CURRENT DEPLOYMENT OF LEAN METHODS IN THE CONSTRUCTION INDUSTRY

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my family

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This report investigates the deployment of lean construction in an attempt to answer the following two questions: 1) what percentage of leading contractors is aware of lean construction techniques, and 2) to what extent has lean construction been accepted into practice by the construction industry in 2008.

The source of the data collected for this report was a survey. This survey was distributed to industry professionals representing the 113 companies who attended the University of Florida's 2008 spring career fair on February 12, 2008. The University of Florida's spring career fair had Project Managers, Project Engineers, Senior Vice Presidents, Presidents, and Chief Operating Officers from some of the world's top general contracting firms in attendance.

Results of the survey indicate that most of general contractors, specialty contractors, and construction management firms in the construction industry are unfamiliar with the term lean construction as an approach to managing the construction process. Lean is consequently not being utilized in the construction industry. It is likely that many of the techniques encompassed under lean principles are being used; however, companies are not utilizing lean construction principles as the overall approach for completing their projects.

CHAPTER 1
INTRODUCTION

The increasingly competitive construction market of today is requiring general contractors (GC) and construction management firms (CMF) to better manage construction projects by increasing profits, while sticking to very strict time constraints. Essentially, it is the job of the GC and CMF to maximize productivity on each project they undertake. In order to do this, many general contractors and construction management firms are turning to continuous improvement techniques as an approach to managing their projects. One of these continuous improvement techniques that have garnered attention in the recent past is what is known as lean construction.

What is Lean Construction?

Lean construction is a new method for managing the construction process. The ideology of lean construction stems from the popular manufacturing production technique developed by the Toyota production company known as lean manufacturing. In theory, lean production can be defined as "a system that delivers a finished product free from defects to a customer, in zero time, and with nothing left in inventory" (Farrar et al. 2004). Moreover, in the construction industry, lean can be described as "the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the constructed project" (Salem and Zimmer 2005).

Problem Statement

There have been few documented research projects that have attempted to determine the construction industry's acceptance of lean construction as an approach to managing the delivery of a project. The construction industry has historically been very slow in the implementation of any kind of change. This has made actualization of continuous improvement techniques such as

lean construction very difficult. This is in direct contrast to the manufacturing industry, which has implemented the lean production approach with great success leading to more efficient and higher quality production.

The construction industry in the United States is an archetype of how the construction industry throughout the world is in great need for continuous improvement techniques and productivity improvements in general. **"**The U.S. Department of Commerce defines productivity as dollars of output per person-hour of labor input" (Adrian 2004). This is annotated in Figure 1-1. One can infer from this definition of productivity the best way to increase productivity is through greater labor efforts. However, increased labor effort is just one of the ways to increase productivity on a construction project. Other ways to increase productivity include: more efficient uses of equipment and tools, use of higher quality materials, improve the training of labor, lessen government induced restrictions, minimize rework, and eliminate idle time (Adrian 2004). The majority of this list can be greatly affected by the decisions made by the management team and the overall approach the GC or CMF uses to manage the construction process.

$$\textbf{Productivity} = \frac{\textbf{Dollars of output}}{\textbf{Person-hours of labor input}}$$

Figure 1-1. A Definition of Productivity

The construction industry in the United States has a declining rate of productivity increases. In 2002, the U.S. Department of Commerce reported that the U.S. construction industry's productivity was increasing at a rate 0.80%, which when compared to other industries ranks among the worst, if not the worst, in the United States. These results can be seen in Table 1-1. Although the U.S. as a whole has been increasing at a rate of 2.70% annually, the construction industry has only been increasing at a rate of 0.80% per year (Adrian 2004).

Table 1-1. Productivity Increases for Various Industries in the U.S.

Industry	Productivity Increases (%)
Agriculture	3.64
Construction	*0.80*
Government	1.64
Manufacturing	2.60
Mining	3.17
Public Utilities	5.40
Transportation	4.60

A quick analysis of Table 1-1 shows that the manufacturing industry is having increases in productivity far beyond that of the construction industry. There are many factors that account for this, such as the construction industry is a stochastic process where things such as labor supply, weather, and material cost are different on every project. Despite the fact that varying conditions are inherent to the construction process, a great deal of research has been done attempting to legitimize lean production techniques as a viable management approach for improving productivity in the construction industry.

Objective of this Study

Table 1-1 shows the U.S. construction industry's need for continuous improvement and lean construction techniques. It is well documented that the manufacturing industry has adopted lean production as a viable technique to improve its business performance and develop a sustainable competitive edge. A great deal less has been researched on the deployment of lean techniques in the construction industry. The objective of this study was to determine the following: 1) what percentage of leading contractors are aware of lean construction techniques and, 2) to what extent has lean construction been accepted into practice by the construction industry in 2008.

CHAPTER 2
LITERATURE REVIEW

It is the job of every General Contracting and Construction Management firm to maximize productivity on every project they encounter. They must do this while also completing the project on time and often within strict budget constraints. In the past, the manufacturing industry has led the way in terms of productivity improvement initiatives. One of the most recent productivity improvement techniques being used by many world-leading manufacturing companies is lean production.

Lean Production

The ideas which formulate what is known as lean production were developed by Taiici Ohno, an engineer working for the Toyota manufacturing company. The term "lean" was later coined by the authors of *The Machine That Changed the World* published in 1990, who used the term to describe Toyota's approach to manufacturing. The result of the research showed that many Japanese automotive manufacturing companies were substantially ahead of their American and European counterparts with regards to productivity, quality, and time-to-market. This was particularly true of Toyota (Taylor and Brunt 2001).

Lean production, as established by Taiici Ohno and the Toyota Company, is vastly different from the "craft production" and "mass production" methods of making things that preceded it. Craft production uses highly skilled workers to produce one-of-a-kind products, using very simple, yet flexible tools to make precisely what the customer wants. Examples of products made from craft production include; works of decorative art, custom furniture, and exotic sports cars. Mass production on the other hand uses lesser trained workers who tend expensive machinery with a single purpose, to produce a high volume of standardized products. The machinery is inherently very intolerable of disruption. The mass production companies

therefore incorporate extra suppliers, workers, and space to insure smooth production. Womack et al. (1990) offered a comparison of these techniques to making things (Table 2-1).

Table 2-1. Comparison of craft production, mass production, and lean production (Womack et al. 1990)

	Craft	Mass	Lean
Work force	Highly skilled in design, machine operations and fitting. Apprenticeship for workers.	Interchangeable workers (division of labour). Improvement responsibility - industrial engineers and foreman	Flexible teams work the process. Little management layers. Improvement responsibility throughout the organization
Organization	Extremely decentralized but concentrated in one city. Most parts and design from small machine shops. Coordinated by owner/ entrepreneur.	Vertical integration. Central organization - design, engineering and production in one place.	Network of suppliers with design and engineering capability. Improvement along supply chain.
Tools	General-purpose machine tools	Dedicated machines	General purpose
Product	Very low production volume - No two exactly alike	High volume. Long product life cycle.	Ever-decreasing model life cycles. Niche models possible.

Lean production combines the advantages of craft and mass production while eliminating the high cost of craft production and the rigidity of mass production. Lean production employs "teams of multi-skilled workers at all levels of the organization and uses highly flexible, increasingly automated machines to produce volumes of products in enormous variety" (Womack et al. 1990). Koskela (1992) summarizes the principles behind lean production as follows:

- Eliminate non value-adding activities (eliminate waste or "muda")
- Increase output value through a systematic approach to analyzing the customer's needs.
- Reduce the time it takes to complete a cycle
- Reduce variability
- Simplify the cycle by minimizing the number of parts, steps, and linkages

- Increase process transparency
- Focus control on the complete process
- Incorporate continuous improvement in the process
- Benchmark

These principles are achieved using the following methodologies and tools also summarized by Koskela (1990):

- Just in Time
- Total quality management
- Time based competition
- Concurrent engineering
- Process design (reengineering)
- Value based management
- Visual management
- Total productive maintenance
- Employee involvement

Lean production seeks perfection in the way things are made. It is the process of delivering a product free of defects, in the shortest amount of time possible, with zero waste, with no inventory, and with an endless amount of variety. It is an endless quest for perfection (Womack et al. 1990).

