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THE NEW LPS® METRICS – What They Are, Why They Are Needed and Where They Are Used

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Introduction

Based on the interviews that were conducted and the review of academic papers on the subject of the Last Planner System® (LPS®) the most commonly cited problem is that of connecting the short term Weekly Work Plan (WWP) cycle to the far longer term master milestone schedule. This was found to be a concern during all phases of a project.

However, there are projects that have implemented LPS that have focused on this shortcoming and solved for it by introducing new metrics that track the impact of the short term WWP on the long-term phase milestones. The new metrics make this impact visible, and in making it visible it allows the team to learn and create countermeasures on a weekly cycle that creates long term schedule stability. It is the invisibility of the impact of the short term on the long term that lies at the heart of the problem.

Specifically, the new metrics are Milestone Variance (MV), Commitment Level (CL) and Percent Required Complete (PRC). Additionally, these new metrics require the introduction of two new terms to LPS®: Required Tasks (RT) and Non-Required Tasks (NRT). More will be said about these new metrics and the new terms in a moment.

Where the Metrics Are Used in the Steps of the Last Planner System®

SHOULD:	Milestone Variance (KMV)
CAN:	*No new metrics are proposed*
WILL:	Commitment Level (CL)
DID:	Percent Required Complete (PRC)
DID:	Percent Planned Complete (PPC)
DID:	Milestone Variance (MV)

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Definitions of the New Metrics and New Terms

Required Task (RT): Any task which if not completed as planned on time will delay a milestone or milestones, thus creating a negative Milestone Variance (MV)

Non-Required Task (NRT): Any task which if not completed as planned on time will not delay a milestone or milestone, thus leaving such Milestone Variances at zero or positive.

- Examples of NRT are workable backlog, and any work on the plan that has significant float.
- Proposal for the Metrics that are included in the new Benchmark

Commitment Level (CL): Is the percentage of Required Tasks (RT's) that a team has committed to completing in the next weekly work plan

Milestone Variance (MV): Is the number of days a milestone is projected to be early (positive variance) or late (negative variance).

Percent Required Complete (PRC): Is the percentage of Required Tasks (RT's) that the team completed in the prior weekly work plan, regardless of whether the team committed to completing them or not. Also allows tasks that are longer duration than the planning cycle to be reported as sufficiently complete this cycle that they will be complete on time in the future work cycle.

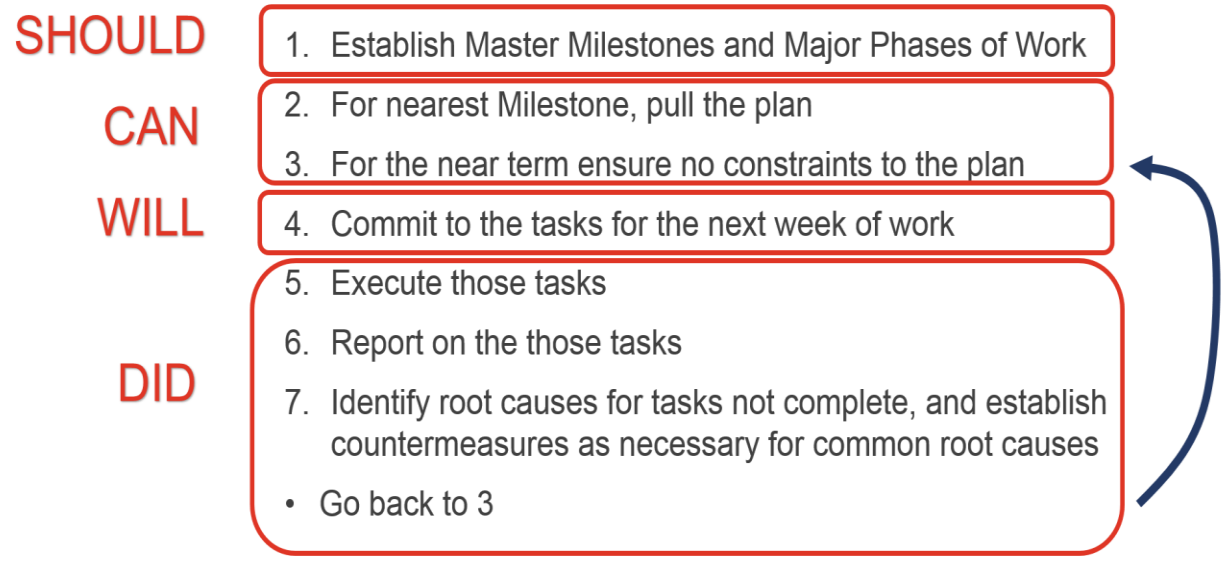

Figure 1: How LPS Process Benchmark 2016 is Currently Typically Executed

Note: No changes to the use and measurement of PPC are proposed. This should happen as previously described per LPS Process Benchmark 2016. It remains a useful measure of behavior – namely is the team developing a habit of aiming to complete 100% of the work it committed to.

