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Looking for Improvement in Last Planner System: Defining Selection Criteria

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ABSTRACT

Last Planner System has been critiqued for an inconsistent application of flows. Central for this critique was that the sequence of activities was determined based on only duration and interrelationships. In an attempt to improve the on-site scheduling processes, an in-depth analysis of selection criteria was carried out. Six flows are identified as relevant: workforce, material, and machinery which comprise the needed resources and safety, climate conditions, and space which affect the pace of the work. Because of the importance to progress in the workflow, and the on schedule completeness of activities, all six flows need to be systematically controlled. The output of the analysis is a list of recommendations of how to refine the schedules by including the six flows both in the Phase Scheduling, the Look-ahead, and the Commitment level.

Key words: Construction management, Flow, Last Planner System, Scheduling, Sequencing

INTRODUCTION

In Last Planner System (LPS) focus is on making the schedule as reliable as possible (Ballard 2000; Ballard and Howell 1995). According to LPS theory, increased schedule reliability does lead to increased on-site productivity (Ballard and Howell 1995; Ballard and Howell 1994). Schedule reliability is measured in the percentage planned completed (PPC) measurement; which is said to be a quality measurement of the schedule (Ballard and Howell 1994; Ballard 1994). In this research, the focus is moved from schedule reliability onto sequence quality. This is done in an attempt to make the sequence as ideal as possible to improve the work flow and processes at site and through that increase on-site productivity.

LPS consist of four schedules: 1) The Master Schedule, containing milestones and deadlines, 2) the Phase Schedule, including the sequencing processes, 3) the Look-ahead Schedule, where activities are made ready for conduction, and finally, 4)

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the Weekly Work Plans which contains the actual commitments to what is carried out on-site (Ballard 2000).

A basic part of Lean Construction is the Transformation – Flow – Value (TFV) theory, which was introduced by Koskela (Koskela 2000; Koskela 1992). Transformation is referring to the transformation of imput to output, flow is referring to the flow of work, and value is referring to the creation of value through fulfillment of costumer value. In LPS the flow considerations are only adopted at the Look-ahead level where activities are made ready for conduction. In the making ready process, the seven flows of construction are applied to ensure that every constraint is removed. The seven flows were introduced by Koskela (1999) as the preconditions which have to be fulfilled to ensure that an activity can be conducted. The seven categories of preconditions are:

1. Construction design; correct plans, draft 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 activity can be executed
6. Connecting works, previous activities must be completed
7. External conditions must be in order

In a research study conducted by Lindhard and Wandahl (2012a) the preconditions to work task were examined. As an output from the research it was proposed to expand the construction design category to include external laws, authorizations, and agreements together with management decisions such as communication, coordination, and collaboration issues. Moreover, it was proposed to split the “external conditions” category into three categories. Currently the “external conditions” category covers several fundamentally different subcategories. The “external conditions” category was divided into the following:

- 7a. Climate conditions must be acceptable. The precondition focuses on the effects from the external environment 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 the 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 ore refurbishment assignments.

In order to improve LPS, and since it is based on lean considerations, flow considerations should be included in the three schedules conducted at site, i.e. the Phase Schedule, the Look-ahead Schedule, and the Weekly Work Plan (Lindhard and

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Wandahl 2013a). A way to incorporate flow conditions into the schedules is, when conducting the schedules, to include flows in the selection criteria. In LPS only duration and interrelations between handoffs are considered. The criteria to the selection of activities are important because it is decisive to the "design" of the schedule. By expanding the selection criteria, sequence quality is improved.

This paper is based on the outcome from the findings in Lindhard and Wandahl (2013a) which through case studies analyzed pros and cons to LPS and found that the current criteria for selecting activities to the schedules needed to be expanded with both flow and CPM consideration. The aim of the paper is to establish a set of recommendations of how flow considerations can be included when selecting activities.

METHODS

Four cases comprise the foundation for the presented research. The study took its outset in Eisenhardt's (1989) case study guidelines. Four cases were selected to ensure a *"theoretical saturation"* of collected data cf. Eisenhardt (1989), and because it enables triangulation of data sources which increases the trustworthiness of the data (Krefting 1991). Triangulation of the data sources revealed a consensus between all the four cases.

The case studies had an exploratory approach (Tellis 1997; Yin 1993) where the nine preconditions were observed in their context. By studying the preconditions in their context the collected data has an increased richness and depth (Ulin *et al.* 2004). Thus, by observing how production progresses on-site and how the individual predefinition affects and is affected a lot is learned. Based on the observations, the relevance and the implication of each preconditions is revealed. Moreover, by observing elements influencing the preconditions an insight of how to manage the precondition is gained. The knowledge gained throughout the case studies is creating the input in the analysis and hence forming the basis for the final recommendations.

