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Looking Into the Limits of the Last Planner System

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Abstract

Scheduling of onsite construction is complex. The Last Planner System (LPS) has been successfully implemented on construction projects to handle variation and to increase schedule reliability. By focusing on fulfillment of preconditions of each activity the amount of non-completions has decreased. In an attempt to further refine the LPS scheduling methodology, the scheduling system has been studied and discussed. The research is based on four case studies and complemented with a review of relevant LPS theory. The research revealed several areas in the existing scheduling system, which could be improved. The absence of flow, quality, critical path, and slack is critical when determining the optimal sequence in the Phase Schedule. Expanding current selection criteria (dependencies and duration) will increase reliability of the sequence, which evidently will improve the efficiency of the schedule and increased productivity onsite. Furthermore, it was discovered that craftsmen's comfort and motivation need to be taken into account. Also precautions to avoid congestions in the making-ready process should be implemented, along with a continuous control of soundness of every task. If these weaknesses are treated, the LPS system will lead to further increase of schedule reliability and possibly onsite productivity.

Keywords: lean construction, Last Planner System, sequencing, scheduling

Introduction

The execution process in the construction industry is dominated by complexity and uncertainty (Aritua *et al.* 2009; Dubois and Gadde 2002). Multiple contractors are subject to firm time, and must conduct interdependent and overlapping activities (Ahmad and An 2008; Bertelsen and Koskela 2004; Bertelsen 2003; Ballard and Howell 1995). Delay is easily transferred from one activity to another, which makes it difficult to keep a realistic schedule (Salem *et al.* 2006; Bertelsen 2004; Howell and Ballard 1994). Different approaches for optimizing the scheduling process exist. The following is based on a study of the Last Planner System (LPS). LPS is based on lean principles, and seeks to improve the quality and reliability of the schedule as a road to increased productivity (Liu and Ballard 2008). The LPS methodology implements four schedules: 1) The Master Schedule 2) The Phase Schedule 3) The Look-ahead Plan 4) The Weekly Work Plans (Lindhard and Wandahl 2012b; Ballard 2000).

The Master Schedule is the result of the initial planning. It is based on several uncertain parameters which, among others, are caused by the unpredictable nature of the construction process. The Master Schedule points out what should be executed and contains main activities and milestones (Howell and Ballard 1994). Furthermore, the Master Schedule serves as guidance for the lower level of planning (Ballard 2000). According to LPS, it is important not rigorously to adhere to the initial schedule but instead continuously update the Master Schedule as deviations in the basis of the schedule will occur (Tommelein 1998). If the underlying assumptions change the schedule as well needs to be changed.

The next step in LPS is the Phase Schedule which secures a thought through sequence and structure of work (Ballard 2000). Phase scheduling is an important part of LPS, and Ballard and Howell (2003) point out that: "*Phase Scheduling is the link between work structuring and production control. Without it, there is no assurance that the right work is being made ready and executed at the right time to achieve project objectives.*"

Based on the Master Schedule the project is divided into main-phases. Milestones in the Master Schedule form a natural border between these phases. Working backwards helps identifying handoffs between crews which restrict the sequence (Hamzeh *et al.* 2008; Ballard and Howell 2003). An essential part of the Phase Schedule is the involvement of all subcontractors in this process. The quality of the Phase Schedule is dependent of all subcontractors actively engaging in the scheduling process (Ballard and Howell 1994). Often unforeseen interdependencies between subcontractors surface during this process, forming important restrictions to the sequence (Howell 1999). The sequence is traditionally carried out by letting the involved subcontractors order their activities on PostIt notes. To incorporate interrelations it is important to include relations and connections to both previous and following activities. The PostIt's are afterwards put onto a whiteboard and collaboratively re-structured to achieve the best sequence (Ballard and Howell 2003; Ballard 2000).

The third schedule is the Look-ahead Plan which is the backbone of LPS (Lindhard and Wandahl 2012b). Look-ahead planning secures that activities can be completed by ensuring that scheduled activities are sound (Ballard 2000). In LPS terms this is called the making-ready process, and it is here constraints to each activity are identified and removed (Jang and Kim 2008).

According to the LPS theory the soundness of an assignment depends on seven preconditions (Koskela 1999). An activity can only be completed if all these seven preconditions are fulfilled (Koskela 1999). The seven preconditions are:

1. Construction design; correct plans, drafts and specifications are present
2. Components and materials are present
3. Workers are present
4. Equipment and machinery are present
5. Sufficient space so that the task can be executed
6. Connecting works, previous activities must be completed
7. External conditions must be in order

Recently research has proposed to divide "external conditions" into three new categories (Lindhard and Wandahl 2012a). In the current form the "external conditions" category covers several subcategories. Putting a name on the specific subcategories brings increased awareness and attention to the preconditions in the making-ready process and avoids the risk that the site-manager overlooks remaining constraints. The "external conditions" category was divided into the following:

7a. Climate conditions must be acceptable. The preconditions focus on external environmental effects such as rain, snow, wind, heat, cold etc.

