

Conceptual Framework for a Lean Construction Capability Model

Somik Ghosh, PhD
University of Oklahoma
Norman, Oklahoma

Lucas T. Heidenreich, MS
Kiewit Construction
Tuscon, Arizona

The Lean Construction capability model can be a beneficial tool for owners to assess contractors' competence concerning the Lean construction process. The benefit of Lean is to focus on the true needs of the customer and prevent any waste from occurring during production. There is very little information available for creating a framework for a Lean Construction capability model that will assist the owners in assessing contractors' Lean capability. This paper has examined the use of capability models in various industries and reviewed their methodological approaches and applications. Based on the commonality of the existing capability models, a conceptual framework for a Lean Construction capability model was developed. Key informants in Lean Construction were interviewed and their feedback was incorporated in the development of the framework. Subsequently, the conceptual framework was reviewed by owners. Overall, this study found that it is possible to create a framework for a capability model in the construction industry using lessons learned from other industries while valuing the foundational philosophies of Lean Construction. The framework used for Lean Construction needs to be flexible to fit the needs of a variety of contractors.

Key words: Lean Construction, Lean competence, capability model, owner

Introduction

Since its inception in the early 1990s, Lean, as a process improvement philosophy, has slowly gained popularity among contractors. While Lean construction is not merely a translation of the Lean manufacturing tools for the construction environment, the theoretical underpinning remains unchanged. With its focus on smooth workflow, elimination of waste, and continuous improvement, many contractors utilizing Lean have claimed substantial performance improvements. Reports of positive performance gains by the contractors have encouraged the owners to seek companies with Lean capabilities (or expertise). Although Lean construction has been in existence for more than two decades, the recent interest among owners has created a huge push among contractors to list their names on the bandwagon of Lean construction. Needless to say, not all the contractors who are claiming to be implementing Lean construction have the same level of expertise or capability. With the increasing competition in the construction industry, companies want to gain advantage over their competitors, and claiming to be Lean is one way to do that. In this context, a tool to measure the Lean capability of certain contractors might be beneficial for the owners and facilitate the contractor selection process.

Available literatures on 'maturity model' and 'capability model' have used these two terms interchangeably. We have followed that trend and not attempted to create a distinction between these two terms. We have adopted the definition offered by Marcolin et al. (2014): "*capability implies an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired stage.*" In the context of Lean Construction capability model, such a model will be able to measure the progression of an organization through different levels of its Lean capability. After reaching a level, the organization will need to reach another set of goals and so on until an organization is considered to have fully embraced the Lean culture. While capability is typically shown in numeric form, the output of the Lean capability model is not shown in the form of a score rather a level. This is because when measuring Lean capability there is no terminal point. There can always be improvements. The proposed model would place organizations in a level of capability from where they can either move up to the next or continuously improve. Since adopting Lean is a culture change, the idea of measuring Lean capability by providing scores based on a few Lean tools that an organization implements contradicts the Lean philosophy of enterprise level change. Before describing the details of the project, a brief background on Lean construction and capability models has been presented in the following sections.

Lean Construction

Lean is well recognized in the manufacturing industry as a systematic method for the elimination of waste. The philosophy of Lean is to continuously improve the production process and maximize the value of the product to the customers. Genaidy et al. (2006) defined Lean as the value of the product/service as perceived by the customers. Although it was first used in the manufacturing industry, the philosophy of Lean is equally applicable to multiple industries. In many cases, some of these fields are very similar to Lean manufacturing and can easily be confused. For example, Genaidy et al. (2006) mentioned that Lean manufacturing and Lean construction techniques share many common elements despite the obvious differences in their environments and processes. A major distinction between the two industries is that the products in manufacturing are movable, while the products in construction are largely anchored in place. Green and May (2005) further identified three characteristics of construction that make it different from manufacturing, which are on-site production, one-of-a-kind projects, and the overall complexity of projects.

