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Strategic Issues in Lean Construction and the Higher Education Construction Market Sector

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Strategic Issues in Lean Construction and the Higher Education Construction Market Sector

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ABSTRACT

There are several, well-known difficulties in building construction that often result in low productivity and poor quality. Recent efforts to minimize their effects resulted in partial improvements but the sources of the problems still exist. Within the manufacturing and service sectors, however, improvements were attained with the introduction of a new production philosophy - later identified as lean production - that initiated in Japan (1945) and was introduced in Europe and in the United States in the 1980's. The primary goal of lean production is the elimination of waste, seen as any non-value-added activity in the production system. The design and implementation of this innovative method of production involves the development of a comprehensive strategic planning by the organization and requires long-term capital and human resources investments.

An academic movement, designated "lean construction" originated in the United States (1994) with the purpose of studying the applicability of the lean production philosophy for the AEC industry. Current lean construction research, however, advances toward improving construction processes at the project level, but limited researchers address the core motives for manufacturing organizations to shift from mass production to lean production. This thesis focuses on the level of understanding on organizational issues in the implementation of lean construction and seeks answers for fundamental strategy-related matters. The thesis provides results of investigating those issues from the perspective of the owners, through an "on-line" survey conducted on the higher education institutions segment and 1) concludes that lean construction is feasible for AEC firms that serve that market and 2) suggests the appropriate business strategy to efficiently compete in that market.

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1 INTRODUCTION

1.1 Conceptual Framework

In the summer of 1992, a Finnish researcher named Lauri Koskela completed a technical report (Koskela 1992) for the Center for Integrated Facility Engineering (CIFE) at Stanford University related to innovative methods of production, more specifically, how the manufacturing sector had made such substantial progress on improving production during the past decades. The objective of the report was to investigate the feasibility of applying innovative methods of production from the manufacturing sector to the Architecture, Engineering, and Construction industry (AEC). In his conclusions, Koskela argued that researchers and industry groups should consider the development of a theory of production that would improve the output of construction projects and he focused on two major concerns: productivity and quality of construction.

The issue of productivity identifies three basic aspects of production. The first aspect is transformation of input into output, i.e., the labor, material, and equipment necessary to physically produce the goods from raw material to final product. The second aspect of production is flow and includes the activities such as moving, storing, waiting, and inspecting. The third and final aspect represents the fulfillment of consumers' expectations through design and conformance to requirements. In addition to productivity, quality issues were also part of the CIFE report and they were described as problems related to deficient design, poor communication, construction materials, and safety.

The contents of the report also included the basic description of a new production philosophy that initiated after World War II in Japan and was introduced in Europe and in the United States in the 1980's. That new method of production - later identified as lean production - represented the basis for the creation of the Toyota Production System and incorporated several innovative concepts and methodologies unknown to the Western industrialized world. The primary goal of lean production is the elimination of waste or, in other words, the minimization of non-value-added activities in the production system. Along with the "waste elimination" concept, lean production also consists of a myriad of managerial methodologies such as continuous improvement, teamwork, demand-pull strategy, inventory reduction, and partnerships, among others. The most important components of lean production are presented in chapter 2.

Another area of development that arose during the 1980's was strategic management. A combination of technology, marketing advancements, and the changing economy were responsible for the shift in American organizations from an expansionist, diversification mentality to more conservative, effective long-term management policies. Likewise, AEC firms are experiencing new forces of competition, especially because the effect of emerging markets and information technology (Chinowsky et al 2001). Additionally, alternative methods of project delivery are increasingly being employed. The Design-Build (D-B) delivery system, for example, sets a different scenario for business competition since D-B firms are selected on past performance and they compete for customers instead of (traditionally) for projects. Chapter 3 covers the fundamental elements of strategic management and competitive strategy.

From the conclusions of the cited CIFE report, which indicated the feasibility of applying the lean production philosophy to the AEC, an academic movement called lean construction originated in the United States (1994) with the purpose of stimulating research on the areas of theory of project-based production systems, the production system itself, and implementation issues. This new field of research within the AEC academic community is still in the early stages of development and literature or journal articles on the subject are still limited. Nevertheless, the basic lean construction concepts and the status of current research are presented and described in chapter 4.

Chapter 5 describes and presents the main components of this thesis work. Among the fundamental conditions for applying lean production, the requirement of long-term investment of capital and human resources is paramount and consequently, the implementation of lean production demands a formal strategy. Those concepts constitute the core of this thesis discussion

This research investigates, from a managerial standpoint, the adaptation of lean production to the AEC industry. It is largely accepted that the new lean production philosophy pioneered by Toyota provides manufacturing and services organizations with competitive advantage mainly because of improved efficiency, cost reduction, and value generation. On the other hand, the implementation process requires a major commitment from the corporation, in both capital and human resources, and success is not always certain. In this context, it would be interesting to determine whether similar tradeoffs exist for an AEC firm implementing lean construction.

The first area of concern relates to the reasons why major manufacturing companies have abandoned the traditional methods of production and implemented the

lean philosophy and whether those reasons are the same for an AEC firm – with limited gains from economies of scale - to adopt lean construction. The question that addresses this area comprises the motivation for an AEC firm to commit to lean construction.

That first area of concern leads to an additional question that aims to determine which competitive strategy an AEC firm should pursue in case it decides to implement lean construction methods. Should the firm position itself as being different from competitors by applying lean construction or, contrarily, should the firm stress its project cost reduction due to lean principles implementation?

For the development of this research, two key decisions were made: First, a survey case-study methodology was chosen and the population targeted for providing data constituted owners that contracted in the AEC industry. The reasoning for surveying owners rather than AEC firms relates to the essences of lean production itself. Lean production pioneers' strategy was to gain market share in the highly competitive automobile industry by performing efficiently and satisfying costumers. Therefore, the feedback from costumers (owners, in the AEC industry) highly contributes to the investigation of implementation issues in lean construction.

The second decision was to focus on a specific segment of the market for AEC firms - the higher education segment - and the different reasons for surveying this particular segment are explained in the body of this report (chapter 5). The central point, however, was the decision to utilize feedback from owners and not from the industry's AEC organizations. One of the fundamental aspects of lean thinking is to deliver "value" from the costumer point of view; this research applies that same philosophy and gathers data utilizing the methodology described in the next section.

Chapter 6 presents the results and analysis of the survey results. In that chapter, there are comments on the development of the questionnaire used to gather data as well as a set of contingency tables that show relationships between the several aspects of the research.

Finally, chapter 7 brings the conclusions and discussion of the concepts that encompass this thesis

The elements of lean production and lean construction, as well as strategic management, constitute the main ideas of this research work. In the past, the manufacturing sector provided excellent practical tools for the AEC industry, such as pre-fabricated construction elements, computer integrated production, and electronic data interchange (EDI). The wish of improving the delivery of construction projects is largely shared within the industry and in light of the increasingly competitive business environment, it is worthwhile to explore the potential benefits of lean production for the AEC industry.

1.2 Methodology

The development of this research work includes an extensive literature review on the subjects presented in section 1.1 above, as well as on related subjects such as concurrent engineering in construction, parametric modeling systems, partnering, and value engineering.

The methodology includes the development of an on-line survey to obtain data from facility planners at American higher education institutions. Efforts were made to design a questionnaire that would effectively address the areas of concern mentioned in the previous section. A 9-question form was made available on a designated Internet address in the form of a web site.

Prior to the development of the questionnaire, three face-to-face interviews were conducted including one facility manager, one D-B local firm president, and one business developer for a major Boston AEC contractor. The results of the face-to-face interviews were essential for the formulation of the survey questions.

Both the distribution of the survey and collection of the data were conducted without any technical or administrative problem. The questionnaire and the summary of the survey, as well as the comments/suggestions collected are presented in appendices A and B respectively.

2 LEAN PRODUCTION

In the fall of 1945, the president of the Toyota Motor Company, Kiichiro Toyoda (1894-1952), predicted: "Catch up with America in three years. Otherwise, the automobile industry of Japan will not survive" (Ohno 1988). Although Toyoda's ambitions were unfeasible in light of the Japanese losses after World War II, his concerns were quite justifiable. In 1950, for example, Toyota produced 2,685 vehicles, a tiny fraction of what American manufacturer Ford was producing per day, around 7,000 cars (Womack et Al 1991). Forty years later, with 37,000 employees, Toyota was producing four million cars per year, half of General Motors' production of eight million units. The remarkable difference, however, was GM's number of employees (over 850,000 people worldwide). Furthermore, by the same time, GM averaged 130 assembly defects per 100 cars while Toyota averaged 45 assembly defects per 100 cars. American and European researchers investigated the reasons for those discrepancies and a subsequent technical report revealed the foremost cause: a comprehensive, innovative production system they called lean production.

Concurrently with the two major oil crisis in the 1970's, one exceptional marketing phenomenon regarding the Japanese cars was evident: a large and increasing number of American and European consumers found that Japanese cars were affordable to buy, were fuel efficient, and featured quality levels that were beyond their expectations. In 1985 - when that marketing scenario started to reflect on the market share distribution among car manufacturers - a comprehensive, five-year study was initiated at the Massachusetts Institute of Technology (Womack et al. 1991) after the creation of the International Motor Vehicle Program (IMVP). The program's objectives

were 1) to gather data on the evolution of the automobile industry, its performance, and future and 2) to apply the data to understand why the changes in the international automobile markets occurred. The study ultimately found enough evidence to propose the reasons for the shift in costumer preferences and exposed to industry leaders a production system that deeply contrasted with the traditional "mass production" method. The following sections attempt to describe the basic ideas of the Toyota Production System, the key concepts of lean production, and its core elements, Total Quality Management, and the Just-In-Time inventory management system.

2.1 The Toyota Production System (TPS)

Taiichi Ohno, the Toyota engineer that initiated the TPS, suggested that any problem solving task should try to address at least five "why's." If the answer to "why a machine has broken" is because of overload, he explains, then the question "why did it overload?" should be asked, and so on, until a root of the problem is identified. In his book (Ohno 1988), he ponders that this is the best approach to access the causes of a particular problem and acknowledges that this simplistic approach was the inspirational idea for the development of the TPS.

The core objective of the TPS is the continuous effort to eliminate waste, defined as any production activity that does not add value to the final product. The formula "Present Capacity = work + waste" illustrates that approach to improving efficiency and through the use of the "5 why's" process Ohno identified seven common sources of waste:

- Waste of overproduction
- Waste of time-on-hand (waiting)
- Waste of transportation
- Waste of processing
- Waste of stock on hand (inventory)
- Waste of movement
- Waste of making defective products

The identification of sources of waste represented not only a significant step towards improving efficiency without adding production costs, but also the introduction of two innovative elements: the Just-In-Time (JIT) inventory management system and the notion of Autonomation. In short, JIT assures that the right, defect-free parts will reach the production line in the right places, by the time when they are needed, and in the specified quantity. Section "2.4 Just-In-Time Management System" below further explores the concept.

Ohno defines Autonomation as "a machine automated with a human touch." This element of the TPS is perhaps the most controversial. Contrarily to the concept of JIT, where the focus is on groups of people working in coordination, Autonomation stresses the input of a single person to whom the power to stop the production line, whenever he/she observes anomalies (defective part or machine), is granted. The goal is to create a working environment where employees are encouraged to solve problems and, therefore, assure that no defective parts will incorporate the final product.

Although the main objective of the TPS is the elimination of waste, it is important to stress that the efforts in implementing it implies the focus on the costumer. Toyota's strategy was to gain market share in the highly competitive automobile industry by both performing efficiently and satisfying costumers. The company's top management understood that offering lower price products with higher quality could only be achieved by reducing certain components of production costs, more specifically, the production costs that did not contribute to enhancing the quality of the final product. Taiichi Ohno brilliantly associated those non-value added costs with the word "waste" and initiated a new production philosophy based on that perception.

2.2 Key Concepts of Lean Production

The cited IMPV research began its surveying work in 1986 at two assembly plants: a General Motors plant in Framingham, Massachusetts and a Toyota plant in Takaoka, Japan (Womack et al 1991). Among the differences in production processes that the researchers found, there were two basic set of observations: 1) the excessive number of workers (called indirect workers) along the GM's production line that were performing non-value added tasks and 2) the excessive amount and transportation of parts at the GM's site. At the Toyota plant, on the contrary, they noticed 1) relatively fewer workers in production and they were all adding value to the product and 2) there was limited physical space for movement or deposit of parts. Those two contrasting scenarios help to illustrate the key aspects of lean production.