7b. Safe working conditions must be present. The national "Health and Safety at Work Act" has to be obeyed to keep employees safe.

7c. The surrounding conditions must be known. The precondition focuses on securing that existing conditions, if necessary, are examined. Problems often arise during excavations or refurbishment assignments.

Activities become sound by analyzing all preconditions for each activity that is scheduled for conduction in a time frame of up to 6 weeks into the future. In LPS this time frame is called the "look-ahead window". The fulfillment of the preconditions secures that manpower, machinery, material, etc. are pulled to the construction site Just-In-Time (Vishal *et al.* 2010; Chua *et al.* 1999; Tommelein 1998).

The look-ahead window is a drop-out from the Master Schedule and forms a link between the Master Schedule and the Weekly Work Plans (Kemmer *et al.* 2007; Chua *et al.* 1999). The length of the look-ahead window depends on project characteristics, the reliability of the planning, and the needed duration for making activities sound and will normally vary between 3-12 weeks (Ballard 2000).

Each week the look-ahead window is sliding one week forward. When sliding the look-ahead window forward only activities expected to be made ready on schedule are sliding forward (Ballard 2000). An activity with all preconditions fulfilled is moved to a buffer containing a workable backlog of activities which are ready for execution. Selecting activities to the Weekly Work Plan only from this buffer secures that the Weekly Work Plan contains only sound activities (Hamzeh *et al.* 2008; Steyn 2001; Ballard 2000; Howell and Ballard 1994). Furthermore, the workable backlog serves as a buffer against unexpected conditions that could constrain the scheduled activities. The buffer is the connection between the Look-ahead Schedule and the Weekly Work Plans. The buffer ads flexibility to the robustness and increases the adaptability of the schedule which helps maintaining a constant workflow.

The final and fourth schedule in LPS is the Weekly Work Plan (Ballard 2000). Sound activities are selected from the buffer and the final and binding commitments of what will be completed the following week are made (Ballard and Howell 1998).

Additional to the Weekly Work Plans, LPS implemented a feedback and learning system called the PPC (Percent Plan Complete) measurement (Ballard 2000). In this feedback system, scheduled activities are compared with the completed activities which provide a picture of schedule reliability and schedule quality (Hamzeh *et al.* 2012). Thus, non-completed activities are identified. In the search for continuous improvement root causes to non-completions are found and eliminated to avoid repetitions and improve the scheduling process (Ballard *et al.*

2009; Ballard 1994; Howell and Ballard 1994). Learning from failures increases PPC and the quality of the schedules which leads to productivity improvements.

Research shows that implementation of LPS has increased the number of planned activities completed (PPC) from 30-60 % to around 70 % (Ballard 1999). But the PPC level is right now stuck at the 70% level (Ballard 2000). To help construction reaching an even higher PPC level the scheduling process, therefore, needs to be further analyzed and improved. The first step is to analyze LPS in order to understand the process and to identify limitations in the current methodology. Therefore, LPS is examined through the following research question: can LPS be further improved? And what are the benefits and shortcoming of the current LPS scheduling methodology?

The introduction section above contains a general and theoretical introduction to LPS which is a lean based scheduling tool. Thus, the research does not look into Lean Construction in general but is limited to focus only on LPS. Therefore, only research directly related to LPS has been found relevant. In the following the methodology and methods are explained. In the result section the identified pros and cons are revealed and afterwards discussed in the discussion section.

Research methodology and methods

The research was based on four construction cases which have been carefully selected. The selection criteria were A) LPS must be implemented. B) The contractor should minimum act as general contractor with associated subcontractors. The selection criteria were added to increase the validity and quality of the research.

To gain insight into LPS, actual application of the scheduling system was observed, archives were inspected, and interviews with site-managers were carried out. This case study took its outset in Eisenhardt's (1989) guidelines. An explorative approach, where application of LPS could be observed, was chosen. Moreover, the qualitative approach was chosen so that LPS could be analyzed contextually. Only in its context the actual application of LPS can be examined and understood. This is supported by both Eisenhardt (1989) and Yin (2003) who state that how and why questions only can be answered with qualitative research. To ensure a well-defined research focus, the objective and research focus of the case-studies were clarified on beforehand and relevant observations and data were determined. The importance of research focus is supported by Mintzberg (1979) who states *"No matter how small our sample or what our interest, we have always tried to go into organizations with a well-defined focus - to collect specific kinds of data systematically."* The onsite observations were supplemented by archived data of former plans and schedules directly downloaded from the contractor's database and through interviews with site-engineers.