One of the first transitions from the concept of Lean manufacturing to Lean construction was conceived by Frank Gilbreth in the 1890s (Ahmed and Forbes 2011). Gilbreth observed brick layers and their process of grabbing bricks. He observed that the brick layers were creating unnecessary motions that were not contributing to the job. To resolve the problem, Gilbreth moved the bricks right next to the brick layers. He utilized low skilled, low paying workers to transport the brick near the brick layers when they were running low. After the change from the master builder concept to the traditional construction concept, the only growth in productivity came from the advancement of tools, the idea of prefabrication, and the use of computers (Ahmed and Forbes 2011). While this did not have a drastic impact on the productivity of the construction industry, a new idea was presented by Koskela (1992) to utilize Lean manufacturing concepts and techniques in the construction industry. Instead of the advancement of technology, Koskela focused on the principles of a production philosophy. Lean construction proposes a list of principles that aid in the improvement of the construction processes through: (1) reducing the share of nonvalue-added activities, (2) increasing output value through systematic consideration of customer requirements, (3) reducing variation in the processes, (4) reducing cycle time, (5) simplifying by minimizing the number of steps, parts, and linkages, (6) increasing output flexibility, (7) increasing process transparency, (8) focusing control on the complete process, (9) building continuous improvements into the process, (10) balancing flow improvement with conversion improvement, and (11) defining clear benchmarks.

Rationale of the Research

The construction industry lags behind the manufacturing and the service industries with regard to their performance. According to the Bureau of Labor Statistics (BLS), in the past 40 years, the productivity of the non-farm industries has increased by over 100%, while that of the construction industry has seen minimal improvement. Several research studies have shown that the current construction processes are plagued with wasteful operations. Studies by the Construction Industry Institute have identified that almost half of the time spent on construction activities are not adding any value to the project. Lean can effectively identify and reduce wastes from the existing process and increase the proportion of value added activities, thus improving project performances. The owners/customers are inclined to take advantage of the benefits of adoption of Lean construction by contractors. Our capability model can benefit the owners/customers by offering a measure of the Lean capability of any contractor.

Literature Review

By definition, a capability model is a methodology used to develop and refine an organization's development process. From this definition, there are many branches of the capability model that can be used to fit the needs of the organization. While these models are very similar and have several branches, this document will explain capability models to better understand their purpose. The existing literature was reviewed to develop an understanding of various capability models, how they are structured, and what they produce (outcome). The review evaluated available studies that implemented any form of a capability model and the disciplines in which they were used (production, software, and others).

Use of Capability Models

A common feature conspicuous among the capability models was the use of five or six "capability" levels from high to low. These "capability" levels are the focus points for an organization that needs to be improved (Earthy et al. 2006). The level of capability indicates the objectives currently satisfied by the organization and the improvements necessary to move to the next capability level. Marcolin et al. (2014) defined the basic components of capability models: (1) multiple levels, (2) description for each level, (3) generic description or summary of the features of each level (4) number of dimension, (5) number of elements/activities for each dimension, and (6) description of element or activity as it might be performed at each level of capability. After reviewing the literature, it was evident that multiple industries utilize capability models which shows the flexibility and wide spread application of the models. The section below presents capability models identified in various industries with their structure and lessons learned.

General Business/ Management

A study designed by Bruin and Freeze (2005) identified ways of cutting costs, improving quality, and reducing time to market. The authors studied management models in IT, business, process, and projects. They stated that the importance of a standard development framework is emphasized when considering the purpose for which a model is applied. Since their focus of work was very general, they decided to do a comparative model. A comparative model can cover many different characteristics (in this case, the different frameworks). In order to obtain a similar outcome, they proposed a capability model that was able to function similarly in a wider variety of grouped frameworks. Bruin and Freeze (2005) established that organizations have greater ability to measure and assess domain capabilities at a given point in time. They also stated that one of their limitations was not experimenting with their framework in more organizations to see if it could be utilized across different organizations and with what degree of success. By understanding the relationship between the comparative model and capability model, the connection can be made that capability models can be flexible in determining outcomes by comparing characteristics of a similar model. With this information, the flexibility of the capability model can be better understood.