Key data to the four cases studied can together with details to the data collection be viewed in Table 1.

Table 1: Data collection from the four case studies

	Case 1	Case 2	Case 3	Case 4
Type	Renovation	Construction	Construction	Renovation
Details	Public housing	Educational institution	Nursing home	Hospital
Contract form	Turnkey contractor	Turnkey contractor	Prime contractor	General contractor

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Contract period	26 month	16 month	17 month	7 month
Contract value	$4.5 million	$29.1 million	$3.9 million	$5.5 million
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
Observation length	10 weeks	10 weeks	10 weeks	6 weeks

ANALYSIS

In a research, conducted by Lindhard and Wandahl (2013a) the selection criteria's within the LPS was critiqued. The critiqued was founded on the fact that LPS only includes duration and handoffs when determining both the overall sequence and the actual work plans. Moreover, Lindhard and Wandahl (2013a) found an inconsistent application of flows in the scheduling process. Today, flows are only considered at the Look-ahead level where they serve as preconditions to ensure that activities are made ready for conduction. As mentioned in the introduction section flow considerations are a central part of Lean Construction and the TFV theory. Thus, to improve the selection criteria flow considerations should be included. This can be achieved by incorporating the preconditions into the selection process.

The following contains an in-depth analysis of selection criteria's. This analysis takes its outset in the above mentioned preconditions of construction, in an attempt to improve the on-site scheduling processes. As mentioned in the introduction section the preconditions to work tasks in construction can be divided into nine key categories. This includes: Construction design, materials, workers, equipment, space, connecting works, climate conditions, safety, known surroundings. All mentioned preconditions have to be fulfilled before an activity can start which is why the preconditions in LPS is used to secure that only sound work enters the Weekly Work Plans.

Not all preconditions are important during the completion phase. The "known surroundings", "construction design" and "connecting works" categories are in general only important to ensure that an activity can start. Only in very rare exceptions, changes in soundness will occur in the three categories. Changes in the "connecting work" category affect the soundness of the activities while changes in the "known surroundings" and construction design" category effects the basics which

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defines the work task, and change the work task itself. In all cases the result is an interruption in the progressing work which leads to decreased productivity.

The known surroundings category provides information to the design process and to determine necessary precautions during execution. When an activity starts all relevant information should already have been collected from the surroundings. Thus, no inputs are expected from the “known surroundings” category when an activity is being “processed”. Even so, not all relevant information from the site is necessarily discovered in the preliminary examinations. Therefore, unexpected discoveries are still able to occur during the execution phase.

Before an activity can start, the construction design has to be decided; this includes relevant drawings and task specifications. Often the construction design changes during the construction face; therefore, it is important to continuously update drawings and specifications to avoid misunderstandings and the possibility to proceed with incorrect plans. Even though design changes are normal in construction project; the risk of design changes in a work task during completion is very minimal.

Likewise “known surroundings” and the “construction design” categories, the completion of connected and interrelated activities is essential in relation to the soundness of the activities in the present Weekly Work Plans. The completions stage of previous activities is especially important between handoffs. Handoffs are important because work is changing hands between the different trades or subcontractors represented on site. Thus, handoffs are important to hinder interruptions in the workflow and to avoid unnecessary waiting. The deadline signals when the handoff shall take place, to avoid interruptions and unnecessary waiting slack can be incorporated in the schedule; these slack considerations are of particularly importance at the critical path to avoid delays in the overall construction process. In rare situations the completeness of previous activity can vary which result in rework, but normally the completion of previous activities has importance only in the handoff between the present and the succeeding trade.

The remaining six preconditions are all important both before and during execution. Three of them, including: qualified workforce, the needed material, the relevant equipment and machinery, are the resources which needs to be present during the execution phase to ensure the completeness of an activity on schedule. The remaining three including safety, climate conditions, and space have to be present to ensure that the process can proceed and affects the pace of the work. In extreme situations safety issues, climate hazards, and lacking space are all able to completely stop all progress at the construction site. Because of the importance to progress in the workflow, and the on schedule completeness of activities, all six preconditions need to be systematically controlled.

