

LEAN ENTERPRISE IN THE CONSTRUCTION INDUSTRY

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(1996)**

**SUBMITTED TO THE DEPARTMENT OF CIVIL & ENVIRONMENTAL
ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF**

MASTER OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE, 2004

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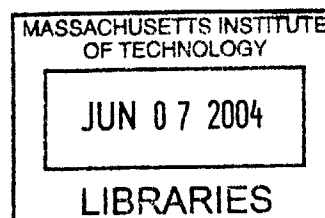
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Submitted to the Department of Civil & Environmental Engineering on May 7, 2004 in
Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil and
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ABSTRACT

This thesis explores the application of the Lean Enterprise Model (LEM) to construction firms. LEM is a framework derived from lean manufacturing principles by MIT's Lean Aerospace Initiative (LAI) for the aerospace industry. Construction firms also need new business models to meet the change in construction industry environment. Lean enterprise could assist in the development of a new business model.

In theory, LEM could be applied to any given industry. A matrix has been created in which six key construction characteristics are compared to six key lean enterprise principles in order to assess how compatible would the lean enterprise model be taking into account the particularities of the construction industry.

The results show that in some aspects the construction industry is already somewhat lean, e.g. it works on the basis of customer pull, while in others the application of lean principles would require a big mindset and cultural change, e.g. adversarial relationships due to the lump sum bidding system.

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ACKNOWLEDGEMENTS

This work would have been impossible without the help and support of many people most of whom I met through the course of my research. I am indebted to all of them.

First, I would like to thank my fellowship sponsor, Fundacion La Caixa, whom provided an ideal level of economical support for the research while allowing me the freedom to pursue a wide range of topics.

Second, I would like to express gratitude to Professor Fred Moavenzadeh for his guidance in choosing this research topic as well as his insights in the construction industry. Also many thanks to Professor Deborah Nightingale for her course “Integrating the Lean Enterprise” which was key for having a good understanding of what it means to be a lean thinker. In addition I would like to mention the advice provided by Professor John Macomber on strategic issues of construction, researcher Kirkor Bozdogan in supplier networks and Jim Becker for his explanation and clarification regarding the Skanska USA Building Inc. organizational structure presented in the examples of the industry chapter.

Special appreciation to Ted Piepenbrock for his vision and with whom I shared vivid discussions regarding many aspects around the lean concept.

Finally I would like to thank my wife Ana for her support and understanding in the ups and downs as the research proceeded.

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1. Construction Industry

The construction industry can be considered as a dynamic system. It has evolved since construction companies were just responsible for the technical aspects of design and construction. Nowadays the business has expanded into other services such as maintenance, operation and in some cases financing of the construction projects. These new set of competencies has changed the way in which companies do business. For the purpose of this thesis we consider the most recent changes (basically in the late XX century) to put us in place for how firms shall do business from now on.

For this chapter I consider the construction industry in a holistic way. I include not only construction companies in the sense of general contractors but also architecture studios, engineering design firms, construction management firms, suppliers and subcontractors. Every player that adds value to the construction supply chain in some way is included.

1.1 Traditional Core Competences

The construction process involves the delivery of any type of facility or infrastructure to a customer which is the owner. It includes the acquisition, design, construction and hand over of the project. An important difference with other industries is that in many cases in construction the end user of the product being delivered is not the owner (e.g. leased apartment buildings).

Architects or engineers produce a design for the owner and then, the contractor executes it (builds it) with the assistance of subcontractors and suppliers. The traditional

construction process is cost driven. Contractors are selected by owners based on the lowest price on project tenders, and accordingly they turn to the lowest price suppliers and subcontractors. The temporary organization of firms expires at the completion of the project.

Each firm is only responsible for its input and has its own domain of expertise, and rarely these organizational boundaries are crossed. It is not surprising then that conflict arises between the parties during the project due to lack of detail in the project description and the interpretation of what is included in the project.

In general the relationship between firms can be characterized by:

Low transaction frequency. Because their interaction is based on bidding procedures in the selection process. This stimulates opportunistic behavior from certain firms. Because the price is usually the lowest lump sum there is an incentive by the contractor (or subcontractor) to cut corners, use lower quality materials or oversee safety regulations in order to obtain a higher margin.

Uncertainty during the construction process. This is due to the fact that each construction requires a new design and production process. There is uncertainty both technically (ground conditions, weather...) as well as organizationally (new team members every time).

Between construction firms and owners there has been traditionally an adversarial relationship, lack of trust and commitment and co-ordination problems. Some of the consequences of this mindset are resumed below:

Communication/information problems: firms try to limit the exchange of information as much as possible and consequently do not respect each other's deadlines.

Win-lose relationship: companies try to procure benefits out of their relationships and often finish with a loose-loose relationship. Contracts are often the fallback used to gain recompense when problems arise. In some cases some companies even decide to bid too low (with no margin) with a strategy of making the profit by taking advantage of the contract pitfalls during the course of construction.

Poor quality/late completion: as a result from a lack of trust and commitment between trading partners, the work is often of a poor quality requiring a time consuming checking process (quality control).

1.2 Competences of the current industry

In recent years a transformation has taken place on the activities that companies perform in the construction industry. New activities fall now within the scope of some projects. These are basically project finance, project operation and project maintenance. While traditionally a construction company only did the assembly part of the business, and get paid for it as work was being completed (General Contract), innovative delivery methods require that the construction companies also design (Design-Build), finance (Turnkey), operate (BOT) and maintain (BOTM) the facility or infrastructure. Typically each

method is suited for different project characteristics and circumstances. Following are the most common current delivery methods:

General Contract (GC). Under this method the client defines a design with the help of an engineering or architecture firm, bids and awards it for construction. The construction company that wins then builds according to the design requirements. 100% of the design is completed when construction companies bid for the job. This is the traditional method.

Design-Build (DB). The client awards both the design and the construction to the same company. The construction company designs and builds based on some general specs but it has a lot of freedom with the detailed design. Normally only the conceptual design is finished at the time of bid.

Turnkey (T). The client awards both the design and the construction to the same company, and the company doesn't get paid until the project is finished. This method is quite similar to DB but it involves some sort of short term financing. It is very suitable for building factory plants where aesthetics are not as important as performance specs.

Build-Operate-Transfer (BOT). The client awards the design, construction and the legal right to operate the infrastructure for a number of years to the same company. The company is paid by collecting revenues from the operation (e.g. pay toll system in a highway). This method is quite similar to DB but it involves some sort of long term financing. Only infrastructures capable of generating revenue can use this delivery method.

Build-Operate-Transfer-Maintain (BOTM). The client awards the design, construction, maintenance and the legal right to operate the infrastructure to the same company. The company is paid by collecting revenues from the operation. This method is similar to DB but it also includes the maintenance of the infrastructure during the years of operation.

We can now define a new type of company in the construction industry: Integrated Service Delivery Firms (ISDF). This would be companies capable of providing all the mentioned new services if required. They must be able to design and manage construction, operate and maintain facilities and seek for outside financing. Construction companies can decide whether to do all of these new activities in-house or outsource them. What is patent is that the scope of their competence is increasing.

From this point and on we will focus this thesis on ISDF firms as being the big players and leaders of the construction industry.

