

REDUCING VARIABILITY OF A VALUABLE CONSTRUCTION INPUT: SUBCONTRACTORS

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ABSTRACT

Subcontractors are critical to the U.S. construction industry. They are used by general contractors (GC) to perform a majority of work. Subcontractors safely install components specified, in the time needed, and at a competitive cost. It appears that some misalignment of Lean Construction (LC) methodologies and realities of managing subcontractors. More research is needed to address this largest input in most projects. Currently, LC suffers from low adoption. Looking ahead to the next 3 years, all contractors plan adoption at the same low rate. This paper will review an action research project and its outcomes which involved a GC and its subcontractors over three years of projects.

KEYWORDS

Lean Construction, LC, production, productivity, variability, subcontractor, PDCA

INTRODUCTION

Subcontractors build specified project work typically at the direction of general contractors that are guided by project plans, specifications, local regulations and demands by the construction services buyer. Subcontractor's actions mostly determine critical outcomes such as safety, cost, schedule and quality. However, more research is needed to understand and improve these critical partners in the construction process.

A recent study concludes a low contractor adoption rate presently and projected in the United States. It may signal a need to reassess the interpretation and application of Toyota's Production System (TPS) to the U. S. Construction Industry.

This paper's aim is to suggest modifications to Lean Construction (LC) Methodology that tailor it more closely to the use of construction subcontractors. Additionally, an analysis is offered of modified Lean processes that appear to cause efficiency gains in study of a General Contractor (GC) and its subcontractors over three years of projects.

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LITERATURE REVIEW

SUBCONTRACTORS AND LC

The contracting industry's combination of peculiarities is unique (Hillebrandt, 1984). For subcontractors, the process of construction may consist of mostly short term employed persons on a temporary team building a project that involves hundreds of sequenced inputs. These inputs, such as information, money, planning, material, equipment and craft workers are iterative. At the same time, each participating company has to manage other ongoing unique projects and these same inputs (Sacks, 2004).

LC has been influenced by a machine environment in a static production setting that characterizes the Toyota Production System, TPS. People operating stationary machines are generally sheltered from the weather. The human element has been assumed as predictable and loyal due to Japan's cultural norms and lifetime employment guarantees (Green, 2002). Many concerns about the application of Lean are based on contextual differences between manufacturing and construction (Jørgensen and Emmitt, 2008)

A recent industry study found only 28% of participating construction firms have adopted at least one Lean Construction (LC) practice. Of those who implemented a single practice, 36% adopted pull planning which is one of five subsets of the Last Planner System[®] (LPS). LPS is the LC community's most prominent process. Although LC research is more complete than ever and prominent projects have been performed with LC methodology, the future is not brighter. Of those classified as familiar with LC, but have not implemented practices, the same low percentage of contractors (28%) plan to implement LC, in any form, in years 2014 – 16 (McGraw-Hill, 2013). Although, no reasons were given for low adoption, it can be assumed that LC is perceived by GCs and Subcontractors as having low improvement value as Green suggests (2002).

Non-LC researchers outlined several fundamental practices critical to managing construction subcontractors. These include several that are in the spirit of LC and others that are opposite of LC's instruction. Those in agreement a) Help subcontractors do timely work by providing assistance and resources as appropriate and b) Walk the job frequently; get to know the subcontractor's workers and offer assistance as appropriate. Those in conflict a) Meet regularly with subcontractor's senior supervisor individually b) Enforce the contract (Thomas and Flynn, 2011).

Edwards Deming, the father of Total Quality Management - the pre-cursor to Lean, is quoted, "Uncontrolled variation is the enemy of quality". Additionally, Plan-Do-Check-Act (PDCA) is a standard 4 step quality process created by Deming has been confirmed as efficient.

Shigeo Shingo, co-developer of Lean, stated that lack of discipline in planning and execution will weaken attempts to improve. Planning is described as "wait to start and then go faster" (Alarcón, 1997). There is a consensus that formalizing pre-construction planning for all contractors regardless of hierarchical level would improve outcomes including productivity and project efficiency (Menches, et al., 2008)

Lean's Heijunka concept teaches levelling work in process which helps control variation and thus, limits a source of waste. A company (manufacturing or

construction) that produces steadily and can keep focus on improvement and ultimately, perfection. This leads to more customer satisfaction, repeat business, and predictable revenue. Empirically, there is a positive correlation in construction between the number of client contracts and the amount of variability (Ko, 2010)

First order results measure inputs placed into the production process. Examples of primary activities are gathering extensive information, planning or compliance to processes. First order activities directly influence second order results which are outcomes such as productivity, schedule adherence or profit. Schonberger stresses the importance of both first and second order (1996).

