INCREASING ADOPTION OF LEAN CONSTRUCTION BY CONTRACTORS

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ABSTRACT

Lean manufacturing became popular in the 1990s and has been increasingly discussed in the construction industry over the last decade. However, by some measures, construction contractors, responsible for project safety, quality, cost, and scheduling, have been slow to adopt it. Better approaches are needed to convince contractors of the benefits of the lean approach in the construction industry. To facilitate adoption, this paper reviews lean's current status in the construction contracting environment and suggests methods to increase its engagement by construction firms. Clarification and realignment of lean's definition and methodology may be needed. A meaningful way to measure the value of lean may motivate more construction firms to adopt lean methods. Empirical studies can show correlations between best practices and desired outcomes. If lean's practices can be demonstrated to increase efficacy, the rest of the industry may be more likely to adopt the lean model.

KEYWORDS

lean construction, construction contractor, production, construction productivity, construction metrics

INTRODUCTION

Lean manufacturing methodology, developed by Toyota and precipitated by post-World War II economic problems, became popular in the 1990s and has been increasingly discussed in the construction industry over the last decade. However, by some measures, construction contractors, responsible for project safety, quality, cost, and scheduling, have been slow to adopt it. If the goal to have a highly efficient, cost-effective organization directing and influencing the construction process, better approaches are needed convince contractors of the benefits of the lean construction (LC) in the construction industry. To facilitate adoption, this paper reviews LC's current status in the construction contracting environment, its application, and suggests methods to increase its proof of value. Some clarification and small adjustments may be needed to align LC to contracting characteristics and needs. Empirical studies demonstrating the superiority of lean are recommended. This paper suggests that more organizational-focused research is needed.

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LITERATURE REVIEW

LC is an attempt to translate and adapt lean manufacturing principles and practice to the design and construction process.

Unlike traditional manufacturing, construction is a project-based production process that is nomadic, customized, and executed with temporary teams in most instances. Variables, either controllable or uncontrollable, in construction are different from those in manufacturing. Hillebrandt noted that many individual factors present in construction are not unique; they are shared by other industries. However, the combination of factors is unique to this industry (1984).

LC proposes changing the way a construction firm operates. This change will not happen unless it is desired and perceived as possible. That desire emanates from external forces or an internal vision (Featherston 1999). McGraw Hill Construction's foremost recommendation for the industry is "Provide education on the need for greater efficiency" (2013).

Construction contracting is the second riskiest business in the United States (Risk Management Association 2013). Its risk profile in other countries can be assumed to be high also. Innovation in construction has been slow (Winch 1998).

Contractor's average net profit margin before tax is approximately 3 percent of revenue (ibid.). This may make them sensitive to extra costs. Thus, slow adoption of LC ideas may be due to the perception of significant expenses related to adoption, including training time.

From these perspectives, construction companies are justified to proceed with caution when considering innovation. What is the learning curve or productivity loss (confusion, missteps, miscommunication, etc.) typical before these gains are realized? What is the cost of training needed to convert to a LC system? These questions will need to be answered to extend LC into construction contractor's organizational approach.

Howell and Ballard noted that uncertainty dampens contractor performance (1994). Contractors appear to know this well and thus, LC suffers from suboptimal adoption. It may be perceived as an uncertain methodology.

By their nature, many of LC tools are heuristic (Ballard et al. 2001). They depend on a discovery mindset. At such low profit levels, can contractors tolerate a lengthy discovery timeframe?

UNCERTAINTY IN THE THEORY AND PRACTICE OF LEAN CONSTRUCTION

LC has been explained in a variety of ways to the construction contracting community. There are inconsistent definitions and little agreement among practitioners (Hines et al. 2004, Pettersen 2009). Green and May's research alludes to three models that have emerged. Each partially competes with each other (2005).

Construction firms may be confused by the various explanations of LC. Green labeled them a "complex cocktail of ideas" (1999a). It has also been defined as several different things at once such as a set of tactics, a social-technical model, a discourse, and a social commodity (Green and May 2005).