The interviews were conducted as semi-structured following the interviewing guidelines of Ritchie *et al.* (2005). Interviews were completed individually for every site manager as a face to face interview. Before the interviews were completed the site mangers and the interviewer meet at several occasions to gain mutual trust which according to Oakley (1981) is essential for face to face interviews. Only the oral communication was of interest. Therefore, no effort was put into capturing kinesic, paralinguistic, or chronemic data. Prior to each interview a number of open ended questions were prepared to help structuring the interview and to ensure that all important topics were covered. Wengraf (2004) suggests that open ended questions are prepared having in mind that questions cannot be planned in detail, since the informants response cannot be predicted in advance. Therefore, questions must be improvised in a theorized and deliberated way (Wengraf 2004).

The interviews were conducted to support and supplement the onsite observations. Moreover, multiple research approaches do add triangulation which increases research validity. Because of the mixed research approach, the contribution of each approach is summarized in Table 1.

Table 1: Clarification of how the research approaches contributed to the results

	Master Schedule	**Phase Schedule**	**Look-ahead Plan**	**Weekly Work Plan**
Primary contribution to results	Interviews with site-mangers	Interviews with site-managers	Onsite observations	Onsite observations
Sub-contributor to results		Onsite observations of conflicts		Archives, ussed to follow PPC-levels

An overview of the data collection from each of the four cases is shown in Table 2. Afterwards, each case is briefly described. Collected data in combination with LPS theory found the basis for the subsequent analysis resulting in a list of pros and cons in regards to current LPS methodology.

Table 2: Data collection at the four case-studies

	Case 1	**Case 2**	**Case 3**	**Case 4**
Contract form	Turnkey contractor	Turnkey contractor	Prime contractor	General contractor
Site observations	Once every forthnight in total 5 observations.	1-2 times every forthnight in total 8 observations.	1-3 times every forthnight in total 8 observations	1 time every week in total 6 observations
Meetings partispated in	Subcontractor, foremen and safety meetings	Subcontractor and LPS meetings	Subcontractor, foremen, emergency and construction meetings	Scheduling of Weekly Work Plans
Observation length	10 weeks	10 weeks	10 weeks	6 weeks
Interviews of site-manager	5 unstructured and 1semi-structured	8 unstructured and 1 semi-structured	8 unstructured and 1 semi-structured	6 unstructured and 1 semi-structured
From archives	Reports from meetings, various schedules and organisation charts	Reports from meetings and various schedules	Reports from meetings and various schedules	Schedules

Case one: Housing

Case one was a renovation project of 16 three-storey residential apartment blocks, containing a total of 309 flats. The blocks were dispersed between 5 blocks containing 15 flats, 11 blocks containing 21 flats, and additionally 3 handicap or senior houses. The project included rehousing of the residents. Rehousing was limited to a period of 7 weeks. This was followed by a period of one week where the residents could compose a fault and deficiency list, and finally a one week period for repairing the deficiencies. The project contract value was $4.45 million, with a duration fixed to 26 months.

Case two: Educational institution

Case two was construction of an educational institution. The project consists of two buildings in total 11000 m^2, and should service 6 different university programs. The main building was a three-storey building plus basement, in total 8000 m^2 and has an autonomous contract value on $21.75 million. The secondary building was a two-storey building with no basement, in total 3000 m^2. In total the secondary building had an autonomous contract value on $7.36 million. The project was prestigious and modern and had to meet the highest standards within sound, fire, ventilation, intelligent control, etc. Simultaneously the construction period was restricted to a duration of 16 months. Therefore, as a turnkey contractor, the primary focus was on keeping the production flows running.

Case three: Nursing home

Case three was construction of a nursing home. The project consists of 6 one-storey apartment blocks in a nursing home. In total 68 flats. The blocks were dispersed between 2 blocks with 10 flats and 4 blocks with 12 flats. Additionally the project includes the construction of 4 common houses. The contractor worked as a prime contractor and had the primary responsibility for in-situ concrete, soil, sewer, concrete elements, steel, and weather covering. The project contract value was $3.89 million, with a contract period of 17 months.

Case four: Hospital

Case four was the refurbishment of a top floor-section at a hospital. The renovation project was carried out while the hospital was fully functioning. This limited the access to the site and complicated the logistics because materials could only arrive late night to early morning. The renovation project had a contract value at $5.5 million, and a contract period of 7 months.

Results

In the following, the data from the four construction cases is presented. In outline, the structure of the results section is divided into the four schedules composing the LPS methodology.