1.3 Industry Characteristics

Construction makes its production through projects. As a productive process, construction consists on the design and assembly of objects in a fixed position, and therefore can be characterized as **site production** of a **customized product** organized with **temporary project driven teams**.

Certainly these characteristics are not exclusive of the construction industry, and can be found in industries like shipbuilding (site construction, project driven) and the automotive

(complex product design / multiple teams). What remains particular of the construction process is the degree of uncertainty involved in each project.

1.3.1 No repetition

It can be fair to say that there are no two identical projects. This industry is characterized by building to order. It typically produces one product per customer and because of the big amount of money involved in each project the customer has a say. Even if the specifications for several projects are the same there will be differences once the projects are completed (different soil conditions impossible to predict in advance, etc).

Construction companies are not speculative by nature. Developers might be but we can argue that their business is not really the construction per se. The few construction companies that have tried to speculate (build before there is a customer expecting that the price would go up) have typically accrued great losses.

This one of a kind nature of the project adds to the complexity. One-of-a-kind undertakings are always experiments or prototypes in some aspects. Although there are some cases where there is some repetition (e.g. Wal-Mart stores) this is not the norm. Even in those cases it is very difficult that the final product is exactly the same as regulations change across regions. This causes unforeseen events, which again give rise to improvisation. This decreases order and increases chaos.

1.3.2 On site production

Production physically takes place at the location where the customer wants to have the product. In this industry the final product is not shipped to the customer. The “raw materials” are delivered to the customer desired location and “assembled” on site. Because the location is different for every project this introduces an extra amount of complexity for the logistics.

A big consequence of this characteristic is that production is widely dispersed geographically. This means that communication among projects is slow and expensive. A construction company will typically have different assortment of projects across its region of influence. Site managers will normally communicate with the company headquarters but not with other site managers. This lack of communication makes the lessons learned diffuse slower across the company.

The on site production with its temporary production facilities adds further to the complexity. What remains particular of the construction process is the degree of uncertainty involved in each project based on each location conditions (soil structure, building regulations, etc).

1.3.3 Long Lifecycle

Projects are delivered to function for a long time. On accounting standards a building can be depreciated over a period of 39 years. Bridges are usually designed to work for periods of 100 years. These two examples already give us an idea of the time frame involved.

Therefore lifecycle costs such as maintenance costs become critical in the design phase. Unfortunately this is not always taken into account as the end user or the party responsible for the operation and maintenance is frequently not involved in the design because the customer is not always the same as the end user. When this is the case many times interests are not aligned as the customer wants a cheaper design (which involve higher lifecycle costs) while the end users would prefer a more expensive design (which involve lower lifecycle costs).

1.3.4 Complexity of organization

All of the previous factors and some other industry related that will be discussed later make constructions projects difficult to organize. The organization involves managing people from different companies that don't know each other, following local regulations where not everyone is an expert together with time and budget pressures. New relationships have to be built every time a new project starts. Especially if the project life is short it makes it difficult to have mutual trust relationships.

The temporary organization is also a source for complexity. Not only by its nature, where the participants are strangers to each other, but also by the lack of capacity for common learning from experience. Once their part of the job is completed, the parties are up and away for their next task. The key activity of project learning which should be done at the end of every project is usually forgotten or not planned at all.

(Koskela 2000). The industry nature calls for a lot of detailed regulation setting rules to protect the small agents, the nature of the industry, etc. This regulation reflects a number

of interests, all concerned with other issues than the industry's productivity, and it adds strongly to its continuing being highly complex.

1.3.5 Fragmented

The amount of companies in the construction industry is overwhelming. About 800,000 companies exist in the United States but 600,000 have a workforce of only one or two employees. The biggest companies in the business only account for a very small percentage of the total market share. This is a market where it is difficult (and often unprofitable) to be big because of all the bureaucracy and overhead costs that it involves.

The typical medium size company only works on their regional area of influence and very seldom get projects in other areas because of lack of knowledge of regulations, unions and local subcontractors.

(Koskela 2000). The nature of construction is that of a service industry. The companies offer skills, not products. This causes a low threshold for entry. Indeed, any skilled craftsman can enter without any substantial capital, making use of the tools he already possesses. This again causes fragmentation, with most firms operating locally only.

1.3.6 Need for outside financing

Construction is a very capital intensive industry. Projects are expensive and construction companies often need to advance some of the cash flow in order to get started. In some cases it has to seek and arrange for the financing of the whole project due to the cash flow problems of some customers.

In addition to this, different kinds of bonds need to be secured in order to be able to bid for projects (at least a performance bond in case that the contractor or the subs walk away). The bond capacity of a construction company becomes critical in order to be able to get projects (usually 10% of their revenues).

2. Lean enterprise

We learn in macroeconomic courses that the economy is cyclical. There are periods of high growth followed by recessions. Experience confirms this phenomenon. When there is a high growth economic period most companies do a good job while in the downturns they try to survive by whatever means they can: laying off workers, downsizing ... Many fail and default but very few manage to go through without being affected that much. How do they do it? What is their secret? How can we design a company that is more robust to business cycles? The answer can be lean as it is behind some of these successful stories in bad times.

2.1 Some general confusion on the term “Lean”

The term “lean” refers to the Japanese philosophy behind the Toyota Production System. It is just the way in which the Western world named it. As with many translations of more or less intangible concepts this is just an approximation to the actual meaning that it would have in Japanese. You will find some authors which say that lean means eliminating waste, others that lean means being flexible to change and some others that it means doing continuous incremental improvements. It probably is all those three at the same time and much more. Lean tries to aggregate all those meanings in one word so it can easily be called upon. Therefore, in this thesis “lean” would be just a short way of referring to the philosophy behind the Toyota Production System.

2.2 Brief Background on Lean

2.2.1 Toyota Production System (TPS)

Throughout most of the XX century the auto industry had long been dominated by the “big three” American car manufacturers (Ford, General Motors and Chrysler). They created and developed the mass production system which led to an incredible reduction in costs. It worked pretty well while demand was much higher than production capacity and every car produced had a customer ready to buy it.

After World War II Japan was immersed in a recession and so was the car industry in that country. Toyota Motor Company was a small car manufacturer which produced around 1000 cars per month which they were not even sure that could be sold. The productivity of Japanese car manufacturers in the early 50s was nine times lower than the American car manufacturers. In this situation both an increase of efficiency and a reduction of production costs seemed essential in order to be able to compete. Taiichi Ohno, one of the plant engineers at that time, started to experience and put into practice some new ideas of production with the goal of improving efficiency without increasing production volume (that they were not able to sell). The result of that work is what we call today the Toyota Production System (TPS) which was finally implemented in Toyota in 1962.

Nobody really paid much attention to TPS until the 70s when the oil crisis hit and most car manufacturers were severely affected. In this downturn Toyota continued its growth (a bit more moderate) and its structure and business goals could be maintained without major changes.

