IMPLEMENTATION OF LAST PLANNER IN A MEDIUM-SIZED CONSTRUCTION SITE

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ABSTRACT

The paper address a pilot project in implementation of Last Planner initiated by the general contractor, Skanska, in a construction project of 6800 square metre made up of a kindergarten, junior high school and a sports and cultural centre. Excavation work started late autumn 2008 and the utility buildings are scheduled to be delivered to the owner in June 2010. The owner is the Municipality of Kristiansand. Action research is applied as research method, where academics take part in the change processes, together with professionals from the construction project and the general contractor's head office. This paper concerns reflections from the ongoing construction process and is based on preliminary data.

The first run is broadly in accordance with the Last Planner concept as outlined by Ballard. It is, however, identified a need to improve the system to link the output from the collective phase scheduling to production planning via the lookahead schedule and constraint analysis, which has been mis-conceptualised in the early phase of the project. The most successful part of the implementation study so far is several phase planning processes, in which the technical sub-contractors have been taking active part in the collective organised planning process. It is too early in the project to see if this also leads to improved PPC in production, but it is expected that it will. However, the same quality of coordination is missing for the architect and the subcontractor for site work.

It is identified a number of empirical difficulties in the implementation the process. The largest challenge seems to be the relationship between the architect, the general contractor and the owner, as the pattern in the relationship appears to be dysfunctional in order to create best possible condition for cooperation, and which need to be further studied. Moreover is it identified proposals for further improvements in the Last Planner concept.

KEY WORDS

Last planner, implementation, first run study, preliminary findings

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INTRODUCTION

Several of the largest construction companies with operations in Norway show increasing interests to apply lean construction oriented methods in their operations. They are, however, on a rather early stage on that path and implementation seem to take place in pilot cases. An exception might, however, be a competitor to SKANSKA on the Norwegian market, which has decided to go for a full implementation of their version of Last Planner, denoted "Involvement in planning"[4].

Last Planner has been in development since 1992 (Ballard and Howell 1997 in Ballard 2000) and is associated to the TFV-theory (Koskela et al. 2002), which Ballard (2000) regard to be synonymios to Lean Construction. Hence, the development of Last Planner started up a couple of years after the Lean Production denotation of Toyota's production system was launched in the *Machine that Changed the World* (Womack et al. 1990). The TFV-theory (Transformation-Flow-Value), as in Lean production/Lean construction, is based on a set of principles associated to transformation, flow and creating value for customers, some of the principles are theory based, while others are based on generalization from best practice (Koskela 2000). Central principles are 1) reduction of waste; 2) reduction in lead time; 3) reduction of variation; 4) simplify the value chain; 5) increase flexibility; 6) increase transparency; 7) produce value for customers and 8) involvement of workers and sub-contractors in planning and improvement work.

A search in accessible literature reveals insufficient documentation on implementation and evaluation of lean construction techniques. Salem (Salem et al. 2006) pursues human and technical learning through the implementation of lean construction. At a construction site with a duration of six months, a set of lean construction techniques was tested: last planner, increased visualization, first-run studies, huddle meetings, the five S's (Sort, Straighten, Standardize, Shine and Sustain), and fail-safe for quality. Salem concludes on this being a success through better control and more involvement between the general contractor and the sub contractors. A tool for measurement of success and presentation in a spider web diagram is also recommended. Formoso (2006) claims that a multitude of publications focus on the success of Last Planner, and it is indicated that the success of this tool is due to the way it manage commitments. However, it is warned against the tendency to equal Lean Construction to implementation of Last Planner only. Also, it is indicated to be a scarcity of quantitative studies that assess Last Planners impact in the performance of construction projects, and properly discussions on the core ideas that underlie this system.

An example of reducing waist in the construction industry could be to reduce waist of time, which is claimed to be some 40 % of total working time on construction projects in Norway[5], hence reduction of waste will also reduce the lead time. To reduce variation could be to establish standardised procedures for project planning,

[4] Veidekke (October 2008). Involvement in planning. From 6 pilots to 27 learning projects (translated by the authors)

[5] The figure is not well documented, but is of a kind that goes from mouth to mouth and being referred to as fact in presentations in different professional gatherings to demonstrate how inefficient the construction industry is.

evaluation and continuous learning, which is at the very heart of "Last Planner". To increase transparency includes making information about drawing, plans and performance easy accessible for all stakeholders in the actual project. Customers in lean thinking are also the supply of materials or work to a downstream process, which in construction could be carpenters delivery of work to electricians. Involvement by suppliers and workers is a central characteristic of lean thinking in order to make work and material flow with small buffers. That aspect could also be seen as a value by itself, which are focused in Scandinavian context in cooperation between employers and labour unions.

