DRIVING CONTINUOUS IMPROVEMENT BY DEVELOPING AND LEVERAGING LEAN KEY PERFORMANCE INDICATORS

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ABSTRACT

Lean advocates defining value from the perspective of the customer, striving for perfection, continuous improvement, and reducing waste. However, unlike formal lean programs in the manufacturing sector, the Architecture-Engineering-Construction (AEC) industry often uses the Last Planner System®(LPS) and forms ad hoc project teams to manage their lean programs.

To advance to the next stage of improving project performance, we propose that the AEC industry begin adopting an available set of lean metrics and analytics that are more effective in evaluating system performance. These metrics and analytics can help project teams aggregate and filter project and enterprise information. They can then determine lean key performance indicators that reveal new opportunities for continuous improvement of the production system.

Ensuring that a holistic objective as well as a good governance structure is in place is important to leverage the metrics and analytics as enablers for global optimization. Otherwise, misuse may lead to measurement drift and local optimization from misguided attempts to improve one metric in isolation. By aligning lean metrics and analytics to delivery, stakeholder management, and risk mitigation strategies, owners of capital programs and their service providers can attain better project outcomes and accelerate continuous improvement objectives.

KEYWORDS

KPIs, measurement drift, lean governance, system performance, metrics, analytics

INTRODUCTION

Accessible metrics that drive lean behavior represent a significant opportunity for increasing transparency and managing accountability. Such lean metrics also enables project teams to become more responsive, adaptable, and effective in managing and executing work to improve production system performance on AEC projects.

This paper introduces an initial series of metrics and analytics with an emphasis on information that already exists or can be quickly obtained by the daily or weekly work planning process and associated production plans (milestone, phase, and look-ahead). We developed our theoretical framework for this discussion based on the lead author's experiences on civil, commercial, industrial, and institutional projects.

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Future research may gather empirical evidence to test our theoretical framework and examine production system characteristics, system integration, value parameters, process complexity, and team development.

Owners and service providers of capital programs can use metrics and analytics to foster a lean culture that prioritizes continuous improvement internally and externally with their supply chain and stakeholders. Leadership from those organizations need to clarify project objectives; identify metrics and analytics that best support those objectives; locate available information; develop a plan to capture missing information; present the information in an easily understandable format; and establish a governance and oversight framework for sustainability.

THE BUSINESS CASE

Public and private organizations are constantly challenged to deliver strategic capital assets within highly competitive marketplaces. Owners, contractors, and vendors of capital projects compete for market share for their products and services. As businesses, they need to operate more effectively and efficiently than their competitors while serving new and existing customers who seek more value for their products and services or risk losing market share. As a result, businesses need metrics and analytics to help them streamline their value generating operations and provide tangible evidence and validation that they are generating value for their customers.

GOOD GOVERNANCE

Team leaders, management, and executives can use metrics to determine the efficiency and effectiveness of their operations (Mitropoulos 2005). However, common metrics are often misused and can have unintended consequences such as sub-optimized behavior, increased resistance to change, creation of adversarial relationships, confusion over corporate or project objectives, and questioning of leadership decisions (Harrington and McNellis 2006). To prevent such problem from developing, we select lean metrics and analytics that support the following project principles / objectives: 1) improve customer satisfaction; 2) reduce errors and waste in the production system; and 3) align processes with customer requirements.

Furthermore, every organization, program, or project deploys (by design or in an ad hoc fashion) three underlying operating principles: governance, value management, and delivery management (España 2012). Regardless if these operating principles are deployed well or poorly, each applies over the project life cycle and integrates with project management practice. Without good governance, we will not achieve optimal value solutions. Without good value management, we will not achieve optimal delivery capability. Without good delivery management, we will not produce the desired operational capital asset.

"Tell me how you measure me, and I will tell you how I will behave."
~ Goldratt (1990)

While the behavioral implications of metrics cannot be denied, the lean approach is focused more on addressing higher order "system" failures than individual "people" failures. As a foundation for developing and improving lean metrics and analytics, creating and maintaining a lean enterprise is essential (Harrington and McNellis 2006), especially in an environment under constantly changing conditions.