Adoption of lean methods has been slow. Of companies surveyed by McGraw Hill Construction, 28 percent have implemented at least one practice; 35 percent are familiar with LC, but not implemented any practices; and 37 percent contractors are not familiar with LC (2013).

LC appears to have the hallmarks of a fad (Seddon 2011, Alves et al. 2012). Additionally, Seddon noted that the private for-profit industry is where the real test of its value takes place. He concludes that Lean is lightly adopted in many commercial industries outside of car manufacturing (2011).

Collins suggests that coining a term to label Toyota's production approach was a mistake. The companies studied by him that become top performers or "great," used no program and had no label for what they did. However, the motivation was high in each of the great companies (2001).

Total Quality Management (TQM) was well established before lean production emerged. Eventually, lean may evolve into another label with a slightly different focus just as TQM did (Dahlgaard-Park 2011) TQM is more established and has a superior track record (ibid., Gao and Low 2014). Should this creditability prompt the LC community to reference TQM when presenting lean as a solution?

Communicating lean as distinct and identifiable actions to contractors has been recommended. Major elements should include "process transparency," which places an emphasis on identifying and describing exact processes and making them an integral part of the lean journey (Eaton 1994). Bridging concepts to methods is needed. Taking LC from a mostly academic environment to a practice-based methodology one is required. Academia should strive to make that bridge a reality (Alves et al. 2012).

Part of Lean's attractiveness to construction has been its use of elemental and therefore, low cost tools. Many of its practices provide good value since they are inexpensive, but efficient solutions. "Kanban" (a method for managing work with an emphasis on just-in-time delivery while not overloading the team members) and "Last Planner" (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 plan percent complete and reasons for variance) are examples. It is interesting that the Kanban methodology was adopted from a non-automotive industry (groceries). Last Planner, lean construction's most prominent tool for making design and construction processes more predictable, has proven value and is already considered an industry standard practice of LC (Lui et al. 2011).

Across the construction industry, LC is currently in an emergent phase. The community is largely focused on the first step of three: lean production (LP). Womack and Jones (1994) suggested that after companies master LP, organizations should evolve into a lean company, which is when the company implements lean into all its strategic and business functions, not just at the assembly line. Lean enterprise is the last step in the evolution, which encompasses the entire supply chain which includes sources of material at one end to customers at the other.

The use of a set of practices in operating a construction firm aligns with a system view. Tommelein stated that a systems view is critical and consistent with lean thinking (1998).

ADOPTING LEAN CONSTRUCTION (LC)

There needs to be a compelling reason for any firm to consider a major operational initiative. There are three which contractors may find important. 1) Wasted time is very high in construction. Koskela suggests 66% of onsite labour performs non-value

activities and 10% of project materials are wasted (2007). Decreasing it leads to a competitive advantage in cost and schedule. 2) Average profits are 3% for contractors. An increase of 10% productivity in a firm in which labour (payroll content) is 35% of total revenue will result in a doubling of net profit. Given the high amount of waste, it is probable that a firm can achieve this with LC's approach. 3) Long-term, contractors want options at the end of their careers. If they have a business that does not demand their full time attention (has employees who can work independently on most tasks) then he or she has a business to sell. If they do not have a business, then they have a job and nothing to sell above the market price of its assets less its liabilities.

LC methodology can be summarized by the 4P model, which instructs that processes be established after adopting a long-term philosophy and before growing its people or seeking partnerships and focusing problem solving. Doing well on the first three steps, contractors will have less need for problem solving and more time to focus on innovation and forward thinking. Gao and Low suggested the 4P model has the most positive attributes of any framework (2014).

Benchmarking of contractor practices is largely ignored in lean research. Surveys based users' opinion of company management of areas such as leadership, technology, planning, training, or control (Ramírez et al. 2004). Some efforts are being made to measure the value of management practices for project performance (Nasir et al. 2012). However, Gao and Low recommend future research to test and validate a framework using empirical data (2014).

