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SUGGESTIONS TO IMPROVE LEAN CONSTRUCTION PLANNING

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ABSTRACT

The Last Planner System® has been one of the most popular lean construction tools that offers a solution to tackle the problems of production management on construction sites. Since its inception almost 20 years ago, construction companies across the world have implemented Last Planner with reported success. However, even as Last Planner was originally designed to address some shortcomings of the CPM method, a particular shortcoming – namely task continuity was not addressed directly. Also, excepting PPC and Reasons for Non Completion charts, there are no explicit visual tools offered by the Last Planner system. On the other hand, Line of Balance based approaches intrinsically support the consideration of task continuity, and offer a basic visual management approach in schedule representation. With some exceptions, Line of Balance is seen as a special technique applicable only in linear or repetitive work based schedules. The authors suggest that i) there is a need for a robust theory of planning and scheduling and ii) there is a need for a more suitable approach that addresses critical aspects of planning and scheduling function for example by integrating Line of Balance and Last Planner to provide a more robust support for construction scheduling.

KEYWORDS

Lean Construction, Last Planner®, Line of Balance

INTRODUCTION

Planning and scheduling are two of the most important functions from construction management viewpoint. However, the predominantly "Transformation" based Critical Path Method (CPM) that is in widespread use, has been criticised for its shortcomings by researchers over the years (Jaafari, 1984; Koskela et al., 2014). One such shortcoming is the absence of spatial information from tasks, task continuity and the visualisation of it as such. To address this shortcoming, location based scheduling or line of balance method of production planning is often used (Kenley and Seppänen, 2010). To overcome the shortcoming of a predominant "top down" approach and to

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better tackle the variability, the Last Planner® system of production planning was developed (Ballard, 2000), which has emerged as one of the most important lean construction tools since its inception. For many construction organisations embarking on their lean journey, Last Planner is one of the first steps taken. Researchers have also discussed integration of Last Planner with Line of Balance techniques to improve the performance of planning and scheduling in construction (Seppänen, Ballard and Pesonen, 2010).

However, there are still gaps both in practice and in research, in the planning and scheduling techniques and how they are applied in a construction project. In particular as the Last Planner system still takes the traditionally prepared Gantt as the main input (in terms of the Master) schedule, hence the shortcomings of the "T" based system are inherently present up to a certain extent. Moreover, the role of scheduling in general is not formally recognised in the Last Planner system. This makes the connection between the master schedule and low level schedules quite difficult.

This paper attempts to highlight the main gaps in current planning and scheduling methods and argues for the need for a better scheduling theory behind construction. The paper follows the constructive research methodology. The paper begins with selection of problem from practical viewpoint, proceeding to explore the problem area further through literature review. In the following section a connection to theory is made through the proposal of a unified theory of planning and scheduling. Finally, candidate solution requirements are outlined. The next steps of selecting a candidate solution, developing it further and evaluating it in real world are not within the scope of this paper but would follow in subsequent research.

PROBLEMS WITH PLANNING AND SCHEDULING - A VIEW FROM PRACTICE PERSPECTIVE

Based on the practical experience of the authors there are a number of problems with the current approach to scheduling. In a study carried out by Dave, Hämäläinen and Koskela (2015), the authors presented findings on Last Planner implementation based on observations from five companies. The findings highlighted the difficulties in implementing Last Planner, especially the scheduling components by the organisations studied. Table 1 provides a summary of the Last Planner components implemented in each of the five organisations studied.

One critical point raised was that there is not enough recognition for the need for properly developed and updated master schedule i.e. if the current situation on site calls for ad-hoc actions (leading to making-do), they are carried out regardless what the schedule demands. The purpose of the schedule then loses its meaning as a driving/controlling document. The root causes of this problem lie deeper, such as the gap between the long-term plan and medium and short term plans (last planner system), and lack of recognition for an up-to-date master schedule, which results in absence of workable backlog.

Another critical aspect raised by the study was that following the implementation of Last Planner system there was somewhat an ambiguity in planning responsibility, i.e. who should be in charge of maintaining and updating the master schedule and the interface between that and the medium and short term plans.