Since the publication of *The Machine That Changed the World*, the benefits of lean manufacturing have been well documented. David Taylor and David Brunt have exclaimed that "we have seen examples where throughput times and defects have been cut by 90 percent, inventories reduced by three-quarters and space and unit cost slashed in half. All of this has been done at very little capital cost to the organizations involved and firms have begun to develop the flexibility necessary to meet their customers' needs. With performance improvement of this magnitude it has been possible for such companies to double output and profits with the same headcount" (Taylor and Brunt 2001).

Many of the ideals encompassed in the lean production system stem from concepts previously encapsulated in Total Quality Management (TQM).

Total Quality Management

The development "Total Quality Management (TQM) can be thought of as a management philosophy of involving everyone in an organization, firm, or process in controlling and continuously improving how work or a service is done with the objective of meeting customer expectations of quality" (Adrian 2004). In order to understand this definition, we must also define the term quality. Quality can be described as freedom from errors, consistency in production, and a means of adding value through improvements (Adrian 2004).

The ideology of Total Quality Management can be traced back to the 1920's where Walter A. Shewart first began statistical analysis of quality control techniques. In his book, *Economic Control of Quality of Manufactured Product,* Shewart outlines a statistical analysis of problems on the production line. "During this time period, American industry shifted focus to maximization of output and the monitoring of results through inspection and work incentives" (Adrian 2004).

After the end of World War II, the Japanese began to focus on quality control techniques to rejuvenate their faltering economy. To do so, American experts such as W. Edwards Deming were called upon to aid in the Japanese economic refurbishment. Deming was invited to the Japanese Union of Scientist and Engineers, a prestigious research center, in March of 1950. Deming went on to work with many Japanese manufacturing companies where he trained hundreds of engineers and managers in statistical product control. Deming had a very clear

message: improvement in quality control will lead to increase revenues as well as a larger share of the market. Deming became somewhat of a Japanese celebrity. However, it was not till much later that his ideas of quality control, and statistical analysis in order to improve productivity began to be accepted in the United States (Austenfeld 2001).

Shortly after Deming made his major contributions to the Japanese manufacturing industry, M. Juran released a manufacturing process he named "total quality control". Juran's total quality control was simply an addition to Deming's earlier statistical models expanding the statistical techniques to everybody, not just the technicians that were Deming's focus. Juran also placed focus on the customer and customer needs (Adrian 2004).

It was not until the 1980's that "statistical techniques, focus on the work process, and an emphasis on people and development of interdisciplinary teams" began to be studied in the United States (Adrian 2004). In the mid 1980's, Phillip Crosby expanded on the focus on the customer. His concept made it so that the worker was not only involved in improvement brainstorming, these same workers who fostered the ideas for improvement, also became vital in the implementation of the quality improvements. The result was a grand acceptance of Total Quality Management as a discipline to improve quality control in the United States (Adrian 2004).

There are three main components to Total Quality Management. These components are: 1) getting everyone involved, 2) customer satisfaction, and 3) continuous improvement. These components make up the framework for a successful Total Quality Management approach to production.

The first step in implementing an effective Total Quality Management approach is to get everyone in the company involved. In years previous to 1980's when Total Quality Management

practices began to be implemented, decision making was left up to upper management. This centralized management group would then tell lower management of the changes, who would then subsequently enforce the changes onto the workers. There was little or no input coming from the employees or subordinates. The construction industry is a perfect example of an industry that has an inherent problem with getting laborers involved. The owner of the construction company makes a decision on how something should be done, this is passed down to the project manager, who relays the decision to the superintendent, who then relays the message to a foreman, who in turn mandates it to a craftsmen. In this situation there is little or no opportunity for the craftsman to get involved in the decision process. The problem, however, is that it is very often the craftsmen who knows the best method of performing the work. This is why under the Total Quality Management approach, Corrective Action Teams or Quality Improvement Teams are formed. These Corrective Action Teams "identify processes or defects in the firm, product, process, or organization" and possible solution to these problems (Adrian 2004). These teams are made up of a diverse group of employees within the organization. Continuing the use of a construction company as an example, a Corrective Action Team may consist of a project manager, a superintendent, a project engineer, a clerical worker or office manager, and a couple of craftsmen from different trades (Adrian 2004).

The second step to implementing a Total Quality Management system is to direct all efforts to satisfy the needs of the customer. A customer-first approach redirects the organization's focus from the people who provide the service or product and focuses it on the person receiving the service or product. Everything the company does should benefit the customer. In the construction industry, the "customer" is the owner, or owner's representative in

the private sector, and the government, government official, or the taxpayers in the public sector (Adrian 2004).

Continuous Improvement

The final step in achieving Total Quality Management is an emphasis on continuous and ongoing improvement. This process can be described as a six step cycle. This six step process is outlined in Figure 2-1 (Adrian 2004).

The first step is to identify the problem, defect, or improvement required. It is important for management to listen to their employees in order to make sure defects do not go ignored or unnoticed. The second step is to assign the problem, defect, or improvement required to the Corrective Action Team or Quality Improvement Team. This team then goes on to measure the defect, how many times it occurs, as well as the variation in performance. The fourth step in the process focuses on analyzing or brainstorming for possible alternatives to the process and how it can be done better. This analysis should be focused on eliminating the defect being studied. Step five in the continuous improvement process is to systemize and implement the solution. These solutions would usually be the ideas that showed the most promise as far as their ability to eliminate the defect (Adrian 2004).

The final step in the process is to re-evaluate the solution and measure again the defect to see if it still exists. This is the most important step in the Continuous Improvement process. Step six involves measuring the solution implemented in step five, then repeating the last four steps of the process. This would begin with step three in which you again measure and analyze the process that spawned the defect. Brainstorm for appropriate solutions. Implement a system to fix the defect. Finally, measure the defect again until the problem is eliminated.

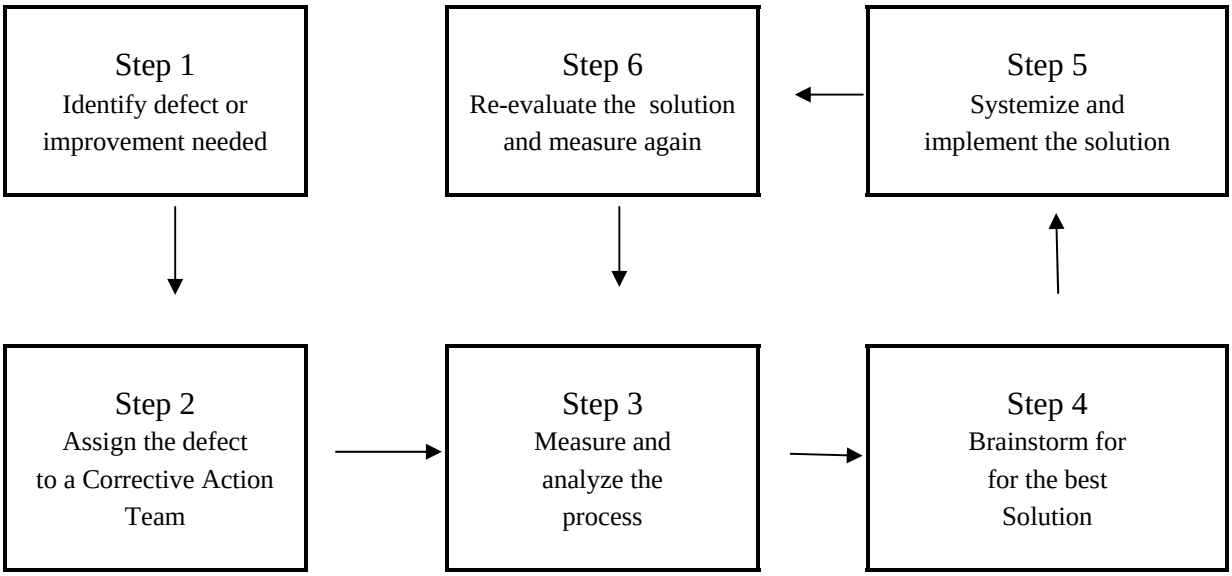

Figure 2-1. The six steps of the Continuous Improvement Cycle (Adrian 2004)

Lean Production in Construction

The manufacturing industry has almost always led the way in terms of productivity improvements. There has been a great deal of research that cites the many benefits of the lean production approach in the manufacturing industry. This begs the question as to whether or not the techniques, processes, and ideology of lean production are applicable to the construction industry.