Unlike conventionally led enterprises, the focus within a lean enterprise shifts from cost and time performance to improving customer satisfaction, reducing errors, and realigning processes with customer requirements (ibid). Accordingly, the organization, program, or project would strive to create, support, and sustain high performance teams in short-term production environments by constantly identifying and removing non-value adding work to improve the delivered value of their processes (ibid). To achieve the desired behaviors, a good governance structure would include an effective lean metrics and analytics program. Then we may better uncover deeply embedded processes and structures that inadvertently introduce higher costs, staffing inefficiencies, bad customer experiences, reduced market share, and bad business decisions while fostering a culture of panic and confusion.

ABOUT METRICS AND ANALYTICS

Every organization, project team, and worker must contend with internal and external factors that impact their work. Making inter-dependencies, interfaces, and degrees of control transparent enables organizations to begin revealing whether projects and workers have common versus competing objectives. As organizations begin to recognize the value of measuring, understanding, controlling, and improving performance (ibid), they need to distinguish between individual vs. systemic performance – i.e., if behaviors support local vs. global optimization.

While it is easier to work on measurements in isolation (e.g., lower cost per unit), measurements of global optimization (i.e., those that align project goals) require more sophistication. Conversely, we need to avoid using complex analytics that are hard to produce or difficult to understand. Rather, metrics and analytics should be outcome-focused instead of output-focused. Common desired performance outcomes should include: 1) planning founded on lean construction principles; 2) high performing and collaborative teams with requisite skills; 3) established culture of responsibility, authority, and accountability; 4) good decision making aligned to project objectives; 5) use of realistic baselines [timelines, scopes, objectives, work structures, resources, etc.]; 6) thorough program execution plans; 7) continuous learning and use of best practices; 8) effective communication; and 9) good governance and oversight. Thus, our metrics support systemic thinking for global optimization.

As the AEC industry is highly interconnected and decisions have to be made at an accelerated pace, understanding the systems in which they operate become more important. Thus, Key Performance Indicators (KPIs) should be leading instead of lagging and used for insight in guiding work towards desired objectives. Furthermore, absolute accuracy should not be the goal of KPIs. Rather, it is better to make the best use out of existing data. Finally, metrics should be embedded in everyday use, clearly communicated, and part of the working experience (Smartkpis 2012).

WHAT WE SHOULD MEASURE

From a business perspective, undertaking a capital program or project represents a significant risk to the organization. The delivery effort occurs in a constantly changing market environment where product development, construction of a "prototype", and operational testing are all performed without the benefit of having fully experienced the actual conditions under which the facility will be designed and constructed. Therefore, organizations should generate critical information throughout a project's life cycle to justify investment in a project, validate key delivery criteria (both interim and final), and achieve operational objectives.

Conventionally, metrics based on earned value are lagging since they compare historical schedule, cost, and quality variance data to the plan, budget, or criteria. They provide evidence but are not true indicators of system performance. In contrast, the lean focus is on ensuring the temporary production system is generating value and achieving desired performance outcomes. Lean metrics must enable managers to assess both system and operator performance (flow, transformation, value) to generate more value out of each decision and ensuing work effort.

With achieving better outcomes as objectives, lean metrics and analytics need to control against strong and realistic baseline requirements to get desired product, time of performance, and investment solutions. If the nine desired performance outcomes identified above become our Key Results Areas (KRAs) to determine organization, program, or project success, metrics and analytics need to be: designed and linked to KRAs and leading KPIs; associated with business objectives; and aligned to lean program and project execution. These metrics and analytics will become part of an effective control system that is monitored and enables improved integration, synchronization, and predictability of work effort. They must align the production system with worker needs by making the work more convenient for the worker as much as aligning workers with the system (Picard and Seay 1996).

