EXPLORATORY STUDY OF LEAN CONSTRUCTION: ASSESSMENT OF LEAN IMPLEMENTATION

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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 which played major influences on successful lean implementation

Key words : Productivity, Lean Construction, Assessment of 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 assessment of how well lean construction is implemented on real construction sites and the evaluation of the attitudes of human resources toward lean construction will be examined as well. Each case study will carry out the examination of 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 the attitude and comprehension of each level of an organization toward lean ideas.
(2) Assess the lean implementation on real construction sites.
(3) Assess contractual effects of implementing lean construction.

1.3 Research Hypothesis

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. The study will test the hypothesis that if the four factors of planning systems, organization, attitudes, and contracts are mutually and effectively combined, lean construction will be successfully implemented.

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. Figure 1 shows the difference in management.

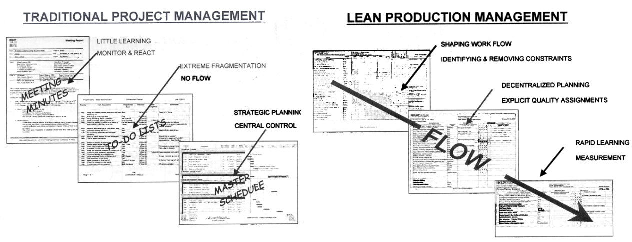

Figure 1. Lean vs. Traditional Management

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 a 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. Consequently, the strategy of lean construction is to reduce variation, then go for speed to increase throughput.

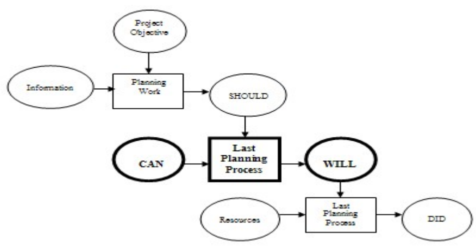

Figure 2. Last Planner System (Ballard and Howell, 1997)

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 "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."

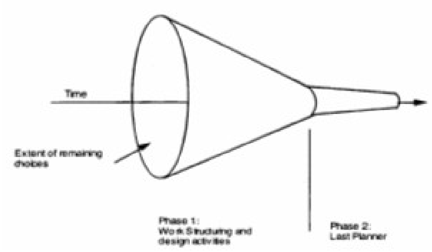

Figure 3. Work Structuring and Operations (LCI, 2002)

2.2.3 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 METHODOLOGY

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. This study began with the assumption that if the four factors of lean planning systems, organization, attitudes, and contracts were mutually and effectively combined, lean construction could be successfully implemented. Table 1 shows the direction of research model.

Table 1. 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

3.2 Research Procedure Development

In this study, data was 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 were limited to active lean construction projects and data were gathered through interviews with project teams and workforces in action. Figure 4 illustrates the research procedure.

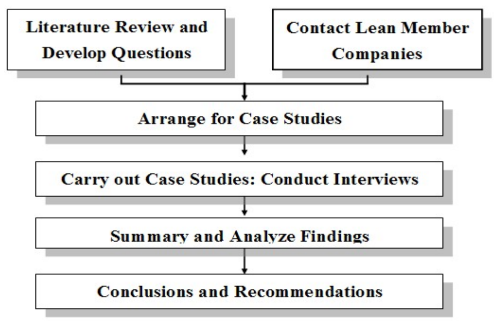

Figure 4. Research Procedure

4. PROJECT CASE STUDIES

4.1 General Information

The study included three projects in Texas, two in California, one in Wisconsin, and one in Michigan. The projects included 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. Table 2(a) and 2(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.

Table 2(a). Project Descriptions

	Project A – TX Renovation of Chemistry. Building	Project B- TX Hospital & Support Buildings	Project C – CA Chemistry Lab & Offices	Project D – CA Office Renovation	Project E – MI Health Center
Budget (approx.)	$ 28.9M	$ 55M	$ 5.5M	$ 1.1M	$ 8M
Project Duration	12 mos.	18 mos.	6 mos.	8 ½ mos.	13 ½ mos.
Contract Form	Cost Plus Fixed Fee / GMP	Cost Plus Fixed Fee / GMP	Unknown	Lump Sum	Lump Sum
Lean Systems	• 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
Interviewee	• GC: PM, Engineers • Subs: Plumbing, Mechanical, Fire Protection,	• GC: PM, Engineers • Subs: Electrical, Mechanical, Steel Erection	• GC: PM, Engineers • Subs: Sheet Metal, Mechanical, Electrical, Plumbing	• GC: PM, Engineer • Subs: Superintendent	• GC: PM, Engineer, Superintendent Subs: Plumbing, Ceiling/Partition, electrical

