MODELING THE LAST PLANNER SYSTEM METRICS: A CASE STUDY OF AN AEC COMPANY

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ABSTRACT

The Last Planner System (LPS) helps increase the reliability of weekly work planning by properly connecting the master or phase schedule to the weekly work plan through lookahead planning. Two key measures for the success of the lookahead planning are the tasks anticipated (TA) and the tasks made ready (TMR); the first measures the percentage of anticipated activities on the look-ahead plan a couple of weeks before execution and the second 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 the relationship between TA, TMR, and PPC by analyzing LPS data collected over two years from several branches of an AEC company in the United States. The results show that company's team was extremely agile in removing constraints which translates into a high PPC despite the uncertain nature of design explained by the low TA.

KEY WORDS

Last Planner System (LPS), Lookahead Planning, Percent Planned Complete (PPC),Tasks Anticipated (TA), Tasks Made Ready (TMR), Weekly Work Plan (WWP)

INTRODUCTION

One of the goals for proper management of production on a construction project is increasing the reliability of workflow and making it more predictable during design and construction (Hamzeh et al. 2009). A major enabler for reliable workflow in a production system is the Last Planner System (LPS) (Ballard and Howell 2004). It includes four basic planning processes: (1) master scheduling, (2) phase scheduling, (3) lookahead planning, and (4) weekly work planning (WWP). In project planning, LPS allows planning in greater detail as execution date gets closer, identifying constrains during lookahead planning, and removing constraints in-time to make work ready for execution; thus increase the reliability of workflow. LPS promotes making reliable promises and drives work execution based on coordination and active negotiation among project participants. It also enables learning from plan failures by identifying main root cause for planning failures and implementing preventive measures (Ballard 2000, Ballard et al. 2009).

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Lookahead planning, as a key process in the LPS that contributes to developing foresight in planning and reducing production variations on a project. This process employs screening and pulling to break down tasks into a more detailed structure, converting tasks that "Should" be done into tasks that "Can" be done (Ballard 1997). Lookahead planning starts by generating a lookahead view of tasks in the next six weeks, then breaks down processes into operations, anticipate tasks, and identify their constraints for removal. Removing constraints is the main indicator of tasks being made ready. After tasks are made ready the planner assigns responsibilities and allocates resources. Figure 1 shows a detailed illustration of the LPS including the lookahead planning process.

Two key metrics used to measure the success of the lookahead planning are the tasks anticipated (TA) and the tasks made ready (TMR). Those two metrics are slightly different, where the first measures the percentage of anticipated activities on the look-ahead plan a couple of weeks before execution and the second measures the performance of lookahead planning in identifying and eliminating constraints to make activities ready for implementation (Ballard 1997).

Studies have been conducted to find a relation between the different metrics of lookahead planning. Hamzeh and Langerud (2011) used simulation to study the role of short term planning and the relationship between Tasks Anticipated (TA) and Percent Plan Complete (PPC). The simulation results showed that increasing TA through a set of enhancements in the team's ability to plan and design activities for execution can have a positive effect on PPC.

Other studies have addressed the impact of LPS on the performance of construction project. Formoso and Moura (2009) focused on the analysis of quantitative data to assess the impact of LPS based production planning on the performance of construction projects in terms of cost and time. The study employed several metrics and indicators such as PPC, cost, and time deviation. Three hypothesis were taken into account, the first assuming an inversely proportional relationship between PPC and the cost deviation, the second between PPC and time deviation, and the third assuming a direct relationship between site management and PPC. Results showed that effective planning comes from site management best practices and thus the relationship found was significant, however, the weak predictive results showed that PPC might be affected by another indices even though the analysis was consistent.

González et al. (2008) studied the relationship between planning reliability and project performance, at the activity and project level. They proposed an activity based planning reliability index (PRI), and a project-based aggregated labor-productivity index (PPI) trying to understand the effect of variance in planning reliability on the project performance. The study compared several performance indicators such as PRI and PPC as well as defined a linear relation between PPI and PPC. Statistical analysis showed that PRI on the activity level is a vital index that overcomes the limitations of PPC, and that PPI is another index that overcomes the limitations of some performance indicators on the project level.

