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Removing Constraints to Make Tasks Ready in Weekly Work Planning

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Abstract

The Last Planner System (LPS) have been used on construction projects to improve reliable work planning. Lookahead planning is intermediate process that connects the master or phase schedule to the weekly work plan. Construction teams employ lookahead planning to achieve various objectives including a breakdown down of activities into the level of operations, operations design, and constraint removal to make tasks ready for execution. Tasks Made Ready (TMR) measures the performance of lookahead planning in identifying and eliminating constraints to make activities ready for implementation. The purpose of this paper is to study through computer simulation the impact of TMR on task execution, reliability of weekly work planning, and project duration. Results show that TMR is a good predictor of project duration. These results advise planners on the importance of the constraint removal process, how it influences the reliability of construction planning, and its impact on project duration.

Keywords: Constraints, Last Planner System, Lookahead Planning, Tasks Made Ready, Workflow.

1. Introduction

Planning is a crucial determinate of the success of any project. It consists of directing a project to meet its objectives in terms of time, cost, quality, and safety [1]. It follows then that any poor practice related to planning could ultimately lead to the project's failure. The traditional planning techniques, particularly the Critical Path Method (CPM), were criticized and deemed insufficient and inadequate by many researchers [2].

One of the major deficiencies of CPM is that it focuses on the logical dependencies between activities with a disregard for the continuity of workflow among different trades [3]. Another problem with CPM relates to allocating time buffers to cover possible uncertainties in activities [4]. This exercise brings about many constraints and especially prerequisite constraints that can disrupt the continuity of work. With these time buffers, it becomes difficult to determine when a certain activity will finish. This adds to the complexity of making tasks ready when needed resulting in a higher cost and longer project duration.

In the light of these and other inadequacies, the Last Planner System (LPS) has been developed for planning and controlling construction projects. It has been used to ensure and improve the continuity of workflow while increasing planning reliability by minimizing the difference between tasks that are planned and those that are actually completed [5,6].

The LPS consists of four planning phases: (1) *master scheduling* which sets major project milestones; (2) *phase* scheduling which identifies the activities that "should" be done as well as the handoffs among the different specialty organizations involved in the project; (3) *lookahead planning* which breaks down the tasks from processes to operations, identifies constraints, and assigns responsibilities to make tasks ready; and (4) *weekly work planning* during which reliable promises and commitments to execute the work are made [7, 8, 9].

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Of the LPS different phases, lookahead planning plays a critical role as it bridges between master and phase scheduling from one side and weekly work planning from the other side. It serves to break down tasks from the process level employed in the master and phase schedules into the operation level of detail that is needed for commitment. Moreover, as previously mentioned, tasks are made ready during this phase after identification and removal of different constraints [7, 9]. These constraints could subsume design or construction related information, equipment and machinery, labor, space, predecessor activities, weather conditions, and others [10, 11]. Thus, the reliability of the construction workflow can increase when tasks are made ready for execution just on time.

In the LPS, the reliability of the construction workflow is generally measured using the metric "Percent Plan Complete" denoted as PPC. PPC measures the percentage of tasks completed at the end of a fixed time interval relative to those that were planned at the beginning of this interval [7, 8]. As for measuring the performance of the lookahead planning phase, two metrics "tasks Anticipated" (TA) and "tasks made ready" (TMR) are used. TA measures the effectiveness of the lookahead planning in anticipating the tasks that are going to be executed in the future. On the other hand, TMR assess the performance of the lookahead planning in identifying and removing the different types of constraints, previously mentioned, for tasks to be ready for execution. TMR denoted as TMR (i, j) refers to the percentage of tasks anticipated on the lookahead plan i weeks ahead of the execution week j [12, 13].

Several studies have targeted the make-ready process [14, 15, 16]. In fact, one of the studies has explored the impact of the make-ready process on PPC. The percent of constraints removed relative to all constraints identified on the lookahead plan one week before execution was measured using a metric called "Percent of Constraint Removal" denoted as PCR_1. A strong correlation between PCR_1 and PPC was found in three case study projects [14, 15]. Other studies have shown that productivity increases with increased reliability of workflow which is reflected as a higher PPC [6]. However, there are no detailed studies addressing: (1) the planning actions followed; (2) the parameters that affect the make-ready process; and (3) the effect of modifying these parameters on the reliability of planning, measured in PPC and schedule performance, measured in project duration [13].

In acknowledgement of the need to explore such aspects, this paper aims at studying the relation between TMR, PPC, and project duration on construction projects by simulating real project conditions. The behaviours of TMR, PPC, and project duration are studied under various conditions enhancing the understanding of the effect of making tasks ready on planning reliability and project duration. For these purposes, a theoretical framework is developed for the make-ready process within lookahead planning. This is accomplished through building a simulation model for the make-ready process and testing different scenarios by varying different parameters. This will be further expanded in the methodology section below.

