KSCE Journal of Civil Engineering
Vol. 10, No. 6 / November 2006
pp. 381~388

Innovative Construction Management Method: Assessment of Lean Construction Implementation

By Daeyoung Kim* and Hee-Sung Park**

Abstract

Since Lean Construction has been introduced as a new management approach to improve productivity in the construction industry, much research is in progress to develop lean concepts and principles for better implementation and to get results of the successful adaptation of lean ideas from manufacturing for application in the construction industry. Currently, several construction companies in the USA are starting to implement lean construction with nebulous hopes of obtaining better results from their current projects than from past projects not employing lean construction. There are many difficulties in adopting lean concepts and systems into construction projects and implementing lean construction in real construction sites. Thus, there are demands to share information how other companies implement lean construction, to identify the benefits and barriers of lean implementation in the construction fields, and finally to improve their lean implementation. This study was the first exploratory study to assess lean construction implementation on overall projects. The case studies carried out the examination of the mutual relationships of lean planning systems, organization structure, attitudes of project participants and company strategy that played major influences on successful lean implementation.

Keywords: *innovative construction management methods, lean construction, lean implementation*

1. Introduction

1.1 Introduction

Lean construction has been introduced as a new management approach to improve productivity in the construction industry. Much research is in progress to develop lean concepts and principles for better implementation and to get results of the successful adaptation of lean ideas from manufacturing for application in the construction industry. However, since the start of work on the lean construction theory and methods in 1992, the construction companies that employ lean construction have been struggling to transform their current forms of project management into the lean management approach.

Now most construction companies in the U.S. that are starting to implement lean construction hope to achieve better results from their current projects than from past projects not employing lean construction. Several studies assess lean implementation and focus on the process of each construction activity, but few empirical studies assess lean implementation on the overall project. Companies need success stories to encourage them to employ lean construction into their work processes. Adopting lean concepts and systems into construction projects is difficult. It is a new philosophy which should make construction companies hesitant to employ it, and companies are not sure that lean concepts will produce benefits. Therefore, it needs to access and analyze lean implementation cases on the overall project.

1.2 Scope and Objective

The scope of this research assesses how effectively lean construction has been adapted in the U.S. construction industry. The study investigates which lean construction systems are implemented on real construction sites and assesses how these systems have the mutual relationships of organization, attitude and contract to achieve a highly successful implementation of lean construction. The objectives to satisfy the scope of this study are as follows:

(1) Assess lean construction from the viewpoint of the various project participants: owner, general contractor and subcontractors.
(2) Evaluate which lean concepts and systems are applied to the sites.
(3) Assess whether lean principles and systems are properly implemented on site.
(4) Identify benefits and barriers associated with lean implementation.
(5) Identify requirements for improvement of lean implementation.
(6) Suggest the idea how to implement lean construction.

This study assumes that lean implementation can be assessed through the evaluation of the lean implementation success factors: planning systems, organization, project participants' attitudes, and contracts.

1.3 Research Methodology

In this study, data are gathered through a combination of a short written questionnaire survey and interviews. It is well-known that human factors have an important influence on implementing lean systems, so case studies are limited to active

*Assistant Prof., Dept. of Architectural Engineering, Kyungnam Univ., Masan, Korea (E-mail:cmrkdy@kyungnam.ac.kr)
**Member, Assistant Prof., Dept. of Civil Engineering, Hanbat Nat'l Univ., Daejeon, Korea (Corresponding Author, E-mail: jackdaniel@hanbat.ac.kr)

lean construction projects and data are gathered through interviews with project teams and workforces in action. Fig. 1 illustrates the research procedure.

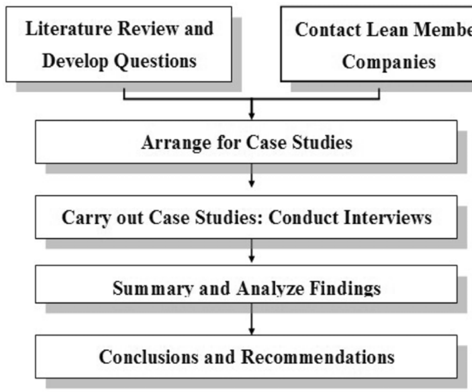

Fig. 1. Research Procedure

2. Literature Review

2.1 Lean Versus Traditional

Major differences between lean construction and traditional forms of project management include control, performance optimization, scheduling viewpoint, production system and process, performance measurement and customer satisfaction. The definition of control in traditional construction is monitoring against schedule and budget projections, while lean construction defines control as causing events to conform to plan. Traditional construction pursues the optimization of a specific activity, while lean construction optimizes the entire project. The most fundamental difference between traditional and lean can be found in scheduling. In scheduling, lean has the "pull" work schedule as opposed to the "push" schedule of traditional construction. Fig. 2 shows the difference in management.