Liu and Ballard (2008), studied the relation between construction labor productivity, PPC, work load, work output, and workers per week. The authors have performed a correlation analysis for the several variables based on the data collected from a pipe installation project. Results showed that productivity can improve when workflow is made more predictable thus matching work done according to plan to the actual work completed.

While the previous studies have looked at LPS from different perspectives, further research is required to study the relation between TA, TMR and assess their impact on PPC and overall project performance. This study analyzes LPS collected data from an Architecture, Engineering and Construction (AEC) firm over 12 months. The AEC Firm has been involved in different projects, with branches spread across different states in the United States (US). It is one of the leaders in the design of healthcare facilities and well known for its interest in lean design and for achieving maximum value for clients by optimizing design efficiency and adopting a process driven design. Understanding the people, economics, technologies, and processes enables designers to create a comfortable, sustainable and satisfying environment for its clients. The award winning firm claims the ability to solve complex design challenges.

Analyzing the collected data from the AEC firm aims at modeling and studying the relationships between TA, TMR and PPC. Understanding these relationships can benefit practitioners understand the operation of the LPS and advise currents practice on construction projects.

METHODOLOGY

This study analyzes data collected from a well-established AEC firm in the US with branches spread in different states like Colorado and California. The company has been using the LPS for a long time and has involved employees in planning and monitoring their own performance. The data collected describes the lookahead planning and weekly work planning efforts for each of the 41 employees working on several projects collected weekly 12 months.

The data will is processed and then fit into an analytical planning model designed by Hamzeh (2009) to mimic the lookahead planning and weekly work planning process in the LPS. The model describes the planning process, measures the performance through certain parameters and variables, and allows the calculation of various metrics, such as PPC, TA, and TMR. The performance of lookahead planning employed by this firm measured thought the individual lookahead planning performance of the employees are evaluated by integrating the collected data with the model using a series of formulas derived from the analytical model.

DATA AND MODEL DESCRIPTION

The data collected by the AEC Company came as a result of a company-wide initiative to improve lookahead planning, increase reliability through capturing variance, and applying the Deming process improvement cycle (Nickerson 2013). The data collected over two years included a lot useful details including:

- individual weekly work planning records
- submittal matrices per employee
- annual dashboards for labor, work planning and variance analysis
- records of different indices and metrics including PPC and TMR on a quarterly basis.

In addition to the well know LPS metrics, the data included other metrics developed by the firm's lean champion to measure and track the success of the program implementation. Some of these metrics are: the number of forms submitted each day, the number of forms submitted by end-of-business Monday, and variance for submission errors.

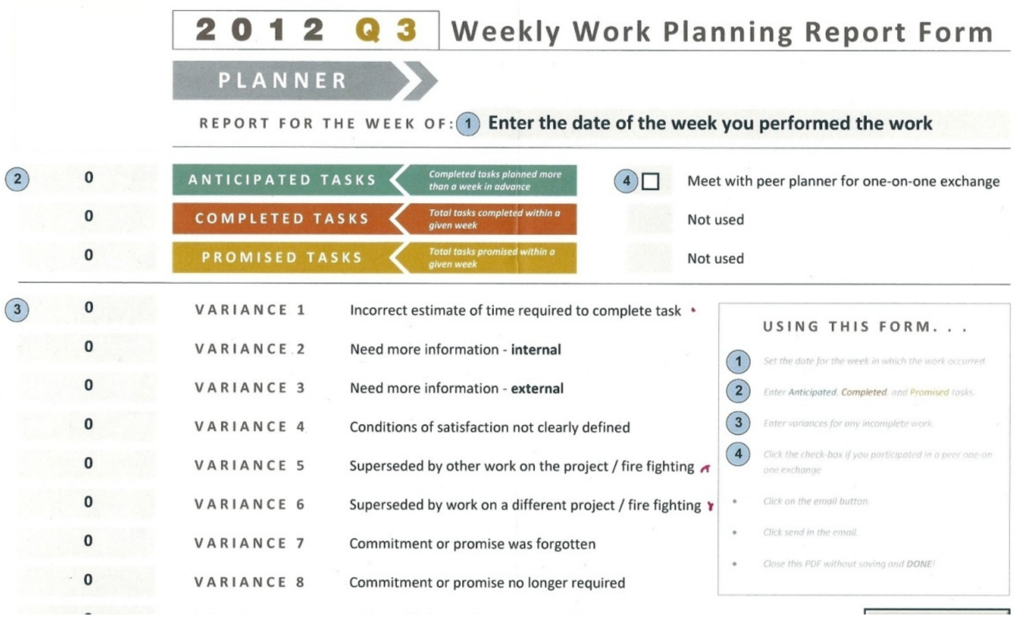
Employees submitted a weekly work planning form as shown in figure 2 below, to a central work planning account. The form included the following submittals: 1) completed tasks planned from the previous week called anticipated tasks in the form, 2) total tasks completed from previous week called total completed tasks, and 3) total promised tasks from the previous week. For each of the non-completed tasks from last week, employees submitted their reasons for non-completion according to nine different variance criteria namely: 1) incorrect estimate of time required to complete a task, 2) need more internal information, 3) need more external information, 4) conditions of satisfaction not clearly defined, 5) superseded by other work on the project/firefighting, 6) superseded by work on a different project/firefighting, 7) commitment or promise was forgotten, 8) commitment or promised no longer required, and 9) technical failure, sickness, or casus fortuitous prevented work completion.