In this paper we address a Norwegian pilot case[6] where SKANSKA Norway is the general contractor company. Research on Havlimyra (2008-2010) is a pilot-case conducted in collaboration between SKANSKA Norway[7] and University of Agder. SKANSKA Finland has, however, experience from applying Last Planner for several years, and there are initiatives to diffuse their knowledge to other SKANSKA regions. SKANSKA Norway is one of the largest construction companies in Norway. The studied case, Havlimyra, includes a new junior high school, together with a kindergarten and a sports and cultural centre. Total area of these utility buildings is app 6800m^2. The erection of these utility buildings is our study object. Havlimyra is a suburb in Kristiansand, which is the capital of the South Coast region of Norway.

The research focus of the case study is to discuss and reflecting on preliminary findings up against the concept of Last Planner. We consider the originally Last Planner Concept in particular as spelled out by Ballard (2000).

Action research (see for example Reason and Bradbury 2001) is applied as research method where academics take part in the change process as such together with professionals from the construction project and the general contractor's head office. The action research process includes reflections on theory and empirical findings to be reported to the international research community.

LAST PLANNER PRODUCTION CONTROL

A critique of the predominant production control system in the construction industry is the point of departure in Ballard's (2000) doctoral thesis addressing the Last Planner system of production control.

He point out the difference between a claimed traditional approach to keep costs and schedule under control by detecting negative variances from target, so corrective actions can be taken (Diekmann and Trush 1986). Ballard holds that reactive approach up against the more proactive approach conceptualised in Last Planner, "in which the purpose of control is to cause events to conform to plan" and to "replanning when events cannot be conformed" (p. 2-7).

Time management in the traditional approach is identified to consist of activity definition, activity sequencing, activity duration estimating, schedule development and schedule control, which in Ballard's interpretation by referring to PMI (1996) is entirely a focus on transformation, not on flow or value generation approaches as in

[6] Financially supported by a Norwegian research program aiming to reduce cost in the construction industry (www.byggekostnader.no).

[7] www.skanska.com/ Skanska Norway is a 100% owned Daughter Company of Skanska AB. Skanska AB is noted on the Stocholm Stock Exchange.

lean thinking. He conceives a project to be a temporary production system linked to other temporary and permanent production system for material, equipment, labour, etc.

Furthermore is it made effort by Ballard to demonstrate inconsistency in traditional project control regarding time and cost (resources) for which utilization of resources are planned through cost control systems aimed at efficient use of resources, which is productivity per se. On the other hand the objective of time control is production or progress, not productivity. Moreover is it applied earned value systems for handling the relationship between productivity and production/progress and the phenomena that progress and expenditure of resources need not coincide, which leads to measurement of production up against schedule. "The obvious weakness in this control mechanism is that projects may exhibit budget productivity and be on the earnings plan, but not be doing the right work in the right way at the right time" (Ballard 2000, p. 2-9). This leads also to weakness in terms of lack of integrated quality control, according to Ballard, as work might being produced that does not confirm to product quality requirements or to process quality requirements (out of sequence), and quality control is established as a separate control mechanism. Moreover is it claimed that quality control lack customer focus in the traditional approach.

Finally does Ballard forward critique to how the traditional control approach apply Work Breakdown Structure (WBS), which provides a framework for integrated schedule and cost planning, but which is not capturing the production process as such. The author aims to structure work for "flow and assembly, not only for budgeting and monitoring" (p. 2-10).

THE LAST PLANNER CONCEPT

The "Last Planner" is the person or team that produces construction assignments of work to be carried out. The "assignment plan" is unique by being a production plan that drives direct work, not production of other plans. Ballard argues that Last Planner production control system "is a philosophy, rules and procedures, and a set of tools that facilitate the implementation of those procedures".

