COLLABORATIVE DESIGN MANAGEMENT – A CASE STUDY

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ABSTRACT

The Last Planner System (LPS) has been successfully implemented in both design and construction phases of projects, but there have been raised questions if LPS in design needs to be changed to better suit the nature of design, due to the inherent differences between design and construction. The Norwegian contractor Veidekke has developed a method based on LPS for use in design called Collaborative Design Management (CDM). This paper looks at how CDM works in practice by doing case study of two projects where the methodology has been employed.

We found that the use of CDM led to better communication and cooperation within the design team and a better understating of and commitment to the project. There are also indications that the methodology should lead to a more efficient and controlled design process which in turn would benefit the following construction process.

Although we have seen positive effects from the use of the methodology, we have also found it lacking in some areas. Specifically the lack of a formalized weekly work plan, approach for constraint analysis and PPC measurements.

KEYWORDS

Design Management, Last Planner System (LPS), Collaborative Design Management (CDM), Percent Plan Complete (PPC)

INTRODUCTION

The Last Planner System (LPS) is a method for improving the reliability of work flow in production and design, and has been developed by Glenn Ballard since 1992 (Ballard, 2000a). To get the full benefits of using LPS in construction projects there is evidence that it should be implemented from the design phase, both in order to coordinate and manage the design process as well as to get construction information into the design in the form of buildability and construction methods (Fuemana et al., 2013). Although there have been successful applications in both design and construction phases of projects, there have been raised questions if LPS in design needs to be changed to better suit the nature of design, due to the inherent differences between design and construction (Ballard et al., 2009). Koskela (2000, based partially on Giard and Midler 1993) describes the difference between design and production in the characterization of design, from the operations management point of view:

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- There is much more iteration in design than in physical production
- There is much more uncertainty in design than in production
- Design is a non-repetitive (i.e. a project type) activity, production is often repetitive.

Hamzeh, Ballard, and Tommelein (2009) tried to adjust and develop LPS to better suit design on a health care project in North America, they focused on "*a milestone schedule, collaboratively created phase schedules, make-ready lookahead plans, weekly work plans, and a method for measuring, recording, and improving planning reliability"*. The study showed that the planning was getting better through more confident architects and designers in the planning process. It also showed the importance of support from management when implementation the process. The use of LPS was also shown to improve the communication in the project. The authors could however not say if using LPS in design had improved the performance of the project.

Kerosuo et al. (2012), doing a case study of the use of LPS in the design process of the renovation a school building, experienced a better completion of the design task in the design meetings with use of LPS, and also increased communication between the different design disciplines.

Hamzeh and Aridi (2013) measured Percent Plan Complete (PPC) of LPS from data collected from several projects in an Architecture, Engineering and Construction company over a period of 12 months. The data collected included lookahead planning, weekly work planning efforts and measurements of PPC. The result of using LPS here showed an average PPC between 80 % and 90 %.

The Norwegian contractor Veidekke has since 2006 used a system they call Collaborative Construction Management, an adapted version of the Last Planner System (Veidekke, 2008), for managing the production on their construction sites. Since 2009 there has been an ongoing work trying to adapt the methodology for use in design. In this paper two building projects using Collaborative Design Management are studied and analysed to see how this adapted version of the Last Planner System works in design, and what outcomes they have achieved on PPC measurements.

COLLABORATIVE DESIGN MANAGEMENT (CDM)

Veidekke (2013) describe the aim of CDM is *"to increase the value of the end product and reduce production costs and the design process"*. The goal is to make the process more efficient through planning and coordination through mutual adjustment so they get a better flow in the design.

Collaboration is the key word for this methodology – everyone should participate in the planning of their own work. Some of the key elements of LPS that have been included are that the plans are made jointly by those who will do the work, everyone has knowledge of and influence on their own work, plans are made by giving mutual promises, lookahead planning where the activities are increasingly detailed as the execution approaches and barriers are removed so that only sound activities are assigned to designers.

In addition to the elements that have been adapted from LPS, CDM also includes several other elements, most notably the use of Integrated Concurrent Engineering

(ICE) and Building Information Modelling (BIM). The main elements of CDM is summarized in figure 1 and the elements of the methodology is described in detail in text below.