The data was accumulated and uploaded into a spreadsheet as seen in figure 3 allowing program administrators to monitor, evaluate and compare data between employees, divisions, and hierarchies. Monitoring the LPS process is performed with the goal of adding value to the firm, although its contribution to improving the overall performance is not directly identified. Although most employees found that learning lookahead planning was a hard task, their performance in terms of lookahead planning metrics have shown significant improvement indicating the possibility of teaching and improving lookahead planning within a firm (Nickerson 2013).

This data collected is studied and analyzed through the lookahead planning process model developed by Hamzeh (2009). Results and data from this case study are fed into the process model to understand the relations between TA, TMR, and PPC. Results of this study are expected to advise practitioners and administrators on employee performance as well as the overall project or company performance.

The model shown in figure 4 consists of 3 main steps spanning throughout a 3 week-ahead planning schedule: 1) three weeks ahead of execution involves breaking down aggregated plans i.e. rocks into pebbles, 2) two weeks ahead of execution constraints are identified and tasks are made ready by removing these constraints, and 3) during execution week: the remaining constrained tasks are made ready and all tasks are either executed joining the pile of completed tasks or not executed joining the pile of not-completed tasks. Incomplete tasks re-enter the model to be executed in the upcoming weeks.

Three weeks before execution plans are still generic in detail, bulky in content and thus are considered as rocks. Two weeks before execution, rocks are to be broken down into pebbles. The pebbles are then separated into tasks that are "Ready" and "Not Ready". R% of the tasks represents those that have been made Ready and are in the workable backlog. And consequently, 1-R% represents those that are Not Ready.



2012 Q3 Weekly Work Planning Report Form

PLANNER

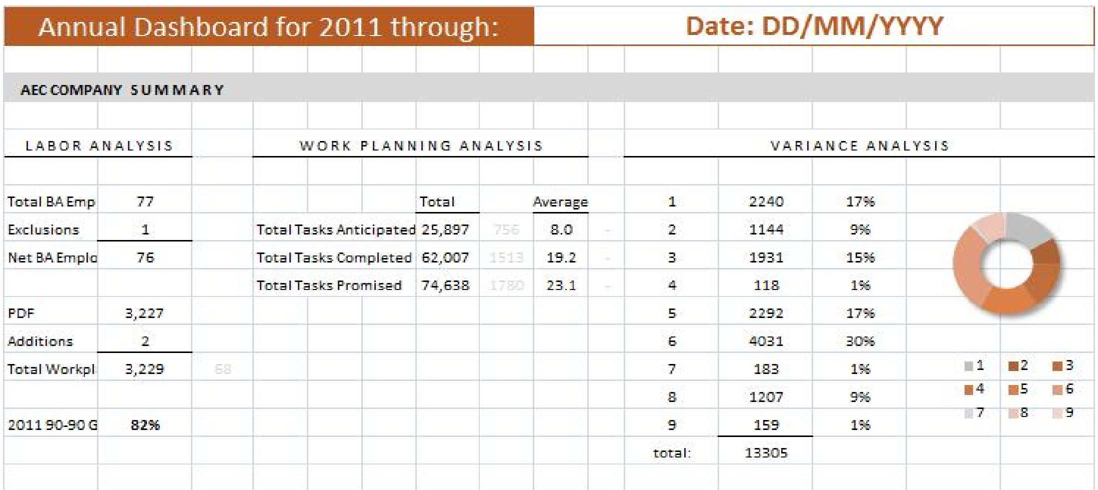
REPORT FOR THE WEEK OF: (1) Enter the date of the week you performed the work