He conceptualise the procedure part to make up two components: production unit control and work flow control. The first addresses assignment of work organized as a process of continuous learning, while the second addresses improvement of flow of work in the best achievable way across production units in term of sequence and rate. In concrete terms we might sum up the Last Planner concept as follows:

1. The weekly assignment plan (production plan/work plan) is made up by selecting, sequencing and sizing of work the last planners know can be done, which is carried out on basis of a workable backlog of production activities. It is also a part of the concept that the production plan is evaluated every week by measuring percent plan completed (PPC), which gives a feedback to continuous learning from reasons why the plan possibly was hampered. The weekly assignment plan is updated every week for 2-3 weeks time period, such that the first week is the production plan.
2. The lookahead plan is a schedule covering 3 to 12 weeks beyond the assignment plan. The output of the lookahead process is the maintenance of a workable backlog (sound activities) for the weekly production plan. It is based upon decomposing master schedule activities into work packages

and operations aiming at shaping flow sequence and rate, capacity planning and developing detailed methods for executing work. Each assignment in the lookahead process is subject to constraint analysis to identify what must be done in order to make it ready for execution and flow. The main coordination between the general contractor and sub-contractors is handled in the lookahead process.

Ballard (2000) also mention that it is often beneficial to bridge the master plan and the lookahead plan by a "phase schedule" that serves to coordinate actions that extend beyond the chosen lookahead time window, as the lookahead schedule is not a simple derivate from the master schedule. A phase schedule is best done collectively by a team that is to do the work. This element of the Last Planner concept is, however, not emphasised in the outline by Ballard.

REFINING RESEARCH QUESTIONS

Research questions we like to answer in our analysis are:

1. Is the application of Last Planner in the studied project in accordance to the theory and which parts needs to be developed further?
2. Which are the main difficulties in implementation of Last Planner?
3. How is coordination being taken care of between the general contractor, sub-contractors, design, engineering and the client?

PRELIMINARY FINDINGS AT HAVLIMYRA

The larger Havlimyra is a new housing estate in Justnes suburb, situated 7,5km north of Kristiansand, which is the capital of the South Coast region of Norway. A total of 1100 new residences are under development, including technical infrastructure for water, wastewater and transportation. Today, Justnes suburb lacks a junior high school. Students are being transported to a city center school in Kristiansand, which is already overcrowded.

As part of the Havlimyra housing estate, a new junior high school is being built, together with a kindergarten and a sports and cultural centre. Total area of these utility buildings is app 6800m^2. Kristiansand municipality is the owner, while Skanska is hired as total contractor. Skanska execute management and concrete- and woodworks, while hiring subcontractors for architecture and all other trades. The erection of these utility buildings is our study object.

Foundations for the buildings are slabs made from traditionally poured concrete. Erection system is a combination of steel and precast concrete pillars, steel beams, and a minority of walls in traditionally poured concrete. Storey floors are precast concrete elements. Outer walls are mainly covered with wood, while inner walls are covered with a variety of environment-friendly materials.

The project is submitted to new and strict regulations concerning energy efficiency for the buildings, and HSE (Health, Safety and Environment) for the construction works. This includes restriction of waste down to 18 kg/m^2, which also should be separated into fractions. Penalty for violation is significant. The HSE-regulations also claim the buildings to be impervious and dried down to a certain level of humidity, before any interior is mounted.[8] Hence, HSE-regulations influence the planning and organization of all works. Erection started in October 2008, and hand-over will take place June 2010.

Figure 1 illustrates the constructed enterprise model in studied construction project.

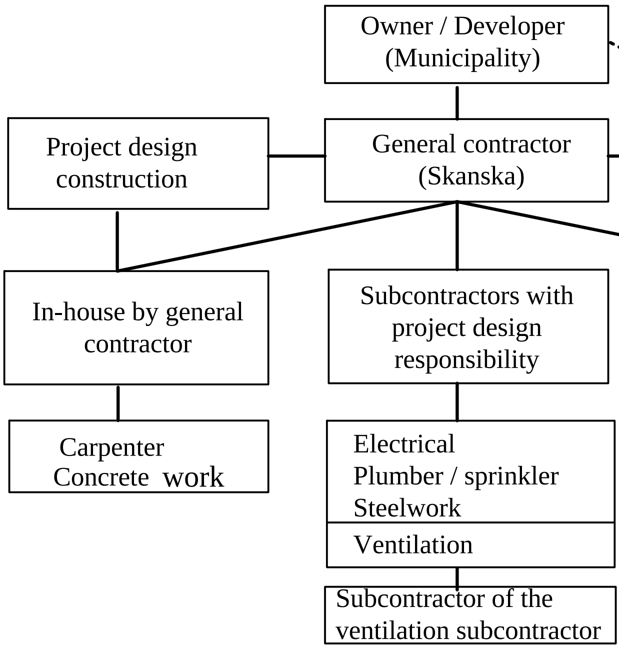

Figure 1: Enterprise Model For Skanska's Havlimyra Project

The responsibility of design was transferred to General contractor after a preliminary design phase. But payments are still controlled by the developer in relationship to the architect based on the initial fixed contract. Excavation and earthmoving have a hybrid contract, where the subcontractor takes responsibility for the excavation masses, but based on drawings from the general contractor.

