

Lean Construction Principles Past and Present – A Business Model Consistency

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Lean construction has been justly one of the most important relatively new trends in the construction industry. In recent years, several tools and innovations became a big part of lean construction, yet overshadowed the lean construction principles. This paper will showcase several past and present experiences to demonstrate that the lean construction success has to be built on a solid foundation of the lean principles. In addition, it needs to be implemented in a holistic approach and not by just using several lean tools to address smaller project components. This paper will also discuss the lean construction as a way of doing business and provide some insight over the management and process implementation as part of consistent lean business model.

Keywords: Lean Construction, Modular Construction.

Introduction

Lean Construction is considered a relatively new concept within the construction industry compared to other industries such as manufacturing. However, several innovations and practices have evolved in this short period of time that became a big part of the lean construction. Some even became very popular to the point that it is commonly, yet mistakenly used as a synonym for lean construction. The most common and trendy innovation is the modular construction that has been one of the most popular construction lean methods that is used all over the world and specifically in manufacturing, healthcare, higher education and public and private office buildings (Schoenborn, 2012).

The modular construction can be a very effective tool within the lean construction approach, but it is commonly misunderstood as the tool that will make the construction process lean just by its sole application. Past and present experiences along with case studies show the contrary. This paper will be discussing past and present experiences in the lean construction process and how using the lean principles consistently as a business model can achieve success.

Lean Concept and Principles

The Lean concept can be best described as an efficient production process which is a combination of concepts such as Just in Time (JIT), Total Quality Management (TQM), supply chain management and others, all which can be tracked to the famous and well known TOYOTA experience (Ohno, 1988; Koskela, 1997). The history of the lean concept can be tracked back to the early 1940s where Ford used flow production charts for the B-24 Bombers and similarly the British used it for the Spitfire production during World War II. However, the lean concepts scientifically stepped into the spotlight through the publishing of the first academic paper published on the Toyota Production Systems (TPS) in 1977 and the Toyota Productions systems book in 1978 (Holweg, 2007).

The lean concept in manufacturing focuses on developing the efficiency of the production process through facilitating a smooth production flow and eliminating waste and unnecessary activities and consequently eliminating errors and rework. A concept which should be very well embraced by construction in a conceptual framework that focuses on the aspects of conversions and flows within the construction process (Koskela, 1992). The transit of the lean production aspects to the construction industry actively began in the early 1990s through several research and scientific studies (Koskela, 1992; Ballard & Howell, 1994; Howell & Ballard, 1994).

Koskela's study in the Center for Integrated Facility Engineering (CIFE) at Stanford University in 1992 established the basic first principles of lean construction. These basic principles dedicated to the construction flow process design and improvement to a more efficient process. Below is a summary of these basic principles (Koskela, 1992):

- 1- Reduce the share of non-value-adding activities (waste).
- 2- Increase output value through systematic consideration of customer requirements.
- 3- Reduce variability.
- 4- Reduce cycle times.
- 5- Simplify by minimizing the number of steps, parts and linkages.
- 6- Increase output flexibility.
- 7- Increase process transparency.
- 8- Focus control on the complete process.
- 9- Build continuous improvement into the process.
- 10- Balance flow improvement with conversion improvement.
- 11- Benchmarking.

The 11 principles mentioned above, form the major foundation of lean construction. The lean concept also developed several methodologies and tools for attaining lean production. Among those tools are JIT which is a strategy to produce and deliver products in small quantities with short lead times which eliminate a lot of process waste in storage, handling and re-handling (Pheng & Shang, 2011). Also, a lot of other tools are used under those principles such as Total Quality Management (TQM), concurrent engineering, value based management, employee involvement and a lot more that are being added to the lean toolbox. One of those recently added tools is the modular construction.

Modular Construction as a Lean Tool

Since construction speed is embodied in the lean construction concept, tools such as modular construction are very important in achieving the lean process goal with respect to adding value and eliminating waste. Even though the modular construction is considered a new, developing trend in lean construction process, modular construction has a long history of existence which dates back to 1850s when the balloon framing system revolutionized the construction speed in U.S and Canada. Also, in the early 19th century where Sears, Roebuck & Co. home builders were producing home kit assemblies that presented the first mass production of modular homes in the history of U.S from 1910s to 1940s, then WWII comes in to revolutionize the modular buildings even further (Marquit & LiMandri, 2013).