Table 1 - Last Planner Implementation Summary

LPS Component	Company A	Company B	Company C	Company D	Company E
Phase Scheduling	Not implemented	Not implemented	Not implemented	Not implemented	Implemented
Lookahead Planning	Partial implementation	Implemented	Implemented	Not implemented	Implemented
Weekly Planning	Implemented	Implemented	Implemented	Implemented	Implemented
Collaborative Planning	Partial implementation	Implemented	Not implemented	Implemented	Partially implemented
Analysis and Continuous Improvement	Not Implemented	Implemented	Not Implemented	Not implemented	Implemented

These problems are not necessarily produced onsite or limited to production either. One of the major inputs in developing a detailed production schedule is design information. However, due to cost based procurement methods, or due to lack of recognition of the interface between production and design schedules, the design information is not released in time for the development of a detailed production schedule. A better interface between production and design schedule should lead to the release of design information with a pull from the master schedule.

Traditionally the schedule is an outcome of a site manager's personal experience combined with the characteristics of the project, where task durations are based on experience rather than information such as quantities, consumptions and resources. Locations in the schedule are identified but overall the schedule presentation or execution is not location based. Typically, the focus is on identifying activities / location, not the flow of locations inside and between activities.

Currently, there is too little focus on integrating various trade activities such as MEP, finishes, etc. with the main schedule, which should be planned along with every construction activity. And the sequencing order should be carefully considered, for example whether the pipes should be installed before or after the wall? That should be planned as well in the master scheduling phase and the dependencies included in the schedule.

LITERATURE REVIEW

CURRENT APPROACH TO SCHEDULING IN LEAN

In lean construction, Last Planner® is the most popular production planning method, and as such, there are no explicit lean scheduling methods yet developed. The Last Planner system takes a master plan as the input and the main starting point and tracking tool (from the perspectives of milestones) (Ballard, 2000). While LPS

attempts to overcome the problems posed by CPM (a predominantly "T" based approach), by tackling "flow" aspects and by providing a stable planning system, it does not appear to be fully addressing the problems of scheduling.

CPM is still the predominant method, which is a mathematical approach to scheduling that is based on a black box model of input>process>output. In general, this shortcoming results in underperformance of the LPS on construction projects (Dave et al., 2015). Also, the general lack of recognition and integration with a scheduling system in LPS makes it difficult to track projects as it is a scheduling system's role to provide tracking. In LPS, Post it™ notes are typically used as a scheduling aid, typically in short (commitment/weekly) and medium term planning (lookahead). However, it is a manual way of managing information that does not synchronise with other planning and scheduling systems. While the collaborative nature of planning in LPS takes care of the planning functions by addressing the shortcomings of traditional planning and scheduling methods, it does not address the scheduling functions completely. Typically, the integration with master planning, tracking, monitoring and detailed prioritisation, and conflict resolution are not explicitly addressed. Also, while LPS prescribes systematic constraints analysis, the scheduling systems used (such as Post It notes, Excel sheets, etc.) do not directly aid constraint identification as suggested by the LPS.

A study carried out in Brazil (Bortolazza and Formoso, 2006) on 133 projects where Last Planner System (LPS) was implemented highlighted that the main emphasis of the implementation had been on short-term planning. The study pointed out that the effective implementation of the lookahead planning function remained a major problem. In a similar study of over 100 projects in Chile (Alarcón et al., 2005), the authors concluded that only a selected elements of the LPS were effectively deployed, in particular, the make-ready (lookahead planning), workable backlog and corrective actions aspects were not in wide-spread implementation. The study also highlighted the lack of supply chain integration as one of the major problems.

A Swedish study (Friblick, Olsson and Reslow, 2009) in implementation of LPS based on a survey of 270 participants concluded that even though the importance of involving physical workers (i.e. the Last Planners) in the planning process is recognised, it still remains a problem area. Hence, the effectiveness of the collaborative planning aspects remains limited in practice.

It emerges from the study of past literature that one of the most widely implemented aspects of LPS is weekly planning, while lookahead planning, continuous improvement, root cause analysis and collaborative aspects remain a major challenge.

Researchers have attempted to align or evaluate integration of other planning and scheduling systems with Last Planner such as line of balance (Seppänen, Ballard and Pesonen, 2010) and critical chain (Koskela, Stratton and Koskenvesa, 2010) to bridge this gap. However, there is still a need to further develop this discussion and continue to search for a more comprehensive approach to unified planning and scheduling in construction.

In general, the main gaps that emerge from study of literature and practice are:

- Planning and scheduling not taken as a continuous activity and not carried out in an integrated manner.

- Interface between difference schedule resolutions – i.e. top level, medium level and short level schedules is not developed well.
- Task continuity and visualization of flow are missing from the plan and schedule.