"The construction industry has rejected many ideas from manufacturing because of the belief that the construction industry is different. Manufacturers make parts that go into projects but the design and construction of unique and complex projects in highly uncertain environments under great time and schedule pressure is fundamentally different from making tin cans" (Howell 1999).

Howell, however, believes that the ideals encompassed in the lean production approach are viable for managing a construction project. Howell summarizes the differences stating that "the

current form of production management in construction is derived from the same activity centered approach found in mass production and project management. It aims to optimize the project activity by activity, assuming customer value has been identified in the design" (1999). In contrast, Howell describes managing under lean construction different "because it; has a clear set of objectives for the delivery process, is aimed at maximizing performance for the customer at the project level, designs concurrently product and process, and applies production control throughout the life of the project" (1999).

Table 2-2 compares the conventional construction management approach with the lean construction management approach (Abdelhamid and Salem 2005).

Table 2-2. Comparison of the conventional CM approach and the lean construction approach (Abdelhamid and Salem 2005)

Conventional CM	Lean Construction
We know how to TRANSFORM materials into standing structures.	We (still) know how to TRANSFORM materials into standing structures.
We expect to have scope changes and design errors during construction, which will be field-engineered by construction team.	We design product and construction process together to avoid design errors/omissions that lead to constructability issues.
We empower managers to be the SOLE planners.	We empower managers to be the FIRST planners of processes and phases and foremen and workers to be the LAST planners of operations.
We assume that reducing cost in one piece will reduce cost of the entire project – the whole is the sum of its parts	We treat entire project as a system and use Target Costing to achieve project cost reductions – the whole is more than the sum of its parts
We push for high local productivity mistakenly thinking that this is a way to achieve global efficiency.	We push for high system throughput which is the only way to achieve global efficiency.
We manage the process using schedules of cost-accruing elements – the ones on which progress payments are based.	We use schedules of cost-accruing elements as INPUT to the planning and control of site production operations.
We are guided by the time/cost/quality trade-off paradigm. You can only get one of the two, but not the third.	We challenge the time/cost/quality trade-off paradigm by removing the sources of waste in the design/production processes to promote better and more reliable WORKFLOW.
We don't plan or control site production operations unless they become off targeted time and cost - we wait until problems happen then react to get project back on track.	We plan and control site production operations to preempt cost-accruing elements from going off targeted time and cost.
We consider VALUE delivered to the owner when product performance is maximized relative to its cost – A Value Engineering (VE) approach.	We consider VALUE delivered to the owner when product value is increased (the facility better fulfills the true needs of the owner purposes) by managing construction process value – a Value-based Management (VBM) approach.

Lean production does not really include any new management principles or techniques that are not currently being implemented, or at least attempted, in the construction industry today. It simply "combines existing principles in a new day" (Shingo 1992). "The basic idea of lean production is very simple. Keep your production system and production organization simple and avoid waste" (Melles 1994). Elimination of waste, or Japanese "muda", is the primary principle behind lean production. Koskela identifies seven elements of waste in the construction industry (1992).

- Work is done below the desired quality (non-conformance)
- External quality cost (during facility use)
- Lack of constructability
- Poor material management
- Excess consumption of materials on site
- Working time used for non-value adding activities (waiting, over processing)
- Lack of safety

"Stimulate your employees to improve their own production process" (Melles 1994). Create bilateral relationships among each task group to heighten communication within the organization. Above all, employees must change their attitudes with regards to productivity. "The most important goal of lean production is to change the attitude of all employees of a company" (Melles 1994).

Previous Research on the Deployment of Lean Construction

A literature search revealed three research projects that have been conducted on the penetration of lean construction into the industry. The first research attempt, done by Common et al. (2000), was an attempt "to test the transfer of lean principles to construction by investigating their penetration into large construction companies in the United Kingdom" (2000). This research determined that in 1999, there were 221 "large" construction companies operating within the UK. After an initial survey attempt that resulted in insufficient data due to a low

response rate, a second survey was completed in which 100 construction companies were surveyed, and 34 of these companies completed the survey. This research concluded that there was limited knowledge of lean techniques. There has been some adoption of lean techniques; however, these only exist while also relying on traditional approaches. Perceptions of lean techniques varied; most of the respondents did not realize the importance of design and planning (Common et al. 2000).

The second research attempt entitled, "Understanding Lean Construction and How it Penetrates the Industry: A Comparison of the Dissemination of Lean within the UK and the Netherlands" was done in conjunction with the previous research done by Common et al. on the deployment of lean construction in the UK. This research was done in order to compare survey results of a similar sample of Dutch contractors with the contractors previously surveyed in the UK. The original questionnaire was translated into Dutch and sent out to 60 medium to large construction companies. Zero questionnaires were returned. A second survey was then sent out in its original English form, and 12 companies responded. This represented a response rate of 20 percent. The results of the survey indicated that "the dissemination of lean concepts in the Netherlands is even lower than the UK although there is more consistency in perceptions" (Johansen et al. 2002). Most believed that either lean production could not be applied to construction or that it could only be applied in a limited way (Johansen et al. 2002).

The third and final research attempt discovered by the literature search built upon the methodologies used in the earlier work in the UK (Common et al. 2000) and the Netherlands (Johansen et al. 2002). This research attempted to range the dissemination of lean techniques within construction companies in Germany in 2007. The questionnaire for the research was sent out to 61 companies taken from Top100 construction companies in Germany (2005), and this

resulted in a response rate of 61 percent. The conclusions that resulted from the analysis of this data were that "there is little awareness of lean in the German construction industry and that hardly any company uses lean concepts on a company wide basis despite evidence that procedures and techniques that are used on German construction sites are generally consistent with lean construction practice. There appears to be cultural resistance to a manufacturing derived, production-system-view of construction" (Johansen and Walter 2007).

The International Group of Lean Construction

Lean construction has been researched by the academic community since its conception in the early 1990s. The group that has probably had the greatest effect in the evolution of its theory as well as the promotion of its practice is the International Group for Lean Construction (IGLC). The IGLC was founded in 1993. It is composed of a network of professionals and researchers in architecture, engineering, and construction. The IGLC believes that the practice, education, and research of design and construction need to be radically renewed in order to adapt to the needs of the ever-growing population.

According to the IGLC website, the goal of the organization is as follows:

> Our goal is to better meet customer demands and dramatically improve the AEC process as well as product. To achieve this, we are developing new principles and methods for product development and production management specifically tailored to the AEC industry, but akin to those defining lean production that proved to be so successful in manufacturing.

The IGLC currently holds annual conferences open to researchers and companies who would like to create and gain knowledge on the subject of lean construction and the advancement of its practice. The organization also post papers on the findings of its research.

The IGLC is not the only organization actively participating in the expansion of lean construction. Other organizations include

- Australian Center for Construction Innovation (ACCI)
- European Group for Lean Construction
- Lean Construction Institute
- Salford Centre for Research and Innovation

These organizations are actively striving to increase public knowledge of lean construction as well as its use in the construction industry.

CHAPTER 3
METHODOLOGY

This report investigates the deployment of lean production techniques in the construction industry. The objective of this study was to determine the following: 1) what percentage of leading contractors is aware of lean construction techniques, and 2) to what extent has lean construction been accepted into practice by the construction industry in 2008.

Sample Selection

The source of the data collected for this report was a survey. This survey was distributed to industry professionals representing the 113 companies who attended the University of Florida's 2008 spring career fair on February 12, 2008. The University of Florida's spring career fair contained Project Managers, Project Engineers, Senior Vice Presidents, Presidents, and Chief Operating Officers from some of the world's top general contracting firms.