Green cautions that lean has weaknesses in addressing people and processes. It has to be tailored thoughtfully to a location's social-technical culture (1999b). It takes people to install construction work. Their wages comprise a significant percentage of the total cost of construction. LC must be understandable to a craft-oriented workforce that has a unique worksite. Womack and Jones state the same thought: "Any manager aspiring to a lean enterprise must understand the conflicting needs of individuals, functions, and companies" (1994).

Lim et al. assert that the means for achieving construction organizational capability has been under-researched (2011). Ballard et al. suggest that production design system research has been minimal (2001). This lack of an identifiable methodology appears to be one of the major objections by contractors. Gao and Low suggested the 4P model (See Figure 1) has the most positive attributes of any LC framework (2014). LC processes are well documented; however, few studies have empirically confirmed the efficiency of lean practices.

The 4P model consists of four sequential phases for a LP adoption. The first is Philosophy described as long term thinking. The next is Processes that eliminate waste. The third phase is People and Partners by respecting, challenging and growing them. The last is Problem Solving by focusing on continuous improvement and learning (Liker 2004).

Promoting the exchange of ideas and meanings between contractors and researchers while guiding the practice is recommended (Alves et al. 2012).

Studying organizations from a management science perspective has been lacking; most studies of the last 50 years have had a social science focus. Additionally, it is critical that academics not only describe the world, but also attempt to improve it (Koskela 2011).

FURTHER EXTENDING LEAN CONSTRUCTION INTO CONTRACTORS' THINKING

To improve LC adoption, we must use an easily accessible efficiency metric. If it is one that can show a construction contracting organization's relative efficiency against its peers, it may convince those that are below average or highly competitive. Even firms that rank close to the top in their market may be motivated to be even better. Among highly motivated companies, the agent for improvement is not crisis or the threat of future change, but competitiveness.

It is important to remember that construction company executives have a limited number of chances to make a change this significant. If there is limited empirical evidence of LC's efficacy, executives will have little faith in the value of adopting LC. Additionally, if an implementation plan is not presented in an organized way, then there may be a concern that little positive change will be achieved. As a separate issue, attempting to implement changes in which the executive has little faith and which have faulty organization may often lead to failure. This failure can cause the construction executive's credibility with their subordinates to decline, which can have a negative impact on their leadership effectiveness for years.

LEAN CONSTRUCTION IS ALIGNED TO SPECIFIC CONTRACTING NEEDS

LC is aligned to minimize or eliminate several major problem areas of construction organizations. Restating general Lean benefits into construction contracting specific benefits may make LC clearer to each firm's senior and middle management.

Practices may be defined as sub-sets to processes. Processes such as work acquisition, project management, and financial management are complex and multi-step. Most practices can be conceptualized as a series of steps that are usually visible or auditable. Practices may include a written document that specifies the actions, such as the Last Planner® System (LPS). Many of them may be monitored by observational work sampling or file inspection. Due their physical nature, construction professionals should understand them more quickly than abstract concepts or general processes.

To address the argument Collins makes concerning labeling of an improvement process, firstly it is important to state LC is teaching an industry and not a company. Secondly, to teach and learn any process with efficacy, it must be formalized. Without labels, graphic representations, case studies etc. leaves the learners at the mercy of the teacher's level of expertise, experience and energy. Ironically, Collins's books can be fairly interpreted as an attempt to formalize an improvement methodology.

The basics of construction are always important to any contracting organization. They are understood by all especially for those who execute the work at the project level. LC appears to cover all the basics. One example is the concept of flow. Koskela and others have researched and written extensively about it. If it is broken down into the behaviors of detailed planning, resource forecasting, and realistic scheduling, part of the concept becomes more understandable. Gathering extensive information is a crucial first step of any planning process.

Most construction cost is controlled and influenced by middle management in the office and field. They are under time and cost pressures and may not have time to understand highly accurate, but complex models. Making LC more understandable in

visual ways, which is a Toyota management hallmark, may help the adoption process. One simple visual model explaining the concept of flow in construction contracting is the Planning, Forecasting, and Scheduling (PFS) model. It applies to project management including field supervision (Stevens 2012).