The Modular construction is a tool that have many advantages that contribute to the lean construction and build on the lean principles foundation. Some advantages of modular construction include; (NRC, 2009; Tam, Tam, Zeng & Ng, 2007; Yahya, 2010; Yahya & Mohamad, 2011):

- 1- Increase the speed of the overall construction process
- 2- Less waste throughout the whole construction process
- 3- Increase labor productivity
- 4- Improve work supervision
- 5- Less environmental impacts such as weather
- 6- Smoother construction schedules
- 7- Less material storage and handling requirements
- 8- Increase worker safety and less risk exposure

The advantages of the modular construction have become even more popular due to their contribution to the concepts of recycled materials usage in the process and the BIM (Building Information Modeling) that improves the communication aspect of lean within these modular or prefabricated construction (MBI, 2010; Hao, 2012; Lu & Korman, 2010). Thus, modular construction is very useful in lean construction process when it comes to increasing productivity and reducing/eliminating waste.

Lean Construction Success Stories - Past and Present

One of the most successful lean construction stories of the past which used a lot of the previously mentioned tools aside from the modular construction, was the Empire State Building. The building which stood as world's tallest with 381 meters (1250-foot), 102 stories was completed and opened in 1931. The building frame construction rate was more than one story a day at its peak production rate. The building took 20 months from the contract signing (September 1929) to the building opening (May 1st, 1931) (Willis & Friedman, 2007).

Although the lean construction concept officially came to light in the 1990s, the Empire state building has totally embodied the lean concept in early 1930s and used a lot of the lean tools that lean construction uses to achieve its goal. Tools such as JIT delivery was used in the form of pull system where designers would work on detailing several floors at a time as work package. Then they provide those drawings to the steel fabricators for detailing "just in time" (Ghosh & Robson, 2014). A lot of other tools were used such as concurrent engineering, time - based competition and project controls. The tools without specifically naming them, were used in this lean process in the form of controlling the project supply chain represented in suppliers, manufacturers and subcontractors along with other stakeholders. In addition, it was used in the form of setting progression pacemakers for the projections to establish a predictable efficient workflow (Ghosh & Robson, 2014). Much of the literature has discussed the lean construction aspects of the Empire state building including all the tools mentioned in a very detailed manner along with the amazing unusual speed, organization and a smooth construction process (Tauranac, 1997; Willis & Friedman, 2007; TroyMedia, 2010; Sacks & Partouche 2010; Ghosh & Robson, 2014).

Another recent success story on the east side of the world that also demonstrated the efficient use of the lean construction concepts using the right tools is the construction of the T-30 Hotel in Changsha, the capital of central China's Hunan Province in 2011. The T-30 Hotel is a 30-storey, 183,000-square-foot hotel, built in just 15 days, or 360 hours (45 8-working hrs. day). The T-30 Hotel was built on Dongting Lake, by Broad Group, a Chinese construction company which specializes in sustainable construction. It was built to withstand a magnitude 9 earthquake, as tested by the China Academy of Building Research, who claim this is five times more quake-resistant than conventional buildings. Most of the building was prefabricated according to the specifications offsite with just in time deliveries. The main building structure was built in 46 hours. The building has a world class soundproof and thermal insulation along with air quality monitoring for every room to overcome some pollution problems. The building project also had a great safety record with zero injuries on the project (Mackenzie, 2012). The Ark Hotel was another similar project that was done before in the same manner by the same builder. The project as a whole used 6 times less material and ended with extremely less waste which is about 1% compared to the building industry average of 10%. The building is considered to be 5 times more energy efficient than its counterparts average energy consumption (Porwal, 2010). These recent projects also enjoyed tremendous success similar to the Empire State building using the lean principles and more advanced tools such as BIM and advanced modular and prefabrication innovations.