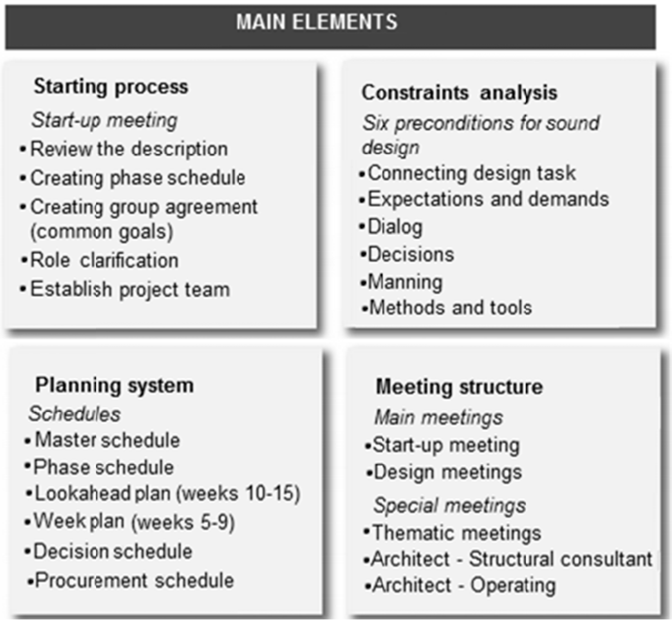

Figure 1: Main elements in Collaborative Design Management as illustrated by Veidekke (2013)

START-UP MEETING

When a new project, where CDM will be used, is started everyone in the design team plus the project manager, construction manager, foremen, the main subcontractors and the client are given an introduction to the methodology at a start-up meeting. Here it is explained what are the six preconditions for sound design, and pull planning is used to work out a joint phase schedule for the design.

ICE & BIM

It is recommended as part of the method to use Integrated Concurrent Engineering meeting (ICE) and Building Information Modeling (BIM). BIM can be used to visualize the entire building in 3D, by connecting all the deliveries from the designers into a unified digital model, run collision controls, do quantity take-offs etc. ICE is collocated, simultaneous design in team of multidisciplinary experts adapted for the method and technology (Jovik, 2011). It helps to achieve good communication between those involved in the design of the building. The idea behind ICE is that by using it, it is possible to make faster decisions and clarifications (Veidekke, 2013).

PLANNING

The planning system is divided into strategic plans and operational plans. Under strategic plans are the master schedule and phase schedules, these are superior and each of these are usually prepared only once in the project. The master schedule contains the main phases with milestones and the phase schedules are the result of pull planning and contain the activities that should be done in the phase. I.e. these plan levels are essentially the same as can be found in LPS. But at the operational levels there are several differences.

In LPS the two operational plan levels are the lookahead plan and the weekly work plan, with an associated time frame of six and one week respectively (Hamzeh et al., 2009). In CDM there no formalized weekly work plan, but there two different lookahead levels called the lookahead- and the week plan. In addition there is also a decisions plan based on the phase schedule, to control when decisions need to be dealt with. All the operational plans in CDM are rotating and should be updated every week.

The difference between the lookahead- and week plans in CDM lies in the time horizons and the focus of them. They are closely tied to the construction process and its plans. Week 0 is considered to be the week that something is to be built and the design and engineering work required should all be done 4 weeks ahead. The purpose of both of the lookahead- and the week plan is to identify whether there are any of the activities in the plan are constrained, and if so, work to remove them (Veidekke, 2013). The lookahead plan describes what drawings and others designs documents are needed on site 10-15 weeks ahead. The planning work here is focused on removing constraints from the required design activities, while the week plan focuses on the 5-9 weeks time frame and on removing any constraints from a construction point of view.

SOUND ACTIVITIES

The figure below shows what is needed to achieve a sound design, and is used as the basis for the constraints analysis. This is based on Glenn Ballard's seven preconditions in production (Ballard, 2000a), but has been adapted by Bølviken et al. (2010) to be more applicable to the design process. Sound design, is when you can do an activity unobstructed, and with the right quality and solution. A design activity is said to contain three steps; decide, process and convey.

Decide what should be done in the further design or what should be built. Process all the solutions jointly, to improve and develop the design. In the end convey the results from the design to the production or subsequent designers (Veidekke, 2013).

Constraints analysis is included in the basis of theory and planning of design. Unlike LPS in CDM there are no specified method or guidelines of how this should be done in practice. And as such neither is there any concept of workable backlog, the idea of which is to have a buffer of tasks that can be switched to if it turns out the assigned task is impossible to carry out (Ballard, 2000a).