LC has largely ignored the professional nature and availability challenges of first line field employees and managers. These people may be seen as inputs and not critical enablers of the construction process in terms of safety, cost, schedule and quality (Green, 1999). Subcontractors represent the majority of first line employees and managers on most construction projects.

Koskela's updated flow theory includes labor input, but not ongoing worker availability during construction (Bertelsen, et al., 2006). This lack of specificity is understandable in an orthodox adoption of Lean. In manufacturing, there is only one place for worker to be: their factory station. In contrast, construction subcontractor front line employee could be working in one of several on-going projects. Some argue that the Toyota Production System (TPS) is not the starting point of LC, but Koskela's theory (Ballard et al., 2001).

TPS is largely enabled by machines, whereas construction is not. In LC, the human element is the most variable of all inputs. Each craftsperson, laborer, and equipment operator perform differently in quality and quantity of work produced. This means variability of input and may mean significant effort should be taken in leading and managing this factor.

One standard lesson of LC has been the "parade of trades". This classroom exercise is illustrative of a major issue of general contractor's use of subcontractors in a majority of building and infrastructure projects. One of its lessons is the effect of discontinuous flow. The result is a cascading effect of a subcontractor's superior or poor performance on subsequent activities on the project schedule. This includes occurrences of (unplanned) high production and the subsequent unmanned space showing production opportunity lost.

LC's standard planning process is the Last Planner System (LPS) which is collaborative, commitment-based planning system that integrates pull planning, make-ready, and look-ahead planning with constraint analysis, weekly work planning based upon reliable promises, and learning based upon analysis of Percent Plan Complete (PPC) and reasons for variance. It requires the subcontractor's on-site supervisor promise to complete work and to keep the promise reliably.

Work is made ready by creating a look-ahead schedule of the upcoming activities and performing constraints analysis. If an upcoming activity has a constraint, then that constraint needs to be identified and solved proactively in order to eliminate impacts to the current schedule (Koskela, 1999).

Front line field managers do not determine the quantity and quality of field workers working on site. Typically, workforce coordination is managed by an executive in the home office. The workforce (and other resources) is shared with

other projects and their flow is affected by the sequencing of all the subcontractor's projects (Sacks, 2004). By LPS's design, this executive's involvement is minimized.

It appears that PPC have led to conservative work commitments (Salem, et al., 2005). In most construction contracts, physical progress determines billing. Under LPS, there may be conflicting incentives for the last planning person a) under-promising due to fear of underperforming per cent plan complete while b) maximizing production to produce as much revenue as possible for their employer, the subcontractor. When a few tasks are completed earlier than promised and others are never promised but completed, may be a form of discontinuous flow and thus, inefficiency.

According the U.S government, its construction industry has a significant job hire and separation rate. If one calculates the annual number of hires and separations, adds them together, and divides this number into the total employment, the resultant is one measure of job turnover. Calculated on an annual basis for years 2004 and 2013, it is 86% and higher (JOLTS, 2014). In one's construction career it may not be a matter of if, but when a person may be released from employment.

This hire/separate/rehire cycle is in sharp contrast to relatively continuous employment as practiced by Toyota. We can assume from this measure that employment separations are part of the construction workforce's experience and expectations.

This seems to call into question the process of the Last Planner since it is partially predicated on the person closest to the work at the field level to promise and achieve their production goals. It appears this front line manager has an incentive to promise a less ambitious production target. If one under promises and over performs, then the "parade of trades" effect may lead to overproduction waste. In contrast, if one ambitiously promises, but breaks those promises consistently, waste results. Also, it may lead to GC and fellow subcontractor conflicts. This poor performance perception could result in an early layoff (and loss of personal income). So the field manager's incentive appears to under promise the next period's work achievement.