2. Methodology

The research method includes 4 main stages: (1) developing a conceptual model for weekly work planning starting form a lookahead schedule, (2) building the corresponding mathematical depiction of system into a computer simulation model; (3) designing an experiment to understand the impact of TMR on project duration while varying input parameters and measuring the output variables as shown in table 1; and (4) analyzing the results. Once the model was set and verified, it was used as a laboratory for testing various scenarios and project conditions.

2.1. *Weekly work planning process*

The lookahead process as it progresses from six weeks ahead of execution until the week of execution was modeled as follows.

(1) *6 to 3 weeks ahead of execution*: Tasks obtained from the phase or master schedule are added on the six weeks lookahead plan. During this period, gross constraints, which relate to phases and processes, are identified and removed. These constraints subsume, for example, design and material information which necessitate long lead time to be removed [5, 9]. Tasks are then broken down into processes and operations.

(2) *2 weeks ahead of execution:* Tasks are continuously broken down until they match the level of detail necessary for production at the weekly work plan level. During this week, specific constraints, relating to specific tasks or operations, are identified and then removed in order to make tasks ready. These constraints include prerequisite tasks, material, space, information, and other resources.

(3) *1 week ahead of execution:* At this stage, the process of *pulling* and *screening* of tasks is conducted. *Pulling* helps in identifying the tasks that should be made ready based on the actual site demand. As for *screening*, it helps determine the actions needed in order to remove the different types of constraints, previously discussed. This prevents commitment to tasks that cannot be made ready [7, 9]. At the end of this process, tasks are divided into two categories: tasks that are made Ready (R % of all) and those that are Not-Ready (1-R % of all). Out of the

Not-Ready tasks, a certain ratio P has a probability of having the constraints removed. These tasks, which are not Ready but can be made Ready (denoted as CMR) are advanced to the weekly work plan (WWP). The remaining portion (1-P) cannot be made Ready (CNMR) and, thus, is not advanced to the WWP. However, this portion will undergo the same analysis in the following lookahead planning cycle.

It should be noted that any task undergoes a process of *shielding* before joining the WWP. In this process, tasks are tested against five quality criteria including definition, soundness, sequence, size, and learning. Any task must be well defined, constraint-free, in a proper sequence, and adequately sized to match capacity and must allow learning for continuous improvement. By ensuring that only such tasks are moved to the WWP, the shielding process protects downstream tasks from uncertainties of upstream tasks and, thus, ameliorates plan reliability [12, 17].

Excess tasks that are ready but not critical are added to the workable backlog and are executed in case of extra available capacity. Some tasks other than those pebbles that were broken at the beginning of this cycle are added at the last moment to the WWP. These tasks (denoted as New) add more complexity to the planning process and might be hard to be made ready just in time for completion.

(4) *During the execution week:* Tasks that are actually unconstrained (denoted as Ready Ready-RR) and constrained tasks that were made ready during execution are successfully executed. On the other hand, some tasks that were perceived as ready before and they were actually not ready or got constrained during execution fail to be executed. These tasks are called “not quite ready” and denoted as 1-RR. As for the CMR tasks, coordinated effort must be made in order to remove their constraints and execute them. These tasks are denoted as NR while those that cannot be made ready are denoted as 1-NR. Regarding the New tasks, a portion of them denoted as N will be made ready and executed while the second portion denoted as 1-N cannot be made ready or executed.

At the end of this week, Percent Plan Complete (PPC) is calculated by dividing the number of tasks executed by the number of those planned. TMR is calculated by dividing the Made Ready task at WK0 (execution week) that have survived from WK2 (two weeks ahead of execution) over the total number of tasks on WK2. This lookahead planning process is repeated until all the tasks are executed denoting the end of the project.

Table 16 below summarizes the parameters used as well as their corresponding values.

Table 16. Test Parameters and Values

Parameters	Description	Values
Rocks	The number of tasks at the level of detail of processes in the project.	2,080
Rocks to pebbles	Ratio of the number of tasks at the lookahead level that an activity gets broken into.	Randomly selected from {2, 3, 4}
R	Percentage of tasks that are made ready during WK1.	{0.1, 0.3, 0.5, 0.7, 0.9, 1}
RR	Percentage of *Ready* tasks that are actually ready or unconstrained.	{0.1, 0.3, 0.5, 0.7, 0.9, 1}
P	Percentage of tasks that are *Not-Ready* but have a chance to become ready some time prior to their scheduled execution.	{0.1, 0.3, 0.5, 0.7, 0.9, 1}
NR	Percentage of *Not-Ready* tasks that will be made ready during the execution week.	{0.1, 0.3, 0.5, 0.7, 0.9, 1}
N	Percentage of *New* tasks made ready during the execution week.	{0.1, 0.3, 0.5, 0.7, 0.9, 1}
NBR	Ratio of *New* tasks at WWP to *tasks* at the end of *WK2*.	{0.1, 0.3, 0.5, 0.7, 0.9, 1}
New	Number of tasks added to the WWP at the last moment without undergoing lookahead planning process.	NBR*Broken Pebbles
Total number of runs	It is equivalent to all the possible combinations of values that the parameters can take which is equal to 6^6, given that each of the 6 parameter can take 6 different values {0.1, 0.3, 0.5, 0.7, 0.9, 1}.	46,656