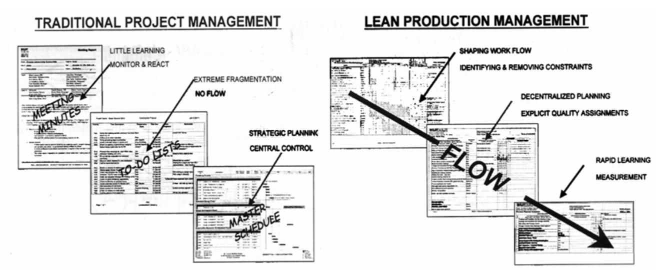

Fig. 2. Lean vs. Traditional Management

As mentioned above, Table 1 describes features of two systems based on the factors such as control, optimization, scheduling, production system and whatnot.

Table 1. Features of Two Systems

	Lean	Traditional
Control	Steering	Tracking
Optimization	The entire project	A specific activity
Scheduling Viewpoint	"PULL" work schedule	"PUSH" work schedule
Production System	Flow production system	Conversion production system
Production Process	Effectiveness	Efficiency
Performance Measurement	PPC	WBS, CPM, Earned Value
Customer Satisfaction	Successor process satisfaction	Owner or final consumer satisfaction
Planning	Learning	Knowing
Uncertainty	Internal	External
Coordination	Keeping a promise	Following orders
Goal of Supervision	Reduce variation & Manage flow	Point speed & Productivity

2.2 Essential Foundations for Lean Construction

2.2.1 Production Control

Production control consists of Work Flow Control and Production Unit Control. The current construction industry seems to prefer speed rather than reliability of work flow. This is a fundamental error that lean construction will prevent: that is, crews that work out of sequence due to other crews going as fast as possible. That causes disruption for the entire project. However, in lean thinking, reliability is emphasized to reduce workflow variability. It can improve total system performance, make project outcomes more predictable, simplify coordination, and reveal new opportunities for improvement. For that, the strategy of lean construction is that a project should make the curve more flat along the X axis by reducing variability and increasing the percent plan complete (PPC) percentage (as shown at Fig. 3). In this case, the project can obtain higher capacity utilization at the same target waste time. Fig. 3 illustrates the impact of variability, PPC and capacity utilization (LCI, 2002).

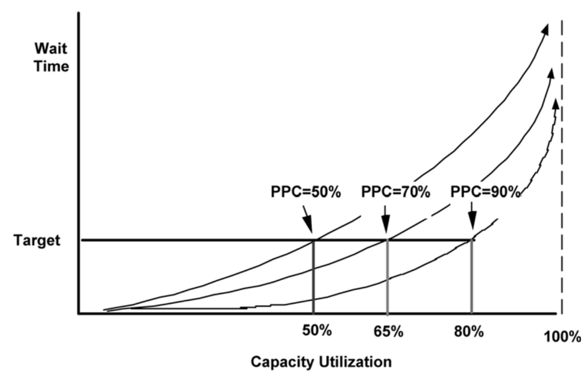

Fig. 3. Impact of Variability, PPC & Capacity Utilization

Consequently, the way to accomplish the PPC in practice is to establish a detailed planning method through the project. Fig. 4 describes the method, Last Planner which comes along with the concept "Should-Can-Will-Did."

2.2.2 Work Structuring

Lean Work Structuring is Process Design. As in project design, options must be considered and may reveal different dimensions of a problem. Work structuring expects iteration between consideration of the design of "What" is to be built, and "How" to build it. Since work structuring recurs, early decisions as to

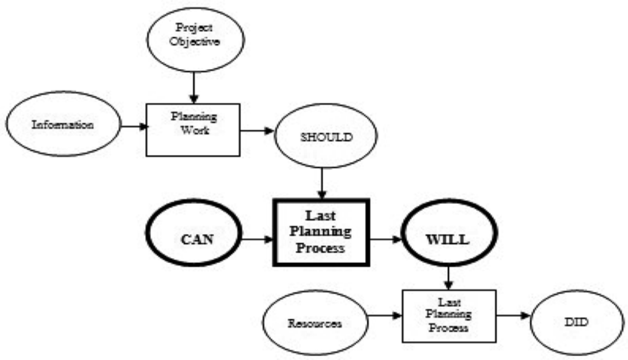

Fig. 4. Last Planner System (Ballard and Howell, 1997)

"What" must fully consider "How" or leave adequate room for later decisions. "Change" often is the result of over-specifying "What" while not considering "How."