Software Industry

Boeham, et al. (1995) conducted a study which found software is becoming more important to companies across all sectors. It covered a wide range of criteria from improving the usability of software in general, to improving the usability of software in specific disciplines. Research by Earthy et al. (2006) states that usability is one of the most important qualities of software intensive systems and products. In their study, Earthy at al. (2006) tried to find how to improve usability in software. A study conducted by Krogulecki et al. (2012) focused more on the construction industry with the same software usability idea. This study created a capability model by evaluating companies that implemented building information modeling (BIM) into their projects. Specifically, the project focused on award winning BIM projects with research emphasis on six of eleven areas of interest. By analyzing the information from these areas of interests, it is easier to understand the capability model that was used to evaluate these projects. The six areas of interests that Krogulecki et al. (2012) focused on are (1) graphical information, (2) data richness (3) interoperability, (4) life-cycle views, (5) roles or disciplines, and (6) business process. They discovered that not all BIMs are created equally due to the different projects and needs of the clients. By studying the capability models of the award-winning BIM projects, it was evident that the maturity model framework was able to compare the projects despite the physical differences among the projects.

Production/Manufacturing Industry

Capability models have been utilized in the production/manufacturing industry as well. A study was conducted by Marcolin et al. (2014) in regard to changing markets and demands. They stated that companies were unable to keep up with the demand that resulted in loss of money due to high labor. In the study, they suggested implementing product lifecycle management to keep pace with these changing variables. Marcolin et al. (2014) evaluated different proposals for a product lifecycle management framework. They established five categories to analyze and assess each proposal, which were (1) detail level, (2) testing, (3) effectiveness, (4) application, and (5) addressed domain. The most effective framework found would be used for the product lifecycle management implementation. Marcolin et al. (2014) stated that the main objective of using the capability assessment was to carefully plan the implementation process. A study done by Jones et al. (2011) showed a similar method of creating a capability model. In this study, the authors wanted to create a better relationship between supply chain management in the construction industry. The criteria they used for the model were (1) procurement objectives, (2) trust, (3) collaboration, (4) communication, (5) problem solving, (6) risk allocation, and (7) continuous improvement. They measured these criteria over four levels of capability, which were price competition, quality competition, project partnering and strategic partnering.

Construction Industry

Within the construction industry, Babatunde et al. (2016) identified 22 process areas and categorized them into four groups for the purpose of development of capability model. These groups, (1) process management, (2) project management, (3) engineering, and (4) support are the areas in the stakeholders' organizations that needed improvement. To make these improvements they proposed five levels of capability for the organizations. Babatunde et al. (2016) reported that the framework was applicable in twelve of the fourteen organizations they studied. Chan et al. (2010) conducted a similar study to investigate the importance of risk management systems and their impacts on organizations. The framework used is very similar to the work done by Babatunde et al. (2016). The difference was apparent in the processes that Chan et al. (2010) focused, which were: (1) management, (2) culture, (3) risk identification, (4) risk analysis, and (5) systematic risk management. The risk management model was tested successfully in different construction organizations. These studies show that frameworks for capability can be implemented for improvement in certain areas. A study conducted by Balonick et al. (2003) sought to understand whether Lean principles are relevant to the construction processes. To do this, they first identified the principles of Lean. After identifying Lean principles, they began researching the construction production value streams. Next, they narrowed the search to evaluating individual firm conformance to Lean principles. Finally, they interviewed early Lean adopters. By taking these steps, Balonick et al. (2003) could identify five Lean principles in construction. These principles were: (1) standardization, (2) culture/people, (3) continuous improvement/built in quality, (4) eliminate waste, and (5) owner focus. Subsequently, they stated that by combining performance on sub-principles, one can assess conformance to the main principles.

The frameworks discussed above have proven to be useful across different industry sectors. Understanding how capability models work across different industries, allowed insights into creating the Lean capability model discussed in this paper. As Balonick et al. (2003) claimed, it is possible to create a capability model for the construction industry with characteristics from other industries such as manufacturing. With this understanding, we attempted to develop a capability model to measure Lean capability of contractors.