Lean production eliminates the figure of the foreman supervising the work of many specialized workers that performed repetitive tasks. The idea is to create teams of

multi-skilled workers led by a team leader. Members of a team are expected to perform any activity within the team's operation and work collectively to improve the process. Additionally, a member of a team may stop the entire production line in case there is a problem. The team leader accesses the conditions of the problem and any member has the opportunity to participate in the solution. It is interesting to notice the philosophy that no problem is treated as random; the team is encouraged to perform the "5 why's" problem solving process to eliminate future occurrences of similar problems.

Lean production also eliminates the space in the assembly line reserved for "rework." The reasoning is that rework should not be a part of the production process and therefore should not exist. Likewise, no dumpers are placed in the assembly plant; if a part has to be thrown away, the production line stops and corrections are made.

From a supply chain perspective, lean production modifies the relatively short-term contractual approach once used in traditional methods as well as increases the participation of suppliers in the development and improvement of products. A lean production manufacturer establishes long-term relationships with reliable suppliers and focus on the following aspects:

- The coordination of processes and schedules in order to facilitate the interaction with and among suppliers
- The opportunity and incentive for suppliers to improve product design based on their experience and knowledge
- Continuous assistance with financial and technological support

There are, however, two distinctive points to analyze when accessing the issues related to lean production: 1) the efforts on identifying and eliminating waste must be in conjunction with cost savings in order to achieve success, and 2) efficiency must be implemented in the whole organization at the same time.

Finally, although the results of lean production are rapidly identifiable both in the assembly line and in the final product, the implementation of this production method requires accessing several organizational issues, especially the issues of organizational behavior, such as values, learning, motivation, reward, among others. The following two sections present the most important managerial tools used for implementing lean production.

2.3 Total Quality Management (TQM)

In essence, TQM is a management practice that emphasizes the organization-wide effort to meet customer needs and to continuously seek improvement of products and services. Generally, however, the literature does not identify a single, meaningful definition for TQM but rather presents a set of principles and methods associated with TQM and for that matter, this section outlines the basic concepts of TQM, its historical background, and basic contrast between TQM and traditional management practices.

2.3.1 TQM Concepts

The focus of TQM is the notion of quality and the application of tools and methods to improve it. Contrary to the traditional views (when quality concerns were restricted to

product and/or service superiority/excellence), and because of changing and increasing global competitive forces – and consequently lesser return on invested capital - organizations started to broadly identify quality as meeting or, more importantly, exceeding costumer expectations. For the last twenty years, for instance, manufacturing organizations are improving the called "fitness for use" concept, which stresses several quality dimensions, such as: 1) performance (product operation), 2) features (what is offered), 3) reliability (probability of no-defect over a period of time), 4) conformance (characteristics matching standards), 5) durability (replacement time-frame), 6) serviceability (quick, inexpensive repairs), 7) aesthetics (how the product looks, feels, sounds, tastes, etc.), and 8) perceived quality (image, user's opinion). Accordingly, the service sector also stresses several quality dimensions that are unique to services: 1) time (how much a costumer wait), 2) timeless (how much time to provide service), 3) courtesy, 4) consistency, 5) convenience, and 6) responsiveness (how efficiently service personnel are able to solve problems), among others.

Different organizations can apply the concepts of TQM in diverse ways depending on the industry they are in or their core competences. There are, nevertheless, four basic attributes for implementing TQM that are crucial to achieving success, more specifically: customer focus, strategic planning, continuous improvement, and teamwork. Those four attributes are the basic elements for describing the concepts of TQM.

Costumer focus is the element of TQM that highlights the importance of knowing and understanding costumers' needs, values, behavior, or any other informative characteristic. The main idea behind this concept is that the costumer defines quality, not the manufacturer/provider that, in the past (operating in a less competitive business

environment), arbitrarily decided what should be placed in the market. Companies that work closely to their costumers aim to achieve higher levels of costumer satisfaction/loyalty and retaining loyal costumers represents a key strategy to maintain market-share. Additionally, from Marketing research efforts, and from a financial analysis perspective, companies realized that it is less expensive to keep existing clients for a long-term business relationship than to constantly attract new costumers.

In addition to the ideas of knowing and understanding costumer needs, the concept of costumer focus is also crucial for 1) detecting changing market requirements, i.e., companies that operate closely to their costumers benefit from up-front information on trends and desires, 2) detecting causes of dissatisfaction, and therefore make necessary, timely corrections, and lastly 3) implementing the notion of internal costumer, i.e., employees in an upstream process perceive the next level people as they own costumers.

Strategic planning represents another important element of TQM and perhaps it is the most extensive of all other elements, mainly because it reaches all stakeholders of an organization. From a quality perspective, strategic planning reflects the firm's long-term commitment to costumers, employees, stockholders, suppliers, and society in delivering quality initiatives. Long-term improvements, for example, may address on-the-job training, supplier and employee development, plant evolution, long-term economical return on capital invested, community involvement, among others. The required period for implementing those improvements demands not only a thorough strategic planning but also the involvement and leadership of top management.

Continuous improvement represents the effort to constantly monitor progress in the implementation of product's expected quality, i.e. quality must be translated into some form of quantitative measure and that information should be used for future cycles. In addition, continuous improvement seeks improved efficiency levels within the entire organization and the objective is to achieve better performance, as measured by costumer satisfaction, product performance, financial reports, or any other reliable performance measurement. An important aspect of continuous improvement in efficiency is the role of designing and improving work processes (design, execution, production, and delivery). In general, efficiency improves through the prevention of future problems and that is the main reason why continuous improvement in both process design and product design is essential.

The fourth element of TQM is teamwork, a management approach that attempts to reduce barriers between individuals, departments, or even between the firm and its suppliers. The notion of teamwork closely relates to the other three previous elements of TQM, more specifically in light of teamwork's main objectives: 1) to achieve a company-wide degree of commitment to the costumers, 2) to allow employees to actively participate in the proposal and implementation of strategic planning, and 3) to stimulate cooperation in the efforts of continuous improvement.

It should be clear that TQM initiatives within an organization seek to meet costumers' needs through continuous improvement and teamwork, and the main goal is to remain competitive based on firm's perceived quality. On the other hand, it is essential to recognize that advancements in innovative managerial methods face several, costly barriers to implement, ranging from organization change issues to rearrangement

of the physical layout of the workplace. Because of the dichotomy concerning those two matters, it is important to look at key historical facts on the development of TQM for a better understanding of its benefits.

2.3.2 Historical Background

Before the Industrial Revolution, the single method of production was through craftsmanship, applying skilled persons who were manufacturers and inspectors concomitantly. Craftspeople had two basic characteristics: 1) they usually added quality to their products as they manufactured them, and 2) they knew exactly what the consumer expected for quality. As the markets and technology developed, this method of production became extremely expensive for consumers to afford and, consequently, the new method of production – industrialization – overtook the work of skilled individuals. Industrialization brought sophisticated machines to production and the aim was to deliver standardized products in a higher volume. Nevertheless, despite the gains in productivity, quality issues arose mainly because of variations encountered in the production process. In an effort to reduce the impact of production variations, scientists and researchers developed new theories and methods of inspection, as well as statistical approaches to improve and maintain quality.

Quality improvement and maintenance studies began in the United States after World War I and culminated with the development of innovative management techniques such as quality control (QC) and industrial engineering (IE). However, it was not until the end of World War II that two Americans, W. Edwards Deming and Joseph M. Juran, introduced statistical quality control to Japanese top managers. By the time Deming and

Juran started their work on Japan's reconstruction efforts, the country was devastated and most of its resources were destroyed; The American scientists found unrestricted support for their techniques and Japan slowly started improving quality levels in a higher rate than the Western world. Americans manufacturers, on the contrary, were dealing with a different, challenging priority: increase production levels to satisfy the post-war booming economy.

The results of the Japanese efforts in applying the TQM concepts in design, production, and services reflected decades later when, in the early 1980's, American consumer products started loosing market share as consumers became aware of less expensive, higher quality Japanese goods and services. Sensitive to the adverse competitive picture, American industry leaders began to understand the need for changes and the press played an important role on disseminating the new concepts. In fact, in 1980, Deming introduced a NBC national television report on quality improvements; also, an article published by Business Week in 1987 brought a direct message to American top managers: "get better or get beat." By the early 1990's, firms worldwide started to apply TQM concepts and techniques with the ultimate goal of maintaining their competitive positions.

2.3.3 TQM versus Traditional Management

In a broad perspective, traditional management denotes the absence of TQM concepts in an organization and the following managerial views illustrate the key differences between that traditional philosophy and the TQM philosophy.

The first contrasting point refers to strategic planning. Traditional organizations developed their strategic plans based mostly on financial and marketing achievements. The concept of quality was not included in the long-term plan but rather isolated inside the quality control department, which internally defined the perception of "good enough." Differently, TQM organizations' strategic plans include quality goals and the definition of quality standards (from the costumer point of view) is constantly assessed; also, long-term resources are invested to improve quality.

The second contrasting point refers to organizational structure. Traditional organizations used functional structure – separate divisions headed by a manager – and internal communication occurred up and down the chain of command. This system, once largely used, provided organizations with 1) a convenient administrative distribution and 2) control over specialized people working in lower levels of the structure. The main problem with functional structure, however, was the inability to provide the customers with the best quality product/service because they were never the objective of the structural system. Contrarily, TQM organizational structures apply the notion of interdependency among the various departments and people and the goal is to create a working environment that reflects a team-oriented culture, commitment to external and internal costumers, and employee participation and collaboration towards quality related matters.

Another contrasting point refers to a set of organizational issues, such as leadership, motivation, and change. Traditional management practices stressed the need for performance measures and internal competition, which inevitably resulted in conflict and adversarial relations. In contrast, TQM organizations recognize and award the work

of groups of employees who, in a more collaborative relation, not only are motivated to share their experiences and contributions to the mission of the firm, but also receptive to change.

The study of TQM and its implementation is broad. There are diverse, interchangeable issues involving the application of TQM as different companies across industries exhibit singular characteristics. This section presented an overall idea of the principles forming this innovative form of management; any attempt to further explore this subject would require a more meticulous analysis. Nevertheless, for the purposes of this report, basic TQM principles essential to better understand the concepts described in the following section, the Just-In-Time inventory management system.

2.4 Just-In-Time Management System (JIT)

JIT represents a management philosophy created and developed within the Toyota Production System shortly after the end of World War II and involves three basic aspects: people, plant, and systems. Initially introduced as a methodology for reducing inventory levels (perhaps the reason for associating JIT with the term "zero-inventory") the system evolved into an extensive managerial philosophy that optimizes quality-cost related elements.

This section presents the fundamentals of JIT, production processes, implementation requirements, and a short analysis of its advantages and disadvantages.

2.4.1 Elements of JIT

The decision to use reduced inventory levels at Toyota was initially associated with reducing production costs. As mentioned in other sections of this paper, by 1945 Toyota was committed to its long-term plan to gain and to maintain market share by offering higher quality cars at a competitive price. However, the efforts on implementing reduced inventory brought most of the TQM principles into the development of JIT and the concepts of quality were integrated into the process. Following is a short view of the elements of JIT.

1) **People**: A fundamental element of JIT refers to the involvement and support of people that are related to the mission of the organization, such as stockholders, employees, labor organizations, suppliers, managers, and costumers.
2) **Plants**: The implementation of JIT requires substantial changes in plant layout for maximum flexibility and flow (suppliers should deliver materials directly to the place where they will be incorporated to the product; workers should be able to perform multi-tasks within the production site). Also, the plant layout should facilitate de implementation of "pull-strategy", where demand indicates when (and how much) production should initiate. Finally, the plant organization must allow workers the flexibility to inspect the production and halt the system whenever he/she encounters a defective part (Autonomation).
3) **Systems**: Involve the processes applied to coordinate activities and materials. JIT envision the involvement of a limited number of specialized suppliers for each part or material the firm buys. Those suppliers work in conjunction with

the organization and receive financial and technical support as well as the assurance of long-term contractual relationship. In exchange, suppliers are expected to promptly deliver defect-free parts in the quantities needed. Quality is a key issue as the parts must be ready for assembly; the supplier must comply with the "quality at the source" thinking, which is the opposite of the traditional "after the fact" inspection/quality control.