So, what does the Toyota Production System consist on? As mentioned before, TPS's goal is to reduce costs without increasing production volume. The basis to achieve it is the absolute elimination of waste (Ohno, 1978). The two pillars that support the system are:

- **Just-in-time:** the later process tells the earlier process how many units it needs. The earlier process only produces that exact amount needed by the later process. Kanban (Ohno, 1978) is a tool for realizing just-in-time by means of tags attached to each part/unit produced. For this tool to work the production processes must be managed to flow as much as possible under a "pull" system.
- **Autonomation:** use of "intelligent" machines that can automatically stop production as soon as products are being produced with defects. This means that you don't need an operator for each machine watching it work in case products start being defective. Instead you can have several machines controlled by a single worker which will act only when a machine has a problem.

Other important conditions for the system to work are levelling of production and using standard work methods. The outcome is a production system where customer requirements can be satisfied immediately without maintaining intermediate inventories.

Another important concept introduced by the TPS is the division of activities within the production process in work and waste:

- **Work** is divided in value-added and non-value added activities.

- *Value-added activities* involve some kind of processing or transformation of the materials towards a next step in the process.
- *Non-value added activities* do not add value to the product but have to be done under the present working conditions.
- *Waste* is activities that can be eliminated without affecting production at all. They just use resources.

In summary, this strategy can be implemented by identifying and delivering customer value (eliminating anything that does not add value). You have to organize production as a continuous and reliable flow, through inventory pulling, decentralized decision making and reinforcing quality assurance. Finally you must pursue perfection by delivering on order a product meeting customer requirements with no inventory.

TPS is also called “lean production” or “lean manufacturing” in the Western world. The main difference between the traditional mass production system and the lean production system (for the auto industry) is that while mass production reduces costs by increasing production volume and mass-producing fewer types of cars (Maxcy-Silberston curve), lean production reduces costs by producing a smaller number of many different cars.

In an industry where demand is higher than supply the mass production system works well because manufacturers can “push” their products into the customers (e.g. products are scarce so whatever you produce you will sell). As soon as the market becomes saturated and low growth appears the industry has to accept orders from each customer

and make products that differ according to individual requirements. In this situation customers are empowered and can “pull” whatever they want from manufacturers.

As a final comment I would like to point out that in a period of high economic growth everybody can, relatively easily, achieve lower unit costs by means of higher production but when growth is low achieving any form of cost reduction is very difficult. Although the principles of TPS were defined in the early 50s by Taiichi Ohno, the implementation took almost 10 years to reach the whole company and further another 10 years to become common practice among its suppliers. It takes strong leadership commitment to be able to migrate from mass production to a lean production.

2.2.2 Lean thinking

As mentioned before, TPS has really a philosophy behind. People need to have a new mindset in order to become lean. Lean thinking summarizes in a way what this new philosophy is about.

- Customer-focused: customer needs and expectations “pull” enterprise activities. The customer provides an orientation (“true north”) for the full enterprise.
- Knowledge-driven: critical role of people in effectuating value (full input from the entire workforce). Draws upon knowledge and innovation from everyone (workers, suppliers, ...).
- Eliminating waste: stresses elimination, not just reduction, of all types of waste

- Creating value: puts premium on “growing the pie”, not just reducing costs, to benefit all stakeholders.
- Dynamic and continuous: Pursues on-going systemic as well as incremental improvement - both innovation and continual improvement.

Some of the differences between traditional manufacturing systems (craft production and mass production) and TPS (lean production) are summarized in the following table:

	CRAFT PRODUCTION	MASS PRODUCTION	LEAN PRODUCTION
Focus	Task	Product	Customer
Operations	Single items	Batch and queue	Synchronized flow and pull
Overall Aim	Mastery of craft	Reduce cost and increase efficiency	Eliminate waste and create value
Quality	Integration (part of the craft)	Inspection (a second stage after production)	Prevention (built in by design and methods)
Business Strategy	Customisation	Economies of scale and automation	Flexibility and adaptability
Improvement	Master-driven continuous improvement	Expert-driven periodic improvement	Workforce-driven continuous improvement

Table 1. Comparison of different production systems

(Source: Lean Enterprise Value, Earl Murman et al., 2002)

2.3 From Lean Production to Lean Enterprise

Many companies have tried to implement TPS both in the auto industry as well as in other high-volume manufacturing industries. A new group of lean consultancy firms have appeared in the last 15 years. They specialize in convincing senior management of the benefits of a lean production system and coach the transformation to lean of such manufacturing companies.

In the 90s, after the cold war ended, the aerospace industry entered into an unprecedented recession. This industry is primarily divided in two types of customers: commercial aircrafts and defense. The military divisions had always been some sort of cushion for the industry. Suddenly the US defense budget dropped when the soviet menace ended. There wasn't a need for such a big defense system anymore. There was a need for reducing costs and production.

Given this situation an alliance was formed between the aerospace industry and a group of researches at MIT: the Lean Aerospace Initiative (LAI). Their goal was to try to apply the lean production principles that proven so appropriate for the automotive industry to the aerospace industry. The challenge was that although both are manufacturing industries each has its own particularities so it wasn't so clear in the beginning whether or not lean production would be applicable or if it would lead to the same kind of benefits. The automotive industry is characterized by high product development costs and high volume production while the aerospace has very high product development costs and very low volume production.

While lean production concentrates in the operations side of business its principles can (and should) be applied to the company as a whole. LAI acknowledges that becoming lean is not just a matter of applying some tools or procedures. It is really a change of mindset, a change in how people think and what they value, thus a change in how people behave. Because lean is about beliefs and behavior, it is applicable beyond the factory floor to encompass the entire enterprise, hence lean enterprise is born.

The breakthrough of lean enterprise with respect to lean production is that it recognizes the fact that greater benefits can be obtained when changing the behavior of the whole enterprise towards lean principles than just applying some practices in the production side of business. If you concentrate only in production you will get partial benefits of the full potential.

The outcome of LAI's many years of research efforts can be summarized in the development of a lean framework that could be applied to any given industry. The framework consists of three key interrelated products:

- LEM (Lean Enterprise Model) integrates the lean principles and practices; it addresses the issue of "what" defines a lean enterprise.
- TTL Guide (Transition to Lean Guide) addresses the issues of implementation. It defines "how" to transition to a lean state. It provides an organizing agenda for achieving a lean transformation.

- LESAT (Lean Enterprise Self-Assessment Tool). Lean transformation is a long journey. This tool provides enterprise leaders a way of assessing their progress once they follow the TTL Guide. It helps answer the question: how much further is it to lean?

This framework helps to explain the “what” is and “how” to achieve lean. Understanding what lean really means is already the first big challenge and it is crucial that everyone in the organization believes in it for a successful transformation. A lean organization must not only change its practices, it must also change its behavior. It is much more difficult to change behavior than to change practices.

Finally it is necessary to comment on a couple of underlining key concepts of the Toyota Production System not so stressed in any lean literature so far. These concepts are, as waste, evils to avoid and eliminate that are not explicitly mentioned by Ohno in his books although they are implicit in his readings (Ted Piepenbrock, 2003):

- Inflexibility: the enterprise has to be able to adapt to what customers want.
- Variability: flow can not be synchronized without maintaining stability. The enterprise must decide its pace.