2.2.3 Production System

The Lean Construction Institute (2002) identifies project problems in production management terms. It also provides metrics and goals of production system design, and suggested the guidelines for self-management as well.

1) Activity/Contract mentality ignores the physics of production.
2) Disregard of variability: Fails to provide a basis for coordination.
3) Processes not in control.
4) Lack production knowledge; e.g., workflow reliability, lead times, defect rates, process and operations design etc.
5) Little learning; repetitive failures.
6) Extreme fragmentation, even inside companies.
7) Central control fantasy; 'push' system ignores the process of making and keeping commitments.

The goal for Production System Design is to increase the throughput rate (TH) to match the demand rate. This is takt, and it shortens cycle time, reduces work-in-process to the level needed to maintain throughput, and minimizes resources required.

Table 2. Key Metrics in Production System

Key Metrics	Definition
Throughput (TH)	Production rate determined by the processing duration at the bottleneck(s).
Cycle Time (CT)	Time required for a single unit of product to transit the system = sum of processing durations + sum of queue times.
Work-in-Process (WIP)	The number of partially completed units of product in the system.
Takt Time	That production rate (TH) which matches the demand rate for the product

2.2.4 Human Resource Management

How to manage people at work successfully has been a major question since industrialization. Greater emphasis is now being placed on maintaining a smaller but highly motivated and highly productive workforce. As such, human resource management (HRM) has come to occupy a more prominent role in the employment relationship.

3. Research Model

3.1 Research Model

A research model is developed to understand the relationship between lean planning systems and other factors such as organization, attitudes, and contracts. Seymour (1999) suggests a conceptual link between systems and organization. Howell, a co-founder of the LCI, agreed that these two factors exerted various influences on lean implementation and added two more factors, attitudes and contracts, at an official meeting held at the University of Texas at Austin on January 15, 2002.

This paper focuses on four major elements in organizational factors – organizational support, training (knowledge), coordination, and communication between the owner and general contractor, owner and subcontractors, and the general contractor and subcontractors.

Project participants' attitudes toward lean construction are also critically sensitive factors for successful lean implementation. Many studies indicate that human resources have a major influence on lean implementation and its success. Coffey (2000), in 'Developing and Maintaining Employee Commitment and Involvement in Lean Construction,' states that "implementation of lean construction is in its infant stage, so that lean construction yet depends upon the potential and abilities of employees in order to successfully perform many of its functions and achieve its potential." Several elements are involved in project participants' attitudes – involvement that is founded upon the employee's ability to participate in decision-making concerning their own work, commitment that drives from genuine involvement, motivation, enthusiasm to employ lean and carry out successful implementation, open-mindedness and having a positive vision to accept changes for lean construction.

Contractual factors have to be initially oriented to create strong involvement of the owner, general contractor and subcontractors, and to define roles and responsibilities of project participants. Miles and Ballard (1997) indicate "contracts are one dimension of organizational relationships," and "cooperation must be based upon realistic appreciation and recognition of the self-interests of the participants in a project." The contracts must support these self-interests and provide a framework for the overall best success of the project. Contracts can create better coordination and help keep a promise among project participants, and should

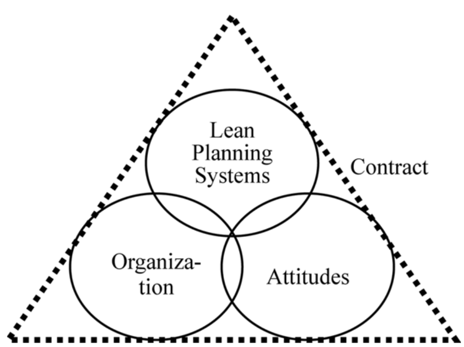

Fig. 5. Relation for Successful Lean Implementation

Table 3. Four Factors of Lean Planning Systems

Elements	Direction
Organization	- Organizational Support - Training (Knowledge) - Coordination & Communication (owner, general contractor, subcontractor)
Attitude	- Involvement upon employee's ability - Commitment
Contracts	- Self interest (derive involvement, coordination) - Role & Responsibility
Planning Systems	- Production Control - Work Structure & Last Planner

support effective implementation of lean systems.