To prove the value of LC to construction contractors, rather than lobby for broad scale, indiscriminate adoption, we need to demonstrate which lean methods align well with the construction industry, emphasize those that have demonstrable merit, and eliminate or modify those that have little value to the industry. For example, the LPS, a production planning system designed to produce predictable work flow and rapid learning in programming, design, construction, and commissioning of projects, One Piece Flow, which ensures that the right parts can be made in the right quantity at the right time, and Heijunka Level Load Production, a way of leveling production schedules to reduce waste, are all well documented to be of higher than average value in lean construction. However, their efficacy in construction contracting has not yet been well researched. As well, Visual Management and Use of Highly Reliable and Proven Technology are lean methods of obvious value and easy application to construction contracting, where 3 percent net profit should motivate cost-effective practices. On the other hand, "pull systems," where all materials necessary to complete a job are kept in a store, pulled when needed, and constantly replenished as used is notably misaligned to the characteristics of construction contracting, since prefabricated items without a demand for it—a contract or customer order—are uncommon in construction contracting. Thus, maintaining a predetermined inventory would be cost-ineffective.

Table 2. Suggested restatement of common LC practices in construction-centric terms.

Lean Construction Practice	**Possible Restatements into Commonly Understood Practices for use with Importance and Performance Assessment (IPA)**
Last Planner® System	"We plan ahead in writing one week or more at a time. Our company uses a complete list of things to consider when making sure an area is ready for work to be installed."
One Piece Flow	"Each person in our company executes tasks from beginning to end as practicable."
Heijunka - Levelled Workload	"We look ahead at least 6 weeks to make sure our field and office staffs are not overloaded with work."
Standardized Work	"We have one company standardized way to perform each office or field task."
Visual Management	"Our preference is to use visible means (versus written means) to communicate information to all company employees."
Use of Reliable and Proven Technology	"Our software is established and proven; we have few, if any problems with it."
Jidoka – Build In Quality	"We consistently discuss and implement value adding ideas."

In construction there is a need to clarify some LC practices such as Jidoka or Build In Quality. The specifications and commercial contract define the performance and quality requirements. The customer writes the specifications and the contract. In so doing, they define value as they see it. Anything delivered more may not be

immediately rewarded per the project agreement, but is an additional cost to the contractor. However on an organizational basis, value added services can provide customer incentive to choose one company over another and raise the level of the relationship once a contract is signed.

Due to the complexity of construction contracting, no one lean practice can assure a company that its processes will be more efficient than those of its peers. However, if combined as a set of practices, a measure of proof might be shown for construction contractors to consider.

Moreover, while the LC community has already endorsed several lean practices, not every aspect of lean methodology, especially its unique terminology, is understood by construction professionals. To extend lean thinking deeper into construction methodology, it may be helpful to restate LC practices into more common construction terms (See Table 2).

DEMONSTRATING THAT LC IMPROVES MEASURES OF EFFICIENCY

Collins (2001) concluded a single metric approach is attractive to for-profit firms. Several "great" companies examined in his research used this approach, which simplified their assessment of critical success factors. The metric chosen, however, varied among companies; e.g., Walgreens uses profit-per-visit, while Abbott measures profit-per-employee. Therefore, a well-chosen metric could be a judge of efficiency as well as a motivator. Having a single measure by which to assess efficiency may show companies that they are not as efficient as they believe they are. Simply put, half of construction contracting firms are below average. If it can be shown that LC offers practices that help them improve their bottom line, then more companies may be motivated to adopt the methodology.

Overhead (indirect expenses of building projects) is a significant cost to all construction organizations. Kim and Ballard (2002) noted the increasing importance of overhead in coordinating and executing both specialty and general contractor work. There is little question that direct cost (costs directly related to the project i.e. labor, materials, equipment etc.) is also important. Taken together, overhead and direct costs comprise the largest expenses of construction firms. The ratio between them measures one type of efficiency of construction organizations.

