer in Construction Management, Salford Centre for Research and Innovation (SCRI), University of Salford, 4th Floor, Maxwell Building, The Crescent, Salford, Greater Manchester, M5 4WT UK. Phone +44 161 295 4284, r.codinhoto@salford.ac.uk

[4] Professor, Salford Centre for Research and Innovation (SCRI), University of Salford, 4th Floor, Maxwell Building, The Crescent, Salford, Greater Manchester, M5 4WT UK. Phone +44 161 295 7960, l.j.koskela@salford.ac.uk,

[5] Professor of Adult Education, Institute of Behavioral Sciences, Center for Research on Activity, Development and Learning, University of Helsinki, Finland, Phone +358 50 415 6634, reijo.miettinen@helsinki.fi

establishing more integrated approaches is required in construction design (Codinhoto and Formoso 2005).

Improving collaboration requires the creation of tools to support information exchange in construction design (Anumba et al. 2008). Practitioners and researchers within the construction industry have commonly recognized the call for the creation of tools. In this respect, the Last Planner System (LPS) has been successfully adopted in production management throughout the world (Ballard and Howell 2004, Alves and Tsao 2007). In construction design, the LPS has been implemented to improve collaboration (Cremona 2011) and in recent studies, Building Information Modeling (BIM) combined with the LPS has been a way to improve the reliability of project programme and the integration between design and construction-related functions (Khanzode and Reed 2008, Eastman et al. 2011). However, despiteits benefits there are only a few cases where LPS has been implemented to construction design management (e.g. Milles 1998, Tzortzopoulos et al. 2001, Codinhoto and Formoso, 2005, Formoso et al. 2006, Hamzeh et al. 2009).

Thus, the purpose of this on-going research is to further explore the use of the LP tools during the design phase of a building project. Specifically, this study focuses on identifying how the implementation of the LP tools affects collaboration during the design process. It also aims at investigating the effects of the implementation of the LP tools on the temporal orientation of designers in the design process.

The research approach based on the cultural-historical activity theory (CHAT) was adopted to answer these questions. The method of data collection involved the non-participant observation of collaboration between designers in traditional design meetings and the LPS meetings. Findings of the study describe the changes in designers' collaboration between the traditional and the LPS meetings. However, the findings of the study are preliminary as the process is still proceeding.

RESEARCH DESIGN

The activity-theoretical approach of this study provides the analytical concepts and tools for the study. In this respect, the concept of a tool has a special meaning in activity theory (Miettinen 2009). An individual's object-oriented actions are mediated by cultural means. The main types of them are tools and signs (Vygotsky 1978). Tools are defined by their functionalities in an activity. For instance, an overall design schedule and the list of design tasks for next two weeks can become tools in collaboration.

A person (or a group) internalizes mediational means during socialization by participating in common activities with other individuals (Miettinen et al. 2012). Learning and development take place in processes of *remediation* during which new mediating means are adopted and developed. In this regard, Engeström (1987) represents human activity as an *activity system* model that consists of a subject focusing on an object of collective activity that is mediated by signs and tools, rules and division of labor in a community. The *object* of an activity is "both something given and something projected or anticipated" (Engeström 1995, p. 397). The object of a collective activity is considered as the basic motive of human activity (Leont'ev 1978). Human beings realize activity as actions that are connected to a collective object through goals and operations directed by the circumstances and tools at hand**.**

Table 1: Research questions and their verification

Research Question	Criteria of Verification
1) How does the implementation of the LP tools change the collaboration of designers?	Increase in the number of designers' speech turns and the number of completed tasks in LPS meetings compared to a traditional meeting.

2) How does the temporal orientation change during the design during LPS meetings?	Increase in the number of discussions concerning the proactive orientation to planning of design tasks compared to traditional meetings. Increase in the number of completing the fixed tasks in the LPS meetings.

The adoption of the LP tools for remediation allows and requires a re-organization of collaboration within the group of designers. Thus, considering the research context and the theory behind, the research questions and their verification in the data are presented in Table 1. In this case, the hypothesis is included already in the research design and not presented separately. The adoption of the LP tools is expected to improve the prevailing collaboration as a starting point of this study.