- Which Metrics are Needed in Which Phase of a Project?

1. Conceptual Design / Ideation / Validation / Value Definition
    - Milestone Variance (MV)
2. Design Development / Production Design / Implementation Documents

- Commitment Level (CL)
- Percent Required Complete (PRC)
- Milestone Variance (MV)
- Planned Percent Complete (PPC)

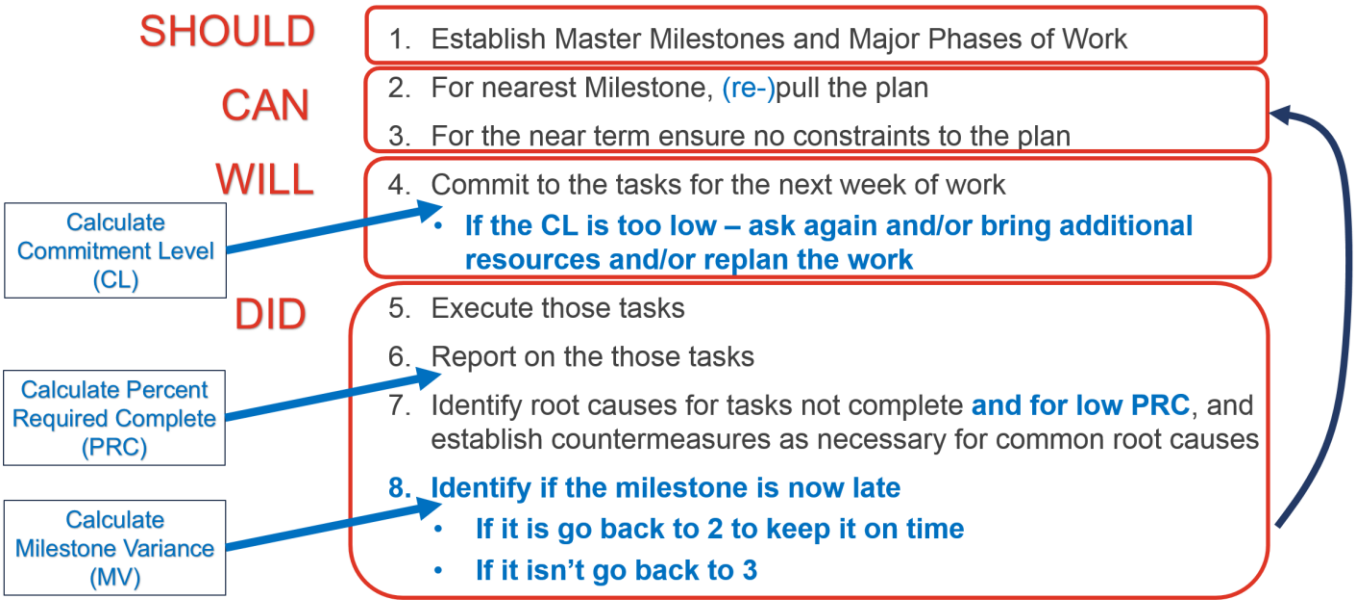

Figure 2: How the New Metrics Create 3 New Opportunities for Action During Every Weekly Cycle

3. Construction
   - Commitment Level (CL)
   - Percent Required Complete (PRC)
   - Milestone Variance (MV)
   - Planned Percent Complete (PPC)
4. Commissioning, Move-In, Activation
   - Commitment Level (CL)
   - Percent Required Complete (PRC)
   - Milestone Variance (MV)
   - Planned Percent Complete (PPC)

Guidance on Use of Metrics Depending on Major Project Phase

Early-Design

The different terms commonly used to describe this phase or parts of this phase include but are not limited to: Ideation, Value Definition, Validation, Conceptual Design and early Schematic Design.

In this major phase the focus is on getting aligned on the major milestones and what those milestones are and what they require and also on what built-environment solution best aligns with the post-project objectives of the key stakeholders.

There is a high-level of discovery so whatever plan of work it is put together is subject to revision fairly frequently and these revisions can be significant.

Rigid adherence to a weekly work planning cycle, and assessing PPC and reacting to it may not be as critical as making sure there's team alignment on the definition of the milestones they are seeking to meet, and agreeing that they have the sequence of the milestones correct to avoid major cycles of rework.

As this major phase often utilizes relatively scarce expertise (space planners, operational analysts, conceptual estimators) and often requires decisions from senior stakeholders who are hard to schedule, issues of a) capacity to do work and b) what decisions are required and when, should be explored and accounted for in the plan of work.

The major habit to develop in the above context and in the context of a skill that will remain valuable through the other major phases is that of regularly replanning the sequence of work so that the Milestone Variance (MV) for the milestones remains at zero or positive.

Therefore, the only recommended metric during this major phase is Milestone Variance. In regard to Milestone Variance (MV) during Early Design the following advice is given?