Having stability is thus not only an aim but a necessity for a lean enterprise. In the end this means that companies should not follow demand but decide internally how fast they can grow while offering an exceptional quality. People in the company are the most valuable asset, is their source of competitive advantage, and they should honestly

communicate to the leadership which is their comfortable path of growth. Leadership has the key role of supporting employees and controlling the demand variability so the company keeps learning in a stable and safe environment. Ultimately how fast can you learn should drive how fast you can grow.

2.4 Lean Enterprise Value

“The core of challenge for industries in the 21st century involves identifying and delivering value to every stakeholder. Meeting that challenge requires lean capability at the enterprise level.” (Ref. Lean Enterprise Value, p3)

Let’s first define some key concepts within the lean enterprise framework:

Enterprise. Any corporate or business-unit organization with a distinct mission, market segment, suit of products or services, customer base, profit/loss responsibility and set of competitors. The purpose of the organization’s existence is to perform its mission and achieve associated goals. (Ref. Techniques for Enterprise Management)

Stakeholder. Any group or individual who can affect or is affected by the achievements of the organization’s objective. All those who have an interest in an organization, its activities and its achievements. These may include customers, partners, employees, shareholders, owners, government and regulators. (Ref. The EFQM Excellence Model Glossary of Terms)

Value. The way in which various stakeholders find particular worth, utility, benefit or reward in exchange for their respective contributions to the enterprise.

Value stream. The specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer. (Ref. Lean Thinking).

Extended enterprise. In the lean enterprise context enterprise is understood in a holistic way. All business along the value stream that contributes to providing value to a customer. (Ref. Lean Thinking). It includes all the stakeholders both inside and outside the company: customer, company leadership, employees, stockholders, suppliers, government and even the society in general.

Now we are in a better position for understanding what a lean enterprise is: “*a lean enterprise is an integrated entity that efficiently creates value for its multiple stakeholders by employing lean principles and practices*” (Ref. Lean Enterprise Value, p144).

The fundamental difference with previous lean enterprise definitions which have been around for some time (Lean Enterprise Value, Ref 24, Chapter 4) is the importance given at last to the creation of value (for all stakeholders). This insight contrasts with most previous authors whom put emphasis on the elimination of waste (muda) and continuous incremental improvement (kaizen). The fundamental principles for creating lean enterprise value are summarized by LAI as follows:

Principle 1: *Create lean value by doing the job right and by doing the right job.* The enterprise must deliver as much value as possible by means of high productivity and performance (doing the job right) making sure that the value delivered is valued by

the stakeholders (doing the right job). In other words, it doesn't make any sense delivering something that stakeholders don't value in the first place even if you are very efficient in delivering it. Unfortunately many companies concentrate so much in doing the job right that they forget if they are doing the right job.

Principle 2: Deliver value only after identifying stakeholder value and constructing robust value propositions. Delivering value will be constrained by poorly structured value propositions, and enabled by robust, well structured ones.

Principle 3: Realize lean value only by adopting an enterprise perspective. While one part of the organization may become lean, the overall net gain will be limited if lean is not integrated as part of an overall enterprise strategy.

Principle 4: Address the interdependencies across enterprise levels to increase lean value. There are different enterprise levels: project, company and national or international. The links between each enterprise level can favour or deteriorate lean value.

Principle 5: People, not just processes effectuate lean value. Lean enterprise value is sustained by people's knowledge, capabilities and new ways of thinking. All people in a given enterprise must understand, believe and help effectuate lean value, not only a set of selected experts (which was typical from the mass production world).

These five principles are meant to guide action and will enable future success for the 21st century industries. We now concentrate in the two new concepts that lean enterprise

value adds to previous lean knowledge: the importance of value and the extended enterprise.

2.4.1 The importance of value

We need a fundamentally different orientation to creating value for the many stakeholders. In this context value is the “true north” that drives enterprises.

Organizations should not just do the job right (value for the customer) but also do the right job (value for other stakeholders).

Value is not fixed – it evolves with stakeholder changes in priorities. Understanding stakeholder value is not easy. Stakeholders can be identified in most cases but not their view of value which may not be in line with the value of the product, service or improvement provided to end users. The values of different stakeholders may conflict so certain negotiation must take place among them in order for all to be satisfied. The following value creation framework is proposed by LAI:

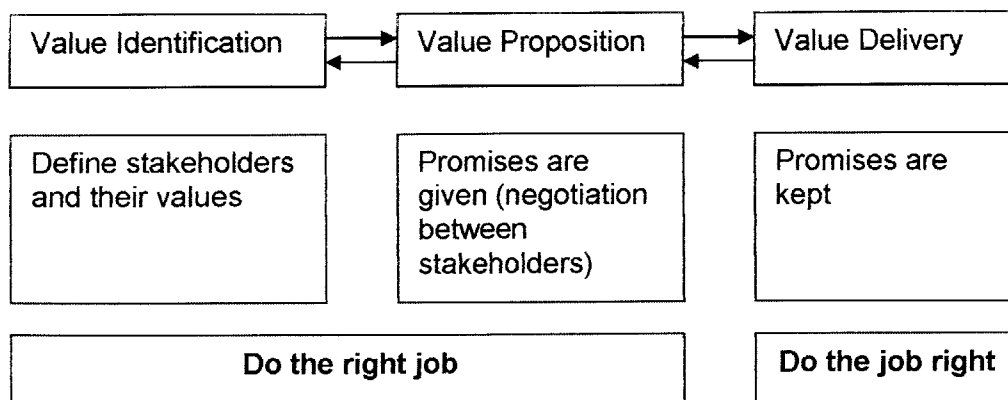


Figure 1. Value creation framework

This framework is based in following principle 2 of lean enterprise value. The order is important. First we identify stakeholders and their values. Second we build a value proposition which promises value to the stakeholders. Finally we deliver value by keeping the promises made to stakeholders in the earlier step. Also important is to continuously review the process at every step and go back to the previous one if problems are found. The process must have as much iteration as needed.

2.4.2 Reaching the extended enterprise

The other new concept behind the lean enterprise value definition is that the full benefits of lean enterprise can only be realized by rethinking the entire enterprise. What processes are there that needs to be transformed? A generic lean enterprise process architecture gathers processes in three groups:

- **Enterprise Leadership Processes:** guide and provide direction to the enterprise. They include processes such as strategic planning, business models, managing business growth, strategic partnering, organizational structure and transformation management. These processes usually do not show up in traditional organizational charts.
- **Life Cycle Processes:** define the product life cycle (traditional functional aspects of a business related to project execution). They determine the value provided to the customer and other stakeholders. They include processes such as business acquisition and program management, requirements definition, product and

process development, supply chain management, product production and product service and distribution.

- **Enabling Infrastructure Processes:** support other organizational units whom they serve as internal customers (traditional corporate support functions). They include processes such as finance, information technology, human resources, quality assurance, facilities, environment, health and safety.