LAST PLANNER AT HAVLIMYRA

Figure 2 illustrates an overview of the Last Planner planning hierarchy which is partly implemented in the construction project by influencing adjustments to the existing project management stile. The different elements are in more detail critical discussed below.

[8] Also embedded in Norwegian Standard regulations and in Consulting engineers association's norm for construction.

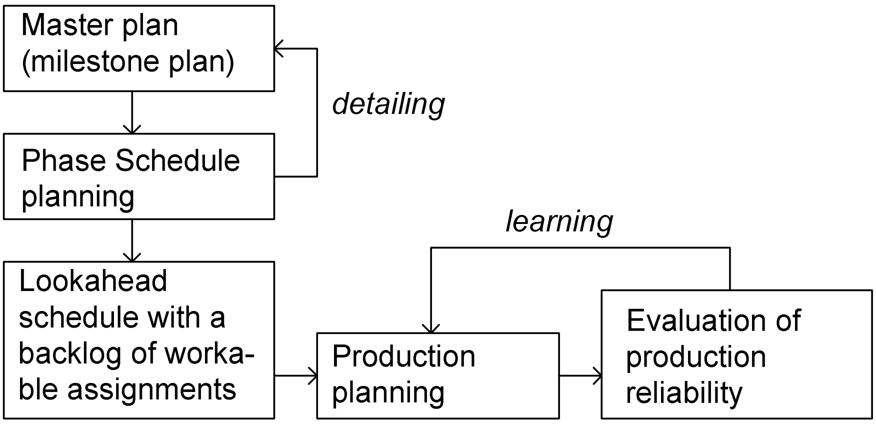

Figure 2: Overview of Last Planner Application at Havlimyra

PRODUCTION PLANS

Production plan reliability is illustrated by the indicator Percent Plan Completed (PPC) in Figure 3 for the period between the first working week in 2009 and the Easter holiday in week 15. Average PPC is found to be 65 %.

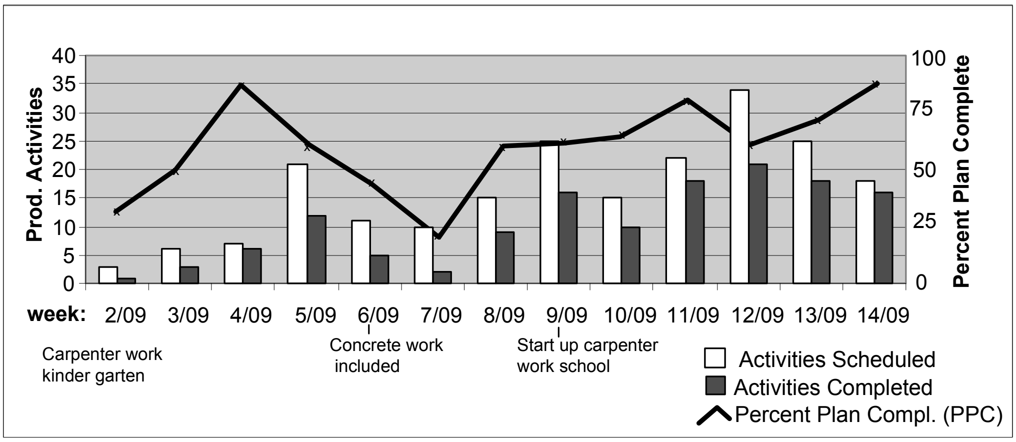

Figure 3: Indication of Production Plan Reliability

The data cover work (carpenter and concrete) done by craftsmen employed directly by the general contractor. The craftsmen are paid by performance (volume and quality) and are permanent employed. Carpentry and concrete work includes three squads, two for carpentry and one for the concrete work. Hence, the underlying weekly production plans are made up by three different foremen and squad-bosses, which are aggregated in Figure 3. The production plan is updated every Thursday/Friday and cover a period of three weeks (Figure 4). It is the first week in the three week plan that is denoted the production plan and for which reliability is indicated by measuring PPC.

