ASSESSING THE IMPACT OF LEAN/INTEGRATED PROJECT DELIVERY SYSTEM ON FINAL PROJECT SUCCESS

by

Mohamed E. Hassan
A Dissertation
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
of
Doctor of Philosophy
Civil and Infrastructure Engineering

Committee:

______________________________	Dr. Michael Casey, Dissertation Director
______________________________	Dr. Mark Houck, Committee Member
______________________________	Dr. Peggy Brouse, Committee Member
______________________________	Dr. Burak Tanyu, Committee Member
______________________________	Dr. Deborah Goodings, Department Chair
______________________________	Dr. Kenneth Ball, Dean, Volgenau School of Engineering
Date: __________________________	Spring Semester 2013 George Mason University Fairfax, VA

Assessing the Impact of Lean/Integrated Project Delivery System on Final Project Success

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

by

Mohamed E. Hassan
Master of Science in Civil Engineering
City College of New York, 1982

Chair: Michael Casey, Assistant Professor
Civil and Infrastructure Engineering

Spring Semester 2013
George Mason University
Fairfax, VA

DEDICATION

To my late father, for instilling in me the value of knowledge and education, and his constant encouragement, support, and understanding which has made this possible. He always encouraged me to learn this lesson: “No money is wasted on your education. Knowledge is the only thing no one can ever take away from you.”

ACKNOWLEDGEMENTS

I would like to thank the many professors who have made this happen: Dr. Michael Casey, who spent many hours reading, discussing, and assisting me in developing my work; Dr. Mark Houck, who advised me on many technical issues and encouraged me to complete the journey; Dr. Burak Tanyu for the time he spent reviewing and commenting on my work and advising me; and finally Dr. Peggy Brouse for all her comments and questions that motivated me to advance with my research. I would also like to extend a special thanks to Dr. Tariq Abdelhamid of Michigan State University for all his help and support and for informing me about Lean Construction. Finally, thanks go out to the Fenwick Library staff for providing a clean, quiet, and well-equipped repository in which to work. I also would like to thank all of the Lean professionals in the Health Care system that provided case studies and made this research possible. Special thanks to United Health Services (UHS) and Turner Construction for their support and participation.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

ASSESSING THE IMPACT OF LEAN/INTEGRATED PROJECT DELIVERY SYSTEM ON FINAL PROJECT SUCCESS

Mohamed E. Hassan, Ph.D.

George Mason University, 2013

Dissertation Chair: Dr. Michael Casey

This research focuses on an in-depth analysis and investigation of lean construction, specifically the impact of Lean/IPD on project success. It also investigates the influence of owner's choice of project delivery system on final project results. It further examines the pattern of Project Success Factors (PSFs) and their impact on productivity, by developing a methodology for a new construction rating system. This methodology was applied to a data collected of real construction projects and used to create the Lean Project Rating System (LPRS). LPRS is a quantitative approach based on the Analytical Hierarchy Process (AHP) and traditional decision theory. The research has

accomplished three goals: First, it has identified 12 Project Success Factors (indicators) and each of their impact on project success which can help in assisting construction stakeholders in improving productivity and induce Lean/IPD practice. Second, it has suggested methods to help eliminate chronic construction problems during all project phases: Conceptual phase, Design phase and Construction phase, and ultimately unify total project success. Third, it created a new tool “Lean Project Rating System (LPRS)” to rate projects in all phases of construction alerting stakeholders on success results and aiding in taking corrective measures to improve final project success.

1. INTRODUCTION

1.1 Overview

Construction productivity, as tracked by the U.S. Department of Commerce, has been constantly declining since the mid-1960s (Teicholz, 2004). The construction industry is a critical sector in the world's economy because it builds and maintains infrastructures on which all other industries depend. However, the construction industry is also one of the most inefficient due to its lack of use of design, product delivery and information technology. Due to the enormous size of the construction industry, small productivity changes can have a significant and direct effect on national productivity and economic wellbeing. The declining trend in productivity is a huge problem that causes billions of unnecessary waste to society. In the United States alone, construction is a $1 trillion/year dollar industry with 30% of waste in the form of time, material, rework, inventory, and over production, amounting to an average of $300 billion per year of construction waste (Bryson, et al., 2010).

There have been many of research studies to identify the factors that contribute to poor construction productivity. The existing traditional construction project delivery system, Design/Bid/Build (D/B/B), has been cited as the primary cause of poor productivity (Ballard, 2000). The use of D/B/B in the past 200 years has created many construction problems. This method of operation is a hierarchy linear system which focuses on non-aligned trade disciplines that prevents designing and managing the project as a whole production system (Howell, et al., 2010). The traditional project delivery system has led to many construction problems such as cost overruns, schedule delays, poor quality, inadequate safety, disputes and litigation. In a recent research study conducted on major projects, surveys concluded that 70% of projects experienced time overruns (Assaf, et al., 2006). Other research studies have reported that owner interference, inadequate contractor experience, improper financing or payments, poor labor productivity, slow decision making, improper planning, and underperforming subcontractors are among the top ten most negative factors that affected productivity and caused many construction problems (Odeh, et al., 2002).

Figure 1 displays the US Department of Commerce labor statistics showing the declining of the labor productivity index in the construction industry in comparison with other industries for the period 1964-2004 (Teicholz, 2004). This graph represents an average for the entire construction industry and shows a major lack of progress in construction productivity when compared with all other non-farm industries. Despite the adoption of new technology by the construction industry in the last 40 years, these applications have not improved productivity. This has been a serious problem causing the construction industry lag behind other industries in developing and applying labor savings.

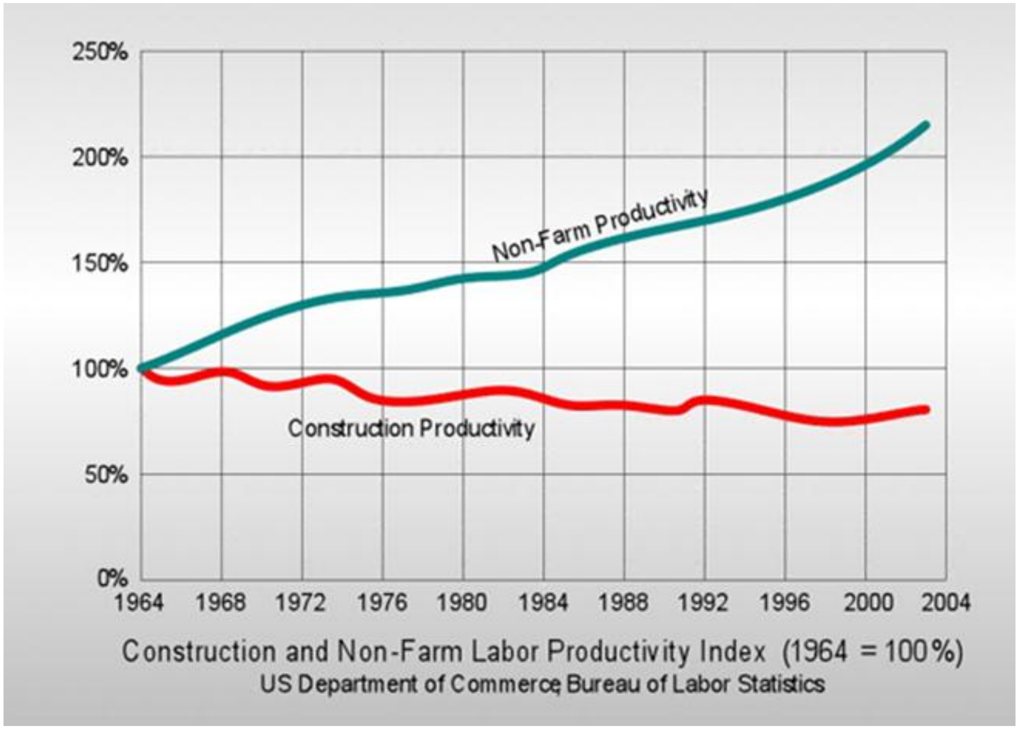


Figure 1 – Labor Productivity Index for US construction industry (Teicholz, 2004)

Figure 2 displays declines in both engineering and construction productivity between 1985 and 2012 (Westney, 2013). The graph shows that the downward trend is continuing and indicates that the decline in both engineering design and construction. Despite the advances in technology, such as GPS machine control, Building Information Modeling, total stations, there are other trends that have resulted in this apparently inexorable decline in productivity. In engineering, projects have been increasing in complexity due the increased expectations of project owners for improvement and efficiency. The sustained economic depression of the last five years has also been a factor causing the decline. Engineering design for complex projects, such as healthcare facilities, has led to a significant increase in engineering data requirements and an increased level of accuracy and precision. In construction, productivity has also been declining. Project execution planning should carefully consider new ways to improve productivity.

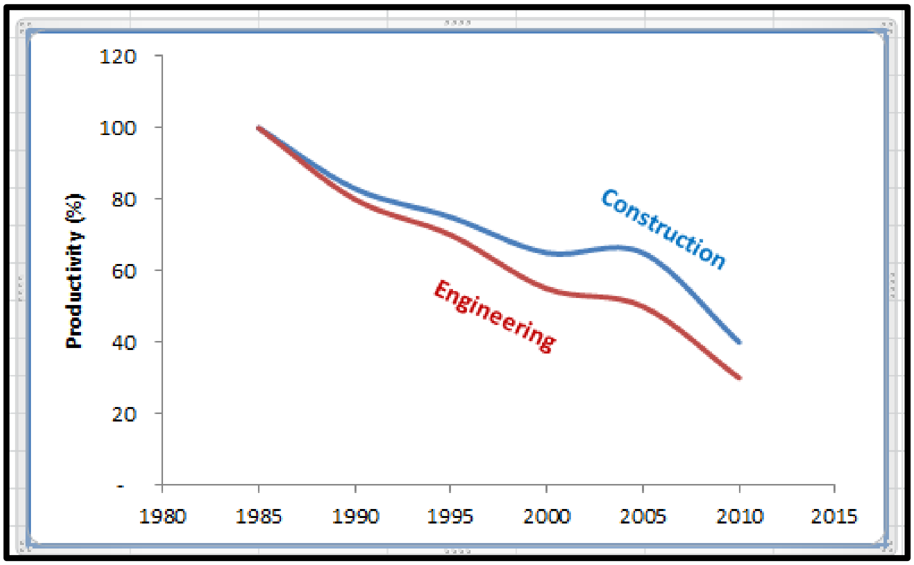


Figure 2: Engineering & Construction Productivity (Westney, 2013)

In 1990, the construction industry started looking to other industries for solutions. Researchers found that in manufacturing, great advances in performance have been realized by a new production philosophy, "lean production". The term lean production was created by researchers involved in a major research project which investigated productivity and management practices in the world motor industry(Womack, et al., 2007). Lean production was being implemented by the Toyota Motor Company in the production of automobiles globally. The Toyota Production system (TPS), as it was called, improved productivity by shifting the attention to the entire production system.

TPS has moved productivity from the narrow focus of craft production and mass production on machinery to a total production system (Womack, et al., 2007). Lean production's main goal is to optimize the performance of the production system by eliminating waste, promoting continuous improvement, and achieving perfection to meet customer value.

The lean concept is composed of five interlocking functions:

1. Product design and engineering
2. Interaction with the customer (through marketing/sales, market/product research, etc.)
3. The supply chain
4. Manufacturing
5. Distribution

These five functions are all interdependent parts of the same system, and ignoring any of them risks failing to achieve the level of success enjoyed by Toyota (Dettmer, 2008). Toyota began eliminating waste from the production process with a vengeance, starting with waste that was obvious and moving later to waste that was hidden. Their philosophy posed two questions, "Where is the waste in the manufacturing system?" and "What's the best way to get rid of it?" (Dettmer, 2008).

Since 2000, the construction industry has attempted to adopt TPS and has developed Lean Construction to help solve construction problems and induce lean practice. Lean construction depends on the same five lean principles introduced by (Womack, et al, 2003). The lean thinking five principles are:

1. Precisely specify value by specific product
2. Identify the value stream for each product

3. Make value flow without interruptions
4. Let the customers pull value from the producer, and
5. Pursue perfection

With the Lean Construction movement, a new project delivery system, Integrated Project Delivery (IPD) was introduced as a method that embraces lean principles to improve productivity by promoting customer value, reducing waste, and maximizing efficiency through all project phases including planning, design and construction. By leveraging early involvement and collaboration of project stakeholders, optimal project success can be achieved. The Lean/IPD term was adopted to indicate that IPD delivery system applies lean principles to reach the ultimate goal of total project success.

In the mid-2000s, Lean/IPD was applied to healthcare construction projects. It was first adopted by the healthcare construction industry because design and construction of healthcare projects required innovation, collaboration and team work. However, applying Lean/IPD project delivery system has produced different success results that have puzzled construction stakeholders. Some projects had excellent results in coming within the owner's budget, achieved high quality but overran their schedule. Other projects resulted in high quality, met the owner budget, came within schedule, but had some problems with collaboration and communications. Some other projects were very successful in meeting the owner's demand within their budget, on time and achieved total stakeholders satisfactions.

This research focuses on an in-depth investigation of Lean/IPD Project Success Factors (PSFs) and their impact on project productivity and ultimately total project success. After investigating the previous research, twelve project success factors (12 Indicators) have been proposed:

1. Initial Team
2. Team Experience
3. Collaboration
4. Communication
5. Target Value Design (TVD)
6. Building Information Modeling (BIM)
7. Last Planner System (LPS)
8. Information Technology (IT)
9. Safety, Building Codes
10. Risk Management
11. Monitoring and Controlling
12. Building Codes

A multi-criteria rating system based on the five lean principles, Lean Project Rating System (LPRS), has been developed that scores the performance of a project during the different project phases: the planning phase, the design phase, and the construction phase. It is designed to identify project success patterns to help construction stakeholders improve project productivity, and also to assist the project team in building better and more successful executing projects consistently.

1.2 Research Hypothesis

The following research hypotheses are presented for evaluating in this research.

Hypothesis (1): Team collaboration and communication has a significant impact on project success.

Hypothesis (2): Lean/Integrated Project Delivery system has a great influence on final project outcome.

Hypothesis (3): Lean Project Rating System (LPRS) can predict project success and help construction stakeholders to improve productivity in all construction phases.

The research will consist of literature review, data collection, analysis, and validation from surveying of construction professionals and stakeholders.

1.3 Research Objectives

The overall objective of this research is to address the currently fragmented and inefficient construction practices by examining existing efforts within the field of construction, specifically in healthcare projects. The research sub-objectives include:

- Identify and categorize Lean/IPD project success criteria and success factors in construction projects based on previous research.
- Elicit industry expertise and practitioners to develop a database of Project Success Indicators.

- Develop a Lean Project Rating System (LPRS) for measuring and comparing final project success.
- Test LPRS on several case studies of Lean/IPD healthcare projects to determine a pattern of success factors.
- Evaluate the impact of team collaboration and communication on the final project success.

1.3 Research Significance

Within the last decade, Lean Construction has been in gradual adoption by the healthcare construction sector, but it has not yet achieved the desired results to solve the many problems that cripple the construction industry. More work and research are needed to produce theories that will improve construction productivity, which is under -researched. The significance of this research is:

- To investigate Lean/IPD project delivery system as a new lean delivery system in the construction industry, specifically in healthcare projects.
- To provide some scientific evidence explaining the different project outcome experienced by owners and stakeholders in applying Lean/IPD.
- To introduce construction rating methodology that can be used and applied universally to the development of project rating system in construction industry.
- To develop a new rating tool, Lean Project Rating System (LPRS), to understand and measure the impact of project success factors on project productivity.
- To alter the behavior of construction practitioners and stakeholders to induce lean/IPD practice.

Figure 3 displays a research flow chart that has been followed to complete this research: First, the research starts by looking into research questions on current construction problems and propose research hypotheses. Second, the research investigates and reviews the background and previous work of the Lean movement. Third, the research review of the current status of construction industry, and all the new theories and techniques to improve its productivity. Fourth, a Survey is conducted to collect relevant data to evaluate the research hypotheses. Fifth, perform data analysis to validate the research hypotheses. Finally, conclusions and recommendations are discussed and summarized.

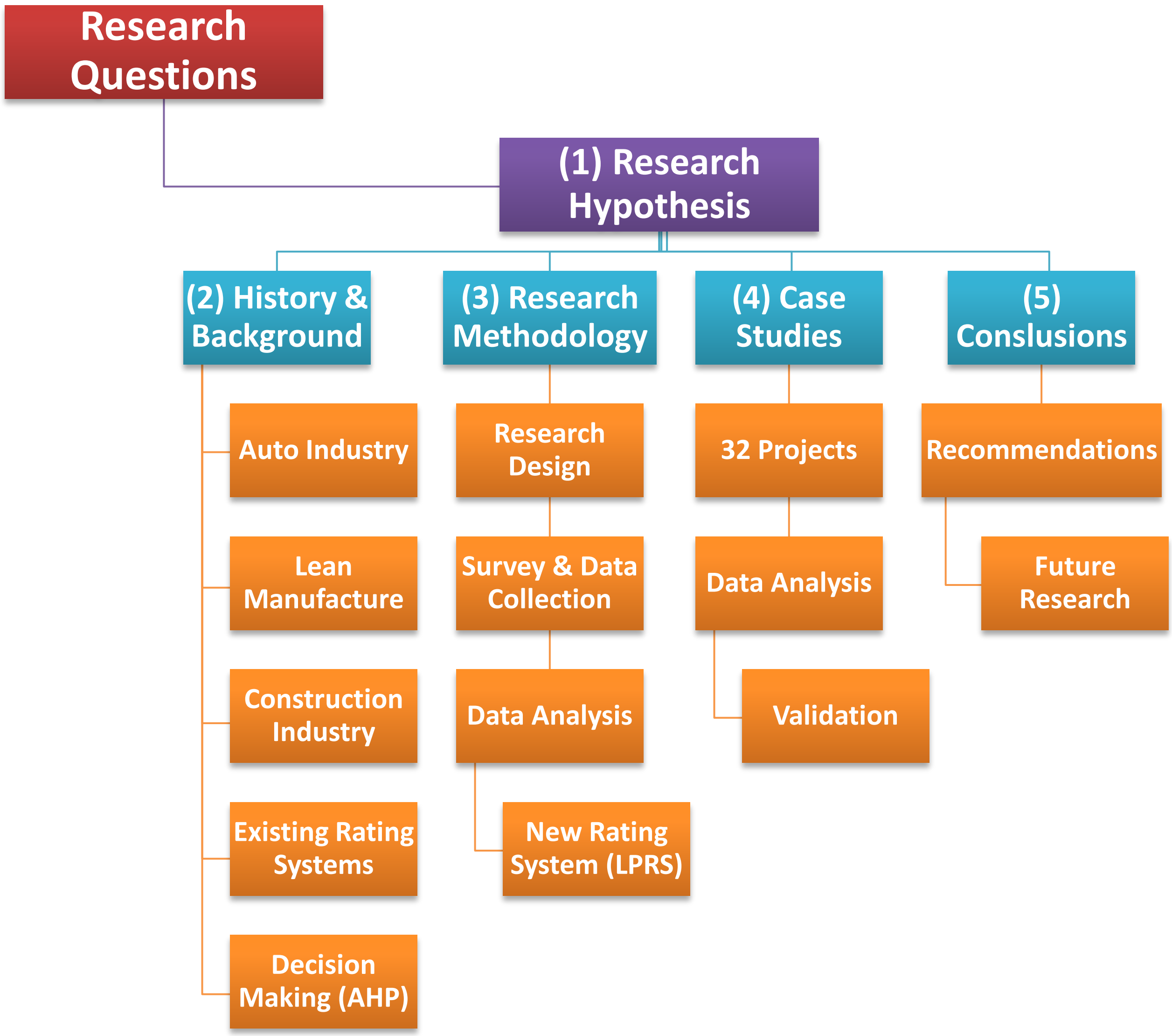


Figure 3: Research Flow Chart

2. PREVIOUS WORK

This chapter focuses on review of the progress of the lean production in the auto industry, latest development of construction project delivery systems, development of previous rating system, and decision making models to develop a methodology for a construction rating system and create Lean Project Rating System (LPRS). Based on the review of the literature on lean production in the auto industry, lean principles that have been adopted by the construction industry to improve productivity can be identified. Review of the latest development of construction delivery systems can help in studying and comparing the effect of the different systems and choose the success factor indicators. Reviewing the development of previous rating systems can help in developing the new construction rating system. Decision making models such as Analytical Hierarchy Process can assist in prioritizing and developing project success factors credit scores.

2.1 Progression of Auto industry and its relevance to lean

Although this research is focused on the Lean/IPD movement to improve construction productivity, the auto industry and its application to lean principles in the past three decades is the basis for lean production. The auto industry is a very important indicator to our evolution toward lean construction. Automobile manufacturing is still the world's largest manufacturing activity, with over 50 million new vehicles has been produced each year (Womack et al., 2007).

Over the last century, the auto industry has undergone three different production transitions:

1. Craft Production
2. Mass Production, and
3. Lean Production.

1. Craft production: is the process of manufacturing by hand, with or without the aid of tools, to produce a unique and high quality product. It was a common method of manufacturing in Europe in the pre-industrialized world.
2. Mass Production: After World War I, Henry Ford and General Motors' Alfred Sloan transformed the world's manufacturing technique from centuries of craft production led by European firms into the age of mass production led by Americans.
3. Lean Production: After World War II, Eiji Toyoda and Taiichi Ohno at the Toyota Motor Company in Japan have pioneered in the concept of lean production (Womack et al., 2007). The adoption of lean production has now spread beyond the auto industry and has positively influenced other industries, thus contributing to their significant progress.

2.1.1 Craft Production in Auto Industry

The era of Craft Production started in 1887, when Emile Levassor of Panhard et Levassor (P&L), a Paris machine tool company, met with Gottlieb Daimler, founder of Mercedes-Benz, and negotiated a license to manufacture Daimler's new high-speed gasoline engine. By the early 1890s, P&L was building several hundred automobiles per year. The workforce was composed of skilled craftsmen who understood mechanical design and assembly principles and the material with which they worked, allowing them to carefully hand build cars in small numbers (Womack et al., 2007).

Craft production had the following defining characteristics:

- Highly skilled craftsmen in design, machine operation and fitting;
- Decentralization of the organization in which most parts of the car came from small machine shops;
- Coordination between owner, customers, employees and suppliers;
- Very low production volume (less than 1,000 cars per year); and
- Very expensive; only those financially fortunate enough could purchase these intricately formed vehicles.

A number of craft production firms have survived up to the present time such as Aston Martin (United Kingdom), Ferrari and Lamborghini (Italy). They continue to focus on tiny niches in the upper luxury cars for customers who desire these unique products.

2.1.2 Mass Production in Auto Industry

In 1903, Henry Ford commenced the production of the original Model A by setting up assembly stands on which a whole car was built, often by one fitter. Within five years, Ford's twentieth design was the T Model, a user-friendly vehicle specifically designed for easy manufacturing. In 1908, Ford had an assembler average task cycle that completed the fitting operation in 514 minutes (8.56 hours). The system consisted of a worker who would assemble a large part of a car before moving on to the next. The assemblers/fitters performed the same set of activities over and over at their stationary assembly stands. The laborers were burdened with the task of obtaining the necessary parts, filing them down for appropriate fitting, then bolting them into place. Soon, Ford assemblers started moving from one vehicle to another to perform a single task around the assembly hall, thus achieving part interchangeability and reducing the manufacturing cycle from 514 minutes to 2.3 minutes (Womack & Jones, 2003).

By the spring of 1913, at Ford Highland Park plant in Detroit, the moving assembly line was introduced, which brought the car past the stationary worker, reducing the cycle time from 2.3 minutes to 1.19 minutes. Eventually, it improved productivity significantly. Ford reached his peak production volume of 2 million identical vehicles a year by the 1920s and had cut costs to the consumer, making cars available to everyone. By 1926, Ford automobiles were assembled in more than 36 cities in the United States and 19 foreign countries; he dominated the world's largest industry by becoming the first to master the principles of mass production (Womack, et al., 2007). Henry Ford had contributed to the greater good of society by creating an affordable car, while at the same time molding the nation's traditions from craft production to the undeniable advantages of mass production.

Henry Ford proposed the term Mass Production in his 1926 article for the Encyclopedia Britannica while many others at the time called his techniques “Fordism” (13th edition, Supply Volume 2, pp. 821-823).

2.1.3 Lean Production in Auto Industry

In 1929, Kiichiro Toyoda, son of Sakichi Toyoda, was sent to England to negotiate the sale of the patent rights of loom spinning and weaving equipment to Platt Brothers. He negotiated a price of 100,000 English pounds for the rights, and in 1930 he used this capital to start building the Toyota Motor Corporation (Liker, 2004). Building small trucks with little success and much struggle to compete within the market, Toyota leaders visited Ford and GM to study the USA assembly lines and took it upon themselves to adopt Henry Ford’s book *Today and Tomorrow* (Liker, 2004).

In 1950, Japan had been devastated by the aftermath of World War II that destroyed many industries, including the automobile industry, leaving suppliers and Japanese consumers without capital. Eiji Toyoda and his managers, including Taiichi Ohno, visited the U.S. for three months to tour the auto industry, inquiring about the manufacturing process there. To their surprise, they found that the production system had not changed since the previous visit in 1930s. They identified many inherent flaws, specifically finding that equipment, inventory, and stored materials overcrowded the system, thus causing workers to struggle to keep the system operative. Toyoda and Ohno noticed that this uneven flow crippled the system, causing overproduction and miniscule, yet crucial defects in the large batches of production.

Returning to Japan, Ohno endeavored to change the rules of the production by applying the fundamentals of a one-piece flow system. With decades of practice on the shop floor, Toyoda, Ohno and their team successfully created the Toyota Production System (TPS). This system is also known as "Lean Production". Lean Production has triggered a global transformation in virtually every industry trying to mimic Toyota's manufacturing and supply chain philosophy and methods over the last two decades (Liker, 2004). By applying lean production, Toyota has become the largest automaker in the world by dominating sales and market shares in every global market. In 2012, Toyota Motor Corporation reclaimed its title as number one automaker in the world rebounding from an earthquake that damaged its factories and embarrassing recalls that dinged its reputation (Dawson, 2013) . Their continuous success created an enormous demand for greater knowledge about lean thinking across all manufacturing industries.

2.1.4 The 14 Principles of the Toyota Way:

In the book *The Toyota Way*, Fujio Cho, President of Toyota Motor Company quotes the keys to a successful system: "The key to the Toyota Way and what makes Toyota stand out is not any of the individual elements…but what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner – not in spurts" (Liker, 2004). The Toyota Way is a system designed to provide tools for individuals to continually improve their work. It is more of a culture than a set of efficiency and improvement techniques through the dependence on workers to reduce inventory, and identify hidden problems, as well as, fix them (Liker, 2004).

The following are the 14 principles that constitute the Toyota Way (Liker, 2004):

1. Base your Management decisions on a long-term philosophy, even at the expense of short-term financial goals: Evaluate every function in the company in terms of its ability to generate value for the customers, employees, the company, society, and the economy as a whole.

2. Create a continuous process flow to bring problems to the surface: Move material and information quickly via a continuous flow and link processes and people together so that the problems surface immediately. Flow is the key to a true, continuous improvement process and to developing people.

3. Use “Pull” systems to avoid overproduction: In the production process, provide your customer with what they want, when they want it, and in the amount they want. Avoid stocking a large inventory; rather stock small amounts of each product based on what your customers actually take away, which is the basic principle of Just-in-time.

4. Level out the workload: The only way to realistically create a continuous flow is to have some stability in the workload, to eliminate unevenness in the production schedule, and to relinquish the overburdening of people and equipment. Strive to level out the workload of all manufacturing and service processes as an alternative to the stop/start approach of working on projects in batches that is typical at most companies.

5. Build a culture of stopping to fix problems, to get quality right the first time: Quality for customers should be the company philosophy driven by stopping or slowing down production to get quality right the first time. This will ultimately enhance the productivity of the company in the long run. Machines with human intelligence and the capability of detecting problems are the foundation for building quality.

6. Standardized tasks are the foundation for continuous improvement and employee empowerment: Standardize the best practice by capturing the accumulated teachings of the process. Allow improvements to the standard, incorporating it into the new standard to permit continuous improvement.

7. Use visual control so no problems are hidden: Design simple visual systems where the work is done to support the flow and pull. This helps others to determine-immediately-whether the work is done in a standardized condition or if there is any deviation.

8. Use only reliable, thoroughly tested technology that serves your people and processes: Reject or modify technologies that conflict with one's culture or that might disrupt stability, reliability, and predictability. Always conduct a practical test before adopting new technology.

9. Grow Leaders who thoroughly understand the work, live the philosophy, and teach it to others: Choose leaders from within your organization who understand the daily work in great detail. They must be a role model in the ways of the company's philosophy and business attributes.

10. Develop exceptional people and teams who follow your company's philosophy: Teach individuals how to work together in teams to achieve exceptional results within company values and beliefs.

11. Respect your extended network of partners and suppliers by challenging them and helping them improve: Your suppliers and partners are the core of your operation and their success will reflect on yours, so help them in achieving higher and better quality, and ultimately success.

12. Go and see for yourself to thoroughly understand the situation: High level managers and executives should develop the habit of going and inspecting things for themselves to understand the situation fully, rather than what other people or reports show or say.

13. Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly: Make your decisions by investigating the problems and all the potential solutions with all of those affected and collect

all the data and the ideas to help contribute to a final decision. Implement the solution quickly but cautiously.

14. Become a Learning Organization, Through Relentless Reflections and Continuous Improvement: Develop principles that are right for your organization, standardize and practice them to achieve high performance that continues to add value to your customers.

The 14 Toyota principles represented by a structure of a pyramid are shown in Figure 4. The pyramid foundation is the long term philosophy principle (principle 1), no quick fix or short term financial gains. The second level built on the foundation is the continuous process flow to eliminate waste, establish pull system, level workload, fix problems, and standardize tasks, visual control, and reliable technology (principles 2 through 8). The third level of the pyramid is People; grow leaders, exceptional people, and respect suppliers & partners (principles 9 to 11). The top of the pyramid is Leadership: go see for yourself, decision making, and learning organization (principles 12 to 14). The 14 Toyota principles are built upon each other and are needed to complete the full pyramid "4 P Model", Philosophy, Process, People, and Problem Solving. Most companies stay focused at the process or tool level during transformation to lean construction, thus missing the long-term success with lean.

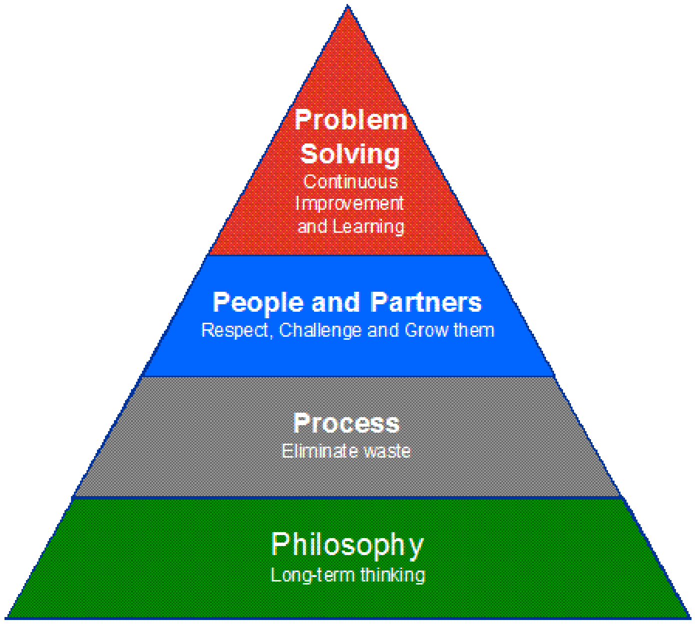


Figure 4 - The 14 Toyota principles (Liker, 2004)

Based on these findings, the following lean principles were developed:

2.2 Lean Principles

Five lean principles were introduced in the book "Lean Thinking" as shown in Figure 5. Lean thinking focuses on how to add value in any manufacturing company or service while simultaneously reducing waste (Womack, et al., 2003).

Figure 5 - Lean Principles (Womack, et al., 2003)

The following are the Five Lean Principles:

1. *Identify Specific Value:* The critical starting point of lean thinking is a value that can only be defined by the customers for their needs and desires; therefore this principle is based on identifying value.

2. *Value Stream:* a step which most companies have rarely attempted to consider, but has always exposed an enormous amount of waste or "Muda" (Liker, 2004). It is the set of all critical actions required to bring a specific product through three critical management tasks:

   - Problem Solving Task: running from concept through detail design to production launch.
   - Information Management Task: running from order taking through detailed scheduling to delivery.
   - Physical Transformation Task: proceeding from raw materials to a finished product in the hands of the customers.

3. *Flow:* Once the value stream for a specific product has been fully specified and mapped by the lean enterprise, and wasteful steps are eliminated, then it is time for the next step, the flow. Flow is the movement of the product through one value by adding steps to the next value and keeping the product in one constant piece flow.

4. *Pull:* The ability to design, schedule and make exactly what the customers want, just when they want it by letting the customers pull the product from the manufacture as needed rather than pushing unwanted products (inventory).

5. *Perfection:* The fifth and final principle of lean thinking is continuous improvement to reach perfection, which is the process of reducing efforts, time, space, cost, and mistakes while offering a product that the customer specifically desires. The most important element in perfection is transparency, whereby everyone can view every aspect of the system.

The five lean principles are the foundation and philosophy of Lean Production because they focus on customer needs and desires by adding value, value stream of production to reduce waste and maximize value, keeping the production as one piece flow to reach perfection.

2.3 Lean Manufacturing (LM)

The adoption of lean principles has spread from auto manufacturing to other industries across the globe. Manufacturers that have successfully adopted lean are enjoying strategic and operational benefits ranging from improvement in manufacturing performance, to better customer responsiveness, and financial improvements. The manufacturers in the high-tech industry are 81% more likely than the general population to have had a Lean initiative in place for more than five years (Shah, et al., 2007).

Lean manufacturing (LM) is considered an enhancement to mass production. Getting the product manufactured right the first time, using continuous improvement efforts, pursuing quality in products and processes, flexible production, and minimizing any kind of waste are the enhancements that produce LM. It is an effective tool for producing the ultimate goal for the manufacture: profit (Motwani, 2003).

Lean thinking can be applied to any industry, including the construction industry. Lockheed Martin Missile and Space Corporation have managed to reduce costs and program cycle times by 50% by applying lean practices into all their satellite production efforts. TRW Automotive Electronics Group adopted lean production reducing labor working days by 81%, time to move raw materials by 61%, increased production inventory by 28%, and decreased capital expenditure by 70% (Motwani, 2003). Many world class companies such as Boeing (largest global aerospace business), Tesco (third largest global retailer), and the U.K. Red Meat Industry have adopted lean principles and applications at their corporate level (Simons, et al., 2005).

In Australia, a study was conducted by the Syme Department of Management of Monash University in collaboration with Smorgon ARC Group to investigate Australian manufacturing companies that implement "lean production". Fifty-one companies participated in the research including: metal processing industry (20 %), food, beverage and tobacco industries (29 %), chemical industries (12%), automotive and transportation industries (10%) and building products industries (10%). The study showed that as a result of the implementation of lean, 74 % of the participated companies had a strategic advantage with the greatest improvement stemming from competitive market positioning, improved customer relationships, and elimination of waste and improved quality constraints. The overall benefits of a lean production system are increasing company flexibility to meet customer needs, the lowering of lead times, greater sensitivity to market changes, higher productivity levels, focusing on performance, improving supplier bonds and changing from reactive to proactive management style (Sohal, et al., 1994).

2.4 Construction Industry

Construction is a high hazard industry that comprises a wide range of activities involving construction, alteration, maintenance, demolition and repair. Construction is a process that consists of planning, designing and assembling infrastructure. There are two types of construction projects: public projects and private projects. Public projects are usually owned by government, state or local authorities that build infrastructure such as highways, bridges, tunnels and dams. Private projects are owned by a private person or an entity which builds private projects such as hospitals, office buildings, and residential projects.

2.4.1 Construction Problems

Construction productivity lags behind that of manufacturing, and the quality of construction is considered exceptionally poor and insufficient with high occupational safety problem (Teicholz, 2004).

Some of the current construction problems are:

- **Cost Overruns**: Also known as a cost increase or budget overrun, it is an unexpected cost incurred in excess of a budgeted amount due to an under-estimation of the actual cost during budgeting. A comprehensive study of cost overruns published in the Journal of the American Planning Association in 2002 found that nine out of ten construction projects had underestimated costs. Overruns of 50% to 100% were common. Cost underestimation was found in each of 20 nations and five continents covered by the study, and cost underestimation had not decreased in the last 70 years for which data were available.

- **Schedule Delay**: Project delay occurs because of many factors such as poor coordination between engineers, poor communication between owner and architect, and delay in the payment to general contractor and more.

- **Poor Quality**: Owners complain about work quality, rework and methods of managing the project which lead to undesired and poor results.

- **Disputes and Litigations:** Disputes between project owners and main contractors or between the main-contractor and sub-contractors about claim, variation order, quality, delay of schedule, can cause many problems to projects.

- **Low Productivity**: According to the Bureau of Labor Statistics, while other industries have recorded productivity increases of up to 250 % since 1964, construction worker productivity has declined by 25%. Another analysis of construction industry productivity found that the average construction worker operates at about 40 % efficiency. More than half of that lost productivity can be traced to delays waiting for equipment and supplies, inefficient company processes, work rules, and congested work areas.

- **Poor Safety**: Construction sites are by nature dangerous. There is a lot of heavy equipment and machinery, and without proper construction safety procedures, accidents can happen.

Many solutions were introduced to solve the chronic construction problems, such as prefabrications, modularization and computer integrated solutions. Although the prefabrication and modularization are construction processes that have been used for centuries, the influence of the new technology and the use of Building Information Modeling (BIM) have influenced the design and construction process and improved the project productivity (Bernstein, 2011). These solutions were to specifically reduce fragmentation in construction, but no major improvements have resulted (Koskela, 2000). Several scholars of construction, such as Koskela and Ballard, have pointed out that the lack of a theoretical foundation in construction is the barrier to construction progress.