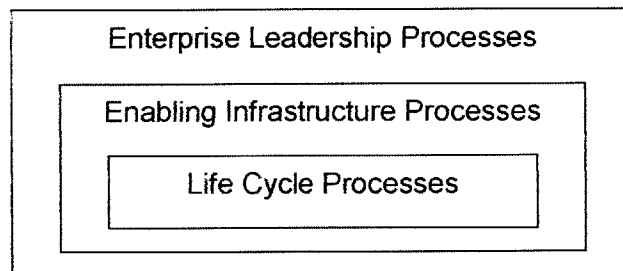


Figure 2. Lean enterprise process architecture

Lean principles and practices must be implemented in all processes in order to obtain the full benefit. Companies should not focus only in “low hanging fruit” (localized improvement opportunities both easily visible and relatively easy to address). Rather they should aim for a lean transformation at all levels and extend the enterprise by establishing true long-term partnerships with suppliers and have a fully integrated product and process design team. These broader enterprise mindsets accrue higher benefits.

2.5 Lean Enterprise Model

To continue our analysis we must now go into more detail and understand what the Lean Enterprise Model (LEM) consists of. LEM is a synthesis of principles and practices, a hypothetical model of a generic lean enterprise.

2.5.1 Core lean principles

We need a set of lean principles that could be applied to all the processes and functions that we have just defined in the generic lean enterprise process architecture. These core principles state the high-level enterprise goals:

1. Waste minimization: so we can reduce the time and resources needed to produce a product or service that delivers value to the customer.
2. Responsiveness to change: agility (flexibility) in responding to market changes, in order to produce the product or service when it is needed and in the amount needed.
3. Right thing at right place, at right time and in right quantity: every enterprise function performing as needed to meet customer demand.
4. Effective relationships within the value stream: people and organizations perform more efficiently when there is mutual trust and respect, sharing of information and open and honest communication among all stakeholders.

5. Continuous improvement: involves the pursuit of perfection in a never ending process.
6. Quality from the beginning: designing processes that turn out near perfect outcomes. If the output of the process is defective, it must be detected and corrected immediately before it becomes the input for the next process.

Lean organizations are more flexible and adaptable to change, continuously evolving with its environment seeking improvement and perfection. Most important, lean does not mean eliminating jobs. Matching lean to cutting jobs, as many people associate, is a very narrow perspective of the real meaning of this concept.

2.5.2 Overarching lean practices

The overarching practices support the core principles. They can be divided in human oriented practices and process oriented practices. Most of these practices are interrelated and usually the human oriented ones are a prerequisite for the process oriented ones. The following table lists the practices.

HUMAN ORIENTED PRACTICES
<ul style="list-style-type: none"> • Promote lean leadership at all levels • Relationships based on mutual trust and commitment • Make decisions at lowest appropriate level • Optimize capability and utilization of people • Continuous focus on the customer • Nurture a learning environment
PROCESS ORIENTED PRACTICES
<ul style="list-style-type: none"> • Assure seamless information flow • Implement integrated product and process development (IPPD) • Ensure process capability and maturation • Maintain challenges of existing processes • Identify and optimize enterprise flow • Maintain stability in changing environment

Table 2. Overarching lean practices

According to LAI these principles and practices should be applicable to any given industry. In the next chapter we will analyse what these principles and practices mean for the construction industry and whether they can or can not be accomplished by integrated construction companies given the particularities of the industry.

3. Construction vs. Lean

It is time now to investigate how close the construction industry is to the lean enterprise concept. In previous chapters an analysis of construction and lean enterprise each has been done separately. In theory, the lean enterprise principles can be applied to any given industry, but it is my belief that different industries have different characteristics so the implementation of those principles can be more or less traumatic.

In particular, I will discuss how compatible is each of the construction characteristics with each of the lean principles. For the sake of simplicity I will narrow down both the characteristics of the construction industry as well as the lean enterprise principles to the ones that I think are more representative. Then I will do an overall evaluation of the applicability of lean enterprise principles in the construction industry.

3.1 Key construction characteristics

The construction industry has been described earlier in this thesis. For the purpose of relating it to the lean enterprise principles only the most relevant characteristics have been considered. The following table lists them and summarizes their meaning for the purpose of the comparison.

Long lifecycle	The product takes long time to produce (build) and it will be used over a long period of time. Lifecycle costs become very important in this kind of products.
Site production	The product is assembled at the point of delivery. Consequently production of any given company is dispersed geographically (each project in a different site).
Build to order	One of a kind nature of products. There is no repetition; each product is customized according to customer specific needs.
Projects need outside financing	Products are expensive and construction companies have high upfront costs. There is a need to seek for project financing outside of the company and the customer.
Complexity of project organization	Authority of project is divided between many parties and built up of temporary teams. The customer is not always the same as the end user.
Fragmented	There are low barriers to entry so there are literally thousands of companies. There is not a big enough company (or group of companies) to lead the industry.

Table 3. Key construction characteristics

The order in which the characteristics are presented has been selected with the criteria of having at the top the ones that are related more to the type of product that this industry delivers and at the bottom the ones related to the industry as a whole.

3.2 Key lean enterprise principles

In the same way as before, for the purpose of relating lean enterprise principles to construction characteristics only the most relevant ones have been considered. The following table lists them and summarizes their meaning for the purpose of the comparison.

Customer pull	Adapt to what the customer really wants. The customer is the "true north" that drives the company.
Deliver value to all stakeholders	It is important that all stakeholders are considered and that each gets as much value as possible.
Seek stability of demand	Stability of demand allows synchronizing flows. Therefore, the company should only meet the demand that it is capable of with its current resources and continuous improvement.
Waste minimization and continuous improvement	Focus on the elimination of waste (non value added work). This is done continuously over time.
Synchronize flows	Synchronization of the internal processes so one does not start until the previous one has finished.
Mutual trust relationships	Trust all involved parties and believe that they will always meet their commitments.

Table 4. Key lean enterprise principles

3.3 Construction vs. Lean matrix

Now we are in a position to establish a matrix where we plot construction characteristics versus lean principles. Each of the cells in the matrix will represent how compatible is a particular construction characteristic with a particular lean principle. A number and color code convention has been used to synthesize the interactions as follows:

Number	Color	Meaning
1.	Green	Compatible
2.	Yellow	Indifferent
3.	Red	Not compatible

Table 5. Number and color code convention

The matrix is composed of six construction characteristics that are compared against six lean principles. The total number of cells is therefore 36 and is presented in the following way:

	Customer pull	Deliver value to all stakeholders	Seek stability of demand	Waste minimization and continuous improvement	Synchronize flows	Mutual trust relationships
Long lifecycle	1	1	1	3	2	1
Site production	1	2	2	2	3	3
Build to order	1	1	1	2	3	3
Projects need outside financing	3	1	3	2	2	3
Complexity of project organization	3	3	2	3	3	3
Fragmented	1	3	3	3	2	3

Table 6. Construction vs. lean matrix

3.4 Explanation of the matrix cells

The decision of what level of compatibility exists among each pair is based on an analysis of whether each of the construction characteristics is aligned with each of the lean enterprise principles. Following is a description for each of the cells:

CONSTRUCTION CHARACTERISTICS	LEAN ENTERPRISE PRINCIPLE: Customer pull
Long lifecycle	Products will last for a long time. This favors customer pull because the customer will have "to live" with the product for a long period of time. He will prefer deals where he can demand customization.
Site production	You have to adapt to the customer's site so in a way you are already adapting to the customer's specific requirements.
Build to order	You are customizing the product to each customer. This characteristic already takes into account the importance of the customer as "true north".
Projects need outside financing	Many times the customer does not have the money to finance the project. Financers can be viewed as helping the customer but at the same time limiting its desires.
Complexity of project organization	The complexity of the organization makes it difficult to hear the "voice of the customer".
Fragmented	The fragmentation involves more competition so it is good for customer pull. It empowers the customer.