The underlying data, though limited, indicates that the concrete squad achieved more reliable production plans than the carpenters. They joined the Last Planner way of planning in week 5 and had a very low score the first three weeks (38 %, 29 % and 14 %), but in week 8-14 the squad have achieved an average PPC of 84 %. However, when we look into reasons for low score the first three weeks we find that it was caused by late delivery of work by subcontractors, but also caused by sickness absence and rough weather conditions, while later work appears to have been less dependent on contributions from subcontractors. Also, the squad has been strengthened with a more experienced foreman.

Table 1 sum up revealed reasons for why activities in the aggregated production plan is not completed in accordance to schedule.

Table 1: Reasons For Activities Not-completed

Reason	**NO**	**%**
Labour shortage	26	35
Plan	23	31
Sub-contractors	9	12
Materials	7	9
Engineering and design	4	5
Weather	4	5
Craft	2	3
Client	0	0
Equipment	0	0
SUM	75	100

The Pareto sorted data in Table 1 uncover that 2/3 of the reasons can be traced back to shortage of labour and the plan it self. Shortage of labour covers underlying reasons such as different forms of sickness absence[9] and redistribution of labour between projects ordered by the general contractor. Absence due to sickness might be a significant factor for reduction in capacity, which is difficult to foresee. Hence sound activities might be transformed to unsound in the production plan if extra manpower is unavailable. The plan is interpreted to be the reason for incompletion due to failure to complete according to rates and changes in priority.

In particular for carpentry, the data indicate difficulties for the craftsmen to identify activities and relate these to productivity rates. It is claimed by respondents that the carpenters are less used to be working against milestones. This is a significant difference to the concrete squad, also including iron fixers, who make up their concrete schedule for the week, which is despatched as delivery orders to the assigned supplier of pouring concrete. The squad makes a lot of effort to keep up with sheathing and iron fixing to fulfil the concrete schedule, also by applying overtime. The progress in concrete work is moreover optimised by utilizing system sheathing which is a limited resource. That is why it is so important to pour concrete at the end of the working day, for reusing the system sheathing the following morning. We

[9] In Norway there are generous welfare regulations that allow people to be home with sick children, etc. while full paid. People also get full pay from the first day they are on sick-leave. The rate of sickness absence is 3-10 % in the construction industry. At the studied project the rate is about 3 %.

might use the metaphor of a heavy vehicle for the concrete works, which moves on and setting the phase of flow, not waiting for subcontractors as electricians or plumbers. If those subcontractors show up late with their cables and pipes though being informed, they subsequently have to take the extra work chiselling for their cables, pipes, etc., which is likely to make reduction in productivity for their part. However, the concrete squad is stopped by delay in deliver of steel pillars that is crucial in load-bearing concrete constructions and by late site work as excavation, which are examples of causes for not complete assigned work in the production plans in the studied period.

It might be somewhat simpler to identify work packages in concrete work compared to carpentry, but the most crucial difference is probably their tradition and the functions of working within a system of several milestones per week. The wage system is similar for the two trade groups. It is confirmed by respondents that there are different cultural aspects characterising these two trade groups, however, the difference is not clearly spelled out.

Though some differences between the three squad’s foremen and squad bosses, they are broadly all familiar with the Last Planner production planning scheme. To improve PPC further, based on above arguments, it is necessary to:

- Create as stable as possible supply of manpower in production
- Make effort to create examples of work packages and associated productivity rates, especially in carpentry
- Make efforts to identify examples of short term milestones in carpentry
- Improve the link between the production schedule and the phase schedule/lookahead schedule, to remove constraints and create a backlog of workable tasks, which are further discussed below.

Strength of the PPC-indicator is its simplicity, but there are also limitations. Is the assigned task executed in accordance to time and quantity? It is crucial to finish a task in due time to create flow, but might not be same importance for cases with dependencies to other actors as for cases where dependency is within the same economic duty assignment. If the task is on a critical path, should it not count more than a task that is not critical? Moreover could task be delayed 1 day or 7 days, but they count the same, and sometime it could be smart to change the scheduled plan due to new insight if the impact does not hamper progress of other trades. Further could the task be small or large but still count the same in PPC. Another critique to the PPC indicator is the possibility the workers have to achieve high score by underestimating production rates. That is, however, way it is important to establish a database with production rates and connect to milestones. Another way to achieve high score is only to plan a highly achievable amount of possible critical tasks, and to use buffer activities to fill up the workweek. This might be a solution that can increase a project’s reliability, and not just an attempt to fix results.