2.4.2 Construction Movement to Lean

In 1993, The International Group for Lean Construction (IGLC) was founded, a network of professionals and researchers in architecture, engineering, and construction (AEC) who started the practice, education, and research of lean construction in order to respond to the challenges above. “The distinguishing trait of this group was its emphasis on theory. They held the view that the lack of an explicit theory of construction has been a major bottleneck for the progress in the AEC field. Conversely, they assumed that the clarification of the theoretical foundation of construction, along with principles and methods emanating from the new foundation, would be the most effective means for the renewal of the AEC industry” (International Group for Lean Construction, 2008). The main objective of IGLC is creating a new Lean Construction methodology by holding annual conferences in different parts of the world to discuss many subjects that concern the construction industry. Much success has resulted out of their annual conferences: Eighteen conferences have been held since 1993 hosting many of the world leading engineers, contractors and researchers to share the latest developments on lean construction. The conference has provided an environment in which researchers and practitioners from around the world shared new ideas, created an opportunity to network with an international collection of colleagues, and obtained feedback on research work from a wide variety of perspectives, and presented workshops to enable construction stakeholders to present their research work to an experienced panel.

In 1997, The Lean Construction Institute (LCI) was founded in the USA to research and develop knowledge regarding project based production management in the design, engineering, and construction of capital facilities by maximizing the value delivered to the customer while minimizing waste (Ballard, et al., 2013). LCI define Lean construction as a production management based project delivery system which emphasizes the reliability and speedy delivery of customer value and it challenges the generally accepted belief that there is always a trade between time, cost and quality (Ballard, et al., 2013). During the 20th century, three major concepts of production have been used separately from one another, resulting in the neglect of issues contained in other models: Transformation, Flow and Value generation.

2.4.3 Theories of Production

In attempting to formulate an explicit theory of construction, Lauri Koskela, 2000, in his PhD dissertation, "*An exploration towards a production theory and its application to construction*" introduces a new theory of production. In his exploration, he identified three existing theories of production: Transformation Concept of Production, Flow Concept of Production, and Value Generation Concept of Production.

1. Transformation Concept of Production:

Transformation production has dominated the major part of the 20th century both in practice and science. The transformation process is a linear process that became an analysis of production in large units, while operation became the analysis of production in small units. Therefore, the processes and operations are perceived as a linear operation lying on the same axis; any improvements in the small unit operation will result in improvements in the total process. Transformation is the use of resources to change the state or condition of something "input" to produce outputs required as presented in figure 6. This Transformation from one set of resources to a second set is the Production process (Koskela, 2000). The transformation process can be decomposed into sub-processes that are also transformation processes; reducing the cost of each sub-process can minimize the cost of the total process.

Input → Production → Output

Figure 6 - Transformation Theory of Production (Koskela, 2000)

Building systems for industrialized construction are defined as the collected experience and knowledge in how to realize a construction project, thus as it can be standardized both in technical solutions and in work methods. Figure 7 displays the Transformation process for building design. It shows the different level of the transformation process from project goal in the planning phase to the operation level of the project.

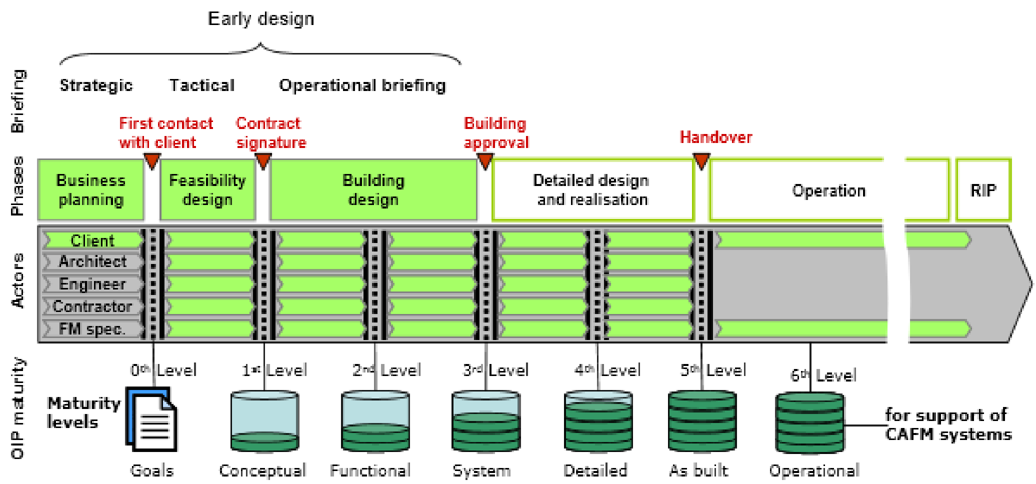


Figure 7: Transformation Process (Jansson, et al., 2009)

2. Flow Concept of Production:

The basic concept of the flow is to eliminate waste from flow processes through the promotion of lead time reduction and variability reduction. Seven construction wastes on construction projects have been defined as follow:

1. **Waiting Waste or Delay**: waiting refers to the periods of inactivity that occur because a preceding activity didn't deliver on time or finish completely. Waiting waste increases cycle time during which no value-added activity is performed.

2. **Motion Waste:** the extra steps taken by people to accommodate inefficient process layout, defects, reprocessing, overproduction or excess inventory which takes time and adds no value to the product or service.

3. **Over Processing Waste**: the unnecessary steps in operations which adds no value to the product or service. Over-processing is often inserted into a process as a result of dealing with defects, overproduction or excess inventory.

4. **Over Production Waste:** when producing more than is needed, faster than needed or before it is needed. This results in product being produced in excess of what's required, products being made too early, and excess inventory carrying costs.

5. **Transformation Waste:** This is unnecessary motion of products or materials that does not directly support immediate production. Ideally transport should be minimized to add time to the process during which no value-added activity is being performed, and the material is exposed to handling damage.

6. **Inventory Waste:** any supply of materials in excess of what is required to build the current phase of the project. Excess inventory can quickly build-up and tie-up money and resources and also requires additional handling and space.

7. **Correction Waste:** products, materials or services that do not meet expectation or conform to specification. Corrections and defects are any work not done correctly the first time and must be repaired, sorted, re-made or re-done, or scrapped due to defects.

In 1988, Shingo introduced a new concept that proclaimed production as a network formed by two axes with similar flow: Process lays on the y-axis and operation lays on the x-axis. The flow concept focuses on how to eliminate or at least reduce non-transformation activities such as transfer, delay and inspection activities (Koskela, 2000).

To improve production flow, Just-in-Time “JIT” was created with the main objective to reduce waste, lead time and variability, and to increase flexibility and transparency.
In controlling the movement of material in the production system, it has been found that the Push system schedules the release of work while the Pull system authorizes the release of work on the basis of system status and requirements.

3. Value Generation Concept of Production:

The Value generation concept focuses on the interaction between customer demands and the supplier value production. Customer value is the benefit that a customer will get from a product or service in comparison with its cost. Product quality, service quality, price, and image shape a customer’s perception of value, as shown in Figure 8. The dimensions of the supplier's value creation in a supplier–customer relationship could be classified according to efficiency, effectiveness and network functions. These functions are interrelated, but they are conceptually distinct. The value creation process could be described as a spectrum ranging from core value, to added value, to future value (Moller, et al., 2003).

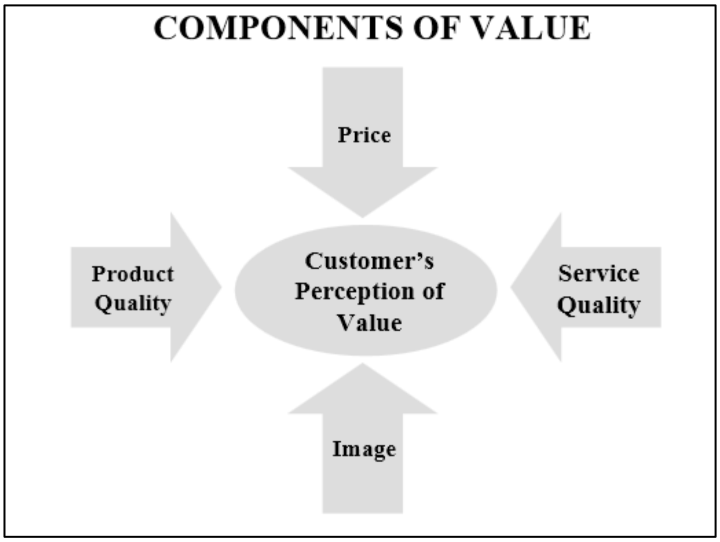


Figure 8: Customer Value

Levitt and Drucker argue that the value of a product can be determined only by the customer, and the goal of production is satisfying customer needs (Koskela, 2000). The transformation of the product itself is not valuable but rather the output that corresponds to the requirements, wishes and needs of the customer is.

Table 1 displays the three theories of productions and their associated principles which identify the focus of each of the theory.

Table 1- Theories of Production (Koskela, 2000)

Main Principles	**Associated Principles**
Transformation View: Realize value adding activities efficiently	Decompose the production task Minimize the costs of all decomposed tasks

Flow View: Reduce the share of non-value adding activities	Compress lead time Reduce variability Simplify Increase Transparency Increase Flexibility
Value View: Improve Customer Value	Ensure all requirements are fulfilled All deliverables to be considered Ensure capability of production system Measure Value

2.4.4 TFV Theory of Production

After investigating the three theories of production, Koskela stated that the three production concepts have been used individually and have not been used in a balanced combination, resulting in the neglect of a good production theory. By integrating the three concepts, Koskela introduced the Transformation-Flow-Value Theory of Production "TFV". The main contribution of the TFV theory of production is its focus on modeling, designing, controlling and improving production in all the three prospective views (Koskela, 2000). Construction problems have remained unsolved, in spite of numerous initiatives for finding a solution. The TFV theory of production is a key step in finding the answer for the construction problems.

It is ironic that the first European scientific journal on construction management was founded only in 1983. Most construction management education is focused only on project planning or economic analysis, and textbooks in the same field also focus on a descriptive account of a construction project, as well as, specific techniques of management and control. There has been a lack of the proper use of project management methods. The TFV theory of production was a step in the right direction in providing a greater understanding of the construction industry and the potential solutions for improvement and creating a new paradigm for major changes in performance. The construction industry requires new tools and methods to recognize the need for an adaption of the TFV production concept. The role of a theory as a communicative device is important; all parties involved in the construction industry should share the common understanding of the success factors, as well as all the other issues.

Table 2 displays Koskela theory of production TFV and how it combines all three previous theories. It explains TFV main principles; conceptualization productions, main principles, methods and practice, practical contributions, and practical application and how each principle looks at the three different views. The table shows the comparison between the three production systems and how each of them method of performance and their effect on project performance. For example, in practice the Transformation view focus on the traditional work breakdown structure (WBS), the Flow view focus on continuous improvement and pull production, and Value view focus on quality function developments.

Table 2 - Integrated TFV Theory of Production (Koskela, 2000)

	Transformation View	**Flow View**	**Value Generation View**
Conceptualization of Production	As a transformation of inputs to outputs	As a flow of material, composed of transformation, inspection, moving and waiting	As a process where value for the customer is created through fulfillment of his requirements
Main Principles	Getting Production realized efficiently	Elimination of waste (non-value-adding activities)	Eliminating of value loss (achieved value in relation to best possible value)
Methods and Practice (examples)	Work Breakdown Structure WBS, MRP, Organizational Responsibility Chart	Continuous flow, pull production control, continuous improvement	Methods for requirements capture, Quality Function Deployment
Practical Contribution	Taking care of what has to be done	Taking care that what is unnecessary is done as little as possible	Taking care that customer requirements are met in the best possible manner
Suggested name for practical application of the view	Task Management	Flow Management	Value Management

2.4.5 Lean Construction Concept

Lean Construction is a production management-based approach to project delivery. It changes the way work is done throughout the delivery process. Lean Construction extends from the objectives of a lean production system - maximize value and minimize waste - to specific techniques and applies them in a new project delivery process.

Lean construction supports the development of teamwork, collaboration, communication, and a willingness to expand responsibility for construction efficiency to people actually performing the field work – the specialty trade and supply contractors. Partnering relationships with trade contractors coupled with lean thinking make rapid implementation of lean principles possible. Projects are built inefficiently when every stakeholder tries to optimize his individual performance without regard for how their actions affect other project stakeholders.

The lean approach is to provide reliable workflow by managing planning and control throughout the project by:

1. Planning: defining criteria for success and producing strategies for achieving objectives.

2. Control: causing events to conform to plan and triggering learning and re-planning.

Lean construction embraces uncertainty in supply and employs production planning to make the release of work to the next crew more predictable (Linbeck Lean, 2011).

The goals of the lean construction process are to:

- Encourage teamwork and open communication
- Enable continuous improvement
- Improve performance reliability
- Have zero incidents and injuries

- Have zero RFIs and rework in the field
- Have zero punch lists
- Create accountability by measuring results

Lean Construction goals are important and essential to improve project productivity and ultimately obtain total project success.

2.4.6 Last Planner System of Production Control (LPS)

Influenced by the movement of the lean production in the auto industry, the Last Planner System (LPS) was developed by Glenn Ballard in 1992, to improve construction productivity. It started by focusing on improving the quality of weekly assignments of the work plans and adding a look-ahead process to shape and control the work flow. First, the focus was on the improvement of productivity; however it shifted to improving the reliability of work flow, which was inspired by the Toyota Production System (TPS) and the Koskela production theory. LPS Production Control is a tool for improving productivity by focusing on improving the reliability of work flow between all the project units. Traditional construction work flow reliability before the Last Planner System's application was 35%-65%, which was measured by the Percent Plan Completed (PPC). By applying The Last Planner System, the PPC has increased above 75%. However, the applications and effectiveness of the Last Planner System to design was not determined even though it was very much needed (Ballard, 2000).

The Last Planner System of Production Control focused only on the construction phase but was not applied to planning and design phases of construction.

2.4.7 Integrated Project Delivery System (IPD)

The careful choice of project delivery system can help overcome many construction problems and challenges. A project delivery system is the contractual structure that details how the final project is designed, built, and delivered to the owner. Owners and stakeholders are generally looking for the same project outcome: highest quality, lowest costs, and completion of the project within required scheduled time frame. In recent years and in the lean construction movement, several alternative delivery methods have been developed to address the weakness and fragmentation of the traditional D/B/B process (Kenig, et al., 2010).

IPD system is a new contractual structure method that applies lean principles to improve productivity, especially in healthcare projects. IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively exploits all participants' experience and talents to optimize project productivity. It focuses on lean principles to increase owner value, reduce waste, and maximize efficiency through all phases of planning, design, and construction. By leveraging early contributions of knowledge and expertise through the utilization of new technologies, this allows all project team members to better realize their highest potentials while expanding the value they provide throughout the project lifecycle.

Table 3 displays the American Institute of Architects comparison between traditional project delivery system (D/B/B) and IPD project delivery system. It clearly displays the advantage of IPD in team work, process, risk management, reward, use of technology and the contractual agreement above the traditional system.

Table 3- Comparison between IPD & Traditional Projects (Kenig et al., 2010)

	Traditional Project Delivery (DBB)	**Integrated Project Delivery (IPD)**
Teams	Fragmented, assembled on as needed basis, Hierarchy, Controlled	Integrated team composed of key project stakeholders, Assembled early in the process, Open, Collaborative
Process	Linear, distinct, segregated, information hoarded, knowledge gathered as needed, silos of knowledge and expertise	Concurrent, multi-level, early contributions of knowledge and expertise, information openly shared, stakeholders trust & respect
Risk	Individually managed, transferred to the greatest extent possible	Collectively managed, appropriately shared
Reward	Individually pursued, minimum effort for maximum return, first cost based	Team success tied to project success, Value based
Technology	Paper based, two dimensional, analog	Digitally based, virtual, Building Information Model (BIM), (3,4 & 5 dimensional)
Agreement	Encourage unilateral effort, allocated and transfer risk, no sharing	Encourage, foster, promote and support multi-lateral open sharing and collaboration, risk sharing

IPD project team consists of the key project stakeholders: owner, architects, engineers, general contractor, main subcontractors, suppliers and fabricators. The goal of the IPD is to create a talent experienced team early on the project that is guided by principles of collaboration, trust, communication, transparency, decision making and use of highest technology available to achieve the optimum project success as shown in Table 4.

Table 4: Integrated Project Delivery Principles (Kenig et al., 2010)

IPD Principle	Goal
Mutual Respect and Trust	Project team commitment to collaborate and communicate to the best interest of the project.
Mutual Benefit and Reward	Compensation is based on value added by team members.
Innovation	Ideas are freely exchanged among the project team to stimulate innovation.
Decision Making	Key decisions are evaluated by the project team through the knowledge and expertise of all participants.
Early Involvement of Key Participants	Owner, designers, consultants, contractors, subcontractors, suppliers and fabricators are involved from the conceptual phase of the project.
Early Goal Definition	Project goals are developed early, holding project success outcomes at the center.
Intensified Planning	Streamlining planning, design and construction demand increasing planning effort, which will have a great impact on efficiency during construction execution.
Communications	Open, direct and honest communications among project team increases team performance and improve productivity.
Appropriate Technology	Information technologies are integrated in the IPD projects such as Building Information Modeling (BIM) to enable communications.
Organization & Leadership	Leadership roles are clearly defined by the team members. Most capable team member with regard to specific service is appointed

2.4.8 Building Information Modeling (BIM)

To improve the construction process, information technology (IT) provided the aid for compiling, editing, evaluating and reporting information about building projects. Building Information Modeling (BIM) is an emerging approach to the design, analysis, and documentation of buildings by the management of information throughout the life cycle of a design process, from early conceptual design through construction administration, and into the facilities management. (Dzambazova, et al., 2009).

BIM is one of the most important developments in architecture, engineering, and construction industries because it improves design and construction efficiency, eases collaboration between project team members, and assists owners and managers to reduce waste (Delacey, 2012). It accommodates many of the functions to model the project lifecycle of a project that facilitate a more integrated design and construction process that results in a better quality at a lower cost and meat project schedule. The National Institute of Building Sciences (NIBS) defines BIM as "an improved planning, design, construction, operation, and maintenance process using standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle (Eastman, et al., 2011).

Lean Construction and Building Information Modeling (BIM) are causing fundamental change in the architecture/ engineering/construction (AEC) industry. While the two are conceptually independent and separate, there appear to be synergies between them that extend beyond the essentially circumstantial nature of their approaching maturity contemporaneously (Sacks, et al., 2009).

BIM software tools are characterized by the ability to compile virtual models of buildings using machine-readable parametric objects that exhibit behavior appropriate with the need to design, analyses and construction (Eastman et al., 2011). The American Institute of Architects recommend that BIM should be used as an to achieve required collaboration for Integrated Project Delivery" (Sacks et al., 2009).
It is evident that the serious implementation of BIM technology in the early stage of any project shall enhance the lean productivity. BIM facilitates a more integrated design and construction process that results in better quality projects at a lower cost and reduced duration (Sacks, et al., 2010).

2.5 Development of Previous Rating Systems

A rating system is a method of classifying things according to their quality or performance. It is a ranking of a list of items or a group according to a system of rating or record of performance. The Rating system covered many fields in our society such as military, sports, television, motion pictures, banking system, construction industry and more. No construction rating system was ever created to measure and predict project performance. To create a new construction rating system, a close look at the different industries rating system is explored.

2.5.1 British Royal Navy Rating System

The first movement towards a rating system was in the 15th century in the British Royal Navy, when the largest carracks in the Navy (such as the Mary Rose, the Peter Pomegranate and the Henri Grâce à Dieu were denoted "great ships". The rating was based only on their size and not on their weight, crew or number of guns.

In the 16th Century, the carracks were superseded by the new-style; the term "great ship" was used to formally delineate the Navy's largest ships from all the rest. This first classıficatıon took place ın 1626, and was substantially altered in late 1653 as the complements of individual shıps were raised. From about 1660, the classification moved from one based on the number of men to one based on the number of carriage guns a ship carried. The rating of a ship was of administrative and military use. The number and weight of guns determined the size of crew members needed, and thus the amount of pay and rations needed. It also indicated whether a ship was powerful enough to stand in the line of battle. The rating system of the Royal Navy formally came to an end in 1876. The main cause behind this declaration focused on new types of gun, the introduction of steam propulsion and the use of iron and steel armor which made rating ships by the number of guns obsolete (Barnsley 2009).

2.5.2 Motion Pictures Rating System

On April 14, 1894, Thomas Edison’s motion picture machine made its first appearance in Broadway, New York City. Two weeks later, angry citizens protested against the movie

“Dolorita in the Passion Dance”. This was the beginning of the motion picture industry ratings to regulate sexually explicit films (Friedman, 1973).

In the early 1900s, American cinema was subject to more than 40 local, city and state censorship boards across the country. Filmmakers had to tailor their movie to the requirements of each board, state and federal government or face being banned from the market.

In 1915, the US Supreme Court made its decision in the case of Mutual vs. Ohio that denied the motion pictures the protection of the First Amendment by ruling them purely a business, not a form of speech (Martin, 2010).

In 1922, Motion Picture Association of America (MPAA) was formed to self-regulate the film industry. It mandated that all major motion picture studios which were responsible for all U.S. filmmaking to submit their movies for approval prior to any distribution.

The process was governed by the Hays Code, named for the first MPAA President, Will Hays. Only correct moral standards of life could be presented, no depictions of childbirth, no criticisms of religion, and any lustful kissing or "suggestive" dancing. Under the Hays Code, films were simply approved or disapproved based on whether they were deemed "moral" or "immoral."

The contemporary rating system was the brainchild of former MPAA Chairman Jack Valenti. He reached out to the National Association of Theatre Owners (NATO) and other stakeholders. Out of this effort came the radically simple notion that continues to define the rating system today: movies would no longer be "approved" or "disapproved." Instead, an independent ratings body, comprised of parents, would give advance cautionary warnings to parents, so that they can make informed decisions about which films their children may see (Martin, 2010).

On November 1, 1968, the modern movie rating system was born and MPAA replaced its outdated production code with an age-based rating system. More than 40 years later, the rating system endures and evolves as a useful and valued tool for parents and an essential guardian of Americans' freedom of artistic, creative and political expression (MPAA, 2011). The MPAA uses five categories for movie ratings: G (general audiences), PG (parental guidance suggested), PG-13 (parents strongly cautioned), R (restricted), and NC-17 (no children under 17) (Figure 6). The process of assigning ratings to movies is a straightforward process based on the rating decisions rendered by parents to what they think is appropriate for children ages 17 and under (Leone, et al., 2005).

Figure 9 - MPAA Rating System (MacLeod, 1990)

2.5.3 Sustainable Building Rating Systems

In the Construction Industry, there is a growing movement of committed practitioners trying to advocate and practice in a more sustainable way. Buildings have a significant effect on our resources, air, water, and land pollution.

In 1987, the World Commission on Environment and Development, established by the United Nations published the Brundtland Report giving the following definition to sustainable development: "those paths of social, economic, and political progress that meet the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987) .

In 1992, more than 150 nations participated in the United Nations Earth Summit, with the exception of the USA, to discuss sustainability and issue a policy formulation to practice sustainability. The Summit results were the publication of Agenda 21, which is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment (Bunz, et al., 2006).

Many assessment rating systems were developed in the building industry to evaluate and differentiate the sustainability and quality of different buildings. World-wide, there is hundreds of building evaluation tools that focus on different areas of sustainable development and designed for different types of projects. These tools include energy system designs, performance evaluations, productivity analysis, life cycle costing, indoor environmental quality, operation & maintenance optimization, and much more. The following five building rating systems are considered to be the most practiced and used:

1. **BREEAM** (Building Research Establishment's Environmental Assessment Method)

One of the oldest rating systems developed in United Kingdom in1990 to cover ratings of offices, homes, retail, and school buildings. The major area covered under BREEAM is Management, Health, Energy, Transport, Water, Material, Land use, Ecology and Pollution.

2. **CASBEE** (Comprehensive Assessment System for Building Environmental Efficiency)

It was developed in Japan in 2001 to cover the building life cycles: conceptual design, new construction, existing buildings, and renovation. CASBEE is a new concept for assessment that distinguishes the building performance quality from the environmental load. The rating is performed by plotting the results on a graph, with environmental load on the x-axis and quality on the y-axis, the best building will produce the lowest environmental load and highest quality. The rating score is between 1.0 to 5.0 credit points, level 1.0 meeting the minimum requirements while level 5 being the highest scoring. The major categories in the CASBEE are: indoor environment, quality of services, and outdoor environment on site.

3. GBTool

In 1998, more than 25 international countries formed the International Framework Committee for the Green Building Challenge and developed the GBTool rating system. The rating system criteria are: site selection, project planning & development, environmental loadings, energy & resource consumptions, indoor environmental quality, functionality, long term performance, and social & economic aspects. Buildings can score between +1 to +5, representing good to high performance. GB Tool consists of two spreadsheets, one for data entry for the project team and the other for measuring weights and assessment to be completed by third party assessors, as illustrated in Figure 10.

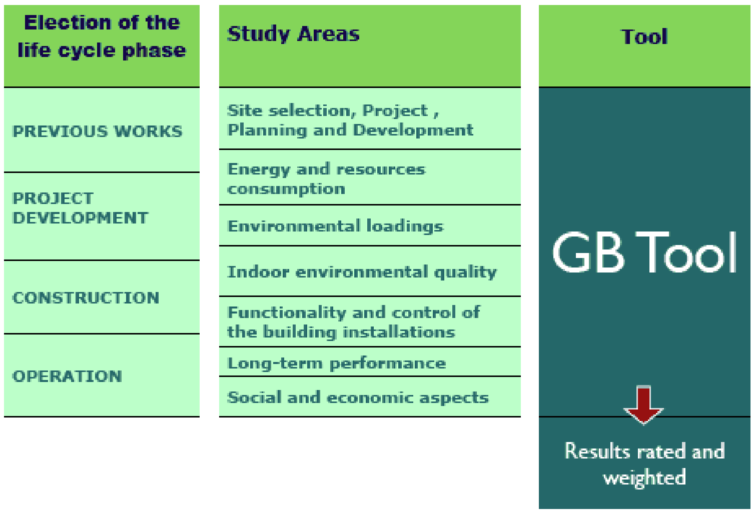


Figure 10 - GB Tool Rating System ("Green Building Initiative," 2011)

4. Green Globes US

It is an online tool designed to be used in commercial buildings by builders and architects. It was adapted in 2004 from the Green Globes Canada rating system. The major categories of Green Globes US are: project management, site, energy, water, indoor environment, and resource building material and solid waste. Figure 11 shows the percentage of each of Green Globes categories in GB Tool rating system. Energy and Indoor Environment cover 58% of the total score.

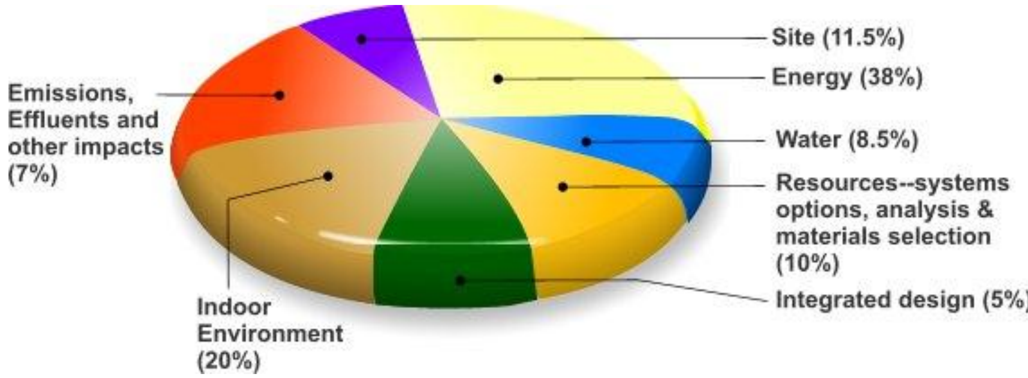


Figure 11 - Green Globes Rating Categories ("Green Building Initiative," 2011)

5. **LEED** (Leader in Energy and Environmental Design)

In 1998, the U.S. Green Building Council, a nonprofit organization based in Washington DC, developed the LEED rating system. The rating system was designed to help in the design and construction practice to eliminate or reduce the negative impact of buildings on the environment. The rating system has four levels of certifications: LEED certified (40-49 points), Silver level (50-59 points), Gold level (60-79 points) and Platinum level (80+ points) as shown in Figure 12.

Figure 12 - LEED Certification Levels (U.S. Green Building Council, 2011)

LEED is currently the dominant system in the USA market and is being adapted by a variety of country in the world. More than 400 US buildings have been certified by LEED and currently 3,400 buildings are registered to be certified.

LEED rating system covers five major categories:

- Sustainable site planning
- Safeguarding water and water efficiency
- Energy efficiency and renewable energy
- Conservation of materials and resources
- Indoor environmental quality

Figure 13 displays the LEED check list with the five main categories and their possible scores. For example the sustainable site possible score is 26 which covers 15 indicators with possible scores of one (1) to six (6). By measuring each project against these categories and indicators credit points, a total score will determine the level of project LEED certifications: Certified, Silver, Gold, or Platinum.

Y	N	?			LEED 2009 for Schools New Construction and Major Renovations		Project Name
					Project Checklist		Date
0	0	0			**Sustainable Sites**	Possible Points: **24**	
Y	N	?					Notes:
Y			c	Prereq 1	Construction Activity Pollution Prevention		
Y			d	Prereq 2	Environmental Site Assessment		
			d	Credit 1	Site Selection	1	
			d	Credit 2	Development Density and Community Connectivity	4	
			d	Credit 3	Brownfield Redevelopment	1	
			d	Credit 4.1	Alternative Transportation—Public Transportation Access	4	
			d	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1	
			d	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	2	
			d	Credit 4.4	Alternative Transportation—Parking Capacity	2	
			c	Credit 5.1	Site Development—Protect or Restore Habitat	1	
			d	Credit 5.2	Site Development—Maximize Open Space	1	
			d	Credit 6.1	Stormwater Design—Quantity Control	1	
			d	Credit 6.2	Stormwater Design—Quality Control	1	
			c	Credit 7.1	Heat Island Effect—Non-roof	1	
			d	Credit 7.2	Heat Island Effect—Roof	1	
			d	Credit 8	Light Pollution Reduction	1	
			d	Credit 9	Site Master Plan	1	
			d	Credit 10	Joint Use of Facilities	1	
0	0	0			**Water Efficiency**	Possible Points: **11**	

Figure 13 - LEED Checklist (U.S. Green Building Council, 2011)

The different sustainable building rating systems help designers to design sustainable buildings for their life cycle only in the area of environmental impact. Current guides do not address the extension of the buildings life span. The design may be extended beyond environmental metrics to include more subjective assessments of building impacts such as: working conditions, culture, quality of life and historic continuity.

2.5.4 Roadways Sustainable Rating System

Affected by the green practice by the building communities in using sustainable rating systems, the transportation sector moved toward creating roadway rating system. There are a number of transportation stakeholders that are interested in a sustainable rating system for roadways, bridges and highways. Stakeholders include: federal, state, county, general public, design consultant, contractors, regulatory agencies, sustainable organizations and research organizations (Soderlund, et al., 2008). To promote sustainable solutions in transportation planning, design and construction, many rating systems have been developed.

2.5.4.1 Green Road Rating System

To encourage more sustainable practice in civil engineering infrastructures, many research studies have focused on roadways. Green Roads is a sustainable rating system developed to produce more sustainable practice associated with design and construction of roadways, bridges and highways (Soderlund et al., 2008). It balances the sustainable requirements in economic, environmental and social by providing a rating system consists of 54 possible credits in 6 categories. Table 4 displays the Green Road rating system with five different categories (material & resources, stormwater management, energy & environment control, and construction activity), goals for each category, and the possible credits for each.

Table 5: Green Road Rating System

CATEGORY	GOAL	CREDIT
Sustainable Design	Reduces impact due to design choices including the roadway alignment	10
Material & Resources	Reduce impact from material extraction,	11

	processing and transport	
Stormwater Management	Reduce impact from polluted Stormwater and treatment devices	8
Energy & Environment Control	Improve Human & wildlife health	12
Construction Activity	Reduces impact from construction activities	9
Innovation	Encourage innovation in design	4
Total Green Road Credit Scores		54

2.5.4.2 Sustainable Corridor Rating System (SCRS)

There are a few researches that focused on the development of roadway rating methodology. In 2008, Oswald developed a methodology for rating systems and applied it to urban corridor transportation investments (Oswald, 2008). Based on the Analytical Hierarchy Process (AHP), the study included a seven step methodology process to develop sustainable Urban Corridors: Corridor Criteria, Indicator Categories, Indicator Development, Indicator Measurements, Prioritization of credits, Allocation of points and Rating Scale (Oswald, 2008). Sustainable Corridor Rating System (SCRS) was developed to promote and encourage roadway stakeholders to plan, design, and construct sustainable transportation.

2.6 Decision Making Models

Decision making models are tools that can be used to prioritize components of complex decisions. The use and application of a decision making model is an important step in the development of the lean project rating system (LPRS). Many of the traditional decision-making methods require specialized knowledge and experience to design the appropriate structure to solve problems. Two decision making models, Analytical Hierarchy Process

(AHP) and Utility Theory (UT), where chosen to select the appropriate model to prioritize credits and allocate points based on credit importance to LPRS.

2.6.1 Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP), developed by Thomas Saaty in 1970 is a tool used to simplify complex decision making process. Logical decision making is an important part of all science-based professions, where specialists apply their knowledge in a given area to make informed decisions (Saaty, 1990). A study by Saaty came to find that "To make a decision we need to identify the problem, the purpose of the decision, the criteria of the decision, their sub-criteria, stakeholders, and alternative actions to take in order to solve the problem. Next in the process includes examining as well as determining the best alternatives and priorities for the alternatives, and from this, making a decision for the best possible solution" (Saaty, 1990).

AHP is a decision-making process that breaks the problem down to small parts and then aggregates the solutions of all the parts into a conclusion. AHP is based on the human ability to make sound judgments about small problems. It is a structured technique to deal with complex decisions in helping the decision makers find the answer that best meets their organization's goal based on their understanding of the problem (Saaty, 1990).

AHP consider decision making as a process that involves the following steps (Saaty, 1990):

1. Structure the problem with a model that shows problem key elements and their relationship.
2. Elicit judgments that reflect knowledge, feelings or emotions.
3. Represent those judgments with meaningful numbers.
4. Use these numbers to calculate the priorities of the elements of the hierarchy.
5. Synthesize these results to determine an overall outcome.
6. Analyze sensitivity to changes in judgment.

AHP enables the user to start with a complex network and finish with a guiding organization that simplifies the decision making process. In the above AHP, total project success depends on the success of three phases: Conceptual phase, Design phase and Construction phase. AHP uses pairwise comparison from expert's opinion to allow the decision maker to specify preference for each pair of alternatives. Each of the phases also depends on the different criteria: budget, time, quality, safety, RFIs, and disputes. These need to be measured to assign weights.

2.6.1.1AHP Mathematical Theory

Fundamentally, AHP works by developing priorities for alternatives and the criteria used to judge the alternative. The criteria are measured on different scale for tangible and intangible objects. To achieve the desired goal, priorities are measured in terms of their impotence based on pairwise assessments using judgment, or ratios of measurements. To solve the problem of dealing with different scales, prioritization is introduced to interpret their significance to the values of the users. The following are the matrix and equations used in AHP:

Eigenvalue formulation:

$$Aw = nw \qquad \textit{Equation 1}$$

Matrix of ratio comparisons:

$$\begin{pmatrix} \frac{w1}{w1} & \cdots & \frac{wn}{w1} \\ \vdots & \ddots & \vdots \\ \frac{wn}{w1} & \cdots & \frac{wn}{wn} \end{pmatrix} \begin{pmatrix} w1 \\ : \\ : \\ : \\ wn \end{pmatrix} = n \begin{pmatrix} w1 \\ : \\ : \\ : \\ wn \end{pmatrix} \qquad \textit{Equation 2}$$

Where:
A = matrix of pairwise comparisons
Priority victor w = (w_1 , w_2 , ……..w_n)
n = number of elements to be compared

The relative ratio scale derived from a pairwise comparison reciprocal matrix of judgment is derived by solving the following equations:

$$\sum_{j=1}^{n} a_{ij}\ w_j = \lambda_{max}\, w_i \qquad \textit{Equation } 3$$

$$\sum_{i=1}^{n} w_i = 1 \qquad \textit{Equation 4}$$

Where:

λ is a simple eigenvalue of the matrix A
a_{ij} = importance of alternative i over alternative j

Measurement of Inconsistency:

As a measure of deviation of matrix A from consistency, AHP uses the following equation for consistency Index:

$$\mu = \frac{\lambda_{max} - n}{n - 1} \qquad \textit{Equation 5}$$

Where:
λ_{max} = largest eigenvalue of the matrix
Variance of the error $\mu \geq 0$ if and only if matrix A is consistent.
Matrix A is consistent if only λ_{max} = n

2.6.2 Multi-Attribute Utility Theory

The Multi-Attribute Utility Theory (MAUT) is a mathematical tool for evaluating and comparing alternatives to assist in decision making about complex alternatives, especially when groups are involved. MAUT was developed by Keeney and Raiffa in 1976 to provide objective measurement to decision making (Zietsman 2008). MAUT measures each alternative and uses a weighting process to aggregate the dimension values and the final utilities are produced from the weighted linear average.

MAUT approach is summarized in the following steps (Zietsman, et al., 2006):

1. Identify the different criteria and sub-criteria for model evaluation
2. Rank each criteria and sub-criteria in order of importance

3. Rate them on a scale from (0) to (1) while setting the relative importance of one over the other.
4. Convert the rating to weights by normalization
5. Determine criteria values for each alternative by using single attribute utility functions on linear, normalized scale.
6. Calculate the utilities for the alternative by obtaining the weighted linear sum for the criteria.

MAUT Mathematical Equations:

The following MAUT two mathematical equations determine utility values and normalize the scale:

$$\mathrm{U}_j = \sum_{k=1}^{n} w_k \, n_k \qquad \textit{Equation 6}$$

$$n_{\varkappa j} = \int (S\varkappa j) \qquad \textit{Equation 7}$$

Where:
Uj = utility of alternative j;
Wk = weight of the kth Criterion;
Nkj = normalized criterion k value for alternative j;
Skj = value of criterion k for alternative j;
Fk = single attribute utility function on a normalized scale.

After reviewing the literature and previous work on the auto industry, lean principles, construction industry, lean construction, development of various rating systems, and decision making theories, the following chapter will illustrate the research methodology to create the Lean Project Rating system (LPRS). This chapter will include the research design which focuses on defining Lean/IPD criteria and success factors indicators. It also includes the survey to construction professionals and stakeholders to measure credit scores for success factor indicators and data analysis using AHP. The chapter will conclude with the creation of the new rating system.

3. RESEARCH METHODOLGY

3.1 Introduction:

This research focuses on the methodology for creating a Lean Project Rating System (LPRS) and its application to understanding, measuring, and assessing Lean/IPD. What led to this study was the persistent construction problems that have been hindering the success of the construction industry for a very long time. Construction problems including poor quality, overrun of project budget, schedule delay, safety, disputes and litigation, have been contributing to the declining of the industry (Teicholz, 2004). As an alternative project delivery system, Lean/IPD system was introduced to improve construction productivity and enhance the management of construction projects. However, using Lean/IPD produced different success results which puzzled the stakeholders of the construction industry. Some Lean/IPD projects were very successful with high quality, within budget and on time. Other projects failed to meet project schedule, budget or expected quality.