DISTINCTION BETWEEN PLANNING AND SCHEDULING

Oberlender (2000) distinguish planning and scheduling activities as "Project planning is the process of identifying all the activities necessary to successfully complete the project. Project scheduling is the process of determining the sequential order of the planned activities, assigning realistic durations to each activity, and determining the start and finish dates for each activity. Thus, project planning is a prerequisite to project scheduling because there is no way to determine the sequence or start and finish dates of activities until they are identified." Both these terms have been used interchangeably in construction and not much distinction has been made. While, it is not within the scope of this paper to provide a conceptually deeper explanation of these two, the main emphasis in this paper is on scheduling. However, it is implied that a better scheduling method would lead to a better planning output.

SUMMARY

A wide range of literature already exists on the performance of the Last Planner system in various countries. While most studies indicate an overall success story where the Last Planner system improves the overall performance of the project, some also highlight the barriers to implementations and challenges. The majority of the barriers indicated tend to be related to the softer aspects of implementation, such as people and organisational processes, however this in this study the focus is mainly on the functional aspects, i.e. components of the Last Planner system.

NEED FOR A UNIFIED THEORY

Construction planning, and indeed subsequently the whole field of project management, has developed through the emergence of new methods rather than as an outcome of new theoretical insights. Here, the foremost method has been the Critical Path Method (CPM). Also several important alternatives to it, such as the Last Planner System (LPS) and Critical Chain (CC) have their origin in attempts to rectify identified shortcomings of CPM. In contrast, the methods based on line-of-balance (LOB) have had an independent origin.

In prior theoretical work, the underlying theory of traditional project management has been decoded, along with alternative, competing theories (Koskela and Howell, 2002). Also the theories inspiring especially the Last Planner System have been analysed (Koskela and Ballard, 2006).

However, in spite of these advances, the full potential of theory has not been utilized. The theoretical critique against CPM has hardly diminished its use. In practice, there is a trend towards integrating different methods. For example, CPM is customarily used in connection to the Last Planner system, for master planning. In the use of LOB based methods, the need for Last Planner has been felt. These practical developments indicate that there would a need for a unified theory of construction planning.

However, the development of a unified theory is not without challenges. Perhaps the most difficult, and also subtle, difficulty is that our theoretical notions are largely CPM centred, either justifying it or providing alternative solutions. This implies that such parts of aspects of construction planning, on which CPM is silent, will not be visible in our theoretical understanding.

This paper does not aim at developing a unified theory. Rather the aim is more modest: to present some elements which arguably should be included into the unified theory, and which might be usable already as such. We contend that the following elements fall into this category:

- The requirement for continuity (of work, location and time)
- The requirement for visuality of the plan and its preparation.

These two elements represent differing shortcomings of the origin of construction planning, namely CPM. The lack of continuity in CPM is an error even when judged against the logic of the CPM itself, namely, without continuity, tasks will not be optimal. This problem has not been solved in LPS or CC.

In turn, the lack of visuality has become visible through the diffusion of visual management techniques as such, and also through attempts to create production control based on visual management (Brady, 2014).

MAIN FEATURES REQUIRED FROM A SCHEDULING SYSTEM

Table 2 attempts to describe the desired functions of planning and scheduling systems and the roles they need to perform on a construction project (Barták, 1999; Garrido, Salido and Barber, 2000). As noted, a scheduling system should be able to meet several purposes, ranging from sequencing and synchronization to management and monitoring (tracking) of operations, among others functions (Table 1). Despite being useful as a starting point for developing a project schedule, this list of features should not be understood as exhaustive, especially when approached from a lean standpoint. So, a question emerges here: is there any other feature that a scheduling system should contain when approached from a lean perspective? The answer is yes; there are other features that could and should be addressed in a scheduling system when it considers the lean concepts and principles as its theoretical background. These are explored as follow.

Flow. First and foremost, flow has to be properly recognized. In order to do that, aspects such as continuity of tasks and transparency, achieved by the use of highly visual scheduling techniques, should always be taken into consideration. Schedulers should be able to identify visually conflicts resulting from poor allocation of trades on site as well as recognizing the project's critical path so better decisions can be made promptly.

Integration between planning levels. Second, a lean scheduling system should allow for integration between different planning levels. The flow of information from the short-term and medium-term schedules to the long-term plan should be seamless. In other words, planners should be able to know quickly the strategic implications of operational problems as well as there should be a better way to evaluate the repercussions in the master plan of decisions made during the scheduling process. Regarding to the latter, this issue can be more easily verified in complex projects

where the high number of workflows and interdependencies might make difficult and laborious the analysis and identification of the best solution in terms of scheduling for the project as a whole.