WHAT WE DO MEASURE

The discussion of metrics in the AEC industry is often focused on the negative aspects that lead to sub-optimization, undesired behaviors, and misaligned efforts. Given how executives and managers rely on metrics for decision-making, conventional AEC practice will have difficulty moving beyond earned value analysis (EVA) (Vargas 2003). As lean construction and its benefits emerge as an alternative approach to conventional project delivery, the dominant benchmark used as a measure of its effectiveness will be Percent Plan Complete (PPC). Then, as organizations continue to adopt and advance Lean Project Delivery (LPD), they will demand more comprehensive real-time metrics to better understand and improve production system performance, with all its dynamics and complexity.

Lean construction practices have introduced several metrics that differ significantly from conventional metrics. The LPS measures planning reliability using PPC (Ballard 2000). Lean financial metrics are focused on target value design. Lean construction improvement metrics are based on the "five whys" root cause analysis and reasons for failure summaries. However, lean construction improvement outcomes are mainly measured using conventional time and cost standards including: unit production rates (hrs/unit of time, unit production per hour), unit costs ($/unit of production), schedule variance (deviation from plan), and total end results (cost versus budget, actual versus planned completion date). Consequently, these comparisons will continue to be used to differentiate and justify lean versus conventional deployments.

WHAT'S AVAILABLE TO MEASURE

While we can measure many things, keeping in mind "what we should measure" will help discern what is meaningful to measure and how well teams are aligned to performance objectives. Initially, we propose teams to leverage existing data and conventional metrics. However, they should be aware that metrics collected solely for the comparison of production performance may, by themselves: have limited value, not matter, and result in non-lean behaviors. Rather, a combination of metrics can provide a more realistic view of system performance and uncover better opportunities for continuous improvement. Table 1 lists metrics from the LPS or existing EVA metrics that provide meaningful production information for near-term operations.

Table 1: Available Metrics and Associated Opportunities and Challenges

METRIC	OPPORTUNITIES AND CHALLENGES
Percent Plan Complete (PPC)	**Opportunities:** Indicator of planning reliability; Combined with associated number of tasks indicates planning capability. **Challenges:** Not a good indicator of performance capability or productivity; Allows for recurrence of non-completed tasks regardless of failure significance.
Cost Reporting (CR)	**Opportunity:** Evidence for use with system improvement indicators. **Challenge:** Potential use as conventional command and control.
Schedule Variation (SV)	**Opportunities:** Indicator of potential milestone delivery issues; Early trigger for rapid re-planning; Compare actual, planned, and forecast info. **Challenges:** Potential use as a conventional command and control tool; Requires reconfiguration of the manner schedules are created & reported.
Quality reporting (QA/QC)	**Opportunity:** Use as validation of performance objectives. **Challenge:** Potential use as conventional command and control.
Planning Event Reliability (PER)	**Opportunities:** Regularity of conducting planning meetings; Indicator of team discipline. **Challenge:** Determining quality of planning events.
Committed Tasks On Plan (TOP)	**Opportunities:** Indicator of team planning capability; Indicator of team execution capability.
Completed tasks Not on Plan (CNP)	**Opportunities:** Identify work performed without incorporating them into the planning processes; Indicator of variability introduced by team and others. **Challenge:** Reluctance to discuss or divulge this information.
Ratio of CNP to total Completed tasks (CNP/C)	**Opportunities:** Indicator of team planning capability; Indicator of extent of variability introduced by team and others; Indicator of team resistance.
Root cause Analysis (RA)	**Opportunity:** Enables determination if there is a structural system failure, planning failure, or activity definition failure. **Challenge:** Failure to identify true root cause.
Reasons Summary for non-completion (RS)	**Opportunity:** Enables the development of a strategy towards addressing the larger structural or planning issues. **Challenge:** Root cause drivers not identified.
Look-Ahead Participants (LAP)	**Opportunity:** Measure robustness of integrated plan. **Challenge:** Assessing level of meaningful participation
Production Plan Participants (PPP)	**Opportunity:** Measure of ideal team size - with ideal team size of 5 to 9 skilled participants (Wittenberg 2006). **Challenge:** Determining ideal team size is dependent on work structure and team competency.
Ratio of Committed Tasks on plan to total Tasks Released (CT/TR)	**Opportunities:** Identify potential bottleneck; Identify workable backlogs; Better prioritization of work.