The University of Florida's 2008 career fair was chosen as the sample selection for this report, because it contained a wide range of general contractors who are located all around the globe. These general contractors range from the very small (annual volume of under $100 million) to the very large (annual volume of $14.6 billion). The University of Florida's 2008 spring career fair also contained a large majority of contractors listed on the ENR's Top 400 Contractors. It can be assumed that the majority of the ENR's Top 400 Contractors have the resources and personnel available to commit time and money to research and productivity improvement techniques. Therefore, the University of Florida's 2008 spring career made a suitable sample for the means of this report.

The Survey

The survey was designed in three sections. This survey and all of its three sections are included in the Appendix A of this report. The first section entitled, "Questions Regarding the

Company", is comprised of multiple choice questions regarding the specifics of each company including its number of employees, its annual turnover in terms of revenue, and the nature of a typical project. This section contains a total of five questions to be answered by the representative of the company.

The second section of the survey entitled, "Questions regarding Lean Construction Practices", contains multiple choice and short-answer questions. These questions attempt to discover the company representative's familiarity with lean construction techniques, the deployment of these techniques within the company, and whether the company has seen any benefits due to the utilization of these techniques. This section contains two multiple choice questions and two short-answer questions.

The third and final section of this survey entitled, "Questions Regarding Research and Industry Involvement", contains four multiple choice questions and two short-answer questions. These questions attempt to identify the company's involvement in lean construction research, as well as any plans to devote resources to lean construction in the future.

In addition to the survey, an introductory letter was composed outlining the purpose of the survey, as well as the rights of all the respondents. Approval for the survey was obtained from the University of Florida's Institutional Review Board.

Analysis Performed

After the survey responses were received, a statistical and analytical examination was done in order to best answer the following questions posed in this report: 1) what percentage of leading contractors is aware of lean construction techniques, and 2) to what extent has lean construction been accepted into practice by the construction industry in 2008. For a few of the survey questions, it was pertinent to calculate the mean and range, responses. It was also necessary to show a significant correlation between the companies using lean construction and

the number of people employed within those companies. Microsoft Excel 2003 was used to calculate these statistical results.

CHAPTER 4
RESULTS AND ANALYSIS

Survey Response Rate

A total of 113 surveys were issued at the University of Florida's M.E. Rinker Hall School of Building Construction spring 2008 career fair on February 12, 2008. A copy of the survey can be found in Appendix A of this report. The University of Florida's spring career fair contained Project Managers, Project Engineers, Senior Vice Presidents, Presidents, and Chief Operating Officers from some of the world's top general contracting firms. A total of 44 companies responded to the questionnaire. This yields a response rate of 39%.

Demographics

Companies that responded to the *Lean Construction Survey* ranged from employing below 200 employees to over 10,000 employees. Of the 44 companies that responded to the survey, 27% of the companies contained below 200 employees, 43% contained between 200 to 1,000 employees, 23% contained between 1,000 and 10,000 employees, and 7% contained over 10,000 employees (Table 4-1). Also, out of the 44 companies that responded to the questionnaire, 7% had an annual turnover in terms of revenue of $1 million to $5 million USD, 2% had an annual turnover between $5 million and $25 million USD, 23% had an annual revenue between $25 million and $100 million USD, and 71% had an annual revenue over $100 million USD (Table 4-2). Additionally, 11% of the respondents said that "infrastructure" best describes the nature of their projects, 5% said that "heavy industrial" best describes the nature of their projects, and 84% said that "buildings" best describes the nature of their projects (Table 4-3).

Table 4-1. Number of employees contained within the responding companies

	Number of Employees Contained within the company			
	Under 200	200-1000	1000-10000	Over 10,000
% of Respondents	27%	43%	23%	7%

Table 4-2. Annual turnover in terms of revenue of the responding companies

	Annual Turnover in terms of revenue (millions USD)			
	1 to 5	5 to 25	25 to 100	Over 100
% of Respondents	7%	2%	20%	71%

Table 4-3. Typical nature of the projects done by the responding company

	Typical Nature of Projects		
	Infrastructure	Heavy Industrial	Buildings
% of Respondents	11%	5%	84%

Out of the responding companies, 75% considered themselves General Contractors, 9% considered themselves Specialty Contractors, 2% consider themselves Suppliers, and the remaining 14% responded "other" when asked the nature of their business (Table 4-4). Of the 44 companies that responded to the survey, 48% of the companies said that their customer most often comes from the private sector, and 52% said that their customer most often comes from the public sector (Table 4-5).

Table 4-4. Nature of the business done by the responding company

	Nature of the business			
	General Contractor	Specialty Contractor	Supplier	Other
% of Respondents	75%	9%	2%	14%

Table 4-5. Customer most often dealt with by the responding company

	Customer is Most Often	
	Private	Public
% of Respondents	48%	52%

Survey Results

In order to better ascertain the deployment of lean construction, respondents were asked to answer questions regarding their familiarity with lean construction, as well as whether or not they currently utilize lean construction methods or concepts on their projects. Twenty three percent of the respondents said that they were familiar with the term "lean construction" as an

approach to managing the construction process (Table 4-6). Every respondent who said that they were familiar with the term lean construction also said that they utilized lean construction concepts or methods on their current projects. Table 4-7 shows a summary of the percentage of companies who responded saying that they currently utilize lean construction concepts or methods on their projects.

Table 4-6. Percentage of respondents who are familiar with the term "lean construction" as an approach to managing the construction process.

	Familiar with Lean Construction	
	Yes	No
% of Respondents	23%	77%

Table 4-7. Percentage of companies who currently utilize lean construction methods or concepts on their projects

	Utilize Lean Construction Currently	
	Yes	No
% of Respondents	23%	77%

In order to further analyze the data, the respondents were then split up into those who said that they currently utilize lean construction concepts and methods, and those who said that they do not. The 23% of respondents that said "yes" to the question of whether or not they currently utilize lean construction were then further examined as to their demographics. Figure 4-1 shows the percent of companies who use lean construction techniques based on the number of persons employed by the company. It was discovered that 8.3% of the companies with fewer than 200 employees utilize lean construction techniques, 10.5% of the companies with between 200 and 1000 employees utilize lean construction techniques, 40.0% of the companies with between 1,000 and 10,000 employees utilize lean construction techniques, and 66.7% of the companies

with over 10,000 employees utilize lean construction. Next, the bar graph of this data was analyzed to determine a trend line for the graph. The R-squared value for the trend was 0.9334 (Figure 4-2).

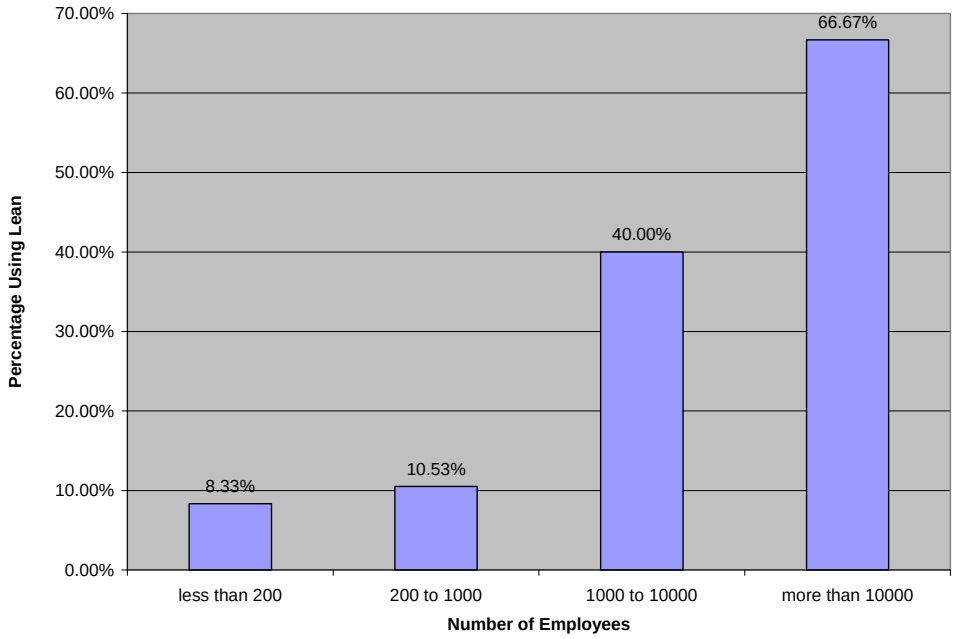

Figure 4-1. Companies using lean construction based on the number of persons employed by the company.