FOUR PRACTICES THAT CONTRIBUTE TO IMPROVED GC AND SUBCONTRACTOR PERFORMANCE

The four processes outlined below closely follow two of Lean's instructions 1) Plan-Do-Check-Act and 2) Limiting throughput so efficiency (and perfection) can be the focus. In the description below, each practice is tailored to the realities of construction contracting.

Planning

Planning is a well-accepted method of reducing variability by LC and other improvement methodologies. Its basis is the simple, but powerful idea of visualizing beforehand the enablers of production which has a positive effect on performance.

An extended pre-project period started immediately after the project is won allows for extensive understanding and planning to be done, but also an atmosphere of acclimation and collaboration. Since some subcontractor field personnel may be newly hired or re-hired, a lengthy pre-project planning phase should familiarize each person to the culture and demands of the project.

Compliance Monitoring to Processes

Efficient processes only are valuable if they are executed. The level of compliance by those who build and manage largely determines the level of outcome as shown in the Case Study contained herein. One critical role of construction executives is to set expectations then inspect compliance to company processes on a continuous basis.

The most effective method for compliance measurement is a virtual one (intranet based). It allows instant updating and measurement.

Measuring Results

Construction results matter greatly in construction. The client is contracting for finished product and not the processes or people involved. Results have to be measured during all phases of the GCs contract. All contractors measure project results even if intuitively and, if deficient, address it with internal and external parties.

Levelling the Amount of Revenue

Winning projects more often is attractive since it increases revenue. Limiting the amount of required work means that estimators and business development personnel may be assigned other tasks at times include cost analysis and project administration.

CASE STUDY OF A U.S. GENERAL CONTRACTOR

The researcher was engaged from 2012 to 2015 as a management advisor by a \$30 million general construction contractor (GCC) based in the United States. The firm, founded in 2008, pursued work mostly related to U.S. government needs. The major focus of the advising and training was to transform the firm to a more efficient one. The approach taken was for the researcher to assess practices currently in use, use practices confirmed by research and experience would align with the company characteristics. LC was a strong, but not total influence on thinking. Individual coaching of key employees was part of the process. Online courses allowed for continuing education of management and staff.

Projects completed by GCC (see Figure 1) show a diversity of general contracting challenges including Design Build, Hard Bid, New Construction, Refurbishment, Demolition, Building, Civil and Marine Work with completion times of three months to over a year. Locations were isolated from population centers and the general conditions amenities were modest due to market characteristics.

The company adopted, trained and implemented the following processes which were formalized and implemented in 2013.

Figure 1 shows a significant improvement over 3 years. For clarity, the first five and last five projects represent before and after adoption fairly accurately. Obviously, higher adherence to efficient processes is correlated to improved outcomes. The first five's unweighted outcomes were average project profit decreased (-81.69%) while exceeding the schedule (18.92%) than originally planned from lower compliance to processes (29%). Interestingly, the last five project's results were more variable as a percentage; average project profit improved (48.68%) over the baseline estimate while shortening the baseline schedule (-28.78%) with a higher compliance to processes (92%). From a cash flow basis, gross profit dollars earned increased on a weekly basis from project estimate. In the researcher's experience these are important outcomes to share with construction contractors if adoption of a new methodology is to increase.