Master Scheduling

The Master Schedule has in all four cases been forming the borderlines to the construction project. Thus, the purpose of the Master Schedule has been to create a holistic understanding of the entire upcoming construction process. The Master Schedule was based on milestones and key deadlines from the contracts. In the four cases this schedule was following either a Gantt or a Location-Based methodology. To maintain overview and transparency the detail level has been kept low, thus only the main activities were included. Moreover, only estimated durations have been of interest at the Master schedule level. Thus, there was no focus on buffers, flows, or constraints at this level.

Phase Scheduling

Phase scheduling has been implemented as a systematic approach to determine the sequence, between milestones or key phases, within the construction project. In all cases observed, the phase scheduling was completed for the entire construction process at a one-day workshop. Still, because the sequence was determined early in the construction process, the reliability was low. The unpredictable nature of the construction processes has in all cases enforced several changes of the sequence throughout the project.

In the Phase scheduling process it was found that the Critical Path Method and slack analysis had no attention. This could have served as guidance to secure a realistic and not to tight sequence. Conflicts caused by a too tight schedule have been observed at all four cases. The effects of a too tight schedule were mainly inflexibility towards changes. In construction, changes occur on a daily basis. Limited slack between activities was making the schedule unable to absorb variation in production rates. Thus, a tight time schedule does increase the number of hot spots causing delays and conflicts to be easily transferred between contractors and leading to a more chaotic, complex and uncontrolled construction site. Conflicts have been observed when attempting to interrupt the workflow and to completely obstruct the subsequent subcontractor in working efficiently.

During the Phase scheduling the detail level has in all cases been increased. This decreases the overview and transparency in relation to the Master Schedule. Still at this level only duration and interrelationships between activities have been of interest. Thus, none of the cases did at this stage shown interest in flows, by for instance seeking to secure a constant workflow or high utilization of machinery. One important element in the Phase scheduling process was the communication and collaboration between contractors and site management which increased the quality of the schedule. Furthermore, involvement increased awareness to interrelations which often helped the contractors to avoid or at least to predict future conflicts.

Look-ahead planning

Look-ahead planning was applied as a tool to ensure that only sound activities entered the Weekly Work Plans. Sound activities have been ensured by applying the making ready process where the necessary preconditions were fulfilled. At all four sites, and in accordance with LPS theory, the seven preconditions were applied as a checklist.

Sound activities were moved to a buffer, hereafter they were, when needed, selected to the Weekly Work Plans. During the case observations it was found that the fulfillment of the seven preconditions had a tendency to change over time, i.e. an activity that has been judged sound could easily later become unsound. To avoid that unsound activities are moved from the buffer into the Weekly Work Plans an additional weekly health check of all buffered activities should be implemented. The health check will discover problems proactively while there still is time enough to make small adjustments in the schedule. Changes in soundness is experienced to occur unexpected, therefore the weekly health check should A) be supplemented by a soundness awareness and B) supported by a action plan of how to handle unsound activities in the work flow.

In all cases the buffer level was kept between one and two weeks. The buffer has throughout the study proven critical to avoid the effect from congestions in the Look-ahead process and thereby to continuously feed the Weekly Work Plans. On site every trade was dependable of tasks that actually could be conducted. When the making-ready process progressed too slowly the capacity of the workforce was starting to exceed the amount of work ready for conduction resulting in unutilized workforce and delays. To avoid this and to handle congestions in the making ready process the production can be simplified by reducing both tasks and trades at the construction site and by supplementing the existing buffer with flexible buffer activities and slack between activities on the critical path. Flexible activities are not tied to the schedule, but can be moved within sequence-defined boundaries (Echeverry *et al.* 1991). Thus, flexible activities do enable adjustments within the sequence, which makes buffering les complex.

The look-ahead Schedule has in all cases been implemented as a systematic approach to increase schedule reliability. Inflow variation has been reduced by securing that sound activities were matched to capacity. Simultaneously, a workable backlog has been maintained serving as a buffer against unexpected constraints in the Weekly Work Plans. Despite of the importance of ready work activities, the responsibility for ensuring progression has in all cases been placed at the individual subcontractor. However, weekly meetings have been arranged between the subcontractors and the site-manager. The weekly meetings were implemented to allow the site-manager to help, support, and follow the process.

The making ready process has successfully increased the number of sound work activities in the schedule (Ballard 1999). When making activities ready for conduction, it is important to stress that it is not enough to only ensure that activities can start on time but also finish on time. In all four cases it has been observed that the fulfillment of constraints was proceeding without regarding the quality of the fulfillment. From the observations it can be concluded that in order to improve productivity on the construction site the making-ready process must seek towards optimal conditions. Not only securing that workers are present, but also focusing on getting the most skilled crew to complete the task. Not only ensuring that enough space is present, but securing optimal working conditions. Not only securing that machinery and equipment is present, but secure the right and most suited equipment is present, etc. Two basic parameters have been observed as important when securing optimal conditions: the presents and the quality of the fulfillment. If optimal conditions are achieved the productivity and likelihood of error within the process will decrease which leads to an increased PPC level. It is important to stress that variations in preconditions still can interrupted the process.