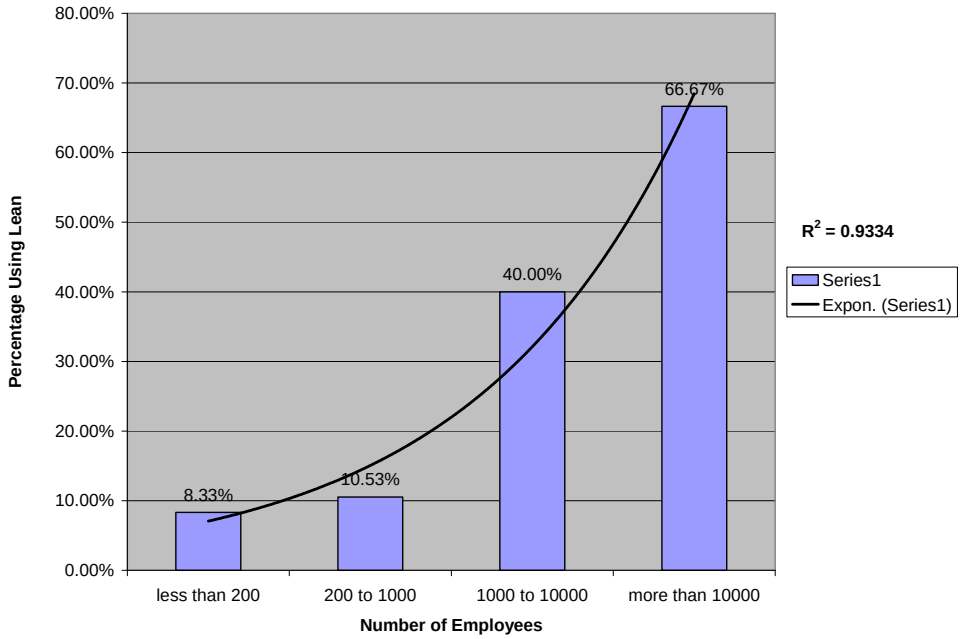

Figure 4-2. Exponential trend of the number of employees in companies utilizing lean construction.

The 23% of respondents who answered “yes” to the question of whether or not they utilize lean construction concepts and techniques were then analyzed to compare there annual turnover in terms of revenue, the typical nature of their projects, the nature of their business, and whether there company was most often from the public or private sector. First, the companies were analyzed in terms of there annual revenue. Of the companies with an annual turnover in terms of revenue of under $25 million, 0% utilizes lean construction. Of the companies with an annual turnover between $25 and $100 million, 33.33% utilize lean construction. As shown in Figure 4-3, of the companies with an annual turnover more then $100 million, 19.4% utilize lean concepts and techniques.

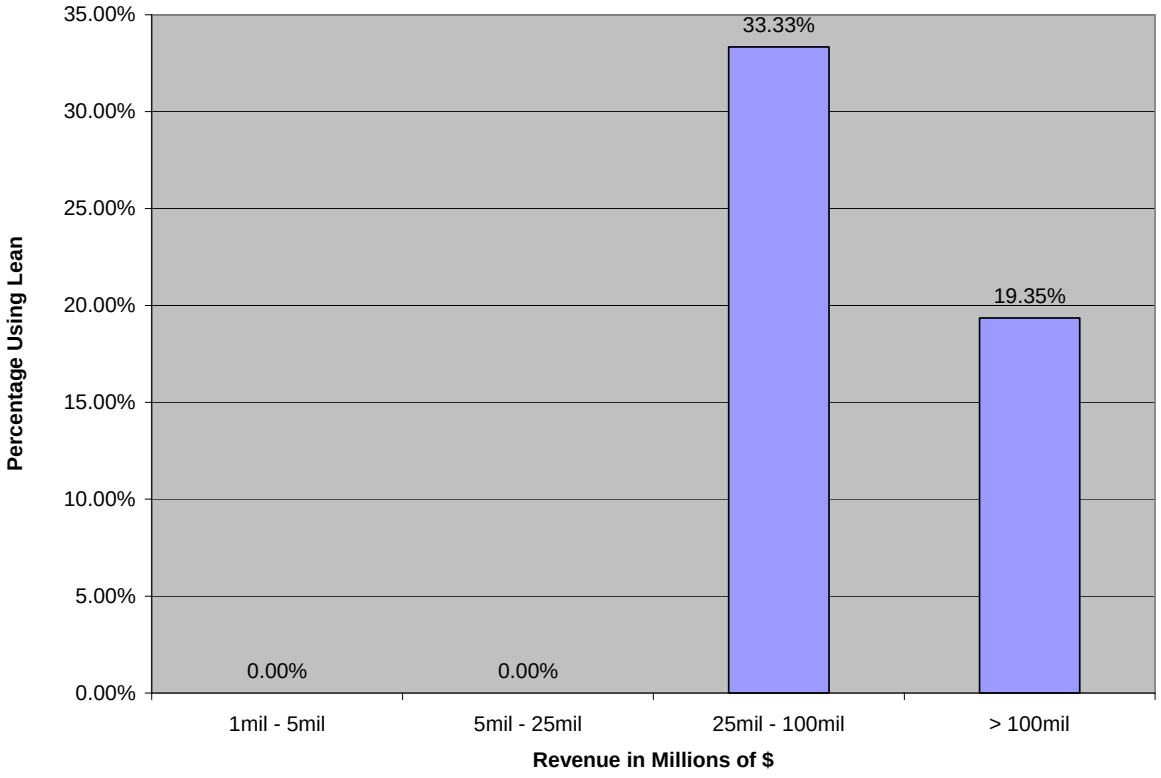

Figure 4-3. Percentage of companies using lean construction based on the company’s annual turnover in terms of revenue.

Next, the companies that use lean techniques were analyzed to compare the nature of their business. Of the companies that said "Infrastructure" to the question asking the nature of their business, 40.0% utilize lean construction techniques. Of the companies that answered "Heavy Industrial" to the question regarding the nature of their business, 50.0% utilize lean techniques. Finally, of the companies that replied "buildings" with regard to the nature of their business, 16. 7% utilize lean on their projects. This data is shown in Figure 4-4.

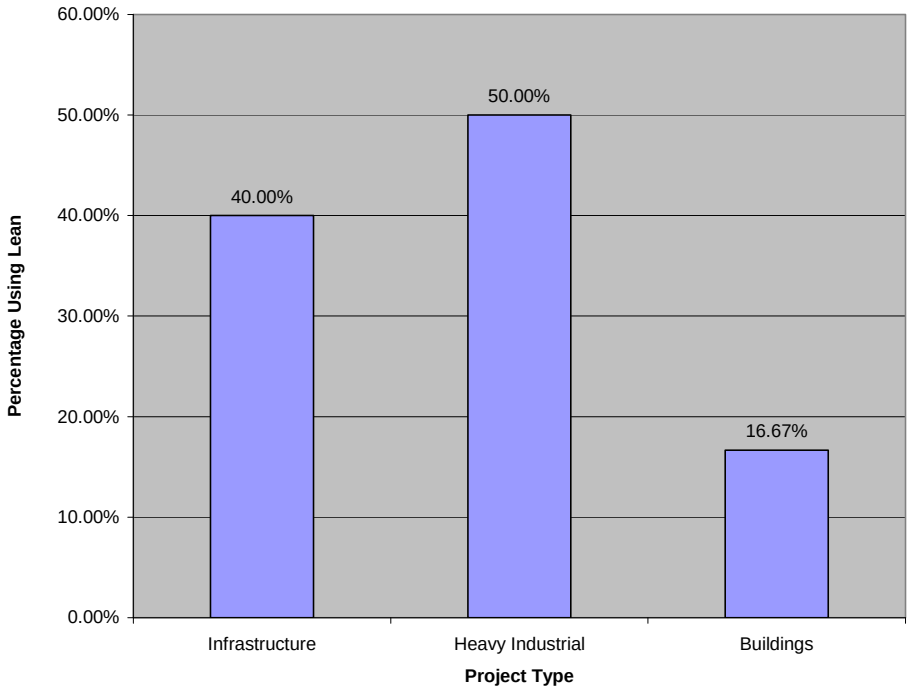

Figure 4-4. Percentage of companies using lean construction based on the typical nature of the company's construction project.