The safety of the workforce is important both before and during the execution. Therefore, necessary precautions have to be taken to ensure the safety of the

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workforce and to obey the national "Health and Safety at Work Act". Before an activity can start the process has to be thought through and safety has to be ensured; during execution all involved should be aware of safety issues and act if detected to hinder accidents in developing. The safety "awareness" could be combined with other preventive precautions such as safety inspections, safety trainings, hazards planning, alcohol screening etc. (Howell *et al.* 2002). Despite the effort, safety issues and hazards cannot be completely avoided. Often hazards develop as a chain of unforeseen events (Howell *et al.* 2002); this happens at a pace where they are difficult to detect and avoid. The risk for hazards increases as the workload increases; thus, is a company's eager to increase productivity pushing workers to work close to the boundary of safe working conditions (Howell *et al.* 2002).

Every construction project is surrounded by an external climate. The external climate does by a number of parameters such as temperature, wind, moisture, rain, snow, waves, and visibility (Lindhard and Wandahl 2012a) influence the work conducted at site. Since the climate itself cannot be changed the possible negative effect of the climate has to be handled to reduce or eliminate the effect. The quick changes in the climate impact makes it very difficult to plan for environmental issues; therefore, long term precautions, which has to be taken before problems can be forecasted, should be based on risk assessments. Some climate parameters changes with the season, for instance temperature; in such cases it is possible to wait and intervene only when necessary. When scheduling next week's work traditional weather forecasts can be used to adjust the schedule. Furthermore, short term precautions can be implemented to avoid the effects from the climate. In general many precautions to handling the surrounding climate has proven very cost full; therefore, price is often the primary parameter when comparing the cost with the benefits.

In construction a great number of work activities have to be completed simultaneously with only limited space available (Bertelsen 2003). The category space includes all elements which are needed to secure optimal working conditions to a specific work activity (Lindhard and Wandahl 2012a). Working conditions include working comfort, for instance temperature, lighting, noise, working postures, working procedures, working base etc. Moreover, working conditions does as mentioned include space issues, which include access to work place, mutual interruptions and delays caused by shared work areas, etc. To achieve ideal working conditions it is necessary to define good and bad working comfort. Afterwards, bad working comfort should be minimized while good working comfort should be maximized.

Construction is dependent on qualified labor. Thus manning is an essential resource which is needed to complete the work tasks on site. Both the basic skill and the motivation of the individual craftsman are important and affect both the pace of

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work and the quality of the output. Due to the relationships to output quantity and quality, the well being and personal comfort of the workforce is crucial important (Lindhard and Wandahl 2012). Aiming towards a steady manning, when scheduling activities, simplifies the buffering of activities, because one week's buffer then equals next week's work. The manning should only be adjusted as a last resort when a problem occurs on site. By lowering the manning the capacity is decreased and production will slow down resulting in delay (Lindhard and Wandahl 2012b).

Material differs from the other resources needed in construction, because materials are depleted during the process. Because materials are depleted new materials continuously have to be delivered to the construction site. Moreover, every task needs its own special materials, resulting in thousands of different component which have to, in time, be delivered to the correct work task. The uniqueness of every work tasks creates complexity and increases the risk of non-present or incorrect materials. Furthermore, materials delivered to early have to be put on stock. Storing of materials has to be done carefully because of the risk of dwindling or damaged materials. Therefore, it continuously has to be ensured that the correct and fully functional materials are on site when needed. Finally, materials delivered just-in-time have an increased risk of not being present at the point of activity start. If the delay is occurring without a warning the delivery risk is combined with a shortened reaction time which makes it difficult to keep the production flow unaffected. In worst case the non-delivery is first discovered at the point of expected delivery. To ensure a constant feed of materials to the construction flow, the material flow has to be carefully thought through and include relevant logistics considerations and limitation. Moreover, the material flow has to be continuously monitored and controlled.

The last preconditions to a construction task are that the needed equipment and machinery are present. During execution phase the construction project is undergoing small sub-phases where different equipment and machinery is required. By compiling activities into small groups in relation to needed equipment and machinery, the gear does only have to be present in a restricted period. Restricting the presents of equipments and machinery by compiling of activities into groups, increase utilization rates and the necessity of sharing equipment and increase the interdependences between the crews on-site. To avoid conflicts and delay it is recommended to incorporate slack between handoffs. If slack is not incorporated the need for detailed plans and scheduled to control the process is increased. Normally breakdowns happen only rarely, but in harsh environment there is an increased tendency to experience breakdowns in the machinery. A breakdown has a major effect and on the work flow; therefore, it is necessary to minimize any downtime by either, maintaining, repairing, or replacing the machinery.

