THE COMBINATION OF LAST PLANNER SYSTEM AND LOCATION-BASED MANAGEMENT SYSTEM

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ABSTRACT

The Last Planner System[4] (LPS) and Location-Based Management System (LBMS) both aim to achieve the lean goals of decreasing waste, increasing productivity and decreasing variability. LBMS is mostly known as a scheduling system, but includes control mechanisms. LPS is primarily a control system, but includes a scheduling component; namely, phase scheduling. How best link these two systems together to achieve better project performance? Further, can the LBMS control mechanisms be integrated with LPS? Can phase pull scheduling be integrated with LBMS?

The goal of this research is to develop a process and best practices to combine the benefits of LPS and LBMS. Skanska Finland has used the two systems together. They observed that the systems support each other well. Because the planning and controlling methods in different industries can vary, a series of workshops was conducted at a hospital project on the US West Coast, and three other US companies were interviewed, to discover the factors specific to industries where activity-based scheduling systems dominate. By combining these three sources of information to the latest case study results on the stand-alone use of LBMS and LPS, the paper proposes processes to integrate LPS and LBMS in pre-bid master scheduling, pull phase scheduling, look-ahead scheduling, and weekly planning.

The proposed processes need to be tested in practice. The hypotheses for future research are that after implementing the proposed process, 1) schedule conformance will improve, 2) project durations will shrink, 3) productivity will increase, and 4) cascading delay chains will show a decrease.

KEY WORDS

Last Planner System, Location based management, Production control, Look-ahead planning, Phase schedules, Lean Construction

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INTRODUCTION

The Last Planner System (LPS) and Location-Based Management System (LBMS) both aim to achieve the lean goals of decreasing waste, increasing productivity and decreasing variability. LPS aims to achieve these goals primarily through a social process, by trying to make planning a collaborative effort and by improving the reliability of commitments of team members (Ballard 2009). LBMS is primarily a technical system, which transforms quantities in locations and productivity information to reliable durations, makes buffers explicit, and forecasts future performance based on historical trends and alarms of future production problems. (Kenley & Seppänen 2010)

Recent research related to reliability of location-based plans found location-based reliability metrics and PPC (Last Planner's weekly plan reliability metric) to be heavily correlated (Seppänen 2009: 78-82). Reasons for low reliability were found to be mostly related to the social process of using the information. Cascading delay chains were found which resulted from GC's lack of understanding of specialty MEP contractor work, lack of common understanding between the GC and the subcontractor about required resources, push controlling the start dates of new contractors leading to location congestion and slowdowns, and not openly discussing production problems in production meetings (Seppänen 2009: 155-156). The controlling features of LBMS were able to forecast 29 % of the production problems (Seppänen 2009: 89-90), and the forecast was further improved to forecast 90 % of the production problems, and 57% of them over two weeks before the problem. (Seppänen 2009: 125-126). However, the information was not used in a systematic fashion and most of the alarms which later resulted in production problems were not discussed. (Seppänen 2009: 154)

The Last Planner System includes social processes which would address many of the process problems encountered in this empirical study. LPS is a pull controlling methodology which allows tasks to start only when all the constraints have been removed (Ballard & Howell 1998). The collaborative phase scheduling process of LPS promotes participation in scheduling the work to be done in each phase by those who are to do the work. Scheduled activities are then made ready by those same participants in a lookahead process, in which constraints are identified and removed. Commitments are made between the various specialists as to what work will be done each day and each week, selecting from activities that are free of constraints. Analysis of plan failures facilitates the discussion of production problems. (Ballard 2000)

This research was motivated by the empirical result that LBMS implementation without adequate social process will lead to sub-optimal results even when the information required to successfully manage the project is available to the decision makers[5] (Seppänen 2009). Both LPS and LBMS research have reported case studies where durations were compressed, schedule conformance improved, and productivity increased (for example, (Kenley & Seppänen 2010: 519-521; Ballard & Howell

[5] In the opinion of the authors, an underlying principle of planning is that all plans are forecasts and all forecasts are inaccurate. Consequently, planning alone is insufficient and steering toward objectives and goals is essential. Forecasting the future from the past is necessary, but insufficient for achieving our desires. The question here is how best to use forecasts and how best to adjust to their inadequacy.

2004). If the systems can be combined, the benefits should increase over and above stand-alone implementation of either system.