CASE DESCRIPTION

The focus of analysis in this study is the renovation of an existing school building, built in 1970s. The case represents the last out of five buildings studied in the on-going research project. Architects, engineers, and site engineers use BIM in the design and construction of the buildings. One specific aim of the companies, at least implicitly, has been to create new BIM-based working procedures for building projects. Engaging the same project team (i.e. main contractor, designers and stakeholders) with the project is expected to improve the building performance. Furthermore, the time-related issues are expected to ease as the project progresses. But in spite of the participants' expectations, the problems related to time persisted throughout the four projects. The delays in design processes had also a negative impact on the quality of designs from the perspective of the performance at the building site. The project team decided to implement LP tools in order to avoid expected delays during the design and construction of the fifth building project.

To this end, the project management hired an LPS consultant to guide the implementation of the LP tools in October 2011. However, the LPS was only partially implemented. The LPS implemented consisted of the short-term planning (excel sheet) and look-ahead-planning. Prior the LPS implementation the design team devised the overall design schedule and the project manager considered the schedule appropriate. The designers agreed to have the LPS meetings every two weeks. These were aligned with the traditional design meetings that took place monthly. The project manager used an LPS excel tool to formalize the plans. In each meeting, the project manager was responsible for writing up short-term tasks for each design discipline and for the dissemination of the plan. Members of the design team were responsible for commenting and adding tasks to the plan whilst the plan was being elaborated. The resulting short-term plans were sent to the designers after each meeting and feedback on the completion of tasks was provided during the subsequent LPS meetings. In each meeting, new tasks were amended on the excel base. Reasons for non-completion were not scrutinized and the percentage of plans completed (PPC) was not measured or reported in the meetings.

DATA AND METHODS

The data of the study include the non-participant observations, audio and video recordings of one traditional design meeting and the four Last Planner meetings. The data were transcribed *verbatim* (see table 2) and divided into speech turns. Every speaker's utterance that can be heard on the recordings was counted as a speech turn.

Table 2: Data of the study

Date	Meeting	Duration/minutes	Number of Speech Turns
29.09.2011	DM 2	115	419
10.10.2011	LP 1	35	111
03.11.2011	LP 2	142	552
08.12.2011	LP 3	103	396
02.02.2012	LP 4	74	296

Data preparation and analysis consisted of four stages. In the first stage, a content analysis was carried out with the objective of identifying design tasks within the transcription. The data preparation involved the tabulation and categorization of these topics according to the formal and emergent agenda(s) suggested by the researchers for the analysis. The second stage consisted of comparing and contrasting traditional and LPS design meetings. To this end, the following structure was used to investigate similarities and differences between the two types of meetings: a) meeting agenda, b) tools in use, c) completion of the design tasks, d) concerns about the interdependency of design disciplines, and d) the temporal orientation in executing the design tasks. During the fourth stage, a quantitative analysis was conducted.

Concerns about the interdependency of design disciplines were analyzed through calculating the number of the designers' and the project managers' speech turns in the transcripts of the planning meetings and in the LPS meetings. The analysis was then continued by scrutinizing the discussions amongst designers, their number in total and the topics covered. The discussions amongst the designers typically concerned technical or architectural solutions, design practices and the temporal coordination of the design work. The numbers of these exchanges were then compared between the different meetings. The initial hypothesis was that the concerns about the interdependency of design disciplines would be illustrated in how much the designers engage in mutual dialogue concerning themes related to design.

To analyze the completion of the design tasks the replies the designers gave the project manager concerning the completion of the agreed tasks were studied. These replies were divided into three categories: 1) the fixed task was non-completed; 2) the fixed task was completed, or 3) the fixed task was partly completed.

The temporal orientation was analyzed through calculating the number of fixed tasks and open tasks committed in the meetings. In addition, the proactive discussions of the designers were studied. The quantitative results are presented in document A3.

FINDINGS

THE ADOPTION OF LAST PLANNER TOOLS: CHANGES IN COLLABORATION PRACTICES WITHIN DESIGN MEETINGS

The findings of the first research question are presented in this section. The first research question is: How does the implementation of LP tools change the collaboration of designers? Findings related to the comparison of the traditional and the LP design meetings revealed differences in the collaboration practices of the design team.

From Formal to Emerging Meeting Agenda

The observed design meeting followed a *formal agenda* set for the building projects in general. The formal agenda of the traditional design meeting is based on the questions related to a firm's responsibility and practical rule-type conventions.

Contrastingly, the formal agenda was not followed in the LPS meetings: the agenda for the meeting emerged as discussions were taking place. The project manager outlined the idea of the LPS meeting as follows:

> "What we are missing in practice is this kind of controlled and systematic listing of different design tasks and problems that possibly impede the design, and [we also] lack a routine to handle these problems. That is what we are lacking. And this is what we should begin to do in this [design] group. What do you think?" (LPS meeting 1, speech turn 35).