This paper establishes the assumption that if the four factors of lean planning systems, organization, attitudes, and contracts are mutually and effectively combined, lean construction could be successfully implemented. Fig. 5 illustrates the relationship between the lean planning system and the other three factors and Table 3 shows the direction of research model.

4. Project Case Studies

4.1 General Information

The paper includes three project cases in Texas, two in California, one in Wisconsin, and one in Michigan. The projects are a new pharmaceutical company office building, an office renovation, a new hospital community center, a hospital renovation, a college of medicine building, a new university dental school, and a university chemistry hall renovation. While carrying out case study G, three project managers from project H-1, H-2 and H-3 were interviewed at the home office. They provided a brief description of each project and lean aspects employed in each project. Table 4(a) and 4(b) summarizes the interviewees and provides a brief project description of the budget, schedule, contract, and lean systems employed in the project at the time of the site visit.

4.2 Interviewees

Total number of interviewees is 42 from 10 projects. Twenty-one interviewees from the general contractors are project managers, project engineers, and superintendents. The others are subcontractor's project managers and foremen of plumbing, mechanical, fire protection, electrical, steel erection, ceiling, partition and drywall and insulation.

4.3 Research Finding, Analysis and Discussion

Through the case studies, this study attempts to determine to what extent lean construction has been adapted by the construction industry and to assess how properly lean construction has been implemented in construction.

A comparison of the case studies is summarized at Table 5. These findings are based on interviews with project participants and observations from the projects. Most of the selected project sites indicate that they are in the experimental stage of implementing lean construction. The projects implement the major lean planning systems such as master scheduling, last planner and weekly meetings, but are less focused on understanding lean concepts and principles. This takes less time and is more comfortable for project participants at real construction sites to accept lean systems rather than spending time to understand the theories. Subcontractors interviewed at

Table 4(a). Project Descriptions

	Proj. A-TX Renovation of Chemistry Bldg.	Proj. B-TX Hospital & Support Bldg.	Proj. C-CA Chemistry Lab & Offices	Proj. D-CA Office Renovation	Proj. E-MI Health Center
Budget	$ 28.9M	$ 55M	$ 5.5M	$ 1.1M	$ 8M
Project Duration	12 mos.	18 mos.	6 mos.	8.5 mos.	13.5 mos.
Contract Form	Cost Plus Fixed Fee/ GMP	Cost Plus Fixed Fee/ GMP	Unknown	Lump Sum	Cost Plus Fixed Fee/ GMP
Lean System Applied	• Master • Phase • Lookahead • WWP • PPC • Const. Planner • JIT	• Master w/CPM • Phase • Lookahead • WWP • PPC • Const. Planner	• Lookahead • WWP • PPC	• Lookahead • WWP • PPC	• Master w/CPM • Lookahead • WWP • PPC • JIT

Table 4(b). Project Descriptions

	Proj. F-TX Renovation of a Factory to a Health Center	Proj. G-WI University Dental School	Proj. H-1	Proj. H-2	Proj. H-3
Budget	N/A	$ 20M	$ 3M	$ 17M	$ 125M
Project Duration	N/A	18 mos.	10 mos.	14 mos.	40 mos.
Contract Form	N/A	Cost Plus Fixed Fee / GMP	Unknown	Unknown	Unknown
Lean System Applied	• Master w/CPM • WWP • PPC	• Master w/CPM • Phase • Lookahead • WWP • PPC	• Master • Look • ahead • WWP	• Phase • Look • ahead • WWP	• Master • Look • ahead • WWP • JIT