- Assess MV as and when necessary rather than per a WWP cycle
- If MV is negative it should trigger a review of one or all of the following:
  - Task durations
  - Task sequences
  - Trends in root causes in tasks not being completed. Such as:
    - Resource capacity
    - Unplanned constraints
- Typical countermeasures include: (note these kinds of countermeasures are rarely realistic options in the construction phase)
  - Discovering that not all the work is required to release the next task
  - Doing work at risk
    - E.g. a prerequisite task is not completed so rather than wait for the certainty that comes with full completion, make an educated guess as to what it will probably be and proceed based on that
- Resequencing the milestones or slicing and dicing them differently is more available in this phase than in later design and construction. But can be an option in this very early, more dynamic phase.
- Solving negative MV's by moving the milestone should only be done with consent of the leadership of the project, as it typically acknowledges the project will be late or indicates the risk of the project being late is increasing.

Later-Design

The different terms commonly used to describe this phase or parts of this phase include but are not limited to: Mid to Late Schematic Design, Design Development, Construction Drawings, Implementation Documents, Production Design

Compared to the construction phase which it supports, this Later-Design phase has more of an emphasis on decision sequencing and planning information workflows, and there are more opportunities do work at risk, or start work based on reasonable assumptions rather than fully-finished prior work, but from the perspective of LPS and LPS metrics, LPS in this phase is very similar to LPS in the construction phase.

- CL – Commitment Level
  - Assessed at the start of the weekly planning cycle
  - Percentage of Tasks Required to be Complete to keep the project on time
    - For simple projects that use manual processes the denominator could be all the tasks in the one week lookahead, and the numerator would the number of tasks that are committed to
    - For complex projects using linked networks of tasks connected to a set of milestones, the denominator would be all the tasks that need to be completed during the upcoming week to keep the milestone variance (MV) for all milestones at zero – i.e. a more sophisticated assessment of whether the project will stay on time or not.
- A Behavioral and Performance Metric
  - Performance because it assesses whether the team is committing to enough work to keep the project on time and gives them an opportunity where it's less than 100% to reassess the plan, and their capacity before the planning window commences
  - Behavioral because consistently low CL can indicate a problem with moral, with cohesion, with trust, with the psychological safety of the project work environment
- PPC – Percent Planned Complete
  - A Behavioral Metric
  - Assessed at the close of the weekly planning cycle
- PRC – Percent Required Completed
  - Assessed at the end of the weekly planning cycle
  - A performance metric
    - Low PRC means the project team is unable to do the work it needs to do to keep the project on schedule.
    - Consistently low PRC means the project is highly likely to finish late.
    - Consistently low PRC means there is something to investigate including but not limited to:
      - Level of resources being brought to the project
      - Breakdown in the Make-Ready process within the Lookahead phase
      - Morale
      - Psychological safety
- MV - Milestone Variance
  - Assessed at the close of the weekly planning cycle
  - Assessed for each milestone

- Negative MV can trigger replanning of
  - Task durations
  - Task sequences
  - Resource capacity
- Solving negative MV's by moving the milestones should only be done with consent of the leadership of the project, as it typically acknowledges the project will be late or indicated the risk of the project being late is increasing.

Construction

The guidance is as follows:

- CL – Commitment Level
  - Assessed at the start of the weekly planning cycle
  - Percentage of Tasks Required to be Complete to keep the project on time
    - For simple projects that use manual processes the denominator could be all the tasks in the one week lookahead, and the numerator would be the number of tasks that are committed to
    - For complex projects using linked networks of tasks connected to a set of milestones, the denominator would be all the tasks that need to be completed during the upcoming week to keep the milestone variance (MV) for all milestones at zero – i.e. a more sophisticated assessment of whether the project will stay on time or not.
  - A Behavioral and Performance Metric
    - Performance because it assesses whether the team is committing to enough work to keep the project on time and gives them an opportunity where it's less than 100% to reassess the plan, and their capacity before the planning window commences
    - Behavioral because consistently low CL can indicate a problem with morale, with cohesion, with trust, with the psychological safety of the project work environment
- PPC – Percent Planned Complete
  - A Behavioral Metric
  - Assessed at the close of the weekly planning cycle
- PRC – Percent Required Completed
  - Assessed at the end of the weekly planning cycle
  - A performance metric
    - Low PRC means the project team is unable to do the work it needs to do to keep the project on schedule.
    - Consistently low PRC means the project is highly likely to finish late.
    - Consistently low PRC means there is something to investigate including but not limited to:
      - Level of resources being brought to the project
      - Breakdown in the Make-Ready process within the Lookahead phase

  - Morale
  - Psychological safety

- MV - Milestone Variance
  - Assessed at the close of the weekly planning cycle
  - Assessed for each milestone
  - Negative MV can trigger replanning of
    - Task durations
    - Task sequences
    - Resource capacity
  - Solving negative MV's by moving the milestones should only be done with consent of the leadership of the project, as it typically acknowledges the project will be late or indicated the risk of the project being late is increasing.