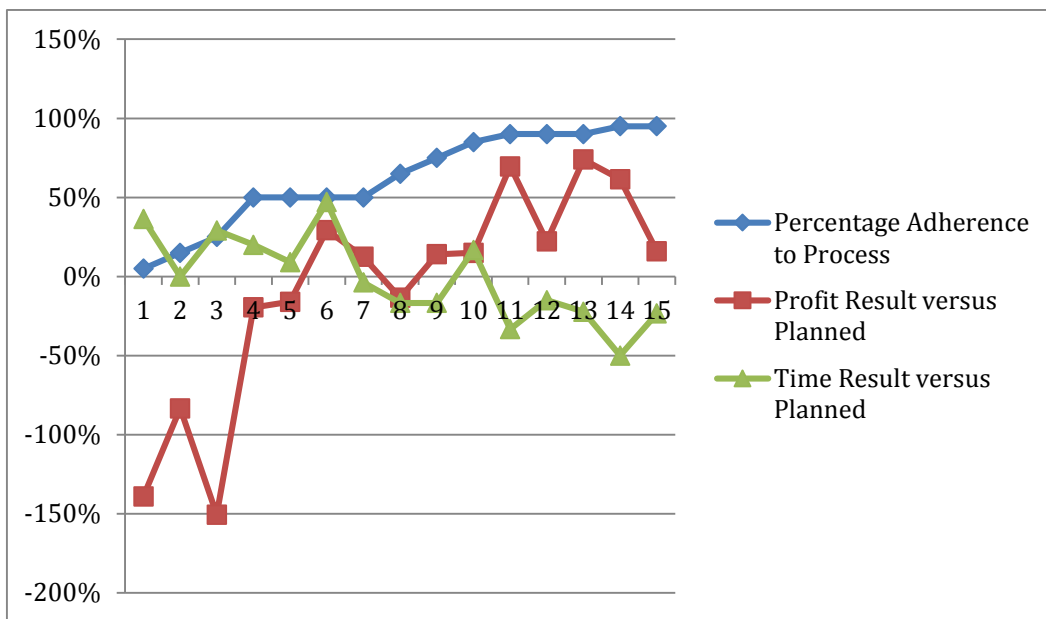


Figure 1: Company Furnished Data of Completed Projects Closed from 2012 to 2014 in Sequential Order Measuring Process Compliance, Cost and Schedule Results.

GCC made the following improvements or refinements to its existing processes. The four listed below were viewed as significant enablers of its improvement program.

Formalized pre-construction and pre-task planning

- Teams sought extensive project information and filled in a preconstruction checklist containing numerous critical items. It assigned specific personnel with responsibility and required timelines. The list was updated weekly with percentage complete for review by Project Manager (PM) and Senior Vice President (SVP) of firm.
- Subcontractor pre-coordination meetings were held with GCC site personnel with minutes and action planning two to four weeks before subcontractor is required to mobilize. Mandatory review of material and man power readiness including a check to see if other subcontractor projects will affect flow of crews to this project. Team reviews plan for completing work in regards to plans, specifications and contract. This meeting includes attendance by subcontractors and their “sub-subs” to assure communication is delivered in full.

Formalized construction phase planning, execution, monitoring and feedback

- Subcontractor coordination meetings with recorded minutes. Each week the Quality Coordinator and Superintendent held a coordination meeting with all trades in the Job Trailer. All trades met to discuss their next steps in scope so that they can work together to find the most efficient way to work around each other based on the current 30 day schedule. This meeting was recorded with minutes and distributed to all attendees and the GCC management staff. Part of this meeting included a review of each subcontractor’s two-week look ahead planning submittal. Individual meetings were held with each sub, each week to ensure the subcontractor was on schedule; had the manpower to maintain the schedule, and would

have the materials on site to complete their scheduled work each succeeding week.

- Weekly submittals register updated. Since most construction products require technical approval from a designer before installation, this was a critical planning and monitoring process. This first component of material logistics, helped assure that a project will not be stopped due to lack of material.
- Progress schedule update. Each week, project manager reviewed the project schedule with the superintendent. Late progress is noted and addressed with deficient subcontractor(s).
- Weekly internal meetings. During this meeting, GCC reviewed the entire project status as a team. PM assigned weekly tasks if necessary. Everything was recorded and part of a later upper management review of project status.

Monitoring compliance to processes.

- The SVP actively measured compliance (as a percentage) to processes in face-to-face meetings and electronically (website and company intranet). He addressed non-compliance issues, as needed, with his staff and senior executives of subcontractors.

Limiting yearly contract revenue for various reasons including its focus on efficiency.

- They had less need to rehire former staff or hire new unproven staff because of this strategic decision. At times each year, estimators and business development personnel did not seek to win projects since company backlog was at a predetermined limit. For purposes of efficiency, when the firm won a project in an unfamiliar location, its first option was to send existing staff and not hire new local employees. Additionally, GCC essentially works with one client, the U.S. Government in repeating locations. This in turn means subcontracting to a significant percentage of familiar specialty contractors.

RECOMMENDATIONS

For the LC community, understanding the most efficient contractor's (GC and Subcontractor) methods of operating offers one way to improve construction's methods and processes. Interestingly, some of the practices shared in this paper align with the teachings of Lean while others do not.

From our case study, GCC's methods of extensive information gathering, engaged planning, measured compliance to processes, monitored schedule and when needed, executive level actions eliminating adverse planned to actual schedule gaps have positively transformed project results over a three year period.