(2) 0	ANTICIPATED TASKS	Completed tasks planned more than a week in advance	(4) ☐ Meet with peer planner for one-on-one exchange
0	COMPLETED TASKS	Total tasks completed within a given week	Not used
0	PROMISED TASKS	Total tasks promised within a given week	Not used

(3) 0	VARIANCE 1	Incorrect estimate of time required to complete task
0	VARIANCE 2	Need more information - **internal**
0	VARIANCE 3	Need more information - **external**
0	VARIANCE 4	Conditions of satisfaction not clearly defined
0	VARIANCE 5	Superseded by other work on the project / fire fighting
0	VARIANCE 6	Superseded by work on a different project / fire fighting
0	VARIANCE 7	Commitment or promise was forgotten
0	VARIANCE 8	Commitment or promise no longer required

USING THIS FORM. . .

Figure 1: weekly work planning (WWP) form used by the AEC firm



Annual Dashboard for 2011 through: Date: DD/MM/YYYY

AEC COMPANY SUMMARY

LABOR ANALYSIS		WORK PLANNING ANALYSIS	Total		Average	VARIANCE ANALYSIS		
Total BA Emp	77					1	2240	17%
Exclusions	1	Total Tasks Anticipated	25,897	756	8.0	2	1144	9%
Net BA Emplo	76	Total Tasks Completed	62,007	1513	19.2	3	1931	15%
		Total Tasks Promised	74,638	1780	23.1	4	118	1%
PDF	3,227					5	2292	17%
Additions	2					6	4031	30%
Total Workpl	3,229					7	183	1%
						8	1207	9%
2011 90-90 G	82%					9	159	1%
						total:	13305	

Figure 2: Firm-Wide Reporting/Monitoring Tool (as set by Nickerson 2013)

Shielding is an important step in lookahead planning required to filter tasks into: 1) Tasks that are critical and ready, 2) Tasks that are critical and can be made ready, and 3) tasks that are not critical and ready. Any excess tasks join the ‘fall back and follow on list’ to be considered in the following weeks.

At beginning of the executing week, the model accounts for the introduction of *New* tasks that have not been broken down or evaluated during the lookahead planning stage but suddenly emerged as required for execution.

At the beginning of the execution week, the WWP contains: 1) tasks perceived as Ready , 2) Not Ready but can be made Ready tasks, and 3) New Tasks. RR represents the percentage of the perceived Ready tasks that will be executed. Those executed are called ‘ReadyReady’. 1-RR is the percentage of the tasks that were perceived as Ready but are actually not quite ready. From tasks that are ‘Not Ready’ but can be made ready, NR is the percentage of the task that will be made ready, while 1-NR% join the batch of those not quite ready. As for the new tasks, N% of the new tasks will be made ready, and so they sum up with the RR% and NR% as 'ReadyReady' tasks. On the other hand 1-N% falls down into tasks not quite ready. The Execution Plan phase is the final stage the tasks pass through in this model. Assuming no failure in execution, all the 'ReadyReady' tasks are expected to be done i.e. complete by end of execution week. Tasks that are not done will be analyzed again in the upcoming planning week so that their constraints will be removed and make it to the weekly work plan.

The model allows visualization of the path of both tasks ready and not ready and enables calculation of the different metrics (PPC, TA and TMR) that last planners need in order to perform the required evaluations. The results are realized from the model using certain theoretical formulae shown in the next section.