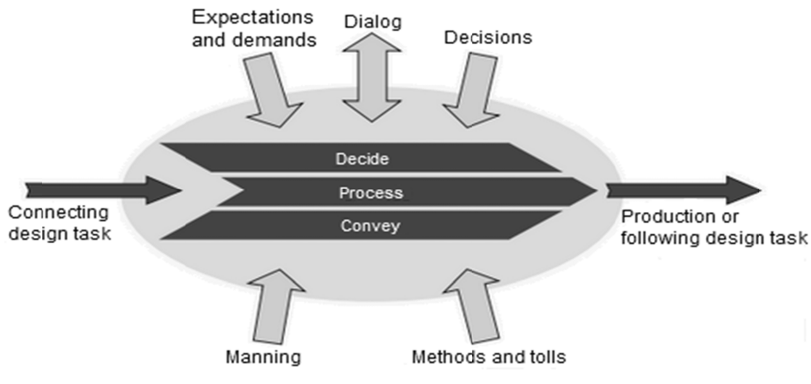

Figure 2: The six preconditions for design tasks as illustrated by Veidekke (2013)

Bølviken, Gullbrekken, and Nyseth (2010) and Veidekke (2013) describe more in detail the six preconditions for constraints analysis in design processes:

1. Connecting design task – previous activity must be completed and with the right quality
1. Expectations and demands – design is the translation of customer requirements into a design solution
2. Dialog – the process needs dialog and mutual adjustment
3. Decisions – necessary decisions must be taken
4. Manning – people who will perform the activity must have the capacity and competence
5. Methods and tools – must be adapted to the design task's scope, complexity and participants

EVALUATION

A part of the methodology is learning from mistakes and deficiencies in the design process. This is done through evaluation meetings midway and ultimately in the design process. In this way the methodology can be adjusted as it progresses if desired.

RESEARCH METHOD

The method of data collection was a combination of qualitative and quantitative method. In order to find how they practiced the method and what experiences they have gained, data collection on Collaborative Design Management started with qualitative face-to-face interviews with both the construction- and design managers. This was done in both the research cases below. The design managers were chosen as interview objects because they are the key persons in the design process and possess first-hand information about the method. The construction managers are involved in both construction and design, and will therefore see in practice in construction how good the results from the design are. It was therefore natural to include them as informants.

The quantitative part of the research was focused on PPC measurements, on both drawing deliveries and completion of planned design activities. The data was primarily gathered from the minutes from the evaluation of building phase one with all 18 key persons in the project. The key persons were architects, designers, design manager, construction managers, plumber, electrician and the client.

RESEARCH CASES

The first case is a shopping centre, with a turnkey contract of 350 million NOK (ca 56 millions dollars). The project started up in February 2012, and shall be finished September 2014. It includes remodelling parts of a shopping centre and building an extension to it. The total project size is around 44 000 sqm (Veidekke, 2012).

This project has been divided into three building phases, simply to make traffic flow around the construction site. When this paper was written, the contractor was at the end of phase two. Every phase involves a handover of a part of the building, for example for phase one this is a parking garage and a new building. The design was done all in one, but because of the complexity of the building, they have to do it again for parts of phase two and three.

From the beginning in the project, Collaborative Management was applied, in both design and construction.

The second case is three apartment blocks with a common underground parking. The building project on the first block with 23 apartments has been going on since autumn 2013, and started with the groundwork in January 2014. This project has also used Collaborative Management in both design and construction, and everyone involved in the design have been through training in the methodology. A prerequisite for the designers in the project was that they should design in 3D and BIM.

FINDINGS AND RESULTS

The finding from the cases are presented below structured in accordance with the elements of CDM as described earlier in this paper.

START-UP MEETING

In both of the cases the design teams were introduced to the methodology at a start-up meeting, were they went through how this method should be implemented with meeting structure and planning. Both projects emphasized this meeting as being important for further cooperation, as it helped them to have better communication in the design teams.

In construction projects the team composition is usually different from project to project, and no project is the same. In both cases they saw that many of the members of the design team were totally new to this way of working. Because of this they used extra time in the beginning of the project to teach people the methodology and associated tools such as BIM.

Several of the informants pointed out that many of the participants did not have enough knowledge about the engineering process flow in construction projects.

ICE & BIM

In case one they used ICE-meeting and Big Room [1] in the design, as part of Collaborative Design Management.

In the beginning the bosses of the various architect and engineering firms would not be a part of the ICE-meetings. They meant that it was an ineffective method to work by. But after they had started up and experienced a good flow, they changed their mind. The ICE-meetings made it easier to get clarification on issues.