LEAN AND THE PRODUCTION SYSTEM

If we pursue the lean objectives of improving customer satisfaction, reducing errors and waste, and realigning processes with customer requirements, then our metrics should enable achieving those objectives. Key to delivering those objectives is aligning the production system to those objectives. For the system to align to those objectives, the system and the participants involved must relentlessly pursue the nine KRAs mentioned earlier. KPIs are the means to validate and verify that all interim and final project milestones and work efforts are aligned and meeting those KRAs. The benefits should include improvements in total project delivery outcomes.

For this paper, the following KRAs are addressed: 1) Basis of planning that is founded on lean construction principles; 2) Established culture of responsibility, authority, and accountability; and 3) Produces strong and thorough program execution plans. The KPIs and associated analytics consist of: 1) Current status evidence-based metrics and data; 2) Trend patterns based on the above; and 3) Analytics based on combinations of the metrics and trends. The current status evidence-based metrics and data for this paper are comprised of a combination of information from both conventional EVA and typical lean production planning processes (daily/weekly work plan and look-ahead plan).

We continuously gauge the success of a lean project by ultimately comparing them against established project data points (e.g., budgets, schedules, production rates, etc.) or other project/portfolio experiences (e.g., see Figures 1 and 2).

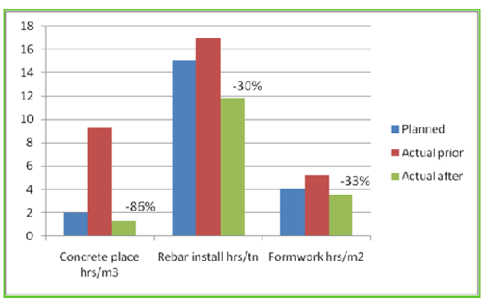

Figure 1: Unit production rate comparison within a project (planned, before, and after lean implementation)

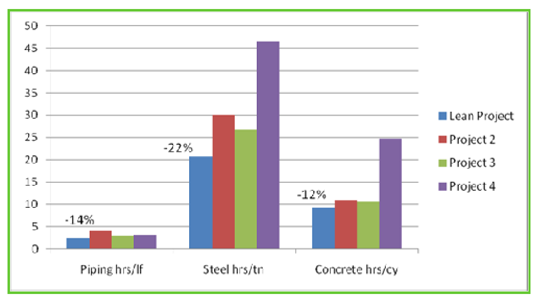

Figure 2: Unit production rate comparison across multiple projects (lean versus three conventional projects)

Conventionally, the primary purpose of such controls is to identify negative deviations from those data points and enable managers to identify corrective actions (Mitropoulos 2005). Table 2 lists information that is typically collected and reported during the EVA and production planning processes.

Table 2: Conventional and Lean Construction Information Collected

Conventional Information	**Description**
Schedule variance	Planned versus actual progress dates
Schedule forecast	Adjustment from planned progress dates to future expectation
Unit cost	Cost per unit of production
Unit production rate	Units per hour or hours per unit

Conventional Information	**Description (continued)**
Total cost	By component or total facility and often related to recognizable per unit cost (e.g., cost for facility, cost per square foot, cost per bed, cost per unit of output, etc.)
Lean Construction Information	**Description**
Working group	Designation of accountability with potential reference to work structure
Assignment and task ID	Production plan and schedule interface data
Duration	Observe progression of task / workstream duration assignments during look-ahead process. Potential to match duration with effort.
Task requested by	Indicator of pull process
Task committed by	Accountability
Constraints & prerequisite work	Make ready process
Completion date	Target date with Last Responsible Moment (LRM) implications
Commitment date(s)	Graphical representation of completion date and duration
Acknowledgement of task completed / not completed	Indication of planning and execution capability
Root cause reason for non-completion	Continuous improvement for specific efforts
Assignment of reason category	Continuous improvement for broader efforts

Due to the emphasis on lean, conventional metrics are only used to support lean construction principles. For example, the LPS enables the linking of progress schedules to production planning (e.g., milestone development to daily execution, including learning loops). Since cost and safety metrics are good outcome indicators of how well work is planned and performed, they should be used to support system improvement and not as individual metrics requiring an isolated response. These metrics trends will become the KPIs in how the production system is performing. Then, this information can be captured and reported in near real time.

