

# Analyzing the Empire State Building Project from the Perspective of Lean Project Delivery System

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The Empire State Building was the tallest building in the world when it was officially opened on May 1, 1931. It held that distinction for over 40 years. In 20 months the building was designed, engineered, permitted, demolition of an existing building completed, and the building constructed. In order to complete the Empire State Building under the allotted 18 month schedule, Starrett Bros. & Eken, the contractors employed innovative construction methods and techniques. Many of these construction methods qualify as tools of lean construction practiced in today's construction industry. Comparing the design and construction processes employed by Starrett Bros. & Eken with the theoretical constructs of Lean Project Delivery System (LPDS), it is evident that several lean construction principles were employed during the construction of Empire State Building, a quarter of a century before lean concepts were formalized. Using archival records and historical accounts, this paper examined the design and construction processes of the Empire State Building and compared them with the LPDS processes that are increasingly employed in the construction industry today.

**Key Words:** Lean construction, Project management, Project delivery methods, Planning

## Introduction

The Empire State Building is arguably one of the most famous buildings in the world. It was the tallest building in the world when it was officially opened on May 1, 1931. It held that distinction for over 40 years. In 20 months the building was designed, engineered, permitted, existing buildings were demolished, and the building constructed. At the peak of construction, framework rose 4 ½ floors a week. The Empire State Building was completed on time and under budget. The contracts with the architects were signed in September 1929 and the first structural columns were set in April 1930. Only one year later, the building was fully enclosed, with a height equivalent to 102 stories and 1.2 million square feet of rentable space (Willis, 1998).

In a project such as the Empire State Building, where 57 thousand tons of structural steel and over 62,000 cubic yard of concrete were erected involving almost 3500 workers on peak days (Willis, 1998), the approach to design and project management played a crucial role for the successful completion of the project. Designers and contractors view any construction project as a transformation process where total production can be broken down into smaller production units, and the total production can be managed by managing the smaller units. The inherent problem with this approach is the failure to acknowledge the interdependencies of the smaller units, as if those units are independent from each other. The Empire State Building project, an anomaly to the traditional practices of design and project management strived to adopt a production management based approach to design and construction. The paper argues that the management philosophy of the Empire State Building was rooted in what has come to be referred as lean construction, and bears a close resemblance to the Lean Project Delivery System (LPDS).

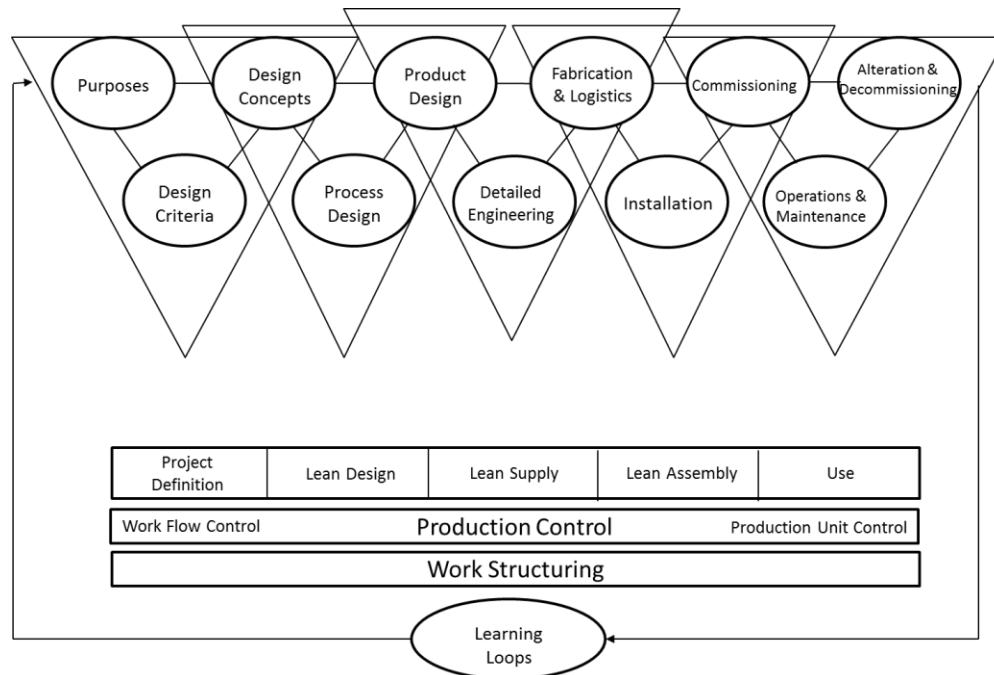
This paper analyzes the design and construction of the Empire State Building project from the perspective of LPDS. In the following sections, the paper presents the conceptual framework of LPDS, discusses how it is different from the traditional approach, and illustrates the resemblance of the production process of the Empire State Building Project with that of LPDS.