The emerging agenda was based on an LP short-term plan (excel sheet) and the overall design schedule. The meetings usually began with a run-through of the committed tasks, completed or non-completed; then, a discussion of the tasks at hand based on the overall design schedule followed, and finally the tasks to be executed during the next two weeks were listed. The execution of future tasks was also assessed in terms of required information or contributions needed from others. The typical questions of running the LPS meetings were: what prevents you from executing your task, and what do you need to execute your task? The emerging agenda changed the orientation of the meeting procedure towards making fixed commitments in the execution of future task compared to more open commitments made in traditional design meetings.

The formal agenda of a conventional design meeting and an emerged agenda of the LPS meeting are presented in Table 3

Table 3: Comparison of the formal agenda of a design meeting and the emerged agenda of LPS meetings

	Agenda of a design meeting	**Agenda of a LPS meeting**
1)	Opening the meeting, the chair and the secretary	1) Opening the meeting
2)	Minutes of previous meeting.	2) Current stage of the tasks committed in the previous meeting
3)	Open tasks in the previous meeting.	3) New tasks for the next two weeks.
4)	Entering the separately hold meetings in the minutes.	4) General discussion
5)	Site, permission and authority issues.	5) Date of the next meeting.
6)	Design approvals and user needs.	6) Closing of the meeting
7)	Current state and progress of the design in terms of overall schedule.	
8)	Main contractor affairs.	
9)	Safety at work.	
10)	Customer affairs.	
11)	User issues.	
12)	Other issues.	
13)	Summary and plan for the future.	
14)	End of the meeting and setting the date for the next meeting.	

From the use of rule-type tools to the use of new tools in the LPS meetings

Rule-type, habitual tools mediated the interaction in the traditional design meetings. The traditional tools were the formal agenda, the minutes of the previous meeting, design stage update, and the overall design schedule for the entire design process. The overall design schedule was created in August, 2011 and it was based on the previous projects. Each design discipline discussed the tasks in progress, made a statement on the status of their tasks, and listed the

information needed from other designers during the discussion of the current design stage (topic 7). Some companies also reported that the special meetings they had organized or participated listed information that they needed from the users, informed about the staff resources involved in the project, and named the future tasks on their list.

The tools used in the LPS meetings were the overall design schedule, the list of the tasks to be completed in the near future, and the list of fixed tasks that were listed in the previous meeting. The overall design schedule had a central role in the LPS meetings compared to the traditional design meeting, because the near-future tasks were mostly picked up from the schedule, and partly created in the discussion. The schedule for the near future included (1) a list of fixed tasks for each design discipline, (2) the person in charge of completing the task, (3) comments related to the tasks or their execution, (4) the weeks in focus, (5) the task completed (yes or no), and (6) a reason for the deviation if there was one. The timespan of the near-future schedule was two weeks, except in LPS meeting 3. Then the timespan was eight weeks due to Christmas break and the phase of the design. Participants of the design meetings used the tools mentioned above as paper copies, or in some cases as the document files on their computers. In LPS meeting 2 the near-future schedule was also projected on the wall for everyone to see. The use of the near-future schedule represented a new practice in the design meetings and it also changed during the LPS meetings.

Towards Better Completion of the Design Tasks

The analysis of the completion of the designs tasks is based on the discussions in the LPS meetings because the PPC figure was not systematically used in the follow-ups of the fixed tasks. The completion of the design tasks differs from the completion of production tasks so that a completed design solution may later require re-design e.g. due to changes in customer demands.

When the project manager asked about the completion of the design tasks in the traditional design meeting, a rather typical answer was “I have not completed” or “I have not received all the information I need for the execution of my task”. A half of the responses were negative. As for “done”, “it is ok”, characteristic to the LPS meetings, over a half of the responses were fully completed or almost completed in all the LPS meetings. But still, there were also tasks that were repeatedly reported incomplete in the LPS meetings. For instance, lack of time or weather conditions were given as reasons for not completing the task, or no explicit reason was given. In some cases, the reasons were more connected to the collaboration between different designers, e.g. information missing from other designers. In these occasions, the LPS meetings became an arena for clarifying the interdependencies between designer disciplines. For instance, the architect could not proceed with the design of flues because he was expecting that the HVAC engineers confirm that the specification of machine rooms and duct routing was completed and approved. Other tasks were not completed because the designers had different interpretations of what should be done. In these cases, the discussion in the LPS meetings was useful. For instance, an energy certificate needed for the building permit was not completed so the application could not be done because HVAC engineers wanted to finalize the certificate properly and some information was still missing. The discussion in the meeting clarified that the certificate required for the building permit with less information would do.