Table 5. Summarization of Case Studies

Category	Description		Case A	Case B	Case C	Case D	Case E	Case F	Case G
Project Plaming Systems	Master Scheduling		O	A	X	X	A	A	A
	Last Planner	Lookahead	O	O	O	A	A	A	O
		WWP	O	O	O	A	O	O	O
		Workable Backlog	O	O	O	X	X	X	A
		PPC (%)	85%	77%	80%	76%	59%	47%	75%
	Weekly Meeting		O	O	O	A	A	A	O
	JIT Delivery		O	X	X	X	O	X	O
Organization	Orgainizational support		O	A	A	X	A	A	O
	Communication	GC+Sube	O	A	O	A	O	A	O
		Sube	O	O	O	X	A	O	O
	Coordination	GC+Sube	O	A	A	A	A	O	O
		Sube	O	O	O	X	X	A	O
	Training	GC	O	O	O	O	O	O	O
		Sube	O	A	O	X	X	X	O
Attitude	Involvement	GC	O	O	O	A	O	O	O
		Sube	O	A	O	X	A	A	O
	Commitment	GC	O	O	O	A	O	O	O
		Sube	O	A	A	X	X	A	A
	Enthusiasm	GC	O	A	O	X	A	A	O
		Sube	O	A	O	X	X	A	A
	Openmindedness	GC	O	A	O	A	O	O	O
		Sube	O	A	O	A	O	O	O
	Motivation	GC	O	O	O	X	X	A	O
		Sube	O	O	O	X	X	A	O
Contractual Restraints	Owner+GC		O	X	X	X	X	X	O
	GC+Sube		O	X	X	X	X	X	O

*Utilized: O, Not effectively utilized: A, Not utilized: X

the projects are not familiar with the theoretical lean ideas, but are interested in using the planning systems.

Based on Table 5, case A successfully implemented most lean concepts in its project and properly implemented them. Cases B and G also utilized most of these concepts as in case A, but were overall less effective. However, the researcher found that these projects were also good lean implementation sites especially compared to other cases in general. Case C obtained high score on its lean implementation, but focused on narrow lean application because it was a pilot project to evaluate the last planner. Observations and interviews from case C showed that this project successfully implemented the last planner and created a good work environment to reinforce organization and improve the attitudes of project participants. Cases D and E were the poorest lean implementation projects. Their major problem was caused from the lack of the subcontractors' participation in lean implementation. The general contractor in case D indicated that it was too small and simple of a project to employ lean construction. The PPC of case D was high, but was due to simple tasks. In case E, lean construction was applied too late and the workers were less cooperative union members. The PPC of case F was the poorest compared to other cases because there was a lack of project definition and insufficient design and information.

4.3.1 Project Planning Systems

Among the project planning systems, lookahead planning, the weekly work plan, PPC and the weekly lean meeting were implemented at all the project sites. The lookahead schedule was used in six-week lookahead and two-weak lookahead. The six-week lookahead schedule was used on most project sites, but the two-week lookahead schedule was used on three projects, cases A, B and C. However, employment of master scheduling and workable backlog showed opportunity for the improvement. As shown in Table 3, master scheduling was not used in cases C or D, and was not used as a fundamental scheduling at most projects. In case G, the project employed the workable backlog, but it was not effectively utilized to provide work assignments based on quality criteria.

After calculating the PPC of the week, root causes of failure to complete planned work are identified by project participants. Then, consistent analysis and action on reasons for failure to complete work have to be performed to prevent future repetitive failures. Most projects, unfortunately, had identified the root causes for failure, but failed to analyze and implement corrective action.

Just-In-Time (JIT) delivery is uncommon on construction sites in this study. While a successful case of JIT was observed in case study A, most subcontractors were against it. The subcontractors commented that at least three days or even a week was needed to obtain materials prior to the start of work if they had to employ JIT.

4.3.2 Organization

4.3.2.1 Organizational Support

Most projects lacked organizational support in the implementation of lean concepts, except for cases A and G. Involvement of the owner is important for successful lean implementation, but excessive participation reduces the overall effectiveness of project performance. Accordingly, company level support is needed to reinforce lean implementation. As observed in the interviews with project participants, the upper-level management in most companies was enthusiastic to apply lean construction to new projects, but little support was found for introducing this change in management.

4.3.2.2 Communication and Coordination

All project participants indicated that a higher execution of coordination, cooperation and communication was developed under lean construction. All foremen agreed that the best benefit of lean construction was the improvement of the working relationship among the trades. As can be seen in Table 5, overall results of communication and coordination among project participants showed improvement compared to projects not employing lean construction. Communication among subcontractors was dramatically increased on lean construction sites except for cases D and E. Some projects failed to create an open-communication environment between the general contractor and subcontractors. Since the general contractors in cases A, C and G had good communication and mutual coordination with the subcontractors, they could successfully implement lean construction.