## Lean Project Delivery System (LPDS)

LPDS has been designed as a framework for a production management based approach to design and constructing capital facilities in which "the project is structured and managed as a value generating process" (Ballard, 2000). The

main intention of LPDS is to provide rules for decision making, procedures for execution, and tools for implementation of production management. Within the lean construction paradigm, a construction project is envisioned as a “project based production system” where resources and value-engineering processes are strategically arranged for new product development.

The LPDS framework (Ballard, 2003) consists of 15 modules, 11 modules are organized in five interconnected triads or phases extending from project definition to design, supply, assembly and use. Two additional production control modules and the work structuring module are conceived to extend through all project phases. The post-occupancy evaluation module, which links the end of one project to the beginning of the next, completes the learning loop (Fig 1).



*Figure 1: Framework of Lean Project Delivery System (LPDS) (Ballard 2003)*

While the individual components contained in the five interconnected triads are considered by the authors to be self-explanatory to the audience of this paper, the two other components that warrant additional discussion are work structuring and production control. Work structuring in lean construction is defined as developing a project’s process design while trying to align engineering design, supply chain, resource allocation, and assembly efforts (Ballard, 1999) with the goal of making “work flow more reliable and quick while delivering value to the customer” (Ballard, 2000). At the beginning of project, work structuring focuses on designing the overall system. As the project progresses, the focus shifts on to guide the design and execution of interdependent work. According to Ballard (1999), work structuring views a project as consisting of ‘production units’ and ‘work chunks.’ Production unit refers to an individual or group of workers (of any skill) that share responsibility of direct production of similar work. A work chunk is a unit of work that can be handed off from one production unit to the next. Production units continue adding value to a work chunk until it becomes completed work. The handing off of work chunks also bears significant meaning in the context of work structuring. Hand off specifically refers to the declaration of completion of work chunk by a production unit and subsequent release to the next unit, with the acceptance of the released work by the next unit.

While work structuring produces strategies for successful completion of the project, production control ensures that works are executed as planned. Thus in the context of LPDS, production control is essentially governing execution of planned work and not just identifying variances between planned and actual work put in place (Ballard, 2000).

Production control uses the look-ahead process to manage work flow control and weekly work planning to manage production unit control (Ballard, 2000). Typically, during the project definition and lean design phases, planners (designers, contractors, suppliers, and other key stakeholders) develop and compare various work structures to determine the appropriate combination for that particular project. During the lean supply and lean assembly phases, project participants start executing the predefined work structures. However, these work structures can always be modified by the participants, if they find they cannot execute certain aspects of the selected work structure based on their resource capabilities. This approach makes work structuring an ongoing, adaptive process throughout the project. Finally, during the facility's use phase, project participants determine if the executed work structure successfully met customer needs. The lessons learned from one project are then used to guide work structuring efforts on future projects (Howell & Ballard, 1999). Thus, work structuring and production control are complementary and managed concurrently during all phases of project delivery.

### *Difference of LPDS from Traditional Project Delivery*

The main difference between LPDS and traditional project delivery lies in the way projects are viewed. By traditional delivery method the authors are referring to design-bid-build approach. In the design-bid-build approach, design and construction are viewed as two independent non-overlapping processes. The designers and contractors rarely consider how to manage the entire production system. In general, planners use a work breakdown structure (WBS) to break down a project into work packages to create a framework for project planning, scheduling, and controls. In this approach, designers and contractors view production primarily as a transformation process where entire production can be managed by breaking it down to smaller units, and managing the units. As a corollary to this disintegrated process, designers often leave interface resolution (interface between product and process design) to the contractors (Tsao, Tommelein, Swanlund, & Howell, 2004). While the design of each part may appear to be reasonable and logical upon inspection (MCAA, 2003), the design of the overall assembly may not be optimal. This method fails to recognize the interdependent and dynamic nature of the construction tasks, and does not take advantage of overlapping disciplines. The uncertainties and errors created upstream (during design) may prove to be detrimental to performance downstream (during installation) (Tommelein, Riley & Howell, 1999).