Before selecting a research methodology, it is important to determine the research topic, question, and purpose.

The Topic of this research is the impact of Lean/Integrated Project Delivery System (Lean/IPD) on final project success; more specifically, measuring, understanding, and assessing the impact of Lean/IPD on project.

The questions driving this research are:

1. Does team collaboration and communication affect project performance?
2. Does project delivery method have any influence or impact on final project success?
3. What new tools could be used to improve construction productivity?
4. Can Lean Project Delivery System (LPDS) predict project outcome and help construction stakeholders improve productivity?

The Purpose of the research is to create a new tool to rate projects and help construction stakeholders achieve the highest success of their projects. This new tool is Lean Project Rating System (LPRS) which should help measure and predict project performance during planning, design and construction phases.

To create a rating system methodology, a seven step process based on the lean principles and the Analytical Hierarchy Process model has been followed based on (Oswald, 2008). The seven steps proposed for this research are as follows:

1. Define Lean/IPD project success criteria
2. Develop Lean/IPD indicator categories
3. Determine Lean/IPD success factors indicators

4. Transform indicators into credits

5. Prioritize credits by assigning weights

6. Allocate points and evaluate requirements

7. Develop Lean/IPD rating scale

This chapter is organized as follows: Section 3.2 Research Design (Structuring the rating system) which includes the first five steps process as defined by Oswald. Section 3.3 Research Method which covers research strategies, survey design, data collection, analysis, and evaluation. Section 3.4 Creating the Rating System by applying steps VI and VII and creating LPRS.

3.2 Research Design: (Structure the rating system)

3.2. 1. Define Lean/IPD Project criteria

After reviewing the literature in chapter two on project success criteria and the initial investigation of Lean/IPD healthcare projects, five lean project success criteria have been chosen for this research: *Cost, Time, Quality, Safety, and Disputes & Litigations*.

3.2. 2. Develop Lean/IPD Indicator Categories

Indicator measurements define the credits that make up the rating system. The final project success depends on the success of three major phases:

Planning Phase: The initial start of the project which includes owner goals, specifications, budget, and time.

Design Phase: Focuses on team collaboration and communications to complete the design documents.

Construction Phase: The actual implementation of the design and completion of the project as planned.

Therefore, *Planning phase, Design phase and Construction phase* shall serve as the main three credit categories for LPRS.

3.2. 3. Determine Lean/IPD success factor Indicators

Indicators are defined and established to become the credits for rating system, and are measured to analyze the progression of goals and objectives of the project. A set of correct indicators should be selected to reflect the goals and objectives of the project (Litman, 2007). After careful review of the literatures pertaining to the Healthcare system, a set of indicators has been chosen for each phase of the project; planning phase indicators, design phase indicators, and construction phase indicators. Table 5 contains all the indicators that have been chosen for the rating system. For example, an indicator such as, Initial Project Team, is developed to promote stakeholders early engagement to impact the final project results. This indicator encourages the early participation of owner, designers, engineers, contractors, sub-contractors, suppliers and fabricators in the initial stage of the project, mainly in the planning phase. Another example, Individual Experience indicator, is developed to promote hiring experienced team members to produce a better project. Therefore, all indicators were developed to fully address all components of Lean/IPD that affect projects outcome

Table 6: Project Indicators

Main Category	ID	Indicator (Project Success Factor)
Planning Phase	P1	Initial Project Team
	P2	Individual Experience
	P3	Collaboration
	P4	Communication
	P5	Target Value Design (TVD)
	P6	Building Information Modeling (BIM)
	P7	Last Planner System (LPS)
	P8	Information Technology
Design Phase	D1	Collaboration
	D2	Communication
	D3	Building Information Modeling (BIM)
	D4	Last Planner System (LPS)
	D5	Target Value Design (TVD)
Construction Phase	C1	Collaboration
	C2	Communication
	C3	Building Information Modeling (BIM)
	C4	Last Planner System (LPS)
	C5	Monitoring & Controlling
	C6	Safety
	C7	Risk Management
	C8	Building Codes

3.2. 4. Transform indicators into credits

Measurements are established based on engineering and stakeholder judgments that will be collected by a survey. After the measurements are developed for each indicator, and for each category, a table is developed listing each credit, the purpose of the credit, its characteristics and the possible score. Under planning phase category, there are eight credits available: Initial Project Team, Individual Experience, BIM, LPS, TVD, Collaboration, Communications, and Information Technology (IT). Each credit has its title, description, purpose and measurement. Similarly, under Design Phase category there are five credits available: Collaboration, Communication, BIM, LPS, TVD. And finally under Construction Phase, there are eight credits: Collaboration, Communication, LPS, BIM, Safety, Risk Management, Building Codes, and Monitoring & Controlling. Tables 6 display the proposed LPRS credits for all Planning phase, for example P1 is the initial team participation in early stage of the project. It is measured by the number of participants including owners, engineers, architects, general contractor, specialty contractors, vendors and suppliers.

Table 7: Planning Phase Credits

Planning phase Credits				
Credi	**Title**	**Description**	**Purpose**	**Measurement**
P1	Initial Team	Early team participation	Promote value	Number of participants (owners, Engineers, GC, ...)
P2	Team Experience	Best man for the job	High qualified team members	Years of experience, same work
P3	Collaboration	Team working together	Common Goal, coherence and creativity	Percent of team collaboration
P4	Communication	Real Communication	Innovation, creativity and trust	Percent of Communication
P5	Target Value Design (TVD)	Real time design with entire team	Customer value, minimize waste, innovation	Was TVD used?
P6	Building Information Modeling (BIM)	3D, 4D and 5D virtual model	Virtual model, quality, conflict detection	Was BIM used?
P7	Last Planner System (LPS)	Pull planning	Look ahead, PPC measurement, quality, seek perfection	Was LPS used?
P8	Information Technology (IT)	Latest Technology in construction	Sharing, control, save time	Percentage of use

Design and construction phase credits are displayed in Tables 7 and 8 which identify each credit, credit title, description, purpose and measurement.

Table 8: Design Phase Credits

Design Phase credits				
Credit	**Title**	**Description**	**Purpose**	**Measurement**
D1	Collaboration	Team working together	Common Goal, coherence and creativity	Percent of team collaboration
D2	Communication	Real Communication	Innovation, creativity and trust	Percent of communication
D3	Target Value Design (TVD)	Real time design with entire team	Customer value, minimize waste, innovation	Was TVD used?
D4	Last Planner System (LPS)	Pull planning	Look ahead, PPC measurement, quality, seek perfection	Was LPS used?
D5	Building Information Modeling (BIM)	3D, 4D and 5D virtual model	Virtual model, quality, conflict detection	Was BIM used?

Table 9: Construction Phase Credits

Construction Phase Credits				
Credit	**Title**	**Description**	**Purpose**	**Measurement**
C1	Safety	Project safety	Insure project safety	Number of accident or injuries
C2	Collaboration	Team working together	Common Goal, coherence and creativity	Percent of team collaboration
C3	Communication	Real Communication	Innovation, creativity and trust	Percent of team communication
C4	Building Codes	Application of building codes	Safety & public welfare	Number of violation
C5	Risk Management	Evaluating construction risk	Minimize risk, mitigate risk	Percentage of effectivness
C6	Monitoring & Controlling	Control of project budget, time & quality	Meet owner requirements	Effectiveness
C7	Last Planner System (LPS)	Pull planning (3-4 weeks ahead)	Look ahead, PPC measurement, quality, seek perfection	Was LPS used?
C8	Building Information Modeling (BIM)	3D, 4D, 5D virtual model	Virtual model, quality, conflict detection	Was BIM used?

3.2. 5. Prioritize Credits by Assigning Weights

To prioritize the credits to develop the rating system, the Analytical Hierarchy Process (AHP) decision making theory was applied to create network structure.

AHP has been selected for the following reasons:

- AHP is simple to apply because it is based on a hierarchy to decompose complex systems, making it possible to judge the importance of the elements in a given level to the respect of all other elements.
- In AHP, a decision maker can insert or eliminate levels and elements as necessary to clarify priorities or to sharpen the focus on one or more parts of the system.
- AHP is a general theory of measurements which is used to derive ratio scales from both discrete and continuous paired comparisons in the multilevel hierarchy structure that is suitable for construction.

- The AHP consistency ratio is helpful in checking the consistency of survey responses.

- AHP can be used to measure tangibles and intangibles without compromising either.

A hierarchy structure of the categories and indicators was created using the AHP structure to represent the LPRS project success problem as shown in Figure 14.
The first level of the AHP structure is the goal: Final Project Success. The second level is the sub-goal which defines the categories: Planning phase, Design phase and Construction phase. The third level is the success criteria; Cost, Time, Quality, Safety, and disputes. The fourth level is the success indicators which are the credits within LPRS.

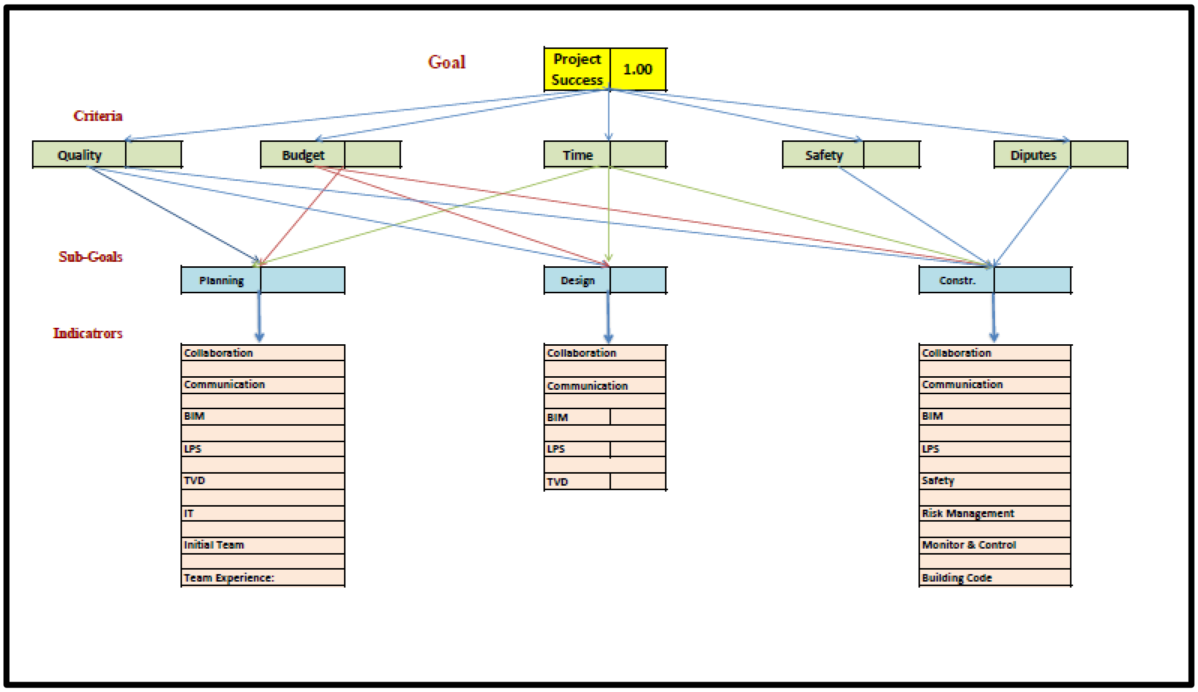


Figure 14: LPRS Hierarchy Network Structure

3.3 Research Method

3.3.1 Research Strategies

There are three traditional research strategies used in quantitative research: experiment, survey, and case study (Robson, 1993). The experimental strategy is unsuitable for this research because it requires the establishment of a control group to be able to control the many variables. Also the experiment requires observation of projects during their life time which sometime takes several years. It is also very difficult to perform due to the lack of owner cooperation in allowing experimentation with their projects based on privacy and proprietary issues. The construction industry is very competitive in nature and most construction stakeholders do not share their project information which make the collection of data extremely difficult.

In this research a survey strategy and case studies will be used to investigate the research hypotheses. These two methods are easier to perform and do not interfere with owner confidentiality issues. The chosen survey strategy requires collection of data and the application of statistical analysis to answer the research questions. This strategy used the Participatory Action Research (PAR) approach because of its double objective: first is producing the knowledge and second to empower stakeholders by using their own knowledge (Reason, 1998).

Research is a participatory process that requires the equal collaborative involvement of the community of research interest. Research should also be more than just finding out but should involve an action that seeks to prompt positive changes (Walter, 2009).
The survey approach which provides statistical generalization from sample to population is an appropriate methodology in testing the current Lean/IPD behavior in healthcare projects. Case Study is a research strategy using empirical investigation with actual projects using multiple sources of evidence (Robson, 1993). Multiple case studies are an important and appropriate strategy for areas of limited knowledge and it allows the testing of hypothesis validity.

Survey strategy shall help in assigning indicators weights thus assigning credit score to each indicator in each phase. Case study strategy shall help validating the accuracy and validity of the LPRS rating system.

3.3.2 Survey Design and Data Collection

The survey was designed to assign credits to the structure network of the rating system. For example, in the success criteria (quality, budget, time, safety, and disputes), participants compare each item to the other regarding importance and intensity.
The targets sample were the construction stakeholders, project owners, architects, engineers, general contractors, specialty contractors, vendors and suppliers. The target response rate was 10% which was achieved. The 10% response was due to the fact that most construction stakeholders don't want to share their project success or failure for confidentiality reasons. Also, online survey responses vary between 5% to 10% because most participants opt out if the survey is lengthy.

AHP pairwise comparison survey was sent to unbiased, practical experts of Lean/IPD healthcare systems stakeholders and other construction professionals. The survey was distributed to Lean/IPD practitioners such as United Health Services, Turner Construction, DPR Constructions as well as other owners, designers, and engineers. The survey participants were selected based on their roles, experience and expertise in healthcare projects. The participant was asked to compare two indicators pairwise with respect to the objectives using a scale ranging from 9 to 1/9. Scale one means both indicators are equal. 9 mean that indicator A is more important than indicator B. Requiring the participants to compare two categories such as comparing initial team (Credit A) to team experience (Credit B), as well as the importance of intensity by circling the intensity of the importance for each pairwise comparison as shown in Table 10. The pairwise comparison is conducted by comparing two indicators, such as initial team to team experience, and choosing which indicator is more important than the other thus ranking the indicators in terms of relative ratio scale (Saaty, 2006). To complete filling the matrix of pairwise comparison, numbers are used to represent the relative importance of one indicator over another with respect to the property. The numbered used is the values 1 through 9 assigned to judgments in comparing pairs of indicators in each level of the AHP (Saaty, 2008). The circles in Table 10 are an example of participant choice in the pairwise comparison for each indicator. For example, when comparing Initial Team with Team Experience, the participant circled 5 which indicate that the Initial Team is more strong and important than Team experience.

Table 10 - Example of Pairwise Comparison

Phase 1 - Conceptual (Planning) Credits

Category	Credit A	Credit B	A is more important than B				Or	B is more important than A			
			Extreme	V. Strong	Strong	Moder.	Equal	Moder.	Strong	V. Strong	Extrem
Planning	Initial Team:	Team Experience	9	7	5	3	1	3	5	7	9
		Collaboration	9	7	5	3	1	3	5	7	9
		Communication	9	7	5	3	1	3	5	7	9
		LPS	9	7	5	3	1	3	5	7	9
		BIM	9	7	5	3	1	3	5	7	9
		TVD	9	7	5	3	1	3	5	7	9
		IT	9	7	5	3	1	3	5	7	9
Planning	Team Experience:	Collaboration	9	7	5	3	1	3	5	7	9
		Communication	9	7	5	3	1	3	5	7	9
		LPS	9	7	5	3	1	3	5	7	9
		BIM	9	7	5	3	1	3	5	7	9
		TVD	9	7	5	3	1	3	5	7	9
		IT	9	7	5	3	1	3	5	7	9

In Table 10, it is required that each participant compare in the conceptual phase the importance of the credits to each other by pairwise comparison. For example, Credit “A” Initial Project Team is compared by Credit “B” Individual Experience. Each participant must circle one choice for each comparison; by choosing (1) he indicates that they are equal. Each credit is compared to the other and answered in the survey. This credit scale is based on AHP scale of one (equal) to nine (extreme) for pairwise comparisons as shown in Table 9 (Saaty, 1990).

Prior to sending the survey to construction stakeholders, a trial survey was reviewed by a sample of close colleagues in Lean/IPD industry to receive feedback regarding the questions, clarity and the format of the survey. Dr. Tariq Abdelhamid, Professor at Michigan State University, and leading practitioner in Lean Construction Institute; Joseph Kranz of Turner Construction; and Tim Ott of Universal Healthcare System were among the participants providing the feedback.

The survey questionnaire was sent to approximately 1,200 construction industry practitioners and stakeholders using online Surveymonkey. The list of 1,200 lean practitioners were collected over the last two years from attending three international lean conferences and three academic forums on lean practice. The data collected by the survey was used to establish a base line weighting for measuring the rating model. Data were collected from participants with approximately 10% return. The survey consisted of 10 sections to help the participants in understanding and encourage participation (please see Appendix A for a printed survey in its entirety). The survey was distributed via internet using the website Survey Monkey in addition to personal collection and field visits to different projects. Personal collection and field visits were the most accurate and correct method for collecting required data because it's personal, easy to explain and if any questions asked it is immediately answered to participants. Online survey was difficult and had many errors and needed lots of follow up and rescoring to correct the data due to misunderstanding questions. Most of the response came from online survey and only 25% of the survey collected in person due to the fact that data were from all over the world.

3.3.3 Data Analysis and Evaluation

After gathering the raw material from the survey, data was organized into information and evidence was abstracted from the information through the process of analysis and testing to finally evaluate the hypotheses and generate conclusions. There are three key concepts for analysis and evaluation of the data: validity, reliability, and accuracy.

> *Accuracy* is the ability to have unbiased results representing the accurate picture of the research.
>
> *Validity* is the accuracy of data collected to represent the true picture of the subject matter.
>
> *Reliability* is the ability to get the same results when the research is repeated by other researchers.

3.3.3.1 Survey Results

Survey participants: The survey was sent to a large number of construction professionals to collect the maximum amount of response among the industry. Figure 15 displays the percentage of the different participants to this survey. The survey responds consisted of 45 % general contractors, 15 % project owners, 13% engineers and designers, 5 % architects, 4 % specialty contractors, 3 % vendors and suppliers and 15 % other professionals.

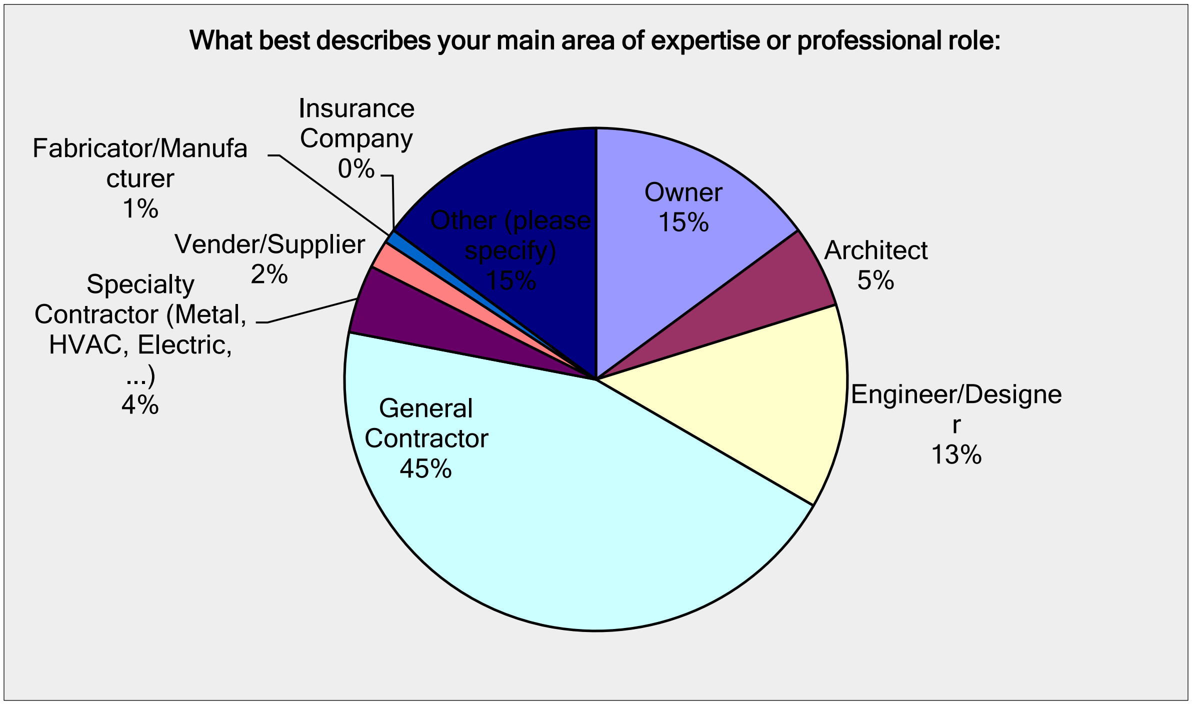


Figure 15: Survey Participants

The survey results also indicated that most of the construction stakeholders had more than ten years of experience in their fields: 75% of the survey participants have more than ten years of experience, 16 % have six to ten years of experience, and 9 % have less than five years. Figure 16 displays the experience of survey participants. The experience of the participants reflects that survey participants have experience and their professional opinion can give a high validity to the rating score.

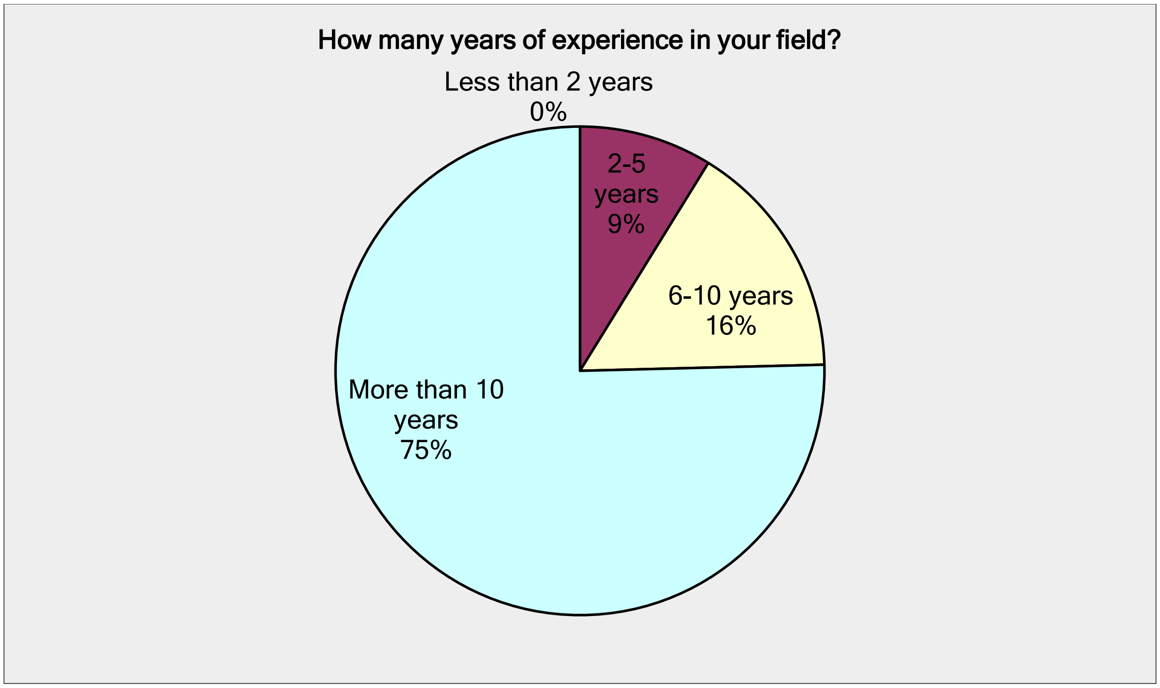


Figure 16: Participant Experience

The survey participants experience was diversified among many construction sectors: 61% of the participants represent the private sector, 15% government sector, 14% public sector, 8% self-employed sector, and 2% of academic sector. Figure 17 displays the distribution of the different participant sectors.

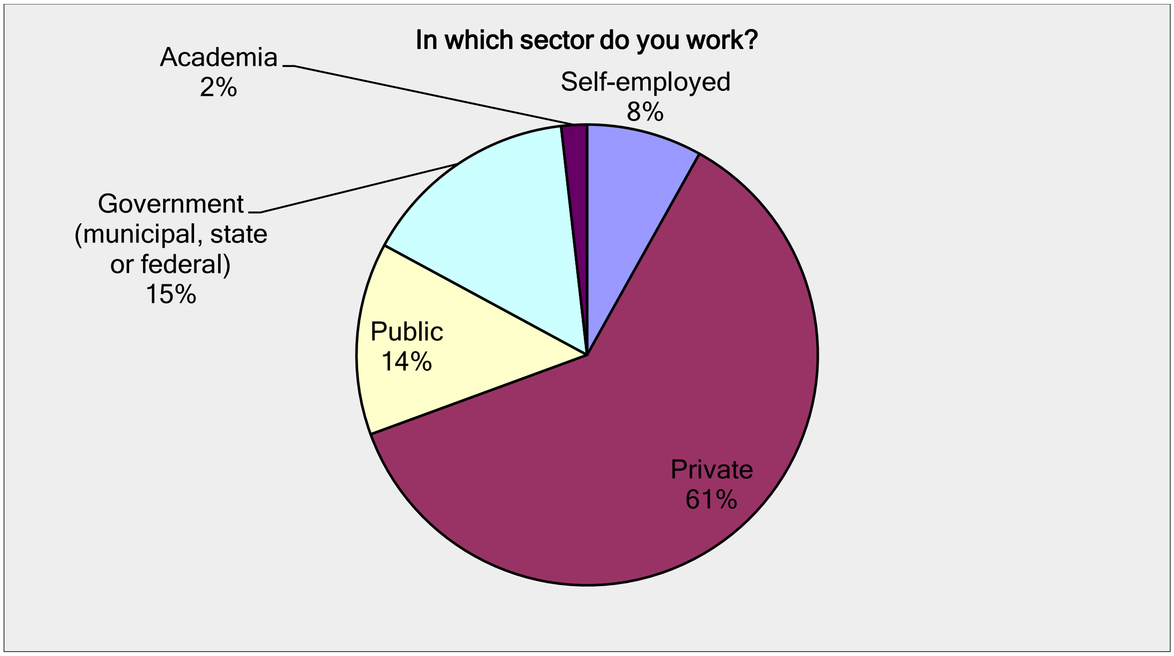


Figure 17: Work Sectors

The survey results in regard to project delivery system revealed that 24% of participants use Design/Bid/Build, 23% use Design/Build, 21% use CM, 11% some form of IPD, 8% program management, 11% Lean/IPD, and 2% other systems. These results conclude that only 11% use Lean/IPD system which is a very small percentage that applies Lean construction. Figure 18 exhibits the project delivery results.

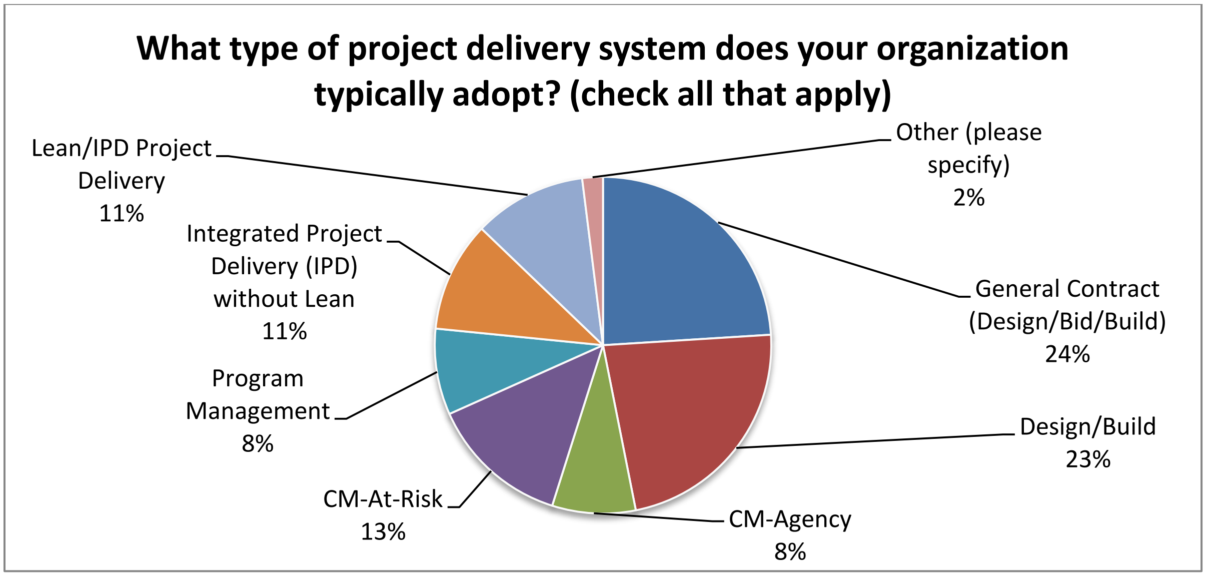


Figure 18: Type of Project Delivery System

When participants were asked about their years of experience in Lean Construction, 52% have less than two years, 28% have two to five years, 10% have no experience in lean, 6% have six to ten years, and only 4% have more than ten years. Lean Construction is new to the industry and only 4% considered to be expert with more than ten years of experience. Figure 19 show the percentage of lean experience among the participants.

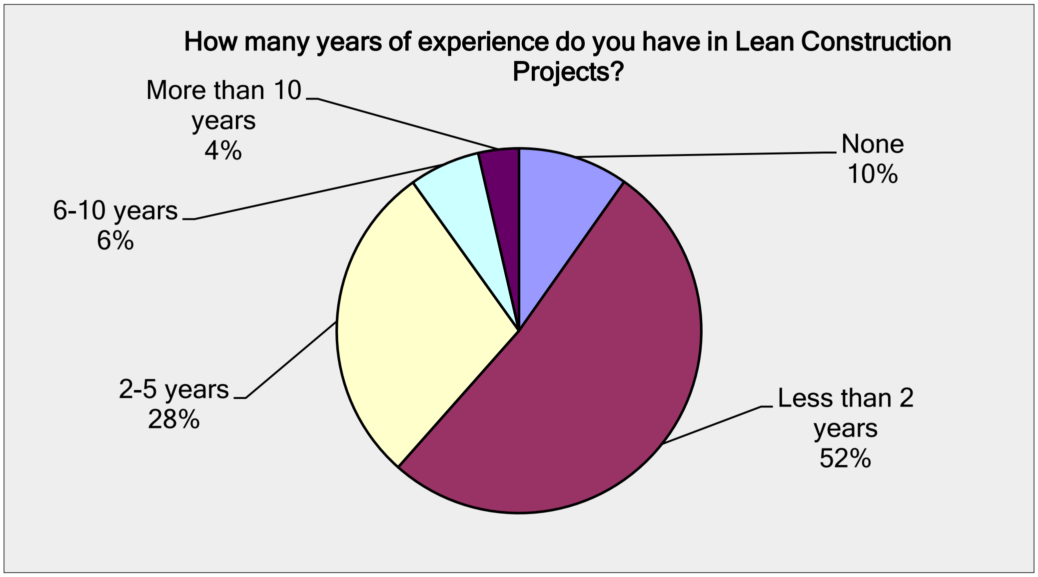


Figure 19: Lean Experience

These data obtained from the conducted survey are very important and extremely valuable because they determine the bases for the scoring points for the LPRS. It was not easy obtaining these data from construction stakeholders but rather very time consuming and it took many attempts and trials to gather the required information.

3.3.3.2 Data Analysis

After collecting the survey results from all the participants, they were entered into Expert Choice software for analysis. Expert Choice is a computer program that employs the Analytical Hierarchy Process (AHP) for analyzing the rating system network structure and assigning weights for the different indicators. In Expert Choice, a model is built to perform a pairwise assessment and a synthesis analysis is performed to get the results.

The overall goal is to obtain total project success. The criteria for success - quality, cost, time, safety and disputes - are entered into the model. The construction stakeholder judgments from the survey are entered for the importance of the criteria with respect to goal, then sub-goals, and indicators. After all judgments have been entered to Expert Choice, a synthesize analysis is performed.

Figure 20 displays Expert Choice Model View results for all the categories and shows the credit weights for each project success indicator based on the survey expert opinions. It displays the goal of the hierarchy model is total project success and the sub-goals are: Conceptual phase, Design phase, and Construction phase. Planning phase credit has 40.1%, Design phase credit 35.1%, and Construction phase credit is 24.9%. The results show two credits: local score and global score. The local score represents the indicator score under the specific phase while the global score represents the indicator score for the entire model. For example, initial team indicator shows 14.7% score for conceptual phase but it shows 5.9% for overall score for the project success. The figure displays local weight (L) and global weight (G). The local weight (L) represents the weight of the indicator in its phase while the global weight (G) represent the indicator weight in reference to the overall project goal. For example, initial team local weigh is 0.147 which represents 14.7% of the conceptual phase. However, the global weight for the initial team is 0.059 which represents 5.9% of the project goal (Total Project Success).

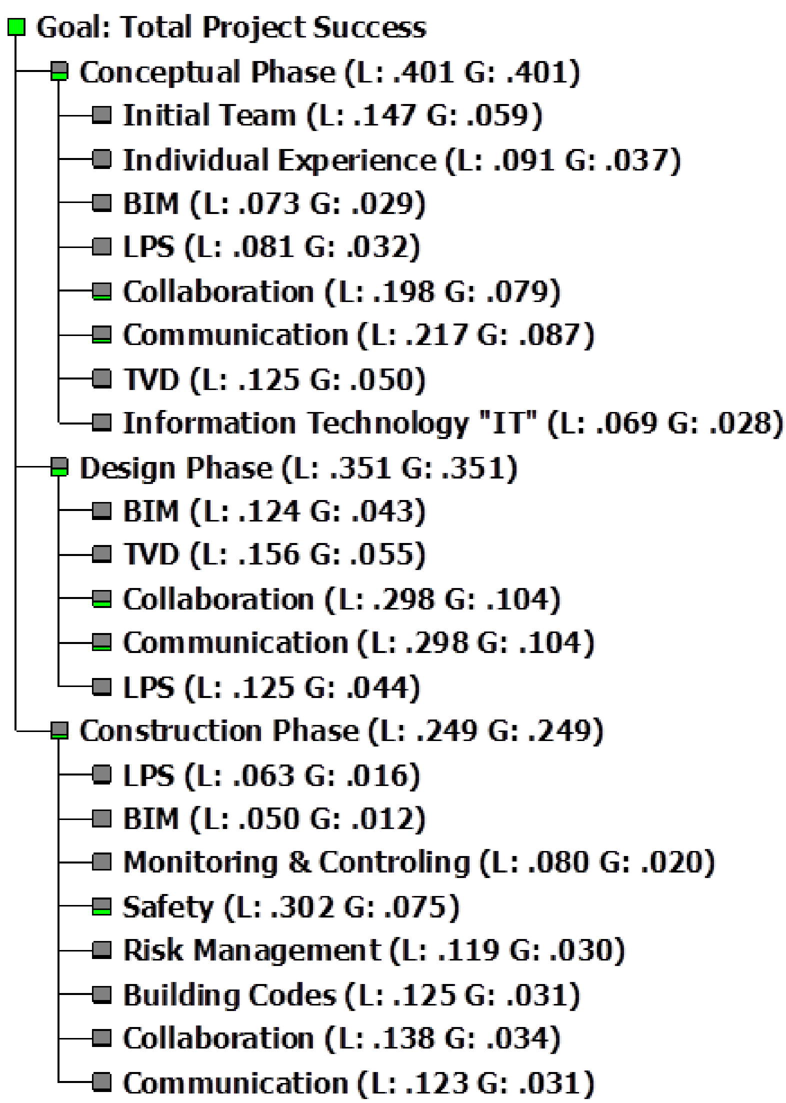


Figure 20: Expert Choice Credit Results

3.3.4 Validation of first hypothesis

After obtaining the survey results reflecting expert opinion and entering them into Expert Choice, the percentage of the twelve indicators credits was stabilized as shown in Table 11. The indicator percentage represents the influence of this indicator on the final project success results. For example, communication between project team members affects the final project by 22.2%.

Table 11: Project Indicator Score

Lean Project Rating System "LPRS"			
NO.	**Indicator**	**Score**	**%**
1	Communications	0.222	22.2
2	Collaboration	0.217	21.7
3	Target Value Design (TVD)	0.105	10.5
4	Last Planner System (LPS)	0.092	9.2
5	Building Information Modeling (BIM)	0.084	8.4
6	Safety Measurements	0.075	7.5
7	Initial Team	0.059	5.9
8	Team Experience	0.036	3.6
9	Building Codes	0.031	3.1
10	Risk Management Plan	0.030	3.0
11	Information Technology (IT)	0.028	2.8
12	Monitoring & Controlling	0.021	2.1

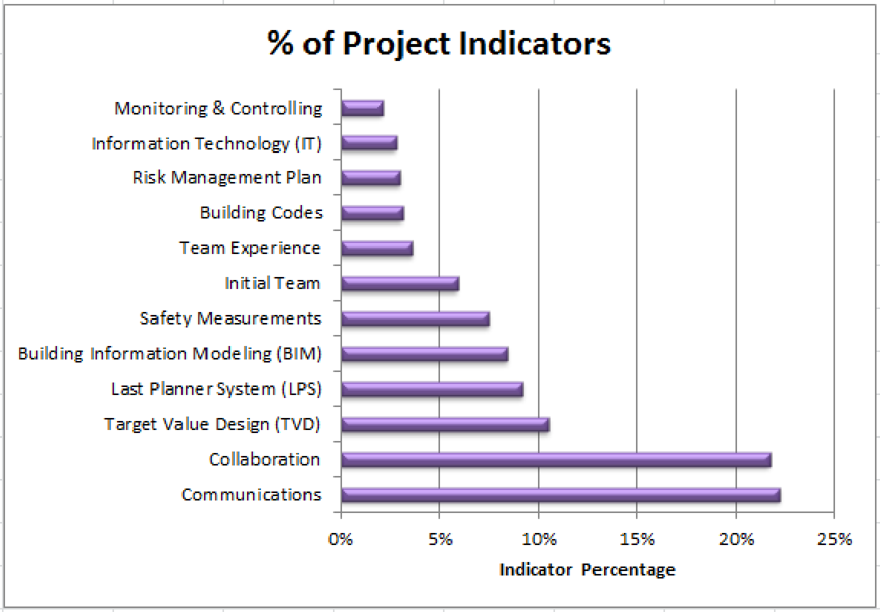


Figure 21: LPRS Indicators

Figure 21 displays Expert Choice results for the twelve indicators which represent the total credit score for the LPRS. Each indicator has a certain percentage representing the required credit which adds up to the final project success. The score for each of the twelve project success indicators will be used as the possible credit for that indicator and all of them make the credit scores for the new rating system.