2.2. *Simulation Model and Experiment*

The conceptual model was then built into a discrete event simulation model in Any Logic 7 (university edition, educational version). To test the relationship between TMR, PPC, and project duration, an experiment was designed to find the possible impacts on PPC and project duration when varying TMR. The experiment tests the impact of various combinations of parameters. To vary TMR, the governing parameters R, RR, P, NR, New, and

NBR are varied in almost all combinations. The resulting TMR, PPC, and project duration are recorded and analyzed as per the parameters shown in table 1. This experiment can resemble almost any type of project. Having six parameters taking on six different possible values, there are 46, 656 possible combinations studied. Results are shown in the next section.

3. Results and Discussion

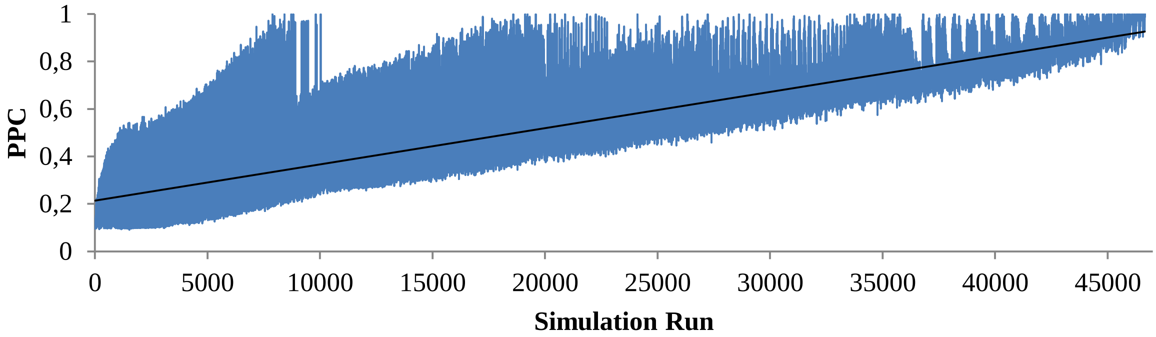
The experiment's objective is try all different combinations of the parameters shown in Table 1 and then analyse the resulting TMR, PPC and Project Duration. These results are shown in Figure 1. For each graph, the x-axis corresponds to the run number where each run consists of a different scenario defined by a certain combination of the project parameters R, RR, P, NR, N and NBR. It is important to note that although N and NBR have no major effect on TMR, they were included as part of the experiment's parameters due to their effect on PPC and project duration.

In order to get a clearer view of the results, the different scenarios are sorted according to increasing project duration. Linear trend lines are also added to both TMR and PPC to have a better idea of these results' overall trend. Moreover, the project duration's y-axis is fixed at 100 weeks even though some runs reached durations over 100. Adding these relatively few high values would have negatively altered the graph's scale, resulting in an insignificant representation of results.

The results show that as project duration decreases both PPC and TMR tend to increase as a general trend. It is also worth mentioning that the project duration's decreasing pattern is not linear but rather logarithmic which means that when PPC and TMR are low, working on increasing their values can greatly improve project performance. However, after a certain point, improving project duration becomes more challenging since the rate of improvement becomes less significant. In fact, a jump of TMR from 0.035 to 0.25 resulted in a total duration reduction of over 40 weeks whereas a jump of TMR from 0.25 to values close to 1 resulted in a reduction slightly greater than 10 weeks. This raises questions on the economic sense of increasing TMR beyond a certain threshold.

When the results are evaluated on a scenario by scenario basis, more interesting inferences can be made, especially regarding PPC. The PPC graph reveals that very high values are reached (values close to 1) for project durations as high as 77 weeks which is 20 weeks greater than the lowest possible duration. The same cannot be said about TMR since there are no instances where a high project duration is coupled with a high TMR. This is the case because PPC does not take into account cannot be made ready (CNMR) tasks unlike TMR. So, a high PPC coupled with a long duration simply means that the project is under-committing by having a high number of cannot be made ready tasks even though all the ready and can be made ready activities are being executed at a high rate.