Even though the Look-ahead Plan has been applied to secure the reliability of the Weekly Work Plans nothing was done to improve the schedule itself. The flow of workers, material, machinery, space etc. has neither been followed nor regulated in the schedule. Therefore, without putting the brains on, the making ready process ends up being a monotone and thoughtless process.

Weekly Work Plans

The lowest level of planning in LPS is the Weekly Work Plans. All cases applied this. The result of the Weekly Work Plans has, besides the "final" schedule, been commitments to the next week's work. To measure the quality of the schedule a PPC calculation was carried out. Both the scheduling of the weekly activities and the follow-up process including the PPC calculation has been taken place at a weekly basis, but only in half of the cases (case 2 and case 4) last week's progress has been examined including calculation of the PPC measurement. This process should ideologically take place as the site-manager and subcontractors walk around the construction site, but in all cases the follow-up process has been completed from a nearby meeting room. After the PPC calculation was completed, next week's activities have been determined. As a part of the scheduling process the sequence and construction flow has been discussed at these meetings. These discussions often revealed unidentified interrelationships. Even though communication and collaboration are important the amount and duration of the meetings need to be limited to avoid long sessions with inactivity. It has been observed that in long scheduling sessions the concentration-level had a strong tendency to decrease resulting in slow progress and low quality commitments.

The quality of the commitments has in all cases been of crucial importance. A good schedule should be robust, reliable and trustworthy, and most importantly consist of binding commitments from all project participants. At situations where the schedule continually was rethought and changed, the schedule lost credibility. Moreover, changes have been observed to cause confusion which has been leading to misunderstandings and in extreme situation it changed how the schedule was perceived. Too many changes had changed the subcontractors' interpretation of the commitments from binding to only guiding.

When applying LPS the only focus has been on obeying the schedule and improving the schedule itself to ensure schedule reliability. Thus, scheduling via LPS had no focus on either the cost or the quality of the outcome. From the observations it can be concluded that quality control was necessary to ensure that activities were rightfully completed. Therefore, quality needs to be considered to achieve a correct impression of the progression within the construction process. Hence, poor quality and the related defects have to be deducted from the performance. Quality can be ensured by controlling, which for instance could be undertaken by either the site-manger or the subsequent crews. Actually quality control is too late because it is not stopping the problem; ideologically quality needs to be ensured.

Non-completions are a fact in today's construction and were observed multiple times in all cases. A main cause for non-completions was, in all cases, changes in soundness of the activity. The observed changes were originating from a changing soundness in ready work or from changes in the basic assumptions in the schedule. According to LPS theory, non-completions should be followed by a root cause analysis to investigate the triggers and to avoid repetitions. In all cases only minimal effort to do so was observed. Understanding the triggers is important and can help the site-managers to predict future changes. Furthermore, to avoid misunderstandings changes should be handled through communication and collaboration between the project participants. In all cases nothing was done to foster and support the communication and collaboration onsite, (i.e. outside the boundaries of the scheduling meetings), which therefore all too often failed.

General comments

A general tendency to ignore flow, critical path, and slack considerations in the scheduling process has been observed. In LPS theory sequencing is only based on interrelationships and durations. Moreover, LPS does not consider the interplay between the schedule and the surrounding world, i.e. a closed system model. Changes outside the schedule itself were in relation to Leavitt's Diamond affecting the schedule. For instance, it could be beneficial for the client to make a "lifecycle" plan considering expected usage within the buildings lifetime. These considerations could then be incorporated in the building's design. By forcing the client to carefully consider the building's usage inappropriateness in design can be caught before execution and possibly limit design changes which change the foundation to the schedules. Thus, the result will be a more reliable and thought through construction project which is easier to schedule.

Finally, the atmosphere wherein the scheduling process proceeds was important to the comfort of the individual participant and should be supported by leadership. In LPS theory, as well as on the four sites followed, there was limited interest in the soft values of such a managerial approach. In all cases, it should have been a crucial management task to ensure comfort because it is the breeding ground for motivation and mutual trust. The motivation of employees had significant impact on the output both regarding quality and quantity.

Discussion

The research of LPS has shown several gaps in the current LPS scheduling methodology which makes improvement possible. Figure 1 illustrates pros and cons in relation to each level of the LPS methodology. Connections between the schedules are also shown.