2.4.2 JIT Production

The new, emerging management philosophy created a system called *kanban* (meaning "card" in Japanese), a pull-driven method for controlling the flow of components where cards were used to authorize production of parts and their movement within the assembly process. The system had the effect of limiting the production of parts to just what was needed in assembly. This pull approach to production was repeated all the way to the beginning; nothing was manufactured at any stage until its need was signaled from the subsequent process via a *Kanban.*

As Toyota started the *Kanban* system, it was imperative that suppliers could deliver needed components in the right quantities when they were required at each assembly station. As a result, the JIT inventory management was implemented to increase the control and allocation of raw materials. Today, the JIT process is largely diffused among many major companies, not only manufacturers but also among retailers and service-provider organizations (Cheng et Al. 1996).

Within the pull approach of production, JIT reduces or virtually eliminates manufacturing inventories by scheduling the delivery of components at the precise times

and locations needed. A factory applying JIT establishes multiple receiving docks assigned to receive deliveries of materials needed at work centers nearby and suppliers deliver the materials in smaller lots but at frequent intervals.

JIT system reduces the cost of material handling and storage. In accordance with Taiichi Ohno's vision of non-value added activities, the JIT method eliminates waste resulted from any activity that adds cost without adding value, such as moving and storing. Moreover, it reduces waste from overproduction, transporting, unnecessary motion, and waste resulted from producing defectives parts.

Some of the most important characteristics of the JIT process are:

- **Limited number of suppliers**: In order to operate, JIT companies must rely on a few suppliers who will make frequent deliveries in small lots. Suppliers must be willing to make deliveries as much as several times a day, and in the exact quantities specified by the buyer. Dependability is essential for the process.
- **Plant Layout**: To implement JIT in a proper manner, companies must improve the manufacturing flow lines. All machines needed to make a particular product are put together in one location, called manufacturing cell, a "factory within a factory."
- **Flexible workforce**: Workers on a JIT line must be multi-skilled and flexible, they must perform minor repairs, and they must do maintenance when their cell is idle.

- **Setup time**: Efforts toward decreasing setup time in a JIT manufacture is essential. Most equipment are dedicated to a single product or a single product line so setups are largely eliminated and products can be produced in any batch size.
- **Defective parts**: Companies that apply JIT are committed to a minimum level of defective parts because it is critical to avoid any delay in the process. Those companies tend to reach a goal of zero defects.

Similarly to the TPS, the JIT philosophy has some elements beyond the theory and that are critical for the companies and their suppliers. First, there is a partnership relation with suppliers because they must deliver parts promptly and with no defects. The firm's rule is: "controlling the quality of raw material is not my function; you, reliable supplier, is expected to deliver no defective parts." Second, the atmosphere in the plant reflects teamwork and problem solving. Employees are involved in contributing for improvement, as well as in deciding about defects on the workstation. Finally, management is committed to the total quality approach. The organizational culture focuses on the customer and JIT plays an important role in customer satisfaction by reducing defects and quickly adapting to consumers' changing needs.

2.4.3 JIT Implementation

There is a cornerstone for any organization implementing the JIT system: it must accept JIT as an organizational philosophy. This requires the organization to change or adapt its operating procedures, production system, and most importantly, the organizational

culture. Additionally, JIT applies to the entire material chain, extending beyond the factory walls and therefore management must practice relationship market in order to receive and exchange information through the distribution channels.

To achieve the objectives of a JIT production, firms should also apply more highly automated manufacturing systems such as:

- **Computer-numerically-controlled Machines**: a stand-alone machine controlled by a computer via a numerical code.
- **Computer-aided Manufacturing System**: a production process in which computers are used to help control production equipment.
- **Computer-integrated Manufacturing System**: represent the most advanced level of automated manufacturing, where the entire production system is an integrated network centrally controlled by a computer.

As stated earlier, the manufacturer-supplier relationship in a JIT environment is also crucial since with little or no safety stock in the system, the timing, quality, and quantity of deliveries are vital. JIT efficiency is primarily achieved through the complete support and coordination of suppliers. In accordance to the fundaments of the TPS, the manufacturer-supplier relationship in JIT environment is a long-term and mutually beneficial partnership as they work together to develop mutual support and trust.

The company utilizing JIT system evaluates and certifies a restrict number of suppliers that will commit to the delivery of materials according to the JIT requirements. Suppliers also may influence in the system by suggesting ways to improve the whole process. The manufacturer may provide assistance to improve the quality of their

suppliers and will introduce future production plans in order to inform suppliers about the level of production and capacity.

The benefits for the manufacturer include a fair price, frequent and reliable deliveries, and high quality parts. The benefits for the supplier include receiving long-term contracts, the participation in product design/improvement, and technical/financial expertise from buyers.

In the JIT environment, the company's customers represent the most important part of the process and therefore the JIT manufacturer allows the customer define quality. The customer will provide feedback on how the products are being made, on how the competitors are performing, and they will define what and how much the company will produce in the future. In other words, the customers will initiate the JIT system each time they demand for goods.

2.4.4 Information Systems for JIT Implementation

The growth of information technology in manufacturing companies is a key factor for the implementation and development of JIT systems. Information technology contributes in improving the reliability, accuracy, speed, and overall potential of equipment and system. Following are the most important computer-based systems used in a JIT environment:

1. **CIM-Computer Integrated Manufacturing**: CIM is a system that minimize waste in providing computer assistance, control, and integrated automation at all levels of manufacturing companies. The technology applied in CIM makes intensive use of computer networks and data processing techniques, data base management systems, and feedback. The activities covered by CIM are:

- Evaluation and development of products
- Marketing research
- Generation of diverse manufacturing systems
- Design components used in manufacturing
- Evaluation of manufacturing capacity
- Analysis of quality control parameters
- Analysis and providing of internal and external data

2. **CAD–Computer Aided Design**: Computer aided design is a process for creating new parts or products, or for improving existing products, using computer software. The central part of CAD consists of desktop computer and graphics software that permits the manipulation of several geometric forms and attributes. Drawings are created on a display monitor so the designer can control and see different views of the part using the CAD. In the JIT environment, design data stored in the computer memory allow operations to be rapidly changed with few errors, as well as the exchange of data between manufacturer and supplier.
3. **CAM-Computer Automated Manufacturing**: Computer automated manufacturing is an extension of CAD. The CAM system transfer final design specifications into instructions on how actually manufacture the part. For JIT use, the CAM is an important way to quickly communicate parts specifications to suppliers that are part of the buyer company network. Suppliers will coordinate their designs and plans with those from the manufacturer, on line.

4. **MRP-Material Requirements Planning**: According to the main elements of the JIT system, the deliver of materials is a key factor for the success of the process. JIT systems apply MRP to plan and control order quantities and specifications, and uses computer systems that process MRP data, bill of materials and other related tasks.

Just-in-time production system provides cost savings by reducing or eliminating inventory at every stage of production, from raw materials to finished goods. The implementation of JIT system allows firms to manage and to reduce non-value-added function, such as storage, setups, and handling and the development of information technology in manufacturing firms represents a facilitator for the implementation of JIT production system.

2.4.5 Disadvantages of JIT

Despite the fact that JIT systems are being employed by an increasing number of large and small companies, some restrictions exist. First, the selection and ability of suppliers is a constraint in the process, especially with regard to prompt delivery reliability. Second, demand forecast is not always easy to determine and changes may occur in the process. Finally, internal company structure has to be adapted to the JIT philosophy and resistance to change, in any level, may cause the process to fail.

The literature stresses that there is not a generic JIT process that can be used by all firms. Each company, within its industry, has to build and to implement its own system according to the particular needs and structure. The role of information technology is increasingly important to JIT implementation but does not guarantee

success. Only the appropriate utilization of the JIT principles – costumer focus, people, plants, and systems – will provide ways for the companies to produce the right products, in the right quantities, and at the right time.

2.5 Conclusions

Particular characteristics of lean production, along with basic elements of different managerial tools, have been presented. It should be noticed that lean production contrasts with two other opposing methods of production, mass production and craft production. Interestingly, it is fair to conclude that lean production combines the positive elements of both traditional methods of production and the result is a product/service that features higher quality at lower production cost.

Perhaps the most significant fact related to lean production is the 1984 contractual agreement between General Motors and Toyota. By that year, a joint-venture initiative created the New United Motor Manufacturing Inc. (NUMMI) in a Fremont, California GM plant that had been closed in 1982. Under the joint-venture agreement, Toyota provided management and design for passenger cars applying the principles of the Toyota Production System. During 1986, the Fremont plant was fully running with only two days of inventory, while the previous cited Framingham GM plant needed two weeks of inventory. The Framingham site was definitely closed by the end of 1986, the same time GM officially adopted the lean production philosophy worldwide.

3 STRATEGIC MANAGEMENT

This chapter presents the general concepts of strategic management, a field of business administration that emerged in the 1950's due to the post-war advancements in organizational structures. That decade market the transition in American business from 1) an entrepreneurial, closely controlled firm to a managerial, technical formalization and 2) from a monopolistic market structure towards perfect competition. The following sections include the basic elements of strategic management that relate to competition.

3.1 Competitive Strategy

"Competitive strategy is about being different" (Porter 1996). This simple definition is a helpful starting point to a field of study known as strategic management. Although the concept of strategy extends back to ancient army, the theory of strategic management did not emerge until the late 1970s, associated with the oil crisis and the changing competitive circumstances (Grant 1995). Since then, rival organizations apply strategic management to constantly search for a favorable competitive position in their industries.

Strategy analysis outlines how an organization relates to its environment and how to position a business aiming the rational utilization of all its capacities in relation to competitors. There are valuable frameworks to analyze a firm's internal factors (strengths and weaknesses) and external factors (opportunities and threats). Those situation analysis tools, along with the organization's own mission statement, allow the firm to formulate a competitive strategy, and therefore to make long-term commitment and investment decisions (Warszawski 1996).

3.2 Generic Business Strategies

Michael Porter (1998) in his book "Competitive Strategy" proposed a classification for business strategies encompassing three generic groups: cost leadership, differentiation, and focus. Porter stresses that a firm should emphasize one of these three generic strategies; simultaneous use is incompatible for the long run. Those strategies are:

1. **Cost leadership:** represents the organization's ability to offer similar products/services at a price lower than the competition; other firms with equivalent offers would not compete without losing money in the long term. Cost leadership emphasizes the management of cost drivers, such as economies of scale, learning curves, capacity utilization, and improved processes technology, among others. It is imperative, however, that the firm keeps the optimum level of customer satisfaction by means of quality, service, etc.
2. **Differentiation**: this generic strategy uses the organization's efforts to continuously offer products/services that present unique characteristics. Customers are willing to pay a premium (or slightly higher) price in exchange for a specific, more valuable feature. In this case, the company does not ignore costs but the effort is toward offering uniqueness, from the customer's perspective. Examples of differentiation are design, image, technology, customer services, post-sale assistance, and so on.
3. **Focus (niche)**: this generic strategy employs the firm's ability to serve a specific customer group, or/and a specific geographical market. The strategy is to offer products/services to a particular segment more efficiently than competitors that operate in a broader market do. A company that operates according to the focus

strategy may emphasize either cost or differentiation. In general, focus strategy suits smaller firms, which operate locally to serve specific customers (Warszawski 1996).

3.3 Conclusions

There are several elements of the Strategic Management theory that were not included in this chapter; nevertheless, for the purposes of this study, those basic concepts above are sufficient for understanding the relevant differences in generic business strategies proposed by Michael Porter.

There are risks involved with the use of any particular competitive strategy but the appropriate match of firm's mission and resources with its environment will define the basis for a sustained competitive advantage.

4 LEAN CONSTRUCTION

This chapter introduces the origins and proposals of lean construction (LC). The advancements of LE, if compared to lean production, is quite recent and contrary to the inspiring methodology, it features singular implementation issues mainly because of what are called peculiarities of construction (Koskela 1992). This chapter includes an overview of two lean construction tools (the last planner and percentage plan complete) as well as the key characteristics of the Architecture/Engineering/Construction (AEC) industry.

4.1 Origins

Following the dissemination of lean production principles in Europe and in the United States, AEC researchers were interested in whether or not those principles and results would apply to construction. As mentioned in chapter 1, Koskela (1992) presented one of the initial investigations involving lean construction through a technical report developed at Stanford University. He conducted a vast literature review and field research to assess whether or not lean concepts have implications for the AEC industry.

Koskela concluded that lean principles should be adapted to construction and he stressed, as a main reason for the transformation, the improved competitiveness that lean manufacturers encountered by eliminating waste. He pointed out that the traditional controlling methods in construction (Critical Path Models, for example) do not address "waste-source" activities in construction (such as waiting, storing, moving, and inspecting) and proposed that actual construction should be broadly perceived as flow processes instead of conversion processes only.