4.3.2.3 Training

Construction training focused on the lean tools that can improve productivity and performance, but minimally focused on the lean concepts and principles. The study found that most owner and general contractor project team members were aware of lean theoretically, but that subcontractors were rarely aware of lean. Only two project sites provided official training sessions to the subcontractors. In case B, the general contractor did not provide any training sessions for the subcontractors, but it requested a subcontractor's foreman instead who had lean experience on a previous project to help the other subcontractors' foremen to implement lean planning systems and their forms.

4.3.3 Attitude

Project participant's attitude toward lean construction is a sensitive factor for successful lean implementation. The study found that overall attitudes of general contractors toward lean construction were good; however, the study also found that attitudes of subcontractors were not as good.

4.3.4 Contractual Restraints

The enthusiasm and involvement of project participants to implement lean construction should be empowered by contractual relationships. As observed from the case studies, only cases A and G had contractual agreements to use lean among the owner, the general contractor, and the subcontractors. The contract required all participants to try to use the lean ideas and systems.

4.3.5 Root Causes of Failure

Fig. 6 shows the average frequency of root causes of failure to complete planned work. The root cause analysis is obtained from only four out of ten projects: cases A, B, D and E. The total effect was scaled to 100% to show the frequency of root causes for all 94 weeks of the four projects. The root causes were identified when PPC was calculated. Generally, each project had similar categories of root causes: make ready, manpower, schedule accuracy, material, coordination, rework, equipment, weather, design, and others. Others include unknown condition, overcrowding, contract, and client decision that were just identified on one or two projects. As can be seen, four major causes are identified from the study: make ready, manpower, material delivery, and schedule accuracy. The failures are due to the lack of schedule accuracy, incomplete pre-requisite work, design changes, lack of information, and ineffective use of the work backlog and constraints analysis.

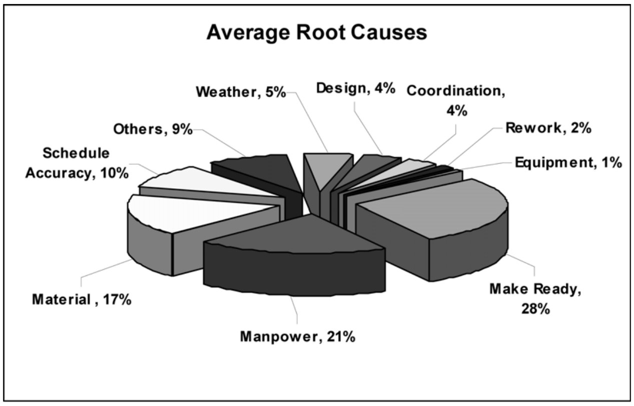

Fig. 6. Average Root Causes

4.4 Perceptive Strengths and Weaknesses

Strengths and weaknesses of lean construction are mainly indicated by the project participants of all case studies. Requirements to implement lean construction are discussed as well.

4.4.1 Perceptive Strengths

1) The most significant benefit of lean implementation is communication and cooperation among the project participants. The subcontractors' involvement and commitment in planning make it possible to know when and what each participant would be doing.
2) Lean construction causes little fluctuation in manpower. The lean planning systems also provide a short checklist of

things that can be easily missed.

3) Lean construction has the benefit of forcing good documentation, and also provides historical data to qualify subcontractors for future lean projects and furthermore provides fast and easy feedback to review the reasons to failure.
4) Prediction for upcoming work and ease of driving the whole project are important factors in lean implementation. Lean promotes planning everything ahead and checking for possible problems to eliminate surprises caused from unexpected problems. It is responsible for a smooth and stable workflow, plus improves project field productivity and work performance. Lean finds and removes constraints prior to the start of work, and helps the owner follow project progress. It can also provide better problem-solving and effective trouble-shooting.
5) Lean construction facilitates better matching of labor, materials and equipment to project requirements. It can also prevent overcrowding and interference in the work place.

4.4.2 Perceptive Weaknesses

The barriers to lean implementation are discussed below.

1) Many believe that there are too many meetings and too much information that have to be discussed in the meeting. The meetings are too repetitive, and take a long time if not well-managed. At the meeting, it is sometimes difficult to make a decision if too much detail information is explained to the other trades or the owner.
2) The subcontractors may reduce the effectiveness of the general contractor with inaccurate planning and PPC. It is also shown to be difficult to qualify and assign proper subcontractors to a project if they have little background in lean construction. Lean implementation is too dependent upon the quality and attitude of the subcontractors, and depends on participants' keeping promises and being truthful.
3) Lean construction may be beneficial to complex and large projects, but does not easily work for small, simple and easy projects.
4) Lean demands extra paper work and time for training and meetings. Usually an extra person is to handle lean issues.
5) Lean implementation is too oriented to computer work and to the spontaneous participation of all trades. Without a mandatory clause in the contract, there is no means to enforce all trades to get involved in lean implementation.
6) Finally, it is not easy to track tasks between all the planning forms.