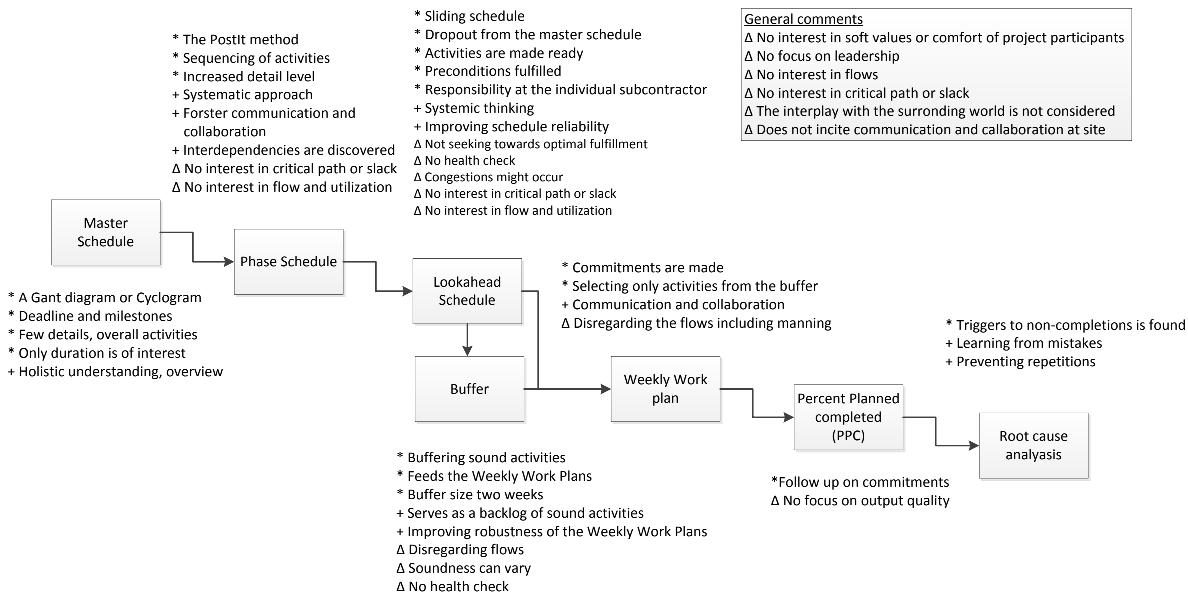

Figure 1: Pros and cons to LPS. (*) marks the subprocesses at the scheduling level, while (+) marks the positive effect and (Δ) marks the downsides or limits in the existing system.

As shown in Figure 1, the research has revealed a number of both pros and cons to the LPS methodology. Several of the revealed pros are related to the selection of activities to the schedule. Today the sequence is mainly grounded on interrelationships and durations of and between activities. To help optimize the sequence the existing selection criteria should be supplemented with flow and slack considerations. These parameters should be included already at the Phase Scheduling level. In the sequencing process variation in flows, such as manning, should be minimized.

Uneven production flows at the construction site are undesirable, because it creates variation in productivity and induces a risk of unutilized "flows", like for instance manning. Furthermore, an uneven flow does affect the efficiency of buffering sound activities. Thus it will be much easier to buffer against variation with even flows. In a workweek containing several activities the buffer should contain several buffer activities. While the buffer, in a workweek with few activities only should contain very few activities. Since the buffered activities are normally next week's work, the buffer should at least be supplemented with flexible activities.

Slack considerations are important in order to increase the robustness of the schedule. Especially slack between activities on the critical path has to be considered. Since slack on the critical path is expensive and postponing the end deadline it is important that the incorporated slack is adequate and fits the uncertainty in the process. If no slack is applied on the critical path variations cannot be absorbed and will therefore cause delays. To avoid daily penalties the work has to be accelerated which is costly (Thomas 2000).

If the determined sequence in the Phase Schedule is including flow and slack considerations these considerations are passed on into the Look-ahead schedule. A constant in- and outbound flow in the Look-ahead plan removes critical situations with many activities to make ready. This makes it easier to observe the making ready process and feed the Weekly Work Plans. The buffering process is made more effective where one week buffer is actually corresponding to one week's work. Finally, on site, the flow and manning are stabilized. Furthermore, the constant flows do make it easier for all project participants to allocate company resources. If the manning is kept stabile the risk of conflicts transmitted from site to site is reduced (Bertelsen and Koskela 2004).

Because changes and variation are facts in onsite construction flows, slack and the critical path need continuously to be monitored. By following these parameters conflicts can be identified before evolving. Small adjustments in the schedules can be used to absorb the conflicts while still keeping a reasonable constant flow and manning.

A critical con in LPS is that scheduling is treated as a mechanical mechanism. Theoretically, there is an absence of management considerations in relation to leadership and the individual's comfort. Comfort is the breeding ground for motivation and mutual trust. Furthermore, increased comfort will increase the schedule reliability because accountability and dedication among the project participants increase (Lindhard and Wandahl 2012a). Therefore, soft values should be fostered by management and should be supported by the leadership onsite.