Following Koskela's technical report, several academic papers and reports exposed the growing interest in the subject. Associations such as the Lean Construction Institute (formed by Professors and professionals in the USA) and the International Group for Lean Construction (IGLC – led by VTT in Finland) developed research agendas in the mid-1990s. As a result, international literature and research are presently addressing the most important aspects of this field, as shown in the following section.

4.2 Characteristics of the AEC industry

The major area of concern in adapting the lean production philosophy to the AEC industry is the set of singular characteristics found in construction, which are diverse, in nature and extent, to the manufacturing or services sectors. Often called peculiarities of construction, those characteristics represent barriers to implementing innovative manufacturing methods or systems in the AEC industry. Koskela identified four key peculiarities of construction that affect the implementation of lean principles:

1. **One-of-a-Kind Product**: owner and/or designer preferences are the most common reasons for this construction characteristic, followed by specific site attributes. The major problems with one-of-a-kind products are the lack of repetitive cycles for feedback within a specific project and restricted means for comparison with finished products.
2. **Site Production**: the construction product is "produced" in the same site it will be delivered. The problems with the site production relate to uncertainty with local labor and materials, problems with coordination of crews around the production

site, and that the "product" is always evolving, which restricts the ability to improve planning.

3. **Temporary Multi-organization**: construction is an organization created specifically for a particular project and several problems surface, such as poor communication among participating organizations, lack of stimulus for long-term improvement, liability issues, and inability to accumulate knowledge.
4. **Regulatory Authorities:** construction projects are subject to approval from authorities and agencies, which brings uncertainties in schedule and design solutions.

In addition to those items above, and from a broader perspective, there are several other characteristics of the AEC industry related to its structure. For example, the AEC is a mature industry –with slower growth rate - presenting the following main characteristics:

1. **Fragmented industry**: in economic terms, fragmentation implies an industry where there is not a single firm with significant market share and/or in conditions to influence the industry's outcome (Porter 1989).
2. **Lower barriers to entry**: in general, entering in the industry requires neither substantial capital requirements - equipment may be rented in an as-needed basis- nor advanced technical expertise.
3. **Lack of economies of scale**: which means no reduced per-unit cost by increasing volume and consequently limited gains from economies of scale.

4.3 Proposals

In general terms, lean construction stresses production control over project control. It is known that the traditional project management approach to construction emphasizes control over schedules, budgets, and contract management. The consequence is the tendency to "push" the schedule to project completion and thus insufficient attention is devoted to the physical circumstances of the site work and to the coordination of tasks, which are sources of waste. Similarly to the automobile manufacturing of the 1980s, the AEC industry seeks improvement and lean construction plays a major role in this effort.

Current lean construction research focuses on adapting the basic principles of the lean thinking and on studying implementation issues, vis-à-vis the AEC industry's complex characteristics and uncertainties. Much of the LC research addresses the issues of both the variables and the uncertainties that negatively affect the continuous production in construction. For example, pioneer studies show the validity of shielding production to reduce workflow uncertainty (Ballard et al. 1998) and the concept of "commitment planning" introduces the ideas of both *quality assignments* (e.g., weekly work plans) and *percent plan complete (PPC)*. In addition, Tommelein (1998) demonstrated the advantages of using a "pull-driven" approach to production systems in construction through computer simulation analysis of a pipe-spool installation. Furthermore, researchers are presenting papers and studies in international lean construction conferences, covering subjects such as concurrent design of product and process, supply-chain management, teamwork, and construction safety, among others (IGLC Proceedings – 1994/2001).

Quality Assignments represents a set of weekly activities that aims at improved productivity. The reasoning is to constantly monitor and improve the "quality" of the assignments in any production unit by assessing certain quality requirements (definition, soundness, sequence, size, and learning). The following is a brief description of each quality assignment requirement:

1. **Definition**: addresses the question "is the assignment specific enough?" It seeks answers to whether the right type and amount of materials can be collected as well as to whether the completion can be defined.
2. **Soundness**: addresses if all materials are on site, design is complete, pre-work done, and so on.
3. **Sequence**: addresses the constructability order as well as other backlog in case of failure.
4. **Size**: addresses the amount and quality of labor.
5. **Learning**: addresses whether non-completed assignments are analyzed and the reasons for failure fully understood.

Percent Plan Complete is an analytical tool that aims to monitor the performance of the quality assignments. The PPC index is a result of dividing the number of completed weekly assignments by the proposed assignments and the objective is to constantly increase the index to the highest feasible level.

4.4 Conclusions

The basic concepts and proposed methodologies for lean construction, as well as main industry's characteristics, have been presented. As mentioned before, the field is evolving but so far there have not been enough research or actual practice to define the applicability of lean principles to construction. Nevertheless, academic research is addressing both the key issues related to adapting lean production to the AEC industry and the fundamental problems related to lean construction implementation.

5 CASE STUDY

5.1 Introduction

This thesis endeavors to explore two issues related to the implementation of lean construction methods for an AEC firm. The first issue refers to the association of 1) AEC firm's commitment to lean construction to 2) the adoption of a particular competitive strategy. This association seeks to improve the understanding on whether AEC industry leaders would perceive lean construction as a competitive tool and what are the motivations for shifting from mass production to lean production. The second issue refers to the determination of which competitive strategy, as described in chapter 3, better suits the characteristics of lean construction within the AEC industry's competitive structure.

This chapter introduces key information regarding 1) the higher education segment of construction and the two higher education associations that provided data for this research (APPA and SCUP) and 2) the reasoning for proceeding with this study.

5.2 The Higher Education Segment

5.2.1 Higher Education Institutions

This sub-section aims to present an overview of this thesis' targeted segment. According to the Higher Education Act of 1965 and for the purposes of this report, the term "institution of higher education" means an educational institution in any U.S. state that (source: U.S. Department of Education):

1) admits as regular students only persons having a certificate of graduation from a school providing secondary education, or the recognized equivalent of such a certificate
2) is legally authorized within such state to provide a program of education beyond secondary education
3) provides an educational program for which the institution awards a bachelor's degree or provides not less than a 2-year program that is acceptable for full credit toward such a degree
4) is a public, private or other nonprofit institution; and
5) is accredited by a nationally recognized accrediting agency or association, or if not so accredited, is an institution that has been granted pre-accreditation status by such an agency or association that has been recognized by the Secretary for the granting of pre-accreditation status, and the Secretary has determined that there is satisfactory assurance that

the institution will meet the accreditation standards of such an agency or association within a reasonable time

The most recent statistical data from the U.S. Department of Education was made available through the National Center for Education Statistics (NCES) and they indicate key percentage numbers of the distribution of higher education institutions in the U.S. The statistical figures were developed based on a countrywide "Fall 1998 Enrolment Survey" (posted on the web at www.nces.ed.gov) summarized as follow:

- 6,630 institutions in the 50 states and the D.C.
- 14.6 million students enrolled
- Owners:
    - Public 76%
    - Private non-profit organization 20.3%
    - Private profit organization 3.7%
- Demographics:
    - White/non-spanic: 69.8%
    - Minorities: 27.2%
    - Non-resident aliens: 3%
    - Men: 43.9%
    - Women: 56.1%

In addition to the 1998 survey, the Department of Education also published statistical data on historical and projected student enrolment within the higher education sector as

well as the ownership distribution. A table with partial figures is presented below, showing data for the years of 1985, 1998, and 2010.

	Total	Men	Women	Public	Private
Fall 1985	12,247	5,818 (48%)	6,429 (52%)	9,479 (77%)	2,768 (23%)
Fall 1998	14,632	6,321 (43%)	8,311 (57%)	11,388 (77%)	3,244 (23%)
Fall 2010	17,490	7,320 (42%)	10,169 (58%)	13,607 (78%)	3,882 (22%)

Table 5.1 – Higher Education Student Enrolment (millions) – Adapted from Projections of Education Statistics to 2010 (U.S. Department of Education)

It is interesting to note that the growth rate of total students enrolled of 19.5% from 1985 to 1998 is repeated for the interval from 1998 to 2010. Also, the distribution between public and private institutions remains basically the same along with the 25-year period.

The basic statistical data and definitions above represented an brief overview of the higher education segment, which is part of this thesis analysis. The following sub-section presents additional information related to the construction market for the higher educational segment.

5.2.2 Higher Education Construction

Over the last five years, the educational segment of non-residential construction provided remarkable statistics regarding its growth and forecasted spending. According to the American School & University's 27th annual Official Education Construction Report (Agron 2001), investment in educational facilities in the year 2000 broke record with $36 billion and the segment will continue to increase. More recently, a U.S. Department of

Commerce report shows educational buildings grew 21.2% from January 2001 to January 2002, one of the strongest building construction markets (ENR 2002). Figure 1 below illustrates the rise in school construction in the 1990s, including new construction, renovations, and additions (Agron 2001).

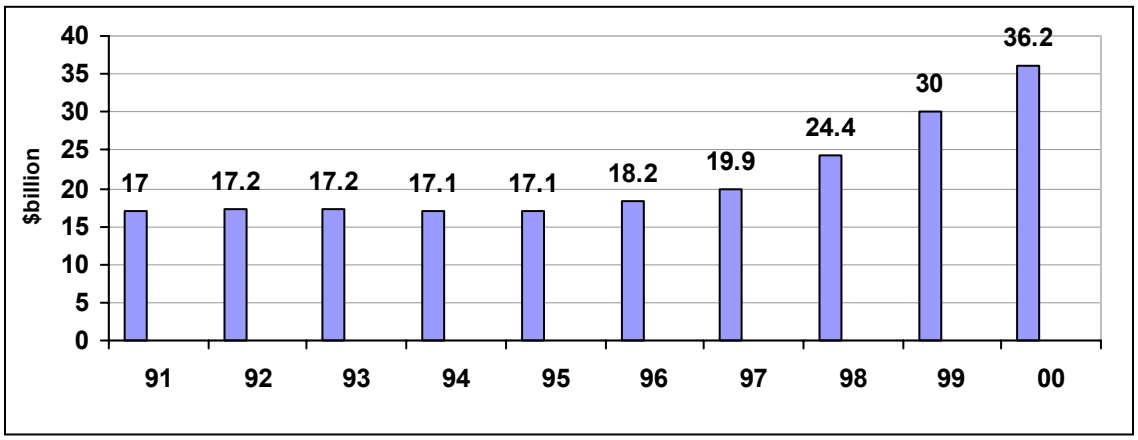


Figure 1- Total school and university construction spending over the last decade

In addition to overall dollar spending figures, the referred report shows that construction of new facilities accounted for 53% of total spending ($19.1 billion), major renovations represented 34% of spending ($12.2 billion), and additions to existing buildings represented 13% ($4.9 billion).

Generally, the healthy growth in educational facilities investment relates to demographic trends, aging educational facilities, and positive federal government policies towards education (Delano 2001). More specifically to colleges and universities spending, these institutions are evaluating their infrastructure needs in order to attract above average students to enroll. Key issues such as environment, modernization, safety, and architectural prestige are the prime focus of campus facilities planners.

5.2.3 APPA and SCUP

This section introduces the two associations that participated on the development of this thesis by providing their membership database for the purposes of the survey.

Founded in 1914, APPA is the Association of Higher Education Facilities Officers, an International association dedicated to maintaining, protecting, and promoting the quality of educational facilities. Established in Alexandria, Virginia, APPA serves and assists facilities officers and physical plant administrators in colleges, universities, and other educational institutions throughout the United States, Canada, Mexico, and some other countries. The organization' mission is to promote excellence in the administration, care, operations, planning, and construction of educational facilities. APPA serves the higher education community by conducting research and educational programs, producing publications, developing guidelines, and serving as a central information source for its members. APPA membership, formed by approximately 4,500 individuals, are facilities professionals from both public and private, two-year and four-year, colleges and universities. APPA members also include specialized institutions, such as medical and law schools, seminaries, and other nonprofit organizations.

SCUP is the Society for College and University Planning established in 1965 (Ann Harbor, Michigan) and it focuses on the promotion, advancement, and application of effective planning in higher education. SCUP envisions planning as an essential tool to improving and maintaining the fitness, vitality, and quality of higher education. SCUP's international membership incorporates the diverse strengths of individuals, institutions, and organizations interested in higher education planning. The Society has a

membership of more than 4,200 individuals representing each type of post-secondary institution—public and private, two-year and four-year, small and large—as well as college and university systems, governing/coordinating boards, companies, and other related organizations.

5.2.4 Reasons for Surveying the Higher Education Market Sector

This section addresses the reasons for focusing the research efforts on a specific segment of the AEC industry - the Higher Educational sector – through members of APPA and SCUP.