COLLECTIVE PHASE SCHEDULING

The first phase schedule was collectively made in week 3 for a technical room in the kindergarten, which was a first try out for all participants that included three technical subcontractors (electrical contractor, plumber and sprinkling, and ventilating) and the general contractor (project manager)[10] who handled carpentry and the work of less central subcontractors, e.g. the painter. It was applied a method of reversed scheduling. Milestones for the technical room was identified, and on a large brown paper on the wall it was drawn a time line between the milestones. It was applied a reversed scheduling technique. Each subcontractor identified backward his work to finish the technical room by writing down the tasks and expected lead time on post-it stickers. One week was defined to be the longest lead time for each task, such that operations with a longer duration were divided or exploded. Each task should be characterized by that it was possible to accomplish it without interfering from other trade specialists. The sequence of the tasks was collectively put in order on the brown wall by considering dependencies and wanted sequence. The process was triggered by question like: What about engineering and design, and do the owner need to make any decisions here?

A review of the process at the end of the planning sessions brought up comments like:

- This was a very good process. The method gives us increased understanding of other professions.
- We (one of the sub-contractors) had thought to make up the plans for this room after the vacation, but then we would have lost activities that better be finished before the vacation.
- We (one of the sub-contractors) would never have remembered all those activities if we were planning individually.
- With this planning process we (one of the sub-contractors) have gone far in also demonstrating the sequence of tasks for other technical rooms

Later it is arranged several joint phase schedule processes applying the same technique as outlined. At one occasion the general project manager had already made up the phase schedule individually a couple of months beforehand, so he thought he might better drop the collective process and gathered the stakeholders around PC-projector images. It took, however, only a few minutes before he shot down the computer and remarked, “This is no longer valid”, and arranged for the collective planning process. However, success on this part of implementation, it has later been revealed a serious mistake by one of the subcontractors that later created a bit of extra work.

When a collective phase plan is completed the output is transformed to a computer based Project Management System in which the Gant diagram is central, and added as detailing to the Master Plan (Figure 2). A weak aspect from the praxis so far might, however, be that the dependencies between the different tasks are not kept in the transformation apart from the sequence. There are some dependencies between tasks that should be considered to be collectively defined, especially those between different trades, such that task “A11” conducted by trade-A must be finished before trade-C and -D can start on task “C12” and “D13”, and that actual trades must have a meeting before the ceiling is closed and mounted by trade-A. In other words, we are arguing to establish data that might be applied for the Critical Path Method.

By observing progress meetings, data indicate that in future projects it should be considered to include the subcontractor for site work in Last Planner, as it is quite a

[10] By mistake the general contractor’s carpentry was not represented by its foreman.

few matters to be coordinated between that subcontractor and the plumber, the electrician and the concrete squad at an early stage in the construction work.

LOOKAHEAD SCHEDULING

It was made two lookahead schedules in the pilot case until week 16 covering a three week time period beyond the weekly production plan, six weeks altogether (Figure 4). It was observed that lookahead schedule was not applied at all in the weekly progress schedule meetings for making work ready for flow and for creating a workable backlog.

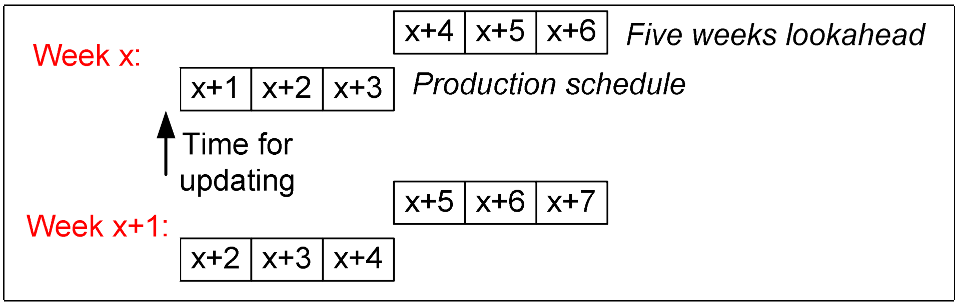

Figure 4: Lookahead Plan. The First Try Out, Week 02-17

The reasons for not being successfully in application of the lookahead schedule might be twofold. The first reason for the early failure in the lookahead plan process is identified to be insufficient support to the general project manager, who owns the lookahead process, by the resources in the lean construction project. The second and associated reason can be identified to the system, which is illustrated in Figure 4. In a progress meeting with subcontractors and own trades, the lookahead schedule ended up in a kind of vacuum. It did not give much more information than could be retrieved from the phase schedule. What have been on the agenda in the weekly progress meetings are to remove the last obstacles for the production plan the week after. Moreover has the lookahead schedule not being updated frequently and not being applied for the purpose of removing constraints to make work flow.