In contrast, LPDS adopts a production management approach and manages the entire construction project as a system. In addition to the transformation view, the primary thrust of LPDS is on flow view and value generation view. The three views of transformation, flow, and value, have been collectively termed "TFV theory of production" (Koskela, 2000). The goal of LPDS is to provide a structured framework that guides project participants to make work flow more predictable and faster while delivering value to the customer (Ballard, 2000).

### **Key Stakeholders in the Empire State Building Project**

The key organizations in the design and construction of the Empire State Building project were Empire State, Inc., the owners, Shreve, Lamb and Harmon, the architects, and Starrett Bros. and Eken, the contractors. These organizations were comprised of many individuals. There were, however, key individuals within each organization that committed their companies to the team approach that was so influential to the success of the project. Their background influenced the management of the project that was close to lean principles, even before lean construction was formalized.

The backgrounds of the key stakeholders were varied and undoubtedly played an important role in the management processes of the Empire State Building's design and construction. The Empire State Building was John J. Raskob, Pierre du Pont and Alfred Smith's first entry into the building/real estate market. Raskob, the driving force of Empire State, Inc., had worked for the du Pont de Nemours Company, and was a trusted advisor to Pierre du Pont. Raskob was a seasoned businessman and advised Pierre du Pont to invest in the stock of General Motors that eventually made du Pont the chairman of GM, and Raskob became the vice-president. Raskob's experience in the automobile industry empowered him to envision construction akin to the manufacturing process. Al Smith provided the public face of the project. His working career included a variety of jobs until he became the governor of New York.

Both Shreve and Lamb were college educated, with Shreve having graduated from Cornell's College of Architecture in 1902. Lamb graduated from Williams College and then attended Columbia's School of Architecture before graduating from Paris' Beaux Arts in 1911. Both joined the architecture firm of Carrere & Hastings and eventually formed their own firm of Shreve and Lamb. Harmon joined the firm in 1929 and it became Shreve, Lamb and Harmon.

Paul Starrett had been employed in the architectural firm of Burnham and Root in Chicago. It was here that he discovered his passion for building while working as a construction superintendent for the firm. Later, working for other general contractor and the War Industries Board he earned his reputation as an efficient builder. Continuous lookout for efficiency perhaps encouraged Starrett Brothers to adopt management techniques that bore resemblance with the lean concepts. In 1922, Paul and William joined forces with Andrew Eken, to form Starrett Bros. & Eken. The key players' careers and management philosophies were developed during a time of rapid change in America - continued industrialization, World War I and the roaring twenties had a great influence on American industry at that time.

### **Comparison with LPDS**

Upon examination of archival documents of the Empire State Building project, it was evident that various aspects of the management of the project bear close similarities with the principles of LPDS. Starting from realizing the importance of collaboration to taking appropriate steps to improve the whole system resonate the underlying principles of lean. The following sections highlight some of the processes adopted during the design and construction the Empire State Building, and compare them with that of LPDS.

#### ***Project Definition and Design Phase***

Empire State, Inc. was quick to realize that the design of the project could not be planned by the architects alone. They assembled an expert team including the owners, contractors, architects, structural and mechanical engineers, elevator consultants, and rental agents was required to collaborate, first to define the problem and then to solve it. This approach of collaborative production and decision making by involving key stakeholders other than the designer from the early stage of the project is suggested by LPDS during the project definition. Further, this provided an opportunity to use inputs from traditional sources for design programming as well as the inputs from the perspective of post-occupancy evaluation from the rental agents. Interesting to note, the requirements of the elevators affected the building's form in both massing and height based on purely economic grounds (Willis, 1998). This approach of design articulates the value generation approach advocated by lean. The importance of the collaboration was realized by the architectural firm of Shreve, Lamb and Harmon; they believed the challenges presented by a project such as the Empire State required the "ability, experience and organization beyond the scope of a single professional unit, or would, if undertaken by the architect's office, involve a duplication of effort and loss of time too expensive to be tolerated in an operation requiring large capital investment" (Shreve, 1930). This resonate the underlying concept of lean project delivery to optimize the system by identifying and eliminating waste in the system.