Apparent Lean Construction underachieving Stories

In contrast, there have been some experiences which can be considered a failure by several project performance standards. One of the prime examples is what was supposed to be the world's tallest modular Tower referring to the Atlantic Yards Tower B2 in Brooklyn, N.Y. This project was supposed to be the leading model for the lower cost, faster modular construction with 32 floors, 322 feet tall and a 346,000 gross square feet. The project in progress should house 363 rental units, 4,000 S.F of ground retail and 15,000 SF of Arena storage in addition to 146 parking spaces and a silver LEED certification achievement. The project is focused on the use of one of the most popular lean tools represented in the modular construction. Using modular construction, the project was projected to be completed within 20 months instead of a conventional construction schedule of 30 months saving 10 months in the process (Forest City Ratner Companies, 2012).

After about a year and a half from the construction commencement, only five of its 32 floors have been erected, making it one of the slowest-moving projects in Brooklyn which is a city with a tremendous need for housing (Bagli, 2014). As of September 2014, only 10 stories have been up, the project is way behind the proposed schedule, way over budget and reached a halt resulted from litigation issues for contract termination between the GC/CM and

the owner/developer. The project is also having some technical problems such as leakage along with other issues (Dailey, 2014).

Differences between the successful and underachieving experiences

As a result of the opposing experiences discussed, a three part question should be raised. What are the similarities between the past and present success experiences represented in the Empire State building and the T-30 or Ark Hotels? What are the differences between the successful experiences and the underachieving ones? And finally what is the difference between the T30 and Ark hotels and the Atlantic Yards B2 tower experiences even though they both extensively used the same lean tool of the modular and prefabricated technologies?

The answer to those questions is two parts. First, is discovering the similarities between the success stories in the past and present and second, is the demonstration of the differences between the two present modular construction emphasis projects.

The similarities between the Empire State building experience in the past and the T-30 and Ark hotel experience in present is actually way more than a project experience similarity, it is actually stemmed from the culture of the corporation and the lean way of doing business of the companies that executed those projects.

As for the Empire state building, one of the key stakeholders “John J. Raskob” brought the automobile industry manufacturing concept into the construction. Even though the most innovative and modern tools of lean construction such as BIM and modernized modular construction was not yet founded, Empire state Inc. was using a solid foundation of the lean principles mentioned earlier in building construction of the Empire state building. They understood that the project scope is beyond the effort of architects alone and included the owners, contractors, engineers, consultants and rental agents in the design process reducing the unnecessary reiterated multiple efforts and applying the first and foremost concept of the lean construction which is to reduce the waste within the process. They increased the output value through systematic consideration of customer requirements by translating those requirements into the project design criteria. They reduced the variability of the workflow for the most dominating resource of the project construction by procuring steel from multiple suppliers to avoid any backlog based on each’s capability (Ghosh & Robson, 2014). There were a lot other lean principles that were being utilized in the Empire State building project such as benchmarking and the production of design variation that increase flexibility and their efforts to reduce cycle times.

Similar to the Empire state building yet a more recent experience. The builder of the T-30 and the Ark hotels is Broad Sustainable Building CO., Ltd (BSB), a lean builder with an added sustainability dimension to all their projects which is inseparable of lean, since reducing energy consumption and preserving the environment is one of the ultimate longtime waste reductions. BSB’s record breaking highlights are the 15 story in 48 hours Ark-hotel in 2010, the 30 story, less than \$1000/sq. meters in 15 days T-30 hotel in 2011 along with other projects like a 6 story dormitory that was built in 5 days, the 25 stories T25 tower that was built in 17 days in 2013 and several other projects. Like the Empire state building Inc., this company is based on the lean principles. They use the customer requirements to add to their product value during their design phase working with collaborative entities that included all the project stakeholders. They reduced much of the process variability by taking on the factory controlled working environment to develop most of their prefabricated sections. They broke down every process within the construction phase to eliminate waste and reduce the process cycle time. They also focused on the complete process control not just the prefabricated skeleton so that they can attain a holistic completed lean project (BSB, 2014). As a result of using a lean business model approach, BSB has been fairly consistent with its project quality since most of its buildings showed a high magnitude earthquake resistance, relatively low construction and maintenance costs, environmentally friendly and high air quality along with significantly very low construction waste and amazing safety records (Alter, 2013). As a further result, using the right innovative tools of modular construction, BIM, JIT and others have been a success story in the BSB projects.