Table 2(b). Project Descriptions

	Project F – TX Renovation of a Factory to a Health Center	Project G – WI University Dental School	Others		
			Project H-1	Project H-2	Project H-3
Budget (approx.)	Not yet determined	$ 20M	$ 3M	$ 17M	$ 125M
Project Duration	Not yet determined	18 mos.	10 mos.	14 mos.	40 mos.
Contract Form	Not yet contracted	Cost Plus Fixed Fee GMP	Unknown	Unknown	Unknown
Lean Systems	• 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
Interviewee	• GC: Engineers, MEPE, Superintendent • Subs: Mechanical, Electrical, Drywall	• GC: PM, Superintendent, Facilitators • Subs: Drywall and Insulation, Electrical	GC: PM	GC: PM	GC: PM

4.2 Research Finding, Analysis and Discussion for the Assessment of Lean Construction

Through case studies, what extent lean construction has been adapted by the construction industry and to assess how properly lean construction has been implemented in construction. To measure these factors, the study compares and analyzes case studies while focusing on the following.

(1) To implement lean construction successfully, lean planning systems are essential tools; however, the success or failure of lean implementation is dependent upon the human resources working on the lean construction sites.

(2) The efficiency of human resources can be improved by company project strategies including contracts, company policies and Human Resource Management (HRM) policy.

A comparison of the case studies is summarized in Table 3.

Table 3. Summarization of Case Studies

Category	Description		Case A	Case B	Case C	Case D	Case E	Case F	Case G
Project Planning System	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	X
Organization	Organizational Support		O	A	A	X	A	A	O
	Communication	GC + Subs	O	A	O	A	O	A	O
		Subs	O	O	O	X	A	O	O
	Coordination	GC + Subs	O	A	A	A	A	O	O
		Subs	O	O	O	X	X	A	O
	Training	GC	O	O	O	O	O	O	O
		Subs	O	A	O	X	X	X	O
Attitudes	Involvement	GC	O	O	O	A	O	O	O
		Subs	O	A	O	X	A	A	O
	Commitment	GC	O	O	O	A	O	O	O
		Subs	O	A	A	X	X	A	A
	Enthusiasm	GC	O	A	O	X	A	A	O
		Subs	O	A	O	X	X	A	A
	Open-mindedness	GC	O	A	O	A	O	O	O
		Subs	O	A	O	X	X	A	O
	Motivation	GC	O	O	O	X	X	A	O
		Subs	O	O	O	X	X	A	O
Contractual Restraints	Owner + GC		O	X	X	X	X	X	O
	GC + Subs		O	X	X	X	X	X	O

4.2.1 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.

4.2.2 Organization

4.2.2.1 Organizational support

Most projects lacked organizational support in the implementation of lean concepts, except for cases A and G. Involvement of the owner was important for successful lean implementation, but excessive participation reduced the overall effectiveness of project performance. Accordingly, company level support was 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.

4.2.2.2 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 5.1, 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.

4.2.2.3 Training

Construction training focused on the lean tools that can improve productivity and performance, and 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

4.2.3 Attitude

Project participants' attitudes toward lean construction were 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.

4.2.4 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.

4.2.5 Root Causes of Failure

Figure 5 shows the average frequency of root causes of failure to complete planned work. The root cause analysis was obtained from only four out of ten projects: cases A, B, D and E. Generally, each project had similar categories of root causes: make ready, manpower, schedule accuracy, material, coordination, rework, equipment, weather, design, and others. Others included unknown condition, overcrowding, contract, and client decision that were just identified on one or two projects. As can be seen, four major causes were identified from the study: make ready, manpower, material delivery, and schedule accuracy. The failures were 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.

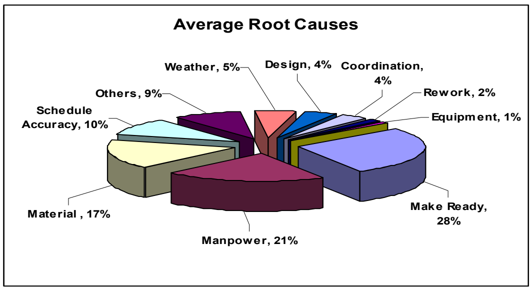

Figure 5. Average Root Causes

5. CONCLUSION

This study was the exploratory study to figure out success and failure factors, and then to assess lean construction implementation on overall projects. 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, 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 current projects 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.

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