Comparisons leveraging existing systems that collect schedule and cost data can provide information for understanding project production system dynamics and the affect it is having on project performance. For example, by providing targeted unit cost and schedule variances on a regular basis, trends can be provided in near real time to indicate desired performance or warnings of undesirable trends. By evaluating cost and schedule trends, management can determine if the system is stable or unstable and introduce corrective action. Similarly, quality indicators can measure integration of quality processes into work execution planning and control, in addition to tracking defects and defect resolution. Information from look-ahead plans can reveal how well the work is being planned, executed, and controlled.

For instance, a team can reach a high PPC if their goals are set too low or if other work is not properly reported. Likewise, a team can reach a low PPC if they are very ambitious or if they substantially complete work but do not complete their commitment. Both situations require different levels of support. Thus, PPC does not convey how well a team is performing their work without observations or associating other factors. Rather, how well a team works to support the KRAs is what matters.

The other common lean metric and accompanying analytics is root cause analysis and the associated reasons for non-completion summary. While they help reveal system failures and opportunities for continuous improvement, they rely heavily on the commitment of both the reporting and supporting organizations towards using the information to drive continuous improvement. More effective teams are establishing working sessions to review and address the information generated by these reports.

The other information we can collect from the lean plans is related to the metrics stated above but begin to give us a more comprehensive view of production system performance. The concept of Planned Work Ready (Mitropoulous 2005) introduced the concept of pro-actively making work ready by identifying action items and making commitments to remove constraints. Tools that automate or enables the collection of the information may facilitate producing KPIs and the analytics (examples shown below were generated from Excel spreadsheets). Metrics include: 1) **Committed Tasks on Plan (TOP)** – record total # of tasks committed by a team = Committed Tasks Completed + Tasks Not Completed (Figure 3); 2) **Planning Event Reliability (PER)** – record time and date of event (Figure 4);

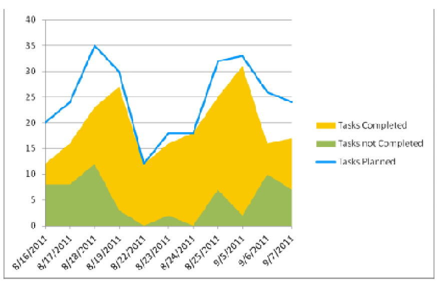

Figure 3: Committed Tasks on Plan (TOP), total tasks completed, and total tasks not completed (variation indicator)

Figure 4: Planning Event Reliability (PER) – a flat line at zero indicates consistency (upward spike indicates skipped planning events)

3) **Look-Ahead Participants (LAP)** – record number of participants and organizations; 4) **Production Plan Participants (PPP)** – record number of participants and organizations; 5) **Ratio of TOP to total tasks released (CT/TR)**; 6) **Completed tasks Not on Plan (CNP)** – count tasks during production planning process (Figure 5); 7) **Ratio of Completed tasks Not on Plan to total Completed tasks (CNP/C)** – based on CNP (Figure 6).