It is registered a need for the lookahead schedule and a two weeks workable backlog of work, such that it is maintained a link between the coordination that take place in the collective phase schedule work and production planning. For instance, it was recently identified that in production planning for week 18-20, the concrete squad did not have engineering drawings for works to be done in week 19. These were late as the engineering subcontractor had not received design drawings from the architect. Moreover is it one week lead time for iron to be delivered. That is an example of a constraint which ought to be sorted out earlier in the lookahead schedule.

The lookahead schedule template has later been reworked compare to what we started up with, and changes are:

- Adding obstacle analysis to the actual phase schedule (convert the tasks from “should do” to “can do”
- A rework of variables in the obstacle analysis to be a better match and improved functional differentiation between tasks handled in the

[11] The one applied so far was a copy from SKANSKA Finland.

lookahead schedule and the more detailed and short time focus in the weekly production plan.

A further possible system improvement is illustrated in Figure 5, which also are more in accordance with Ballard's (2000) intention.

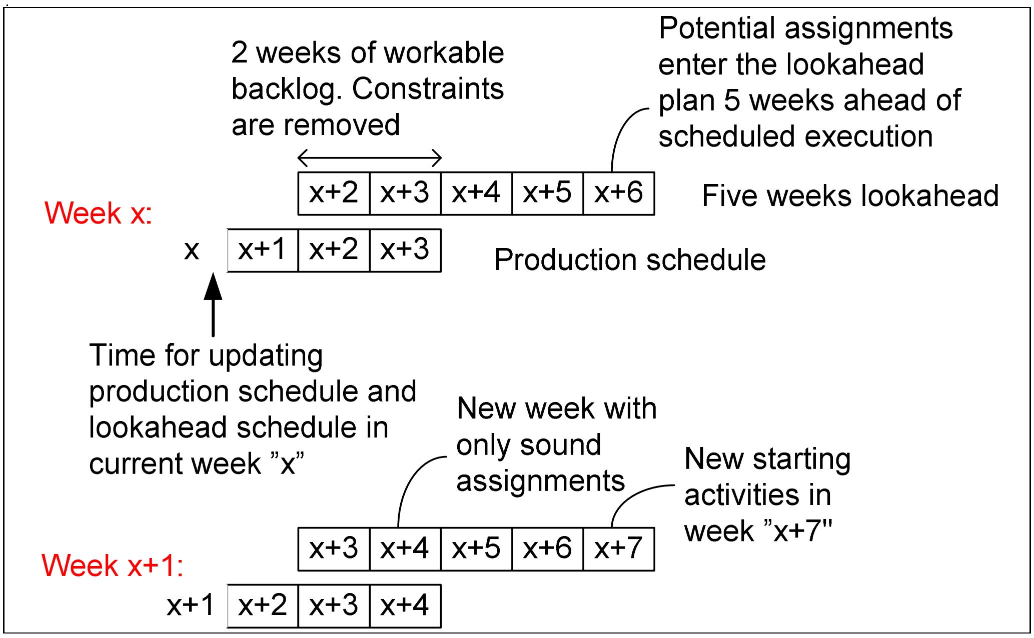

Figure 5: Possible Solution to the Lookahead Challenge

In week "x" the intention is that there are only sound activities for the lookahead in week "x+2" and "x+3". Constraints on this level have been removed. However, more detailed constraints might first be solved by the last planners in connection to the production schedule. Hence, it is necessary to make up some rules for the division of labour between these two levels, of which the lookahead is owned by the general project manager and the different production plans by the actual foremen and bosses. When we move to week "x+1" (Figure 5) week "x+4" is entered into the backlog, and a week "x+7" is entered into the lookahead. For the last entered week the process managed by the general project manager has three weeks to its disposal to clear possible obstacles before the scheduled work can be entered into the backlog.

The third week in the production plan (Figure 5) could, however, be considered to be omitted when the lookahead schedule is properly implemented. It could also be discussed for how long time period the lookahead process should cover. For time being it is registered to be a challenge for the project that the subcontracted architect fails to deliver drawings in due time and communication as well is not working well. This has serious impact for subcontracted consultant engineers who base their work on the architect drawings. From time to time work is done without drawings at all, when possible, or the general contractor's staff is engineering technical solutions which are claimed to be part of the responsibility of the architect. This situation makes it a challenge to clear all constraints before assigned work is entered into the backlog. It appears as an improvement that the architect should be better integrated in the construction project an part of the Last Planner system. Currently is it made up schedules for delivery of drawings, but the schedule seems to live its own life and is rarely updated.