The reasons for surveying this segment of the market, as well as those specific associations are the following:

- The sector is formed by organizations that demand fast, complex projects (laboratories, dorms, sport facilities, etc.): The nature of higher education projects is consistent with the notion of lean construction. This research seeks to know the perception of owners that demand fast and complex projects on the issues of lean production.
- Country wide projects representing public and private customers: The research enhances its output by generalizing the geographical and ownership characteristics of the population.
- Customers that are highly sensitive to life-cycle and maintenance issues: Those topics are important for the analysis of value from the customer's point of view.

- Design requirements that include style, prestige, and aesthetics factors: Those topics are also important in the development of the research, especially in the analysis of differentiation issues, as opposed to cost issues.
- This segment represents a growing market: A sustainable growth in this market translates into opportunities for AEC firms to invest capital and human resources on improved methods of production.
- AEC firms in this market encounter fierce competition: The forces of competition in a specific market define the competitive strategy that firms apply to overcome threats and weaknesses.

Those are the most important reasons for surveying the higher education market sector. The key characteristics of this sector were presented and the identification of those six points of interest were highlighted. The following sections apply the characteristics of the higher education market in the context of the research.

5.3 Lean Construction as a Competitive Strategy

Chapter 2 summarized the key elements of lean production and its implementation tools within the Toyota Production System. It is imperative for this thesis, however, to consider and to describe the utmost conditions inherent to the implementation of this innovative method of production. The literature emphasizes the following *sine-qua-non* conditions:

1. **Top management leadership**: the lean philosophy started from the top to the bottom of the company and this arrangement is essential to success. If

management fails to exercise leadership, the degree of commitment from lower levels of the organization is at risk.

2. **Efficient organization**: efficiency must reflect the organization as a whole. The importance of multi-skilled workers and teamwork is evident; partial implementation of lean concepts will lead to failure (Ohno 1988).
3. **Reliable suppliers**: lean production drastically reduces inventory and consequently if a single part of the system fails, the entire system breaks off. For that reason, lean production must rely on selected suppliers with long-term commitment to the production.
4. **Costumer in mind:** All the efforts directed to lean production must include the costumer, the ultimate judge of a firm's efficiency. The modern organization must know its costumers, know their needs, and communicate with them constantly.

Those fundamental conditions for implementing lean production described above share a distinctive common point: they require long-term investment of capital and human resources. In other words – and from the basic concepts presented in chapter 3, section 3.1 – the implementation of lean production demands a formal strategy.

A preliminary review of the lean construction literature shows that the current research advances toward improving construction processes (flow, look-ahead planning, etc.) at the project level, only; few researchers in lean construction address the core motives for manufacturing organizations to shift from mass production to lean production. This thesis is concerned with the level of understanding on organizational

issues in the implementation of lean construction and seeks answers for fundamental strategy-related questions.

Featherston (Featherston 2000) stressed the concept that any change to occur should be both desirable and possible. Utilizing the academic survey described in following chapter 6, this thesis aims to verify whether that concept applies to the implementation of lean construction.

6 ACADEMIC SURVEY

6.1 Objectives

The objectives of the survey were:

- To collect data from a specific segment of the construction industry
- To determine the sample's profile (location, size, and ownership)
- To assess the level of knowledge those institutions have on improved methods for the AEC industry, such as Design-Build, Partnering, Value Engineering, Lean Construction, and Concurrent Engineering.
- To determine the owners' perceptions on issues such as cost and value
- To collect feedback from professionals (owners) in the field

6.2 Data Collection

The segment selected for the survey represented facility planners for higher education institutions in the United States and abroad. The target respondents of the electronic

survey were reached through the assistance of two non-profit organizations: APPA (Association of Higher Education Facilities Officers) and SCUP (Society for College and University Planning). Those two organizations conceded their database for academic use and their members were asked by the author (via e-mail) to voluntarily reach the survey's web site and submit their answers.

A 9-question form was made available on a designated Internet address in the shape of a web site previously set up within the WPI's Unix system (the form is presented in appendix A). In addition to the nine questions, a last question asked for the respondent's feedback on the subject of the survey; the respondents were able to write their comments/suggestions directly on the web site form and submit them.

6.3 Survey Results

The members of APPA and SCUP were asked to submit their answers within a one-week period. Approximately 80% of the respondents, from both institutions, returned their answers within one-day period. After one week, another follow-up message was sent to remind the members about the deadline on the survey, which resulted on an additional 10% of responses. The results of the survey were transferred and organized into a database using a Microsoft® Excel spreadsheet. Through the use of that software, the data were sorted and fields were filtered in accordance to the analytical work. In addition, the survey-related figures and tables presented in the body of this paper were constructed using the mentioned software. The summary of the survey results is included in Appendix A and the list of comments/suggestions is presented in Appendix B.

6.4 Analysis

To summarize the analysis of the survey results, the data collected from the survey are presented in this section in form of graphs and tables. For the purpose of organization of the data, this section is divided into six overall categories: general statistics of the survey, general information of respondents, the owners' knowledge of construction processes, cost and value perceptions, methods of production, and contingency tables. In each of those six categories, a short description of their significance, the data obtained, and the analytical assessment are presented.

6.4.1 General Statistics of the Survey

The following table is a summary of the response rates:

Forms sent (e-mail)	468	Via e-mail
Undeliverable (bad address)	17	
"Away of Office" messages	10	
Professionals reached	441	100%
Did not respond	328	76%
Responded	113	24%
Sent comments	51	45% of respondents
Return e-mail addresses	57	50% of respondents

Table 6.1 – General Statistics

The survey questionnaire was distributed (via e-mail) to 468 facilities planners chosen from both APPA and SCUP database; an Internet web-site set up specifically for the respondents to submit their answers and comments was used. Among the total group of potential respondents, 27 (10%) could not be reached either because they were away from their offices for an extended period (10) or because their e-mail addresses were defective (17).

From the members actually reached (441), 328 of them did not respond the questionnaire and within those 328, two of them replied the invitation stating they did not have necessary background or experience to answer the survey. Therefore, the rate of response for the survey was 24%, with 113 responses. Among the respondents, 51 of them included comments/suggestions by the end of the survey form and 57 included an e-mail address confirming they would like to know the results of the survey.

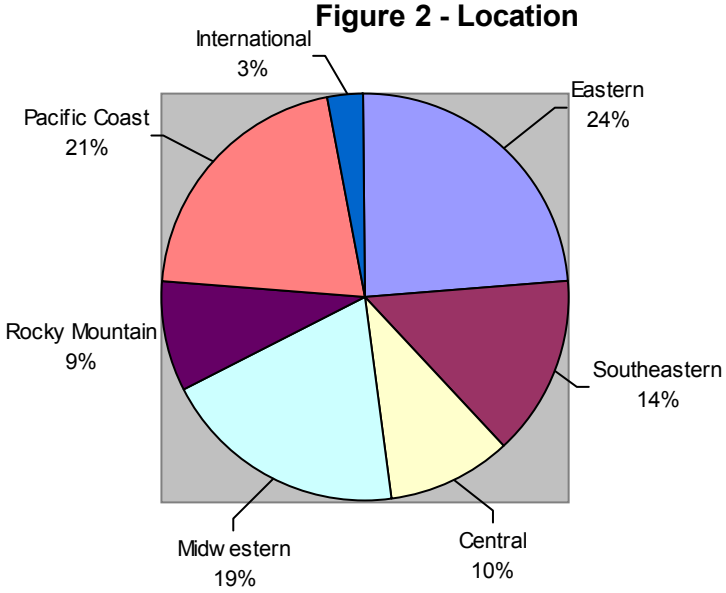
6.4.2 General Information

This category refers to information on respondent's location, size, and whether the institution is public or private. The following sub-sections describe the data for each of the general information item.

6.4.2.1 Location

The location of the respondents is illustrated in Figure 2:

Figure 2 - Location



If "International" location is disregarded as an outlier, it could expect an average number of 16% (100/6) response from each remaining region. Overall, there was a greater than expected distribution from the Eastern (24%), Pacific Coast (21%), and Midwestern (19%) regions. By the same token, it was noticed a lower participation from the Central (10%), Rocky Mountain (9%), and Southeaster (14%) regions. Nevertheless, we can conclude that the distribution of location is uniform, especially if we consider the "west-central-east" geographical distribution, as it is summarized below:

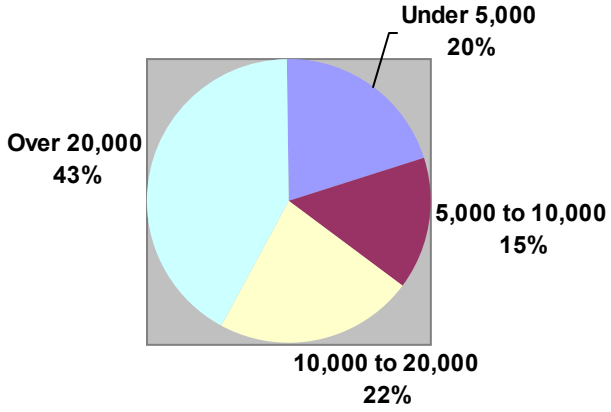
WEST		**CENTRAL**		**EAST**	
Rocky Mountain	10%	Midwestern	19%	Eastern	24%
Pacific Coast	22%	Central	11%	Southeastern	14%
TOTAL	**32%**	TOTAL	**30%**	TOTAL	**38%**

Table 6.2 – Geographical Distribution

6.4.2.2 Student Enrolment

The Student enrolment distribution is illustrated in Figure 3 below:

Figure 3 - Student Enrolment

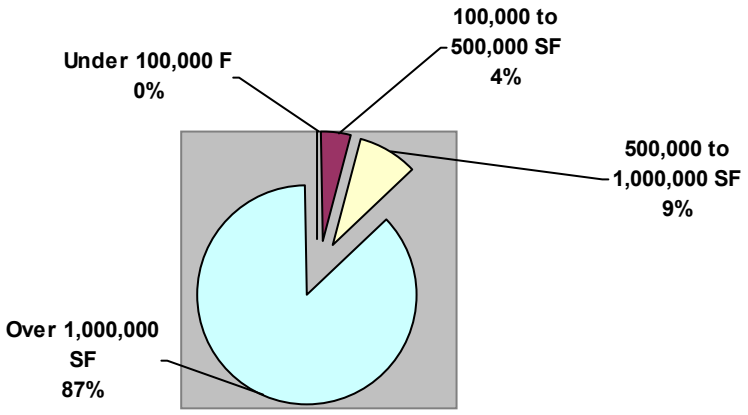


The outcome of student enrolment data indicates that more than 40% of the respondents were from institution with more than 20,000 students and that percentage decreases as the number of students decreases as well. This trend allows a direct relationship between the number of students enrolled and the need for facilities and therefore facility planning presence on campus. Nevertheless, it is important to point out that organizations with less than 5,000 students enrolled corresponded to 20% of the respondents, which may indicate that, even for a relatively small number of students, the role of the facility planner is present in a higher education organization.

6.4.2.3 Size of Facilities

Figure 4 illustrates the size of facilities distribution:

Figure 4 - Size of Facilities



The results of the Size of Facilities indicate that a better "size break down" option should be presented in the survey questionnaire. As we can see from figure 4, the majority of respondents (87%) were from campus of size more than 1,000,000 SF, which give us limited information regarding the size distribution of those 87% organizations. Also, the option "Under 100,000 SF" did not have any response and therefore indicate an erroneous survey division of facility size.

Despite the questionnaire issues above, the results of the survey allow the following tabulation regarding Number of Students and Size of Facilities:

		STUDENTS				
		Under 5,000	5,000 to 10,000	10,000 to 20,000	Over 20,000	Total
SIZE (SF)	Under 100,000	0	0	0	0	0
	100,000 to 500,000	3 (3%)	1 (1%)	1 (1%)	0	5 (4%)
	500,000 to 1,000,000	6 (5%)	2 (2%)	0	2 (2%)	10 (9%)
	Over 1,000,000	14 (12%)	14 (12%)	24 (22%)	46 (41%)	98 (87%)
	Total	23 (20%)	17 (15%)	25 (22%)	48 (42%)	113

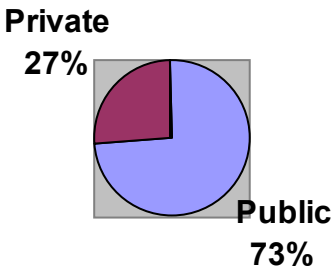
Table 6.3 – Students Enrolled and Size of Facilities

Table 6.3 above shows more clearly the deficiency of size "break-down". There is no clear relation between size and number or students enrolled for facilities of size under 100,000 SF to 1,000,000 SF. On the other hand, for responding organizations with facility size of more than 1,000,000 SF, we can verify the direct relationship between students and size. It is interesting to note that 12% of all respondents are from facilities with both more than 1,000,000 SF and with only less than 5,000 students enrolled. In the same way, we can verify that 14 out of 23 organizations with less than 5,000 students have campus size of more than 1,000,000 SF. Those numbers became important for the study as they may bring substantial information regarding quality of academics (fewer students per classroom/laboratory?), facilities planning, and any issue related to value.