Commissioning, Move-In, Activation

This phase has a lot in common with the latter Phase in the sense that there is a similar emphasis on more of an emphasis on decision sequencing and there are more opportunities than in construction do work at risk, or start work based on reasonable assumptions rather than fully-finished prior work.

- CL – Commitment Level
  - Assessed at the start of the weekly planning cycle
  - Percentage of Tasks Required to be Complete to keep the project on time
    - For simple projects that use manual processes the denominator could be all the tasks in the one week lookahead, and the numerator would the number of tasks that are committed to
    - For complex projects using linked networks of tasks connected to a set of milestones, the denominator would be all the tasks that need to be completed during the upcoming week to keep the milestone variance (MV) for all milestones at zero – i.e. a more sophisticated assessment of whether the project will stay on time or not.
- A Behavioral and Performance Metric
  - Performance because it assesses whether the team is committing to enough work to keep the project on time and gives them an opportunity where it's less than 100% to reassess the plan, and their capacity before the planning window commences
  - Behavioral because consistently low CL can indicate a problem with morale, with cohesion, with trust, with the psychological safety of the project work environment
- PPC – Percent Planned Complete
  - A Behavioral Metric
  - Assessed at the close of the weekly planning cycle
- PRC – Percent Required Completed
  - Assessed at the end of the weekly planning cycle

- A performance metric
  - Low PRC means the project team is unable to do the work it needs to do to keep the project on schedule.
  - Consistently low PRC means the project is highly likely to finish late.
  - Consistently low PRC means there is something to investigate including but not limited to:
    - Level of resources being brought to the project
    - Breakdown in the Make-Ready process within the Lookahead phase
    - Morale
    - Psychological safety

- MV - Milestone Variance
  - Assessed at the close of the weekly planning cycle
  - Assessed for each milestone
  - Negative MV can trigger replanning of
    - Task durations
    - Task sequences
    - Resource capacity
- Solving negative MV's by moving the milestones should only be done with consent of the leadership of the project, as it typically acknowledges the project will be late or indicated the risk of the project being late is increasing.

Basis for Further Research: Potential Additional Metrics to help LPS Implementations

Based on the interviews and literature review additional metrics have been identified with the potential to further improve LPS implementations. These currently have only conceptual definitions and only proposed methods to calculate them.

Potential Additional Metrics and Terms and Their Definition

Unanticipated Tasks (UT): Tasks that need to be done that were not anticipated in the agreed work plan.

Capacity Buffer (CB): A measure of how much capacity exists in a team to handle variations in the workload such as UT's, or imperfect assessments of the effort required to complete a planned task

Capacity Shortfall (CS): Measures how much work is not getting done due to unavailability of the required labor resource

Resource Leveling (RL): A measure of how much variation there is in the required size of a given crew week to week

Plan Stability (PS): How similar is the plan in the upcoming weekly work plan to the plan for that same week of work a week ago, two weeks ago, three weeks ago, etc.

Which Metrics are Needed in Which Phase of a Project?

1. In Early Phase Design

- Unanticipated Tasks (UT)
- Capacity Buffer (CB)

2. In Later Phase Design
   - Unanticipated Tasks (UT)
   - Capacity Buffer (CB)
   - Capacity Shortfall (CS)
3. In Construction
   - Unanticipated Tasks (UT)
   - Capacity Shortfall (CS)
   - Resource Leveling (RL)
   - Plan Stability (PS)
4. In Commissioning, Move-In, Activation
   - Unanticipated Tasks (UT)
   - Capacity Buffer (CB)
   - Capacity Shortfall (CS)

Guidance on Use of Potential Additional Metrics Depending on Major Project Phase

Early Design

There is a high-level of discovery so the plan is subject to a relatively high number of Unanticipated Tasks (UT) and a relatively high incidence of incorrectly estimating the amount of effort it will take to complete a planned task. The amount of capacity a team has to deal with such occurrences without impacting the milestones could be a big driver of overall success so the ability to assess this capacity could be important.

- CB - Capacity Buffer
  - How much resource capacity should you add during design to catch all the Unanticipated Tasks (UT) and the additional effort discovered for any given planned task.
  - Can you develop guidance to teams in this phase to only, say, commit 75% of their capacity to the WWP?
  - Can you identify when the CB is dangerously low?
  - What metric would be easy to measure and useful to track?
    - Could it be total team FTE expressed as an hourly amount per week (or whatever cycle time works for this early phase of work) divided into the total estimate hours for the committed tasks in the WWP

Later Design

- CB - Capacity Buffer
  - How much resource capacity should you add during design to catch all the Unanticipated Tasks (UT) and the additional effort discovered for any given planned task.