Another challenge is the relationship to the owner, the Municipality of Kristiansand. The client is fronted by a land and building property department, but the users are other actors, and there are unsolved conflicts of interest within the client's organisation, which spill over to the general contractor. The spillover is registered by expressions such as "we do not agree with anything in this plan" during inspection visits by users. The actual representative for the municipality park department in the example had tried to influence the plan such that more space was used for playground and less for parking and roads. As a standard it is made up a client decision schedule in all Skanska projects. In the studied construction case the decision schedule is already outdated, and the client frequently comes up with new solutions which might hamper reliability and progress, hence it appear to be benefits if it is achieved increased discipline by the client and improved integration of the decision schedule in Last Planner. A solution to this has to be close considered but it might be an alternative that the client/owner participates in appropriate phase scheduling processes, which could be used for updating and exploding an early made schedule.

As pointed to above, the general contractor experience that late delivery from the architect is a huge problem in the case. However, that is not well discovered in the way flow of work is measured. The problems are for a large parts solved before they enter the production plan as measured by the PPC-indicator, but still it is a problem as it impose uncertainty and reduce the possibility to select the most productive sequence of work, and could be a source for work that best can be characterized as fire-fighting for actors dependent on the input from the architect, other subcontracted consultants included.

Main input from the architect, consultant engineers and the client could be considered to be included as tasks in the lookahead process, even though it is also part of the constraint analysis. The lookahead plan could then serve as a mean for communication to those parties who clearly need to see how it might hamper progress and costs by not deliver in due time, as they maybe from experience are used to the habit of the general contractor to add extra lead time when making up delivery and decisions plans.

CONCLUSIONS

The first run is broadly in accordance with the Last Planner concept as outlined by Ballard (2000). It is, however, identified, a need to improve the system related to link the output from the collective phase scheduling to production planning via the lookahead schedule and constraint analysis, which has been mis-conceptualised in the early phase of the project, from which data is gathered.

The most successful part of the implementation study so far is several phase planning processes, in which the technical sub-contractors have been taking active part in the collective organised planning process. It is too early in the project to see if this also leads to improved PPC in production, but it is expected that it will. However, the same quality of coordination is missing for the architect and the subcontractor for site work.

When it comes to identified main difficulties in the implementation process, when putting the focus on improvement, these are found to be:

- The need for the actors to create as stable as possible supply of manpower in production
- Make effort to create examples of work packages and associated productivity rates, especially in carpentry
- Make efforts to identify examples of short term milestones in carpentry in order to try to impose some of the dynamic revealed in the concrete squad
- Improve the link between the production schedule and the phase schedule/lookahead schedule, to remove constraints and create a backlog of workable tasks
- Consider the possibility to also include the main subcontractors' production schedules in Last Planner
- Include also the subcontractor for excavation and grading in phase planning when appropriate
- Include dependencies between trades in the collective phase scheduling in order to simulate the critical path.
- Make efforts to include the subcontracted architect in the Last Planner concept, which appears to be a serious obstacle to achieve control of time and probably cost. The architect might join the phase scheduling process, so that he can be more involved and committed and see the whole picture. Also improved processes with the owner should be considered from the same reason.
- Consider to supplement the PPC indicator with other flow indicators. May be in particular considering measurement of constraint release in the lookahead schedule. Continues learning is also an aspect to be considered for measurement.
- Elaborate the possibility of including quality, risk and cost management aspects in the Last Planner concept.

FURTHER STUDY

The need for further study follows from the listed improvement aspects above, but we will emphasise the challenge related to the relationship between the architect, general contractor and the owner. What are the lessons to be learned? The architect became an agent to the current owner at the idea phase in the project, and when the general contractor was appointed, the architect became the agent (as in principal agent theory) for the general contractor and paid by him. The architect initial contract was fixed, and the payments are still being organized by the owner. So the general contractor does not have a possibility to stop payment as a mean to force the architect to deliver his work. This is a case where asymmetric information and opportunistic behaviour is prevalent and for which the principal agent theory could be applied for analysis purpose, and may be for suggesting future sound contractual relationships (Askildsen and Kalsaas 2009).

In refining this paper we would also like to address the difference between Last Planner and the traditional SKANSKA approach in project management.

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