In construction contracting, the resources included in overhead (personnel, office space, technology, etc.) manage the project factors that are the source of direct costs. Done well, the ratio of overhead to direct costs' will be lower than peer benchmarks. The presumption is that higher ratios than peer benchmarks indicate relative inefficiency; e.g., companies with higher ratios are spending more capital than others producing the same work.

This data is available in the United States for that country's construction contracting businesses from The Risk Management Association (RMA). *The Annual Statement Studies* are an accepted source of composite performance metrics including direct cost and overhead averages, derived directly from the financial statements of financial institutions' borrowers and prospects. These financial statements are sent to RMA from their member institutions, which get their data directly from their customers.

As examples from the researcher's pilot study in 2011, electrical firms (SIC 1631) between $25 and $50 million in annual billing had a median overhead to direct cost

ratio of 27.3%. Earthwork contractors (SIC 1794) between $5 and $25 million in annual billing had a median overhead to direct cost ratio of 29.6%.

To encourage construction contracting companies to adopt LC, it should be demonstrable that LC firms' ratio of overhead to direct costs should compare favorably to their peers.

A POSSIBLE EMPIRICAL RESEARCH DESIGN TO DEMONSTRATE THE VALUE OF LEAN CONSTRUCTION

Importance-Performance Analysis (IPA) offers a research framework to assess and compare value of construction practices. One application of IPA is to measure the difference between the rating of importance and performance of a practice. The importance rating gives respondents an opportunity to rate a practice regardless whether it is used by their firm. The performance scale rates the level to which the firm executes the practice. (See Figure 1).

Practice: We require specific packaging / labeling on supplier shipments to keep our labor productivity high.								
	Rating: 1 for low and 7 for high	1	2	3	4	5	6	7	Rating Average
Importance to the Efficiency of our Company		0	2	1	3	3	1	3	4.69
Performance of our Company		2	4	3	2	1	0	1	3.00

Figure 1: Importance Performance Analysis survey example showing multiple responses.

The difference between importance and performance provides a relative disparity. By comparing the overhead to direct cost ratio among firms in the same Standard Industry Classification (SIC) furnishes a useful efficiency metric. Each practice's difference of importance to performance would be correlated against the respondent firm's percentage difference between its peer benchmark and its own overhead to direct cost ratio. This disparity correlated to a company's efficiency measure can provide a measure of proof of practices' value. (See Table 3).

The IPA approach has another benefit; it may introduce a previously unknown LC concept to a respondent helping to increase awareness and education.

Survey respondents' should include middle managers such as project managers, field managers, financial staff, estimators, and human resource professionals. These employees have intimate knowledge of practices' importance and the company's performance in executing them. Given the worldwide audience of lean, a statistically significant number of respondents can be achieved.

While any outcome would be difficult to completely satisfy all parties involved in construction, correlating already valued construction contractor practices with LC methods would lend credibility to LC. Each correlation coupled with its significance value would clarify the effect of each LC practice to construction contracting's efficiency.

Table 3. Example of Survey Summary and Overhead to Direct Cost Ratio

Organization	Average Importance Rating of Practices	Average Performance Rating of Practices	Average Disparity Between Importance and Performance	Company Percentage Difference to Peer OH/DC
Smith Construction	5.09	4.46	-0.64	+69.60%

There are many analyses to conduct including multivariate correlations. Here are three simple ones that would give more clarity to LC's practices value 1) A ranking of practices' importance. This provides a perception of value. 2) A ranking of practices' importance to performance disparity. This shows the implementation activity of practices including ones with high importance rankings. 3) A ranking of practices' performance. What is highest may show what is easiest to adopt. It could point to the first practice(s) to implement. These measures and others when taken together would provide the respondents' assessment and point to general industry impressions.

It appears that several practices could be added to this empirical research. As an example, financial practices significantly affect construction production, especially between general contractors and subcontractors. In the researcher's experience, subcontractors choose between projects to staff in light of client payment habits. General contractors that pay timely tend to receive more resources (craftspeople, operators, equipment etc.) than those that do not. Promises to staff projects are kept or not kept sometimes due to a general contractor's payment habits.