Once all the credits for each indicator have been identified, they are entered in a score card for each construction phase. Figure 22 displays the entire rating score model with all the credits to each indicator.

Survey Results of Construction Expert Opinions

Lean Project Rating System (LPRS)
1.00

Conceptual Phase 0.40

Planning Phase	Local Wt.	Global Wt
Initial Project Team	0.147	0.059
Individual Experience	0.090	0.036
BIM	0.073	0.029
LPS	0.081	0.032
Collaboration	0.198	0.079
Communication	0.217	0.087
TVD	0.125	0.050
IT	0.069	0.028
	1.00	0.40

Design Phase 0.35

Design Phase	Local Wt.	Global Wt
BIM	0.124	0.0434
TVD	0.156	0.0546
Collaboration	0.298	0.1043
Communication	0.297	0.10395
LPS	0.125	0.04375
	1.00	0.35

Construction Phase 0.25

Construction phase	Local Wt.	Global Wt
LPS	0.063	0.016
BIM	0.05	0.013
Monitoring	0.08	0.020
Safety	0.302	0.076
Risk Management	0.119	0.030
Building Codes	0.125	0.031
Collaboration	0.138	0.035
Communication	0.123	0.031
	1.00	0.250

Figure 22: Survey Results

The first hypothesis stated that team communications and collaboration has a great impact on the final project success. As we see from Expert Choice results, team collaboration and communication indicators contribute 43.9 % of the total project success which validates the first hypothesis. It is also evident that collaboration and communication affect the success results in all project phases: Planning phase 41.50 %, Design phase 59.50%, and construction phase 26.10 %. These results validate the first hypothesis by showing the high impact, represented by percentage of influence, of team collaboration and communication on the total project success.

3.2 Creating Lean/IPD Rating System

3.2.1. Allocating points and evaluate requirements

The maximum points allowed for each credit has been determined by the results of Expert Choice. The total sum of all the credits will determine the final rating score. Table 12 has the final distribution of the rating system credit score for each indicator in the three phases; planning, design, and construction.

Table 12: LPRS Credit Score

LPRS Credit Score

Main Category	Name	Indicator (Project Success Factor)	Credit	Phase
Planning Phase	P1	Initial Project Team	5.90	40.00
	P2	Individual Experience	3.60	
	P3	Collaboration	7.90	
	P4	Communication	8.70	
	P5	Target Value Design (TVD)	5.00	
	P6	Building Information Modeling (BIM)	2.90	
	P7	Last Planner System (LPS)	3.20	
	P8	Information Technology	2.80	
Design Phase	D1	Collaboration	10.40	35.00
	D2	Communication	10.40	
	D3	Building Information Modeling (BIM)	4.30	
	D4	Last Planner System (LPS)	4.40	
	D5	Target Value Design (TVD)	5.50	
Construction Phase	C1	Collaboration	3.40	25.00
	C2	Communication	3.10	
	C3	Building Information Modeling (BIM)	1.20	
	C4	Last Planner System (LPS)	1.60	
	C5	Monitoring & Controlling	2.10	
	C6	Safety	7.50	
	C7	Risk Management	3.00	
	C8	Building Codes	3.10	

3.2.2 Develop Lean/IPD rating scale

A rating scale ranking is chosen to identify the performance of the project. Five different level certifications were assigned to identify project performance; Excellent, Very Good, Good, Fair, and Poor. Table 13 represents LPRS rating scale ranking and the percentage corresponding to each rank.

Table 13 - Proposed LPRS Rating Scale

Project Rating	**Percentage (%) of project success**
Poor	Score ≤ 60%
Fair	Score > 60%
Good	Score > 70%
Very Good	Score > 80%
Excellent	Score > 90%

3.4 Lean Construction Rating System Score cards

The following are the rating system score cards in all three phases of the project:

Planning phase score card:

This score card measures the project success in the planning phase, which represents 40% of the total project success. The eight indicators in this phase may be checked anytime during this phase and if the score card is low, then adjustment to the indicators that give low scores can be made to increase the possibility of success. Each indicator has its possible score and how to measure the indicator as illustrated in table 14. For example, Initial Team indicator has a possible score of 5.9 points which is the participation of project stakeholders from the beginning of the project. If only the owner and the architect participate, then the actual score will be 1.9 points (0.9 for the owner and 1.0 for the architect). Once actual score is measured construction stakeholders can be able to determined which area needed to be improved.

Table 14: Planning Phase Score Card

Lean Project Rating System (LPRS)

(Planning Phase)

Project Name:
Location:
Project Description:
Owner:
General Contractor:
Proposed Budget:
Proposed Schedule:
Project Delivery Method:

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	Initial Project Team: How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	0
			0.9	1	1	1	1	1		
	P2	Team Experience:	< 5 years		5-10 years		> 10 years		3.6	0
		Owner	0.2		0.3		0.6			
		Architect	0.2		0.3		0.6			
		Engineers	0.2		0.3		0.6			
		General Contractor (GC)	0.2		0.3		0.6			
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	0
			7.9	7.0	5.0		3.0	0.0		
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	0
			8.7	8.0	6.0		4.0	0.0		
	P5	Target Value Design (TVD): Was TVD used in planning phase?	Full		Partial		None		5.0	0
			5.0		3.0		0.0			
	P6	Building Information Modeling (BIM):Did you use BIM?	Yes			No			2.9	0
			2.90			0.00				
	P7	Last Planner System (LPS): Was the LPS Used?	Yes			No			3.2	0
			3.20			0.00				
	P8	Information Technology (IT): RFI communication, Project Tracking, Internet tracking	Yes			No			2.8	0
			2.80			0.00				
Total Planning Phase Score									40.00	0.00
										0%

Design phase - Score cards:

Similar to planning phase, design phase score cards measure the five indicators in this phase: Communication, Collaboration, Target Value design "TVD", Last planner System "LPS", and Building Information modeling "BIM". Each indicator has a possible score and actual score that is the earned credit. The total possible credit in this phase is 35 points. Table 15 displays Design Phase Score Card with possible credit scores.

Table 15: Design Phase Score Cards

Lean Project Rating System (LPRS)
(Design Phase)

Project Name:
Location:
Project Description:
Owner:
General Contractor:
Proposed Budget:
Proposed Schedule:
Project Delivery Method:

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	0.0
			10.4	10.0	8.0	6.0	0.0		
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	0.0
			10.4	10.0	8.0	6.0	0.0		
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
	D4	Last Planner System (LP Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
Total Design Phase Score								**35.00**	**0.00**
									0%

Construction phase - Score Card:

This score card measures the performance of the project during construction phase. It consists of eight Indicators: collaboration, communication, safety, building codes, risk management, monitor and control, BIM, and LPS. LPRS score cards can be used at any time during the construction phase. Based on the rating scores obtained for each indicator, construction manager can adjust and take the necessary steps to correct low score indicators to improve project performance.

Table 16 displays Construction Phase Score Card and shows all eight indicators and their possible scores.

Table 16: Construction Phase Score Card

Lean Project Rating System (LPRS) (Construction Phase)									
Project Name:									
Location:									
Project Description:									
Owner:									
General Contractor:									
Proposed Budget:									
Proposed Schedule:									
Project Delivery Method									
Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	0.0
			7.5	7.0	6.0	3.5			
	C2	Collaboration	Excellen	Very Goo	Good	Fair	Poor	3.4	0.0
			3.4	2.45	1.7	0.85	0		
	C3	Communication	Excellen	Very Goo	Good	Fair	Poor	3.1	0.0
			3.1	2.55	1.6	0.85	0		
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	0.0
			3.1		1.6	0.0			
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	0.0
			3.0		1.5	0.0			
	C6	Monitoring & Controlling:	Yes			No		2.1	0.0
			2.10			0.00			
	C7	Last Planner System (LPS Was the LPS Used?	Yes			No		1.6	0.0
			1.6			0.0			
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0.0
			1.20			0.00			
Total Construction Phase Score								25.00	0.00
									0%

Actual Project Performance – Score Card

This score card measures the actual project performance in the five success criteria: Quality, Budget, Time, Safety and Disputes. Once a project is completed, it could be applied to measure the actual results. For example, if a project scores 40 points in Safety, 17 points in Quality, 15 points in Budget, 12 points in Schedule, and 4 points in Disputes, then the project total score is 88 points. This means that the project performance is very good (88%). Table 17 represents the actual project results score card.

Table 17: Actual Project Score card

Lean Project Rating System (LPRS)

Project Name:
Location:
Project Description
Owner:
General Contractor:
Proposed Budget:
Proposed Schedule:
Project Delivery Method

Actual Project Results

Project Success Criteria								
Safety	Number of Accident						Possible Points	Actual Credits
	None	Minor Accidents			Major			
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0			
							45	0
Quality	Excellent	Very Good	Good	Fair	Poor		Possible Points	Actual Credit
	19	17	15	10	0			
							19	0
Budget	Greater than proposed		Equal	Less than proposed			Possible Points	Actual Credits
	0		15	15				
							15	0
Schedule	Overrun		On Time	Less than proposed			Possible Points	Actual Credits
	0		12	12				
							12	0
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)			Possible Points	Actual Credits
	9		4	0				
							9	0
Total Project Success Score							100	0.00

3.5 How to Use LPRS Score Cards

To use LPRS score cards on a new project, the project manager or lean expert will use the three score cards for each of the project phases: planning, design and construction. Each phase will have its total predicted score and adding all three scores will result in the total predicted score for project success.

In the planning phase, the eight indicators P1 through P8 will be scored as shown on the planning phase score card. For example, Case Study 01 in appendix D displays the credits for this project. P1, Initial Project Team, has 0.9 credits for the owner, 1.0 credit for the architect and 1.0 credit for the general contractor, totaling 2.9 credits out of 5.9 possible credits. Also, collaboration score is 7.9 credits out of 7.9 possible credits which indicate full collaboration between project teams. After adding all eight indicators for this case study, the total planning phase score was 29.1 out of 40 possible credits. The project manager can look at this score and know that his project is predicted to succeed by 73% only in the planning phase. To improve or increase project success, corrective measurements shall be taken to the indicators that have lower score such as the initial project team, target value design TVD (scored zero) and building information modeling BIM (scored zero). The project manager can suggest that TVD must be implemented as well as BIM to have a higher possibility of project success.

The same steps shall be used for design phase and construction phase to score the performance of the project. Construction stakeholders can take corrective measurements for each phase to improve the rating scores and ultimately the project success.

After completing the creation of the rating system and preparing the score cards in all project phases, the next step is to validate the rating system.

The next chapter covers the validation methodology including the random selection of different projects, data collection, organization, statistical analysis and evaluation or the rating system. Case Study is considered to validate LPRS. The case study to be performed on a project which has completed all three phases: planning, design and construction. First, using actual project result score cards, data is collected for each of the success indicators to measure performance of quality, budget, time, safety and disputes. Second, using the LPRS predicted score cards; data are collected for each phase to measure indicators performance. Finally the actual score and LPRS predicted score is compared to each other for validity of the scoring system. A case study survey was carefully prepared to solicit the construction industry and collect many completed projects to be considered for the validation. The survey was sent by internet poll to construction professionals including owners, architects, engineers, general contractors, special contractors and construction suppliers. The survey was also conducted by personal observation of different projects and by interview of a variety of construction professionals and managers. Once the data for case study was collected, statistical analysis was performed to check the validity of the rating system. Regression analysis and t-Test were performed on all 30 case studies and comparison tables and charts were prepared for final conclusions.

4 CASE STUDIES

The main objective of this chapter is to discuss the validity of the proposed rating system by reviewing the results of a number of case studies collected form actual completed projects that were conducted. Thirty case studies were collected from construction industry practitioners including healthcare systems, commercial buildings, and highway projects. The evaluation results obtained, and the conclusions reached based on these case studies were prepared mostly for the purpose of verifying the feasibility of the proposed LPRS. Each case study included four parts:

1. Measuring actual project performance
2. Measuring planning phase performance
3. Measuring design phase performance
4. Measuring construction phase performance

The main objective is to measure actual project performance and compare it with predicted LPRS performance which is the total score of planning, design, and construction phases. Once the actual score and predicted scores for all thirty case studies is calculated, a statistical analysis is performed and the final results are presented and discussed in this chapter. The discussion of each part of the experiments is presented in the following sections.

4.1 Project Selection for Case Study

Several construction projects were identified and chosen as case studies to measure the validity of the new rating system. Many construction stakeholders - owners, architects, engineers, and general contractors - were solicited to provide actual completed project data for the case study requirements. Universal Healthcare Services (UHS) and Turner Construction were the leading companies participating in this research and provided several of the case studies presented. The projects collected were primarily from the healthcare industry, recognized as the pioneers in applying Lean/IPD methodology within the construction process. Alternative project delivery methods were also investigated to compare their performance and influence on project outcome.

4.2 Data Collection and Survey Results

Once the rating system has been created and the score cards prepared, a survey for the case study was sent to a many of construction stakeholders collecting data on completed projects. The first step was to create a survey representing all pertinent information required for the case study. To collect the required data the following two methods were implemented:

a) Internet survey using Surveymonkey.

b) Personal interview of construction professionals for collection of data

c) Project observation and data collections.

Data were collected from 30 varying projects from random selections of participants. The projects consisted of 15 hospitals, 14 commercial buildings, and three highway projects, all located in United States, China and the Middle East.

The data for each project were entered into two types of score cards:

- The first is Actual Score measuring final project success using the five success criteria: Quality, Budget, Time, Safety, and Disputes.
- The second is LPRS Score in the three project phases - planning, design, and construction - to measure the predicted rating score.

Both actual and predicted scores were tabulated, compared and analyzed to measure the validity of the rating system.

The score for the 30 project data samples collected including project success indicators is listed in the Table 18. The last two columns of the table compare the Actual results with the Predicted LPRS results. For example, for case study (1) located in Appendix “D”, the initial team indicator scores 2.9 points out of 5.9 possible score and the team experience scores 3.6 points out of 3.6 possible score points. Each case study was identified by type of project and the project delivery system used.

Table 18: Case Study - Raw Data

Case No.	Project Delivery Method	Project Type	Actual Results	LPRS Predicted Score
1	IPD	Hospital	96	78
2	IPD	Hospital	96	90
3	IPD	Hospital	95	75
4	IPD	Hospital	91	70
5	Design/Build	Building	96	75
6	Design/Build	Building	98	78
7	Design/Build	Building	84	71
8	Design/Build	Building	98	68
9	D/B/B	Hospital	57	49
10	D/B/B	Building	85	65
11	D/B/B	Building	64	44
12	Design/Build	Hospital	98	90
13	D/B/B	Building	91	81
14	Design/Build	Building	73	73
15	D/B/B	Building	85	65
16	D/B/B	Higway	71	50
17	IPD	Hospital	80	65
18	IPD	Hospital	95	81
19	IPD	Hospital	95	87
20	IPD	Hospital	54	13
21	IPD	Hospital	86	85
22	D/B/B	Building	78	60
23	D/B/B	Building	81	63
24	Design/Build	Highway	86	66
25	Design/Build	Highway	78	59
26	IPD	Hospital	98	94
27	IPD	Building	95	94
28	IPD	Hospital	85	74
29	Design/Build	Building	84	71
30	IPD	Hospital	98	91

4.3 Data Analysis

To evaluate the validity of the Lean Construction Rating System, two types of analysis were performed. First is the descriptive analysis to compare the Actual Score and the LPRS Predicted Score. Second is inferential analysis determining the relationship between the Actual Score and the Predicted Score.

4.3.1 Descriptive Analysis

The collected data were tabulated, summarized and organized as shown in Table 10. In this table the data were grouped according to the project delivery methods IPD, Design/Build, and D/B/B. Each row in the table represents one case study scoring all the indicators, project delivery method, project type, actual and LPRS scores.

Table 19: Case Study - Sorted Data

Case Study	Project Delivery Method	Project Type	Actual Results	Rating Score
1	IPD	Hospital	96	78
2	IPD	Hospital	96	90
3	IPD	Hospital	95	75
4	IPD	Hospital	91	70
5	IPD	Hospital	80	65
6	IPD	Hospital	95	81
7	IPD	Hospital	95	87
8	IPD	Building	86	85
9	IPD	Hospital	98	94
10	IPD	Building	95	94
11	IPD	Hospital	85	74
12	IPD	Hospital	98	91
13	D/B	Building	96	75
14	D/B	Building	98	78
15	D/B	Building	84	71
16	D/B	Hospital	98	68
17	D/B	Hospital	98	90
18	D/B	Building	73	73
19	D/B	Highway	86	66
20	D/B	Highway	78	59
21	D/B	Hospital	84	71
22	D/B/B	Hospital	57	49
23	D/B/B	Building	85	65
24	D/B/B	Building	64	44
25	D/B/B	Building	91	81
26	D/B/B	Buildign	85	65
27	D/B/B	Highway	71	50
28	D/B/B	Hospital	54	13
29	D/B/B	Building	78	60
30	D/B/B	Building	81	63

A summary of descriptive statistics for all case studies is tabulated in Table 20.

From the table it is evident that the mean and median for both Actual score and LPRS predicted score are the similar.

Table 20: Descriptive Data Summary

	Actual Score	LPRS Score
Mean	85	72
Median	86	70
Mode	98	70
Std.Dev	14.31	13.00
Maximum Score	98	94
Minimum Score	42	43

Plotting the histogram for both Actual and LPRS scores provide a snapshot of 30 case study data. Figures 23 and Figure 24 represent Actual and LPRS histogram respectively. Both actual and LPRS histograms are close in shape and have some similarity which significantly indicate that they are very close. By examining both histograms, we find that the highest score for the actual results fall between 75 and 95, while the highest score for the predicted LPRS fall between 60 and 92.

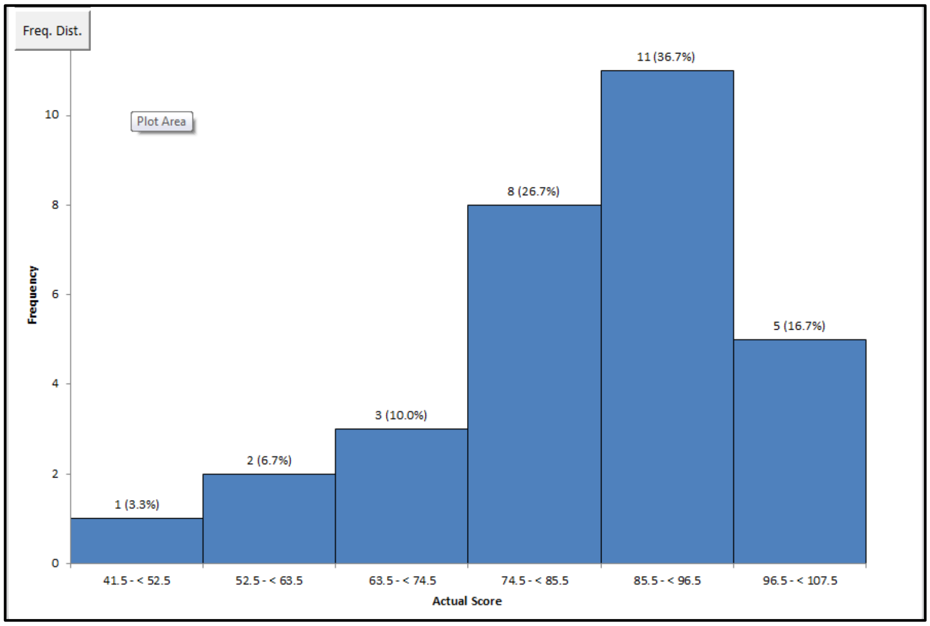


Figure 23: Actual Score Histogram

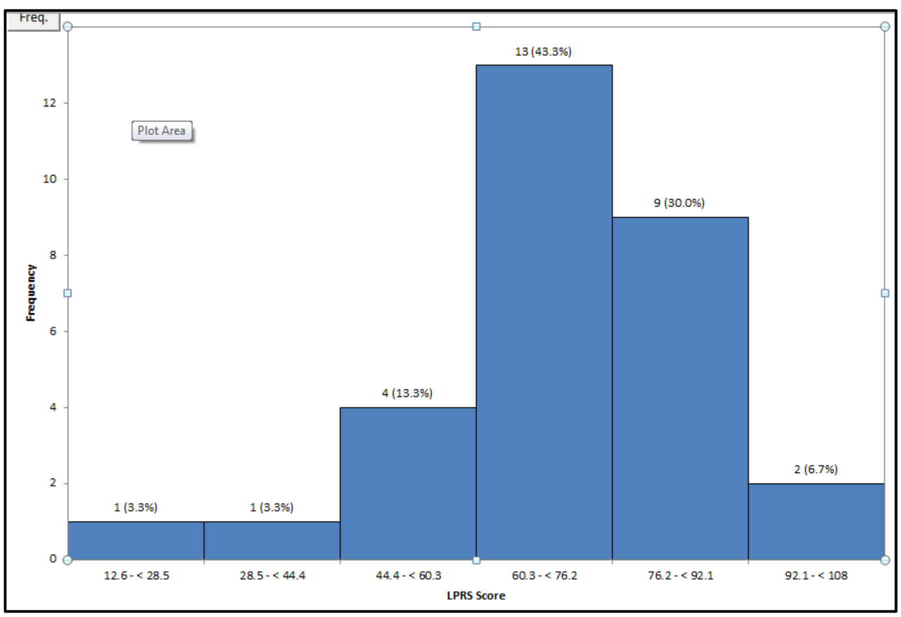


Figure 24: LPRS Score Histogram

4.3.2 Regression Analysis

A regression analysis is a statistical technique to study if there is any linear relationship between a presumed dependent variable and a set of independent variables. It is conducted for two purposes: first to predict the value of dependent variable, and second to estimate the effect of some explanatory variable on the dependent variable.

By applying a regression analysis on the survey results of the case studies, the dependent variable (Actual score) and explanatory variable (LPRS predicted score) are examined to find if there is any relationship between them. Once there is a linear relationship between the two variables, a correlation interpretation (the strength and direction of the linear relationship between the two variables) is conducted. A regression model will also help find the equation of a line that best fits the data, and to use the result to make prediction for future projects.

After sorting the data, project score observation has been plotted on a scatterplot as shown in Figure 25 with two coordinates (x - coordinate representing LPRS Score) and (y - coordinate representing Actual Score). The figure shows a positive correlation between the two variables. The coefficient of determination R^2 is 0.7547 indicate a strong relationship between the Actual score and LPRS predicted score. The coefficient of determination can be used as a measure of the proportion of variability that two variables share, or how much one can be explained "predicted" by the other.

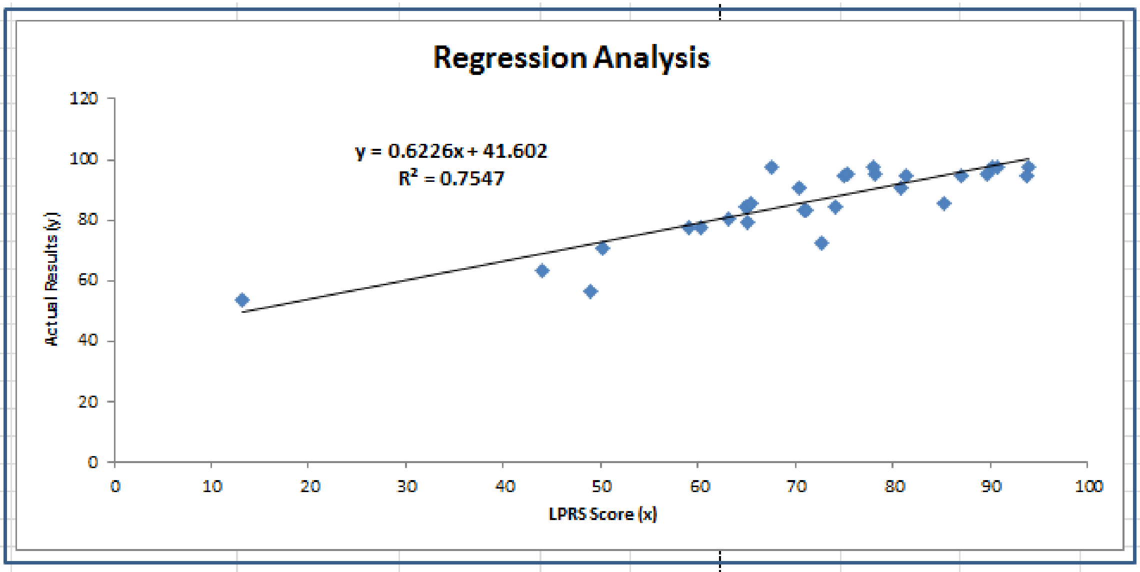


Figure 25: Scatterplot Actual vs. LPR Score

Figure 26 displays the output summary of the regression model for our case studies.

SUMMARY OUTPUT (30 Case Study)								
Regression Statistics								
Multiple R	**0.8687**	**Strength and directoin of the relationship**						
R Square	**0.7547**	**Goodness of fit for equation line**						
Adjusted R Square	**0.7459**							
Standard Error	6.1624							
Observations	30							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	3271.002562	3271	86.13589059	**4.86756E-10**			
Residual	28	1063.297438	37.9749					
Total	29	4334.3						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95%*	*Upper 95%*
Intercept	**41.6020**	4.883	8.52004	**2.91259E-09**	31.6000	51.6041	31.6000	51.6041
LPRS Score (x)	**0.6226**	0.067	9.28094	**4.86756E-10**	0.4852	0.7600	0.4852	0.7600

Figure 26: Regression Statistics

Examining the regression model shown in figure 26, we conclude the following:

1. Overall regression accuracy measured by R^2 equal 0.7547 and adjusted R^2 0.7459
2. Probability that regression output is not random is very high. Significance F is zero (0.000) which indicated the output is not due to any chance.
3. Reliability of y-intercept and LPRS coefficients is very strong. P-Value for both equal to zero (0.000) that causes the rejection of the null hypothesis ($B_o = 0$) and accept the alternative hypothesis ($B_a \neq 0$). There is an actual relationship between the two variables and it is presented by the equation:

$$y = 0.6226\ x + 41.602$$

4. The residual values (Actual value of y – Predicted value of y) in Figure 28 show no pattern and concentrate around zero access as shown in figure

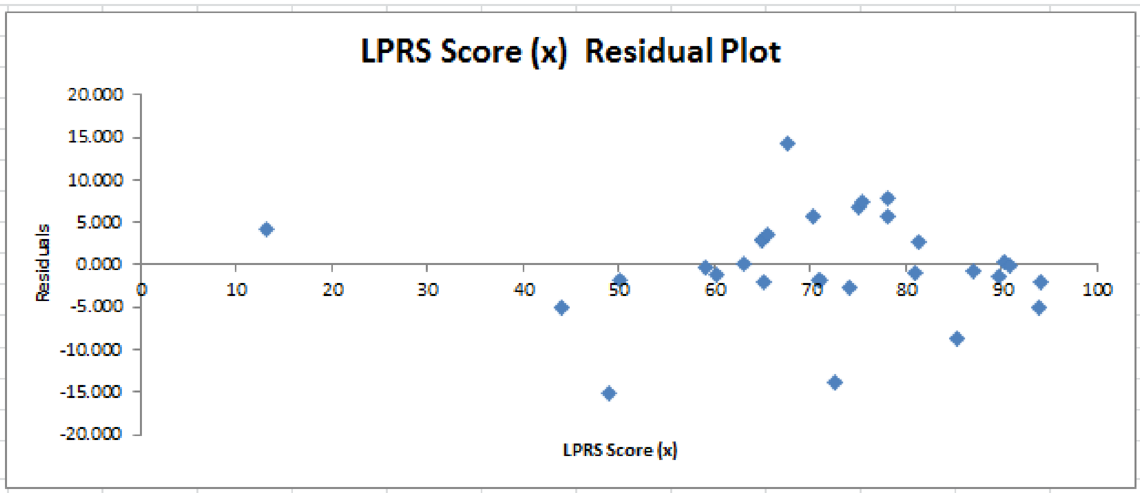


Figure 27: Residual Plot

From the above analysis we conclude that the Lean Project Rating System (LPRS) is a valid system and can be used to predict project success using the prediction equation.

4.3.2.1 Modifying Regression Line

After performing the regression analysis on the case study data and obtaining the prediction equation for the two variables (y=0.6226 x + 41.602), a new score was derived and tabulated. By substituting LPRS score (x) in the equation for all 30 cases, we obtained a new predicted y score. Tabulating both predicted and actual score and performing a regression analysis we obtained a new scatter as shown in Figure 28. Table 21 displays Equation predicted score vs. Actual score

Table 21: Actual & Equation Predicted Score

Case Study	Project Delivery Method	LPRS Score (x)	LPRS Equation (y)	Actual Results (y)
1	IPD	78	90	96
2	IPD	90	97	96
3	IPD	75	88	95
4	IPD	70	85	91
18	IPD	81	92	95
19	IPD	87	96	95
21	IPD	85	95	86
26	IPD	94	100	98
27	IPD	94	100	95
30	IPD	91	98	98
17	IPD	65	82	80
28	IPD	74	88	85
20	IPD	13	50	54
9	D/B/B	49	72	57
10	D/B/B	65	82	85
11	D/B/B	44	69	64
13	D/B/B	81	92	91
15	D/B/B	65	82	85
16	D/B/B	50	73	71
22	D/B/B	60	79	78
23	D/B/B	63	81	81
5	D/B	75	89	96
6	D/B	78	90	98
7	D/B	71	86	84
8	D/B	68	84	98
12	D/B	90	98	98
14	D/B	73	87	73
24	D/B	66	82	86
25	D/B	59	78	78
29	D/B	71	86	84

Figure 28 displays the new line between the two variables. The slope of the line is 45 degree and the coefficient B_0 is zero. The new R^2 equals to 0.9071 indicating a very strong correlation between the actual score and the LPRS predicted score.

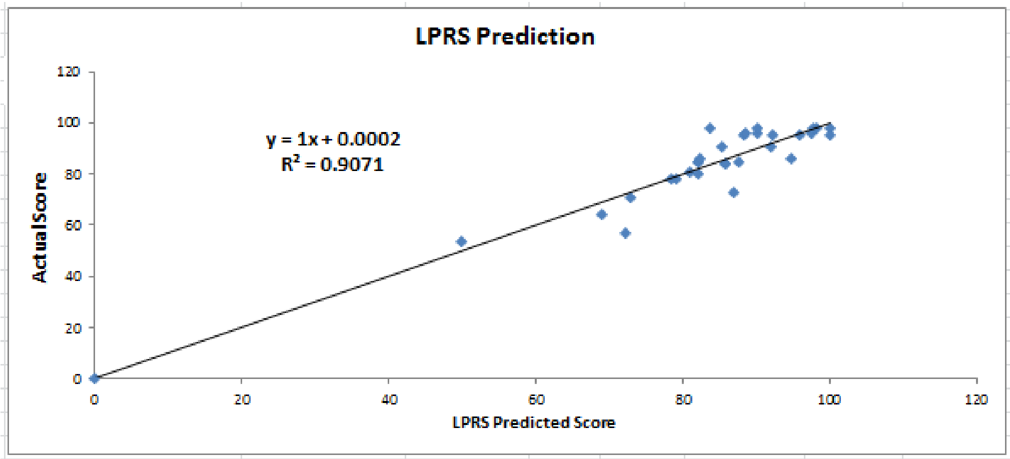


Figure 28: Modified LPRS Prediction

The result of the modified regression analysis is presented in Figure 29.

SUMMARY OUTPUT (Using the LPRS Prediction)

Regression Statistics		
Multiple R	0.8687	Strength and Direction
R Square	0.7547	Goodness of Fit
Adjusted R Square	0.7459	
Standard Error	6.1624	
Observations	30	

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3271.003	3271	86.1359	4.86756E-10
Residual	28	1063.297	37.975		
Total	29	4334.3			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	0.0007	9.3022	8E-05	1.000	-19.05	19.06	-19.05	19.06
LPRS Equation (y)	1.0000	0.1077	9.2809	5E-10	0.78	1.22	0.7793	1.2207

Figure 29: Regression Analysis (LPRS Predicted)

4.3.3 T-Test for Project Delivery Systems

To evaluate the similarity of the Actual score and the LPRS score, a t-Test is conducted to check if the two means are reliably different from each other. After tabulating the two scores as shown in Table 22, several t-Tests were conducted on the 30 case studies projects.

Table 22: T-Test Data (Project Type)

Case Study Results				
Case Study	Project Delivery Method	Project Type	LPRS Score (x)	Actual Score (y)
1	IPD	Hospital	78	96
2	IPD	Hospital	90	96
3	IPD	Hospital	75	95
4	IPD	Hospital	70	91
6	IPD	Hospital	81	95
7	IPD	Hospital	87	95
8	IPD	Building	85	86
9	IPD	Hospital	94	98
10	IPD	Building	94	95
12	IPD	Hospital	91	98
5	IPD	Hospital	65	80
11	IPD	Hospital	74	85
28	IPD	Hospital	13	54
13	D/B	Building	75	96
14	D/B	Building	78	98
15	D/B	Building	71	84
16	D/B	Hospital	68	98
17	D/B	Hospital	90	98
18	D/B	Building	73	73
19	D/B	Highway	66	86
20	D/B	Highway	59	78
21	D/B	Hospital	71	84
22	D/B/B	Hospital	49	57
23	D/B/B	Building	65	85
24	D/B/B	Building	44	64
25	D/B/B	Building	81	91
26	D/B/B	Buildign	65	85
27	D/B/B	Highway	50	71
29	D/B/B	Building	60	78
30	D/B/B	Building	63	81

T-Test Parameters: (two tail test)

Null Hypothesis:

Ho: $\mu\,(actual) = \mu\,(LPRS)$

Alternative Hypothesis:

Ha: $\mu\,(actual) \neq \mu\,(LPRS)$

Significance Level (α):

A = 0.05

T-Test (1) All Project Cases:

In this test, all 30 project are tested to find if the two variables (Actual & LPRS scores) are similar or significantly different.

Table 23: T-Test results on all Projects (30 cases)

t-Test: Two-Sample Assuming Unequal Variances (All 30 cases)		
	Actual Score (y)	***LPRS Score (x)***
Mean	85.7	71.323
Variance	149.459	271.817
Observations	**30**	**30**
Hypothesized Mean Difference	0	
df	53	
t Stat	**3.837**	
P(T<=t) one-tail	0.000	
t Critical one-tail	1.674	
P(T<=t) two-tail	**0.000**	
t Critical two-tail	**2.006**	

From the results of the t-Test shown in table (17), we conclude the following:

T-Stat (3.837) > t-Critical (2.006) and
The probability p-value (0.00) < α (0.05)

The null hypothesis Ho is rejected and the two variables are significantly different.

T-Test (2) Lean Project (IPD only):

In this t-Test, only lean projects including IPD projects where tested.

Table (15) shows the results which conclude that we fail to reject the null hypothesis.

There is a similarity between the two variables (Actual score and LPRS). This results support the research second hypothesis that Project Delivery Method does impact project success outcome. Using integrated project delivery method and applying lean principles will result a higher success than using other traditional project delivery methods.

Table 24: T-Test on Lean/IPD projects

t-Test: Two-Sample Assuming Unequal Variances (IPD Only)		
	Actual Score (y)	***LPRS Score (x)***
Mean	89.54	76.74
Variance	144.603	449.141
Observations	**13**	**13**
Hypothesized Mean Difference	0	
df	19	
t Stat	**1.894**	
P(T<=t) one-tail	0.037	
t Critical one-tail	1.729	
P(T<=t) two-tail	**0.074**	
t Critical two-tail	**2.093**	
Null Hypotheis:		
H_o : μ actual = μ LPRS		
H_1 : μ actual ≠ μ LPRS		
From the above we find that:		
t Stat (1.89) < t Critical (2.093) =====> We fail to reject the null hypothesi		
LPRS Score is simillar to Actual Score Also, p (.074 > α (0.05)		

T-Test (3) Projects (IPD, GMP & D/B):

Similar t-Test was performed on the combinations for IPD, GMP & D/B projects and same results as the first test as shown in table (19):

t-Stat (3.275) > t-Critical (2.028)

p-value (0.002) < α (0.05)

Based on the p-value, the null hypothesis is rejected and there is a significant difference between the two variables (Actual and LPRS) scores.

Table 25: T-Test results on IPD, GMP & D/B Projects

t-Test: Two-Sample Assuming Unequal Variances (IPD, GMP & D/B)		
	Actual Score (y)	*LPRS Score (x)*
Mean	89.05	74.94
Variance	117.474	290.749
Observations	**22**	**22**
Hypothesized Mean Difference	0	
df	36	
t Stat	**3.275**	
P(T<=t) one-tail	0.001	
t Critical one-tail	1.688	
P(T<=t) two-tail	**0.002**	
t Critical two-tail	**2.028**	

T-Test (4) D/B/B Projects:

This t-Test was performed on D/B/B projects to check if there is a similarity between the variables.

From table (20), we conclude the following:

T-Stat (3.247) > t-Critical (2.170)

P-value (0.007) < α (0.05)

The null hypothesis is rejected and there is a significant difference between the two variables (Actual Score and LPRS Score).

Table 26: T-test results on D/B/B Projects

t-Test: Two-Sample Assuming Unequal Variances (D/B/B)		
	Actual (y)	*LPRS (x)*
Mean	79.286	63.129
Variance	84.905	88.376
Observations	**7**	**7**
Hypothesized Mean Difference	0	
df	12	
t Stat	3.247	
P(T<=t) one-tail	0.003	
t Critical one-tail	1.782	
P(T<=t) two-tail	**0.007**	
t Critical two-tail	**2.179**	

The t-Test performed on the different project scenarios indicate that the only similarity between the two variables (Actual & LPRS) occur when integrated project delivery system was applied.

Figure 30 displays the relationship between the different types of project delivery systems. The trend line for actual score indicate that Integrated Project Delivery system have the highest score among all delivery systems. Also, the figure displays that the trend line for LPRS score for Integrated Project Delivery system has the highest score among the other delivery systems.