Both projects make use of BIM as a part of the design, where they gathered all the different disciplines in 3D models. BIM makes it easier for the projects to detect faults such as collisions between different pipes.

[1] Big Room is a room that is typical furnished with desks located in a horseshoe around one or more SMART boards (Østby-Deglum, E., et al., 2012).

PLANNING

A lot of Collaborative Design Management is about making work plans. In both cases they used pull planning to plan the progress in design. Here everyone in the design team, and also the construction managers, took part in making a common plan of tasks to be performed. When they used people with different backgrounds, they got a fine interplay between practical and theoretical experience into the plan. Other experience from applying pull planning was that it made them more aware of the design process; they became more aware of the connection between the different tasks.

They pointed out in both projects that there is a large amount of information that has to be communicated to different parties. All the information in the each of the projects is stored on a web hotel. It allows participants to receive continuous background info, progress reports, decisions, status quo and the minutes from the meetings.

The evaluation of case one mentioned that it was often unclear who should do what in which time frame, and the expectations that are between the different operational plans of CDM. It also expressed the desire that the link between design and construction could have been stronger. In case two they had positive experiences of having a fixed agenda for project meetings, so it was predictable what was going to happen. The design manager follows the plan strictly and it provides flow through the design week.

In both projects, when a problem occurs a special meeting of the relevant professions is held. This is perceived as important and effective, and a smart solution to solve single problems.

Although CDM does not specify any weekly work plans as in LPS, in both projects it could be observed that there was actually de facto work plans. Design meetings were held weekly or bi-weekly. At these meetings it was agreed upon what would be done until the next meeting. And at each meeting what had been done or not was also reviewed, which gave the basis for PPC measurement.

SOUND ACTIVITIES

In case one, the shopping centre, a lot of redesign was required, because of wrong assumptions made initially with regards to both the condition of the existing building and what requirements the future tenants would make. This is an indication that constraints were not analysed and handled to the degree that is suggested by the methodology.

PPC MEASUREMENTS

PPC is describe by Ballard (2000a) as" A key metric of the Last Planner system is the percentage of assignments completed (PPC)". This is not a part of CDM yet, but has been performed in both cases. In the apartment block project (case two), they measure PPC of the completion of the activities planned in the design meetings, and they also analysed what the reasons were for non-completion. Here they measure how good the architects, structural-, mechanical-, plumbing-, electrical engineers, owner and the turnkey contractor are in carrying out the tasks they have committed to in the meetings. The measurements frequency was weekly or bi-weekly.

Everyone gets the results of the measurements, so they have possibility to see not only why they deliver or not, but also so they can improve. The reason why tasks are not completed are sorted in five categories; unrealistic planning, lack of information, lack of decisions, lack of personnel/priority, wrong method/tools.

At the time of writing this paper there was done 12 measurements over a period of 17 weeks on case two. The results from the measurements are shown in figures 3 and 4.

The measurements helped to generate involvement in the design team, and there are indications that it was instrumental in getting several tasks completed on schedule. The construction manager believes that it gives a bigger pressure to deliver, because they are held accountable for what they have done or not.

The goal was to complete 85% of the task/activities. As you can see below in figure 3, they did achieve a average result of 81 %.

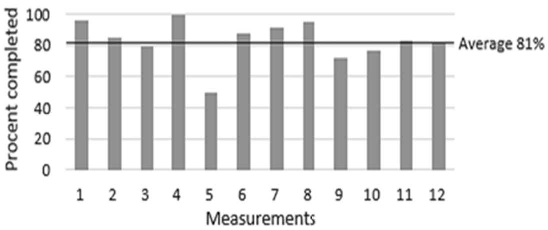

Figure 3: PPC of completion of design tasks from case two

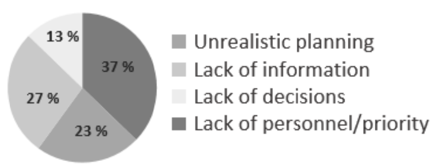

Figure 4: Reasons for non-completion of activities from case two

The same project also measured PPC on drawing delivery, where they set a target value on 90 %. They did 9 measurements in a period of 10 weeks, and showed an average result of 91% in drawing delivery, the reasons for not delivering on time was 80% due to lack of personnel/priority and 20% due to lack of decisions.