6.4.2.4 Ownership Organization: Public or Private

Figure 5 shows the percentage of Public and Private organizations:

Figure 5 - Public and Private



The results show that 83 (73%) of the 113 responding organizations were Public institutions and the survey outcome is consistent with data collected by the U.S. Department of Education and shown in chapter 5 (page 39).

The analysis of Public versus Private in the context of the survey becomes important because of several issues such as specific legislation, bid requirements, procurement mechanisms, owners' attitudes, among others. The remaining of this analysis will bring the Public-versus-Private ratio deficiency within the context of the results.

6.4.3 Knowledge of Construction Concepts

This refers to the question number five; this question was designed to gather data on awareness of recent studies in construction (such as Lean Construction and Concurrent Engineering) and compare the results with the degree of awareness/experience on construction innovative methods, such as the Design-Build delivery system, Partnering, and Value Engineering. The results of the survey for that question are shown in table 6.4 below:

	Never Heard		Have Heard		Know the Concept		Have Used	
Design-Build	**0**	0%	**2**	2%	**32**	28%	**79**	70%
Partnering	**4**	4%	**8**	7%	**43**	38%	**58**	51%
Value Engineering	**5**	4%	**2**	2%	**17**	15%	**89**	79%
Lean Construction	**79**	70%	**15**	13%	**15**	13%	**4**	4%
Concurrent Engineering	**63**	56%	**0**	0%	**15**	13%	**35**	31%

Table 6.4 – Question-Five Responses

Some comments from the respondents indicated the absence of another important project delivery system, Construction Management, in the questionnaire. After an initial analysis of the results, we can conclude that feedback on the Construction Management project delivery system would certainly enrich the survey. Nevertheless, the core of the question focuses on Lean Construction awareness and therefore the objectives of this part of the questionnaire are satisfactory. This analysis will attempt to summarize the results from each of the concepts/methods as follow:

6.4.3.1 Design-Build

From the data collected and since no single respondent has answer "Never Heard", we can infer that all educational organizations within the scope of the survey have at least heard about Design-Build. Moreover, from those organizations, not only they have heard about Design-build, but also 28% of them (32) stated that they know the concept, despite never had used. Finally, 70% of the respondents (79) indicated that they have used Design-build.

Further analysis of the survey results database indicates the level of knowledge/use of the Design-Build delivery system for public and private institutions. From the database analysis, the results are as follow:

	Know the Concept	**Have Used**
Public	24	57
Private	8	22

Table 6.5 – Public versus Private Design-Build

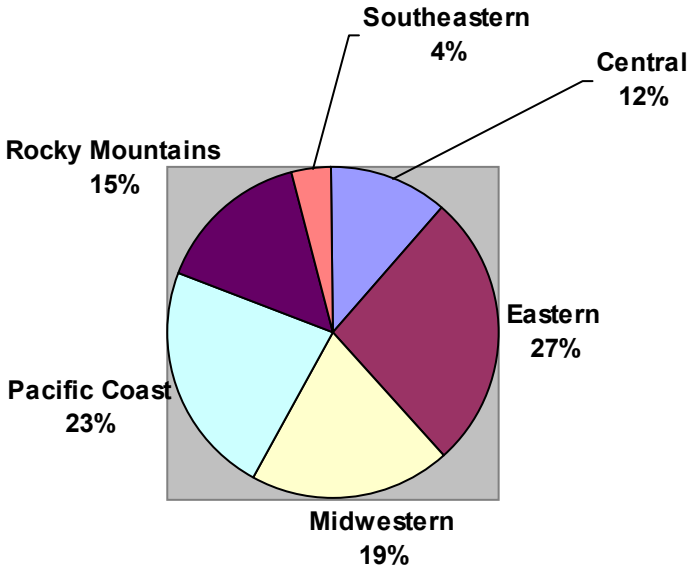
Among those 32 that stated "Know the Concept", 75% (24) are Public institutions and 25% (8) are Private institutions. As for those 79 that stated "Have Used", 72% (57) are Public institutions and 28% (22) are Private institutions.

The outcome of this question leads to two important remarks:

- We can infer from the survey that Design-Build (D-B) project delivery system is at least "well known" in the educational sector, with the majority of respondents (70%) indicating they have used this particular project delivery system.
- The result points to an unexpected fact: that is a greater use of D-B within the Public sector, since legislation has been an obstacle for D-B use in this sector. For that reason, it would be interesting to know the geographical regions associated with the use of B-D.

Further analysis of the responses, however, show inconclusive data as (exception to the Southeastern region) the distribution is fairly uniform. The following figure illustrates the percentages of "Have Used" Public institutions, by region:

Figure 6 - DB Public Locations



6.4.3.2 Partnering

The distribution of Partnering responses is similar to the distribution found in D-B. From all the institutions, only four out of 113 (4%) stated "Never Heard". Moreover, 38% of the respondents "know the Concept", and another 51% have used Partnering.

6.4.3.3 Value Engineering

Value Engineering (VE) responses indicate the most clear usage rate among responding institutions as 79% (89) stated they have used VE. From those 89 institutions, 31% (28) are Private and 69% (61) are Public; this trend is similar to that one found in the D-B analysis.

6.4.3.4 Lean Construction

Data from the survey indicate that 70% (79) of the respondents "Never Heard" the term Lean Construction and therefore only 30% are aware of the concept. Among those 30%, 15 indicated they have heard, 15 indicated they know the concept, and four indicated they have used Lean Construction. The results of this question clarify the degree of knowledge of LC within the educational sector and provide the following facts:

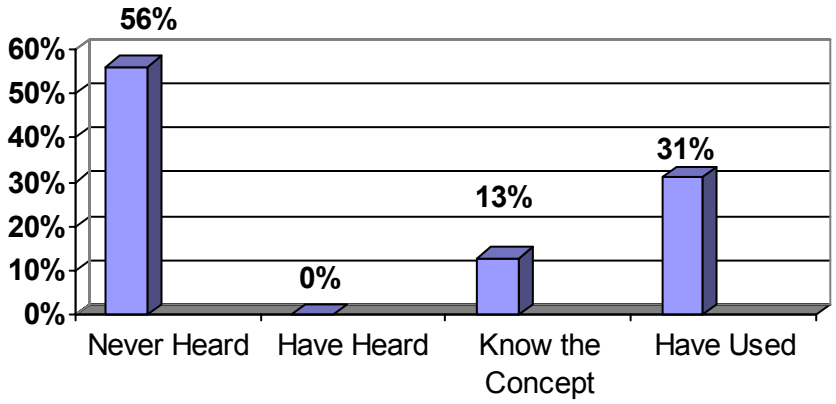
From the four institution that have used LC, one is a Public, Rocky Mountain, under 5,000 students, 500,000 to 1,000,000 SF institution. The other one is a Private, Midwestern, under 5,000 students, over 1,000,000 SF institution. Another is International, with more than 20,000 students. Those figures, thus, not allow a conclusion regarding using Lean Construction in relation with location or size.

Two of the institutions indicated they "Never Heard" the term Concurrent Engineering.

6.4.3.5 Concurrent Engineering

Concurrent Engineering (CE) data show a different pattern if compared to the other four preceding questions. Figure 7 below illustrates the distribution of responses.

Figure 7 - Concurrent Engineering



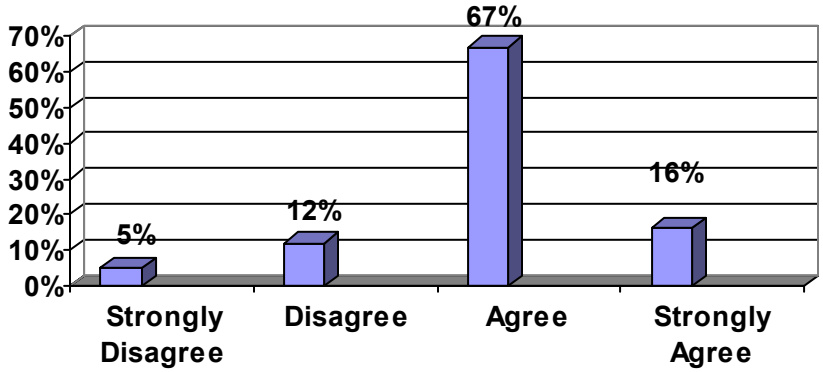
We can infer from the distribution above that, if in one hand, a large number of respondents (56%) never heard the term Concurrent Engineering, on the other hand, almost 31% of the respondents have used CE in their construction projects. One-half of that 31% represents institutions with more than 20,000 students.

6.4.4 Perception on Value and Cost issues

This category refers to questions number six and seven of the questionnaire. Those two questions aimed to gather information on owner's perception on value, i.e., whether or not they would agree they have a clear definition of value, distinguished from the notion of quality as well as on cost versus a differentiating factor, such as aesthetics.

The objective of question 6 was to learn how strongly professionals in the sector would agree they have a fair definition of value. The data collected indicates that the answers were satisfactory for the purposes of the research. Figure 8 illustrates the distribution of the responses for the statement: "When contracting construction services, my institution has a fair definition of value."

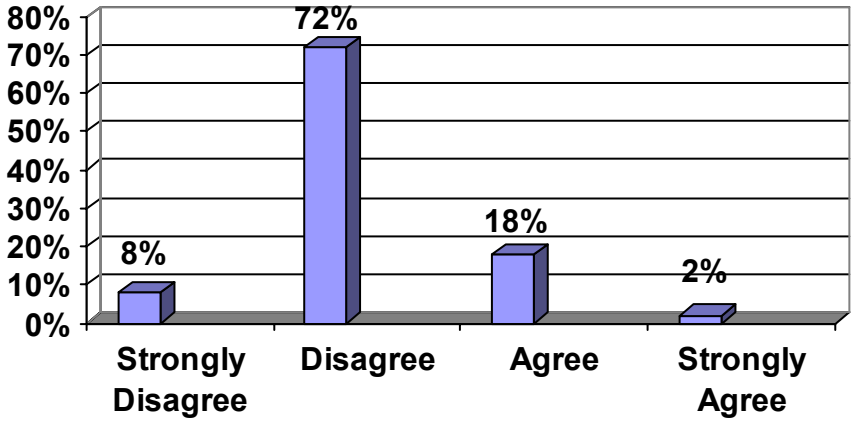
Figure 8 - Value



We can infer from figure 8 that only 17% of the respondents do not have a fair definition of value in the context of the survey, and there is an unbalanced response as far as the 'intensity" of the statement. As for agreement with the statement, 83% did agree, 16% of the total strongly.

Question 7 was designed to compare, from the owner's perspective, the importance of cost with any other differentiating feature, in this case, aesthetics. The answers for the statement "In general, cost is a lesser issue when compared to aesthetic issues" are presented below:

Figure 9 - Cost vs Aesthetics



The majority of the responses (80%) indicate that owners in this sector would perceive cost as a more important issue if compared to aesthetics issues.

From the 113 responses, 20% (23) indicated they generally agree that cost is a lesser issue. Interesting to observe is that out of those 23 institutions that agreed, eight are Private institutions. This represents 35% of responses from Private organizations, a percentage higher than the ones in preceding questions – we have been observing 20% to 22% responses from Private institutions.

6.4.5 Construction Methods

This last category refers to questions eight and nine. The category addresses the issue of owners' involvement with the contractor's methods of production/construction. The objective of those two questions was to better understand whether owners in this segment of the market review the contractor's methods of production and how important is that reviewing process in the decision to enter into a contract.

Question 8 asks for feedback on the statement: "When deciding among contractors, my institution reviews their construction methods of production." The objective of the question was to learn to what extent owners in this sector are concerned with construction methods and whether they take those methods in consideration when deciding on a particular contractor. Table 6.6 below shows the responses:

Response	Responses	Percentage
We do not review	44	39%
We review but it is not important	11	10%
We review and take into consideration	58	51%

Table 6.6 – Construction Method Review

The most interesting information from this question is that fewer (39%) of the respondents stated that they do not review construction methods before deciding on a contractor. This information is relevant for the purposes of this research because it indicates the degree of interest of owners regarding construction processes, which constitutes a major issue for Lean Construction contractors.