Table 2 - Features of planning and scheduling (Barták, 1999; Garrido et al., 2000)

Planning	Scheduling
What to make	How best to make it – execution
When to make it – initial sequencing and temporal constraints (at the milestone level)	Detailed sequencing at the task level
How much to make	Synchronisation of activities and resources
Where to make it	Priorities, constraints and conflict
What resources are required	Monitoring execution (tracking) and resequencing/rescheduling

Value Generation. Last, but not least, it is important to mention the need for maximizing value generation through scheduling. This feature has been addressed previously in the paper wrote by Ballard (2000) and (Ballard and Howell, 2003). In order to further develop the Last Planner System of production control, the authors introduced a technique called phase scheduling as a way to perform the scheduling function in construction projects. According to those authors, the purpose of using such a technique is "*to produce a plan for completing a phase of work that maximizes value generation and one that everyone involved understands and supports*". To this end, they recommended the use of pull techniques along with team planning to develop the phase scheduling.

It is worth mentioning that (Ballard and Howell, 2003) acknowledge that the phase scheduling is not the only technique for performing the scheduling function. In this respect and in view of the features aforementioned, the line of balance (LOB) emerges a suitable option as it provides great visibility for the flows of work in a construction site as well as spatial information, therefore enabling managers to assess easily whether tasks have been schedule continuously and whether there are spatial conflicts occurring between different trades. Also, current LOB computerized systems (e.g. Vico System) allow for the identification of the critical path as well as resource allocation, not to mention its ability to speed up the analysis and update of project schedules in an efficient manner. Therefore, it is argued that LOB should be seen as the proper technique for scheduling when lean principles are taken into consideration.

SUGGESTIONS FROM PRACTICE FOR A PLANNING AND SCHEDULING PROCESS

The following has been developed through observations from implementing integrated planning and scheduling in construction projects. It is not meant to be taken as a wholesome solution, but an initial attempt to overcome the difficulties raised above.

- Planning and scheduling should start with these basic steps:
- Creating the location breakdown structure (LBS)

- Identifying the activities and their dependencies (completion order) required for constructing the building (both structural and MEP)
- Dimensioning the activities based on the information available, quantities, consumptions, resources (production factors) and also the know-how of the specific trade contractor. After this the schedule optimization should be carried out.

LBS is one of the main required aspects for the flow. Sometimes it is needed to have different LBS for different phases of the project such as the frame phase and the interior phase as the focus in production is on different things. Activities should be based on locations and should be planned as continuous tasks through the locations to ensure flow is maintained.

The next and as important thing is to identify the correct activities for the project and visualize these activities at the right level. Figure 1 demonstrates one such activity, where screeding and painting are represented as a single activity (as they are in most instances). Figure 2 shows the same activity after it has been expanded and both screeding and painting are displayed as separate activities. It can be seen here that there are clashes between these activities that would lead to problems in execution. However, these problems would not be identified if the activities are not visualized at the correct level.

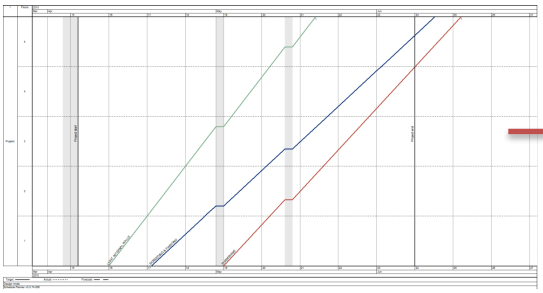

Figure 1 - Summary task of screeding and painting

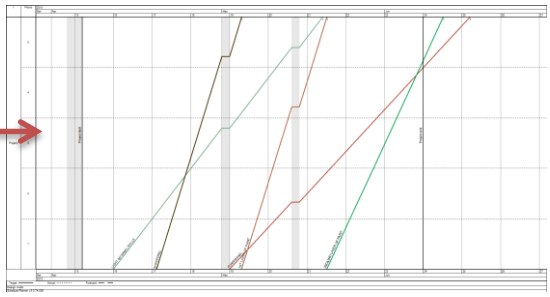

Figure 2 - Screeding and Painting after expanded

In addition to the location based scheduling, and visualizing activities at the correct level, it is also possible to explain each location and timeframe as a self-contained box (albeit with interfaces with other boxes) as shown in Figure 3. In other words, all work related to that activity and location should be completed within the time-location box, if this principle not followed then it may result in delays or clashes with other activities. For example, it is pertinent for the last planners to understand that they have required resources to perform all activities within a time location box once it is expanded.