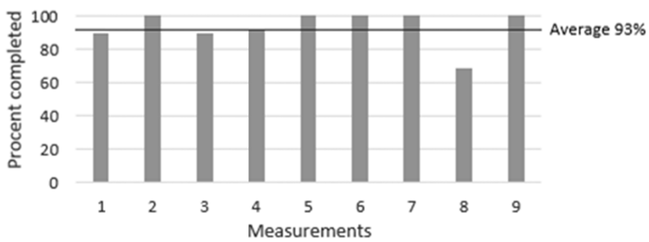

Figure 5: PPC from drawing delivery from case two

PPC measure was also done in the shopping centre (case one), the results from measure PPC in action plan showed 41% in average. Here the measurements varied from 18-86%. The measurements were done weekly, and a total of 18 measurements were performed. The PPC of drawing delivery had better results, 60% in average with 22 measurements. The variation between the different weekly measurements was large, from 28% at the lowest, and 100% at the highest. In an internal project survey where 13 people were asked “Would measuring be motivational for drawing delivery?” 38.5% believe it would be highly motivational and an equal percentage thought it would have some effect on the motivation. This means three quarters of the participants believed it would have a more or less a positive effect to be measured.

The same question was asked relative to the completion of the weekly planned design tasks. Here 46.2% believed it would be highly motivational and an equal percentage thought it would mean something for motivation.

Although measurements were done in case one, the project made little use of the results; they felt that the measurements were too complex and that it was difficult to find the reasons for non-completion of tasks. They also quit measuring after a while, stating the reason to be time limitations and that the project was too complex to measure.

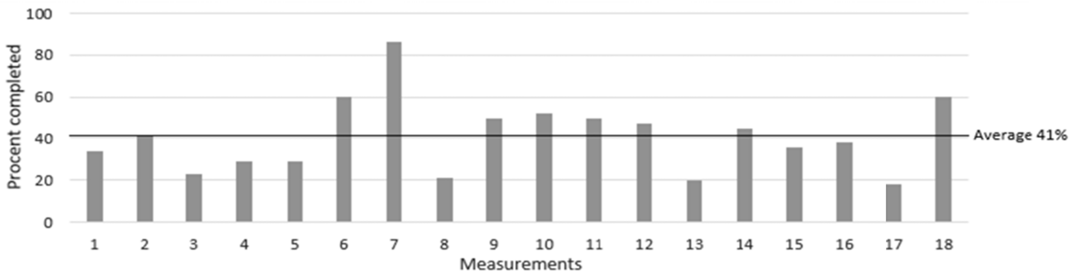

Figure 6: PPC of completion of design tasks from case one

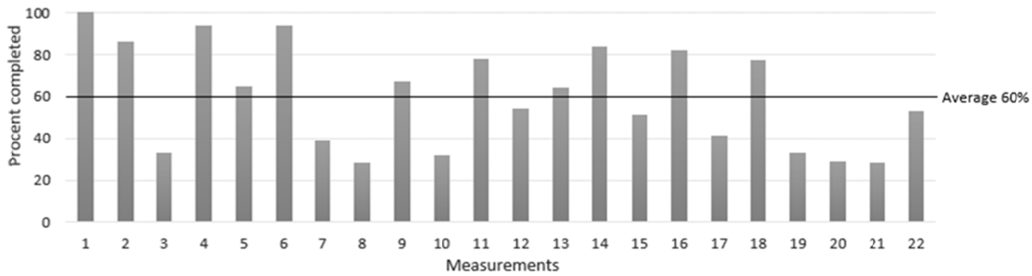

Figure 7: PPC from drawing delivery from case one

EVALUATION

After building phase one in the shopping centre case (case one), the design team with architects, designers, design manager, construction managers, plumbing and electrical contractors and the client, evaluated the process and their experience with CDM, and used it to make some adjustment for further work.

The negative result that emerged in the evaluation was that that the activities planned each design meeting needed to be more specific; the plan must be followed, decisions need to be taken faster and competence was too low when using digital tools such as BIM. On the positive side, the ICE-meetings saved time and money through quick decisions and good solutions. Even if competence was too low in BIM, the design team thought the BIM model helped to get a better a multidisciplinary understanding. And they felt that the use of CDM had facilitated good cooperation.

OTHER RESULTS

In both of the cases it was pointed out that the methodology seems unfinished, but specific areas that were mentioned need improvement.

In case one some of the designers and the design manager felt that it would have been more efficient to use a more traditional planning approach in the parts of the project that were subject to redesign.

DISCUSSION

The purpose of the case study has been to look at how CDM works in practice. Even though we have only looked two cases over a limited time period we think there are several indicators about how well the methods work and what should be improved.