The paper starts with a short introduction to LBMS and LPS. Then research questions and methods are presented. The majority of the paper is devoted to the proposed process description. Finally, hypotheses for future research and conclusions are presented.

LOCATION-BASED MANAGEMENT SYSTEM

The Location-based management system is the culmination of a long research tradition starting from Line-of-Balance (Lumsden 1968) and Flowline method (Mohr 1979). Most of the research related to location-based methods have concentrated on the theoretical aspects of planning, and ignored the opportunities for using location-based methods for controlling (for example, Arditi et al 2002, Arditi, Tokdemir & Suh 2001, El-Rayes & Moselhi 1998, Yang & Iannou 2001). Controlling has been emphasized in the Finnish research tradition (mostly published in Finnish but summarized in Kenley & Seppänen 2010: 115-117). A full description of LBMS and the history of its development can be found in Kenley and Seppänen (2010). The overview in this paper summarizes the most important aspects.

LOCATION-BASED PLANNING SYSTEM

Locations of the project are hierarchical and are defined by a location breakdown structure (LBS). Each task is defined at a hierarchy level and includes one or more locations. (Kenley & Seppänen 2010: 125-128).

The bill of quantities of a task explicitly defines all the work that must be completed before a location is finished and the crew can move to the next location. (Kenley & Seppänen 2010: 128-131). Quantities by location are required as a starting data for a location-based plan. Durations are calculated by multiplying the quantities in each location by a labor consumption factor (manhours / unit) and dividing by crew size. (Kenley & Seppänen 2010: 131-133). Because quantities can be different in locations, and each task can contain multiple quantity items with different productivity rates, LBMS is not restricted to repetitive projects only.

LBMS integrates the Critical Path Method (CPM) into flowline scheduling. Logic can be automatically generated by considering tasks composed of multiple locations. There are many different ways that logic generation can be automated, and therefore the resulting logic is called *layered logic* (term coined by Kenley in Kenley & Seppänen 2010:133). LBMS includes an augmented CPM algorithm which allows the planning of continuous labor flow by delaying the start date of tasks such that work can be implemented continuously. (Kenley & Seppänen 2010: 133-144). An additional important logic component is the explicit handling of buffers, in addition to lags, which are a well-known component of CPM logic. The buffer operates in the same way as lag in planning but can be absorbed during controlling. (Kenley & Seppänen 2010: 144). The goal of location based planning is to optimize the labor flow so that work does not wait for workers and workers do not wait for work.

Location-based planning requires a lot more data than CPM scheduling, including quantities by location, and productivity rates for subcontracted tasks. Location Breakdown Structure needs to be decided before starting the planning. These facts have been seen as limitations by CPM schedulers who are used to a more free-form planning approach.

LOCATION-BASED CONTROLLING SYSTEM

In LBMS, there are four stages of information: baseline, current, progress and forecast. The baseline schedule sets constraints to current, more detailed schedules and functions as an Owner reporting tool in the same way as the baseline in a CPM schedule. The current stage enables the changing of quantities, productivity rates, logic and plans during production. Each current task, or *detail task*, is linked to one baseline task for comparison purposes. The progress stage monitors the actual performance of the project for each location and task. The actual dates do not replace the planned dates in LBMS – they are rather used for detecting deviations from commitments. In addition to start and finish dates, information about days when tasks were suspended, and actual resources are required to calculate the actual resource consumption (manhours / unit) and actual production rate (units / day) for each trade. (Seppänen 2009: 42-43). The forecast combines the information from the current and progress stages to give early warnings of problems.

The forecasts assume that production will continue with the same productivity, with the planned resources, and follows the current logic. If the forecast of a predecessor delays the forecast of a successor, an alarm is generated. LBMS tries to prevent cascading delays by concentrating production control resources to prevent these alarms from happening by correcting the production rate of a predecessor or by slowing down the successor. In many cases, alarms can be given two weeks before the problem, giving enough time for planning and implementing corrective action (Seppänen 2009: 123-126).

Location-based controlling requires weekly or daily progress reporting. Instead of just recording activity start and finish dates, accurate productivity calculations require information about actual crew sizes, quantities in place and days on which tasks were suspended. Thus implementing location-based controlling requires a significant process change and a major shift from monthly CPM updates to real-time controlling using the schedule.