CONSTRUCTION CHARACTERISTICS	LEAN ENTERPRISE PRINCIPLE: Deliver value to all stakeholders
Long lifecycle	Products will have a big impact on the owner and the end user in the long run (huge lifecycle). Construction industry does already try to address this so typically the owner and end users have a lot to say.
Site production	Site production is not relevant to delivering value to all stakeholders.
Build to order	This characteristic places the customer as one of the key stakeholders.
Projects need outside financing	This characteristic adds a new stakeholder to the picture (the financier); it will also be required to satisfy him.
Complexity of project organization	There are usually many stakeholders so it can be a difficult task to align everyone's interests.
Fragmented	It will be difficult to have "everyone on the same boat".

CONSTRUCTION CHARACTERISTICS	LEAN ENTERPRISE PRINCIPLE: Seek stability of demand
Long lifecycle	Because the company is engaged in a project for a long time, this favors a closer relationship with the customer which might make easier to have a steady demand in the future (if you do the work right). It gives you a chance to build up customer loyalty.
Site production	Site production is not relevant to seeking stability of demand
Build to order	By building to order you first sell it and then build it. This allows you to control better the demand.
Projects need outside financing	Projects are expensive so making the decision of investing depends a lot on the external economic situation; hence it is difficult to stabilize demand.
Complexity of project organization	Complexity of organization is not relevant to seeking stability of demand.
Fragmented	Having many companies (competitors) does increase instability of demand

CONSTRUCTION CHARACTERISTICS	LEAN ENTERPRISE PRINCIPLE: Waste minimization and continuous improvement
Long lifecycle	Products take a long time to build so the waste reduction and continuous improvement is much slower than in a faster clockspeed industry.
Site production	Site production is not relevant to reducing waste and continuous improvement
Build to order	Build to order is not relevant to reducing waste and continuous improvement
Projects need outside financing	Outside financing is not relevant to reducing waste and continuous improvement
Complexity of project organization	Because teams are temporary it is challenging to translate what was learnt in one project to the next one in a formal way (currently done by personal experiences and best practices).
Fragmented	Difficult to impose this mode of operating to many small companies.

CONSTRUCTION CHARACTERISTICS	LEAN ENTERPRISE PRINCIPLE: Synchronize flows
Long lifecycle	Lifecycle is not relevant to flow synchronization
Site production	It might be more challenging to synchronize flows on a site as opposed to a factory because every project takes place in a new location (logistic issues with the supply chain).
Build to order	It might be more challenging to synchronize flows when building to order because every product will be different than the one before requiring different inputs.
Projects need outside financing	Outside financing is not relevant to flow synchronization
Complexity of project organization	The amount of parties involved involves complex logistics so synchronizing work becomes a challenge.
Fragmented	The fragmentation is not relevant for flow synchronization

CONSTRUCTION CHARACTERISTICS	LEAN ENTERPRISE PRINCIPLE: Mutual trust relationships
Long lifecycle	Stakeholders will be together for a long time in each project so it is in their interests to base their relationship in mutual trust and commitment.
Site production	Different site production means that you will have to build new relationships with local officials and subs, if the company works over a large geographical area this can be a problem.
Build to order	Specifications will be different from product to product so different relationships will be required every time, and it takes time to build them.
Projects need outside financing	Due to the fact that a lot of money is involved in producing each unit (project) it is difficult to have mutual trust relationships.
Complexity of project organization	It takes time to develop mutual trust relationships but teams are temporary (solution: partnering). Also there are adversarial relationships due to the nature of the bidding system.
Fragmented	Having too many companies difficult the establishment of mutual trust relationships.

3.5 Analysis of the matrix

After building the matrix we are now in a position to perform an overall analysis of the interaction between lean enterprise principles and construction characteristics.

The first thing that we can notice if we look at the top left side of the matrix is that several lean principles are already quite aligned with some of the construction characteristics. These principles are customer pull, delivering value to all stakeholders and seeking stability of demand. This alignment is especially strong at the project level (long lifecycle, site production and build to order). This implies that due to the nature of the product that the construction industry delivers those lean principles can be easily applied and in some cases are already satisfied (e.g. the fact that the construction industry is build to order means that the lean principle of customer pull is already satisfied). In other words, the construction industry is really a services business (as opposed to a product business) where most revenues come from special products or projects (customization) tailored for new and existing customers.

The second insight that can be extracted is that at the industry level almost none of the lean enterprise principles are aligned with the construction characteristics.

- Construction is expensive so there is the need for outside project finance. This brings in a new stakeholder that must also be satisfied limiting the wishes of the customer. The financier is a very powerful stakeholder (like the producer in the movie industry) because without him there is no project. Demand will depend on the general economic situation as more or less capital will be available so more or

less projects will take place. In addition the big dollar amount of the projects imply a high risk (everyone has a lot at stake) favoring adversarial relationships.

- The simple fact that the construction industry is fragmented makes lean principles difficult to implement. There is big competition in the market which makes demand hard to control. Mutual trust relationships take a long time because of the low barriers of exit. Finally projects have a huge number of stakeholders (mainly due to the large amount of specialty subcontractors).
- There is high complexity in the project organization, too many stakeholders in the same project that will all change for the next one. This makes things hard to synchronize, stabilize and learn from one project to the next one (continuously improve).

Finally we can say that some of the lean principles, waste minimization and continuous improvement, synchronizing flows and mutual trust relationships) are not aligned at all in any level. These will be difficult to apply in this industry basically because learning takes a long time and there are too many adversarial relationships.

4. Industry Examples

Several companies are already practicing lean principles in one way or another. In this chapter, I present some examples from the industry to illustrate the challenges of implementing the lean philosophy. The examples try to give an idea of the changes that lean enterprise implies from different points of view: a contractor, a developer and an owner.

The first example presents how a powerful global contractor is thriving to reduce its overhead costs by organizing itself in an innovative way. The second example introduces a regional real state vertically integrated company that is trying really hard to create value by considering the construction process in a holistic way with the eyes of the customer. Finally a third example shows how a large owner is changing the name of the game for construction and delivery of airport facilities.

4.1 SKANSKA USA Building, Inc

The giant Swedish contractor SKANSKA AB is a good example of a company, within the construction industry, that is putting into practice some concepts that are close to the lean enterprise principles discussed in this thesis. In fact, the operating principles of SKANSKA USA Building Inc. already underline the basic lean principle of creating value to all stakeholders when it reads “We respect the diversity of our backgrounds as we work together to support the success of our clients, the growth of our company, the empowerment of our people and the interests of our shareowners”.

4.1.1 Decentralization and integration

SKANSKA AB is organized in what it calls a “decentralized/integrated” approach. The rationale for decentralization is that construction and development are local businesses (local projects executed under local conditions). The rationale for integration is to take advantage of some synergetic opportunities such as having one strong brand, shared knowledge, financial strength and economies of scale. The organization of SKANSKA USA Building Inc. (one of SKANSKA AB’s 15 business units) also follows this organizational principle.