Research Objectives and Methods

The goal of the project was to develop the framework for a Lean capability model for the owners/customers to facilitate the selection of contractors. The specific objectives for completing the research goal were as follows:

Obj. # 1: Review existing capability models to explore methodological approaches and identify criteria to measure Lean capability of contractors
Obj. # 2: Develop a conceptual framework for measuring Lean capability of contractors
Obj. # 3: Test efficacy of the Lean capability model on a pilot basis

Research Method

The research method adopted for accomplishing the above listed objectives is discussed in this section. To accomplish Obj. # 1, an extensive literature review was conducted using databases such as Web of Science, Engineering Village, Science Direct, Green FILE, Google scholar, and similar databases. Some of the keywords that were used for searching the databases are 'capability model', 'maturity model', 'Lean capability/maturity', 'capability model/future', etc. Searching these key words uncovered hundreds of similar articles. To establish some boundaries and narrow the search, time relevancy (articles published in the last 10 years) and topic relevancy were used. To increase the depth of the literature search, subsequent to the initial database search, bibliographies of shortlisted articles were scanned to identify relevant citations using the 'snowball' approach. From the literature review, it was evident that the criteria used for the various existing models were different; the main objective was to understand the methodological approaches that have been adopted for the existing models.

Two main categories were discovered from the existing literature. Each of the categories had a list of their own criteria that could be used for measuring Lean capability among the contractors. The first category was the organizational context, whose criteria consisted of: size of the organization, support of upper management, inclusion of employees at all levels, and workshops/training offered to employees. The second category was Lean practices. The criteria for this category were the tools utilized in Lean organizations: pull planning, last planner system, workplace organization (5s), location based management system, standard procedures of operations in the office, employee involvement, cross functional teams, supply chain relationship, continuous improvement program, quality improvement plan, safety improvement program, alternative project delivery, and use of building information modelling.

After the identification of the categories from the literature, we conducted a focus group interview consisting of eight individuals who worked in the industry as practitioners and key informants on Lean construction. All the individuals had more than 10 years of experience in Lean construction and were active members of a Lean Community of Practice. Lean Community of Practice (under the auspices of Lean Construction Institute) is a group of professionals representing different stakeholders of the construction industry who lead the evolution and practice of Lean in the local area. Hence, it was a conscious decision to include these individuals in the focus group interview. The rationale behind using a group interview was the lack of experience in capability model among the participants. The participants were introduced to the concept of capability model, thus stimulating a group dynamic on the basis of shared understanding of the topic. The data from the focus group interview were analysed using the framework method, which is a widely used method for qualitative data analysis developed from the National Centre for Social Research (NatCen Social Research 1999). Follow up interviews with five additional experts in the field of Lean construction, who were based in USA, UK, Australia, and Norway, were conducted to validate the outcome of the focus group interview.

Considering the main focus of the Lean capability model on facilitating the owners in their selection of contractors, the developed model was provided to three owners (who were part of the previous focus group interview) to review the efficacy of the model on a pilot basis. Subsequent to reviewing the model, the owners were interviewed as a group to get feedback, and followed up for individual discussions.

Findings

Appendix – I shows the list of criteria identified from the literature review and from the feedback of the focus group participants. While review of the existing literature provided the basic list of criteria, the participants suggested additional criteria they felt were important and needed to be included when measuring Lean capability. For the category of organizational content, the additional suggested criteria were: culture of innovation, collaborative decision making, advocate for success of owner, culture of constructive content, management for Lean culture, and strategy development. The suggested added criteria for Lean practices were: five why root cause analysis, A3 decision making, production control, target value design, visual management, and just in time (JIT) delivery.