MODEL INPUT AND RESULTS

Data from the AEC Company was processed to be compared to the process model in the form of total tasks anticipated, complete and promised. The output is TMR and TA. This exercise enables company managers to assess and evaluate the performance of the employees and thus the overall performance of the company

To explain how the data was fitted into the model, a sample calculation was developed. Data used in the sample is an accumulation of results from 41 employees over one year.

The input for the data includes: 1) TTA: Total Tasks Anticipated = 25897 which is the number of tasks completed during previous execution week that were successfully anticipated more than a week in advance, 2) TTC: Total Tasks Completed = 62007 which the total number of tasks completed from previous weeks and 3) TTP: Total Tasks Promised = 74638 which the total number of tasks promised from previous week.

From the model, the total tasks anticipated accounting for both tasks ready and tasks that can be made ready (CMR) is:

1. TTA= Ready × RR + CMR × NR , where RR is the percentage of tasks that are 'ReadyReady', and NR is the percentage of tasks that are Not Ready. This formula describes tasks during the 'Shield' phase.

The total tasks promised but not completed are given as:

2. Ready * (1-RR) + CMR * (1-NR) + New (1-N) = 12631 = TTP - TTC

Formula 2 represents tasks that are ready but were not completed plus those that can be made ready and are not completed yet, in addition to the new tasks that emerged and are still not completed. In other words this formula which describes