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Recommendations at the Phase Scheduling level

At the initial scheduling level the main task is to create the network of activities. The basic parameters to define this network include duration and handoffs to identify interrelationships and draw the overall connections. The critical path should be calculated to gain insight to critical activities and if possible slack should be incorporated to minimize the risk of delay. To refine the network of activities the six preconditions, which have importance during the execution process, are systematically linked to the schedule. This is done to identify and consider all critical elements in the schedule. Linking the six preconditions to the schedule supplements and enhances the existing management tools and increases the insight and understanding. The six preconditions include: safety, climate, space, workers, material, and machinery. The key points to go through are:

- Identify necessary safety precautions to the individual activity and plan for implementation.
- Identify critical climate parameters, consider possible precautions, and make a plan of action to different critical scenarios.
- Define the working area and space requirements to each activity. Ensure that space is available by linking usage to the schedule. Identify all elements which affect working comfort and seek to improve the conditions.
- Define the needed workforce to each activity and calculate the manning throughout the construction project. Aim towards a steady manning. Moreover, to improve output quantity and quality initiatives to secure comfort of the individual craftsman should be implemented.
- Define needed material to each work activity, and consider relevant logistic issues in relation to the material flow.
- Link shared material and equipment to each activity. Group the activities to improve the utilization rates. Create a back-up plan to minimize the effect of breakdowns.

Recommendations at the Look-ahead level

At the Look-ahead level the key purpose is to make activities ready for conductions. All nine preconditions have to be considered and fulfilled to ensure the soundness of every individual activity. Throughout the making-ready process it has to be ensured that all nine preconditions are fulfilled when the activity is scheduled to start. Activities with no constraints should be moved to a buffer but all preconditions have to be monitored to prevent resurrecting constraints. At risk

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activities should be kept in a "at risk buffer" until the risk is removed or the activity enters the Weekly Work Plan. At risk activities are activities which still contain constraints when entering the Weekly Work Plans (Liu and Ballard 2008). It is important to notice that the remaining constraints are expected to be removed before activity start, and could for instance be a late delivery of materials. Finally, the making ready process should seek towards optimal fulfillment of the preconditions to secure the best possible working conditions to improve the workflow and hinder negative variation which results in delay (Lindhard and Wandahl 2013b).

Recommendations at the Commitment level

Binding commitments are made at the point when an activity enters the Weekly Work Plan. To improve the quality and reliability of the commitments, they have to be reached in mutual agreement and with the best possible information in hand. First, the schedule has to be updated and reflect the current situation at the construction site. Based on the completion stage of the individual activity adjustments in the schedule has to be made to avoid any upcoming conflicts in handoffs. Second, the six preconditions which are linked to the schedule at the Phase Scheduling level need to be reincorporated to the schedule. This is achieved by systematically following the six preconditions and continuously update and integrate the results into the schedule. The key points to go through are:

- Consider the selected safety precautions to the individual activity, and follow up by site monitoring during the completion phase. Act immediately if anything critical is detected to hinder accidents in developing.
- Consider the implemented climate precautions and scenario plans and update if relevant. When scheduling next week's work, use weather forecast to keep track on the short-term effect of the climate parameters. Constantly follow the weather and act if critical changes occur.
- Update working areas and space requirements to each activity. Ensure that space is available by linking usage to the schedule. Consider the effect, of the initiatives implemented to improve the working comfort, and continuously seek for new ways to improve them.
- Make the final decision regarding the needed workforce to each activity and calculate next week's manning. Aim towards a steady manning throughout the entire construction project. Consider the effect of initiatives implemented, to improve the comfort of the

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individual craftsman, and continuously seek for new ways to improve them.

- Update needed material to each work activity and check for material availability. Consider site logistics and continuously seek for improvements.
- Update and link shared equipment and machinery to each activity to ensure availability. Group the activities, in relation to machinery usage, to improve utilization rates. Evaluate the maintenance and consider the effect of back-up plan in the search of improvements.

CONCLUSION

In an attempt to improve schedule quality, the criteria to the selection of activities to the schedule were examined. In a study conducted by Lindhard and Wandahl (2013a) it requested that today's criteria should be supplemented with flow considerations. Therefore, the nine flows were analyzed. Throughout the analysis it was found that only six of the flows were relevant as selection criteria. Of the six relevant flows three comprised the needed resources (workforce, material, and machinery) and three affecting the pace of the work (safety, climate conditions, and space). Because of the importance to progress in the workflow, and the on schedule completeness of activities, all six flows need to be systematically controlled. The output from the analysis is a list of tangible recommendations on how to include the flows as selection criteria both in the Phase Schedule, the Look-ahead Schedule, and the Weekly Work Plans.

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