Its organization is depicted in the following matrix type of structure (Figure A).

- Vertically it is composed of 14 operational divisions that are geographically located across the US. Each of these operational divisions operates quite independently from each other. In fact, originally they were independent companies that were acquired by SKANSKA in successive steps.
- Horizontally it is composed of several functions with different levels of formality. Among them we can find:
 - Enabling infrastructure processes. To support operating divisions whom they serve as internal customers (traditional corporate support functions).
 - Human Resources, Legal, Communication, etc. These activities are lead by the corporate headquarters and each group is considered very “lean” meaning that they consist of a very small number of

employees in each operational division (maybe just one person) and a reduced number of resources located in the headquarters. Their integration provides great benefits due to economies of scale.

- Accounting and IT. These activities have been centralized in a separate company (100% owned by SKANSKA) that makes sure that the accounting principles and information systems used are the same and consistent in every operational division. The personnel of this separate company physically work at the headquarters and in each of the operational divisions. The structure of these “departments” is still somehow formal (there is an IT director...)
- Centers of excellence. The expertise of the company is shared by a number of employees in specific technical area networks.
 - There are more formal networks like the National Markets Group which include expertise in Science, Technology and Healthcare projects.
 - At the same there are also more “virtual” networks such as Aviation with employees that communicate with each other via the web with very little protocol. In each of the operational divisions there will be a number of employees assigned to each of these “virtual networks”, typically with a leader plus two or three other experts in that particular technical field.

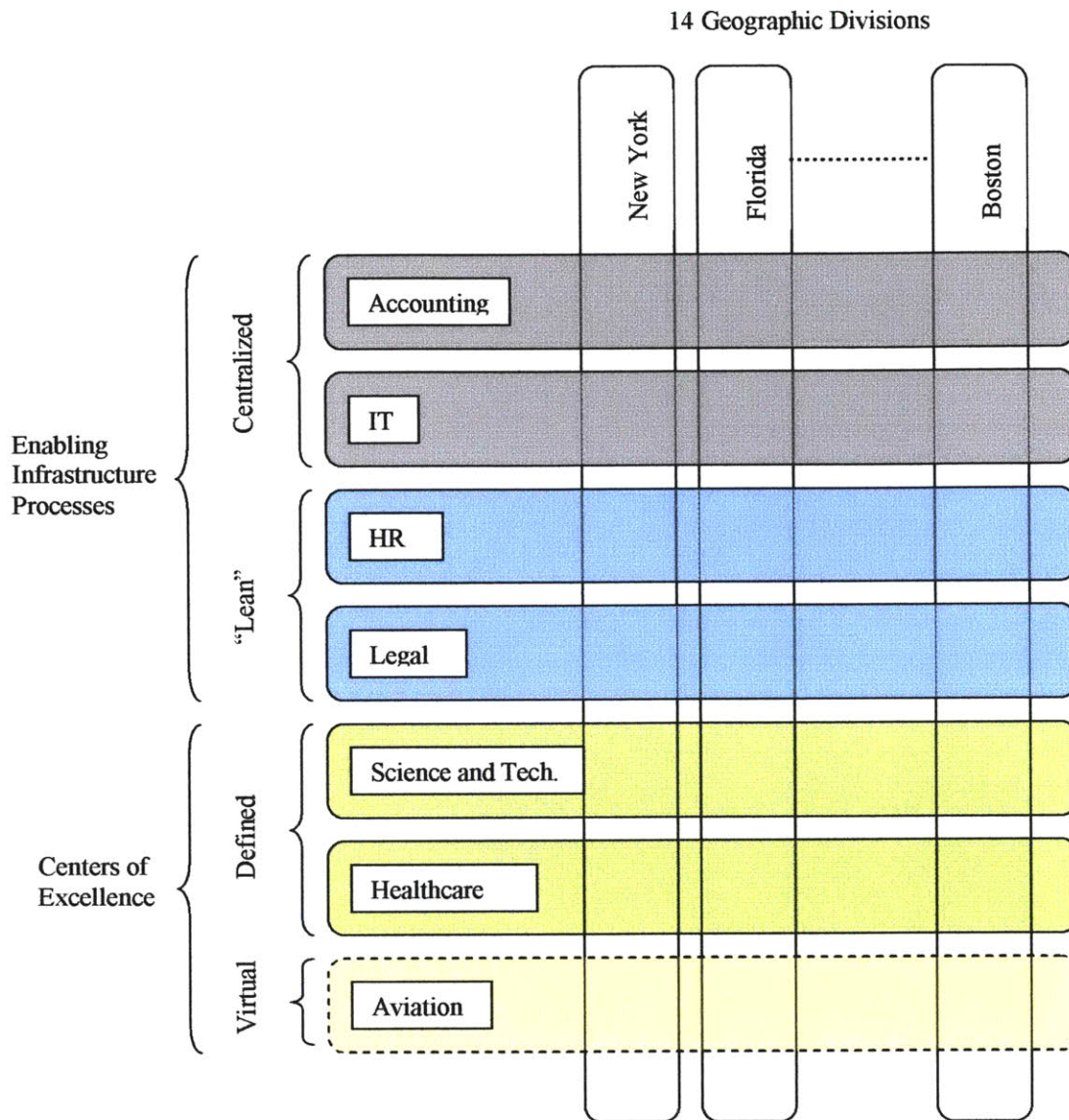


Figure 3. Organizational Structure

This organizational structure, which is still evolving, aims to balance the decentralization and integration concepts. Its virtue is that it allows the operations to take place with a very limited corporate structure. Bottom line, the overhead costs are smaller.

4.1.2 Empowering the individual

Another interesting concept from the SKANSKA business model, which is directly related to lean principles, is the empowerment of the individual. Whenever there is a new business opportunity employees are encouraged to have the individual initiative to call other SKANSKA operational divisions directly instead of using a prearranged system via headquarters. For example, if I belong to SKANSKA New York and one of my customers wants to build a project in Florida I am encouraged to contact somebody in the Florida office directly and work with them to satisfy my customer needs. The important thing is to always maintain client focus. The advantage is that the communication is very fast, the challenge is contacting the right person in the other operational division.

4.1.3 Knowledge sharing

The organizational structure enables technical knowledge to flow across operational divisions. The Centers of Excellence described above are not located in the same physical place. Employees are spread across operational divisions and information is shared. Furthermore, employees could be assigned to a primary and a secondary (somehow related) virtual network of expertise. The advantage would be that, if customer demand falls in your primary network you can instantly start contributing to your secondary network of expertise.

4.2 THE NEENAN COMPANY

Based in Colorado, US it is a major real state developer, designer and contractor in that region. Competitive pricing, on-time delivery and high quality are Neenan hallmarks. Neenan manages site selection and land acquisition. Its architects collaborate continually

with its construction teams, to ensure that the design delivers the most value for the client.

4.2.1 Defining value for the customer

The Neenan Company's proprietary Collaborative Design Process (CDP) identifies scope, price and customers' needs in a one or two-day event that accomplishes what non-integrated competitors require four to six weeks to produce. They bring together key players over the course of one or two days to discuss every facet of the project. With input from the client, subcontractors, industry consultants, financiers, economic development experts and municipality staff, Neenan can conceptually design and estimate an entire project from start to finish. Its package provides scope definitions, guaranteed costs and timelines in just 21 days so clients can move forward quickly to secure financing and start construction.