The comparison of the traditional and the LPS meetings shows that the juxtaposition of completion and incompletion of tasks is not clear. Tasks may be signed as completed when they are that only to a certain degree. For instance, the HVAC engineers reported already in the design meeting in September that the main routing and space claim for ducts has been designed. However, the main duct routing and flues were not satisfactorily completed for the main designer to complete the architectural design in the Last Planner meeting in November.

Increased concern on the interdependency between design disciplines

The design activity is fragmented into a chain of tasks executed by architectural, geotechnical, structural, HVAC, and electrical designers (Forbes and Ahmed 2011). In spite of this fragmentation, the tasks of different design disciplines are interdependent in terms of contents, time and practical procedures. In this analysis, the passages, in which the designers discuss the execution of tasks, indicate the increase of concern on the interdependencies between designers.

The number of these passages is interpreted to describe the change of collaboration between the design meetings and the LPS meetings. The emerging concern of the interdependency led to the discussions on reciprocal courses of action in the design activity. For instance, what kind of collaboration and temporal consolidation was required in the execution of a design task? The number of this kind of discussion passages increased in the LPS meetings compared to the design meeting.

An example on the designers' concern on the interdependency between disciplinary tasks is related to complicated tasks in which the designers felt it was important to discuss the prevailing procedures of conducting tasks. The main designer was one of the designers whose role gained strength in discussions of the interdependencies between designers. For instance, the design group decided to follow a new procedure and schedule in the design of suspended ceiling, HVAC units and main routing. Due to the change, some designers were not required to do their task twice during the design process as was the case in previous projects.

CHANGE OF THE TEMPORAL ORIENTATION IN PLANNING OF DESIGN TASKS

The proactive orientation to future tasks involved giving "reliable promises" (Hamzeh et al. 2009) and fixing the execution of the task.

The division of time also guided the emergent agenda of the Last Planner meetings. For instance, the discussion proceeded from the uncompleted tasks to the design of future tasks. The discussion of the tasks not yet completed and future tasks was proactive in charting the information required from others for the completion of the tasks. Furthermore, the proactive orientation was useful in registering the breaks in the flow of information and division of labor between design groups. In this regard, the structural designer pointed out in the second LPS meeting that a preliminary design of the rooftop was needed from the architect in order to proceed with the design of the pipelines and drains. The architect was in good faith that the location of the drains would not change and the design of the rooftop was not needed from him at that moment. However, because of the renovation of the machine rooms, new drains needed to be designed.

Besides the temporality, the proactive orientation increased the precision of fixing the goals of the future tasks. The number of open goals decreased during the LPS meetings. However, there was variation in the different LPS meetings. Did the variation emerge due to the design stage, or was it due to the return to the old ways of working is not yet known as we have not analyzed all the remaining meetings and interviewed the participants.

The findings of the second research questions are presented in this section. The second research question is: how does the use of LP tools change the temporal orientation in planning of design tasks? Change of temporality is analyzed in relation to task-orientation. This means that the temporal terms in which tasks were discussed during design meetings are considered. Also, the consideration of how the participants addressed the relation between time and tasks and the temporal orientation was contrasted between traditional design meetings and LPS meetings. Two orientations of temporality were identified in the analysis: the reactive and the proactive temporality.

The reactive orientation to time was especially characteristic to the traditional meeting. The tasks were discussed in the past tense, as completed tasks or not completed tasks. Some references were made to future design tasks in terms of the overall design schedule. Another characteristic of a discussion related to the reactive orientation was that each designer used most of their time to describe what they had done and what was currently in progress. This discussion was run in the past tense and designers did not commit themselves to reporting whether the completed tasks were on schedule or not, and whether there were other tasks that should have been completed by then. Furthermore, the tasks on schedule in the near future received also less attention than the completed ones.

The proactive orientation to time emerged in the Last Planner meetings. This is hardly a surprise as this kind of orientation is considered to support relationships among designers (Codinhoto and Formoso 2005). In the focused LPS meetings, the project manager made an explicit difference between the "history" of design tasks and future tasks. By history, the project manager referred to the tasks that were not completed although they should have been.