  - Can you develop guidance to teams in this phase to only, say, commit 75% of their capacity to the WWP?
  - Can you identify when the CB is dangerously low?
  - What metric would be easy to measure and useful to track?
    - Could it be total team FTE expressed as an hourly amount per week (or whatever cycle time works for this early phase of work) divided into the total estimate hours for the committed tasks in the WWP
- CS – Capacity Shortfall
  - How much work whether planned or unplanned is not getting done due to unavailability of labor resources.
  - What metric would be easy to measure and useful to track?
    - Could it be
      - Count the number of tasks not done due to labor not available
      - Add to that the number of tasks done
      - Divide that total into the total number of tasks not done due to labor not available.
    - If this is high and stays high, it allows a conversation to be had around whether the project has an appropriate level of resources available on the project.

Construction Phase

- CS – Capacity Shortfall
  - How much work whether planned or unplanned is not getting done due to unavailability of labor resources.
  - What metric would be easy to measure and useful to track?
    - Could it be
      - Count the number of tasks not done due to labor not available
      - Add to that the number of tasks done
      - Divide that total into the total number of tasks not done due to labor not available.
    - If this is high and stays high, it allows a conversation to be had around whether the project has an appropriate level of resources available on the project.
- RL – Resource Leveling
  - How stable is the crewing of the project? This can indicate how good the team is at creating flow, and at anticipating the work ahead.
  - What metric would be easy to measure and useful to track?
    - Perhaps each trade notes its crew size this week compared to last week.
    - Perhaps this change is reviewed in combination with the Capacity Shortfall metric.

- Note if the team is employing Takt successfully the RL and the CS metrics should both be very low. This might be a reason why the method is very successful.

- Plan Stability (PS)
  - Teams can have high PPC, high PRC yet they are spending hours each week successfully replanning the work. This would be an example of low Plan Stability and might be a good metric to track for otherwise high performing teams.
  - Low PS might indicate a poor 'CAN' phase where either the Lookahead process and/or the Make-Ready process are not functioning well. This might in turn indicate a resource issue and/or mentoring opportunity.
  - What metric would be easy to measure and useful to track?
    - How similar is the plan in the upcoming weekly work plan to the plan for that same week of work a week ago, two weeks ago, three weeks ago, etc
    - It might be hard to find an easy way to measure this. It might require a team using sophisticated software for their Last Planner System to have someone run a data analysis that could create an aggregate standard deviation for how much plan is varying week to week before it finally reaches the week of the WWP.
    - There are details of how this has been attempted in some of the academic papers referenced in this document.

Commissioning, Move-in, Activation

This is the major phase of the project that is closest to the final completion date for the project as a whole and typically has the least ability to buffer against schedule impacts. Therefore, the ability to deal with whatever happens during any given week without impacting milestones is even more important during this phase than the others. Thus, metrics around resource capacity have the potential to be particularly important here.

- CB - Capacity Buffer
  - How much resource capacity should you add during design to catch all the Unanticipated Tasks (UT)?
  - Can you develop guidance to teams in this phase to only, say, commit 75% of their capacity to the WWP?
  - Can you identify when the CB is dangerously low?
  - What metric would be easy to measure and useful to track?
    - Could it be total team FTE expressed as an hourly amount per week (or whatever cycle time works for this early phase of work) divided into the total estimate hours for the committed tasks in the WWP

- CS – Capacity Shortfall
  - How much work whether planned or unplanned is not getting done due to unavailability of labor resources.
  - What metric would be easy to measure and useful to track?
    - Could it be

  - Count the number of tasks not done due to labor not available
  - Add to that the number of tasks done
  - Divide that total into the total number of tasks not done due to labor not available.
- If this is high and stays high, it allows a conversation to be had around whether the project has an appropriate level of resources available on the project.

LITERATURE REVIEW & KEY FINDINGS

List of Papers Reviewed

Emdanat S. and Azambuja, M. (2016). "Aligning Near and Long-Term Planning for LPS Implementations: A Review of Existing and New Metrics" In: Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction, Boston, MA, USA, sect.5 pp. 103–112.

El Samad G., Hamzeh F. R., and Emdanat S. (2017). "Last Planner System – The Need for New Metrics" In: LC3 2017 Volume II – Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC), Walsh, K., Sacks, R., Brilakis, I. (eds.), Heraklion, Greece, pp. 637-644. DOI: https://doi.org/10.24928/2017/021

Emdanat, S., Linnik, M. & Christian, D. 2016, 'A Framework for Integrating Takt Planning, Last Planner System and Labor Tracking' In:, *24th Annual Conference of the International Group for Lean Construction*. Boston, USA, 20-22 Jul 2016.

Rizk, L., Hamzeh, F. & Emdanat, S. 2017, 'Introducing New Capacity Planning Metrics in Production Planning' In:, *25th Annual Conference of the International Group for Lean Construction*. Heraklion, Greece, 9-12 Jul 2017. pp 679-686

Hamzeh, F., Al Hattab, M., Rizk, L., El Samad, G. and Emdanat, S. (2019). Developing new metrics to evaluate the performance of capacity planning towards sustainable construction. *Journal of Cleaner Production*, 225, pp.868-882.