Their long-term relationships with subcontractors also drive costs down and quality up. Their knowledge, experience and input are tapped early since they competitively price jobs at the preliminary design stage. In this way, they can remedy problems before they cause budget busts or construction delays. They have worked hard to develop mutual respect, sincerity and trust in order to smooth workflows and control costs. Their approach has led to change orders averaging under 2%, one of the lowest in the industry.

The Neenan Company takes a unique approach to design and construction project delivery, which is to work together as one team to satisfy the goals of the integrated real

estate team. They bring the disciplines of Architecture and Construction together to create a methodology for every project they undertake.

4.2.2 Making the construction process flow

They have developed a cutting edge comprehensive job-management tool – the Neenan Reliability Planning System (NRPS). The system is specifically designed to identify and avoid potential break downs, speed progress and eliminate wasted effort. This system is based on a workflow model with a master schedule format that contains all the major project milestone phases and activities. Then they derive eight-week look-ahead schedules and team weekly work plans from this master schedule that allow them to accurately plan and track all project design and construction tasks and deliverables. They have increased their reliability on projects to levels that exceed the construction industry average by a factor of two, utilizing this planning system.

Through the use of NRPS and client collaboration, they are able to maintain project design/construction budgets and schedules with a great deal of success, resulting in competitive pricing. They procure all its subcontractor services through a three-phase (Design-build/Long lead, Midstream and Commodity) procurement process and utilize a competitive Request for Proposal (RFP) format to solicit pricing and select subcontractors and suppliers.

4.3 BAA plc

Based in United Kingdom is considered as the world's leading airport company. Some of the key features of their business are:

- It owns and operates 7 airports in UK (including Heathrow, Gatwick and Stansted which work as one integrated airport system making London the world's number one air travel destination).
- It has management contracts or stakes in other 11 airports outside UK (Indianapolis in the USA, Naples in Italy, Seeb and Salalah in Oman and six airports in Australia).
- It has retail management contracts in two airports in the US - Pittsburgh and Boston Logan.
- All their airports serve around 200 million passengers worldwide, including over 120 million in the UK. One in five of the world's international air passengers travel through their UK airports.

Their capital investment program spends around £2 million a day which makes it one of the UK's principal developers of infrastructure and one of the construction industry's largest customer. This has encouraged them to revolutionize the way they spend their money and the construction industry in particular to adopt sweeping changes in the way that major projects are handled. The cost of construction in Britain is among the highest in the world and they constantly need to upgrade and develop its infrastructure to meet the growing demands for air travel. As a result, they are driven to ensure that their airport facilities are built more efficiently and at a lower cost, without compromising on safety and the environment. To achieve this they are striving to change the way the construction industry handles major projects such as new airport infrastructure.

They are the first company to be honored with an award from the International Air Transport Association (IATA). Presenting BAA with the Partnership for Productivity award, IATA ranked them above its competitors for controlling infrastructure costs while providing airlines with quality of service and value for money.

5. Conclusion

Basically there are two approaches for applying lean to the construction industry: at the project level and the enterprise level. Extensive research has been done in the last decade regarding the application of lean production principles to the construction industry at the project level (Koskela, Tommelein, Ballard and Howell), most of which is referenced in the International Group for Lean Construction and the Lean Construction Institute. The focus of this thesis has been to explore the applicability of lean principles at the enterprise level. In particular I have tried to apply the lean enterprise model developed by MIT's Lean Aerospace Initiative (LAI) to the construction industry. It is time now to summarize key insights from this analysis.

The first conclusion that I would like to point out is that although some benefits can be achieved by applying lean production principles at the project level, greater benefits can be achieved by applying it at the enterprise level. "Do the job right and do the right job". As has been uncovered by the matrix, the construction "production" is already quite lean according to its intrinsic characteristics. You shouldn't look only inwards trying to improve your own operational efficiency as a company, but try to look at the value that the customer wants as seen by him in a holistic way. We as a company would have to collaborate with other companies that add value to the customer in a way in which we can better maximize the customer's overall value. A good example of this idea is in the airline travel business ("Lean thinking" p.32-34). There are around 26 activities when traveling abroad on holiday including different waiting times and documentation processing. More benefits for the passenger will be obtained if all companies providing

the service (airline, travel agency, taxi agency, customs, etc) figure out a different way of providing the service where activities such as waiting can be eliminated instead of just concentrating in improving the efficiency of each of the 26 steps separately.

The lean enterprise model can help the construction industry by allowing construction companies to operate with very limited overhead. The increase in overhead costs has always been a major barrier for the growth of construction companies above a certain threshold size. Once a construction company gets to be too big it also starts having too much overhead costs to continue growing. The current business model doesn't work in the construction industry. The construction industry is really a services business (as opposed to a product business) where most revenues come from special products or projects (customization) tailored for new and existing customers. The key is to understand specific customer needs as opposed to general customer needs. The problem with being in the services business is that it is very labor intensive and hard to scale up without adding people. If you want to grow you need to grow your resources almost in the same proportion. Economies of scope (not scale) are the ones that work in this context.

Lean implementation in the construction industry is not easy. It requires strong leadership to transform a particular company to be a lean enterprise. The key problem is that lean is difficult to understand and has a weak tie to the bottom line. For this reason in most companies top management only has a superficial view of lean. Their continuous support and commitment to lean is absolutely essential for the transformation to happen.

The real challenge is whether it would be possible to change the mentality of the construction industry in order to substantially improve the construction process. Currently there is no clear incentive for the industry to change because the only one really interested in the improvement is the customer whom by the way doesn't have much bargaining power. Only very powerful customers such as BAA who was presented earlier as an example can start imposing lean thinking on the contractors. Furthermore there isn't a big enough player to lead a change in the industry as major companies only account for less than 1% of the total market volume. It imposes a tremendous culture change on contractors, but when a construction firm can be open minded enough to identify and eliminate wasteful internal processes, while working with other project team members to streamline projects, its lean construction journey has officially begun.

The application of lean production principles can not be directly applied to the construction industry. Construction can be conceived as a product development process under great uncertainty. In addition there is a complex set of relationships and interests among the parties involved which makes it difficult to align interests. Companies have to start looking at projects as enterprises where many companies add value to the customer and the goal is to maximize that value.

Lean is a philosophy that introduces stability in a company. The benefits of lean show off in a downturn economic situation by maintaining sales. In an upturn situation other business approaches possibly lead to higher growth. In the private sector the lean enterprise principles can be applied more easily than in the public sector. This is due to the fact that in the public sector projects are awarded using a lowest bidder system

making it impossible to have long term relationships with customers. In the private sector negotiated agreements with innovative delivery formulas (Design-Build, GMP, etc) are far more common.

The construction industry is notorious for wasting substantial amounts of time, money, and effort. With today's still uncertain economy, contractors are increasingly facing pressure to do things better, faster, and smarter than ever before. Indeed, creating an efficient organization today can mean the difference between success and failure for a construction company.

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