Unlike the traditional approach, estimations of costing and project duration were integrated with the production of the project definition of the Empire State Building. The design of the project was driven by its schedule. All the design decisions were made based on the owners' requirement that the building be completed by May 1, 1931. This was influenced by the real estate practices of that time when the lease agreements used to be of annual terms commencing on May 1<sup>st</sup> (Willis, 1998). Thus, if the building was not leasable by that date, the owners would have lost one year's revenue from rent. In addition, a longer schedule would add to the running costs of interest and taxes, which were estimated to be \$10,000 per day (Willis, 1998). The tight schedule for the Empire State Building was influenced by these various financial factors, which in turn interacted and produced a complex equation that influenced the building's final form. This concept of translating needs into design criteria has been advocated by LPDS during the project definition phase. However, it is not known whether any formal method of translating needs to design criteria was used (such as Quality Function Deployment). LPDS also encourages the establishment of a target cost whenever appropriate during the project definition phase. Ballard (2000) mentioned that target costs are appropriate for clients whose business case is based on a return-on-investment strategy such as commercial building developers as in the case of Empire State, Inc. That target cost approach was adopted in the Empire State Building

project is evidenced in Starrett's comment: "When the architects made their preliminary sketches, they found that eighty-five office floors reached about the height which could be consumed with the money available."

The design strategies of the Empire State Building resemble various aspects of the lean design process. The main ideology of lean design is to simultaneously design the product and the process – work structuring. In the Empire State Building project, the stakeholders realized the importance of considering the process design along with the product design. As time was of essence, they tried to produce a product design that would simplify site installation. The work structure of the outer shell of the building was designed as an assembly of stainless steel mullions, limestone faced piers, aluminum spandrels, and metal window with the intention to create "a sort of kit of parts that would speed both fabrication and erection." (Willis, 1998). During the design process of the Empire State Building, the expertise of the specialty contractors were utilized for some of the design elements required close collaboration of the design team and the manufacturer. Within the lean design paradigm, the specialty contractors are encouraged to assist in the design process with process design, if not acting as a designer.

To produce a design for the world's tallest skyscraper (at that time) and to ensure it could be constructed in less than 20 months, it was important to design the process itself. The Building Committee of the Empire State Building project simplified the design process so much that they could produce 16 design variations in a span of four weeks' time with an average cycle time of less than two days for each option. Each new design required input from the consultants and revised cost estimates. In this process, every effort was made to maximize customer value in the making of trade-offs between needs and objectives. Finally, the 17th version, Scheme K was adopted on October 3, 1929 by the owners. The contractors, engineers and subcontractors had taken just 2 hours the night before to give their approval to "Scheme K" (Tauranac, 1995).

As suggested by Ballard (2000), the design phase transitions to the supply phase upon the development of the product and process designs from the project definitions, which have translated the customers' needs and stakeholders' input.

### ***Detailed Design Development and Construction Phase***

The phase consisting of detailed engineering of the product design produced during the design phase, followed by fabrication, purchasing, and logistics management of deliveries and inventories is called the lean supply phase. The detailed engineering design of the Empire State Building project was created a few floors at a time, with input from Starrett Bros. and Eken, and then sent to subcontractors and suppliers for detailing and fabrication. To ensure smooth workflow during the production process (to avoid any confusion that might result in delays) the detailed specifications were prepared to express the consensus of opinion and experience of the architects, contractors, the engineers, and the owner, as mentioned by Shreve (1930). Immediately after the preliminary drawings were produced, the architects developed a set of outline specifications. These specifications were sent to the builders, owners, subcontractors and material suppliers for comments and inputs. Decisions reached collaboratively on the working documents, contracts and the job schedule were made with an eye to maximize the value generation.

With the production of detailed design, the design of the production process is also further detailed in this phase. In the lean supply phase, Ballard (2000) recommended the use of lean manufacturing techniques to fabrication shops. Interestingly, due to his background in manufacturing industry, Raskob believed that construction was akin to the manufacturing process. This belief was translated in the form of pull system and just-in-time deliveries being utilized in the construction of the Empire State Building project. Structural steel is a prime example of the pull flow in the project, beginning at the design level. Designers would detail several floors at a time from the bottom up as work chunks and provide those drawings to the steel fabricators for detailing "just in time." Fabrication of the steel began only hours after receipt of drawings and detailing (Sacks & Partouche, 2010). In order to avoid variability of the workflow, structural steel was procured from multiple suppliers so as not to create a backlog based on the capabilities of each supplier.