The duration of an activity is the third important step before the schedule optimization. The duration of a task comes from the equation: quantities x consumption (man-hours / units) divided by the number of resources. The technique is widely used in Finland due to the popularity of the RATU database (see Ratu website, accessed April 6th, 2015), which provides consumption information and standard work methods for construction activities. If one wants to assign the duration based on the experience, the schedule should still be updated with information mentioned in the equation above. Then in case of a production problem, one can find out which part was incorrect: miscalculated quantities, wrong resource assumption or

wrong consumption, which would aid continuous learning and help predictability of resource allocation in future.

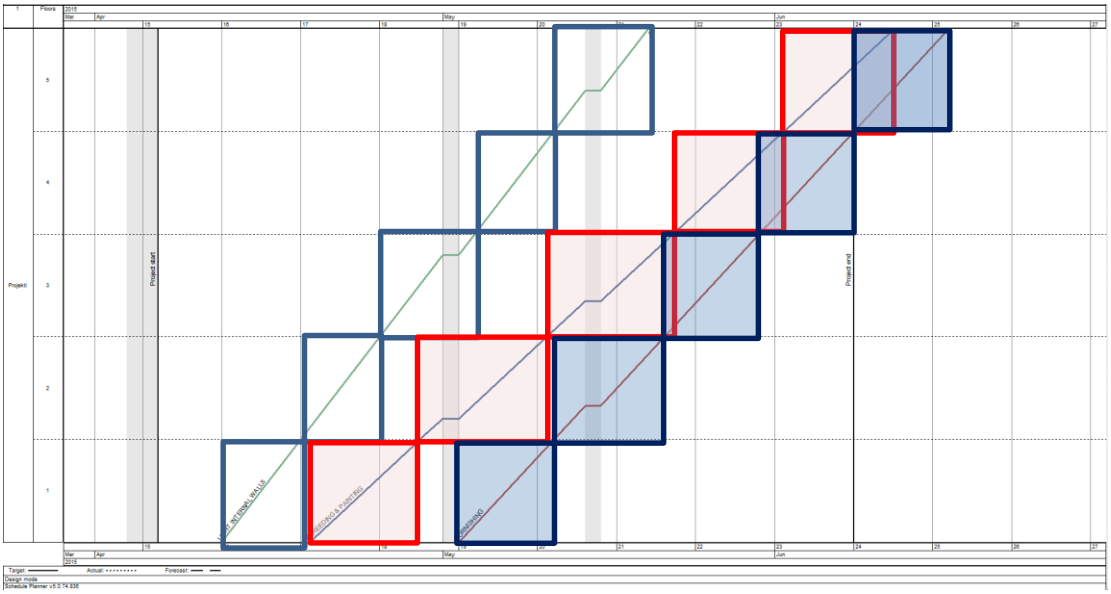

Figure 3 - Activity planning visualisation with location-time boxes

When these steps are done properly one can optimize the schedule, optimize the flow of resources and make sure that the production rates are consistent through every location and communicate the findings with the sub-contractors. It is important to pay attention to resource allocation based on resource consumption, as with Lean and Last Planner while it is possible to steer the project execution towards the schedule and minimize variation, it does not help if the original schedule is inadequate.

In practice, it is observed that quite often these basic things are not done correctly (or at all) and there is a strong need for intervention, which is where Last Planner is useful. But from lean perspective, these aspects should be managed in advance, and the need for intervention should be minimised. The main ingredients of People, process and tools should be sufficient for proper planning and scheduling if they work in a synergistic way.

CONCLUSIONS

The Last Planner system of production management is one of the most popular lean tools being deployed in construction companies across the world. It was originally designed to address practical gaps in the production management process in construction, specifically those left by the Critical Path Method system. However, there are still gaps in the overall planning and scheduling system in construction and role of long range, medium range and short range scheduling system and their interfaces with Last Planner and Location Based Scheduling are not fully understood or explained. This results in gaps in the overall production management system. The lack of an authoritative and in-detail exposition of this system, as well as the missing of an accessible theoretical explanation, figure among the main reasons. While a wider and deeper analysis is warranted, the initial insights discussed provide directions for further amelioration of production control in construction.

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