Furthermore, the data indicate that other 10% of the respondents do review but do not consider the results as a deciding factor and 51% review contractor's methods of production and take into consideration.

Question 9 refers to the role of lean construction methods according to owners' perception of differentiation. The development of the thesis work includes strategic issues and competitive strategies. As was mentioned in the body of this report, differentiation is a key component for strategic analysis. The intent of this question was to gather information on whether owners consider a Lean Construction contractor different from other contractors that do not apply lean principles. The concept of uniqueness was used solely to exemplify a differentiating item.

There were comments from respondents asserting they did not have enough information on Lean Construction to answer the question appropriately. It was expected, however, that respondents did not know the concepts of lean construction – and that was

verified on the survey as 70% indicated they never heard about lean construction. Because of the lack of knowledge, 27% (31) of the professionals declined to answer the question. The results of the answers are shown in table 6.7 below:

Perception	Responses	Percentage
Strongly Disagree	9	8%
Disagree	34	30%
Agree	39	35%
Strongly Agree	0	0%
Declined to Answer	31	27%

Table 6.7 – Lean Construction Perception

If we disregard those that did not respond for lack of knowledge, the distribution of the answers would result as follow:

Perception	Responses	Percentage
Strongly Disagree	9	11%
Disagree	34	41%
Agree	39	48%
Strongly Agree	0	0%
Declined to Answer		

Table 6.8 – Lean Construction Perception within Informed Owners

The outcome of the table above would suggest that almost 52% of the "informed" respondents disagree with the statement and therefore would not perceive a Lean Construction contractor as being different.

6.4.6 Contingency Tables

For a better understanding of the relations between the issues addressed on the questionnaire, the following set of tables represent percentage figures in form of contingency tables. For the purposes of this additional set of table, the options "strongly disagree" and "disagree" were condensed, as well as the "strongly agree" and "agree" options.

6.4.6.1 Cost-Aesthetics Issues VERSUS Definition of Value

		Aesthetics is more important than Cost	
		Disagree	Agree
Institution has a fair definition of value	Disagree	16%(18)	1%(1)
	Agree	**64%(72)**	19%(22)

6.4.6.2 Lean Construction Perception VERSUS Definition of Value

		Lean Construction provides uniqueness	
		Disagree	Agree
Institution has a fair definition of value	Disagree	9%(7)	11%(9)
	Agree	**45%(37)**	35%(29)

6.4.6.3 Cost-Aesthetics Issues VERSUS Lean Construction Perception

		Aesthetics is more important than Cost	
		Disagree	Agree
Lean Construction provides uniqueness	Disagree	**33%(37)**	5%(6)
	Agree	28%(32)	6%(7)

6.4.6.4 Review of Construction Methods VERSUS Definition of Value

		Do not Review	Review but not Important	Review and Consider
Institution has a fair definition of Value	Disagree	9%(10)	0%(0)	8%(9)
	Agree	30%(34)	10%(11)	**43%(49)**

6.4.6.5 Review of Construction Methods VERSUS Cost-Aesthetics Issues

		Do not Review	Review but not Important	Review and Consider
Aesthetics is more important than Cost	Disagree	32%(37)	6%(7)	**41%(46)**
	Agree	6%(7)	4%(4)	11%(12)

6.4.6.6 Review of Construction Methods VERSUS Lean Construction Perception

		Do not Review	Review but not Important	Review and Consider
Lean Construction provides Uniqueness	Disagree	26%(21)	5%(4)	23%(19)
	Agree	15%(12)	3%(3)	**28%(23)**

7 CONCLUSIONS AND FUTURE WORK

7.1 Conclusions

The analysis of both the survey results and the written comments from respondents provide support for the following conclusions:

1. The strategic implementation of lean construction methods by an AEC firm serving the higher education segment provides competitive advantage in the long-term.
2. AEC firms in that market benefit from a general business strategy that emphasizes the "focus" (niche) model proposed by Michael Porter and described in section 3.2.

The findings of this research that support those conclusions can be summarized as follow:

1. Owners in the higher education segment of construction demonstrated knowledge and interest in both improved and innovative methods of construction/delivery methods, such as value engineering, partnering, and design-build. However, they are not sufficiently aware of or educated on recent additional efforts being researched and implemented, as they indicated limited knowledge regarding lean construction and concurrent engineering in construction. There are opportunities for AEC contractors adopting lean construction to introduce improved methods of construction earlier than competitors do.

2. Owners in that segment are value conscious as they indicated that mentality in the survey. The utilization of lean construction facilitates and encourages the AEC firm to gather, interpret, and communicate the notion of value for each single owner. A construction company that focuses on its costumers' values establishes a beneficial relationship and delivers the "product" that the costumer needs.
3. In addition to value, owners in that segment signaled their clear perception regarding cost. Both private and public institutions largely ranked cost as more important issue if compared to – what could be expected as major factor for a higher education building – aesthetics. In terms of strategic planning, this is an important feedback from owners because it indicates the importance of applying lean construction methods for cost reduction in construction. If other factors are equal, a lower cost firm in the higher educational segment experiences competitive advantage.
4. Another finding of this research comes from responses regarding owners reviewing contractors' methods of production for construction projects. The results indicated that the majority of owners in that segment review methods of construction and considered the results as a decision factor. This finding is also valuable for strategic planning because an improved, more efficient method of production signifies a differentiating factor. A contractor that features a method of production that highlights the elimination of non-value added activities establishes a better competitive position.

5. Finally, the results from owners' perception regarding the "lean methods-project uniqueness" issue confirm the adoption of the focus strategy in that segment. The distribution of the data indicates a balanced perception regarding this subject as owners, in similar percentages, revealed conflicting views. The analysis of this perception suggests the adoption of a focus strategy. The following statement summarizes the issue: a successful contractor in the higher education segment focuses on the costumer's needs, strives for reducing construction costs and transfers most of the gains to the costumer, and serves its costumers according to their stated values – either by stressing improved methods of production, an unique final product, or a combination of both. Those are the basis for designing a long-term competitive strategy.

7.2 Future Work

The means utilized in this research, although appropriate for the purposes of the thesis, are limited. The survey targeted a smaller fraction of the construction industry and additional work in this subject should attempt to reach different segments of the AEC industry.

In addition to alternate segments, further research should explore the applicability of the lean construction methods in different types of AEC firms, such as a general contractor, a design-builder, a pure design-build company, and a project management

firm. It would be interesting to address the key lean construction implementation issues for each type of organization and investigate their relations with specific strategic plans.

In respect to lean construction, future analysis is also needed on the fields of organizational theory and organizational behavior. The subject of strategic planning encompasses different aspects of an organization and those two areas are crucial. As mentioned in section 5.3, the *sine-qua-non* conditions for implementing the lean principles involves fundamental aspects - leadership, change, job satisfaction, motivation, and company restructuring – and any advance in lean construction implies discussing those factors.

Future research should verify the application of lean construction methods in different geographical regions and verify whether customary practices or business relations inherent to a particular region is a factor to the implementation and success of lean construction.

Finally, the research efforts should monitor the growth and developments of the higher education market sector and confront the results against the assumptions asserted in this thesis. Recent developments on "long-distance" learning with extensive use of Internet based programs may affect the growth of physical facilities construction in the educational segment, making the sector unattractive for AEC firms.

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APPENDIX A – SURVEY RESULTS

Academic Survey for SCUP and APPA members

1. In which region is your institution located?

Location	Responses	Percentage
Pacific Coast	24	21%
Eastern	27	24%
Midwestern	22	19%
Southeastern	16	14%
Rocky Mountains	10	9%
Central	11	10%
International	3	3%

2. What is your student enrolment?

Number or Students	Responses	Percentage
Under 5,000	23	20%
5,000 to 10,000	17	15%
10,000 to 20,000	25	22%
Over 20,000	48	42%

3. What is the total size of facilities?

Size of Facility	Responses	Percentage
Under 100,000 SF	0	0%
100,000 to 500,000 SF	5	4%
500,000 to 1,000,000 SF	10	9%
Over 1,000,000 SF	98	87%

4. Is your institution public or private?

Institution	Responses	Percentage
Public	83	73%
Private	30	27%

5. Please indicate your knowledge regarding the following construction terms:

	Never Heard		Have Heard		Know the Concept		Have Used	
Design-Build	**0**	0%	**2**	2%	**32**	28%	**79**	70%
Partnering	**4**	4%	**8**	7%	**43**	38%	**58**	51%
Value Engineering	**5**	4%	**2**	2%	**17**	15%	**89**	79%
Lean Construction	**79**	70%	**15**	13%	**15**	13%	**4**	4%
Concurrent Engineering	**63**	56%	**0**	0%	**15**	13%	**35**	31%

6. Recent academic research in construction explores the issue of "value" `(not quality) from the owner's perspective. Please indicate your perception regarding the following assertion:

   "When contracting construction services, my institution has a fair definition of value"

Perception	Responses	Percentage
Strongly Disagree	6	5%
Disagree	13	12%
Agree	76	67%
Strongly Agree	18	16%

7. Concerning your construction contracts, please indicate your perception of the following statement:

"In general, cost is a lesser issue when compared to aesthetics issues"

Perception	Responses	Percentage
Strongly Disagree	9	8%
Disagree	81	72%
Agree	21	18%
Strongly Agree	2	2%

8. Concerning your construction contracts, please indicate your response to the following statement:

   "When deciding among contractors, my institution reviews their construction methods of production"

Response	Responses	Percentage
We do not review	44	39%
We review but it is not important	11	10%
We review and take into consideration	58	51%

9. Recent academic research explores the adaptation of the lean production system from manufacturing environment to construction projects. From your experience and knowledge, please indicate your response to the following statement:

   "A construction contractor that applies improved methods of production (such as lean construction) would provide my institution with a final project that is unique."

Perception	Responses	Percentage
Strongly Disagree	9	8%
Disagree	34	30%
Agree	39	35%
Strongly Agree	0	0%
Declined to Answer	31	27%

APPENDIX B – COMMENTS FROM RESPONDENTS

The following list represents the comments and suggestions that respondents of the survey included in their responses to the questionnaire.

1) "In overall terms, the value of a project is best assessed by how it fits into a master plan for development of the University. Does it meet the highest-priority needs for a reasonably foreseeable future in a cost-effective manner? Institutions that are subject to public contracting law have difficulty in taking advantage of project delivery systems that have the potential to attract better-quality contractors and reduce construction-phase problems by involving the contractor officially in the project during design to assist in providing the most complete and correct contract documents possible."

2) "We are limited by state statute to use the contractor with the lowest bona fide bid. Therefore the contractor who bids the least expensive way to build what is designed and specified gets the contract. This does not always lead to value or good relationships."

3) "I am a long range space planner and am not directly involved in facilities construction/management, so my understanding of lean construction is superficial at best. Sounds interesting, though. Good luck on your thesis."

4) "So, what is meant by "Lean Construction" and why have I never heard of the term in almost 25 years of practice?"

5) "I don't think that Lean construction will provide a unique product. We are working with Boldt Construction from Wis. and they provide lean construction. While I agree in principle about lean construction, I think that it helps to reduce the cost of construction and not change the final product. I could be wrong but that is the perception I have."

6) "Cannot answer 9. No basis for opinion."

7) "Sorry, but my academic knowledge is 30 years old. Your new concepts have not found their way to the wild west. Value is a subjective term and I would see it as a mixture of both cost and aesthetics which cannot be separated without great peril. I am unaware of the "academic research" concerning this. I would be interested in being pointed towards that information. I also do not understand why the owner would be concerned with the "construction methods of production". The owner and Architect have traditionally stayed out of this discussion for liability reasons. Of what value do you see our involvement.
Sorry, but your question 9 cannot be answered properly since I am unaware of the concept or definition of "lean contracting". Any reference sources on these subjects would be helpful."

8) "Regarding Q8: We may review, but cost and schedule are more important. It is IMPERATIVE from a risk management standpoint that the contractor retain full control over means and methods of construction; this effectively means "I don't care HOW you build it, just build it on schedule, on budget, and to the specs." I can't answer Q9 as I am not familiar with the term "lean construction." In our experience design/build requires much more diligence on the Owner's part than traditional design/bid/build; I do not have the staff to use D/B on very many projects, and will only do so when they are heavily weighted towards mechanical and electrical trades. Engineers, whether consulting or on-staff at a contractor, are NOT trained to coordinate the work of the various disciplines; this is best done by architects regardless of the scope of the "architecture" when compared to the overall project cost."