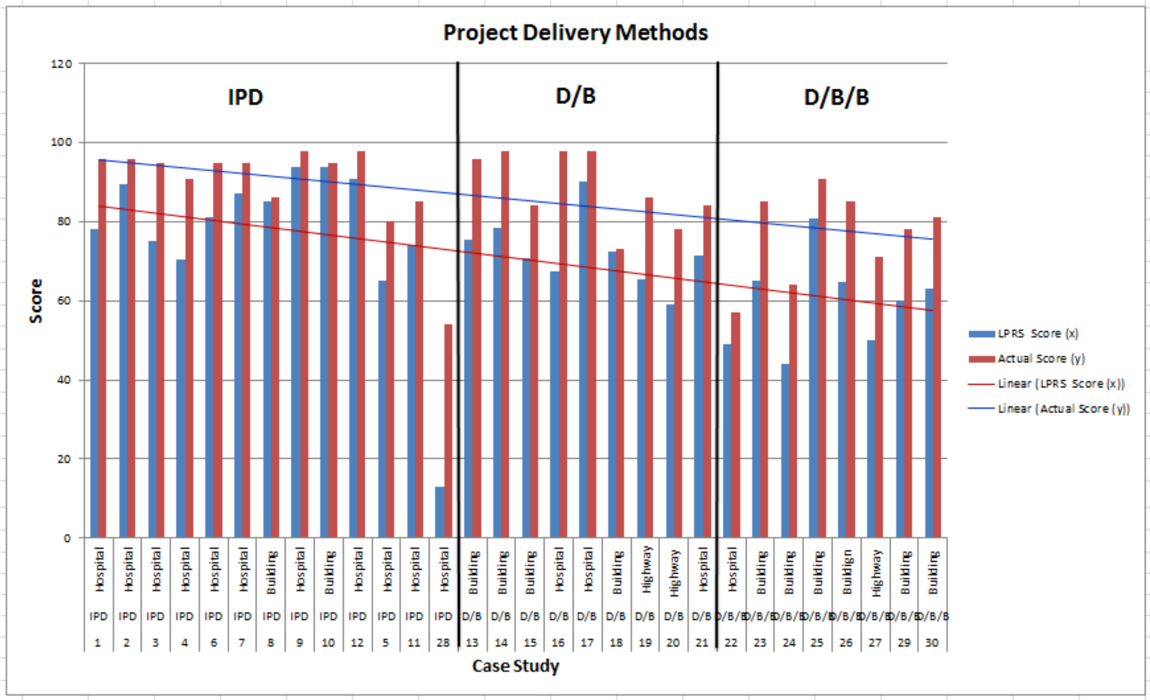


Figure 30: T-Test results – Comparison of Project Delivery Method

4.3.4 T-Test for Project Type

Case study results were organized based on the project type. Data collected had three major project types: hospitals, commercial buildings, and highways. The data were reorganized as shown in Table 27, to perform several T-Tests on project type combinations to see if there is any similarity between the variables using project type. Many T-Tests were performed on IPD, Design/Build, D/B/B, and combination of (IPD, D/B & D/B/B),(IPD &D/B), (IPD & D/B/B), and (D/B & D/B/B).

Table 27: T-Test Data on Project Type

Case Stud	Project Delivery Method	Project Type	Actual Result	Rating Score
1	IPD	Hospital	96	78
2	IPD	Hospital	96	90
3	IPD	Hospital	95	75
4	IPD	Hospital	91	70
5	IPD	Hospital	80	65
6	IPD	Hospital	95	81
7	IPD	Hospital	95	87
8	IPD	Hospital	98	94
9	IPD	Hospital	85	74
10	IPD	Hospital	98	91
11	D/B	Hospital	98	68
12	D/B	Hospital	98	90
13	D/B	Hospital	84	71
14	D/B/B	Hospital	57	49
15	D/B/B	Hospital	54	13
16	D/B	Highway	78	59
17	D/B	Highway	86	66
18	D/B/B	Highway	71	50
19	IPD	Building	86	85
20	IPD	Building	95	94
21	D/B	Building	96	75
22	D/B	Building	98	78
23	D/B	Building	84	71
24	D/B	Building	73	73
25	D/B/B	Building	85	65
26	D/B/B	Building	64	44
27	D/B/B	Building	91	81
28	D/B/B	Building	78	60
29	D/B/B	Building	81	63
30	D/B/B	Buildign	85	65

After performing the T-test on several combinations of project type, the null hypothesis has been rejected in all cases. All the T-Tests performed support the alternative hypothesis that there is no similarity between the actual and LPRS scores when categorized by project type. Figure 31 represents all the T-Test results for different project types.

t-Test: Two-Sample Assuming Unequal Variances		
Hospitals		
	Actual Results	*Rating Score*
Mean	88	73.12
Variance	206.4285714	420.1117143
Observations	15	15
Hypothesized Mean Difference	0	
df	25	
t Stat	2.3024	
P(T<=t) one-tail	0.0150	
t Critical one-tail	1.7081	
P(T<=t) two-tail	0.0299	< α (0.05)
t Critical two-tail	2.0595	
t stat > t Critical & P-value < α =====> Reject the null hypothesis		

t-Test: Two-Sample Assuming Unequal Variances		
Hospital & Highways		
	Actual Results	Rating Score
Mean	86	71
Variance	190	386
Observations	18	18
Hypothesized Mean Difference	0	
df	30	
t Stat	2.78429	
P(T<=t) one-tail	0.00460	
t Critical one-tail	1.69726	
P(T<=t) two-tail	0.00920	< α (0.05)
t Critical two-tail	2.04227	
t stat > t Critical & P-value < α =====> Reject the null hypothesis		

t-Test: Two-Sample Assuming Unequal Variances		
Buildings		
	Actual Results	*Rating Score*
Mean	84.67	71.21
Variance	97.88	170.89
Observations	12	12
Hypothesized Mean Difference	0	
df	20	
t Stat	2.8438	
P(T<=t) one-tail	0.0050	
t Critical one-tail	1.7247	
P(T<=t) two-tail	0.0100	< α (0.05)
t Critical two-tail	2.0860	
t stat > t Critical & P-value < α =====> Reject the null hypothesis		

t-Test: Two-Sample Assuming Unequal Variances		
Highways		
	Actual Results	*Rating Score*
Mean	78	58
Variance	56	60
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	3.2298	
P(T<=t) one-tail	0.0160	
t Critical one-tail	2.1318	
P(T<=t) two-tail	0.0320	< α (0.05)
t Critical two-tail	2.7764	
t stat > t Critical & P-value < α =====> Reject the null hypothesis		

t-Test: Two-Sample Assuming Unequal Variances		
Highways & Buildings		
	Variable 1	*Variable 2*
Mean	83	69
Variance	92	172
Observations	15	15
Hypothesized Mean Difference	0	
df	26	
t Stat	3.5279	
P(T<=t) one-tail	0.0008	
t Critical one-tail	1.7056	
P(T<=t) two-tail	0.0016	< α (0.05)
t Critical two-tail	2.0555	
t stat > t Critical & P-value < α =====> Reject the null hypothesis		

t-Test: Two-Sample Assuming Unequal Variances		
Hospital & Buildings		
	Actual Results	*Rating Score*
Mean	87	72
Variance	155	299
Observations	27	27
Hypothesized Mean Difference	0	
df	47	
t Stat	3.4714	
P(T<=t) one-tail	0.0006	
t Critical one-tail	1.6779	
P(T<=t) two-tail	0.0011	< α (0.05)
t Critical two-tail	2.0117	
t stat > t Critical & P-value < α =====> Reject the null hypothesis		

Figure 31: T-Tests results on Project Type

T-Test analysis has been performed on all different combinations of projects types: hospitals, buildings, highways, hospitals and buildings, hospitals and highways, highways and buildings, and all three project types. All the results of the T-Tests concluded that there are no similarities between any combinations.

Similarities existed between Actual score and LPRS score only when Integrated Project Delivery (IPD) system is used alone.

4.3.5 Chapter Conclusion

A new methodology to create Lean Project Rating System was proposed and it was proven that it is a pioneer idea in construction, specifically in healthcare facilities. It is designed to help predict and explain the performance of construction projects in all phases and ultimately the total project success. It gives direction for further research, and measures practical conditions to help construction professionals improve projects productivity.   Applying the new rating system to case studies was helpful in validating the accuracy of the LPRS. It was demonstrated that LPRS can predict project performance in planning phase, design phase and construction phase and ultimate the final project success. Statistical analysis, such as T-Test and regression analysis were performed to validate the research hypotheses. It can be concluded that these case studies presented in this research have successfully provided a proof of concept for the hypotheses presented.

5. CONCLUSIONS AND RECOMMENDATIONS

This chapter revisits the research hypothesis and questions proposed earlier to draw conclusions based on the findings from the study. It also summarizes the purpose of developing the new rating system (LPRS) and its application to predict the behavior of construction projects. The chapter concludes with recommendations for future work.

5.1 Summary of Research Results

The ultimate objective of the present research in the area of lean construction was to develop a better understanding of the entire construction process, including planning, design and construction phases and help improve the final project results. The quality and final success of construction projects will be improved by applying the new rating system (LPRS) developed in this research. By applying LPRS in all construction phases, construction stakeholders can improve productivity and predict final project success results.

In the context described above, this research concludes the following:

Hypothesis (1): Team collaboration and communication has a significant impact on final project success.

As a result of applying the seven steps methodology defined in the research, to create the new rating system (LPRS), team collaboration and communication contributes 43.9 % of final project success score. It also attributes 41.5 % of planning phase score, 59.43 % of design phase score, and 26 % of construction phase score. This attribute is significant enough to affect the project final results. Review of the case studies suggests that team collaboration and communication during all phases of the project improve productivity and have significant impact on project final success. Figure 32 displays collaboration and communication indicator percentage in relationship to final project success.

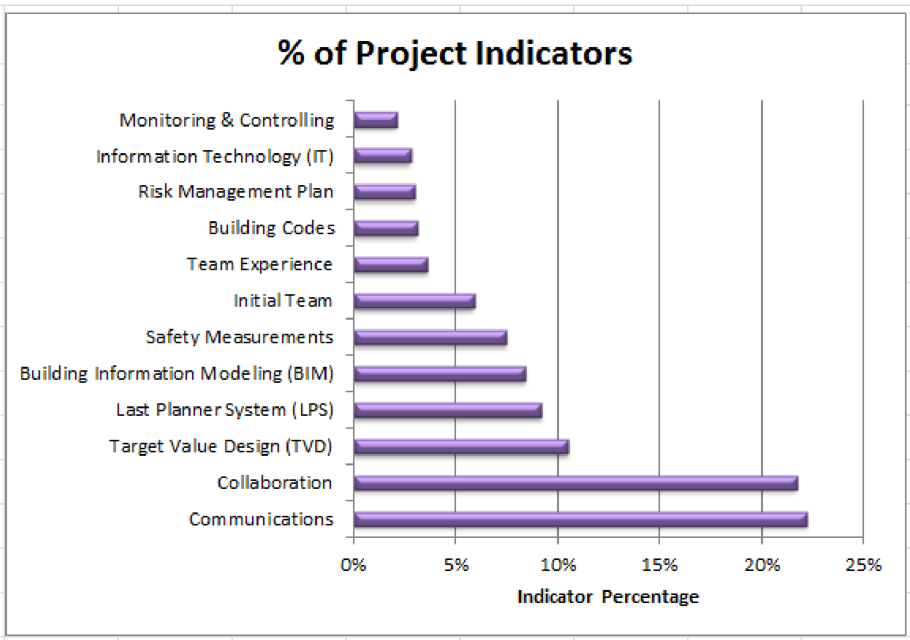


Figure 32: Project Indicators

These results validate the first hypothesis and proof that team collaboration and communication does have a significant impact on final project success

Hypothesis (2): Lean/Integrated Project Delivery system has a great influence on final project outcome.

Review of the thirty case studies indicates that three project delivery methods were observed: Integrated Project Delivery (IPD), Design/Build (D/B), and Design/Bid/Build (D/B/B). As data were summarized and categorized based on the project delivery methods, a T-Test was performed on the actual project score and predicted LPRS score. The purpose of the T-Test was to determine the similarity and significance of the project delivery method on the two variables (Actual and LPRS scores). The test was performed on all 30 cases which has all the projects and all three delivery methods. Then, it was also performed on each project delivery method separately and in various combination such as (IPD & D/B), (IPD & D/B/B), and (D/B & D/B/B).

As a result of running all the tests, only IPD was significant, we fail to reject the null hypothesis and prove that there was a significance similarity between actual and predicted LPRS scores. All other cases and combination, the null hypothesis was rejected indicating no similarity between the two variables. The results of the T-Test for IPD are displayed in Figure 35 below:

t-Test: Two-Sample Assuming Unequal Variances (IPD Cases)		
	Actual Score (y)	*LPRS Score (x)*
Mean	89.54	76.74
Variance	144.603	449.141
Observations	**13**	**13**
Hypothesized Mean Difference	0	
df	19	
t Stat	**1.894**	
P(T<=t) one-tail	0.037	
t Critical one-tail	1.729	
P(T<=t) two-tail	**0.074**	
t Critical two-tail	**2.093**	
Null Hypotheis:		
H_o : μ actual = μ LPRS		
H_1 : μ actual ≠ μ LPRS		
From the above we find that:		
t Stat (1.89) < t Critical (2.093) =====> We fail to reject the null hypothesi		
LPRS Score is simillar to Actual Score Also, p (.074 > α (0.05)		

Figure 33: T-Test results on IPD projects

Hypothesis (3): Lean Project Rating System (LPRS) can predict project success and help construction stakeholders to improve productivity in all construction phases.

After creating the Lean Project Rating System and collecting data from 30 case studies, a statistical analysis was performed to determine the validity of the rating system. A regression analysis on the observed and predicted score concluded the following:

1. $R^2 = 0.7546$ which indicate the overall regression accuracy
2. Multiple R = 0.8687 showing a strong relationship between the two variables (Actual & Predicted).

3. Significant F= 0.000 < 0.10 output that the regression output is not random.
4. Reliability of y-intercept and coefficient of x is very strong: the null hypothesis ($B_0 = 0$) is rejected:
    a. P-Value for y-intercept and Coefficient is 0.00 < 0.05
5. The residuals show no pattern and centered around 0.0

From the regression analysis, a significant relationship between the two variables (Actual & LPRS) exists and represented by the following linear equation:

$$Y = 0.6226\ x + 41.6$$

This finding provides support to the hypothesis that LPRS model can predict the degree of success for future construction projects. Figure (36) displays LPRS regression model.

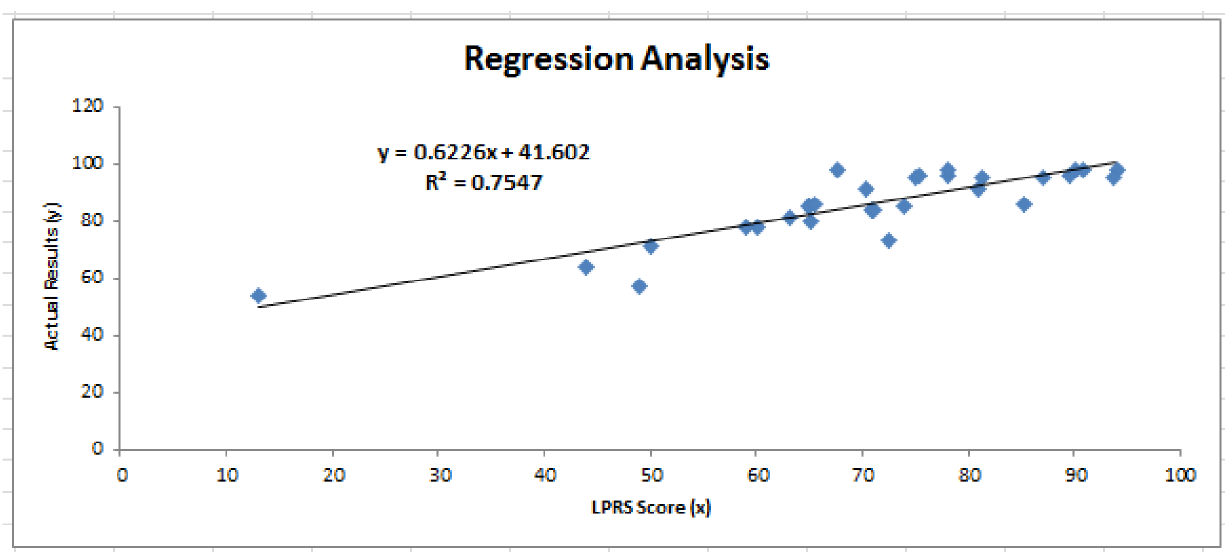


Figure 34: LPRS Regression Model

5.2 Conclusions

The research study for creating the LPRS gives support to a number of conclusions:

First, Lean Project Rating System is a new active tool that can predict the final success of construction projects. It can be applied to the project during planning phase, design phase, and construction phase to measure performance and alert for improvements.

Second, it can help construction stakeholders in correcting construction problems by rating the process at any phase and taking corrective measures to achieve project goals.

Third, the LPRS is new to construction projects and it is in the initial state. Further development and improvement to the rating system is recommended to the different project types such highways, residential, and buildings.

Fourth, although twelve success indicators have been identified in this research, more research is needed to identify more success indicators that contribute to the final success of construction projects and assure customer values such as quality, time, cost, and safety.

Fifth, the effectiveness of the LPRS remains to be determined by applying it on more new projects and evaluating the system further.

5.3 Research Limitations

Although this research was carefully prepared and reached its goal, there were unavoidable limitations:

First, access to information and resources to create the credit weight for the rating system was extremely difficult to obtain and limited. The pairwise comparison survey used for creating the credit score was sent to approximately 1,200 lean construction professionals but only 120 participants completed the survey. Therefore the return rate was small and might influence the results.

Second, to validate the rating system a second survey was sent to over 1,200 construction professionals and stakeholders and only 30 cases were completed. This small sample case study was also a limitation and can affect the accuracy, confidence and reliability of the results.

Third, access to experts, construction organizations, and stakeholder participants for guidance was very difficult and time consuming. Due to the nature of the construction industry, the majority of construction professionals would not share their project information. This behavior can affect the accuracy of the research results and might affect the sample selection and produce biased results. To improve the results, a more extensive data collection effort is required but it will be very time consuming and extremely costly.

Fourth, the statistical analysis was able to show that using Lean Project Rating System was an effective tool to predict the final project success outcome. However, correlation research may also have its limitations with respect to generalizing of findings. The study involved a specific group of projects in the healthcare system implementing lean principles. It is uncertain whether correlation findings may generalize to other project type or situations.

Finally, this research was conducted by the researcher with limited help and collaboration of the construction industry. To achieve better results, the research requires the adoption of owners and large construction organizations that can provide the required data, case studies and support.

5.4 Recommendation for Future Research

Despite the research limitations, the positive results suggest the need for this type of rating model in construction projects. Before application of LPRS, owners and construction stakeholders must prepare the project team for the use of the rating system and track and record their project's performance to further evaluate and enhance the system.

Further development of the LPRS should be applied to the development of different rating system for different project types such as bridge rating system, home rating system, and highway rating systems. This research might produce results helpful in rating lean projects in the healthcare system and assist construction stakeholders in predicting the results of projects and take active role in improving the process in all phases.

More investigations of the five major success criteria - quality, cost, time, safety and disputes - proposed for evaluating the actual project success are recommended. It is important to determine whether more criteria should be added to the identified criteria, or if the existing group should be modified. Moreover, additional verification of the success criteria is also recommended.

The proposed Lean Project Rating System is based on the Analytical Hierarchy Process theory and it is recommended to follow further development for possible modification and improvement of the rating system. Further evaluation of indicator credits is required to refine the measure of lean rating system. The statistic results of case studies suggest the need for further modification to improve the Lean Project Rating System.

APPENDIX A: SURVEY 1(PAIRWISE COMPARISON)

Lean Construction Rating System

1. INFORMED CONSENT

1. Framework for Lean Construction Rating System (LCRS)

RESEARCH PROCEDURES

This research is being conducted to help identify the key criteria to be considered when rating and assessing Lean Construction projects. If you agree to participate, you will be asked to complete a survey about potential relevance, practicality (measurability), reliability (availability of data), and significance (importance) of a set of Lean and Integrated project delivery (Lean/IPD) factors. The response to the survey will be used to establish a baseline weighting for Lean/IPD measures in the Lean Construction Rating System. It is expected that completion of the survey will take approximately thirty minutes.

RISKS

There are no foreseeable risks for participating in this research.

BENEFITS

There are no benefits to you as a participant other than to further research in the area of Lean Construction.

CONFIDENTIALITY

The data in this study will be confidential. The results of this survey will be integrated into the Lean Construction Rating System and will be included in a PhD graduate dissertation, presented at conferences, and may also be published in journal articles. All results will be presented in aggregate and no data will be directly related to a respondent. While it is understood that no computer transmission can be perfectly secure, reasonable efforts will be made to protect the confidentiality of your transmission.

PARTICIPATION

Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party.

CONTACT

This research is being conducted by Mohamed E. Hassan, a doctoral student at the Civil, Environmental, and Infrastructure Engineering at George Mason University. He may be reached at (703) 898-0204 or via email mhassana@gmu.edu for questions or to report a research related problem. Dr. Michael J. Casey, Assistant Professor at Civil department is directing this research project and may be reached at (703) 993-2091 or via email

Page 1

Lean Construction Rating System

mcasey4@gmu.edu.
You may contact the George Mason University Office of Research Subject Protection at (703) 993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research.

NOTE 1: If you would like to have a copy of this consent form, please print this page prior to proceeding to the survey.
NOTE 2: If you would like to receive a copy of the public report of this research please check the box below and provide your email address.

☐ I would like to receive a copy of the public report of this research project.

☐ I have read this form and agree to participate in this study.

My email address:

Page 2

Lean Construction Rating System

2. DEFINITIONS

LEAN CONSTRUCTION:
Lean Construction is a production management based approach project delivery system that promotes owners value, reduces waste and maximizes efficiency through all project phases (conceptual, design and construction) to deliver successful projects.

INTEGRATED PROJECT DELIVERY (IPD):
IPD is a new contractual agreement structured to enable lean principles by leveraging the early contributions of knowledge and expertise of project stakeholders to deliver successful projects.

LEAN CONSTRUCTION RATING SYSTEM (LCRS):
LCRS is a new rating tool to predict project success pattern.

LEAN PROJECT TEAM:
Lean Project Team is the early participation of all project stakeholders, including owners, architects, engineers, General contractors, speciality contractors, vendors, suppliers and fabricators, of the project at the beginning of the project (Conceptual phase) throughout the total completion.

Lean Construction Rating System

3. GENERAL INFORMATION

1. What best describes your main area of expertise or professional role:

- Owner
- Architect
- Engineer/Designer
- General Contractor
- Specialty Contractor (Metal, HVAC, Electric, ...)
- Vender/Supplier
- Fabricator/Manufacturer
- Insurance Company
- Other (please specify)

2. How many years of experience in your field?

- Less than 2 years
- 2-5 years
- 6-10 years
- More than 10 years

3. In which sector do you work?

- Self-employed
- Private
- Public
- Government (municipal, state or federal)
- Academia/Research

Other (please specify)

Lean Construction Rating System

4. What type of project delivery system does your organization typically adopt? (check all that apply)

- ☐ General Contract (Design/Bid/Build)
- ☐ Design/Build
- ☐ CM-Agency
- ☐ CM-At-Risk
- ☐ Program Management
- ☐ Integrated Project Delivery (IPD) without Lean
- ☐ Lean/IPD Project Delivery
- ☐ Other (please specify)

Lean Construction Rating System

4. LEAN CONSTRUCTION

1. Does your organization practice any form of Lean Construction?

- ○ No, I have not heard of Lean Construction
- ○ Yes
- ○ No, But I have heard of Lean Construction

2. How familiar are you with Lean Construction?

- ○ Not familiar
- ○ Somewhat familiar
- ○ Familiar
- ○ Very Familiar

3. How many years of experience do you have in Lean Construction Projects?

- ○ None
- ○ Less than 2 years
- ○ 2-5 years
- ○ 6-10 years
- ○ More than 10 years

4. What is the percentage of successful Lean Construction Projects in your organization? (Projects that met their objectives)

- ○ Less than 25%
- ○ 25% - 49%
- ○ 50% - 75%
- ○ Greater than 75%

5. What have been the most difficult steps in implementing Lean Construction in your organization?

Page 6

Lean Construction Rating System

5. PROJECT PHASES (Conceptual, Design and Construction

INSTRUCTIONS FOR THIS SECTION:

Assuming that you are involved in assessing and rating construction projects; for the different project phases, the following categories should be considered in rating the project:
On scale from (1) to (5) where:
1- not important, 2- somewhat important, 3- Important, 4-Very Important, 5- Extremely Important.
Express your level of agreement that such category should be considered.

1. Rate the following categories based on their importance for the Conceptual phase:

	Not Important	Somewhat important	Important	Very Important	Extremely Important
Initial Lean Project Team	○	○	○	○	○
Company Experience	○	○	○	○	○
Individual Experience	○	○	○	○	○
Project Scope Definition	○	○	○	○	○
Validation of Owner's Budget	○	○	○	○	○
Develop Master Schedule	○	○	○	○	○
Use of Building Information Model (BIM)	○	○	○	○	○
Use of Last Planner (R) System (LPS)	○	○	○	○	○
Collaboration	○	○	○	○	○
Commmunication	○	○	○	○	○
Target Value Design (TVD)	○	○	○	○	○
Use of Information Technology (IT)	○	○	○	○	○

Other (please specify)

Page 7

Lean Construction Rating System

2. Rate the following categories based on their importance in the Project Design Phase:

	Not Important	Somewhat Important	Important	Very Important	Exteremely Important
Project Team					
Target Value Design (TVD)					
Building Information Model (BIM)					
Last Planner (R) System (LPS)					
Team Collaboration					
Team Communications					
Standardization					
Innovation					
Risk Assessment					

Other (please specify)

3. Rate the following categories based on their importance in the Construction Phase:

	Note Important	Somewhat Important	Important	Very Important	Extremely Important
Planning					
Last Planner System (LPS)					
Building Information Model (BIM)					
Safety Program					
Risk Management Plan					
Monitoring & Controling					
Collaboration					
Communication					
Building Codes					

Other (please specify)

Page 8

Lean Construction Rating System

6. PAIRWISE COMPARISON

This survey includes three sections of pairwise comparisons.

The three sections of pairwise comparisons are based on different categories (Project phase category, Success Criteria category, and Success Indicator category) in which they are compared to each other. Scores are indicators of Lean Construction and serve as the criteria for Lean Construction Rating System (LCRS).

1. Please complete the following credit pairwise comparison with respect to the Category of Project Phases.

	Extremely Important	Very	Important	Moderately Important	Equal	Moderately Less Important	Less Important	Much Less Important	Extremely Unimportant
Conceptual Phase is more important than Design Phase	○	○	○	○	○	○	○	○	○
Conceptual phase is more important than Construction phase	○	○	○	○	○	○	○	○	○
Design Phase is more important than Construction phase	○	○	○	○	○	○	○	○	○

Page 9

Lean Construction Rating System

2. Please complete the following table of credit pairwise comparisons with respect to Success Criteria Category (Budget, Schedule, Quality, Safety, and Disputes).

	Extremely Important	Very	Important	Moderately Important	Equal	Moderately Less Important	Less Important	Much Less Important	Extremely Unimportant
Budget is more important than Schedule	○	○	○	○	○	○	○	○	○
Budget is more important than Quality	○	○	○	○	○	○	○	○	○
Budget is more important than Safety	○	○	○	○	○	○	○	○	○
Budget is more important than Disputes	○	○	○	○	○	○	○	○	○
Schedule is more important than Quality	○	○	○	○	○	○	○	○	○
Schedule is more important than Safety	○	○	○	○	○	○	○	○	○
Schedule is more important than Disputes	○	○	○	○	○	○	○	○	○
Quality is more important than Safety	○	○	○	○	○	○	○	○	○
Quality is more important than Disputes	○	○	○	○	○	○	○	○	○
Safety is more important than Disputes	○	○	○	○	○	○	○	○	○

Lean Construction Rating System

7. CONCEPTUAL (PLANNING) PHASE CREDITS

Pairwise Comparisons

1. Rate Team Experience Factor with respect to its impact on the other success factors in the Conceptual phase?

	Extremely Important	very	Important	Moderately	Equal	moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Team Experience more important than Individual experience									
Team Experience more important than the use of BIM									
Team Experience more important than the use of Last Planner System									
Team Experience more important than Collaboration									
Team Experience more important than Communication									
Team Experience more important thanTarget Value Design									
Team Experience more important than use of IT									

Page 11

Lean Construction Rating System

2. Rate the Individual Experience Factor with respect to its impact on the other success factors in the Conceptual phase?

	Extremely important	Very	Important	Moderately Important	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Individual Experience is more important than BIM	○	○	○	○	○	○	○	○	○
Individual Experience is more important than Last Planner System (LPS)	○	○	○	○	○	○	○	○	○
Individual Experience is more important than team Collaboration	○	○	○	○	○	○	○	○	○
Individual Experience is more important than Communication	○	○	○	○	○	○	○	○	○
Individual Experience is more important than Target Value Design	○	○	○	○	○	○	○	○	○
Individual Experience is more important than use of IT	○	○	○	○	○	○	○	○	○

Lean Construction Rating System

3. Rate Building Information Model (BIM) factor with respect to its impact on the other success factors in the Conceptual phase?

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
BIM is more important than Last Planner System									
BIM is more important than Collaboration									
BIM is more important than Communication									
BIM is more important than Target Value Design									
BIM is more important than use of IT									

4. Rate Last Planner System (LPS) factor with respect to its impact on the other success factors in the Conceptual phase?

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
LPS is more important than Collaboration									
LPS is more important than Communication									
LPS is more important than Target Value Design									
LPS is more important than use of IT									

Lean Construction Rating System

5. Rate Collaboration factor with respect to its impact on the other success factors in the Conceptual phase?

	Extreme	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Collaboration is more important than Communication									
Collaboration is more important than Target Value Design									
Collaboration is more important than use of IT									

6. Rate Communication factor with respect to its impact on the other success factors in the Conceptual phase?

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Communication is more important than Target Value Design									
Communication is more important than use of IT									

7. Rate Transparency factor with respect to its impact on the other success factors in the Conceptual phase?

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Transparency is more important than Target Value Design									
Transparency is more important than use of IT									

Page 14

Lean Construction Rating System

8. Rate Target Value Design Factor with respect to its impact on the other success factors in the Conceptual phase?

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Target Value Design is more important than use of IT	○	○	○	○	○	○	○	○	○

Lean Construction Rating System

8. DESIGN PHASE CREDITS

Pairwise Comparisons

1. Indicate your agreement with the following as it relates to Design Phase of projects:

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
BIM is more important than Target Value Design									
BIM is more important than Collaboration									
BIM is more important than Communication									
BIM is more important than Last Planner System (LPS)									

2. Indicate your agreement with the following as it relates to the Design Phase of projects:

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Target Value Design is more important than Collaboration									
Target Value Design is more important than Communication									
Target Value Design is more important than Last Planner System									

Lean Construction Rating System

3. Indicate your agreement with the following as it relates to the Design Phase of projects:

	Extremely Important	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Collaboration is more important than Communication									
Collaboration is more important than Last Planner System									

4. Indicate your agreement with the following as it relates to the Design Phase of projects:

	Extremely	Very	Important	Moderate	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Communication is more important than Last Planner System									

Lean Construction Rating System

9. CONSTRUCTION PHASE CREDITS

Pairwise Comparisons:

1. Rate the impact of LAST PLANNER SYSTEM on the other construction success factors:

	Extremely Important	Very	Important	Moderately	Equal	moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Last Planner System is more important than BIM	○	○	○	○	○	○	○	○	○
Last Planner System is more important than Monitoring & Controlling	○	○	○	○	○	○	○	○	○
Last Planner System is more important than Safety	○	○	○	○	○	○	○	○	○
Last Planner System is more important than Risk Management	○	○	○	○	○	○	○	○	○
Last Planner System is more important than Building Codes	○	○	○	○	○	○	○	○	○
Last Planner System is more important than Collaboration & Communication	○	○	○	○	○	○	○	○	○

Lean Construction Rating System

2. Rate the impact of BIM on the other construction success factors:

	Extremely Important	Very	Important	Moderately	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
BIM is more important than Monitor & Control									
BIM is more important than Safety									
BIM is more important than Risk Management									
BIM is more important than Building Codes									
BIM is more important than Collaboration & Communication									

3. Rate the impact of MONITOR & CONTROL on the other construction success factors:

	Extremely Important	Very	Important	Moderately	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Monitor & Control is more important than Safety									
Monitor & Control is more important than Risk Management									
Monitor & Control is more important than Buidling Codes									
Monitor & Control is more important than Collaboration & Communication									

Lean Construction Rating System

4. Rate the impact of SAFETY on the other construction success factors:

	Extremely Important	Very	Important	Moderately	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Safety is more important than Risk Management									
Safety is more important than Building codes									
Safety is more important than Collaboration & Communication									

5. Rate the impact of RISK MANAGEMENT on the other construction success factors

	Extremely Important	Very	Important	Moderately	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Risk Management is more important than Building Codes									
Risk Management is more important than Collaboration & Communication									

6. Rate the impact of CONSTRUCTION LAWS on the other construction success factors:

	Extremely Important	Very	Important	Moderately	Equal	Moderately Less Important	Less Important	Very Unimportant	Extremely Unimportant
Buiding Codes is more important than Collaboration & Communication									

Page 20

Lean Construction Rating System

10. GENERAL

1. Do you believe that we need Lean Construction Certification in the construction industry? Please Explain.

- Yes, We need Lean Certification
- No
- Not sure

Please Explain your position

2. Please share with us any general comments you may wish to add (for example, Does Last Planner System help construction industry? Is BIM important? the use of Integrated Project Delivery?)

3. If you are interested in sharing more insights about Lean Construction, please email us at mhassana@gmu.edu.

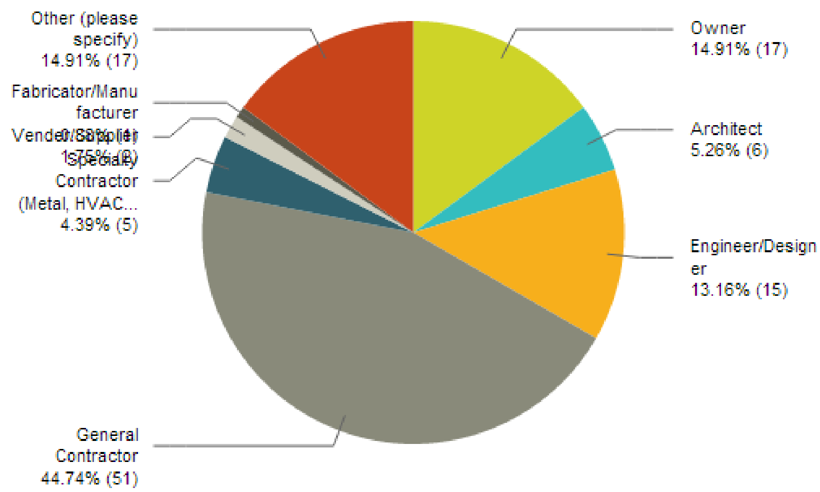
Thank you for taking the time to complete the survey.

Page 21

APPENDIX B: SURVEY (1) RESULTS

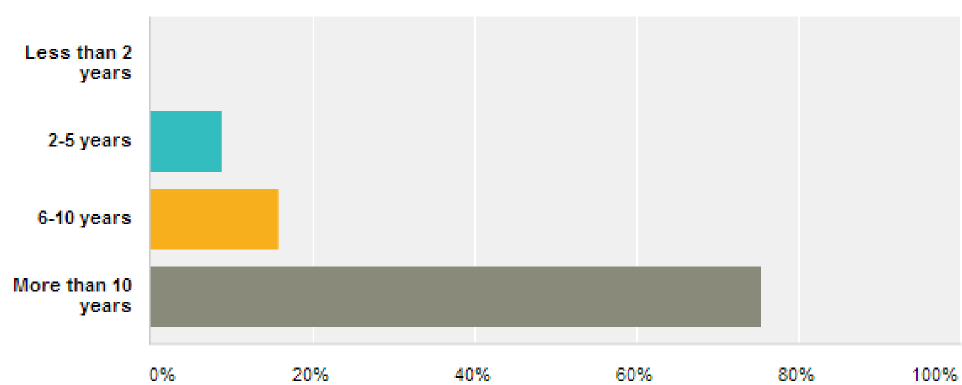
What best describes your main area of expertise or professional role:

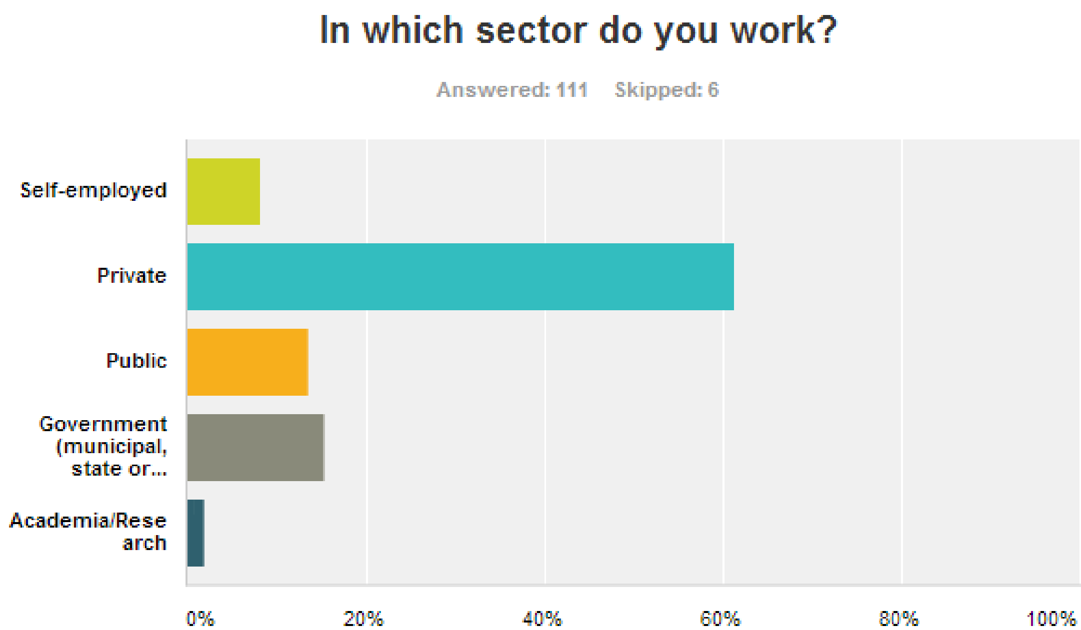
Answered: 114 Skipped: 3

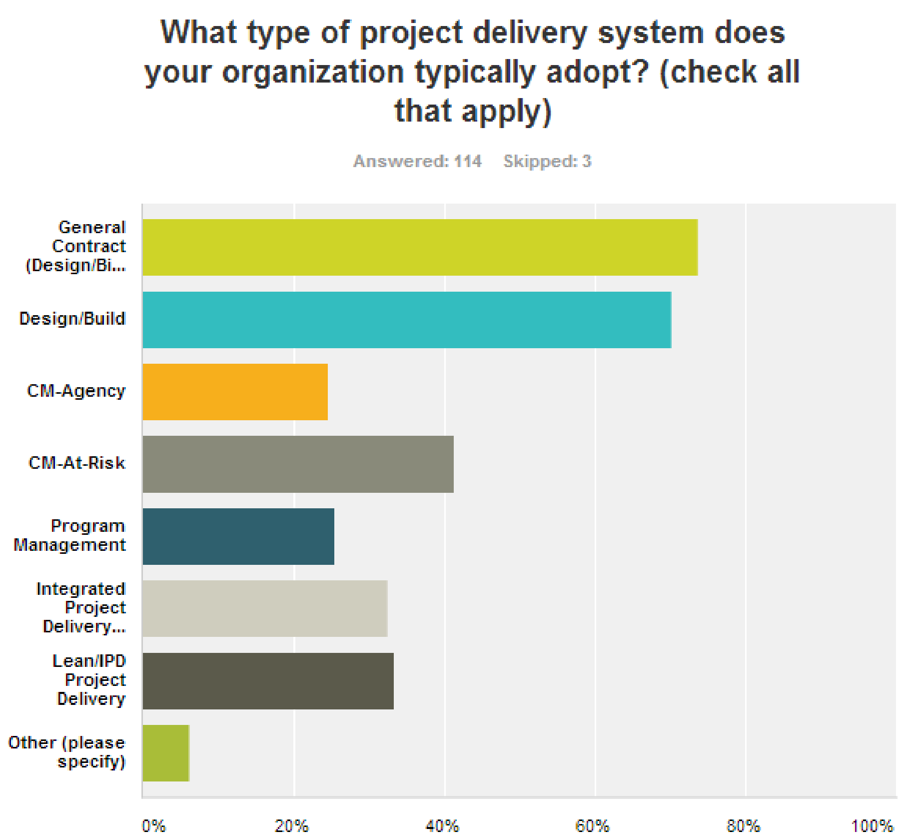


How many years of experience in your field?