It is rumored that the just-in-time, pull flow of materials to the site was so efficient that "steel beams arrived from the steel forging plants to the building site too hot to touch with bare hands" (Munson, 2005). Whether this is true or not, it provides a vivid picture of how well the information and materials flowed – from design, to fabrication to

delivery to installation. Due to limited space on the site, inventories were minimized and deliveries were sized so that materials were typically used after no more than three days following their arrival to the site. Prefabricated items were stored at offsite staging areas, pulled to the site when needed and immediately set in place. As described in an article in the New York Times, “trucks drove directly into the belly of the building and the material they carried never hit the ground; it was snatched right off the truck beds and hoisted immediately to the floors where it was needed” (Kelly, 2006). This is as close as it can get to “one-touch material handling” ideals advocated by lean assembly principles.

To ensure predictable supply of materials, Starrett Bros. & Eken kept a close control of the supply chain by pre-qualifying suppliers, manufacturers and subcontractors to determine if they had the desire, facilities, manpower and capacity to accomplish a job of this magnitude. For example, the steel erection was let to Post & McCord, who attacked its problem on its own initiative and worked out a plant layout and performance schedule highly satisfactory to the builder. Prior to and during the construction of the Empire State Building, Starrett Brothers & Eken employed expeditors to determine the production capacities at quarries in Italy, Belgium and Germany, study of railroad facilities to ports and connections with Atlantic shipping. On the basis of the facts thus developed, a production, shipping, milling and placing schedule was worked out (Carmody, 1931).

Lean supply transitions to lean assembly with the beginning of delivery of tools, labor, materials or components to the worksite, or in other words, when physical change in the worksite is visible. In this phase, production control becomes of prime importance to conform execution to previously developed plans and strategies. William Starrett (1928) mentioned that a contractor’s function was “not to erect steel, brick or concrete, but to provide skillful, centralized management for coordinating the various trades, timing their installations and synchronizing their work according to a predetermined plan, a highly specialized function the success of which depends on the personal skill and direction of capable executives.”

Work structuring was applied in the Empire State Building project to create work chunks that facilitated predictable work flow. For example the work chunk for steel erection consisted of two floors at a time, and caulking between steel trim and floor consisted of five floors (Sacks & Partouche, 2010). By organizing the work chunks in this way, unnecessary traffic could be limited and more work could be completed. On a project the size of the Empire State Building, the contractors could have harmed themselves more than they helped if they had not divided the work in manageable chunks. The pace of the entire schedule for the Empire State Building project was controlled by four major structural operations: erection of structural steel, construction of floor arches, exterior metal trim and aluminum spandrel, and exterior limestone. The intention was to control the production of more than 60 major trades grouped into four streams, each led by a pacemaker. In lean assembly, establishing work flow predictability is of paramount importance - a set amount of time for specific activities helps to regulate production levels more than any other technique. The pacemaker approach adopted in the Empire State Building project allowed Starrett Brothers & Eken to know exactly how far ahead or behind they were on any particular task. On a close examination of the schedule, it was evident that time buffers were incorporated for decoupling of tasks (Sacks & Partouche, 2010) with the purpose of absorbing variability in the workflow.

Lean thinking focuses on the elimination of non-value added activities. One such non-value added activity is extra movement performed by a worker to obtain tools or materials that could be eliminated simply by having the materials needed close to the worker when they are needed and located in a place that requires very little effort by the worker to obtain. Methods used on the Empire State Building project to transport materials to where they were needed, when they were needed, were not only innovative, but they were efficient. The site contained 11 derricks – nine of these dedicated to lifting steel and two for large machinery, 17 hoists and two concrete plants. The derricks and hoists took care of the vertical movement of materials and on-site concrete plants allowed for the concrete to be immediately moved to where it was needed as opposed to losing time having to wait on it. Figure 2 below shows the layout of a typical floor. One of the most effective tools on the project was the rail cars that were built and provided the horizontal material transportation. There were four overhead monorail systems used for transporting material to the main floor and narrow railways – with carts that could hold eight times the amount of a wheelbarrow – with a complete loop on each floor. When material arrived on site, it was either lifted upward by a hoist or derrick or put in a rail car and sent to the appropriate floor.