THE LAST PLANNER SYSTEM

LPS aims to improve productivity by only allowing assignments which have been made ready to enter weekly work plans, and concentrates on actively making work ready. Assignments are well defined and sound directives which determine what specific work will be done. The person or group that produces the assignment is called the Last Planner (Ballard & Howell 1994).

In LPS, master schedules are limited to phase milestones, special milestones, and long lead time items. Phase schedules are planned by the team who will do the work by using pull techniques – working backward from a target completion date, which causes the tasks to be defined and sequenced so that their completion releases work (Ballard & Howell 2003). Resources are also considered in this stage and as part of First Run Studies (Howell & Ballard 1999).

The look-ahead process selects work from the phase schedule, but only if the planners are sure that all the constraints can be removed in time. The phase schedule tasks are exploded into assignments. The targets of the next week are selected from the look-ahead plan. Work that is ready, but is not included in weekly plan, is part of the workable backlog. The reliability of weekly work plans is measured by calculating the percentage of plan completed (PPC). For each failed assignment, a root cause analysis is done to prevent the problem from happening again. (Ballard 2000)

RESEARCH QUESTIONS AND METHODS

The descriptions of the two systems above highlight the main difference between the two systems: LBMS is mainly a technical, data-driven system to provide information to decision making. LPS is primarily a control system focusing on improving the execution of assignments, but it also includes a planning component: phase scheduling. LPS concentrates more on the social process of continuous improvement, collaborative planning and improving the reliability of commitments, rather than providing explicit tools to implement these planning actions. The research questions driving this research are:

1. How to best link LBMS and LPS to achieve better project performance?
2. Can the LBMS control mechanisms be integrated with LPS?
3. Can phase pull scheduling be integrated with LBMS?

Three sources of information were used to propose informed answers to these questions and to develop a process and best practices to combine the systems. Skanska Finland's practical experience in using the two systems together was used as the starting point. Secondly, a series of workshops was conducted at Cathedral Hill hospital project in San Francisco. Additionally, three California General Contractors with some experience in both LBMS and LPS were interviewed to discover factors specific to an industry where activity-based scheduling systems dominate. These three sources of information were combined with the latest case study results on the implementation of stand-alone LBMS and LPS to determine a combined process.

PROPOSED COMBINED PROCESS

MASTER SCHEDULES

In LPS, master schedules are limited to phase milestones, special milestones, and long lead time items (Ballard et al. 2002: 227-229). Location-based planning systems have spent more effort on pre-planning, analyzing and optimizing master schedules before subcontractor selection. Typical preplanning methodologies are described in (Kenley & Seppänen 2010: 201-249).

Skanska Finland uses LBMS to plan a reasonably detailed schedule in the preplanning phase. This includes planning a rough Location Breakdown Structure of 15-20 locations, estimating quantities by location, and synchronizing the production of main trades. Typical master schedules include 20-30 tasks. Master schedules are scheduled by using average productivity rates or historical information from previous projects. Skanska Finland has the goal of improving productivity by the use of LBMS and LPS and then using LBMS controlling features to track improved productivity numbers which can then be used to compress durations in the master schedule phase. Even though the master schedule is scheduled in detail to establish realistic milestones based on quantities and scope, phase schedules are started from scratch by the production team using only milestone information.

Most of the interviewed US contractors preferred to add detail only together with subcontractors during phase scheduling. US General Contractors do not currently track productivity rates from project to project nor use those results in the planning of future projects. The interviewed contractors said that even though they will use LBMS in production, they will also plan and maintain a separate CPM baseline schedule to support claims. That baseline schedule has traditionally not been used to manage production, so the interviewees did not see a conflict. However, they did not want to add another step to the process by creating another master schedule using LBMS. Instead all interviewed contractors preferred to implement LBMS in collaboration with their subcontractors in phase scheduling.

Empirical research about the reliability of baseline schedules in location-based projects shows that there are so many changes during implementation that using the planned start dates of the baseline is detrimental because it leads to a push controlling mentality where tasks are started according to the baseline without considering the status of production (Seppänen 2009: 165-166). However, Location Breakdown Structures on rough level (phases, floors) typically stayed constant throughout the case studies, and overall actual production rates for a median task in each of the three case projects were within 5-20% of that planned. (Seppänen 2009: 74-77).