9) "I am sorry that I am not adequately informed regarding the term "Lean Construction." I assume it is delivering the project in a most efficient manner by applying manufacturing principles to the construction process, but I am not sure. In my experience, construction related professionals (contractors, architects & engineers) are always interested in implementing new, more efficient processes, but in my experience it often takes many years to change existing methods and procedures as everyone gets set in their ways and there is often too much risk to "experiment." If I understand your underlying intent, this could be a very worthwhile alternative to construction delivery methods. I noticed that you did not include Construction Management above."

10) "I don't think anyone in our procurement area care about quality vs. cost. We're a state institution and projects generally go to the low bidder. As a result, our two newest buildings have significant construction defects."

11) "As a public university in CA, we are required to award to the lowest bidder who is pre qualified for the type and fiscal ceiling matching the project. Campuses are now looking at CM at Risk as another option."

12) "Regarding Q7: As worded, this question is difficult to answer because it fuses design and construction issues, which usually occur at different points in time in the course of a project. At this institution, where design-build contracts are typically not used, the aesthetic versus cost issues, especially on large projects, would be handled during the design process, during which there may or may not be a construction consultant depending upon the type and complexity of the project. Aesthetic concerns will be evaluated in terms of the cost consequences, but this does not mean that design elements that are recognized as being more expensive are not considered, and, in fact, a more costly option may be the one selected based on the aesthetic implications. The point is to understand the cost implications of aesthetic choices at the point decisions are being made. By the time documents are put out to bid for construction, these decisions typically have already been made. Regarding Q8: Methods of construction are contractually considered the responsibility of the contractor. We are certainly concerned about how they are intending to do the work,

but only in rare instances (a special type of construction) would this be the determining factor in deciding which contractor's bid or proposal is accepted, unless the means and methods have an impact on the costs which make that contractor's bid the most competitive of those received. Regarding Q9: I responded to this question, but have to admit I'm not entirely clear what you're asking - whether by "unique" you are referring to the type of construction, or whether use of this lean construction contractor would be considered experimental and only on a trial basis, and hence depending upon the result a one-time event - a single project."

13) "Being a public institution, we have fairly strict parameters that must be followed in bidding our projects. Therefore, we have few methods of pre-qualification or contractor review/selection. We are attempting to create pilot projects to explore and prove the benefits of alternative delivery systems, such as design-build and CM at Risk."

14) "A public institution may be limited in its contractual relationships due to the state requirements."

15) "We do backwards planning in higher education. We project a budget, build high expectations, over plan the project, hire the low bid, value engineer, cover cost overruns. We are state related, so we are not totally public."

16) "Since I am not familiar with the term "lean construction", I couldn't respond to Q9. It would be better if a choice was provided to deal with that situation. Construction projects for state agencies (including higher ed.) in Idaho are managed by the Division of Public Works. They always award construction contracts to the low bidder (responsible or not). Pre-qualification of contractors is not allowed by Idaho statutes. Needless to say, this creates a situation in which the State trains contractors at the public's expense by giving work to the low bid contractor, regardless of qualifications or previous performance. This has led to significant quality control problems on our projects."

17) "I am not familiar with the term "lean construction". Since my campus is a public institution, most of our construction projects are bid on the open market and the low bidder is typically selected to provide construction services. However, our University System does use other alternative procurement methods for these services on a case by case basis. Quality is sometimes sacrificed in order to meet budget."

18) "Sounds like you've created a new term "lean construction" for principles already widely used in the profession."

19) "We are limited by state statute to use the contractor with the lowest bona fide bid. Therefore the contractor who bids the least expensive way to build what is designed and specified gets the contract. This does not always lead to value or good relationships."

20) "I don't know what Lean Construction is, so I cannot answer #9. My perspective is that most "Construction Phase" problems can be avoided by involving the contractor in the design process. This can be accomplished by contracting for Pre-Construction services separately or as part of a Design-Build or CM@Risk contract."

21) "State law drives construction procurement in PA. Innovation is not in the vocabulary. Quality is defined by professional facilities staff for A&E incorporation in design."

22) "I cannot answer question 9 since, as I identified earlier in this survey, I do not know what "lean construction is."

23) "I have not heard the expression "lean" construction, so I can only surmise what it means. With most of our work being publicly bid, we cannot get too creative with construction contractors. We have had a few opportunities to use design-build effectively. We include value engineering with varying levels of intensity during design, intensity depending on budget pressure. (By the way, great to hear from a WPI student. I am class of 1977 in Civil Engineering, and I just visited the Institute earlier in June for my 25th reunion.)"

24) "You probably should have included somewhere what your definition of Lean Construction is."

25) "It is our general practice to retain a construction management firm at the same time an architect is retained. This allows the CM to have input into design decisions, prior to finalization. I am not familiar with "lean construction" making it difficult to provide an valid answer to Q9. Also, for Q7, there is no answer that fits all situations. Sometimes, cost overrides aesthetics, but other times it does not."

26) "State statutes and public funding do not lend themselves to negotiated outcomes. If we don't get it right in the project scope and budget request it doesn't happen. To correctly scope a project out is nearly impossible, especially as it gets more complex or longer term."

27) "We make "Best Value" selections (Competitive Sealed Proposals or CM at Rick) for all major projects. The firm's expereince, reputation and construction methodolgy all count heavily in the selction as does the quality and experience of the proposed construction team. We partner on all major projects as well."

28) "Facility size and student enrollment are both defined in different ways by various institutions. On our campus alone we have five different definitions of 'student' as defining enrollment size. This number is full student headcount. In addition to instructional buildings Facilities can include; leased out retail and office buildings, owned & partnered apartment buildings, owned and public/public parking structures. Are you sure your comparing equivalient institutional capacities? This number includes all buildings except partnered apartments and parking structures."

29) "Two years ago we finished construction on a new dorm that cost approx. 52 million dollars. This was done on a design build arrangement with a contractor who was interested in our input and gave us ideas on money saving aspects of the construction process. However it is most important that the owner give their input into the project especially on maintenance matters that occur after completion. I want to be able to repair without total shut down of systems and without giving the contractor this input from our own maintenance people we would not be serving the students properly. The design build type of construction helped in the time of completion for us. We felt that with this type of construction our time frame was met and we were able to house students at semester start. We will be building another dorm next year and will probably use the same type of construction."

30) "lean or not, a contractor who provides the information requested by a contract, as well as the specified product, will provide a valued project to the university. More often than not, state systems do not support or allow that kind of process and thus result in a project that is either very costly (financial), untimely, less durable than specified due to component substitutions, or a combination of all three. In addition, the general reluctance of the contracting community to utilize systems and technologies that are actually quite old (50+ years) to provide information to the owner (such as CPM/PERT) increases the frustration and dissatisfaction of the owner (and owner's clients in a university environment). This reluctance supports the continued adversarial relationship between contractor and owner and limits opportunities for creative construction methods. Finally, in a state where there is little association between capital and operating budgets the notion of value is immaterial."

31) "Major state funded projects in a public institution are handled much differently that projects funded with "local money". The state funded projects are not monitored as closely and typically have greater costs(less value) than local projects. This is strictly my opinion."

32) "Our practice in the United Kingdom (UK) generally involves the designers (architects and engineers being directly appointed by the client and retained until completion of the project. In these circumstances a 'lean' project can also be unique. It is less likely to be unique if the responsibility for the design rests with the contractor under a design and build arrangement."

33) "Alternate construction methods are becoming the norm at our institution, specifically the use of Contract Manager at Risk. These methods allow for a faster development process, contractor input into programming, and less construction time. However, greater review of plans and specs is needed from the institution to ensure that needed changes are communicated effectively and quickly."

34) "I believe that public or private organizations/institutions should develop architectural and engineering design standards for their facilities and once in place, should be adhered to for any construction or renovation project. This concept would lead to a better product being delivered, less chance of value engineering taken place, a better understanding of what is expected from the engineers, architects, and contractors. If standards are maintained, then most institutions would not start projects that are inadequately funded. Even in a design build scenario, the A&E design standards would take precidence and the finished project should meet all expectations. The A&E design standards should be updated probably every 2 to 3 years. Having these type of standards in force keeps all parties on the same page. Certainly, this can lead to improved owner- contractor relations."

35) "I think you have to consider the Owner-Architect Agreement as a part of this review. Just looking at the Owner-Contractor relationship does not fully consider the impact the Architect has on the process."

36) "Value is a missundestood term at my institution. Asthetics and achitectural significance are more important than use, functionallity and economy."

37) "Most public universities have to accept bids for projects from the lowest responsible bidders or responsive bidders. The method and means of how a project is construction are the capability of the successiful bidder. Each institution has its stipulation who is a qualified contractor and most of this is spelled out in the general or special conditions of a contract documents what the expectaions are, skill sets, experience and bonding capacity. Most of our contractors are local and have worked with us for many years and know university quality or value requrements and we have staff who are professionals that monitor construction in the best interest of the university."

38) "While we do not review the "construction methods of production" we do take the time to visit past projects to see the finished products produced by the contractor."

39) "Q9 should have had a check for "Not sure what lean construction is and not qualified to answer.". But I based my response on the statement "improved methods of production" so my response if clarified."

40) "In a public institution there are quite strict contracting rules. Design/Build is discouraged by our state board, so it is either low bid or a CM/GC. The latter is only cost effective if done on projects of at least $5M. So, while we would like to take other factors into consideration when awarding contracts, the Attorney General's Public Contracting Rules, which we must follow, are very restrictive. Aesthetics is extremely important, along with systems and sustainability. But the bottom line always comes down to dollars. And often compromises are made."

41) "We look at longevity of the construction projects rather than asthetics. Mantenance of what we get from construction is more important than cost. Keeping with building standards rather than archetectural design is more important."

42) "In the public sector, we have to put everything above a certain dollar amount out to bid. We have been taken to task by low bid/change order galour contractors with lousy reputations. Not many public agencies have the resources to setup a prequalified bidders system and any suggetion of "blacklisting" will subject the agency to costly legal entangements. The whole public bidding system discourges excellent local contractors from establishing long term business relationships with public agencies which usually generate the largest construction budgets for the local area. I do appreciate the need to insure that public funds are properly used but there should be other means to insure accountability. The owner's representative has to be on the construction site at all times to insure that problems are dealt with quickly and to insure that value is in everything the contractor executes. There is no substitute for owner's project manager and/or inspector on the jobsite. The above opinion is based on my over 40 years of experience in construction and facilities management. I am retired from San Jose State University, California as the Director of Facilities Management and last year assisted the University of Nevada Las Vegas as their Interim Executive Director of Facilities Management. I would gladly be of assistance if required. Stephen Quock."

43) "The term "value engineering" has come to mean what a contractor does to get his price in the money, and in our experiece has little to do with value or engineering. It is a phrase that is used to make owners feel good about the items cut out of the contract."

44) "Since I've not heard of Lean Construction, I could not provide a meaningful answer to #9."

45) "We have a strong standard specification and design guidelines documents. We also strongly support fully commissioning as a process from craddle to grave. We are only recently beginnig to learn ablut lean construction so my answer to question 9 is debatable."

46) "It takes two dedicated partners to achieve real savings."

47) "It would usefull to hear some more about these three unknown contractinform,s.We use more and more projekt management contracting.Our staff is involved in subcontractor,s asessment with arhcitect."

48) "commissioning is also a valuable process."

49) You posed an interesting question, particularly where the concept of "value" should be distinct from "quality". If all other things are equal, what constitutes "value" that would separate one contractor from another? I think those concepts of "value" become more of gradation of non-specific qualities most of which are wrapped up in the people or corporate identity. Some of the possible adjectives that come to mind are:
Responsiveness. I think an owner would prefer to work with a contractor that is self-starting and responsive. One does not like to feel that you are always trying to drag someone to do something.
Thoroughness/Completeness: It is always a pleasure for an owner to have information, options, data, anything of this nature provided clearly and effectively.
Cooperative: I guess this runs close to responsiveness, but in this case it is more of a give and take relationship that satisfies both parties.
Ownership: The best situation for an owner would be a relationship with a contractor who sees the project as a joint effort to succeed, not simply a business relationship.
Compatability: This may be more difficult to define, and it is sometimes just a feeling, but there needs to be compatability of personnel involved with the project. This is really an outlook toward project goals that is similar, a good working association, and mutual goals.
All these are "soft" in nature not something that can always be quantified, or counted. Accordingly they are probably better answered by questions that have an importance scale connected to them. When you take price, schedule, quality etc out of the mix, everything is different.