The analysis did furthermore reveal a number of cons. The remaining cons are treated in the result section at the relevant schedule. Therefore, the key cons are just listed underneath:

- Nothing is done to prevent or handle congestions in the making ready process.
- The soundness of ready work can vary, but nothing is done to secure that the buffered activities are ready when moved to the Weekly Work Plan.
- Output quality of completed tasks is not considered.
- The interplay with the surrounding word is ignored.
- No initiatives incite to communication or collaboration at site.

In future research more specific selection criteria will be determined and a practical and direct usable approach to determine the schedule which handles flows and slack will be developed. Future research might also include simulations to document the effect of the changes in the scheduling system.

Conclusion

LPS was analyzed in an attempt to develop scheduling at onsite construction. The research is based on four case studies which are combined with theory. The research revealed several weaknesses in the existing system. Eliminating the weaknesses by rectifying and making small changes will increase the quality of the schedule. The paramount critic point, found during the analysis, was that the sequence only was based on interdependencies between and duration of activities. In this process, flows and slack also needs to be considered. Deliberate involvement of flows and slack will lead to reduced variation and secure increase utilization rates on site.

LPS's mechanical scheduling process needs to be carried out with focus on the comfort of the individual craftsman. Management and leadership need to foster and support soft values. Increasing comfort will lead to improved schedule reliability, and increased onsite productivity because motivation, accountability and dedication among the project participants will increase.

Congestions in the making ready process can occur. This is critical because the making-ready process constantly needs to feed the Weekly Work Plans. A constant flow will reduce the risk of congestions because situations where a lot of activities suddenly need to be squeezed through the process are avoided. Additionally, to prevent congestions minimizing tasks and trades at site and using flexible buffer activities are suggested.

Furthermore, LPS does not consider the risk that the soundness of buffered activities changes. To minimize the risk of moving an unsound work task from the buffer to the Weekly Work Plans a weekly health check is proposed. Finally, LPS is only measuring the quality of the schedule and not the quality of the work. The output quality should be included in a measurement to monitor and achieve a correct impression of the progression at the construction project.

In general construction is dominated by poor scheduling. Poor scheduling has a negative effect on the performance onsite, which results in a mediocre workflow, a mediocre productivity, and delay. Therefore, to utilize the capabilities in the production system, onsite scheduling needs to be improved. In this research scheduling has been sought to be improved by analyzing LPS. Pros and cons has been identified and discussed in the search of improvement.

References

Ahmad, H.S. and An, M., (2008), Knowledge management implementation in construction projects: a KM model for Knowledge Creation, Collection and Updating (KCCU) *International Journal of Project Organisation and Management,* 1 (2), pp. 133.

Aritua, B., Smith, N. and Bower, D., (2009), Construction client multi-projects – A complex adaptive systems perspective *International Journal of Project Management,* 27 (1), pp. 72-79.

Ballard, G., Hammond, J., Nickerson, R., (2009), Production Control Principles, *Proceedings of the 17th annual conference of the International Group for Lean Construction*, pp. 489-500.

Ballard, G., (2000). *The Last Planner System of Production Control,* University of Birmingham,.

Ballard, G., (1999), Improving Work Flow Reliability, *Proceedings for the 7th annual conference of the International Group for Lean Construction*26-28 July, Berkeley, USA, , pp. 275-286.

Ballard, G., (1994), Implementing Lean Construction: Stabilizing Work Flow, *Proceedings for the 2nd annual conference of the International Group for Lean Construction*28-30 September, Santiego, Chile, , pp. 101-110.

Ballard, G., Howell, G., (1995), Towards construction JIT, *Proceedings of the 3rd annual conference of the International Group for Lean Construction*, Albuquerque, New Mexico, .

Ballard, G., Howell, G., (1994), Implementing Lean Construction: Improving Downstream Performance, *Proceedings for the 2nd annual conference of the International Group for Lean Construction.*, Santiego, Chile, , pp. 111-125.

Ballard, G., (2000). *Phase scheduling* LCI White Paper,.

Ballard, G. and Howell, G., (1998), Shielding production: essential step in production control, *Journal of Construction Engineering & Management,* 124 (1), pp. 11-17.

Ballard, G., Howell, G., (2003), An Update on Last Planner, *Proceedings for the 11th annual conference of the International Group for Lean Construction*, Virginia, USA, .

Bertelsen, S., (2003), Construction as a Complex System, *Proceedings for the 11th annual conference of the International Group for Lean Construction*, Virginia, USA, .

Bertelsen, S., Koskela, L., (2004), Construction Beyond Lean: A New Understanding of Construction Management, *Proceedings for the 12th annual conference of the International Group for Lean Construction*25-27 July, Copenhagen, Denmark, , pp. 1-11.