Based on the Skanska process and empirical results, the proposed process is to define the overall Location Breakdown Structure for the project during master scheduling (on building and floor level of detail), and to use available productivity rates and quantities to evaluate the required production rates. This will help to identify any subcontractors with high resource needs who may become bottlenecks if a reliable subcontractor is not selected. The actual dates of this master schedule are used only for long lead time items, and to establish realistic phase milestones. The master schedule will be gradually replaced by the phase schedules which will be used as control standards for execution.

PHASE SCHEDULES

In LPS, a big part of scheduling happens in phase scheduling meetings. The planning is done by starting from the milestone and working backwards so that each task releases work to the next task. Typically phase scheduling meetings have been carried out by using sticky notes where task names and durations are written. Predecessors are placed to the left and successors to the right (Ballard & Howell 2004). Phase scheduling produces better schedules because of the knowledge the specialists bring and because the participants have power over resources and knowledge regarding availability and capability.

Skanska Finland has experience of about a hundred phase scheduling meetings. Location-based thinking is used in the phase scheduling meetings. The wall is divided vertically by locations (from master schedule) and horizontally by time. Skanska takes the milestones from the master schedule. If time is left after building the baseline schedule, the remaining time is allocated as buffers between tasks.

One of the authors has implemented a collaborative phase scheduling approach in two location-based projects in Finland. To get all the data for a collaborative planning session, the phase scheduling needed to be broken into two meetings. The first meeting defined the detailed Location Breakdown Structure for the phase as a collaborative effort. The normal sticky note exercise was done then to identify task types and logic. However, durations were not yet defined. After tasks and locations were known, all the subcontractors had a homework assignment to estimate the quantity of work and labor consumption (manhours / unit) for each task in each location. This gave all the information required creating a location-based plan before the second meeting, assuming one crew for each task. The second meeting was to optimize workflow by looking at the bottleneck trades with the lowest production rate, and increasing or decreasing resources, and changing logic to optimize the schedule.

This approach was described to the Cathedral Hill team and in the interviews. There were some concerns about how the use of LBMS would impact the collaborative nature of phase scheduling meetings. For example, the location breakdown and flow should be understood through conversations before entering any information into the planning system. On the other hand, having more information and using it to optimize the end result was a benefit that was seen by all.

There were additional concerns about the level of detail. Phase scheduling meetings often go to a level of detail which would lead to a cluttered image in flowline making any collaborative optimization difficult. There are also many non-location based tasks which need to be incorporated in the planning process, and flowline does not help in their visualization.

The proposed process for phase scheduling follows the outline described above with two meetings and data collection as homework between the meetings. The first meeting can be organized exactly as a LPS phase scheduling meeting (as implemented in Skanska Finland), except that durations should not be discussed and the Location Breakdown Structure is defined in addition to tasks and logic. In the preparation of the second optimization meeting, the tasks should be formed so that all the hand-offs between subcontractors are accurately modeled. Any internal hand-offs can be simplified and lumped to the same task. Non-location-based tasks do not need to be shown during flowline optimization but should constrain the start dates of tasks through CPM logic. Instead of following the Skanska Finland process of automatically allocating all the time between phase schedule finish date and master schedule milestone date to buffers, we propose asking the participants what time buffer is needed to absorb the variation. In this way, schedules can also be compressed during phase scheduling.

LOOK-AHEAD SCHEDULES

In LPS, look-ahead schedules explode phase schedule tasks into assignments, and define their constraints. The assignment is allowed to proceed in the look-ahead schedule only if it can be made ready in time. In LBMS, the current tasks and forecasts could be used for look-ahead functions. Seppänen (2009: 120-121) proposed that a location-based look-ahead schedule could be formed by adjusting the forecasts with control actions planned to remove alarms, and by taking into account actual resource information.

Skanska Finland uses LBMS progress and forecasts to select those tasks which can be started in 4-6 weeks. More detail is added to those tasks during look-ahead planning, Two weeks before starting the work, a meeting is held where the detailed implementation is agreed upon with the subcontractor crew.

All of the interviewed US contractors as well as CHH workshop participants were concerned that increasing the level of detail in LBMS to that required in look-ahead planning would clutter the flowline schedule and burden the system without additional benefit. The feedback from the workshops was that the look-ahead schedule would operate better as a checklist which is cross-checked with the forecast information from the LBMS. LBMS gives an early warning when tasks cannot be implemented according to the phase schedule because of resource problems or conflicts between subcontractors.