The next step was to analyze the type of company and whether they utilize lean construction techniques. Of the companies that answered "General Contractor" as the nature of their business, 18.2% use lean techniques. Of the companies that answered "Specialty Contractor", 25% utilize lean techniques. Zero percent of the companies that consider themselves suppliers utilize lean techniques. Of the companies that said "Other", 33.3% utilize lean techniques (Figure 4-5).

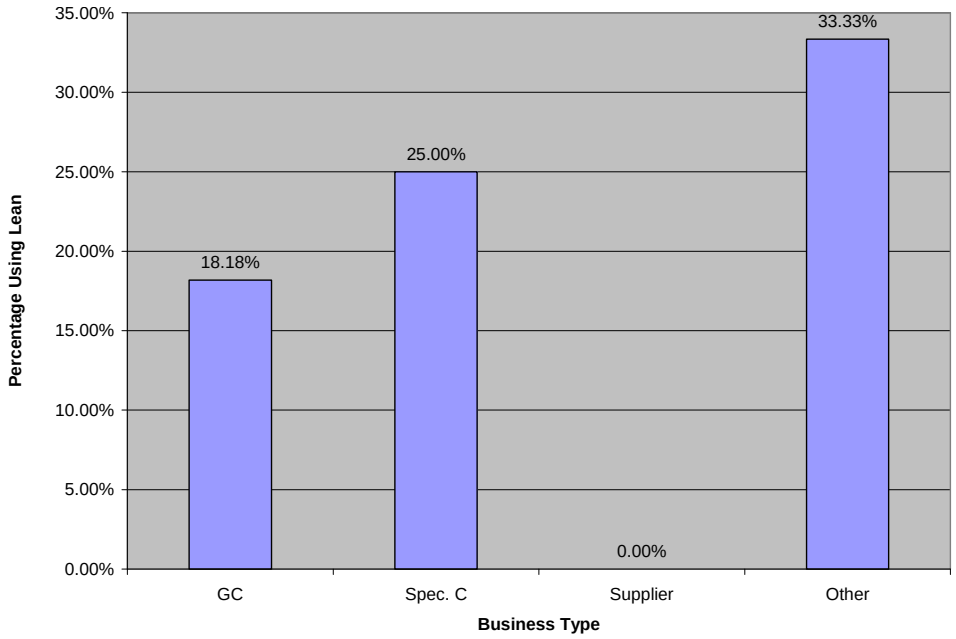

Figure 4-5. Percentage of companies utilizing lean construction techniques based on the nature of their business.

Finally, the companies that utilize lean techniques were compared as to what sector the customers that they most often do business with. Of the companies that answered "Public", 30.4% utilize lean techniques. Of the companies that answered "Private", 9.5% use lean techniques (Figure 4-6).

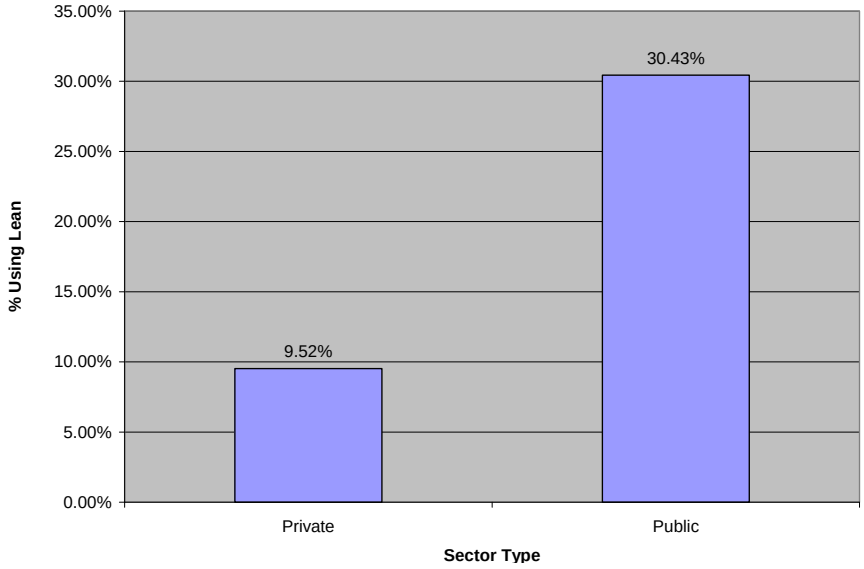

Figure 4-6. Business sector of the customer most often dealt with by construction companies utilizing lean construction.

The eighth question of the survey asks the respondent to state the year in which their company started utilizing lean construction. The responses of the ten companies that responded to this question are summarized in Table 4-8. The mean year and range of the amount of time elapsed from the year are summarized in Table 4-9.

Table 4-8. Year started and the number of years that have elapsed since the companies began using lean construction.

Year Started	Years Elapsed
2004	4
2003	5
2000	8
2000	8
2003	5
2000	8
1998	10
1994	14
2000	8

Table 4-9. Mean and range of the number of years since the companies implemented lean construction as an approach to managing the construction process

Number of Years since implementation of Lean		
Mean	Minimum	Maximum
7.78	4	14

The ninth question of the survey asks the respondent if they have identified any tangible benefits from utilizing Lean Construction practices. Of the companies utilizing lean construction, 88. 9% believe they have identified tangible benefits. Question nine also asks the respondent to list examples of the benefits they have identified. The three responses were "limited supply chain = more profit = simplification and increased customer satisfaction"; "Constructability increases on every project" and; "We staff our projects based on lean ideology and constructability increases as a result."

The tenth and eleventh questions pertain to if the company has made a conscious decision not to utilize lean techniques. Question ten of the survey asks if the respondent's company has evaluated lean construction concepts and methods and reached a decision not to utilize these techniques. Every person who responded to this question answered "no." The eleventh question asks, "if your company has decided not to adopt Lean Construction to your practices, what was the critical deciding factor driving the decision?" Since every respondent who answered question ten answered "no", question eleven went unanswered by every person responding to the survey.

The final section of the survey asks questions regarding the responding company's research and industry involvement. Of all the 44 persons that responded to the questionnaire, only one respondent (2.3%) said that their company actively participates in research projects conducted by academic institutions regarding lean construction. Zero respondents said that members of their company participate in an annual lean construction conference such as the IGCL. When asked the question of "which group does your company interface with more often regarding adoption and application of Lean Construction concepts and methods", 13.6% responded "Customers/Owners", 0% responded "Academic Institutions", and 86.4% responded "neither" (Figure 4-7).

Question 15 of the survey asks the quantity of time and resources the respondents company plans to devote to lean construction. 11.4% of the respondents said "more time". None of the respondents responded "less time". 77.3% responded, "no time and resources" The summary of this data can be seen in Figure 4-8.