There are clear indications that the use of CDM has had a positive effect on the cooperation and communication in the projects and the commitment of the project participants. The foundation for this is laid in the start-up meeting where a common understanding of what is to be done and how the team are going to work together is reached. The pull planning done at these meetings is particularly instrumental in this. Having the whole team work together to develop the phase schedules, leads to a more holistic understanding and ownership of the entire project.

Another factor that seems to have contributed to the cooperation and communication on the projects is the use of ICE and BIM. The ICE meeting helps greatly reduce the latency in communication, ensuring that decisions are made faster and better solutions are often found due to having more points of view available. It also reduces the possibility of having what Ballard (2000b) has called negative iterations in design.

The plan levels of CDM seem to have worked well for the projects. They make visible what is needed to do at the different levels of design in order to get the required drawings and design documents to the construction site on time. The methodology, as described in Veidekke's guide (Veidekke, 2013), has some shortcomings though. The lack of an analogue to the Weekly Work Plan of LPS has led to ad-hoc solutions being found to weekly task assignments in the projects. These being found at the design meetings. In our opinion a official approach to this should be developed and included in the official description of the methodology.

Another thing that is lacking from the official CDM description is any formalized approach to how constraint analysis should be done. There are general guidelines stating that constraints should be removed, but nothing on how this should be done. We feel that this is weakness in the methodology that should be corrected. It is difficult to make any clear conclusions from the data we have, but it is likely that a lot of the problems related to the redesign in case one could have been avoided if a more stringent approach to constraint analysis had been in place.

Both projects included PPC measurements as part of the design process, even though this not a prescribed part of CDM. The measurements were seen to have a positive effect on the projects in terms of commitment to the deliveries and an increased pressure to deliver on time. Most of the project participants were positive to these measurements even though the results from them are varying.

Case one chose to stop doing PPC measurements after a while. According to them doing these measurements was too complicated and time consuming. This is in stark contrast to case two where these measurements were done as a part the design meeting consuming very little extra time. We think that if some sort weekly work plans are used and the PPC measurements are done as an integral and standardized part of the planning process, then the measurements should not cause any significant burden for the projects. In any case the positive effect that has been observed in the cases should greatly outweigh the extra work that has done for the measurements. This is therefore another element that should become a part of CDM.

There is as of yet no clear indication to whether or not the use CDM has led to better productivity and reduced costs in either of the cases. But according to Liu et al. (2011) there is a significant correlation between PPC and productivity on projects. Their findings propose that completing tasks according to plan is critical for improving productivity. And as such it can assumed that at least in case two , which achieved an average PPC of 81% for completion tasks and 93% for drawing deliveries, that the project has a better than average productivity.

The achieved PPC in case two is comparable to the results Hamzeh and Aridi (2013) have reported from using Last Planner in design.

It was pointed by some of the informants that the methodology felt unfinished and that it is still under development. Even so, we have observed that to get any benefit from using CDM it is important to fully commit to the methodology through the entire process.

CONCLUSIONS AND FURTHER WORK

Earlier it has been indicated that this method is suitable for the construction process, in this study we have seen it can be used in design as well. On the basis of our research findings we think CDM enables positive changes in the design process compared to more traditional approaches. For instance it creates involvement and ownership in building project, and is a useful method to plan a project with involving all members of the design team as well as construction managers, the client and other parties involved in the project.

Although we have seen positive effects from the use of the methodology, we have also found it lacking in some areas. Specifically the lack of a formalized weekly work plan, approach for constraint analysis and PPC measurements. We feel that CDM would benefit a lot from adding these elements to the methodology.

It is important to point out that CDM is still being developed, and in every new project, there will be people without any theoretical or practical experience of the methodology. Because of this the potential benefits of using the methods should be higher than what has been observed in these two cases.

There are certain weaknesses in the case study. The measurements should have been over a longer period of time, and it would have been desirable to follow the projects through the entire design process, in order to validate the results further. Unfortunately the time period available was constrained due to this research being a part of a master thesis, the thesis work being limited to 20 weeks. In further research it is recommended to follow cases through the whole design period into the production, so the entire result of how successful CDM is can be seen.

The possibility of reductions of costs and construction time with the use of CDM could be a subject for future investigations, since there at the moment does not exist any clear evidence of what effect the methodology has on this. Another possibility for further research is to look at how to include constraints analysis as a part of CDM.

ACKNOWLEDGEMENTS

The authors would like to thank Veidekke and their workers who provided information for the research.

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