Hamzeh, F., El Samad, G. and Emdanat, S. (2019). Advanced Metrics for Construction Planning. *Journal of Construction Engineering and Management* Vol 145, Issue 11, Nov 2019.

Summary of Metrics in Literature

Note: the term in many of the papers, PRCO / Percent Required Complete or On-Going and On-Track is identical in meaning to the proposed PRC / Percent Required Complete metric in this document.

Paper	Topic	Metric Name	Metric Initials	Formula
Ballard and Tommelein 2016	WWP Performance	Percent Plan Complete	PPC	Did / Will
Ballard and Tommelein 2016	WWP Performance	Tasks Made Ready	TMR	Did / Can
Ballard and Tommelein 2016	WWP Performance	Tasks Anticipated	TA	Will / Can
Emdanat and Azambuja 2016	Aligning Near and Long-Term Planning	Commitment Level	CL	Required Will / Should
Emdanat and Azambuja 2016	Aligning Near and Long-Term Planning	Percent Required Completed or Ongoing	PRCO	(Required to be Done + Ongoing On Track) / Required Will
Emdanat and Azambuja 2016	Aligning Near and Long-Term Planning	Milestone Variance	MV	Not Available
Samad et al 2017	WWP Performance	Planned Work Ready	PWR	Work Expected to be Performed in Lookahead / Work that Should be Performed in Lookahead
Samad et al 2017	WWP Performance	Delta_1	Δ_1	Constraints Promised to be Removed / Constraints Identified
Samad et al 2017	WWP Performance	Delta_2	Δ_2	Constraints Removed / Constraints

Paper	Topic	Metric Name	Metric Initials	Formula
Samad et al 2017	WWP Performance	Delta_3	Δ3	New Constraints / Constraints Identified
Samad et al 2017	WWP Performance	Percent of Constraint Removal	PCR	Ready / Can OR Number of Constraint Free Tasks When Scheduling WWP / Number of Planned Tasks at Lookahead Plan
Samad et al 2017	WWP Performance	Performance Factor	PF	Actual Labor Hours / Earned Labor Hours
Samad et al 2017	WWP Performance	Labor Utilization Factor	LUF	(Effective Work + 1/4 Essential Contributory Work) / (Effective + Essential Contributory + Not Useful)
Samad et al 2017	WWP Performance	Project Productivity Index	PPI	(ΣAPI / N) x 100
Samad et al 2017	WWP Performance	Process Reliability Index	PRI	(AP / PP) x 100
Samad et al 2017	WWP Performance	Activity Productivity Index	API	Average Labor Productivity / Maximum Labor Productivity
Samad et al 2017	WWP Performance	Lean Workflow Index	LWI	LWI (t) = 7% x A2 + 33% x C2 + 4% x D2 + 31% x E2 + 25% x F2
Samad et al 2017	WWP Performance	Required Level	RL	Required Will / Will
Samad et al 2017	WWP Performance	Completed Uncommitted	CU	(Executed - Executed from Will) / (Did + Backlog + New) = (Executed from Backlog + Executed from New) / (Did + Backlog + New)
Samad et al 2017	WWP Performance	Labor Hours Reliability Index	LHRI	% of Work Completed x Expected Labor hrs / Total Expected Labor hrs

Paper	Topic	Metric Name	Metric Initials	Formula
Samad et al 2017	WWP Performance	Progress Priority	PP	∑Time Plus Sum of Successors Completed / ∑Time Plus Sum of Successors of WWP Should
Rizk et al 2017	Capacity Planning	Capacity to Load Ratio	CLR	Total Completed / WWP
Rizk et al 2017	Capacity Planning	Capacity to Load Ratio man-hrs	CLR man-hrs	Actual man-hours / WWP man-hours Worked
Rizk et al 2017	Capacity Planning	Required Capacity Ratio	RCR	Required Executed / Total Executed
Rizk et al 2017	Capacity Planning	Required Percent Complete	RPC	Required Executed / Total Required
Rizk et al 2017	Capacity Planning	Weekly Deviation	WD	WWP - Total Executed
Rizk et al 2017	Capacity Planning	Weekly Deviation Ratio	WDR	(WWP - Total Executed) / WWP
Hamzeh et al 2019	Capacity Planning	Glut		Total Completed - Required Completed
Hamzeh et al 2019	Capacity Planning	Starvation		Total Required - Required Completed
Hamzeh et al 2019	Capacity Planning	Misallocation Factor	MF	Glut + Starvation

Conclusions from Literature Review & Interviews

- Only one metric is regularly used in Last Planner System (LPS) implementations – Planned Percent Complete (PPC).
- PPC is a behavioral measure rather than a performative one.
- No clear correlations between high PPC and keeping a project on schedule has been proven.
- There is a need for performative metrics for LPS so that teams can connect the short term workplans with the longer-term project schedule.
- Performative metrics have been suggested based on research and have been successful where they have been implemented, but these are not yet in wide use across LPS implementations.
- Metrics that can assess how the team is doing against its Master Milestones (MM's) and Intermediate Milestones (IM's) are needed.