The discussions among the participants of the focus group and the outcome could be categorized into three main themes, which are discussed here. The participants strongly voiced that Lean capability model should not have any endpoint as contractors could continuously increase their capability in Lean, but could never reach a point beyond which there is no improvement. One of Lean's foundational principles is continuous improvement; there is no end to improvement. Thus, a Lean journey has no end goal. Secondly, participants debated about the distinction of a Lean capability model from other capability models. It was the consensus of the group that the Lean capability model should be a measure of the understanding of the philosophy of Lean by the contractors. This presented an inherent challenge of creating a model to measure the Lean capability, as measuring the level of understanding could be vague and subjective. Not only did this indicate the lack of shared understanding about capability model among the participants, but this also emphasized the uncertainty in the participants' mind around what is 'capability' in a Lean construction context. Lean maturity models are in existence in other industries, such as in aerospace, where such models are successfully utilized. However, there seemed to be lack of assurance whether similar models would be applicable in the Lean construction context. Questions were raised such as 'how does a Lean capable organization differ from others?', 'how will a Lean capable organization further increase its capability?', 'is there an epitome of Lean capability?' These queries lead to the third theme in which the participants agreed that Lean capability of any organization would be an evolving process. The participants were not sure how the path through the evolution would proceed. The evolution of Lean could be compared with the evolution of human beings. With the analogy of the evolution of human beings, five out of the eight participants were inclined towards using 'maturity' instead of 'capability' for the ease of comprehension and 'maturity' being the most commonly used term in similar context. However, the follow-up discussions with the subject matter experts did not result in any such distinctions among the two terms. Thus, we decided to refer to the mode as Lean capability model.

The participants of the focus group showed reluctance to measure Lean capability of contractors solely based on adoption of tools, rather they chose to emphasize the path of Lean evolution. Due to the focus of this capability model on the owners/customers, it was necessary to maintain a balance between the tools adopted by the contractors and their journey in the path of Lean evolution, so that they could assess the contractors' Lean capability. As a result, the suggested model included all the identified criteria with five capability levels, with level one representing the lowest and level five representing the highest level of maturity. The section below describes the five levels with their operational definitions.

Capability Level 1-Ad hoc/Absent
Capability Level 2-Isolated Projects
Capability Level 3-Deploy in Multiple Projects
Capability Level 4-Formal Organizational Standards
Capability Level 5-Using as Competency

Capability Level 1- Ad hoc/absent represents contractors that have not started utilizing Lean yet. It also represents a contractor, which had ideas about Lean but very little experience with it. **Capability Level 2**-Isolated Projects represents contractors that have used Lean tools on a project. This level could also represent pilot projects to ascertain how well they could handle Lean philosophy in their organizations. **Capability Level 3**-Deploy in Multiple Projects is exactly what it sounds like. Contractors at level three would have multiple projects that are utilizing Lean. This would show that the contractor would be able to handle and understands how the process works. **Capability Level 4**-Formal Organizational Standards represent a new set of standards that are established throughout an organization. In construction, this would mean the contractors have Lean standards on project sites or in offices, for everyone to follow. The final capability level (**Capability Level 5**) is achieved when a contractor can successfully identify problems and fix them in order to be efficient and successful. Another way to word this would be continuous improvement. The framework can be used to measure the capability of any contractor at an organizational level or to measure capability in one or two specific criteria.

The capability levels can also be used to measure the effectiveness of the individual criteria that were found in the literature review. Operational definitions were given for each level. Take pull planning for example, as it was identified as important by the participants' responses (Appendix – II). If pull planning was not used by a contractor, it would start out at Capability Level 1. Pull planning would move into being applied into a pilot project to understand how it will work. If pull planning succeeded it would then be introduced into multiple projects to achieve Capability Level 3. If the method failed on the pilot project, changes would have to be made until it is efficient enough to move to the next level. This process would then continue to progress through the levels as greater competence is achieved (see appendix for capability level examples). This approach could be used on all the criteria a specific contractor has adopted. This would result in the contractors becoming familiar with each process, allowing them to achieve a full Lean capability.