4.4.3 Perceptive Requirements

Opportunities for the improvement of lean implementation include developing honesty and trust among project participants, increasing upper level management's checking of the planning and performance progress of subcontractors, and increasing the designer's involvement in project.

The requirements for successful lean implementation are education and a contract that requires full implementation of lean construction. Upper level management's involvement and assistance are also beneficial for better coordination and open-communication. Lean should work better on the project that provides full information, complete design, and complete submittals from an owner and an architectural engineer.

5. Summary

In conclusion, the study found that lean construction is efficient in managing projects by using lean tools, and improves other project success factors associated with project completion. The success factors are better communication, effective coordination, increased involvement and commitment, trust, and better motivation. Lean construction emphasizes and focuses on improvement of relationships among project participants. Even though lean construction still stands on the bridge crossing from current practice to lean practice, lean construction could be successfully adapted to the construction industry in the near future and will be recognized as an effective management technique.

5.1 Conclusion

The following are the conclusions drawn from the lean construction assessment:

1) Lean construction has initially a major influence on improvement of communication and coordination between participants (the owner, general contractor, and subcontractors).
2) Weekly lean meetings are extremely crucial to deliver the most optimized planning and scheduling based on communication and coordination among the participants and to develop involvement and commitment of subcontractors.
3) Lean pull schedule also encourages all participants to be involved in the schedule, and to develop the most optimized schedule for all. This scheduling process strongly ties the project participants together and improves team building.
4) Metrics to calculate the PPC and to analyze root causes are one of benefits. Whenever calculating the PPC, the participants must identify the root causes of failure to complete planned work. However, most projects tend to fail to effectively implement root cause analysis.
5) Lean construction improves human relationships if effectively implemented. Lean construction crosses all organizational boundaries and is a key component of the corporate strategy. Roles and responsibilities are defined throughout all levels of the organization.
6) Lean construction should be a manageable work package that may be combined with the tools such as CPM that are already used in the industry to obtain better management and a well-run job.

5.2 Recommendations for Implementation

Based on the findings of this study, the following recommendations are offered to support the effort of continuous lean construction improvement.

1) Lean training programs need to be developed for subcontractors. Lean concepts and principles may be complex for the subcontractors to understand, but training

can focus on lean implementation: the "how-to," rather than on lean theories.

2) Project problems occur with activities where the subcontractor's planning is insufficient and their involvement is lacked. As a result the subcontractor's lookahead schedule is not detailed enough. To prevent these problems in the future, management's patience and persistence at enforcing consistency of practice at every level of the organization is required.
3) Lean expert/consultant can more effectively help a general contractor and subcontractors to establish all aspects of lean at the beginning of a project and implement lean construction.
4) It is important to note that the previous recommendations may result in a more effective lean construction project. However, many of the case studies indicate that the contractors failed to implement many of the lean construction techniques yet they are beneficial from better planned work activities. Thus, the contractors are encouraged to begin to employ the lean construction techniques without going through all the changes at once rather than considering this approach is too radically different not to be considered on their projects.

Acknowledgements

The author would like to acknowledge the support for this research from the Korean Ministry of Construction and Transportation, Research Project 05 CIT D05-01.

References

Ballard, G. and Howell, G. (1997). "Shielding production: an essential step in production control." *Journal of Construction Engineering and Management*, Vol. 124, No. 1, pp. 11-17.

Coffey, M. (2000). "Developing and maintaining employee commitment and involvement in lean construction." *Proceeding, 8th Conference of the International Group for Lean Construction*.

Miles, R. and Ballard, G. (1997). "Contracting for lean performance: contracts and the lean construction team." *Proceeding, 5th Conference of the International Group for Lean Construction*.

Lean Construction Institute Seminar (2002). Notes from Introduction to Lean Construction.

Seymour, D. (1999). "Lean construction: Towards an agenda for research into systems and organization." *Proceeding, 7th Conference of the International Group for Lean Construction*.

(Received April 21, 2006/Accepted October 9, 2006)