This last method violates LC's instruction against command and control. However, most of the processes address decreasing the variability of inputs. Adhering to first principles appears to have efficacy in construction contracting. Based on the following recommendations, LC's outputs may improve even though causing more variability.

Planning

An extended and formalized pre-construction planning period is suggested. This process and its steps should be considered for LC to adopt in its library of practices. A formal period should be allocated where project teams are gathered to create many planning deliverables before construction may start. This requirement should be part of the bidding document's instruction and the project contract.

An extended pre-project planning period has many benefits such as normalizing the project team culture, setting expectations, and a deep familiarization of the project. Said differently, owners requiring extensive formal planning protect themselves and their projects against negative occurrences such as arbitrary change orders, unexamined risk events with no alternative planning, and unperfected communication systems.

On a highly organized construction project, acceptable planning deliverables could be compensated as pay item from each stakeholder's total contract amount. This would assure unanimous participation. The time period would be predetermined and articulated in the bid documents. When construction starts, all subcontractors should execute a short interval planning form and GC's should monitor for quality of thought including alternative plans.

Monitoring Compliance to Processes

It is widely believed that efficient processes executed consistently lead to the best outcome. Therefore, compliance measurement must be part of any improvement program. Employees consistently executing beneficial process give their project and company the best chance for positive result.

Measuring Schedule Results and Take Action

The last two components of PDCA, CA (Check and Act) are contained in this recommendation. Once results are measured, immediate action should be taken to replicate the superior result or correct the deficient outcome in concert with Subcontractor Senior Management.

Limited Revenue Business Model

All contractors aspiring to be Lean should commit to a targeted amount of contracted work annually that is a reasonable to their current capabilities. Part of this action should include attempting to work with familiar clients. Once the revenue goals and backlog are met, all company employees execute project work. This will help prevent high variability of client demand which leads to waste and in some cases, unfulfilled promises. To keep learning and constant improvement high, consistent employment of workforce members is needed. This influences each employee's learning and commitment to the company.

Large and often prestigious projects attract most contractors' attention. The effect of winning such work has to be analysed in regard to Lean principles including the impact on its long term philosophy and operational variability. Large resource demanding projects cause significant swings in several areas such as employee hiring and separation. Clearly, Lean instructs about being the best (most efficient), not the biggest or most prominent.

The seasonal and itinerant nature of construction is a barrier to a keeping a consistent employee population engaged. However, options exist for subcontractors

to minimize this effect such as specialised winter work, excelling in a market niche or pre-fabrication of future work. At a minimum, keeping core employees working throughout the year has several benefits to a contractor on its Lean journey.

In all, monitoring of projected labour hours needed for each period (week or month) should be reviewed by executive management. Managing this actively should keep variability low and waste less than an ad hoc method. In the case of winning too much work, business development and estimating staff may have to be assigned to other duties such as field management or cost analysis for a period of time.

CONCLUDING REMARKS AND EXPECTED OUTCOMES

Familiar practices included in a new methodology increase confidence by construction professionals. At the same time, their efficient understanding in this unfamiliar methodology may be achieved. In some instances, LC may cloud contractors' understanding of LC processes or not inspire confidence with its unfamiliar vocabulary, processes and measurements. Further, it may be focusing on higher order behaviours when basic ones are more efficacious.

Some analysis of the most efficient contractors that may be practitioners of Lean or not, appears to be in order. This should help evolve LC into a more robust improvement methodology.

Currently, LC suffers from low adoption and the prospects in the future are poor. LC should consider adjusting its processes in the areas of information gathering, planning processes, process compliance and schedule adherence. If done, there is evidence that more successes may occur and LC's value would be easily recognizable by most construction firms. Shedding its manufacturing centric appearance and adopting familiar and proven practices of construction contracting should increase use by industry. LC possesses the framework, tools and practices that can transform the construction industry. However, its semi-rigid application of TPS to construction appears to not inspire contractor confidence.

Further research is needed to reformulate some methods of LC to address realities of GCs using subcontractors. Additionally, research of proven production methodologies executed by the most efficient construction contractors can help tailor LC closer to the needs of industry. Collecting more case studies examining processes coupled with quantitative results should help increase creditability and adoption.

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