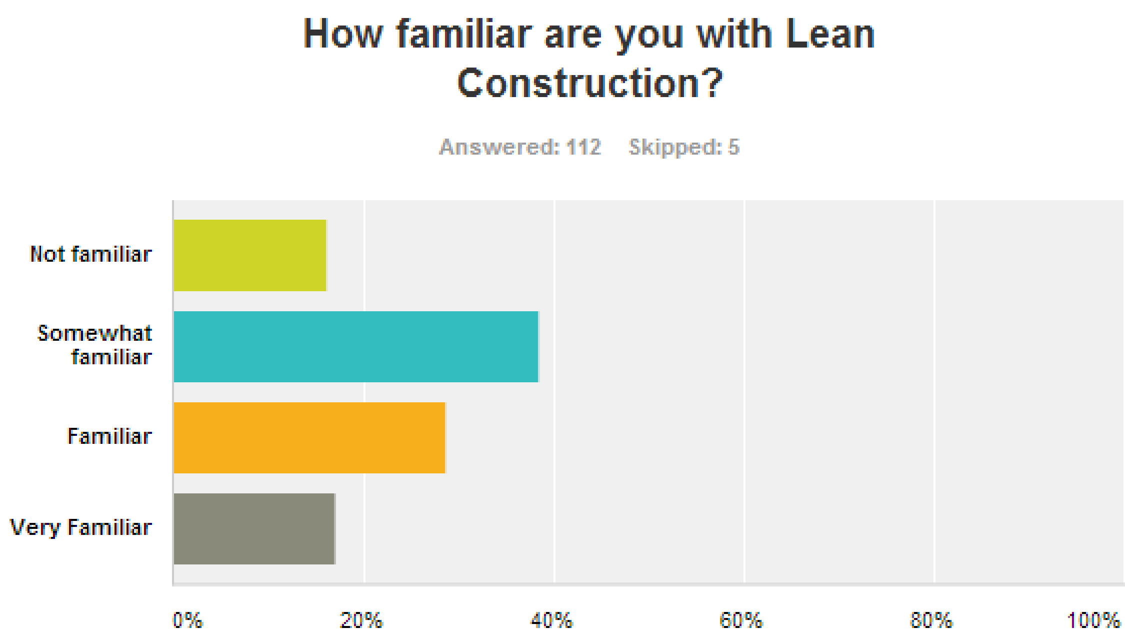
Answered: 114 Skipped: 3




In which sector do you work?
Answered: 111 Skipped: 6
Self-employed
Private
Public
Government (municipal, state or...
Academia/Research
0%
20%
40%
60%
80%
100%

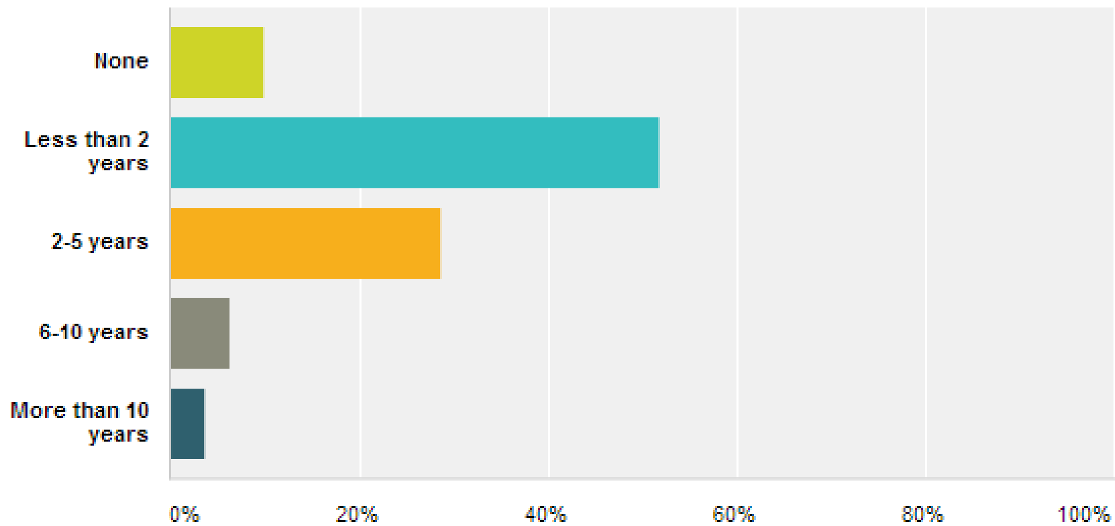

What type of project delivery system does your organization typically adopt? (check all that apply)
Answered: 114 Skipped: 3
General Contract (Design/Bi...
Design/Build
CM-Agency
CM-At-Risk
Program Management
Integrated Project Delivery...
Lean/IPD Project Delivery
Other (please specify)
0%
20%
40%
60%
80%
100%


Does your organization practice any form of Lean Construction?
Answered: 111 Skipped: 6
No, I have not heard of Lean...
Yes
No, But I have heard of Lean...
0%
20%
40%
60%
80%
100%


How familiar are you with Lean Construction?
Answered: 112 Skipped: 5
Not familiar
Somewhat familiar
Familiar
Very Familiar
0%
20%
40%
60%
80%
100%

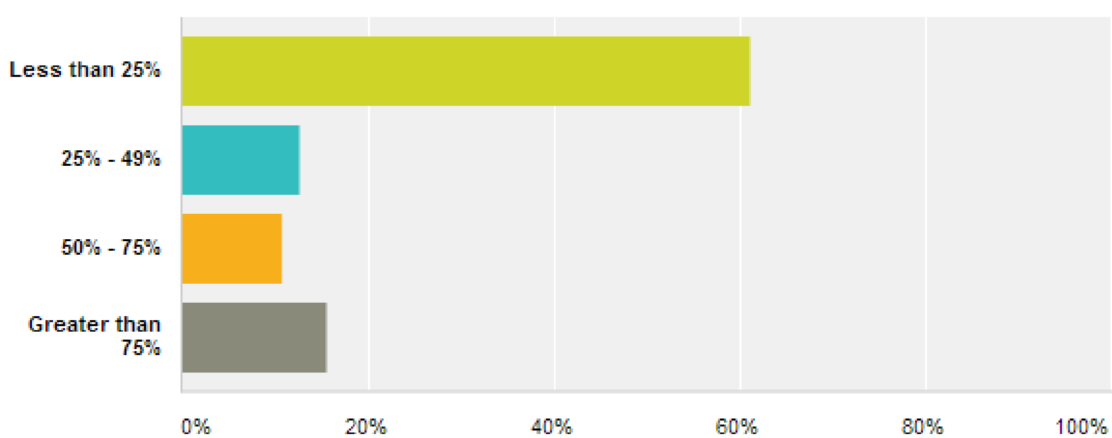
How many years of experience do you have in Lean Construction Projects?

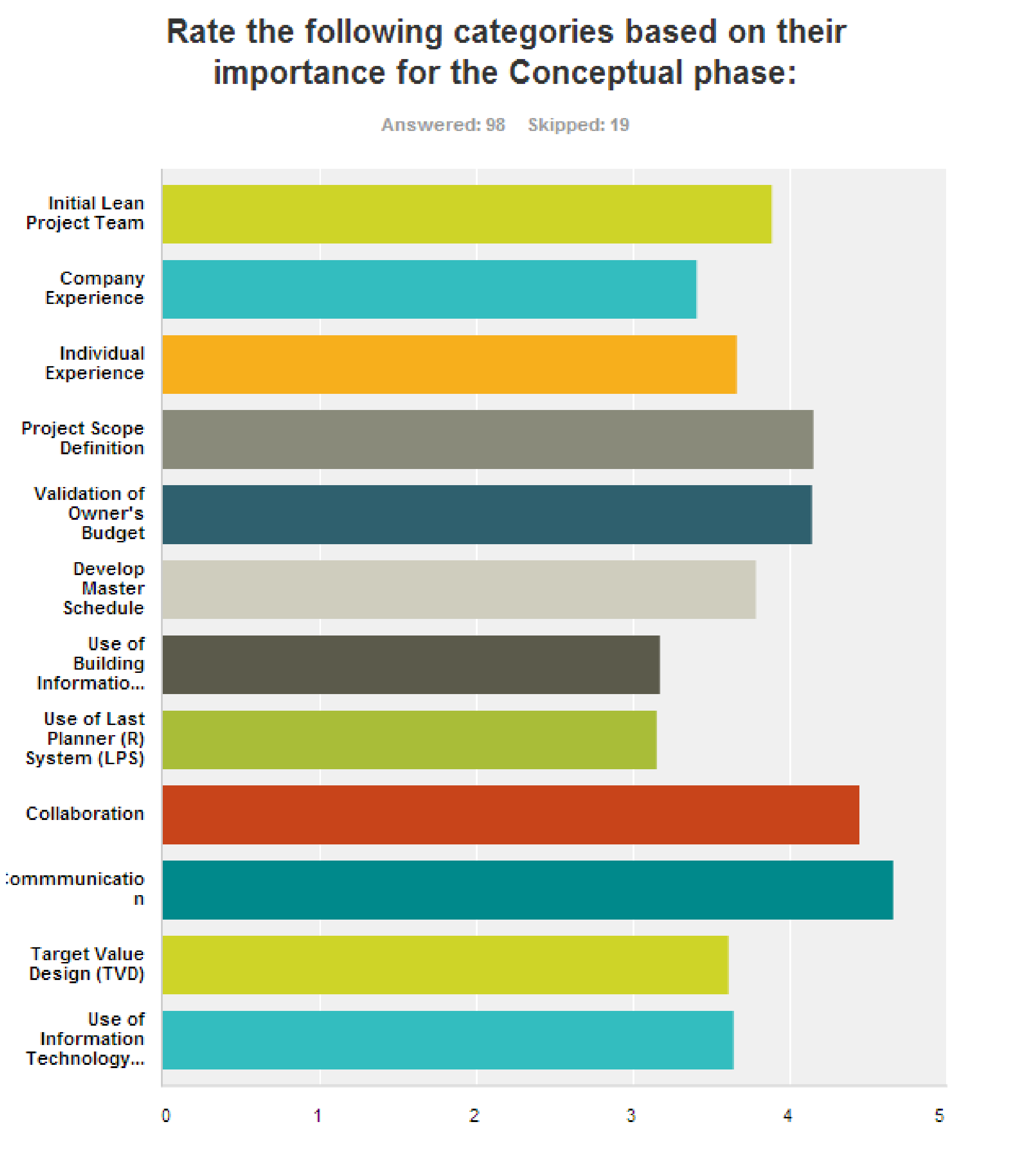
Answered: 112 Skipped: 5

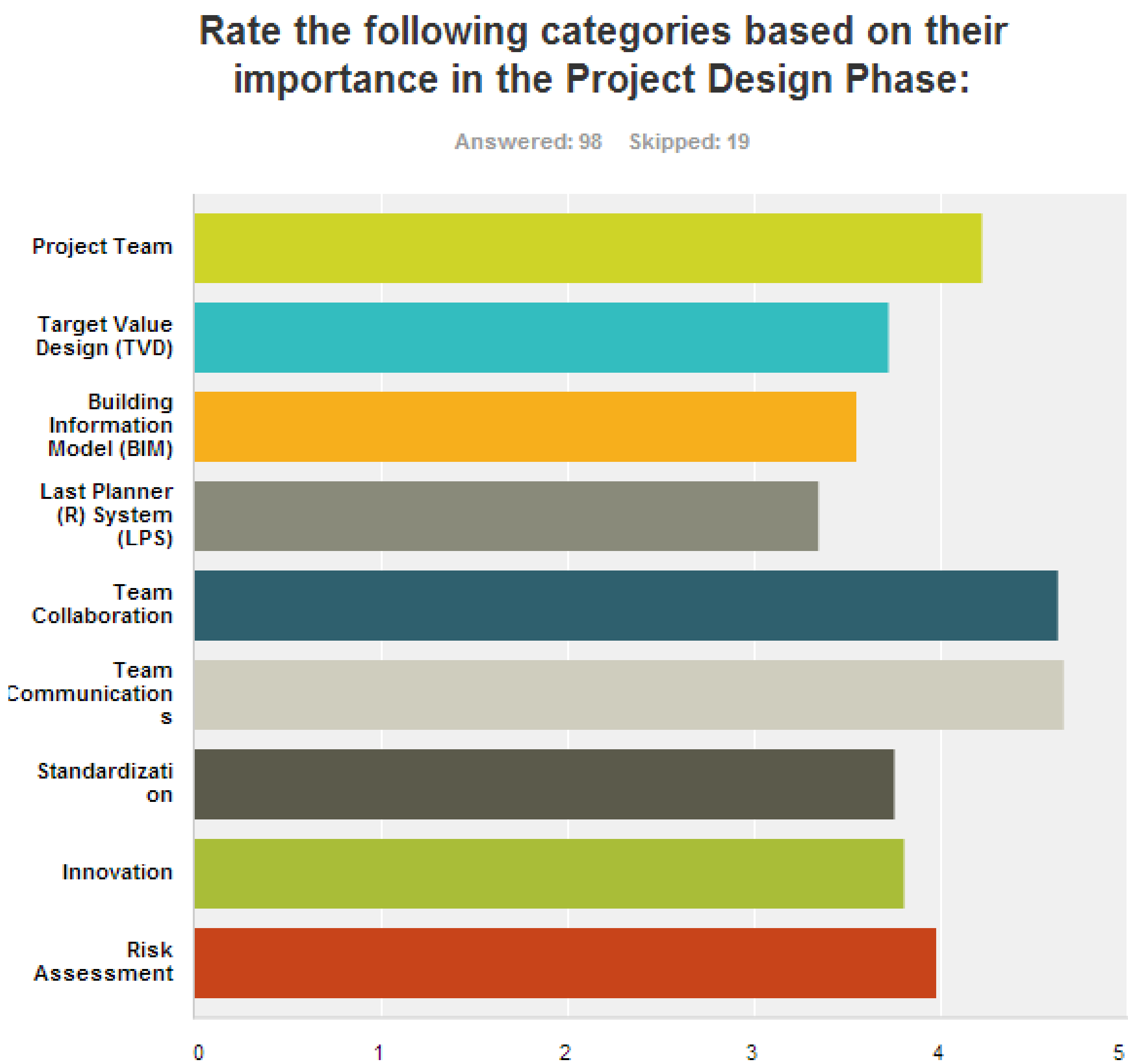


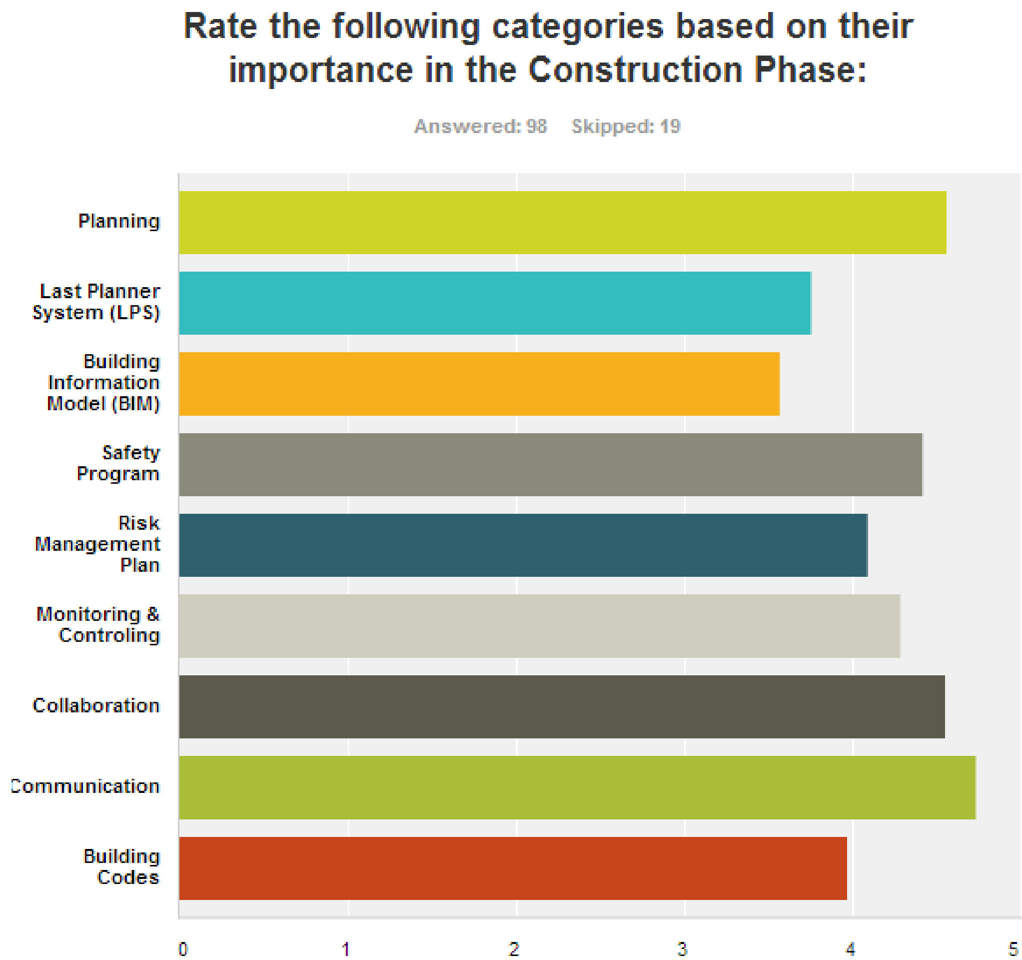
What is the percentage of successful Lean Construction Projects in your organization? (Projects that met their objectives)

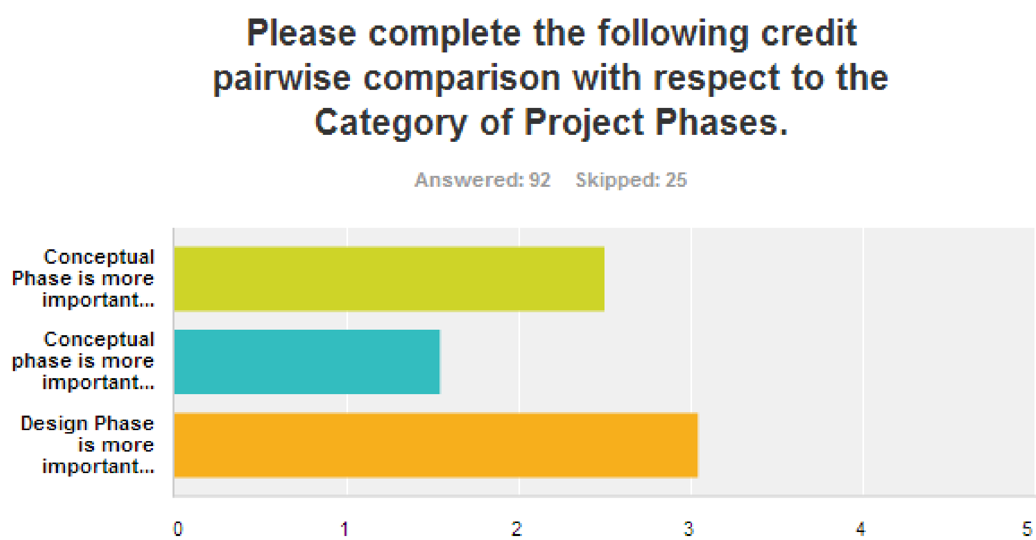
Answered: 103 Skipped: 14

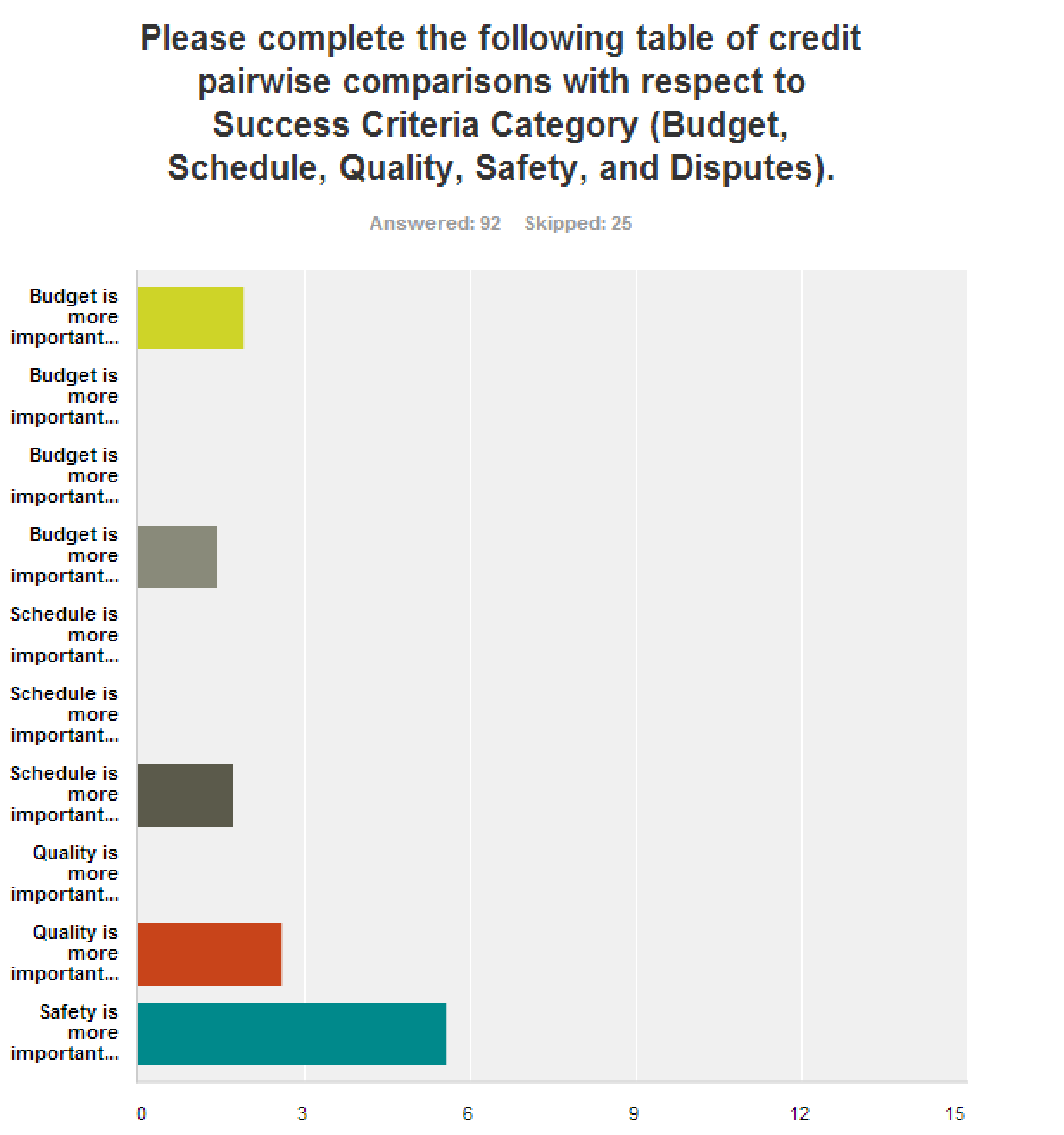



Rate the following categories based on their importance for the Conceptual phase:
Answered: 98 Skipped: 19
Initial Lean Project Team
Company Experience
Individual Experience
Project Scope Definition
Validation of Owner's Budget
Develop Master Schedule
Use of Building Informatio...
Use of Last Planner (R) System (LPS)
Collaboration
:ommmunicatio n
Target Value Design (TVD)
Use of Information Technology...
0
1
2
3
4
5

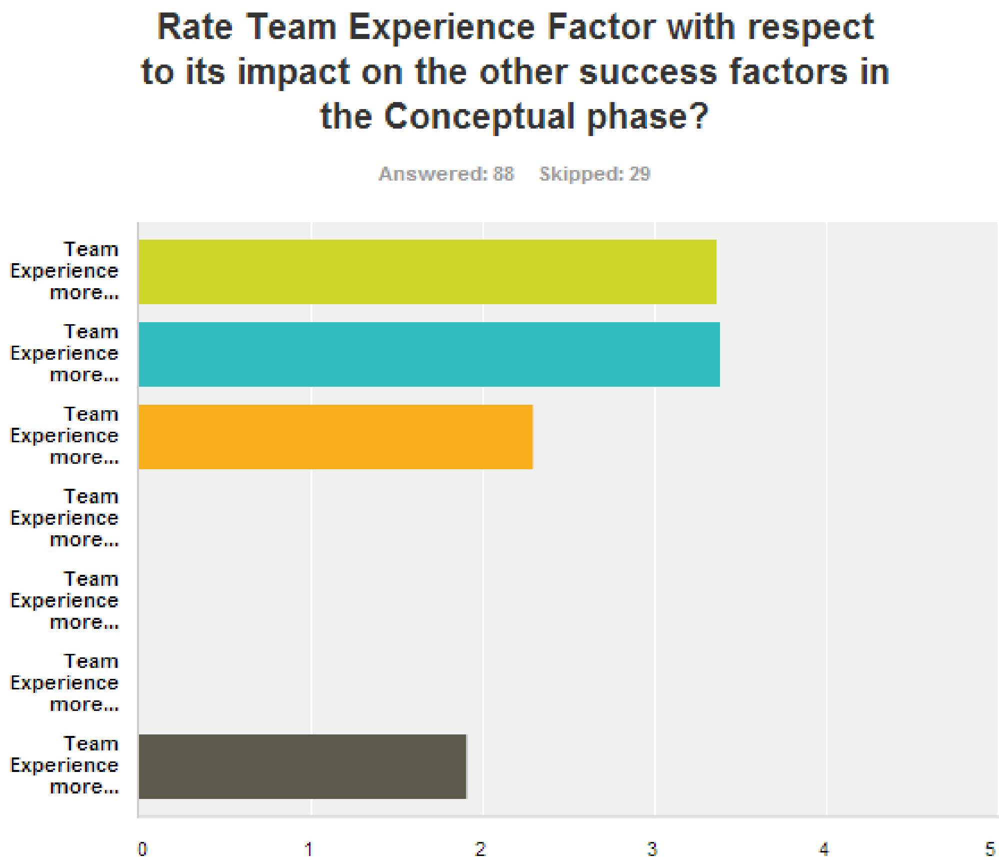

Rate the following categories based on their importance in the Project Design Phase:
Answered: 98 Skipped: 19
Project Team
Target Value Design (TVD)
Building Information Model (BIM)
Last Planner (R) System (LPS)
Team Collaboration
Team Communications
Standardization
Innovation
Risk Assessment
0
1
2
3
4
5


Rate the following categories based on their importance in the Construction Phase:
Answered: 98 Skipped: 19
Planning
Last Planner System (LPS)
Building Information Model (BIM)
Safety Program
Risk Management Plan
Monitoring & Controling
Collaboration
Communication
Building Codes
0
1
2
3
4
5


Please complete the following credit pairwise comparison with respect to the Category of Project Phases.
Answered: 92 Skipped: 25
Conceptual Phase is more important...
Conceptual phase is more important...
Design Phase is more important...
0
1
2
3
4
5

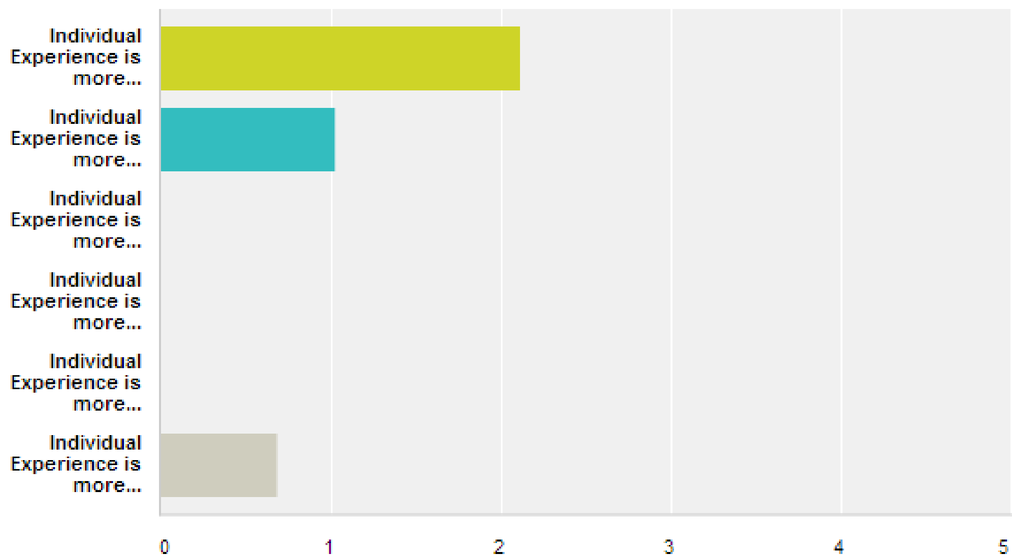


Please complete the following table of credit pairwise comparisons with respect to Success Criteria Category (Budget, Schedule, Quality, Safety, and Disputes).
Answered: 92 Skipped: 25
Budget is more important...
Budget is more important...
Budget is more important...
Budget is more important...
Schedule is more important...
Schedule is more important...
Schedule is more important...
Quality is more important...
Quality is more important...
Safety is more important...
0
3
6
9
12
15


Rate Team Experience Factor with respect to its impact on the other success factors in the Conceptual phase?
Answered: 88 Skipped: 29
Team Experience more...
Team Experience more...
Team Experience more...
Team Experience more...
Team Experience more...
Team Experience more...
Team Experience more...
0
1
2
3
4
5

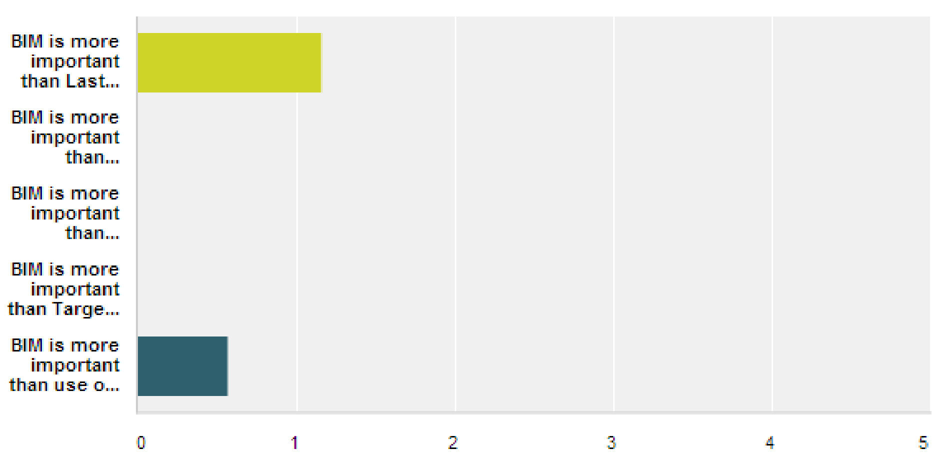
Rate the Individual Experience Factor with respect to its impact on the other success factors in the Conceptual phase?

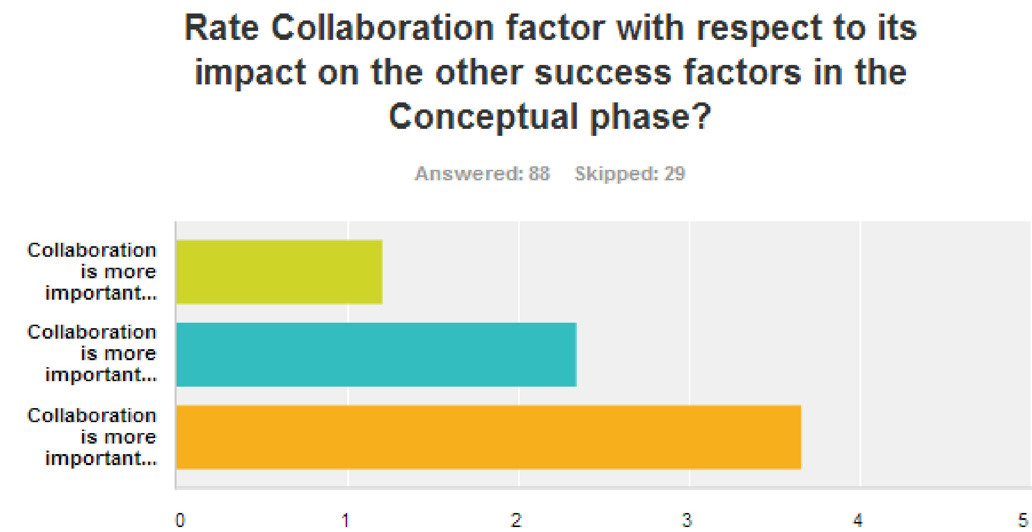
Answered: 88   Skipped: 29

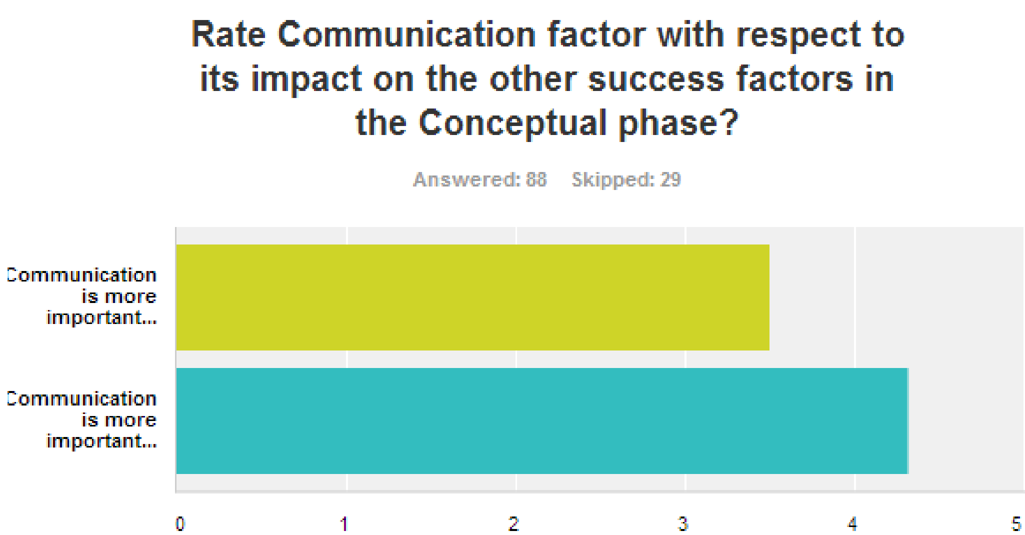


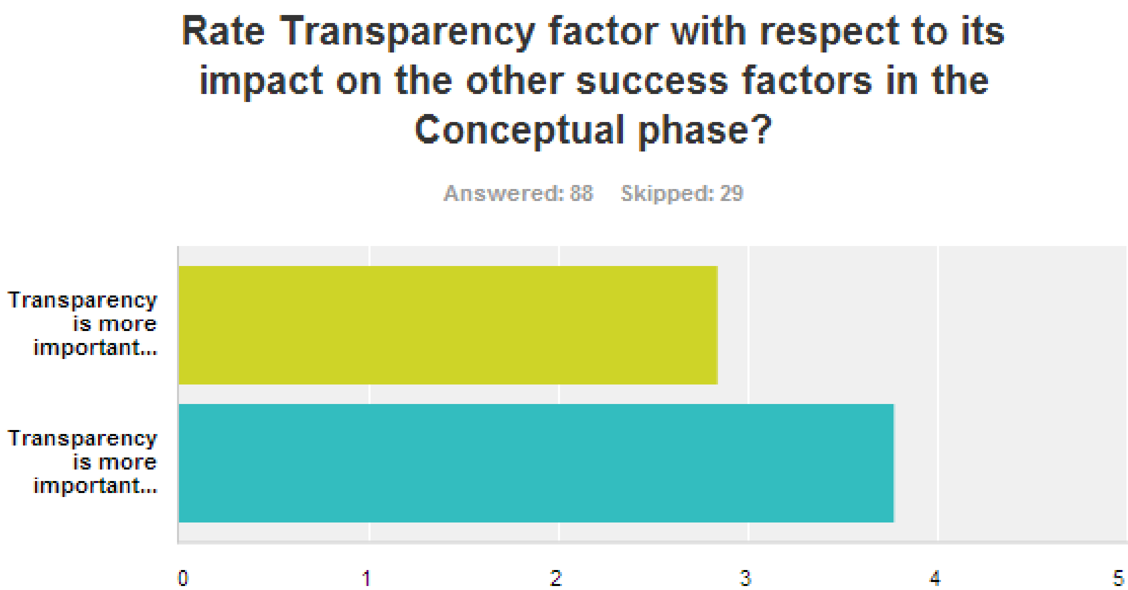
Rate Building Information Model (BIM) factor with respect to its impact on the other success factors in the Conceptual phase?

