MEASURING LEAN CONFORMANCE

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ABSTRACT

The Construction Industry Institute (CII) is interested in the applicability of lean thinking to the construction process. CII has formed a research team to understand lean principles and to evaluate their applicability to their members' construction processes. As part of the work, the research team has developed a questionnaire to measure a firm's "conformance" to lean ideals. This paper presents the questionnaire, describes its formulation, and illustrates its use.

KEYWORDS

Lean production, lean principles, lean construction conformance, lean construction questionnaire.

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INTRODUCTION

CII's overall goal for this research team is to develop an understanding as to whether lean principles are relevant to the construction processes most commonly used by their member companies. The CII research team consists of professionals and academics from CII companies and institutions. The team members work for owner's organizations as well as individuals associated with design and construction companies. The mission and scope of work for the research team are:

Mission: *The purpose and mission of the PT191 team is to examine the potential for the use of Lean Principles that were developed in the manufacturing industry for adaptation and use in the Engineer, Procure, Construct [EPC] Industry. This examination will result in recommendations for application and tools for implementation of these recommendations.*

Scope of Work:

1. *Define "Lean Construction" in the world of Engineering, Procurement, and Construction.*
2. *Determine the current state of "Lean" practices in the EPC industry.*
3. *Demonstrate high- value applications of "Lean" practices for the EPC industry.*
4. *Recommend appropriate tools or processes to be developed.*
5. *The primary focus of the team in executing Items 1-4 [above] will be on the project and process level.*

The research team has focused specifically on the following work tasks:

1. identifying lean principles
2. evaluating construction production value streams
3. evaluating individual firms conformance to lean principles
4. interviews with early lean adopters

After significant debate, the research team chose to focus their investigations on the construction production and give relatively less attention to lean design and supply chains. The team decided to focus on production aspects in order to limit the scope of their research efforts. The research team has devoted significant time to identifying lean principles and refining the principles found in the manufacturing domain to better reflect the idiosyncratic nature of construction. The team is also carrying out a series of value steam studies to help understand and characterize waste in construction production process. In all of these efforts, the research team is using the experiences of early adopters of lean construction to inform the research process. Finally, the team is developing a "lean conformance" tool to help companies assess the extent to which a company conforms to lean ideals. The focus of this paper is the creation, validation, and use of this lean conformance questionnaire.

LEAN PRINCIPLES IN CONSTRUCTION

If one wishes to assess lean behavior, one must first define lean principles and ideals. The basis of lean thinking started with manufacturing. Toyota developed the production principles for lean in their Toyota Production System. Others, such as Womack and Jones (Womack and Jones 1996), General Motors Corporation (GMS 2001), Walbridge Aldinger (WA 2002), Ballard et al. (2001), Picchi (2000), Koskela (2000) and other lean adopters have refined and expanded the lean concept for construction. Our research team developed a set of "lean construction principles" that we believe capture the best and most relevant principles from each of these participants. Using all of the above-mentioned sources, our team identified the following five topmost principles of lean construction:

1. Standardization
2. Culture/People
3. Continuous Improvement/Built-In Quality
4. Eliminate Waste
5. Customer Focus

WHEEL FOR LEAN CONSTRUCTION

It is often stated that one should not recreate the wheel, however, our team has created a wheel that serves both to depict lean principles and to rate a companies' adherence to those lean principles. Our wheel, shown in Figure 1, is fashioned after a similar device used in the Value Stream Management text (Tapping, Luyster, Shuker, 2002). In this wheel, each main principle is divided into numerous sub-principles. For example, ***Standardization*** encompasses three sub-principles; *Workplace Organization, Visual Management*, and *Defined Work Processes*. The number of sub-principles varies for each main principle, but we believe, all important lean principles (for construction) are included in this wheel.

Each sub-principle is, in turn, divided into a number of questions. Each question is designed to measure a firm's conformance to the sub-principle. The number of questions associated with each sub-principle is variable and all questions carry the same weight or importance. Each question is answered along a continuum that ranges from "lean" behavior to un-lean behavior. Thus, by answering each question one evaluates conformance to a lean sub-principle. By combining performance on sub-principles, one assesses conformance to the main principles.

QUESTIONNAIRE DESIGN

The following paragraphs describe the intent and scope of each sub-principle included within the main principles:

STANDARDIZATION

As previously mentioned, ***Standardization*****,** contains *Visual Management*, *Workplace Organization* and *Defined Work Processes* sub-principles. *Visual Management* is defined as

posting of relevant information concerning schedule, cost, safety, and productivity about the job in a location that is convenient for all managers and crafts. *Workplace Organization* encompasses the degree to which the jobsite material, equipment, tools, and resources are organized and structured for efficient project execution. This sub-principle also encompasses the 5s's (Separate/Scrap, Straighten, Scrub, Sustain, and Systematize) (Walbridge Aldinger 2002). The third sub-principle, *Defined Work Processes*, deals with the documentation of all critical work processes and the understanding of these processes by the project team. ***Standardization*** is one of the main features of lean construction since it adopts the philosophy of keeping things consistent for the workers. A clean, organized, and logical jobsite will lead to shorter cycle times and increased productivity. Typical questions included in the ***Standardization*** Principle are shown below, (The lean behavior is on the right side, and the non-lean behavior is on the left. Survey participants will rate their company on a 1 to 5 scale, with the leanest behavior being a 5.):

There is no posted information regarding schedule, quality, safety, productivity, or job status.	1 2 3 4 5 N/A	The jobsite uses visual devices that communicate job status and requirements on schedule, quality, safety, and productivity to everyone.
The posted information is not up to date.	1 2 3 4 5 N/A	The posted information is up to date and easy to understand by everyone.