Although the TMR trend is closer to that of project duration than PPC, it is still not completely linear, having a range of value for given project durations. This range is due to the presence of *New* tasks which are not part of the original weekly work plan. A high number of *New* tasks coupled with a low N (making them ready) will negatively affect project duration without affecting TMR since the latter does not take *New* into account. Similarly, a high number of *New* activities and a high N would positively impact project duration without affecting TMR. A high N is a sign of an agile project team who can work fast on removing constraints for tasks that emerge at the last moment. Despite this range of TMR resulting from variations in New and N, TMR still proves to be a better and more reliable indicator of project duration than PPC.



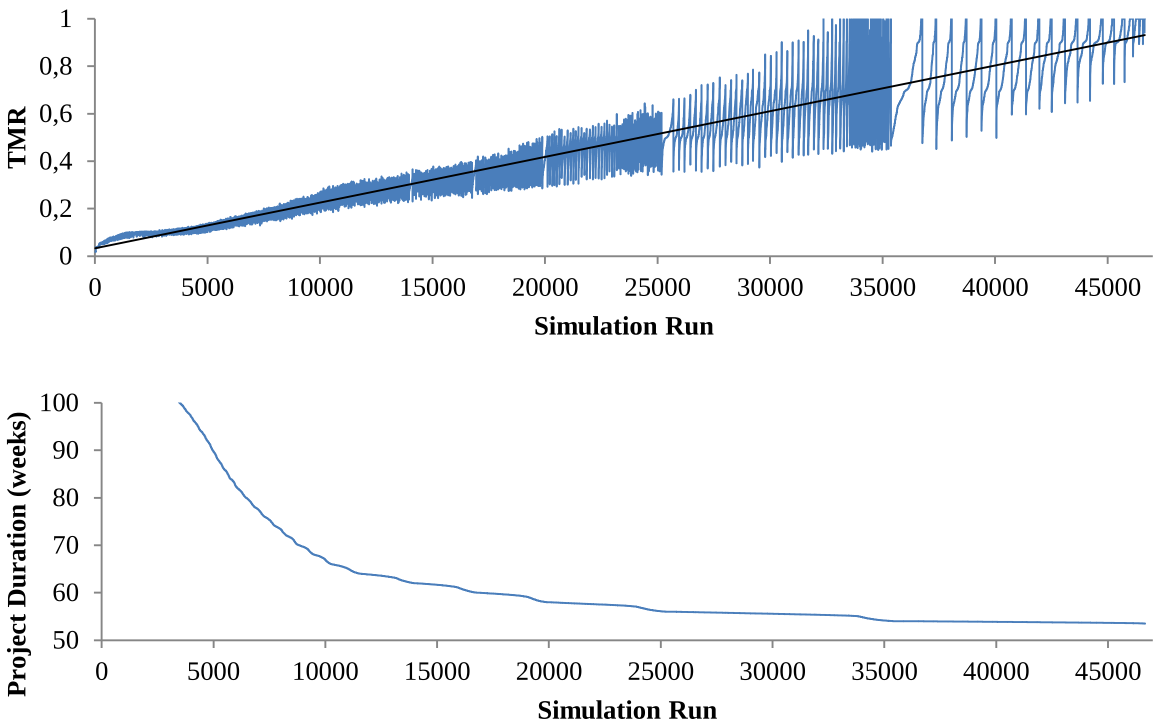


Figure 17. Results for TMR, PPC, and Project Duration

4. Conclusions

This study presents results from simulation experiments conducted to investigate the relationship between TMR, PPC, and project duration. The results confirm the importance of the make-ready process and how constraint removal can influence project duration. The practical impact of this finding suggests that improving the team's ability to perform sound lookahead planning, design operations to match load and capacity, and remove constraints before and during execution can have a profound impact on improving plan reliability measured by PPC and overall project duration.

As TMR increases, the project duration decreases in a clear fashion. However, the decrease in project duration flattens and becomes asymptotic for higher values of TMR. When New is high, the impact of TMR on project duration is shared with the impact of N. If TMR and N are high then project duration is at a minimum. A high N is a sign of an agile project team who can work fast on removing constraints for tasks that emerge at the last moment.

The results show that a high TMR can result in a reduced project duration but the same cannot be always said about PPC. A schedule with a high number of 'cannot be made ready' (CNMR) tasks can result in a high PPC but would most probably result in a long project duration. PPC can also be gamed by a project team on a real-life project to appear high by under committing.

In conclusion, TMR serves as a better indicator for project duration than PPC. The practical implications of this finding invites practitioners to put more focus on sound look ahead planning where future weekly work plans are studied early, operations are designed to match load and capacity, and constraints are successfully removed before and during execution. The fruits of this focus would show through improved plan reliability measured by PPC, a higher rate of constraint removal measured by TMR, and a reduced overall project duration resulting from executing more tasks on-time and enabling a timely start for more downstream tasks.

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