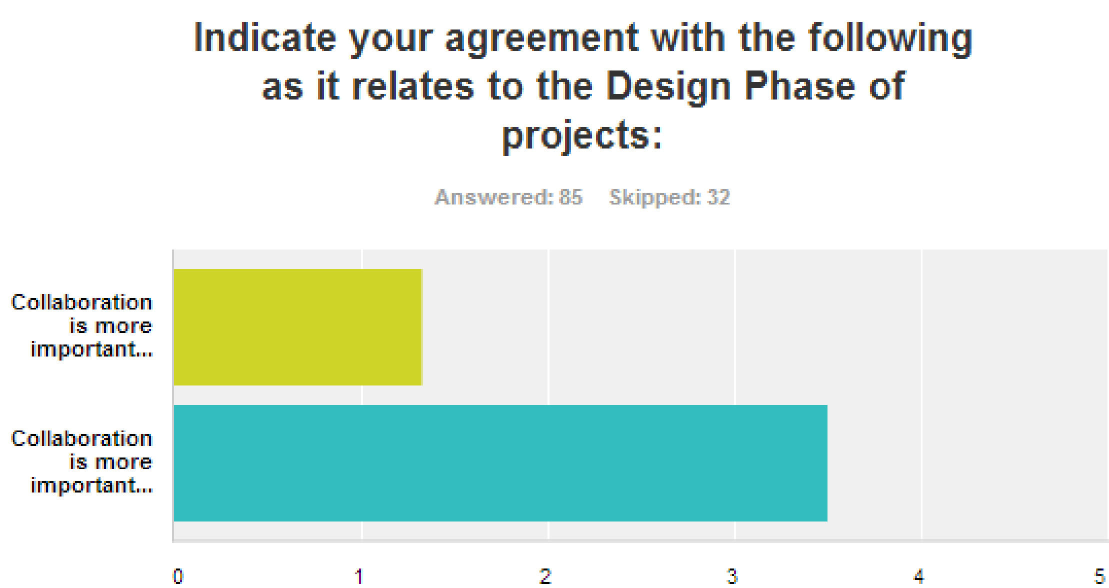
Answered: 88   Skipped: 29

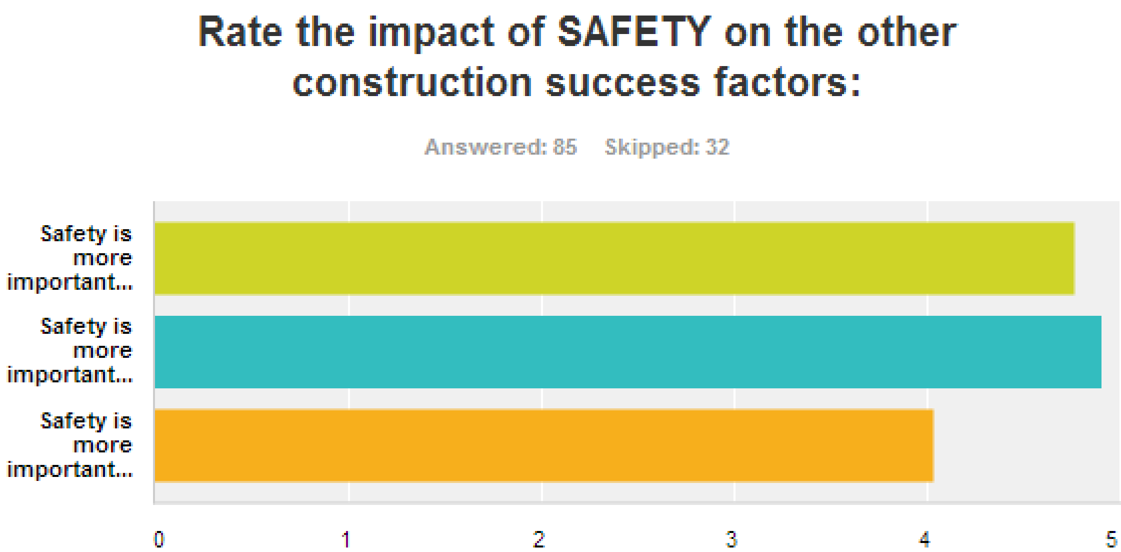



Rate Collaboration factor with respect to its impact on the other success factors in the Conceptual phase?
Answered: 88 Skipped: 29
Collaboration is more important...
Collaboration is more important...
Collaboration is more important...
0
1
2
3
4
5


Rate Communication factor with respect to its impact on the other success factors in the Conceptual phase?
Answered: 88 Skipped: 29
Communication is more important...
Communication is more important...
0
1
2
3
4
5


Rate Transparency factor with respect to its impact on the other success factors in the Conceptual phase?
Answered: 88 Skipped: 29
Transparency is more important...
Transparency is more important...
0
1
2
3
4
5


Indicate your agreement with the following as it relates to the Design Phase of projects:
Answered: 85 Skipped: 32
Collaboration is more important...
Collaboration is more important...
0
1
2
3
4
5


Rate the impact of SAFETY on the other construction success factors:
Answered: 85 Skipped: 32
Safety is more important...
Safety is more important...
Safety is more important...
0
1
2
3
4
5


Do you believe that we need Lean Construction Certification in the construction industry? Please Explain.
Answered: 84 Skipped: 33
Yes, We need Lean Certification
No
Not sure
0%
20%
40%
60%
80%
100%

APPENDIX C: SURVEY 2 (CASE STUDY)

Case Study - Lean Project Rating System

INFORMED CONSENT

RESEARCH PROCEDURES:
THIS research is being conducted to help identify the key criteria to be considered when rating and assessing Lean Construction Projects.
If you agree to participate, you will be asked to complete a Case Study survey about potential relevance, practicality (measurability), reliability (availability of Data), and significance (importance) of a set of Lean Integrated Project Delivery factors (Lean/IPD). The case study you provide will be used to test the Lean Project Rating System score card and its relevant to the rating system.

RISKS:
There are no foreseeable risks for participating in this research.

BENEFITSI
There are no benefits to you as a participant other than to improve construction industry and provide a new toll to measure project success and enable the construction industry to rate their project success.

CONFIDENTIALITY:
The data in this study will be confidential. The results of this survey will be integrated into the construction rating system and will be included in a PhD graduate dissertation, presented at conferences, and may also be published in journal articles. All results will be presented in aggregate and no data will be directly related to a respondent. While it is understood that no computer transmission can be perfectly secure, reasonable efforts will be made to protect the confidentiality of your transmission.

PARTICIPATION:
Your participation is voluntary, and you maywithdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no penalty or loss of benefits t which you are otherwise entitled. There are no costs to you or any other party.

CONTACT:
This research is being conducted by Mohamed E. Hassan, a doctoral student at the Civil, Environmental, and Infrastructure Engineering at George Mason University. He may be reached at (703) 898-0204 or via email: mhassana@gmu.edu for questions or to report a research related problem. Dr. Michael Casey, Assistant Professor at the Civil department is directing this research project and may be reached at (703)993-2091 or via email: mcasey4@gmu.edu.
you also may contact George Mason University office of Research Subject Protection at (703)993-4121 if yo have questions or comments regarding your rights as a participant in the research.

*** 1. I have read this form and agree to participate in this study.**

○ I agree

Page 1

Case Study - Lean Project Rating System

PROJECT INFORMATION

Please provide the following information on the project to be used as CASE STUDY.

Please note that all project information such as project name, owners, location, budget, and schedule is totally confidential.

***2. Project Name:**

***3. Project Location:**
(City, and State)

***4. Project Description:**
Please provide a brief description of the type of project (Hospital, Office building, ..etc), size, SF.

***5. Owners:**

***6. General Contractor (GC):**
Please Provide the name of the GC

***7. Budget:**
What was the original project Budget ($$)?

***8. Schedule:**
What was the planned Time for completing the project (months)

Page 2

Case Study - Lean Project Rating System

***9. Project Delivery Method:**

Which project delivery method used in this project?

- Design/Build
- Design/Bid/Build
- Integrated Project Delivery (IPD)
- Construction Management at Risk (CM at Risk)

Other (please specify)

***10. Start Date:**

What is the project start date?

***11. Completion Date:**

What is the project completion Date?

Case Study - Lean Project Rating System

ACTUAL PROJECT PERFORMANCE

Project Performance is measured in five (5) Success Criteria:
1. Quality
2. Budget
3. Time
4. Safety
5. Disputes & Litigations

*** 12. Quality:**

What was the owners satisfaction with final Quality of the project?

- Excellent
- Very Good
- Good
- Fair
- Poor

*** 13. Budget:**

What was the Final Budget of the project?

- Over Budget
- Equal to Budget
- Under Budget
- Explain

*** 14. Schedule:**

Did the project meet the Proposed Schedule?

- Overrun
- On Time
- Under schedule

Please explain

Page 4

Case Study - Lean Project Rating System

***15. Safety:**

- No Accident
- Minor Accident (Returned to work within one day)
- Minor Accident (Returned to work within one week)
- Minor Accident (Returned to work within one month)
- Major Accident (Loss of life or limbs)

16. Disputes & Litigation:

- No Disputes
- Minor Disputes (Resolved)
- Major Disputes (Law suites)

***17. In the case study you provided, please indicate the percentage (%) of your project success?**

- 100%
- 90%
- 80%
- 70%
- 60%
- 50%

***18. What other Success Criteria does your company consider in evaluating the success of the project?**

Case Study - Lean Project Rating System

1. PLANNING PHASE

Planning Phase is the initiation phase of the project where the conceptual design starts.

In this phase we measure eight (8) categories; Project Team, Team Experience, Collaboration, Communication, Target Value Design (TVD), Building Information Modeling (BIM), Last Planner System (LPS), and the use of Information Technology (IT)to record the project.

*19. P1 - Initial Project Team:

Who participate in the initial phase?

- [ ] Owner
- [ ] Architect
- [ ] Engineers (Civil, Structure, MEP)
- [ ] General Contractor (GC)
- [ ] Major Subcontractors (Subs)
- [ ] Suppliers & Vendors

20. P2 - Team Experience:

How many years of experience each team have in his field?

	< 5 years	5-10 years	> 10 years
Owner	○	○	○
Architect	○	○	○
Engineers	○	○	○
GC	○	○	○
Subs	○	○	○
Suppliers/Vendors	○	○	○

*21. P3 - Collaboration:

How well did the project team collaborate with each other?

- ○ Excellent
- ○ Very Good
- ○ Good
- ○ Fair
- ○ Poor

Case Study - Lean Project Rating System

***22. P4 - Communication:**
How well the communications between project team?

- Excellent
- Very Good
- Good
- Fair
- Poor

***23. P5 - Target Value Design (TVD):**
Was TVD used in planning phase?

- Full
- Partial
- None

***24. P6 - Building Information Modeling (BIM):**
Did you use BIM in planning phase or any 3D program?

- Yes
- No

25. P7 - Last Planner System (LPS):
Did you use Last Planner System in planning phase?

- Yes
- No
- What other Lean principles did you use?

26. P8 - Information Technology (IT):
Did you use IT in RFI communication, project tracking, Communications, ..etc?

- yes
- No

What IT system did your company use?

Page 7

Case Study - Lean Project Rating System

2. DESIGN PHASE

This is the design phase of the project that involves owners, engineers, architects, and GC using Target Value Design (TVD), BIM, and total collaboration to produce an excellent valuable design.

***27. D1 - Collaboration:**

How well project team collaborate with each other during this design phase?

- Excellent
- Very Good
- Good
- Fair
- Poor

***28. D2 - Communication:**

How well the design team communicate in this design phase?

- Excellent
- Very Good
- Good
- Fair
- Poor

***29. D3 - Target Value Design (TVD):**

Was Target Value Design used in the design phase?

- Yes
- No

Other (please specify)

***30. D4 - Last Planner System (LPS)**

Was the LPS used in the design phase?

- yes
- No

***31. D5 - Building Information Modeling (BIM)**

Was BIM used in the design phase?

- Yes
- No
- Partially

Other (please specify)

Case Study - Lean Project Rating System

3. CONSTRUCTION PHASE

***32. C1 - Safety:**

Has any accident been reported during construction?

- None
- Minor (Loss of work)
- Major (Loss of life or Limbs)

***33. C2 - Collaboration:**

What is the degree of Collaboration between project team in the construction phase?

- Full Collaboration
- Partial Collaboration
- Poor Collaboration

***34. C3 - Communications:**

How well project team communicate during construction?

- Full communication
- Partial communication
- Poor communication

***35. C4 - Building Codes:**

Was any building code violations cited on the construction site?

- None (No Violations)
- Minor (Resolved violations)
- Major (Construction work stopped by officials)

***36. C5 - Risk Management:**

Was Risk Management Plan implemented by General Contractor?

- Totally applied
- Partially applied
- None

Other (please specify)

Page 10

Case Study - Lean Project Rating System

***37. C6 - Monitoring & Controlling:**
Was construction operation been monitoring and controlled by project team?

- Yes
- No

Other (please specify)

***38. C7 - Last Planner System (LPS):**
Was the LPS used in the construction phase?

- Yes
- No

***39. C8 - Building Information Modelling (BIM):**
Was BIM or other 3D program used in the construction phase?

- Yes
- No
- Other 3D Program

Which 3D program?

APPENDIX D: RATING SCORE CARDS

The following are the score cards of the thirty (30) case studies which represent the Actual score and the corresponding LPRS score for each project. The Actual score card measure the actual project performance and its final score. The LPRS score has three score cards representing the planning phase, design phase and construction phase. Adding all three phases score cards represent the final LPRS score card for that project. Finally the Actual and LPRS are compared.

The case study score cards represented in this study consists of the following project delivery systems:

1. Integrated Project Delivery (IPD)
2. Guaranteed Maximum Price (GMP)
3. Design/Build (D/B)
4. Design/Bid/Build (D/B/B)

Lean Project Rating System (LPRS)

Project Type:	Hospital					Case Study 01	
Project Delivery Method	IPD						

Actual Project Results

Project Success Criteria						Possible Points	Actual Credits
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					45	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
			15			19	15
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
				15		15	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
				12		12	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					9	9
Total Project Success Score						100	96

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		Hospital							Case Study 01	
Project Delivery Method:		IPD								

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	2.9
			0.9	1	1	1	1	1		
			0.9	1	0	1	0	0		
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.9
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.7
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	0
			5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM)**	Yes			No			2.9	0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	3.2
			3.20			0.00				
			3.2							
	P8	**Information Technology (IT):**	Yes			No			2.8	2.8
			2.80			0.00				
			2.8			0				
Total Planning Phase Score									40.00	29.10
										73%

Lean Project Rating System (LPRS)
(Design Phase)

	Hospital						Case Study 01	
Method:	IPD							
Name	**Indicator**	**Earned Credits**					**Possible Credit**	**Actual Credit**
D1	Collaboration	Excellen	Very	Good	Fair	Poor	10.4	10.4
		10.4	10.0	8.0	6.0	0.0		
		10.4						
D2	Communication	Excellen	Very	Good	Fair	Poor	10.4	10.4
		10.4	10.0	8.0	6.0	0.0		
		10.4						
D3	Target Value Design (TVD):	Yes		No			5.5	0
		5.50		0.00				
				0				
D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	4.4
		4.4		0.0				
		4.4		0				
D5	Building Information Modeling (BIM):	Yes		No			4.3	0
		4.30		0.00				
				0				
Total Design Phase Score							**35.00**	**25.20**
								72%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type:		Hospital						Case Study 01	
Project Delivery Method:		IPD							
Main Category	**Name**	**Indicator**	**Earned Credits**					**Possible Credit**	**Actual Credit**
Construction Phase	C1	Sagety: No of Accidents	None		Minor	Major		7.5	7.50
			7.5		4.0	0.0			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.40
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.10
			3.1		1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.10
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.00
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.10
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.60
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.00
			1.20		0.00				
					0				
Total Construction Phase Score								**25.00**	**23.80**
									95%

Lean Project Rating System (LPRS)

Project Type:	Hospital					Case Study 02	
Project Delivery Method:	IPD						

Actual Project Results

Project Success Criteria							
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					45	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
			15			19	15
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
				15		15	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
			12			12	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					9	9
Total Project Success Score						**100**	**96**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Hospital		Case Study 02
Project Delivery Method:	IPD		

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	5.9
			0.9	1	1	1	1	1		
			0.9	1	1	1	1	1		
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.9
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.7
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	3.0
			5.0		3.0		0.0			
					3.0					
	P6	**Building Information Modeling (BIM)**	Yes			No			2.9	0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	3.2
			3.20			0.00				
			3.2							
	P8	**Information Technology (IT):**	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**35.10**
										88%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital

Project Delivery Method: IPD

Case Study 02

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellen	Very	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D2	Communication	Excellen	Very	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D3	Target Value Design (TVD):	Yes			No		5.5	5.5
			5.50			0.00			
			5.5			0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	4.4
			4.4			0.0			
			4.4			0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	0
			4.30			0.00			
						0			
Total Design Phase Score								**35.00**	**30.70**
									88%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital

Project Delivery Method: IPD

Case Study 02

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1		1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	1.6
			1.6			0.0			
			1.6						
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0
			1.20			0.00			
						0			
Total Construction Phase Score								**25.00**	**23.80**
									95%

Lean Project Rating System (LPRS)							
Project Type:	Hospital					Case Study 03	
Project Delivery Metho	IPD						
Actual Project Results							
Project Success Criteria							
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		40				45	40
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
	19					19	19
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
				15		15	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
				12		12	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					9	9
Total Project Success Score						**100**	**95**

Lean Project Rating System (LPRS) (Planning Phase)										
Project Type:		Hospital							Case Study 03	
Project Delivery Method:		IPD								
Main Category	**Name**	**Indicator**	**Earned Credits**						**Possible Credit**	**Actual Credit**
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	**5.9**	**3.9**
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		**3.6**	**3.6**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	**Collaboration**	Excellent	Very	Good		Fair	Poor	**7.9**	**7.9**
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	**Communication**	Excellent	Very	Good		Fair	Poor	**8.7**	**8.7**
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		**5.0**	**0**
			5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM)**	Yes			No			**2.9**	**0**
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			**3.2**	**0**
			3.20			0.00				
						0				
	P8	**Information Technology (IT):**	Yes			No			**2.8**	**2.8**
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**26.90**
										67%

Lean Project Rating System (LPRS)

(Design Phase)

Project Type: Hospital

Project Delivey Method: IPD

Case Study 03

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellent	Very	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes			No		5.5	0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	4.3
			4.30			0.00			
			4.3			0			
Total Design Phase Score								**35.00**	**24.30**
									69%

Lean Project Rating System (LPRS)

(Construction Phase)

Project Type: Hospital

Project Delivery Method: IPD

Case Study 03

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.0
			7.5	7.0	6.0	3.5			
				7.0					
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.45
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	2.45
			3.1	2.45	1.6	0.85	0		
				2.45					
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	1.6
			1.6			0.0			
			1.6						
	C8	Building Information Modeling (BIM):	Yes			No		1.2	1.2
			1.20			0.00			
			1.2			0			
Total Construction Phase Score								**25.00**	**22.90**
									92%

Lean Project Rating System (LPRS)

Project Type:		Hospital				Case Study 04	
Project Delivery Method:		IPD					

Actual Project Results

Project Success Criteria	Number of Accident					Possible Points	Actual Credits
Safety	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		40				**45**	40
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
			15			**19**	15
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
				15		**15**	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
				12		**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**91**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		Hospital							Case Study 04	
Project Delivery Method:		IPD								

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:**	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	4.9
		How many initial participants?	0.9	1	1	1	1	1		
			0.9	1	1	1	1			
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.0
			7.9	7.0	5.0		3.0	0.0		
				7.0						
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.0
			8.7	8.0	6.0		4.0	0.0		
				8.0						
	P5	**Target Value Design (TVD):**	Full		Partial		None		5.0	0.0
		Was TVD used in planning phase?	5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM)**	Yes			No			2.9	0.0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):**	Yes			No			3.2	0.0
		Was the LPS Used?	3.20			0.00				
						0				
	P8	**Information Technology (IT):**	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**26.30**
										66%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital

Project Delivery Method: IPD

Case Study 04

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellent	Very	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes			No		5.5	0.0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	0.0
			4.30			0.00			
						0			
Total Design Phase Score								**35.00**	**20.00**
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital

Project Delivery Method: IPD

Case Study 04

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.0
			7.5	7.0	6.0	3.5			
				7					
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	2.6
			3.1	2.55	1.6	0.85	0		
				2.55					
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	1.6
			1.6			0.0			
			1.6						
	C8	Building Information Modeling (BIM):	Yes			No		1.2	1.2
			1.20			0.00			
			1.2			0			
Total Construction Phase Score								**25.00**	**23.95**
									96%

Lean Project Rating System (LPRS)

Prject Type: Building (Industrial) — **CASE STUDY 05**

Project Delivery Method: IPD

Actual Project Results

Project Success Criteria						Possible Points	Actual Credits
Safety	**Number of Accident**						
	None	**Minor Accidents**			**Major**	Possible Points	Actual Credits
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
			15			**19**	15
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
			15			**15**	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
			12			**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**96**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type: Building (Industrial) — **CASE STUDY 05**

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	3.9
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.9
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.7
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	0.0
			5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM)**	Yes			No			2.9	0.0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Tracking, Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**26.90**
										67%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (Industrial) — **CASE STUDY 05**

Project Delivery Method: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D3	Target Value Design (TVD):	Yes		No			5.5	5.5
			5.50		0.00				
			5.5		0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0
			4.30		0.00				
					0				
Total Design Phase Score								**35.00**	**26.30**
									75%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (Industrial) — **CASE STUDY 05**

Project Delivery Method: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								**25.00**	**22.20**
									89%

Lean Project Rating System (LPRS)							
Project Type:	Building (Bank)					CASE STUDY 06	
Project Delivery Method:	Design/Build						
Actual Project Results							
Project Success Criteria							
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					45	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
		17				19	17
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
			15			15	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
	0		12			12	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					9	9
Total Project Success Score						**100**	**98**

Lean Project Rating System (LPRS) (Planning Phase)										
Project Type:		Building (Bank)							CASE STUDY 06	
Project Delivery Method:		Design/Build								
Main Category	**Name**	**Indicator**	**Earned Credits**						**Possible Credit**	**Actual Credit**
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	**5.9**	**3.9**
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		**3.6**	**3.6**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very Good	Good		Fair	Poor	**7.9**	**7.9**
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very Good	Good		Fair	Poor	**8.7**	**8.7**
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		**5.0**	**3.0**
			5.0		3.0		0.0			
					3.0					
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			**2.9**	**0.0**
			2.90			0.00				
						0.0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			**3.2**	**0.0**
			3.20			0.00				
						0.0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			**2.8**	**2.8**
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**29.90**
										75%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (Bank) — CASE STUDY 06

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D3	Target Value Design (TVD):	Yes			No		5.5	5.5
			5.50			0.00			
			5.5						
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0.0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	0.0
			4.30			0.00			
						0.0			
Total Design Phase Score								35.00	26.30
									75%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (Bank) — CASE STUDY 06

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	0.0
			1.6			0.0			
						0.0			
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0.0
			1.20			0.00			
						0.0			
Total Construction Phase Score								25.00	22.20
									89%

Lean Project Rating System (LPRS)								
Project Type:		Building (TH)					CASE STUDY 07	
Project Delivery Method:		Design/Build						
Actual Project Results								
Project Success Criteria	**Safety**	Number of Accident					Possible Points	Actual Credits
		None	Minor Accidents			Major		
		45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		45					45	45
	Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
		19	17	15	10	0		
				15			19	15
	Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
		0		15	15			
					15		15	15
	Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
		0		12	12			
		0					12	0
	Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
		9		4	0			
		9					9	9
Total Project Success Score							**100**	**84**

Lean Project Rating System (LPRS)										
(Planning Phase)										
Project Type:		Building (TH)							CASE STUDY 07	
Project Delivery Method:		Design/Build								
Main Category	**Name**	**Indicator**	**Earned Credits**						**Possible Credit**	**Actual Credit**
Planning Phase	**P1**	**Initial Project Team:**	Owner	Architect	Engineers	GC	Subs	Suppliers	**5.9**	**3.9**
		How many initial participants?	0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		**3.6**	**2.4**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	**Collaboration**	Excellent	Very	Good		Fair	Poor	**7.9**	**7.9**
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	**Communication**	Excellent	Very	Good		Fair	Poor	**8.7**	**8.7**
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):**	Full		Partial		None		**5.0**	**3.0**
		Was TVD used in planning phase?	5.0		3.0		0.0			
					3.0					
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			**2.9**	**0.0**
			2.90			0.00				
						0.0				
	P7	**Last Planner System (LPS):**	Yes			No			**3.2**	**0.0**
		Was the LPS Used?	3.20			0.00				
						0.0				
	P8	**Information Technology (IT):**	Yes			No			**2.8**	**2.8**
		RFI communication, Project Internet tracking	2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**28.70**
										72%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (TH) — CASE STUDY 07

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0.0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0.0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0.0				
Total Design Phase Score								35.00	20.00
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (TH) — CASE STUDY 07

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0
			1.6		0.0				
					0.0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0
			1.20		0.00				
					0.0				
Total Construction Phase Score								25.00	22.20
									89%

Lean Project Rating System (LPRS)								
Project Type:		Building (Data Center)					CASE STUDY 08	
Project Delivery Method:		Design/Build						
Actual Project Results								
Project Success Criteria	**Safety**	Number of Accident					Possible Points	Actual Credits
		None	Minor Accidents			Major		
		45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		45					**45**	45
	Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
		19	17	15	10	0		
			17				**19**	17
	Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
		0		15	15			
				15			**15**	15
	Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
		0		12	12			
				12			**12**	12
	Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
		9		4	0			
		9					**9**	9
Total Project Success Score							**100**	**98.00**

Lean Project Rating System (LPRS)										
(Planning Phase)										
Project Type:		Building (Data Center)						CASE STUDY 08		
Project Delivery Method:		Design/Build								
Main Category	**Name**	**Indicator**	**Earned Credits**						**Possible Credit**	**Actual Credit**
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	4.9
			0.9	1	1	1	1	1		
			0.9	1	1	1	1			
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.0
			7.9	7.0	5.0		3.0	0.0		
				7.0						
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.0
			8.7	8.0	6.0		4.0	0.0		
				8.0						
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	0.0
			5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	0.0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**26.30**
										66%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (Data Center) — **CASE STUDY 08**

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes			No		5.5	0.0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	0.0
			4.30			0.00			
						0			
Total Design Phase Score								**35.00**	**20.00**
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (Data Center) — **CASE STUDY 08**

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.5
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	0.0
			1.6			0.0			
						0			
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0.0
			1.20			0.00			
						0			
Total Construction Phase Score								**25.00**	**21.25**
									85%

Lean Project Rating System (LPRS)

Project Type: Hospital

Project Delivery Method: D/B/B

Case Study 09

Actual Project Results

Project Success Criteria						Possible Points	Actual Credits
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		40				45	40
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
		17				19	17
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
	0					15	0
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
	0					12	0
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
				0		9	0
Total Project Success Score						**100**	**57.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type: Hospital

Project Delivery Method: D/B/B

Case Study 09

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	2.9
			0.9	1	1	1	1	1		
			0.9	1	1					
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.4
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	3.0
			7.9	7.0	5.0		3.0	0.0		
							3.0			
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	4.0
			8.7	8.0	6.0		4.0	0.0		
							4.0			
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	0.0
			5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	2.9
			2.90			0.00				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**18.00**
										45%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital

Project Delivery Method: D/B/B

Case Study 09

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D3	Target Value Design (TVD):	Yes			No		5.5	0.0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	0.0
			4.30			0.00			
						0			
Total Design Phase Score								35.00	16.00
									46%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital

Project Delivery Method: D/B/B

Case Study 09

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.0
			7.5	7.0	6.0	3.5			
				7.0					
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	0.9
			3.4	2.45	1.7	0.85	0		
						0.85			
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	0.9
			3.1	2.55	1.6	0.85	0		
						0.85			
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	1.6
			3.1		1.6	0.0			
					1.6				
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	1.5
			3.0		1.5	0.0			
					1.5				
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								25.00	15.10
									60%

Lean Project Rating System (LPRS)

Project Type:	Building					Case Study 10	
Project Delivery Method:	D/B/B						

Actual Project Results

Project Success Criteria

Safety	**Number of Accident**					Possible Points	Actual Credits
	None	**Minor Accidents**			**Major**		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
	19					**19**	19
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
	0					**15**	0
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
				12		**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**85.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Building		Case Study 10
Project Delivery Method:	D/B/B		

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	**P1**	**Initial Project Team:**	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**2.9**
		How many initial participants?	0.9	1	1	1	1	1		
			0.9	1	1					
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**3.6**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	**Collaboration**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**7.0**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
				7.0						
	P4	**Communication**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**8.0**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
				8.0						
	P5	**Target Value Design (TVD):**	**Full**		**Partial**		**None**		**5.0**	**0.0**
		Was TVD used in planning phase?	**5.0**		**3.0**		**0.0**			
							0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	**Yes**			**No**			**2.9**	**2.9**
			2.90			**0.00**				
			2.9							
	P7	**Last Planner System (LPS):**	**Yes**			**No**			**3.2**	**0.0**
		Was the LPS Used?	**3.20**			**0.00**				
						0				
	P8	**Information Technology (IT):**	**Yes**			**No**			**2.8**	**2.8**
		RFI communication, Project Internet tracking	**2.80**			**0.00**				
			2.8							
Total Planning Phase Score									**40.00**	**27.20**
										68%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building

Project Delivery Method: D/B/B

Case Study 10

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8				
	D3	Target Value Design (TVD):	Yes			No		5.5	0.0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	4.3
			4.30			0.00			
			4.3						
Total Design Phase Score								**35.00**	**20.30**
									58%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building

Project Delivery Method: D/B/B

Case Study 10

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None		Minor	Major		7.5	7.5
			7.5		4.0	0.0			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	1.7
			3.4	2.45	1.7	0.85	0		
					1.7				
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	1.6
			3.1		1.6	0.85	0		
					1.6				
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	1.5
			3.0		1.5	0.0			
					1.5				
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	0
			1.6			0.0			
						0			
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0
			1.20			0.00			
						0			
Total Construction Phase Score								**25.00**	**17.50**
									70%

Lean Project Rating System (LPRS)

Project Type:	**Building (Hotel)**			**CASE STUDY 11**
Project Delivery Method:	**D/B/B**			

Actual Project Results

Project Success Criteria	**Safety**	**Number of Accident**					Possible Points	Actual Credits
		None	**Minor Accidents**			**Major**		
		45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		45					**45**	45
	Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
		19	17	15	10	0		
					10		**19**	10
	Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
		0		15	15			
		0					**15**	0
	Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
		0		12	12			
		0					**12**	0
	Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
		9		4	0			
		9					**9**	9
Total Project Success Score							**100**	**64**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	**Building (Hotel)**		**CASE STUDY 11**
Project Delivery Method:	**D/B/B**		

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**3.9**
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**1.5**
		Owner	0.2		0.3	0.3	0.6			
		Architect	0.2		0.3	0.3	0.6			
		Engineers	0.2		0.3	0.3	0.6			
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	**Collaboration**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**3.0**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
							3.0			
	P4	**Communication**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**3.0**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
							3.0			
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	**Full**		**Partial**		**None**		**5.0**	**0.0**
			5.0		**3.0**		**0.0**			
							0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	**Yes**			**No**			**2.9**	**0.0**
			2.90			**0.00**				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	**Yes**			**No**			**3.2**	**0.0**
			3.20			**0.00**				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	**Yes**			**No**			**2.8**	**2.8**
			2.80			**0.00**				
			2.8							
Total Planning Phase Score									**40.00**	**14.20**
										36%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (Hotel) — **CASE STUDY 11**

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	6.0
			10.4	10.0	8.0	6.0	0.0		
						6			
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D3	Target Value Design (TVD):	Yes			No		5.5	0.0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	4.3
			4.30			0.00			
			4.3						
Total Design Phase Score								**35.00**	**18.30**
									52%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (Hotel) — **CASE STUDY 11**

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	6.0
			7.5	7.0	6.0	3.5			
					6.0				
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	0.0
			3.4	2.45	1.7	0.85	0		
							0		
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	0.0
			3.1	2.55	1.6	0.85	0		
							0		
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	1.6
			3.1		1.6	0.0			
					1.6				
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	1.5
			3.0		1.5	0.0			
					1.5				
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	0.0
			1.6			0.0			
						0			
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0.0
			1.20			0.00			
						0			
Total Construction Phase Score								**25.00**	**11.20**
									45%

Lean Project Rating System (LPRS)

Project Type:	Hospital					CASE STUDY 12		
Project Delivey System:	Design/Build							

Actual Project Results

Project Success Criteria							Possible Points	Actual Credits
Safety	**Number of Accident**						Possible Points	Actual Credits
	None	**Minor Accidents**			**Major**			
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0			
	45						**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor		Possible Points	Actual Credit
	19	17	15	10	0			
		17					**19**	17
Budget	Greater than proposed		Equal	Less than proposed			Possible Points	Actual Credits
	0		15	15				
			15				**15**	15
Schedule	Overrun		On Time	Less than proposed			Possible Points	Actual Credits
	0		12	12				
			12				**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)			Possible Points	Actual Credits
	9		4	0				
	9						**9**	9
Total Project Success Score							**100**	**98.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Hospital					CASE STUDY 12		
Project Delivey System:	Design/Build							

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**5.9**
			0.9	1	1	1	1	1		
			0.9	1	1	1	1	1		
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**3.6**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	**Collaboration**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**7.9**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
			7.9							
	P4	**Communication**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**8.0**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
				8.0						
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	**Full**		**Partial**		**None**		**5.0**	**3.0**
			5.0		**3.0**		**0.0**			
					3.0					
	P6	**Building Information Modeling (BIM):Did you use BIM?**	**Yes**			**No**			**2.9**	**2.9**
			2.90			**0.00**				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	**Yes**			**No**			**3.2**	**0.0**
			3.20			**0.00**				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	**Yes**			**No**			**2.8**	**2.8**
			2.80			**0.00**				
			2.8							
Total Planning Phase Score									**40.00**	**34.10**
										85%

Lean Project Rating System (LPRS)
(Design Phase)

CASE STUDY 12

Project Type: Hospital

Project Delivey System: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes		No			5.5	5.5
			5.50		0.00				
			5.5						
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	4.4
			4.4		0.0				
			4.4						
	D5	Building Information Modeling (BIM):	Yes		No			4.3	4.3
			4.30		0.00				
			4.3						
Total Design Phase Score								35.00	34.20
									98%

Lean Project Rating System (LPRS)
(Construction Phase)

CASE STUDY 12

Project Type: Hospital

Project Delivey System: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	0.0
			3.1		1.6	0.0			
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								25.00	21.90
									88%

Lean Project Rating System (LPRS)

Project Type: Building (Courthouse) — CASE STUDY 13

Project Delivery Method: D/B/B

Actual Project Results

Project Success Criteria

Criteria						Possible Points	Actual Credits
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		40				45	40
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
			15			19	15
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
			15			15	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
			12			12	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					9	9
Total Project Success Score						**100**	**91.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type: Building (Courthouse) — CASE STUDY 13

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	4.9
			0.9	1	1	1	1	1		
			0.9	1	1	1	1			
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.9
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.7
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	3.0
			5.0		3.0		0.0			
					3.0					
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	2.9
			2.90			0.00				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**33.80**
										85%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (Courthouse) — CASE STUDY 13

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes			No		5.5	0.0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	4.3
			4.30			0.00			
			4.3						
Total Design Phase Score								35.00	24.30
									69%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (Courthouse) — CASE STUDY 13

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1day	RTO 1wk.	RTO 1mo.	Major	7.5	6.5
			7.5	6.5	5.0	3.5	0.0		
				6.5					
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	1.6
			1.6			0.0			
			1.6						
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0
			1.20			0.00			
						0			
Total Construction Phase Score								25.00	22.80
									91%

Lean Project Rating System (LPRS)

Project Type:	Building (Expo)					CASE STUDY 14	
Project Delivery System:	Design/Build						

Actual Project Results

Project Success Criteria							
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
	19					**19**	19
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
	0		**Owner changes**			**15**	0
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
	0		**Owner changes**			**12**	0
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**73.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		Building (Expo)							CASE STUDY 14	
Project Delivery System:		Design/Build								

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**3.9**
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**3.6**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	**Collaboration**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**5.0**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
					5.0					
	P4	**Communication**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**6.0**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
					6.0					
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	**Full**		**Partial**		**None**		**5.0**	**5.0**
			5.0		**3.0**		**0.0**			
			5.0							
	P6	**Building Information Modeling (BIM):Did you use BIM?**	**Yes**			**No**			**2.9**	**0.0**
			2.90			**0.00**				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	**Yes**			**No**			**3.2**	**0.0**
			3.20			**0.00**				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	**Yes**			**No**			**2.8**	**2.8**
			2.80			**0.00**				
			2.8							
Total Planning Phase Score									**40.00**	**26.30**
										66%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (Expo) — **CASE STUDY 14**

Project Delivery System: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D3	Target Value Design (TVD):	Yes			No		5.5	5.5
			5.50			0.00			
			5.5						
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	4.3
			4.30			0.00			
			4.3						
Total Design Phase Score								35.00	25.80
									74%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (Expo) — **CASE STUDY 14**

Project Delivery System: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.5
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	2.6
			3.1	2.55	1.6	0.85	0		
				2.55					
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	1.5
			3.0		1.5	0.0			
					1.5				
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								25.00	20.40
									82%

Lean Project Rating System (LPRS)

Project Type:	**Building (Factory)**				**CASE STUDY 15**	
Project Delivery Method:	**D/B/B**					

Actual Project Results

Project Success Criteria							
Safety	**Number of Accident**					Possible Points	Actual Credits
	None	**Minor Accidents**			**Major**		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
	19					**19**	19
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
	0					**15**	0
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
			12			**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**85.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	**Building (Factory)**				**CASE STUDY 15**	
Project Delivery Method:	**D/B/B**					