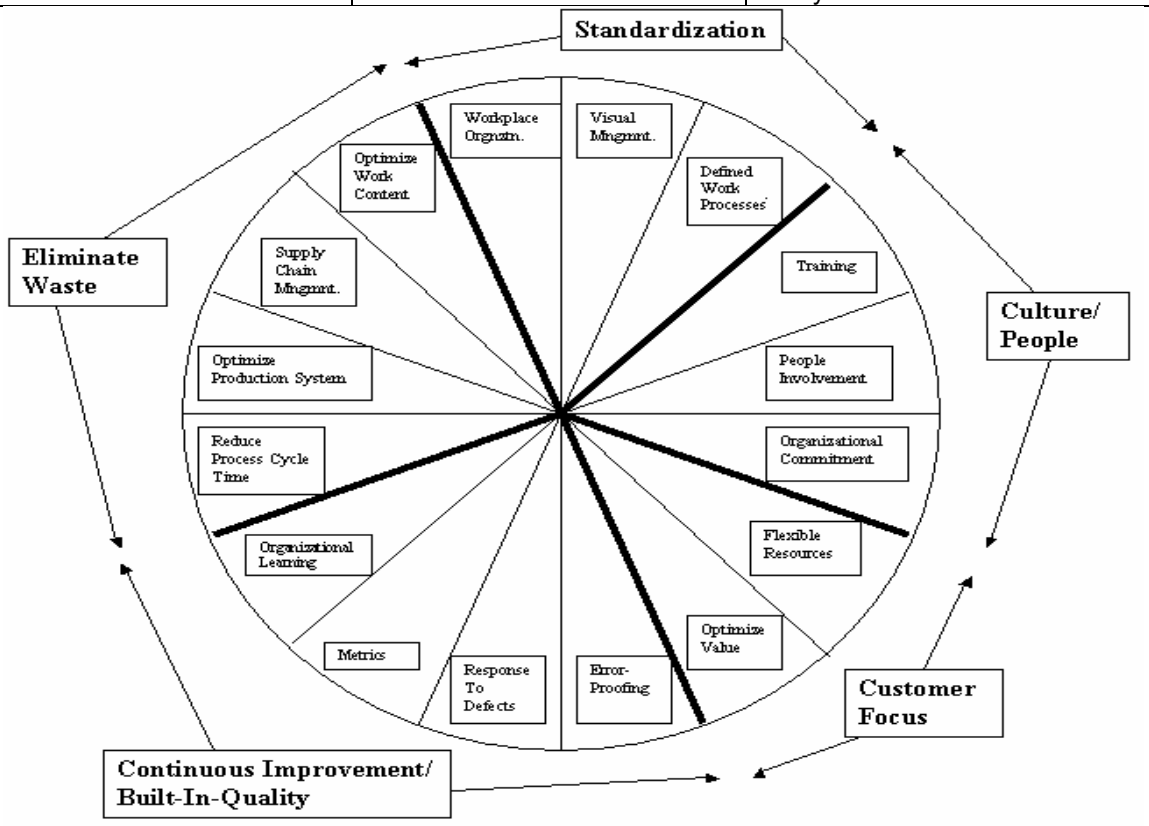

Figure 1: Lean Construction Wheel

CULTURE / PEOPLE

Culture/People consists of three sub-principles: *Training, People Involvement*, and *Organizational Commitment*. *Training* is defined as the degree to which project personnel are educated to execute a designated role to accomplish specific activities. This sub-principle includes how often employees are trained, the documentation of what they have been trained in, and the overall training plans. *People Involvement* is the degree of empowerment, understanding, and commitment of people to the goals of waste reduction and continuous improvement for the company or project. The third sub-principle *Organizational Commitment* reflects the degree to which all levels of management and supervision are committed to the principles and practices of lean execution and continuous improvement.

Culture/People is included as a standard for lean construction because it lets the employee know that their involvement in the process is the reason that the company will be successful in the present and future. The adherence to lean behavior lies in the hands of the employees working both upstream and downstream, and without the full participation by everyone involved, lean construction will not reach its full potential. It is an understatement to say that lean behavior starts and ends with the chain of employees, from top management to the field laborer.