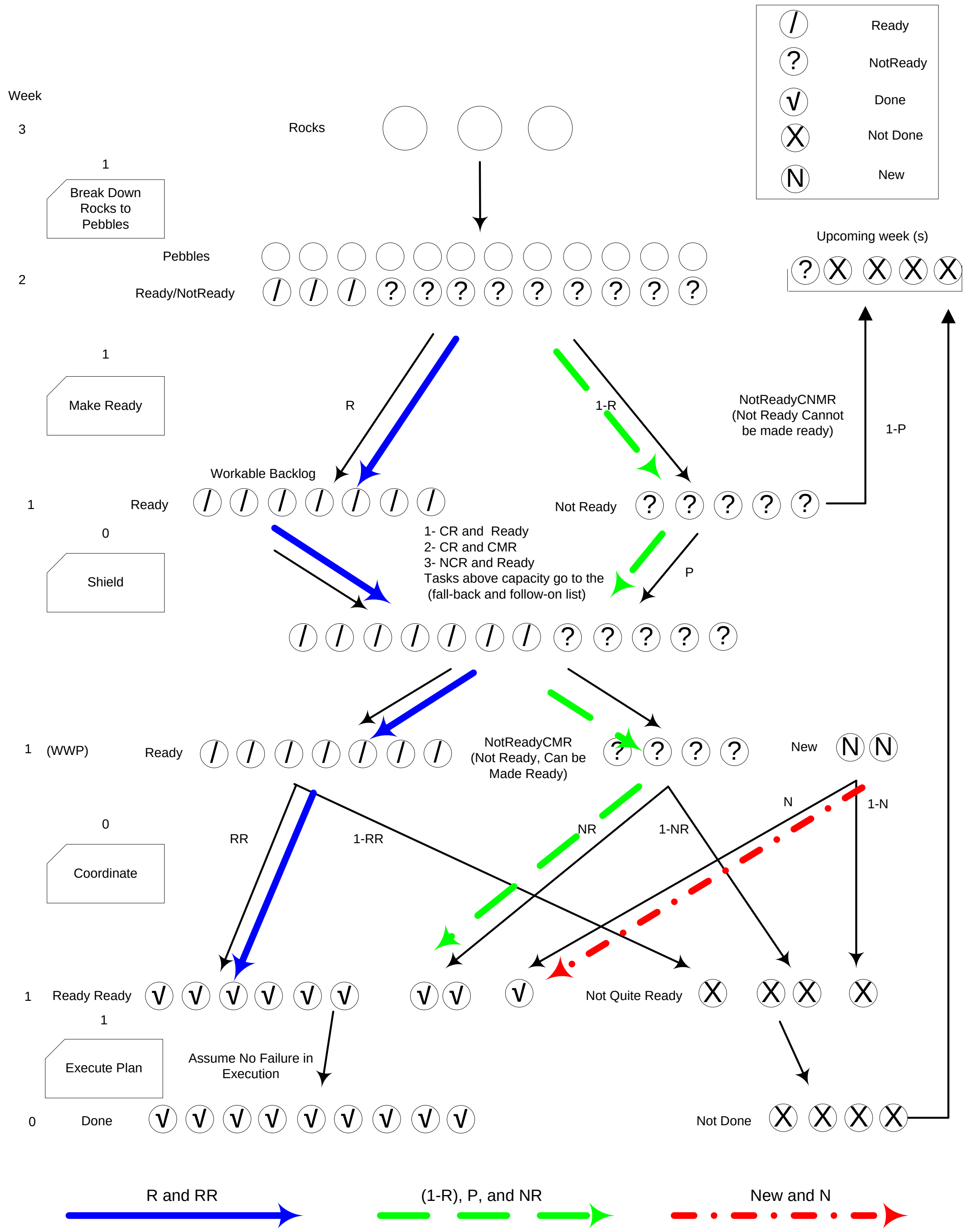


Figure 3: Possible paths that tasks take from the lookahead plan to the weekly work plan (Hamzeh 2009)

'Coordination' within weekly work planning represents all the tasks that will be reconsidered in the upcoming planning week, and pass through the same filtering procedure again, until the tasks are made ready and constraints are fully removed.

The new tasks that were completed can be calculated by subtracting the total number of completed tasks within a given week from the completed tasks planned more than a week in advance:

3. New × N = TTC (62,007) – TTA (25,897) = 36110
4. New (1-N) =0→(TTP-TTC) or 0→12631 (as minimum and maximum value)
5. Total New Tasks (complete + Incomplete) = 36110 + 12631 = 48741
6. Therefore, N% = 36110/48741=74%
7. N ranges: (0.74→1)

This allows us to determine the Tasks Anticipated (TA), PPC and TMR:

8. TA=(TTP-New)/TTP, TA ranges between a Min and a Max
9. TA(Min)= TTA/TTP
10. TA(Max)= [TTP- (TTC-TTA)]/TTP
11. TA = 0.347→0.516

The metrics can be summarized as follows:

12. PPC = TTC/TTP = 62,007/74638 = 0.83
13. TMR = TTA/TTC = 25,897/62,007 = 0.42
14. N= 0.74 => New = 48741, & TA=0.35
15. N= 1.00 => New = 36110, & TA=0.52

It is noticed that the number of New tasks per week is high and is even higher than those already anticipated. The good thing is that the company was able to make the majority of the New tasks ready during the execution week. This is required for design processes where there are a lot of New tasks coming up during the execution week.

ANALYSIS AND CONCLUSIONS

The LPS data collected for 135 employees was then sorted and six employees were selected from each hierarchy in the company for a better and generic representation. The staff selected varied from being interns to architects and leader architects. Each employee was listed along with his/her relevant TTA, TTC, and TTP for each week as shown in Table 1.

Based on the data given as well as the formulae realized from the model, the 'New x N' tasks were calculated for each employee along with the PPC and TMR. From the collected data a deterministic result for TA was not possible, that is why it was sorted within a min-max range. Accordingly, TA was given a range value between a minimum and a maximum as calculated above.

Table 2 shows the results generated for the last 12 months of data collection. The average values were then sorted out in one table and graphs were generated illustrating the PPC, TMR, TA range (min→ max), with x being the resultant of the TA formula after subtracting TTP from TTC in the numerator. Below is the table showing values calculated for the last two months of data collection

Table 1: Sample of the different metrics calculated for 6 employees

		TTA	TTC	TTP	NewxN	TA (min)	TA (max)	PPC	TMR
Week1 7/2/2011	Intern 2	6	12	14	6	0.43	0.57	0.86	0.50
	Intern 3	8	23	28	15	0.29	0.46	0.82	0.35
	Arch 1	21	24	24	3	0.88	0.88	1.00	0.88
	Arch 2	8	17	18	9	0.44	0.50	0.94	0.47
	Arch 3	8	36	38	28	0.21	0.26	0.95	0.22
	Arch 4	23	46	55	23	0.42	0.58	0.84	0.50
				AVG =	14	0.44	0.54	0.90	0.49

As noticed, PPC maintained a proper acceptable value throughout the whole year ranging between 90% and 80%. The TA's Paths (min and max) are quite similar ranging between 45% and 55%. What is interesting is that although TA is low (close to 50%) the company has maintained a high PPC. This can be due to the uncertain nature of design where forecasting tasks two weeks in advance is difficult. However, since the number of new tasks is high and PPC is high, the only explanation is that the team is extremely agile in removing constraints and making tasks ready during the execution week.