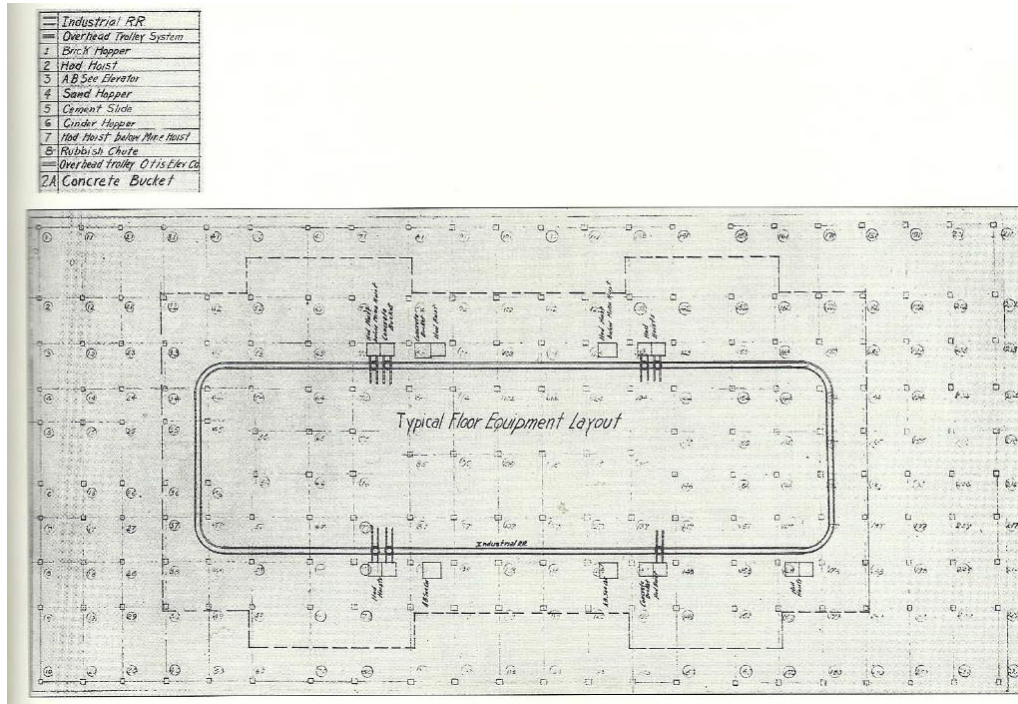


Figure 2: Typical floor layout of the Empire State Building (Willis & Friedman, 1998)

In order to ensure smooth flow of work, Starrett Brothers and Eken realized the essence of “keep moving with a continuous feed of materials to the men” and “getting men and materials present when and where they were needed” (Willis and Friedman 1998). The movement of bricks to the masons was an example of how redundant movements were eliminated to ensure constant feed of materials to workers. Bricks in those days were typically dumped in the street and then the masons would move them by wheelbarrow to the place in which they were needed, as they were needed. For the Empire State Building project this method simply would not have worked. With 10 million bricks to be laid, a more efficient method had to be devised. Answering the need for innovation, the construction team designed a chute that led to a hopper in the basement where the bricks were dumped. When bricks were needed the hopper would release them into rail cars and they would be moved to the correct floors where they were needed.

## Conclusion

The stakeholders of the Empire State Building was guided by the sole goal of building the tallest building in the world and have it completed and ready for tenants by May 1, 1931. In order to achieve the goal, the stakeholders of the project adopted the Transformation-Value-Flow model of production management in place of the transformational model that was prevalent at that time. Empire State, Inc. set up a building committee to make timely decisions in order not to impede progress on the plans and construction. Shreve, Lamb and Harmon made innovative design decisions in consultation with the committee to speed construction. Starrett Bros. & Eken continued to look for more efficiency by improving the system. They were able to realize that in order to achieve their goal they had to focus on the overall system. Thus, they could simplify the overall system of design and construction, and were able to identify the wastes in the system and eliminate them. This simple understanding forms the underlying principle of lean construction. The collaborative team approach, united under the common goal of providing the owner with the tallest building in the world, with approximately 1.2 million square feet of rentable space, in record setting time was a unique concept employed during the management of the design and construction of the Empire State Building.

Comparing the various techniques adopted in the Empire State Building project, it is evident that they bear very close resemblances with that of the lean principles. Interestingly, these techniques were practiced at a time when principles of lean construction were not formalized, or the term ‘lean’ was not even coined.

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