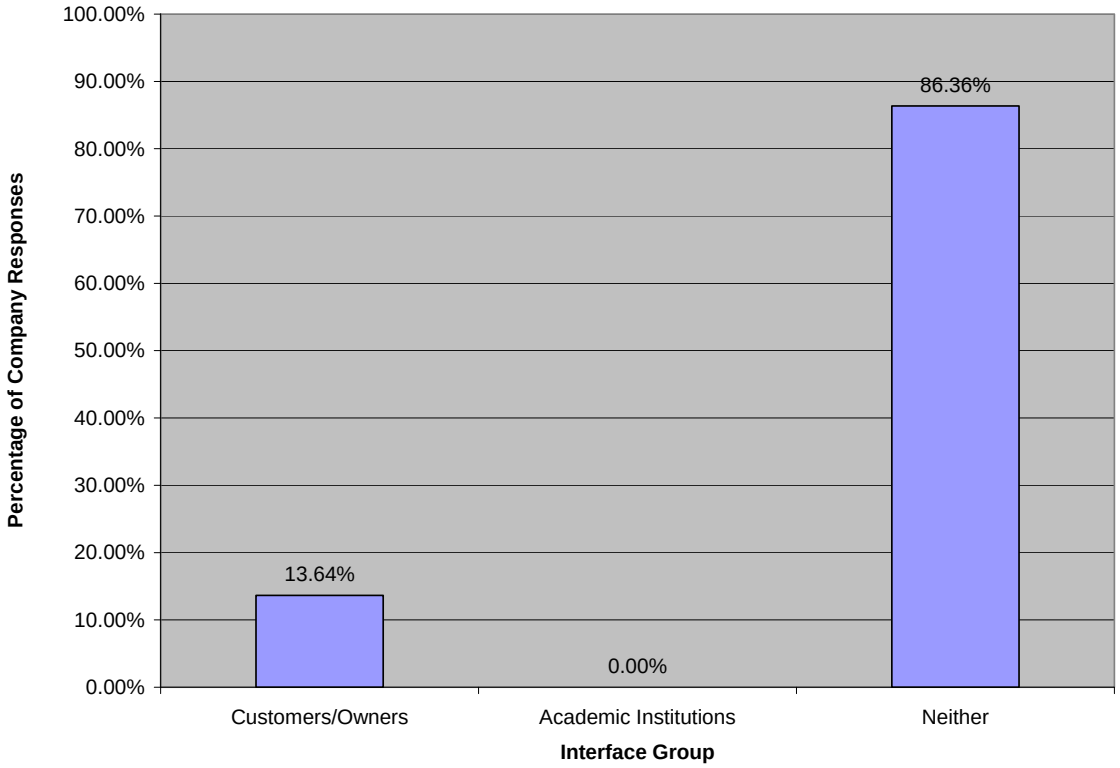

Figure 4-7. Groups the companies interface with most with regards to lean construction.

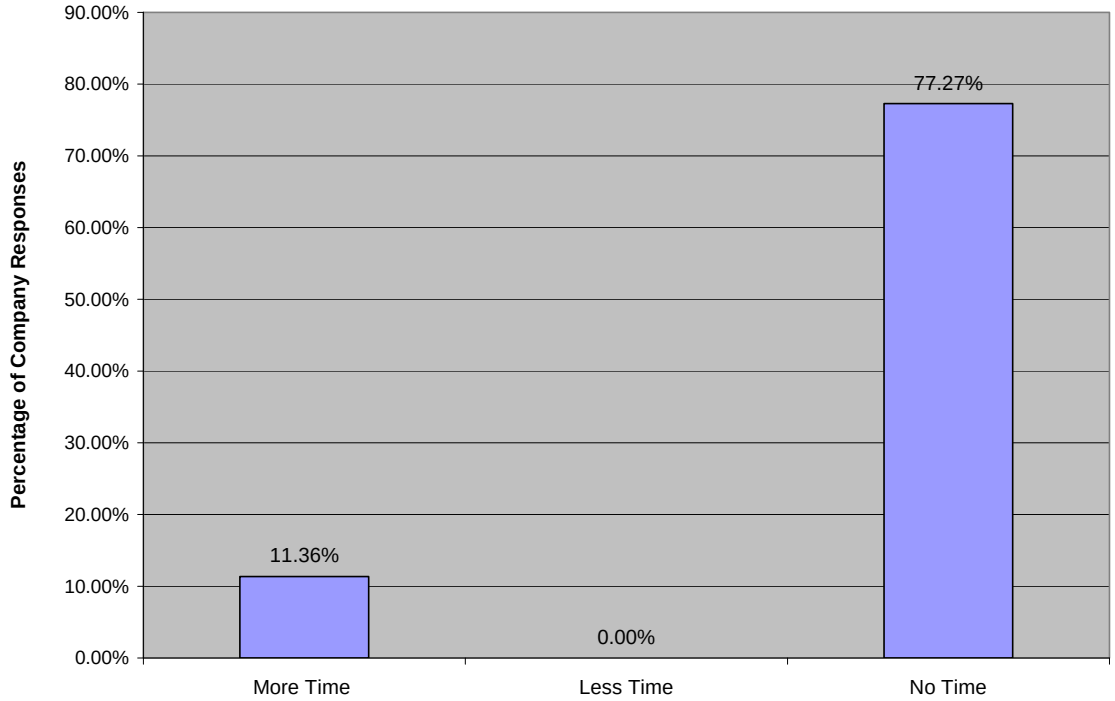

Figure 4-8. Amount of time companies plan on devoting to lean construction in the future

The final multiple choice question of this survey asks the respondents to choose the definition of lean construction that most closely resembles their own. 22.7% of the respondents chose "the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the construction project". The remaining 77.3% of the respondents chose "other" when answering the question. This data can be seen in Figure 4-9.

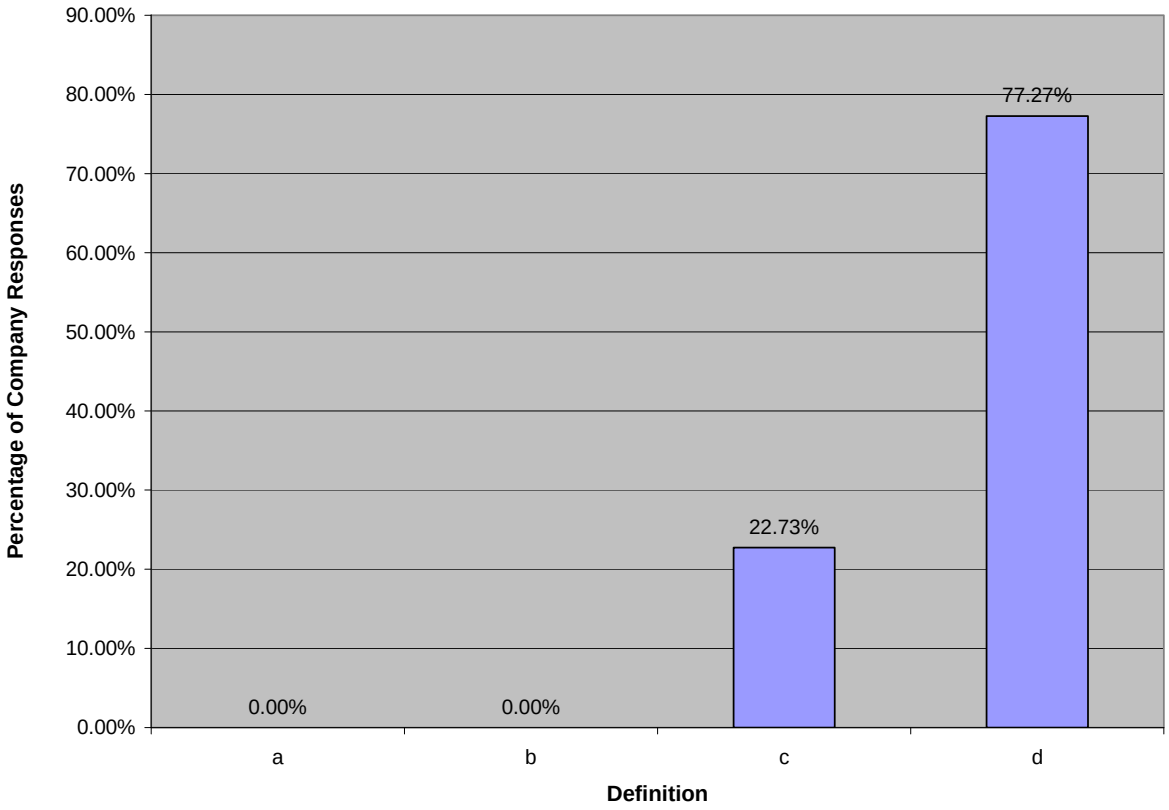

Figure 4-9. Definition of lean construction chosen by companies: A) "the holistic pursuit to the elimination of material waste on a construction project" B) "Kaizen (Japanese for permanent and stepwise quality improvement)" C) "the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the constructed project" D) "Other"

CHAPTER 5
CONCLUSIONS

The results of the survey indicate that the deployment of lean construction within the industry is low. Lean construction, as a concept appears to be largely unknown.