Example questions from ***Culture/People***:

Employees do not share their ideas on how to improve the company.	1 2 3 4 5 N/A	Employees share their views/ideas on how to reduce waste and improve processes.
Top management is satisfied with the status quo.	1 2 3 4 5 N/A	Top management is committed to changing the company's culture to improve organizational

CONTINUOUS IMPROVEMENT/BUILT-IN QUALITY

Another topmost principle that comprises part of the lean wheel is ***Continuous Improvement/Built-In Quality.*** There are four sub-principles that define this segment of the wheel: *Error Proofing, Response to Defects, Metrics*, and *Organizational Learning*. Each one of these sub-principles adds to the notion that quality should be inherent in a project, and that the quest to attain this level of near perfection should be an on-going and continuous pursuit. The first sub-principle, *Error-Proofing*, deals with taking proactive measures to eliminate improper assembly or installation. *Response to Defects* is the effective resolution to problems, and the retention of those solutions for use in the future. The quicker a problem is identified and resolved, the less time is lost to rework and other wastes. The next sub-principle under ***Continuous Improvement/Built-In Quality*** is *Metrics*. *Metrics* is the development and use of standardized measures that are used to manage and improve all project processes. These measurables must be consistent throughout time, and easily read and understood by all employees. Some common manufacturing metrics that have been classified by General Motors (GMS 2001) include Days of Inventory On-Hand, Total Lead Time, Defective Parts per Million, and On-Time Delivery. There are many possibilities for measurement in construction that could be developed and used as a tool to improve the

overall process. The final sub-principle in this category is *Organizational Learning*. This sub-principle is a necessary tool for the continuous improvement. The research team's definition of *Organizational Learning* is the assimilation, retention, and transfer of knowledge throughout the company to enhance continuous process improvement. This main principle of inherent quality and the need for improvement is central to lean construction. Pascal (2002) relates a Toyota proverb in his book on Lean Production, "Improvement is endless and eternal."

Example questions from Continuous Improvement/Built-In Quality:

Unused materials and supplies are put aside and wasted or returned to the supplier at the end of the job.	1 2 3 4 5 N/A	There is a system in place that measures and quantifies the amount of unnecessary or unused supplies that are ordered.
Defects are discovered and the project crew(s) shut down or pass the defect downstream to other work processes.	1 2 3 4 5 N/A	A quality plan exists that defines roles and responsibilities at the project level to a course of action at the discovery of a defect.

CUSTOMER FOCUS

This is a principle that is often overlooked, but is as intrinsic to the Value Generation aspect of lean behavior. ***Customer Focus*** is comprised of two sub-principles: *Flexible Resources* and *Optimize Value*. *Flexible Resources* deals with the ability to adapt to customer requirements and change to meet their needs. This includes the capability to order necessary materials and equipment immediately, the skill to quickly inform the personnel of the change in scope and help them adapt to the new requirements. It is not the actual resources that need to be flexible, but the company that needs to have the ability to change directions for the customer without losing much time or money. The second sub-principle of *Optimizing Value* concerns maximizing the utility/outcome of the project by understanding the requirements of the customer. If the has a clear understanding of the customer's needs, it can plan accordingly and meet these needs in the most effective manner.

Example questions from ***Customer Focus***:

Contractor is unable to refocus to meet changing customer requirements.	1 2 3 4 5 N/A	Contractor is often able to refocus and reorganize to meet changing customer requirements.
Value is defined individually by each project participant.	1 2 3 4 5 N/A	Value add is defined in terms of the entire project and communicated to the customer.

ELIMINATE WASTE

The process of eliminating waste is a familiar activity to those who understand lean production. Waste reduction is the basis of Ohno's production system, and many early adopters of lean measures have implemented it. ***Eliminate Waste*** has been divided into four

sub-principles; *Supply Chain Management, Optimize Production System, Reduce Process Cycle Time,* and *Optimize Work Content. Supply Chain Management* incorporates those aspects of just-in-time delivery and minimizing the number of times materials are moved or relocated. *Optimize Production System* includes ideas of work sequencing, crew balancing and WIP reduction. Alarcon's concepts of measuring waste through surveys helped a great deal in configuring some of these aspects of ***Eliminate Waste*** (Alarcon, 1997). *Reduce Process Cycle Time* contains concepts relating to work flow and task organization. *Optimize Work Content* deals with issues associated with the impact of design on the ability to achieve lean performance. *Optimize Work Content* considers standardization, repetition and pre-assembly and pre-fabrication.

Example questions from ***Eliminate Waste***:

Materials are stored on-site in a local warehouse.	1 2 3 4 5 N/A	Materials are delivered just prior to installation.
Completed work products are made available to the next crew in large batches or when all items are completed.	1 2 3 4 5 N/A	Completed work products are made available to the next crew in a continuous stream or in small batches.

CONCLUSION

We believe that most of the fundamental ideas from lean manufacturing have been incorporated in this questionnaire in one form or another. However, construction is not manufacturing; some essential lean manufacturing ideas have been de-emphasized in this questionnaire. Other ideas that are not central to lean manufacturing have received more emphasis. We have attempted to incorporate and synthesize all of the best thoughts of the various authorities and experts on lean construction. Currently, the CII Research Team is testing and validating this questionnaire; accuracy, validity, and usefulness of this tool will improve with increased use. We believe that both the content and structure of the questionnaire can be improved. We invite all members of the lean community to provide use with feedback concerning this work.

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