DISCUSSION

Our hypothesis of the study was that the implementation of the LP tools (e.g., short term plan, excel sheet) changes the collaboration of designers in the meetings. The analysis of the meetings suggests that there are clear signs of change in the agenda, execution of tasks, of the interdependency between different design disciplines, and temporality in the LPS meetings compared to traditional design meetings. To summarize, Table 4 highlights the issues identified throughout the investigation.

Table 4: Comparison of designers' collaboration in traditional meetings and LPS meetings

	Traditional meetings	**LPS meetings**
Agenda	Formal agenda of traditional meetings based on a firm's responsibility and rule-type conventions	Emerging agenda based on short term planning and look-ahead planning
Tools	1) Meeting agenda 2) Minutes of the previous meeting 3) Design stage update 4) Overall design schedule	1) Overall design schedule 2) List of tasks fixed in the previous meeting 3) List of design tasks for next two weeks in each design discipline presented in the excel sheet
Execution of tasks	Completed or not completed tasks	Increase in the number of completed or nearly completed tasks
Interdepen-dency between tasks		Designers' concern on the interdependency of tasks
Temporality	Reactive task orientation	Proactive task orientation

The emerging agenda changed the orientation of the designers towards making fixed commitments to the execution of the future tasks in the LPS meetings. The overall design schedule had a central role in the LPS meetings and the tasks to be discussed were selected from the schedule. The number of completed or almost completed tasks increased during the LPS meetings. However, not all fixed tasks were completed. Lack of time, weather conditions, lack of information, and different interpretations of the task itself were reported as reasons for not completing the task. According to our observations, much of the discussion was often centered on a project manager in the traditional design meetings. It is not common that designers make initiatives for discussion in traditional meetings. Instead, it is typical that a project manager is the one who asks the questions and designers are the ones who give answers. The fragmentation of discussion in the traditional meetings may have been caused by the formal agenda used. The formal agenda directs the discussion in such a way that each designer focuses only on their tasks, and he or she does not commit themselves to other designers' tasks. Although there is also discussion among designers in the traditional meeting, during the LPS meetings the concern on

the interdependency between design disciplines increases and the designers reflect together the design solutions and the effects of the solutions on each other's work and production costs.

The change in temporal orientation from reactive and proactive was identified in the study. The reactive orientation in planning the design tasks characteristic to traditional design meeting seems to relate to reporting the completed tasks whereas proactive orientation characteristic to the LPS meeting refers to being punctual and precise in fixing the future tasks. New kind of conversation emerged also in the LPS meetings. Especially, the main designer made initiatives to discuss the reorganization of the design work, in the design of complex structures in situations when shared knowledge from different design disciplines was needed.

All members of the design group did not want to adapt to the changes enabled by the Last Planner tools. They were rather persistent with their traditional work procedures. One example is the analysis of existing underground drains. Although it was agreed in the September meeting, it was still undone when the winter came in February. There are many reasons for this, one of them being the confusion related to the division of labor. Whose job would it be and who would be involved? Another example is the accomplishment of the list of devices to be kept in the technical work classroom. This was also agreed in September but still undone in December. Our interpretation is that failing to complete tasks could relate to the persistence of old ways of working. Our interpretation is supported by a reference from the interview with the project manager: according to him, the old ways of working are deeply embedded in design activity. This is obvious especially in problematic situations when the solutions at hand are usually the best solutions.

CONCLUSIONS

On the basis of our research findings the LPS enables changes in the construction design. The implementation of brought about positive results in our case organization. For instance the building permit was received on time. This was not the case with all the previous projects! However, the process is still going on in our case. We follow how the use of LPS proceeds in the design and construction activity of the case project. We will also interview the members of the design team to find out if they consider the LPS procedures and tools useful for the design process. It is also important to find out how the procedures and tools should be developed for the next projects. The case company is aiming to deploy the LPS meetings also in some of their upcoming projects. We will follow those projects to examine how the LPS implementation will proceed.

The project management's feedback on the LP tools is positive, but according to them, it suits the construction management better than design management. Design management involves grey areas in terms of achieving goals and quality demands. In every case, it is useful to reach the main targets by discussing in good collaboration. However, as our findings show, old practices and procedures are persistent and the change of the prevailing practices takes time.