The companies that are familiar with the term “lean construction” as an approach to managing the construction process all believe that they are currently utilizing these techniques and concepts on their projects. Also, a large majority of the companies that are familiar with lean believe that they are receiving tangible benefits. No company said that they consciously decided not to use lean concepts. Based on these findings, the conclusions of the research are that although most the representatives of today’s General Contractors and Construction Management firms are unaware of lean construction as a technique, the representatives that are familiar with it, are using it and believe that it is beneficial to their company. The benefits most often listed by the respondents were related to better constructability.

The next most noteworthy results gained from this research are illustrated Figure 4-2. Figure 4-2 shows the percentage of companies using lean construction based on the number of persons employed by the company. The R-squared value of the graph is very close to 1. Therefore, the graph has an exponential trend. The conclusion that can be drawn from this graph is that as the number of employees in a company increases, so does the knowledge and use of lean construction.

Another important result gained from this research is that companies that produce an annual turnover in terms of revenue of less than $25 million are unfamiliar with the term “lean construction” as a technique to manage the construction process. These companies subsequently do not utilize lean construction on their projects.

Most of the companies who responded said that they began utilizing lean construction within the last eight years. The longest period that any company surveyed has been implementing lean construction on their projects is 14 years.

Only one company of the 44 companies who responded to the survey actively participates in research projects conducted by academic institutions or other organizations regarding lean construction methods and techniques. None of the companies who responded to the survey currently attend any conferences regarding lean construction.

Based on the findings of this research, the main conclusion is the majority of GCs and CMFs in the construction industry are unfamiliar with the term lean construction as an approach to managing the construction process. Lean is subsequently not being utilized in the construction industry. It is likely that many of the techniques encompassed under lean principles are being used; however, companies are not utilizing lean construction as the overall approach for completing their projects. Organizations such as the International Group for Lean Construction believe that the practice, education, and research of design and construction need to be radically renewed in order to adapt to the needs of the ever-growing population. If lean is an answer to this change, it appears that it is going to be a slow process.

CHAPTER 6
RECOMMENDATIONS

Recommendations for Further Research

Additional research on the topic of lean construction will be greatly beneficial to productivity in the construction industry. The first recommendation for further research is to increase the sample size. This research surveyed 113 companies at the University of Florida's spring 2008 Building Construction career fair. Forty four companies responded to the survey. A research effort that targeted the ENR top 400 general contractors would enlist the best group of general contractors in the world. It is assumed from this research that by targeting the top 400 countries in the world, a larger percentage of companies will be aware of the concepts and benefits of lean construction.

The second recommendation for future research is to ask questions about the principles of lean construction individually to determine whether or not companies are utilizing the principles of lean construction without knowing the formal term. This research can be done on a point system in which for every principle of lean construction that the company says it is utilizing, they receive a point. This point system can then be used to calculate what principles of lean construction are being utilized the most, what companies are utilizing these concepts, and whether these techniques appear to be effective.

The third recommendation for future research is to survey the academic community. Knowledge of new topics often comes from universities, schools, and other academic organizations. Research into whether the academic community is aware and teaching about lean construction principles and techniques could be very beneficial. This will help to determine why lean construction is having a difficult time in its penetration of the construction industry.

The final recommendation for future research is to limit the survey to only U.S. or Japanese based companies. The data obtained from this research could be contrasted to the findings of Johansen et al. (2007) for the Netherlands, the UK, and Germany.

APPENDIX A
LEAN CONSTRUCTION SURVEY

LEAN CONSTRUCTION SURVEY
Rinker School of Building Construction

The following questions will require 10 – 15 minutes of your time. Kindly respond to all the questions you are comfortable answering.

SECTION 1 – Questions Regarding the Company: *(please circle your answer)*

1. How many persons do you employ in your company?
   a) Under 200 employees
   b) 200 to 1,000 employees
   c) 1,000 to 10,000 employees
   d) over 10,000 employees

2. What is your annual turnover in revenue terms?
   a) $ 1 million to $ 5 million USD
   b) $ 5 million to $ 25 million USD
   c) $ 25 million to $ 100 million USD
   d) over $ 100 million USD

3. What is the typical nature of your projects?
   a) Infrastructure
   b) Heavy Industrial
   c) Buildings

4. Which of the following best describes the nature of your business?
   a) General Contractor
   b) Specialty Contractor
   c) Supplier
   d) Other

5. Your customer is most often from which sector?
   a) Private
   b) Public

SECTION 2 – Questions regarding Lean Construction practices: *(please circle your answer)*

6. Are you familiar with the term “Lean Construction” as an approach to managing the construction process?
   a) yes
   b) no

7. Do you currently utilize Lean Construction methods or concepts on your projects?

a) yes
b) no

8. In what year did your company start to utilize Lean Construction concepts and methods on your projects?

Year started _____

9. Has your company identified tangible benefits from utilizing Lean Construction practices that have enhanced your company profits?

a) yes Examples:_____
_____
_____
b) no

10. Has your company evaluated Lean Construction concepts and methods and reached a decision not to utilize these techniques?

a) yes
b) no

11. If your company has decided not to adopt Lean Construction to your practices, what was the critical deciding factor driving this decision?

a) concluded the concepts & methods do not add value
b) lack resources to fully evaluate the concepts
c) lack resources to incorporate, train and deploy
d) other _____

SECTION 3 – Questions regarding Research and Industry Involvement: *(please circle your answer)*

12. Does your company actively participate in research projects conducted by academic institutions or other organizations regarding Lean Construction methods and techniques?

a) yes
b) no

13. Do member(s) of your company participate in an annual Lean Construction conference such as the IGCL conference?

a) yes
b) no

14. Which group does your company interface with more often regarding adoption and application of Lean Construction concepts and methods?

a) Customers/Owners
b) Academic Institutions
c) neither

15. During the next year your company will devote which of the following to the subject of Lean Construction?

a) more time and resources
b) less time and resources
c) no time or resources

16. The following choices represent opinions expressed in recent editorials and publications. Which of these definitions of Lean Construction is closest to your own?

a) the holistic pursuit to the elimination of material waste on a construction project
b) Kaizen (Japanese for permanent and stepwise quality improvement)
c) the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the constructed project.
d) Other

_____.
Please Fill In

17. Please add any other thoughts or views you have regarding the application and use of Lean Construction methods and concepts in the industry in 2007 below.

_____
_____
_____
_____
_____
_____

Thank you for your time and support!

APPENDIX B
INSTITUTIONAL RESEARCH BOARD SURVEY COVER LETTER

February 12, 2008

Subject: Survey Request

Dear Sir/Madam:

I am a graduate student at the University of Florida completing a Master's Degree in Building Construction from the Rinker School of Building Construction. A requirement for the degree is to produce a master's thesis pertinent to the industry. My subject research is to explore the extent to which Lean Construction has penetrated the business and is being practiced within construction contractor environments.

I respectfully request and would greatly appreciate your time and consideration in completing the enclosed questionnaire regarding Lean Construction. I will be back to pick up any completed surveys around **1:00 pm**. You may also submit the completed form to stofmind@ufl.edu if you do not have time to complete the form today. I assure you that your response will be treated confidentially and no firms will be individually identified in the report.

The survey should take approximately ten minutes to complete. I sincerely thank-you for your; time, thoughts, and cooperation in completing this survey.

Very truly yours,

D R Gilbert

Dane Ryan Gilbert
Masters in International Construction Management Program
Rinker School of Building Construction, University of Florida
Research Committee Chairman: Dr. Raymond Issa

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BIOGRAPHICAL SKETCH

Dane Gilbert received a Bachelor of Design in Architecture from the University of Florida, Gainesville, Florida in May 2006. After graduation, he enrolled at the M.E. Rinker, Sr. School of Building Construction at the University of Florida to pursue a Master of Science of Building Construction.

Dane Gilbert was born in Tampa, Florida. Upon graduation, he will move back to Tampa to work as a project engineer. He hopes to become very successful in the construction industry so that he can give back to the University of Florida's Rinker School of Building Construction.