What do the papers on LPS metrics say about PPC?

- "It is designed to measure the reliability of the near-term plans." (Emdanat and Azambuja, 2016).
- "It does not provide the metrics necessary to measure against what should be done at any given planning cycle." (Emdanat and Azambuja, 2016)
- "It is a post-production measure of the reliability of weekly work planning." (Samad et al., 2017)
- "It naturally assumes that all activities are of equal value and importance." (Samad et al., 2017)

What do these papers say about connecting the short term to the long term?

- There is no positive correlation between lookahead performance (as measured by TA and TMR metrics) and team's ability to reliably achieve milestone targets.
- "The alignment of near-term and long-term planning requires a systematic adherence to the process of the LPS workflow from Phase Planning to Weekly Work Planning and Commitment Management, and, the continuous capture of the data in an integrated and uniform way." (Emdanat and Azambuja, 2016)
- "Teams that constantly re-plan to maintain CL, PRCO, and PPC appear to have lower overall MV and appear to maintain better alignment between their near-term plans and their long-term plan target milestones and are thus more reliable." (Emdanat and Azambuja, 2016)

What do the papers say about how you measure the three new proposed metrics?

Commitment Level (CL)

- "Measures the total committed required activities as a percentage of total required activities for any given work plan cycle each time a new work plan is created." (Emdanat and Azambuja, 2016)
- "Required Activity is an activity whose LS date falls within the work planning cycle window of time." (Emdanat and Azambuja, 2016)

Percent Required Completed (PRC)

- "Measures the percentage of the required activities that are completed on or before their promised completion dates including the required ongoing activities that are projected to be completed on or prior to their promised completion date after the responsible team updates the remaining duration to align with the remaining work." (Emdanat and Azambuja, 2016)
- "When reviewed in conjunction to CL on an ongoing basis it provides a comprehensive metric that captures that the level of completion of critical activities on the near-term plan is in alignment with the long-term target milestone dates." (Emdanat and Azambuja, 2016)

Milestone Variance (MV)

- "Reports on the variance in days between the forecast to complete all remaining activities against the milestone required date." (Emdanat and Azambuja, 2016)
- "Designed to be reviewed with CL metric to provide context to the reported CL percentages and ensure that the remaining work in in alignment with the original milestone targets." (Emdanat and Azambuja, 2016)

APPENDIX 1: The interviewees & Highlights from the Interviews

Summary of Learnings from Interviews with Experienced Practitioners

Table 1: Summary of Interviewees

Discipline	Position	Markets	Number of Years using LPS	Number of Projects using LPS	Min Project Size	Max Project size
Construction (GC)	Senior Continuous Improvement Engineer	Healthcare, Education	6	3	$168M	$1.273B
Construction (MEP)	Operational Excellence Manager	Healthcare	20	2	$100M	$200M
Construction (GC)	General Superintendent	Commercial, Education, Healthcare, Industrial	10	8	$5.6M	$900M
Design (Architecture)	Architect	Commercial, Healthcare	15	100	$1K	$2B
Construction (GC)	Project Manager	Industrial	-	2	$41M	$200M
Design (Architecture)	Chief Process Officer	Healthcare, Hospitality, Education, Commercial	11	50	$50K	$400M
Construction (GC)	Director of Production	Commercial, Healthcare	12	30	$5M	$2B

Table 2: Summary Regarding Metrics

2016 Benchmark Metrics Used				Other Metrics Used	
PPC	TA	TMR	Frequency of Plan Failures	CL	Milestone Variance
X				X	
X			X		
X				X	X
X		X			
X					
X					

Wish List of Metrics

*"There's got to be some metric that combines the intelligence of PPC and commitment level. That is what **required work complete** gets us to. That allows us to say of all the critical work how are we doing." (GC1)*

*"I think there needs to be more thoughtfulness in allocating a **weight of distribution** [to tasks]. I don't know how that looks, how you assign importance to these tasks." (GC1)*

*"It would revolve more around **actual production rates** and the producing side… For me it's important when I am trying to set Takt with the trades." (GC2)*

*"I wish there was a way to **define more tasks**. I know it's very fluid when designers design and it's hard to track what their physical turnover is going to be. I wish there was a way to figure that out." (GC2)*

*"It may not be a metric as much as a **standard method of understanding constraints** and then being able to group them over time, so that when they do come up in projects that you would have a way of Kanban to countermeasure." (Arch1)*

"I would love a metric around how much of this WWP is standard work and how much of it is custom work." (Arch1)

"Quality is a tough one to measure. Quality of the work. Is it done to the level you want it done…It would be awesome that you could just have commissioning built into this all the way to the end." (Owner)

"It would be interesting to see some type of metric that shows consistently what is the design time for certain types of projects." (Arch2)

"I wish people would retroactively keep track of the length of time it took them to do a specific task." (Arch2.