In contrast, the Atlantic yards have been focused on the tool more than anything else. All what was advertised and planned for what was presumed to be the tallest modular construction tower is the lean tool that was supposed to be less expensive, faster and save about one-third of the conventional schedule. However, a closer look at the project will reveal that the lean principles were not really a base for that project. From the beginning, there was no process

transparency or a buy in from major project stakeholders much less the future customers represented in the community public representatives of the city of Brooklyn (DEVELOP DON'T DESTROY BROOKLYN INC., et.al. against EMPIRE STATE DEVELOPMENT AND FOREST CITY RATNER COMPANIES, LLC., 2009). This also failed the concept of increasing the output value through systematic consideration of customer requirements.

Although the modular tower is one of the most important components of this project. The project as a whole was planned to be over more than a decade of construction. However, the Empire State Development Corporation (ESDC), which is supposed to oversee Forest City Ratner's Atlantic Yards project, only looked at the environmental impact of 10 years' worth of construction even though the development agreement between the agency and the owner withheld from the public earlier actually allows for construction to continue for 25 years. The potentially serious effects of that longer period were never analyzed by ESDC (Herman, 2010). This project did not take the lean principles as a solid foundation from the start and didn't establish the right business model to handle this project in its long construction process, yet they tried to solve some of the issues they are facing in this project using certain lean tools and innovations that are focused on smaller pieces within the whole process. As a result, the project is more of an example of litigation, contract breach and community revulsion, instead of a success story.

Conclusion and Discussion

As demonstrated in the examples above, the Lean approach has to be adopted as a holistic system based on the solid foundation of the lean principles. Therefore, like any new approach, it has to have the commitment from the top management as one of the main concerns to make the lean system as part of a company's culture and changing the way of doing business. In many cases, failure to do so will result in some individual trials to implement some lean tools here and there on a need-basis. Even though they might succeed with some of these tools occasionally, sooner or later they will clash with the conventional ways of doing business and when everything comes together, it often ends up in major setbacks. This is why certain aspects of the construction business model have to be changed to meet the lean model concepts.

The construction business has been taught and inherited as a project oriented focus based on meeting four main goals represented in scope, budget, schedule and quality in addition, to the safety component. Even though those goals have to be met, a more customer oriented lean model can surpass those simple goals, add value to the customer and improve the overall process. A lean-driven business model should establish a customer focused strategy that increase/add value to the customer and reduce the waste and risk in the process. Like any business, the main three elements of the construction business are the resources, the process and the management. The resources in lean are mostly about eliminating the waste component that can be represented in the form of waiting time, motion time, over processing, transportation, storage, correction and most importantly underutilized resources whether it is human resources, building material or equipment. The management and process lean approach can be summarized as in Table 1.

Table 11.

Difference between the conventional current business model and the lean business model in terms of management approach and process implementation

Management Approach		Construction Process	
<i>Conventional Model</i>	<i>Lean Model</i>	<i>Conventional Model</i>	<i>Lean Model</i>
Phased and individual approach	Collaborative approach	Project dictates the process	Continuous effort to standardize the process
Deliver the project	Deliver/meet customer needs	Linear process	Concurrent (multi-level)
Individual risk management or transfer	Shared risk and reward approach	Trade-based interrupted flow	Continuous flow
Lean is a tool	Lean is a culture and a way of doing business	Separate logistics	Shared integrated logistics

These many differences in the management approach and implementing the construction process can definitely change the outcome of a company's culture yet alone the project lean successful outcomes. This paper re-establishes the founding principles of lean construction and demonstrates the difference in a company's management and process implementation that can be the real distinction between success and failure of the lean application. Finally, it is of utmost importance to stress that lean model is a holistic approach and construction companies should start to implement the lean approach as a system and a way of doing business, not as a tool. Thus, the modular construction can only be successful if it is used as a tool for the execution of a holistic lean process that have a foundation of the lean principles.

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