Table 2: Average Metrics Calculated over the last 12 months of data collection

	Week	NEW	TA(min)	TA (max)	PPC	TMR
January	J0	13.83	0.35	0.42	0.92	0.37
	J1	14	0.37	0.50	0.87	0.42
	J2	16.33	0.41	0.51	0.90	0.45
	J3	15.17	0.38	0.49	0.89	0.42
	J4	12.67	0.39	0.60	0.79	0.51
February	F1	14	0.44	0.54	0.9	0.49
	F2	10.5	0.45	0.56	0.89	0.5
	F3	13.33	0.44	0.5	0.94	0.47
	F4	11.67	0.46	0.55	0.9	0.51
March	M1	9.33	0.44	0.63	0.81	0.56
	M2	12.50	0.41	0.54	0.87	0.49
	M3	7.83	0.52	0.70	0.82	0.64
	M4	13.33	0.40	0.55	0.85	0.48
April	A1	12.83	0.47	0.63	0.85	0.56
	A2	10.40	0.42	0.58	0.84	0.49
	A3	11.50	0.48	0.59	0.89	0.53
	A4	10.80	0.46	0.60	0.87	0.53
May	M0	10.17	0.48	0.59	0.88	0.53
	M1	13.50	0.39	0.54	0.84	0.47
	M2	13.33	0.48	0.58	0.90	0.53
	M3	10.33	0.52	0.62	0.90	0.57
	M4	8.50	0.51	0.64	0.87	0.59
June	J1	11	0.33	0.44	0.89	0.36
	J2	10	0.52	0.65	0.87	0.60
	J3	5.75	0.51	0.64	0.87	0.57

	Week	NEW	TA(min)	TA (max)	PPC	TMR
July	J1	8.2	0.47	0.63	0.84	0.55
	J2	11	0.48	0.60	0.88	0.55
	J3	10.33	0.49	0.74	0.75	0.84
	J4	11.17	0.52	0.64	0.88	0.59
August	A1	8.2	0.59	0.71	0.88	0.66
	A2	8.67	0.52	0.64	0.87	0.58
	A3	7.33	0.54	0.65	0.90	0.59
	A4	10.5	0.35	0.51	0.85	0.42
	A5	12.4	0.39	0.56	0.83	0.47
September	S1	7.6	0.50	0.65	0.85	0.59
	S2	8.67	0.52	0.63	0.89	0.58
	S3	8.17	0.56	0.69	0.87	0.62
	S4	10.4	0.46	0.57	0.89	0.51
October	O1	11.3	0.35	0.54	0.82	0.44
	O2	10.7	0.51	0.56	0.95	0.53
	O3	12	0.44	0.54	0.90	0.47
	O4	9.8	0.46	0.59	0.87	0.52
	O5	7.25	0.49	0.67	0.82	0.56
November	N1	15.5	0.33	0.43	0.90	0.35
	N2	11	0.44	0.54	0.90	0.48
	N3	4.25	0.69	0.75	0.94	0.72
	N4	9.33	0.45	0.53	0.92	0.48
December	D1	9.33	0.44	0.55	0.88	0.50
	D2	9.5	0.44	0.54	0.91	0.48
	D3	9	0.42	0.54	0.88	0.46

Although the employees were still learning and perfecting the lookahead planning process, PPC recorded is high relative to the calculated TA. The interesting factor is the firm's ability to making new tasks ready during the execution week although many of the tasks listed on the WWP were not present during the lookahead planning stage two weeks ahead of execution. Employees seem to excel at removing constraints of new unforeseen tasks and making them ready for execution. The learning process and the strategy adopted by this firm is remarkable. However, further research is required to learn about the constraint removal process that the company is applying within the execution week.

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