Additionally, if common practices which are outside of Toyota's production and management methods are not included, there may be statistical invalidity. As in the famous study of ice cream consumption, hot weather and murder rates in New York City. Considering only ice cream consumption and murder rates leads one to believe a direct positive correlation.

Quality empirical data should result in a high degree of confidence in subsequent recommendations. Positive outcomes of such a study would further build the case for the adoption of LC practices and its philosophy.

AN IMPLEMENTATION FRAMEWORK

There is little question that changing human behaviors is a difficult task. However from the researcher's advising experience, the following basic framework has helped construction organizations and their personnel adopt new processes and thinking. Firstly, the formal leader of the organization should explain that the overall change is realistic and needed. Also, he or she should communicate that the innovation methodology works and involves incremental steps which are comfortable to execute. Secondly, implement a highly efficient – low cost practice in the beginning phase with those employees who are thought leaders. Respected employees who have success with a new practice will sell its value to others. Starting with a high payoff practice implemented well produces confidence for continuing the improvement

methodology. Practices that are project specific such as the LPS are good candidates due to limited change required. Thirdly, document success extensively and communicate to all employees. Fourthly, providing formal and informal rewards keep the change alive. This is organizational executive's function. He or she has several ways to influence behavior. This four step cycle repeats as each new practice is introduced and implemented. Implementing valuable practices one at a time keeps training investment less. Training is needed as each new practice is introduced and implemented. It is universally recommended that it occur close in time to when the skill is needed. Training assures that people's skills are aligned with the requirements of the practice. Additionally, it has been the researcher's experience that trained employees are comfortable in suggesting improvements.

Lastly, the new processes should be captured in writing with full descriptions including responsibilities, practice illustrations, flow diagrams and forms to assure full implementation. This should be a virtual document which allows for instant updating among other benefits. Additionally, a virtual monitoring system of practice execution allows executives to keep compliance high.

There are several things to consider in any change methodology depending on the culture and sophistication of individual construction organizations. This basic framework may expand to encompass those company specific considerations. In the end, this structured and iterative process changes a company's management method from an ad hoc management method to a LC one.

CONCLUSIONS

Increasing construction project outcomes through better contractor performance benefits everyone. Construction is a business that is competitive and risky. Bankruptcy rates are high. The lean community believes that LC offers a straightforward process to higher-than-average performance. To them, the case for adoption is evident, yet construction contractors as a group have not fully adopted LC. What appears to be lacking is evidence that contractors understand. The case for lean's value may simply have to be restated in contractor-centric terms. More research is needed to demonstrate that LC practices are closely aligned with construction contractors' characteristics and operational demands, and that using LC can improve efficiency.

A metric that compares a contractor's efficiency with that of its peers will show the need for improvement for a significant population of construction contractors. We suggest that overhead to direct cost ratio should be considered. In some cases, already superior firms, a competitive spirit to be the best may be the incentive for LC adoption.

There may be several non-lean practices that improve efficiency; i.e., decrease waste and increase speed. The source of those practices is not required to be from the car manufacturing industry. Just as the Kanban was found in the grocery business, there are other industries, including construction where valuable practices may be found. These practices should also be included in the study. Whatever their origin, the results would highlight practices that best improve efficacy.

The 4P model provides a valuable framework to conceptualize the overall construction contracting improvement process. It instructs that companies should

establish processes after adopting a long-term philosophy and before growing its people or seeking partnerships and focusing problem solving. From a long term philosophy and good practices, people and partnerships will grow in quality; therefore contractors will have less need for the fourth level, which is problem solving. This sequential pathway is illustrated by the 4P model. However, research on contractor practices has been limited. It is suggested empirical studies be performed to understand the correlation of lean practices and other common ones to a desired outcome(s).

Lean has been researched in many areas. The work has helped practitioners to understand the concept and its application to construction. If this middle phase on the continuum of LC is done well, the majority of contractors will start asking about the last phase, Lean Enterprise.

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