The proposed process for look-ahead planning is to update progress in LBMS weekly, which will update the forecast. As an additional step to Skanska's process, this forecast is discussed in a superintendent meeting devoted to lookahead planning. Any control actions are updated in the LBMS by either changing the detail schedule or by revising the forecast. The look-ahead and weekly work plans are developed by using the LBMS forecast as one information source.

WEEKLY PLANS

Skanska Finland sees the benefit of LPS coming from more efficient execution, . LBMS provides support by giving numerical and graphical information about root causes and effects of failures, and by forecasting future problems. The weekly plans are presented as bar charts. Skanska is not updating the weekly plan level of detail in LBMS schedules or comparing the weekly plans to the forecast.

The interviewed US contractors saw the commitment and communication part of weekly planning so important that it could be detrimental to implement it in a technical system. Because LBMS operates on crew, task and location levels, and the actual assignments are often more detailed and apply to individual workers, it would be difficult to model the weekly plans in LBMS. One US contractor said that updating the progress information to both LBMS and LPS seems like double work, and they have decided to only utilize the planning functions of LBMS and leave controlling to LPS.

The LBMS updated forecast (in superintendent meetings, see look-ahead planning section) can be used to know where and how much production should be happening. This information is used by the Last Planners to add detail to the assignment, and ultimately to commit to the weekly plan. If the commitment is less than the location-based forecast, the forecast should be updated to see what will happen if the installation rate is not increased in the future. For root cause analysis and learning, LBMS contributes numerical information about planned and actual productivity and production rates, and planned and actual resources.

HYPOTHESES FOR FUTURE RESEARCH

In future research, the proposed process presented in this paper should be tested in real production and the following hypotheses evaluated in projects where LBMS and LPS are used together:

H1: Schedule conformance should increase

H2: Project durations should shrink

H3: Productivity should increase

H4: Cascading delay chains should show a decrease

There are metrics to evaluate each one of the hypotheses. LBMS metrics related to schedule conformance include deviations of start and finish dates from planned, actual continuity of workflow, following the planned sequence and production rate deviation (Seppänen 2009: 54-57). LPS metrics include PPC, TMR (Tasks Made Ready), and TA (Tasks Anticipated) (Ballard 1997; Hamzeh 2009). Project durations can be compared with previous similar projects. LBMS data can be used to calculate actual labor consumption (manhours / unit), which is a measure of productivity. This can be compared to that of other projects. Methods to measure cascading delays in LBMS have been developed (Seppänen 2009: 57-60).

Skanska Finland has started the measurement of benefits in a 21 story residential case project. They are recording the PPC, and comparing master schedule and actual durations for each phase. In this project, they had a tighter structural schedule than normal (5 days for each floor). Actual durations decreased to 4 days / floor after the third floor and the four week rolling average of PPC increased from the initial 64% to 78%. Although this is a good start, data is required from many more projects and construction phases using a consistent set of metrics before drawing overall conclusions about the benefits.

CONCLUSIONS

LBMS and LPS were found to be complementary. LPS focuses more on the social process of planning and commitment, and LBMS is mainly a technical system using structured information to improve the quality of plans in the planning phase and to calculate progress metrics, forecasts and early warnings during the controlling phase. Although the information of LBMS has been shown to be useful in empirical research, there have been deficiencies in the social process of using the information in projects.

The process of Skanska Finland was used as the starting point. In master scheduling, Skanska Finland's process was directly adopted. LBMS can use the data gathered from previous projects to create realistic phase milestones. In phase scheduling, LBMS provides a graphical representation of the plan based on solid data, and optimized in collaboration with all parties using the social planning process of LPS. Although Skanska Finland was already using location-based ideas in phase scheduling, it was proposed that an additional LBMS schedule optimization meeting should be added to the process. During construction, Skanska Finland had been using forecasts only to inform look-ahead planning process about starting tasks in the next 4-6 weeks. In addition, LPS look-ahead plans and weekly plans can utilize the LBMS progress and forecast data to give early warnings of problems and to evaluate the total effects of deviations. However, it is not recommended that the LBMS schedule be developed into assignment level of detail.

By combining the systems, schedule conformance should increase, project durations should shrink, productivity should be further increased, and cascading delay chains should show a decrease. These hypotheses will be evaluated in future research.

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