ACKNOWLEDGEMENTS

We owe our sincere thanks to the management and the design group of the construction project involved in our analysis. We also thank M.Sc. Jenni Korpela for her help with the quantitative analysis. She has also recorded the data in some design meetings when the first two authors of the paper have been hindered.

REFERENCES

Alves, T.C.L. and Tsao, C.C.Y. (2007) Lean Construction – 2000 to 2006. *Lean Construction Journal*, 3 (1), 46-70.

Anumba, C. J., Pan J., Issa, R. R. A. and Mutis, I. (2008). Collaborative Project Information Management in a Semantic Web Environment. *ECAM*. 15 (1) 78-94.

Ballard, H. G. (2000). *The Last Planner System of Production Control*. Doctoral Dissertation, Faculty of Engineering, University of Birmingham.

Ballard, G. and Howell, G. (2004). An Update on Last Planner. *Proc 11th Annual Conference International Group for Lean Construction*. Blacksburg, Virginia, USA.

Codinhoto, R. and Formoso, C. T. (2005). Contributions for the Integration of Design and Production Management. *CIBW96/2005.*

Cremona, M. (2011). Enhancing Collaboration and Decision-making through Application of Last Planner System in Construction Design. The University of Salford School of the Built Environment, MSc Project Management in Construction.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011). *BIM Handbook. A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors*. John Wiley and Sons, New Jersey.

Engeström, Y. (1995). Objects, Contradictions and Collaboration in Medical Cognition: An Activity-theoretical Perspective. *Artificial Intelligence in Medicine* 7, 395-412.

Engeström, Y. (1987). *Learning by Expanding. An Activity - Theoretical Approach to Developmental Research.* Orienta konsultit, Helsinki.

Forbes, H. L. and Ahmed, S. M. (2011). *Modern Construction – Lean Project Delivery and Integrated Practices.* CRC Press, New York.

Formoso, C.T., Trescastro, M. and Codinhoto, R. (2006) Planejamento e controle integrado do projeto e da produção em ambientes simultâneos na construção civil. In: (*NUTAU) Núcleo de Pesquisa em Tecnologia da Arquitetura e Urbanismo, 2006, São Paulo.* Anais... São Paulo.

Hamzeh, F. R., Ballard, G. and Tommelein, I. D. (2009). Is the Last Planner System Applicable to Design? A Case Study. *Proceedings 17th Annual Conference of the International Group for Lean Construction* (IGLC 17). Taipei, Taiwan, 15-17 July 2009, 399-410.

Kanzode, A. and Reed, D. (2008). A practitioner's Guide to Virtual Design and Construction (3D/4D) Tools on Commercial Projects: Case Study of a Large Healthcare Project. In W. Kymmel *Building Information Modeling. Planning and Managing Construction Projects with 4D CAD and Simulations,* McGrawHill, New York 173-204.

Kerosuo, H., Miettinen, R., Mäki, T., Paavola, S., Korpela, J. and Rantala, T. (2012). Expanding Uses of Building Information Modeling in Life-cycle Construction Projects. *Work* 41(1) 114-119.

Koskela, L. (2000). An Exploration towards a Production Theory and Its Application to Construction. *Technical Research Centre of Finland* (VTT). Espoo, Finland.

Leont'ev, A. N. 1978. *Activity, Consciousness and Personality*. Prentice-Hall, Englewood Cliffs, New Jersey.

Miettinen, R. (2009). *Dialogue and Creativity. Activity Theory in the Study of Science, Technology and Innovations.* Lehmanns Media, Berlin.

Miettinen, R., Kerosuo, H., Korpela, J., Mäki, T. and Paavola, S.(2012). An Activity-theoretical Approach to BIM research. *A Paper at the ECPPM 2012 Conference.*

MILES, R.S. (1998) Alliance lean design: construct on a small high tech project. IGLC conference 6th., Guaruja, Brazil.

Paavola, S., Kerosuo, H., Mäki, T., Korpela, J. and Miettinen, R. (2012). BIM Technologies and Collaboration in a Life Cycle Project. *A Paper at the ECPPM 2012 Conference.*

Tzortzopoulos, P., Formoso, C.T., and Betts, M. (2001) Planning the Product Development Process in Construction: an Exploratory Case Study. *Proc. 9th Annual Conference of the International Group for Lean Construction (IGLC-9),* Singapore, Singapore.

Vygotsky, L. S. (1978). *Mind in Society. The Development of Higher Psychological Processe.* Harvard University Press, Cambridge, Massachusetts, and London, England.