Discussions and Conclusions

All the three owners who reviewed the conceptual framework agreed with the notion of not having an endpoint to the Lean journey of the contractors. The approach of the framework to focus on the journey and not measure "how Lean is a particular contractor?" was commended by two out of the three owners. In a true Lean journey, the contractor should always be aspiring to make continuous improvements; a contractor will never get matured on Lean as it does not involve doing the same thing repeatedly. Instead, the contractors will increase their capability to identify wastes in the current processes and make changes/modifications to reduce or eliminate the wastes to improve the future processes. The owners agreed that it is typical for an organization to ask, "what is the next level to go to?" The conceptual framework will guide such contractors to identify their next step in the evolution, but it will not be a standard target for everyone. All the three owners agreed to the framework's flexibility by not providing any standard target for all the contractors across the board. The owners shared their personal experiences where they have seen contractors start their Lean journey in different ways. One owner even went to the extent of questioning the different levels of the conceptual framework by citing the example of Toyota, which always strives to achieve the ideal state of zero inventory without any incremental levels. However, the other owners were inclined to keep the different levels in the conceptual model, as they would provide a measureable way to assess the contractors' Lean capabilities.

This paper has examined the use of capability models (or referred to as maturity models) in various industries and reviewed the methodological approaches adopted for developing those models and their applications. Based on the lessons learned from reviewing the existing capability models, the criteria for a conceptual framework of Lean Construction capability model was developed. Expert informants on Lean Construction were interviewed to identify any additional criteria and their perceptions on the need and use of the capability model. This paper indicates there are no major constraints on developing the conceptual framework to an operational one, contextualized to Lean Construction. However, it was evident from the findings that a Lean Construction capability model will need to have metrics that are congruous with the foundational Lean philosophy of continuous improvement. The operational model would have to capture the understanding of Lean by contractors. The participants agreed that a Lean Construction capability model will differ from other existing models, in that, it does not have an endpoint. Our future efforts will focus on getting reviews from additional owners and identifying appropriate metrics to the measure Lean Construction capability of contractors for employment by owners.

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Appendix - I

CRITERIA TO MEASURE LEAN-CAPABILITY OF AN ORGANIZATION

What best describes the primary responsibility of your organization? ______________________

Since how many years is your organization in business? ______________________

How many employees do you currently have? ______________________

Rate the importance of the following factors to measure Lean Capability

ORGANIZATIONAL CONTEXT	IMPORTANCE (1 = MIN.; 5 = MAX)					
	NOT APPLICABLE	1	2	3	4	5
Size of organization						
Union status of the organization						
Support of upper management						
Inclusion of employees at all levels						
Workshops/Training offered to employees						
List Other:						
List Other:						
List Other:						

Rate the importance of using the following practices to measure Lean Capability

LEAN PRACTICES	IMPORTANCE (1 = MIN.; 5 = MAX)					
	NOT APPLICABLE	1	2	3	4	5
Pull Planning						
Last Planner System						
Workplace Organization (5S)						
Location Based Management System						
Standard Procedure of Operation in Office						
Employees' Involvement						
Cross functional Employees						
Manage relationship with suppliers/supply chain						
Continuous Improvement Program						
Quality Improvement Plan						
Safety Improvement Program						
Alternative Project Delivery (IPD, Design Build)						
Building Information Modeling						
List Other:						
List Other:						
List Other:						
List Other:						
List Other:						

If you agree to be contacted in future, please provide your name and email id:

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Appendix – II

Pull Planning -A pull system consists of tasks that are pulled by successive workstations, as and when required. Pull planning in simplest terms means that no one upstream should produce a good or service until the customer downstream asks for it (Powell et al. 2013).

- **Capability Level 1 –** Traditional practice is in place. Call one or two contractors that have implemented pull planning. Research about pull planning.
- **Capability Level 2 –** Meeting with subcontractors is held to discuss and create a test schedule using pull planning on isolated project (as pilot). A pilot project has partially implemented pull planning.
- **Capability Level 3 –** Pull planning is implemented into some projects. A schedule has been created with the sub-contractors.
- **Capability Level 4 –** Company implements pull planning into all projects. All projects have meeting with sub-contractors to create schedule from the pull planning strategy.
- **Capability Level 5 –** Continuous improvement on the pull planning strategy. Record data from projects. Identify areas of issue and resolve.