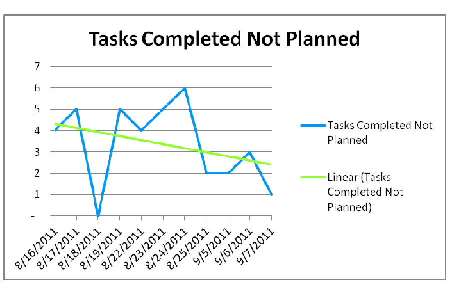

Figure 5: Completed tasks not planned with trendline

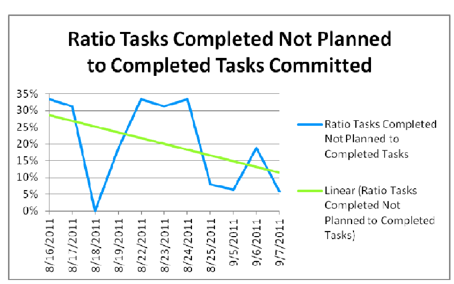

Figure 6: Ration of CNP versus completed tasks with trendline

When combined, these various metrics provide leadership and project teams with production system performance information. Analyzing PPC, SV, CR, QA/QC, PER, TOP, CNP, CNP/C, RA, RS, LAP, PPP, and CT/CR help make determinations where support may be necessary or improvement opportunities exist. Each metric will need defined parameters to configuration the indicator analytics. Setting the appropriate parameters and interpreting the information will be unique to the organization and the team. The parameters may be initially established and adjusted by the team themselves with guidance from managers and leadership. Table 3 provides a dashboard view (Barth and Formoso 2008) of the metrics and analytics based on the established parameters and using the following legend:

Table 3: Metrics and Analytics in dashboard format

Comb Metric	PPC	SV	CR	QA/QC	PER	TOP	CNP	CNP/C	RA	LAP	PPP	CT/CR	Analytic Synopsis
1	red ↓	red ↑	yellow ▢		red ●		red ↑	red ↑	red ●	red ●	red ●		Ineffective team planning requiring team training in planning skills and modifications to team structure. With CR neutral, performance improvement opportunities clearly available.
2	green ↑	red ↑			green ●	red ↓	yellow ▢	green ↓				red ↓	Despite good PPC, schedule is not advancing. Expected tasks on plan is inadequate for team. Team meetings showing good lean metrics but not planning meaningfully, may not be committing released tasks to support agreed plan and giving priority to non-planned tasks. May also indicate team is subject to large amount of variability from other teams or sources.
3	green ↑	green ↓	red ↓	red ●	green ●	green ●	yellow ▢	yellow ▢		red ●	red ●		Suspect sub-optimization when CR is trending negative and participant mix is not ideal or indication that the team would benefit from an improved process. May be hoarding resources or evidence of inadequate team structure.
4	green ↑	green ↓	yellow ▢		green ●	green ●	green ↓	green ↓				yellow ▢	Highly productive team with additional performance capacity. Opportunity to reconfigure team or resources to improve or assist efforts elsewhere (i.e., stress the system).

LEGEND: green ↑ green ↓ Desired performance and trend
red ↓ red ↑ Undesired performance and trend
green ● Desired performance
red ● Undesired performance
yellow ▢ Acceptable or neutral performance

The effort of evaluating and monitoring the various metrics from different perspectives (i.e., ability to filter the data) will provide the team and managers with a better understanding of the production system, integration with other teams, and better understand the cause and effect of the various actions taken in response to addressing team or system challenges and opportunities. If taken from a supporting continuous improvement and business improvement perspective, the outcome should result in more optimal time, cost, quality, and safety performance.

CONCLUSION

Owners and service providers of Capital Programs that have adopted Lean Project Delivery (LPD) have an opportunity to develop a meaningful set of metrics and analytics that enable their organization to embed a lean culture. Leadership from those organizations need to confirm their LPD objectives; determine the metrics and analytics that best ensure meeting those objectives; identify information already available to them and what is needed; use meaningful metrics and analytics to support that effort; present the information in an accessible, easily understandable format; and establish a governance / oversight framework for sustainability. Performance metrics that links actions to performance objectives exposes the underlying production system infrastructure, provides visibility and accountability, benefits the whole, and enables better decision making. Just by collecting information from the production and look-ahead plans give us a more comprehensive view of production system performance. When metrics are analyzed in combination, leadership and project teams can be provided with valuable production system performance information. Beyond what is available through production planning, additional KPI development will bring additional value by focusing on the production system characteristics, system integration, value parameters, process complexity, and team development.

Leadership must ensure a holistic objective and a good governance structure (e.g., policies and business rules, oversight responsibilities, and risk identification) are in place to leverage the metrics and analytics as enablers for global optimization. By aligning lean metrics and analytics to delivery, stakeholder management, and risk mitigation strategies, owners and providers of capital programs can attain better project outcomes and accelerate continuous improvement objectives.

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