Bertelsen, S., (2004), Lean Construction: Where are we and how to proceed? *Lean Construction Journal,* 1 (1), pp. 46-69.

Chua, D.K.H., Jun, S.L., Hwee, B.S., (1999), Integrated production scheduler for construction Look-ahead planning, *Proceedings for the 7th annual conference of the International Group for Lean Construction*, pp. 287-298.

Dubois, A. and Gadde, L.E., (2002), The Construction Industry as a Loosely Coupled System: Implications for Productivity and Innovation *Construction Management and Economics,* 20 (7).

Echeverry, D., Ibbs, C.W. and Kim, S., (1991), Sequencing Knowledge for Construction Scheduling, *Journal of Construction Engineering and Management-Asce,* 117 (1), pp. 118-130.

Eisenhardt, K.M., (1989), Building theories from case study research, *Academy of Management Review,* 14 (4), pp. 532-550.

Hamzeh, F., Ballard, G. and Tommelein, I., (2012), Rethinking Lookahead Planning to Optimize Construction Workflow, *Lean Construction Journal,* , pp. 15-34.

Hamzeh, F., R. Ballard, G., Tommelein, I.D., (2008), Improving Construction Work Flow - The Connective Role of Lookahead Planning, *Proceedings for the 16th annual conference of the International Group for Lean Construction*16-18 July, Manchester, UK, , pp. 635-644.

Howell, G., Ballard, G., (1994), Implementing lean construction: reducing inflow variation *Proceedings for the 2nd annual conference of the International Group for Lean Construction*, Santiego, Chile, .

Jang, J.W., Kim, Y.W., (2008), The Relationship Between the Make-ready Process and Project Schedule Performance, *Proceedings for the 16th annual conference of the International Group for Lean Construction*16-18 July, Manchester, UK, , pp. 647-656.

Kemmer, S.L., Heineck, L.F.M., Novaes, M.d.V., Mourão, A.M.A., Alves, Thais da C. L., (2007), Medium-term planning: Contributions based on field application, *Proceedings for the 15th annual conference of the International Group for Lean Construction*, Michigan, USA, , pp. 509-518.

Koskela, L., (1999), Management of production in construction: a theoretical view *IGLC 8*, Proceedings IGLC, Berkeley, California, , pp. 241-252.

Lindhard, S., Wandahl, S., (2012a), Adding production value through application of value based scheduling, *COBRA 2012-RICS International Research Conference*, Las Vegas, USA, .

Lindhard, S. and Wandahl, S., (2012b), Scheduling of Large, Complex, and Constrained Construction Projects - An Exploration of LPS Application, *International Journal of Project Organisation and Management (IJPOM),* .

Liu, M., Ballard, G., (2008), Improving Labor Productivity through Production Control *Proceedings for the 16th annual conference of the International Group for Lean Construction*, Manchester, UK, .

Mintzberg, H., (1979), An Emerging Strategy of "Direct" Research, *Administrative Science Quart,* 24 (4), pp. 582-589.

Oakley, A., (1981). Interviewing Woman: A Contradiction in Terms? In: H. Roberts, ed, *Doing Feminist Research.* Routledge & Kegan Paul, London, UK.pp. 30-61.

Ritchie, B.W., Burns, P. and Palmer, C., eds, (2005). *Tourism research methods: integrating theory with practice.* 1. edn. CABI Publishing. Cambridge, USA.

Salem, O., Solomon, J., Genaidy, A. and Minkarah, I., (2006), Lean Construction: From Theory to Implementation, *Journal of Management in Engineering,* 22 (4), pp. 168-175.

Steyn, H., (2001), An Investigation Into the Fundamentals of Critical Chain Project Scheduling, *International Journal of Project Management,* 19 (6), pp. 363 - 369.

Thomas, H.R., (2000), Schedule Acceleration, Work Flow, and Labor Productivity, *Journal of Construction Engineering & Management,* 126 (4), pp. 261-267.

Tommelein, I.D., (1998), Pull-driven scheduling for pipe-spool installations: Simulation of a Lean Construction technique, *Journal of Construction Engineering and Management - Asce,* 124 (4), pp. 279-289.

Vishal, P., Jose, F., Sarel, L., Zofia K., R., (2010), Last Planner System Implementation Challenges, *Proceedings for the 18th annual conference of the International Group for Lean Construction*, Haifa, Israel, .

Wengraf, T., (2004). *Qualitative Research Interviewing: Biographic narrative and semi-structured methods.* SAGE Publications, Thousand Oaks, USA.

Yin, R.K., (2003). *Case Stydy Research - Design and Methods.* Sage Publications Inc., London.