Measuring Capacity

"I think that when you say in the next 3 weeks you have 5 times as many tasks as you have in the past, that would be helpful for lookahead planning to staff up as we need to." (GC1)

"We do productivity tracking, and we capture [it] in feet per man day. So we know based on our crew size, scope and complexity of installation our expectation." (MEP)

"We do manpower loading that shows you a resource loaded workplan and spikes that we are trying to level out… A lot of our long-term planning happens with our historical productivities." (MEP)

"We do the color up process" (GC2)

"We've moved more in the direction of SCRUM. There it's about velocity and that's all based on using planning poker to determine amplitude of tasks". (Arch1)

Measuring Reliability

"We measure Percent Improvised Tasks (PIT). We capture how long those tasks actually took because it allows us to, over time, develop a recommended buffer." (Arch1)

Measuring Near/Long Term Alignment

"Where we flag it is where we take the productivity element (are we hitting the right numbers) and are we hitting the schedule… And you are assuming that the person who created that [CPM Schedule] put the right critical path to get to the end." (MEP)

"I run a milestone variance report every week on the upcoming milestones that we track." (GC2)

"The emphasis that I place right now has been really focused on when a project activity should start." (Arch1)

Comments on using Metrics

"From the planner's perspective we don't want to bug down the system so that it becomes so cumbersome and difficult to manage." (GC1)

"We struggle as a company capturing metrics, which takes time away from what people consider the value added work, so how do we minimize the effort to capture them so that we have the right data to make the right decisions." (MEP)

"I think honestly we've de-emphasized the metrics in favor of the consistent communication and re-planning behavior and so the metrics inform an action but to us the action is more important of re-planning." (Arch1)

"PPC only works if in design people are realistic about the commitments and they are specific and detailed enough about what it is they are actually providing." (Arch2)

Additional Metrics Used and Definitions

"We use PPCO (Plan Percent Committed and Ongoing) which is the whole plan, so we are measuring every task that's committed to in a plan, not just the tasks that are critical to the plan." (GC2)

"I like to use a metric to measure lookahead planning commitment to see if we make a commitment today for 5 days from now and 10 days from now, how accurate are we with our planning." (GC2)

APPENDIX 2: The Interview Questionnaire

Prerequisites to be Interviewed:

- Interviewees are familiar with the Last Planner System and apply its fundamentals in project production planning and control.
- Interviewees are experienced professionals in the construction industry and manage/oversee project teams.
- Interviewees represent a range of stakeholder perspectives. Owner, Designer, General Contractor, Trade Partner.

Questions:

5. **Background**
    a. What is your name?
    b. Who do you work for now?
    c. Who have you worked for previously implementing LPS?
    d. On how many projects have you personally implemented the Last Planner System?
        i. Note this means implementation of most of the Should-Can-Will-Did process as outlined in the P2SL Benchmark Document
        ii. What is the range of size of these projects?
        iii. What, if it's possible to say, was the approximate average value
        iv. What types of project? (e.g. Health, Education, Commercial etc)
    e. For how many years have you been implementing LPS – from when you first started to implement a part of it, until today
6. **LPS Metrics - What is Working**
    a. What metrics do you use for your implementation of LPS and what do you use them for?
    b. How do these metrics help you with delivering projects?
    c. How, exactly to you calculate these metrics?
    d. Do you calculate these metrics with software, or do it manually?
7. **LPS Metrics - What is Not Working**
    a. Which of the following metrics, as listed in the current P2SL Benchmark do you use?
        i. PPC – Percent Plan Complete
        ii. TA – Tasks Anticipated
        iii. TMR – Tasks Made Ready
        iv. Frequency of Plan Failures
    f. What metrics do you wish you had but you don't?
    g. What would you use these 'missing metrics' for?
8. **Specific Metrics Areas: If not covered above here are some specific questions on different types of potential areas for LPS metrics:**
    a. CAPACITY: The LCI/P2SL Benchmark has a significant focus on "capacity" (The amount of work that can be produced by an individual specialist or work group in a given period of time)
        i. Within your LPS implementation do you measure capacity?
        ii. What do you call that metric?

iii. How do you measure and/or calculate it?

b. RELIABILITY:
   iv. Do you track the number of tasks added to a committed work plan during the week of execution of that plan?
   v. Do you categorize those tasks at all? (e.g. “rework”, “unanticipated work”, etc.?)

c. NEAR/LONG TERM ALIGNMENT:
   i. Do you measure the alignment of near- (intermediate milestone) and long-term (master schedule milestone) goals?
   ii. How do you measure the impact of ability to get near term work done, on the overall project milestones?
   iii. If you don’t measure it how do you assess the impact of tasks in the weekly work plan failing to be finished, or failing to be finished as requested?