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**2.9**
			0.9	1	1	1	1	1		
			0.9	1	1					
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**3.0**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	**Collaboration**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**7.0**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
				7.0						
	P4	**Communication**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**8.0**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
				8.0						
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	**Full**		**Partial**		**None**		**5.0**	**3.0**
			5.0		**3.0**		**0.0**			
					3.0		0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	**Yes**			**No**			**2.9**	**0.0**
			2.90			**0.00**				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	**Yes**			**No**			**3.2**	**0.0**
			3.20			**0.00**				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	**Yes**			**No**			**2.8**	**2.8**
			2.80			**0.00**				
			2.8							
Total Planning Phase Score									**40.00**	**26.70**
										67%

Lean Project Rating System (LPRS)
(Design Phase)

CASE STUDY 15

Project Type: Building (Factory)

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
			10.4	10.0	8.0	6.0	0.0		
					8.0				
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								**35.00**	**16.00**
									46%

Lean Project Rating System (LPRS)
(Construction Phase)

CASE STUDY 15

Project Type: Building (Factory)

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								**25.00**	**22.20**
									89%

Lean Project Rating System (LPRS)

Project Type:	Highway (Bridge)					CASE STUDY 16	
Project Delivery Method:	D/B/B						

Actual Project Results

Project Success Criteria

Criteria	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
Safety	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					45	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
		17				19	17
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
	0					15	0
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
	0					12	0
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					9	9
Total Project Success Score						**100**	**71.00**

Lean Project Rating System (LPRS)

(Planning Phase)

	Highway (Bridge)							CASE STUDY 16	
Method:	D/B/B								

Name	Indicator	Earned Credits						Possible Credit	Actual Credit
P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	2.9
		0.9	1	1	1	1	1		
		0.9	1	1					
P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.4
	Owner	0.2		0.3		0.6	0.6		
	Architect	0.2		0.3		0.6	0.6		
	Engineers	0.2		0.3		0.6	0.6		
	General Contractor (GC)	0.2		0.3		0.6	0.6		
	Subcontractors (Major Subs)	0.2		0.3		0.6			
	Suppliers/Vendors	0.2		0.3		0.6			
P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	3.0
		7.9	7.0	5.0		3.0	0.0		
						3.0			
P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	4.0
		8.7	8.0	6.0		4.0	0.0		
						4.0			
P5	Target Value Design (TVD): Was TVD used in planning phase?	Full		Partial		None		5.0	0.0
		5.0		3.0		0.0			
						0			
P6	Building Information Modeling (BIM):Did you use BIM?	Yes			No			2.9	0.0
		2.90			0.00				
					0				
P7	Last Planner System (LPS): Was the LPS Used?	Yes			No			3.2	0.0
		3.20			0.00				
					0				
P8	Information Technology (IT): RFI communication, Project Internet tracking	Yes			No			2.8	2.8
		2.80			0.00				
		2.8							
Total Planning Phase Score								**40.00**	**15.10**
									38%

Lean Project Rating System (LPRS)
(Design Phase)

	Highway (Bridge)						CASE STUDY 16	
Method:	D/B/B							
Name	**Indicator**	**Earned Credits**					**Possible Credit**	**Actual Credit**
D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
		10.4	10.0	8.0	6.0	0.0		
				8.0				
D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	8.0
		10.4	10.0	8.0	6.0	0.0		
				8.0				
D3	Target Value Design (TVD):	Yes		No			5.5	0.0
		5.50		0.00				
				0				
D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
		4.4		0.0				
				0				
D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
		4.30		0.00				
				0				
Total Design Phase Score							**35.00**	**16.00**
								46%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type:		Highway (Bridge)						CASE STUDY 16	
Project Delivery Method:		D/B/B							
Main Category	**Name**	**Indicator**	**Earned Credits**					**Possible Credit**	**Actual Credit**
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	1.7
			3.4	2.45	1.7	0.85	0		
					1.7				
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	1.6
			3.1	2.55	1.6	0.85	0		
					1.6				
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								**25.00**	**19.00**
									76%

Lean Project Rating System (LPRS)

Project Type:	**Hospital**					**CASE STUDY**	
Project Delivery Method:	**GMP**						

Actual Project Results

Project Success Criteria	Category						Possible Points	Actual Credits
	Safety	**Number of Accident**					Possible Points	Actual Credits
		None	**Minor Accidents**			**Major**		
		45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		0		25			**45**	25
	Quality	Excellent	Good	Fair	Poor		Possible Points	Actual Credit
		19	14	9	0			
		19					**19**	19
	Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
		0		15	15			
					15		**15**	15
	Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
		0		12	12			
				12			**12**	12
	Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
		9		4	0			
		9					**9**	9
Total Project Success Score							**100**	**80**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		**Hospital**				**CASE STUDY 17**	
Project Delivery Method:		**GMP**					

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	**P1**	**Initial Project Team:**	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**3.9**
		How many initial participants?	0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**3.6**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	**Collaboration**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**7.0**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
				7.0						
	P4	**Communication**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**8.0**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
				8.0						
	P5	**Target Value Design (TVD):**	**Full**		**Partial**		**None**		**5.0**	**0.0**
		Was TVD used in planning phase?	5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM)**	**Yes**			**No**			**2.9**	**0.0**
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):**	**Yes**			**No**			**3.2**	**0.0**
		Was the LPS Used?	3.20			0.00				
						0				
	P8	**Information Technology (IT):**	**Yes**			**No**			**2.8**	**2.8**
			2.80			0.00				
			2.8			0				
Total Planning Phase Score									**40.00**	**25.30**
										63%

Lean Project Rating System (LPRS)

(Design Phase)

Project Type: Hospital

Project Delivery Method: GMP

CASE STUDY 17

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellen	Very	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellen	Very	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	20.00
									57%

Lean Project Rating System (LPRS)

(Construction Phase)

Project Type: Hospital

Project Delivery Method: GMP

CASE STUDY 17

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Sagety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	6.0
			7.5	7.0	6.0	3.5			
					6				
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.5
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								25.00	19.75
									79%

Lean Project Rating System (LPRS)

Project Type:	Hospital			CASE STUDY 18
project Delivery Method:	IPD			

Actual Project Results

Project Success Criteria

Criteria	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
Safety	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		40				**45**	40

Criteria	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
Quality	19	17	15	10	0		
	19					**19**	19

Criteria	Greater than proposed	Equal	Less than proposed	Possible Points	Actual Credits
Budget	0	15	15		
			15	**15**	15

Criteria	Overrun	On Time	Less than proposed	Possible Points	Actual Credits
Schedule	0	12	12		
		12		**12**	12

Criteria	None	Minor (Resolved)	Major (Law suits)	Possible Points	Actual Credits
Disputes & Litigation	9	4	0		
	9			**9**	9

Total Project Success Score	**100**	**95.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Hospital	CASE STUDY 18
project Delivery Method:	IPD	

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	5.9
			0.9	1	1	1	1	1		
			0.9	1	1	1	1	1		
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.9
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.7
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	3.0
			5.0		3.0		0.0			
					3.0					
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	0.0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	3.2
			3.20			0.00				
			3.2							
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**35.10**
										88%

Lean Project Rating System (LPRS)
(Design Phase)

CASE STUDY 18

Project Type: Hospital

project Delivery Method: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	4.3
			4.30		0.00				
			4.3						
Total Design Phase Score								35.00	24.30
									69%

Lean Project Rating System (LPRS)
(Construction Phase)

CASE STUDY 18

Project Type: Hospital

project Delivery Method: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.0
			7.5	7.0	6.0	3.5			
				7.0					
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.5
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	2.6
			3.1	2.55	1.6	0.85	0		
				2.55					
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								25.00	21.80
									87%

Lean Project Rating System (LPRS)

Project Type:	Hospital	Case Study 19
Project Delivery Method:	IPD	

Actual Project Results

Project Success Criteria							Possible Points	Actual Credits
Safety	Number of Accident						Possible Points	Actual Credits
	None	Minor Accidents			Major			
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0			
	45						45	45
Quality	Excellent	Very Good	Good	Fair	Poor		Possible Points	Actual Credit
	19	17	15	10	0			
		14					19	14
Budget	Greater than proposed		Equal	Less than proposed			Possible Points	Actual Credits
	0		15	15				
			15				15	15
Schedule	Overrun		On Time	Less than proposed			Possible Points	Actual Credits
	0		12	12				
				12			12	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)			Possible Points	Actual Credits
	9		4	0				
	9						9	9
Total Project Success Score							100	95.00

Lean Project Rating System (LPRS)
(Planning Phase)

Project Type:	Hospital	Case Study 19
Project Delivery Method:	IPD	

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	5.9
			0.9	1	1	1	1	1		
			0.9	1	1	1	1	1		
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.9
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.0
			8.7	8.0	6.0		4.0	0.0		
			8.0							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	5.0
			5.0		3.0		0.0			
			5.0							
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	2.9
			2.90			0.00				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									40.00	36.10
										90%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital

Project Delivery Method: IPD

Case Study 19

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes		No			5.5	5.5
			5.50		0.00				
			5.5						
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	25.90
									74%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital

Project Delivery Method: IPD

Case Study 19

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								25.00	25.00
									100%

Lean Project Rating System (LPRS)

Project Type:		Hospital					CASE STUDY 20	
Project Delivery Method:		D/B/B						

Actual Project Results

Project Success Criteria								
	Safety	Number of Accident					Possible Points	Actual Credits
		None	Minor Accidents			Major		
		45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
			40				45	40
	Quality	Excellent	Good	Fair	Poor		Possible Points	Actual Credit
		19	14	9	0			
			14				19	14
	Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
		0		15	15			
		0					15	0
	Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
		0		12	12			
		0					12	0
	Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
		9		4	0			
					0		9	0
Total Project Success Score							100	54

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		Hospital							CASE STUDY 20	
Project Delivery Method:		D/B/B								

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	2.9
			0.9	1	1	1	1	1		
			0.9	1	1					
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.6
		Owner	0.2	0.2	0.3		0.6	0.6		
		Architect	0.2	0	0.3		0.6	0.6		
		Engineers	0.2	0	0.3		0.6	0.6		
		General Contractor (GC)	0.2	0	0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2	0	0.3		0.6			
		Suppliers/Vendors	0.2	0	0.3		0.6			
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	0.0
			7.9	7.0	5.0		3.0	0.0		
								0		
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	0.0
			8.7	8.0	6.0		4.0	0.0		
								0		
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	0.0
			5.0		3.0		0.0			
							0.0			
	P6	**Building Information Modeling (BIM)**	Yes			No			2.9	0.0
			2.90			0.00				
						0.0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):**	Yes			No			2.8	0.0
			2.80			0.00				
						0				
Total Planning Phase Score									40.00	5.50
										14%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital

Project Delivery Method: D/B/B

CASE STUDY 20

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	0.0
			10.4	10.0	8.0	6.0	0.0		
							0		
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	0.0
			10.4	10.0	8.0	6.0	0.0		
							0		
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	0.00
									0%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital

Project Delivery Method: D/B/B

CASE STUDY 20

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	6.0
			7.5	7.0	6.0	3.5			
					6.0				
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	0.0
			3.4	2.45	1.7	0.85	0		
							0		
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	0.0
			3.1	2.55	1.6	0.85	0		
							0		
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	1.6
			3.1		1.6	0.0			
					1.6	0			
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	0.0
			3.0		1.5	0.0			
						0			
	C6	Monitoring & Controlling:	Yes		No			2.1	0.0
			2.10		0.00				
			0		0				
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								25.00	7.60
									30%

Lean Project Rating System (LPRS)

Project Type:	Hospital (Data Center)					CASE STUDY 21	
Project Delivery System:	IPD						

Actual Project Results

Project Success Criteria

Category						Possible Points	Actual Credits
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
		17				**19**	17
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
				15		**15**	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
	0					**12**	0
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**86.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Hospital (Data Center)					CASE STUDY 21	
Project Delivery System:	IPD						

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	4.9
			0.9	1	1	1	1	1		
			0.9	1	1	1	1			
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.7
		Owner	0.2		0.3	0.3	0.6			
		Architect	0.2		0.3	0.3	0.6			
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3	0.3	0.6			
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	**Collaboration**	Excellent	Very	Good		Fair	Poor	7.9	7.9
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	**Communication**	Excellent	Very	Good		Fair	Poor	8.7	8.7
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	5
			5.0		3.0		0.0			
			5							
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	3.2
			3.20			0.00				
			3.2							
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**35.20**
										88%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital (Data Center) — CASE STUDY 21

Project Delivery System: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D3	Target Value Design (TVD):	Yes		No			5.5	5.5
			5.50		0.00				
			5.5						
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	26.30
									75%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital (Data Center) — CASE STUDY 21

Project Delivery System: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								25.00	23.80
									95%

Lean Project Rating System (LPRS)

Project Type:	**Building (Office)**					**CASE STUDY 22**	
Project Delivery Type:	**D/B/B**						

Actual Project Results

Project Success Criteria

Safety	**Number of Accident**					Possible Points	Actual Credits
	None	**Minor Accidents**			**Major**		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
			25			**45**	25
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
		17				**19**	17
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
				15		**15**	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
			12			**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**78.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		**Building (Office)**							**CASE STUDY 22**	
Project Delivery Type:		**D/B/B**								

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**2.9**
			0.9	1	1	1	1	1		
			0.9	1	1					
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**1.8**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6			
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	**Collaboration**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**5.0**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
					5.0					
	P4	**Communication**	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**6.0**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
					6.0					
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	**Full**		**Partial**		**None**		**5.0**	**0.0**
			5.0		**3.0**		**0.0**			
							0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	**Yes**			**No**			**2.9**	**2.9**
			2.90			**0.00**				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	**Yes**			**No**			**3.2**	**0.0**
			3.20			**0.00**				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	**Yes**			**No**			**2.8**	**2.8**
			2.80			**0.00**				
			2.8							
Total Planning Phase Score									**40.00**	**21.40**
										54%

Lean Project Rating System (LPRS)
(Design Phase)

CASE STUDY 22

Project Type: Building (Office)

Project Delivery Type: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	20.00
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

CASE STUDY 22

Project Type: Building (Office)

Project Delivery Type: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	6.0
			7.5	7.0	6.0	3.5			
					6.0				
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	1.7
			3.4	2.45	1.7	0.85	0		
					1.7				
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	1.6
			3.1	2.55	1.6	0.85	0		
					1.6				
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	1.5
			3.0		1.5	0.0			
					1.5				
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								25.00	18.80
									75%

Lean Project Rating System (LPRS)

Project Type:	Building (Office)						Case Study 23	
Project Delivery Method:	D/B/B							

Actual Project Results

Project Success Criteria								
Safety	**Number of Accident**						Possible Points	Actual Credits
	None	**Minor Accidents**			**Major**			
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0			
	45						**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor		Possible Points	Actual Credit
	19	17	15	10	0			
		17					**19**	17
Budget	Greater than proposed		Equal	Less than proposed			Possible Points	Actual Credits
	0		15	15				
			15				**15**	15
Schedule	Overrun		On Time	Less than proposed			Possible Points	Actual Credits
	0		12	12				
	0						**12**	0
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)			Possible Points	Actual Credits
	9		4	0				
			4				**9**	4
Total Project Success Score							**100**	**81.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Building (Office)								Case Study 23		
Project Delivery Method:	D/B/B										

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	3.9
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.6
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2	0.2	0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	Collaboration	Excellent	Very Good	Good		Fair	Poor	7.9	5.0
			7.9	7.0	5.0		3.0	0.0		
					5.0					
	P4	Communication	Excellent	Very Good	Good		Fair	Poor	8.7	6.0
			8.7	8.0	6.0		4.0	0.0		
					6.0					
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	3.0
			5.0		3.0		0.0			
					3.0					
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	0.0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**23.30**
										58%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building (Office) — **Case Study 23**

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes			No		5.5	0.0
			5.50			0.00			
						0			
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	0.0
			4.4			0.0			
						0			
	D5	Building Information Modeling (BIM):	Yes			No		4.3	0.0
			4.30			0.00			
						0			
Total Design Phase Score								**35.00**	**20.00**
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building (Office) — **Case Study 23**

Project Delivery Method: D/B/B

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.5
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	1.5
			3.0		1.5	0.0			
					1.5				
	C6	Monitoring & Controlling:	Yes			No		2.1	2.1
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	0.0
			1.6			0.0			
						0			
	C8	Building Information Modeling (BIM):	Yes			No		1.2	0.0
			1.20			0.00			
						0			
Total Construction Phase Score								**25.00**	**19.75**
									79%

Lean Project Rating System (LPRS)

Project Type:	Highway (Tunnel)					CASE STUDY 24	
Project Delivery Method:	Design/Build						

Actual Project Results

Project Success Criteria

	Number of Accident						
	None	Minor Accidents			Major	Possible Points	Actual Credits
Safety	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		40				**45**	40

Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
			15			**19**	15

Budget	Greater than proposed	Equal	Less than proposed	Possible Points	Actual Credits
	0	15	15		
			15	**15**	15

Schedule	Overrun	On Time	Less than proposed	Possible Points	Actual Credits
	0	12	12		
		12		**12**	12

Disputes & Litigation	None	Minor (Resolved)	Major (Law suits)	Possible Points	Actual Credits
	9	4	0		
		4		**9**	4
Total Project Success Score				**100**	**86.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Highway (Tunnel)	CASE STUDY 24
Project Delivery Method:	Design/Build	

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	3.9
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.1
		Owner	0.2		0.3	0.3	0.6			
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.0
			7.9	7.0	5.0		3.0	0.0		
				7.0						
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.0
			8.7	8.0	6.0		4.0	0.0		
				8.0						
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	0
			5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**23.80**
										60%

Lean Project Rating System (LPRS)
(Design Phase)

CASE STUDY 24

Project Type: Highway (Tunnel)

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	20.00
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

CASE STUDY 24

Project Type: Highway (Tunnel)

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.0
			7.5	7.0	6.0	3.5			
				7.0					
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								25.00	21.70
									87%

Lean Project Rating System (LPRS)

Project Type:	Highway (Tunnel B)				CASE STUDY 25	
Project Delivery Method:	Design/Build					

Actual Project Results

Project Success Criteria	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
Safety	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		40				45	40
	Excellent	Very Good		Fair	Poor	Possible Points	Actual Credit
Quality	19	17	15	10	0		
	19					19	19
	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
Budget	0		15	15			
				15		15	15
	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
Schedule	0		12	12			
	0					12	0
	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
Disputes & Litigation	9		4	0			
			4			9	4
Total Project Success Score						100	78.00

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		Highway (Tunnel B)					CASE STUDY 25	
Project Delivery Method:		Design/Build						

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	Initial Project Team:	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	3.9
		How many initial participants?	0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	Team Experience:	< 5 years		5-10 years		> 10 years		3.6	2.1
		Owner	0.2		0.3	0.3	0.6			
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	5.0
			7.9	7.0	5.0		3.0	0.0		
					5					
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	6.0
			8.7	8.0	6.0		4.0	0.0		
					6					
	P5	Target Value Design (TVD):	Full		Partial		None		5.0	0
		Was TVD used in planning phase?	5.0		3.0		0.0			
							0			
	P6	Building Information Modeling (BIM):Did you use BIM?	Yes			No			2.9	0
			2.90			0.00				
						0				
	P7	Last Planner System (LPS):	Yes			No			3.2	0
		Was the LPS Used?	3.20			0.00				
						0				
	P8	Information Technology (IT):	Yes			No			2.8	2.8
		RFI communication, Project Internet tracking	2.80			0.00				
			2.8							
Total Planning Phase Score									40.00	19.80
										50%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Highway (Tunnel B) — CASE STUDY 25

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	20.00
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Highway (Tunnel B) — CASE STUDY 25

Project Delivery Method: Design/Build

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	6.0
			7.5	7.0	6.0	3.5			
					6.0				
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.5
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	2.6
			3.1	2.55	1.6	0.85	0		
				2.55					
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								25.00	19.20
									77%

Lean Project Rating System (LPRS)								
Project Type:	**Hospital**						**CASE STUDY 26**	
Project Delivery System:	**IPD**							
Actual Project Results								
Project Success Criteria	**Safety**	**Number of Accident**					Possible Points	Actual Credits
		None	**Minor Accidents**			**Major**		
		45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		45					**45**	45
	Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
		19	17	15	10	0		
			17				**19**	17
	Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
		0		15	15			
					15		**15**	15
	Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
		0		12	12			
					12		**12**	12
	Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
		9		4	0			
		9					**9**	9
Total Project Success Score							**100**	**98.00**

Lean Project Rating System (LPRS) (Planning Phase)										
Project Type:		**Hospital**							**CASE STUDY 26**	
Project Delivery System:		**IPD**								
Main Category	**Name**	**Indicator**	**Earned Credits**						**Possible Credit**	**Actual Credit**
Planning Phase	**P1**	**Initial Project Team:** How many initial participants?	**Owner**	**Architect**	**Engineers**	**GC**	**Subs**	**Suppliers**	**5.9**	**5.9**
			0.9	1	1	1	1	1		
			0.9	1	1	1	1	1		
	P2	**Team Experience:**	**< 5 years**		**5-10 years**		**> 10 years**		**3.6**	**3.6**
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**7.9**	**7.9**
			7.9	**7.0**	**5.0**		**3.0**	**0.0**		
			7.9							
	P4	Communication	**Excellent**	**Very**	**Good**		**Fair**	**Poor**	**8.7**	**8.7**
			8.7	**8.0**	**6.0**		**4.0**	**0.0**		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	**Full**		**Partial**		**None**		**5.0**	**5**
			5.0		**3.0**		**0.0**			
			5.0							
	P6	**Building Information Modeling (BIM):Did you use BIM?**	**Yes**			**No**			**2.9**	**2.9**
			2.90			**0.00**				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	**Yes**			**No**			**3.2**	**3.2**
			3.20			**0.00**				
			3.2							
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	**Yes**			**No**			**2.8**	**2.8**
			2.80			**0.00**				
			2.8							
Total Planning Phase Score									**40.00**	**40.00**
										100%

Lean Project Rating System (LPRS)
(Design Phase)

CASE STUDY 26

Project Type: Hospital
Project Delivery System: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	4.4
			4.4		0.0				
			4.4						
	D5	Building Information Modeling (BIM):	Yes		No			4.3	4.3
			4.30		0.00				
			4.3						
Total Design Phase Score								**35.00**	**29.50**
									84%

Lean Project Rating System (LPRS)
(Construction Phase)

CASE STUDY 26

Project Type: Hospital
Project Delivery System: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.0
			7.5	7.0	6.0	3.5			
				7					
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								**25.00**	**24.50**
									98%

Lean Project Rating System (LPRS)

Project Type: Building

Project Delivery Method: IPD

CASE STUDY 27

Actual Project Results

Project Success Criteria

Criteria						Possible Points	Actual Credits
Safety	**Number of Accident**					Possible Points	Actual Credits
	None	**Minor Accidents**			**Major**		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
		17				**19**	17
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
	0		12	Slightly over the budget 1%		**15**	12
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
			12			**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**95.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type: Building

Project Delivery Method: IPD

CASE STUDY 27

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	5.9
			0.9	1	1	1	1	1		
			0.9	1	1	1	1	1		
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.3
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3	0.3	0.6			
	P3	Collaboration	Excellent	Very Good	Good		Fair	Poor	7.9	7.0
			7.9	7.0	5.0		3.0	0.0		
				7.0						
	P4	Communication	Excellent	Very Good	Good		Fair	Poor	8.7	8.7
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	5.0
			5.0		3.0		0.0			
			5.0							
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	2.9
			2.90			0.00				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	3.2
			3.20			0.00				
			3.2							
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**38.80**
										97%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building — CASE STUDY 27

Project Delivery Method: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.4
			10.4	10.0	8.0	6.0	0.0		
			10.4						
	D3	Target Value Design (TVD):	Yes		No			5.5	5.5
			5.50		0.00				
			5.5						
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	4.4
			4.4		0.0				
			4.4						
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
Total Design Phase Score								35.00	30.70
									88%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building — CASE STUDY 27

Project Delivery Method: IPD

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.55	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	2.3
			3.1	2.33	1.55	0.78	0		
			2.33						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								25.00	24.23
									97%

Lean Project Rating System (LPRS)

Project Type:	Hospital					CASE STUDY 28	
Project Delivery Method:	IPD						

Actual Project Results

Project Success Criteria

Criteria						Possible Points	Actual Credits
Safety	**Number of Accident**						
	None	**Minor Accidents**			**Major**		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0	Possible Points	Actual Credits
	45					**45**	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
	19					**19**	19
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
	0					**15**	0
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
			12			**12**	12
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					**9**	9
Total Project Success Score						**100**	**85.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:		Hospital							CASE STUDY 28	
Project Delivery Method:		IPD								

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	3.9
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.4
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.0
			7.9	7.0	5.0		3.0	0.0		
				7.0						
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.0
			8.7	8.0	6.0		4.0	0.0		
				8.0						
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	0
			5.0		3.0		0.0			
							0			
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	2.9
			2.90			0.00				
			2.9							
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	3.2
			3.20			0.00				
			3.2							
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**30.20**
										76%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital

Project Delivery Method: IPD

CASE STUDY 28

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	20.00
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital

Project Delivery Method: IPD

CASE STUDY 28

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0						
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	1.6
			1.6		0.0				
			1.6						
	C8	Building Information Modeling (BIM):	Yes		No			1.2	1.2
			1.20		0.00				
			1.2						
Total Construction Phase Score								25.00	25.00
									100%

Lean Project Rating System (LPRS)

Project Type: Building

Project Delivery Method: Design/Build

CASE STUDY 29

Actual Project Results

Project Success Criteria						Possible Points	Actual Credits
Safety	Number of Accident					Possible Points	Actual Credits
	None	Minor Accidents			Major		
	45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
	45					45	45
Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
	19	17	15	10	0		
			15			19	15
Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
	0		15	15			
			15			15	15
Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
	0		12	12			
	0					12	0
Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
	9		4	0			
	9					9	9
Total Project Success Score						**100**	**84.00**

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type: Building

Project Delivery Method: Design/Build

CASE STUDY 29

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	3.9
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	2.4
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6			
		Suppliers/Vendors	0.2		0.3		0.6			
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.0
			7.9	7.0	5.0		3.0	0.0		
				7.0						
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.0
			8.7	8.0	6.0		4.0	0.0		
				8.0						
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	5.0
			5.0		3.0		0.0			
			5.0							
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	0.0
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	0.0
			3.20			0.00				
						0				
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.8
			2.80			0.00				
			2.8							
Total Planning Phase Score									**40.00**	**29.10**
										73%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Building

Project Delivery Method: Design/Build

CASE STUDY 29

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10.0					
	D3	Target Value Design (TVD):	Yes		No			5.5	0.0
			5.50		0.00				
					0				
	D4	Last Planner System (LPS): Was the LPS Used?	Yes		No			4.4	0.0
			4.4		0.0				
					0				
	D5	Building Information Modeling (BIM):	Yes		No			4.3	0.0
			4.30		0.00				
					0				
Total Design Phase Score								35.00	20.00
									57%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Building

Project Delivery Method: Design/Build

CASE STUDY 29

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.5
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	3.4
			3.4	2.45	1.7	0.85	0		
			3.4						
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	3.1
			3.1	2.55	1.6	0.85	0		
			3.1						
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.1
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.0
			3.0		1.5	0.0			
			3.0			0			
	C6	Monitoring & Controlling:	Yes		No			2.1	2.1
			2.10		0.00				
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes		No			1.6	0.0
			1.6		0.0				
					0				
	C8	Building Information Modeling (BIM):	Yes		No			1.2	0.0
			1.20		0.00				
					0				
Total Construction Phase Score								25.00	22.20
									89%

Lean Project Rating System (LPRS)

Project Type:	Hospital						CASE STUDY 30	
Project Delivery Method:	IPD							

Actual Project Results

Project Success Criteria								
	Safety	Number of Accident					Possible Points	Actual Credits
		None	Minor Accidents			Major		
		45	Return to work within 1day (40)	Return to work within 1 week (25)	Return to work 1 month (10)	0		
		45					45	45
	Quality	Excellent	Very Good	Good	Fair	Poor	Possible Points	Actual Credit
		19	17	15	10	0		
			17				19	17
	Budget	Greater than proposed		Equal	Less than proposed		Possible Points	Actual Credits
		0		15	15			
					15		15	15
	Schedule	Overrun		On Time	Less than proposed		Possible Points	Actual Credits
		0		12	12			
					12		12	12
	Disputes & Litigation	None		Minor (Resolved)	Major (Law suits)		Possible Points	Actual Credits
		9		4	0			
		9					9	9
Total Project Success Score							100	98.00

Lean Project Rating System (LPRS)

(Planning Phase)

Project Type:	Hospital							CASE STUDY 30		
Project Delivery Method:	IPD									

Main Category	Name	Indicator	Earned Credits						Possible Credit	Actual Credit
Planning Phase	P1	**Initial Project Team:** How many initial participants?	Owner	Architect	Engineers	GC	Subs	Suppliers	5.9	3.90
			0.9	1	1	1	1	1		
			0.9	1	1	1				
	P2	**Team Experience:**	< 5 years		5-10 years		> 10 years		3.6	3.60
		Owner	0.2		0.3		0.6	0.6		
		Architect	0.2		0.3		0.6	0.6		
		Engineers	0.2		0.3		0.6	0.6		
		General Contractor (GC)	0.2		0.3		0.6	0.6		
		Subcontractors (Major Subs)	0.2		0.3		0.6	0.6		
		Suppliers/Vendors	0.2		0.3		0.6	0.6		
	P3	Collaboration	Excellent	Very	Good		Fair	Poor	7.9	7.90
			7.9	7.0	5.0		3.0	0.0		
			7.9							
	P4	Communication	Excellent	Very	Good		Fair	Poor	8.7	8.70
			8.7	8.0	6.0		4.0	0.0		
			8.7							
	P5	**Target Value Design (TVD):** Was TVD used in planning phase?	Full		Partial		None		5.0	3.00
			5.0		3.0		0.0			
					3					
	P6	**Building Information Modeling (BIM):Did you use BIM?**	Yes			No			2.9	0.00
			2.90			0.00				
						0				
	P7	**Last Planner System (LPS):** Was the LPS Used?	Yes			No			3.2	3.20
			3.20			0.00				
			3.2							
	P8	**Information Technology (IT):** RFI communication, Project Internet tracking	Yes			No			2.8	2.80
			2.80			0.00				
			2.8							
Total Planning Phase Score									40.00	33.10
										83%

Lean Project Rating System (LPRS)
(Design Phase)

Project Type: Hospital

Project Delivery Method: IPD

CASE STUDY 30

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Design Phase	D1	Collaboration	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D2	Communication	Excellent	Very Good	Good	Fair	Poor	10.4	10.0
			10.4	10.0	8.0	6.0	0.0		
				10					
	D3	Target Value Design (TVD):	Yes			No		5.5	5.5
			5.50			0.00			
			5.5						
	D4	Last Planner System (LPS): Was the LPS Used?	Yes			No		4.4	4.4
			4.4			0.0			
			4.4						
	D5	Building Information Modeling (BIM):	Yes			No		4.3	4.3
			4.30			0.00			
			4.3						
Total Design Phase Score								35.00	34.20
									98%

Lean Project Rating System (LPRS)
(Construction Phase)

Project Type: Hospital

Project Delivery Method: IPD

CASE STUDY 30

Main Category	Name	Indicator	Earned Credits					Possible Credit	Actual Credit
Construction Phase	C1	Safety: No of Accidents	None	RTO 1 day	RTO 1 wk	RTO 1 mo.	Major	7.5	7.50
			7.5	7.0	6.0	3.5			
			7.5						
	C2	Collaboration	Excellent	Very Good	Good	Fair	Poor	3.4	2.45
			3.4	2.45	1.7	0.85	0		
				2.45					
	C3	Communication	Excellent	Very Good	Good	Fair	Poor	3.1	2.55
			3.1	2.55	1.6	0.85	0		
				2.55					
	C4	Building Codes: Building Code Violations	None		Minor	Major		3.1	3.10
			3.1		1.6	0.0			
			3.1						
	C5	Risk Management: Does Risk Management plan exist?	Totally applied		Partially applied	None		3.0	3.00
			3.0		1.5	0.0			
			3						
	C6	Monitoring & Controlling:	Yes			No		2.1	2.10
			2.10			0.00			
			2.1						
	C7	Last Planner System (LPS): Was the LPS Used?	Yes			No		1.6	1.60
			1.6			0.0			
			1.6						
	C8	Building Information Modeling (BIM):	Yes			No		1.2	1.20
			1.20			0.00			
			1.2						
Total Construction Phase Score								25.00	23.50
									94%

REFERENCES

Assaf, S., & Al-Hejji, S. (2006). Causes of delay in largte constructin projects. *International Journal of Project Management*, *Vollume 24*(May 4, 2006), 349–357.

Ballard, G., & Howell, G. (2013). About the Lean Construction Institute. Retrieved March 4, 2013, from http://www.leanconstruction.org/about.htm

Ballard, H., G. (2000, May). *The Last Planner System of Production Controll*. The University of Birmingham.

Bernstein, harvey. (2011). Prefabrication and Modularization: Increasing Productivity in the Construction Industry. *McGraw Hill Construction*. Retrieved from http://construction.com/market_research/freereport/prefabsmr/MHC_Prefabrication_Modularization_SMR_2011.pdf

Brundtland, G. H. (1987). World commission on environment and development. *Our common future*, 8–9.

Bryson, B., & Yetmen,. (2010). *The Owner's Dilemma*. Atlanta, Gorgia: Greenway Communication, LLC. Retrieved from www.greenway.us

Bunz, K., Henze, G., & Tiller, D. (2006). Survey of Sustainable Building Design Practices in North America, Europe, and Asia | Browse - Journal of Architectural Engineering. *ASCE*, *12*(1), 30.

Dawson, C. (2013, January 28). Toyota Again World's Largest Auto Maker. Retrieved April 7, 2013, from http://online.wsj.com/article/SB10001424127887323375204578269181060493750.html

Delacey, M. (2012, November). Why BIM Will Become Even More Important in 2012. Retrieved March 5, 2013, from https://enr.construction.com/technology/bim/2012/0111-why-bim-will-become-even-more-important-in-2012.asp

Dettmer, W. (2008). Beyond Lean Manufacturing. *Goal System International*.

Dzambazova, T., Krygiel, E., & Demchak, G. (2009). *Introducing Revit Architecture 2010: BIM for Beginners*. John Wiley and Sons.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM Handbook, A guide to Building Infromation Modeling* (Second Edition.). Hoboken, New Jersey: John Wiley and Sons.

Friedman, J. (1973). 73 Columbia Law Review 1973 Motion Picture Rating System of 1968: A Constitutional Analysis of Self-Regulation by the Film Industry, The, 185.
Green Building Initiative. (2011). Retrieved March 5, 2013, from http://www.thegbi.org/green-globes/

Howell, G., Ballard, G., & Tommelein, I. (2010). CEC: Construction Engineering: Reinvigorating the Discipline | Browse Manuscript - Journal of Construction Engineering and Management. *ASCE*. Retrieved from http://ascelibrary.org/coo/resource/3/jcemxx/186

Jansson, J., Olofsson, T., & Tarandi, V. (2009). Requirements Transformation in Construction Design. University of Technology, Sweden. Retrieved from http://www.inpro-project.eu/media/RequirementsTransformation.pdf

Kenig, M., Allison, M., & Black, B. (2010). integrated Project Delivery For Public and Private Owners. Retrieved from http://www.agc.org/galleries/projectd/IPD%20for%20Public%20and%20Private%20Owners.pdf

Koskela, L. J. (2000). *An exploration towards a production theory and its application to construction*. Teknillinen Korkeakoulu (Helsinki) (Finland), Finland.

Leone, R., & Bissell, K. (2005). Movie Raings and Third-Person Perception. *Atlantic Journal of Communication*, *13(4)*, 279–291.

Liker, J. K. (2004). *The Toyota Way 14 Management Principles from the World's Greatest Manufacturer*. New York: McGraw-Hill.

Linbeck Lean. (2011). Lean Operating System. Retrieved May 21, 2011

Litman, T. (2007, February 4). *well measured: Developing indicators for comprehensive and sustainable transport planning - Google Search*.

MacLeod, C. (1990). mpaa rating system - Google Search. Retrieved February 27, 2013, from http://www.google.com/search

Martin, C. (2010). Cinema's Scarlet Letters: the MPAA Rating System and Film Education in the Christian University. *Libety University*.

Moller, K., & Torronen, P. (2003, February). Business suppliers' value creation potential: A capability-based analysis. Retrieved March 4, 2013, from http://www.sciencedirect.com/science/article/pii/S0019850102002250

Motwani, J. (2003). A business process change framework for examining lean manufacturing: a case study. *Industrial Management & Data Systems*, 339.

Odeh, A., & Battaineh, H. (2002). Causes of Construction delay: traditional contracts. *International Journal of Project Management*, *20*(January 01, 2002), 67–73.

Oswald, M. (2008). *Rating The Sustaiability of Transportatio Investment: Corridors As A Case Study*. University of Delaware.

Robson, C. (1993). Real world research: A resource for social scientists and practitioners-researchers. *Blackwell Publishers Ltd., Oxford*.

Saaty, T. (1980). *The analytic hierarchy process: Planning, priority setting, resource allocation*. McGraw Hill International Book Co.

Saaty, T. (1990). How to make a decision: The analytic hierarchy process. *ScienceDirect - European Journal of Operational Research :*, *48*(1), 9–26.

Saaty, T. (2006). *Fundamentals of Decision Making and Priority Theory* (Vol. VI of the AHP Series). RWS Publications.

Saaty, T. (2008). *Decision Making For Leaders*. RWS Publications.

Sacks, R., Dave, B., Koskela, L., & Owen, R. (2009). *Analysis framework for the interaction between lean construction and building information modelling - University of Salford Institutional Repository* (Conference Paper). University of Salford.

Sacks, R., Koskela, L., Dave, B., & Owen, R. (2010). Interaction of Lean and Building Information Modeling in Construction. *ASCE, Journal of Construction Engineering and Management*. Retrieved from www.ascelibrary.org

Shah, M., & Littlefield, M. (2007). High-Tech Manufacturers: Ahead in the Lean Journey. *Aberdeen Group*, (February 23, 2007).

Simons, D., & Zokaei, K. (2005). *Performance Improvements through Implementation of Lean Practices: a Study of the U.K. Red Meat Industry*. Cardiff University, United Kingdom.

Soderlund, M., Muench, S. T., Willoughby, K. A., Uhlmeyer, J. S., & Weston, J. (2008). Green Roads: A Sustainability Rating System for Roadways. In *Transportation Research Board's 2008 Annual Meeting* (pp. 13–17).

Sohal, A. S., & Egglestone, A. (1994). Lean Production: Experience among Australian Organizations. *International Journal of Operations & Production Management*, *14*(11), 35–51. doi:10.1108/01443579410068639

Teicholz, P. (2004). Labor productivity declines in the construction industry: causes and remedies. *AECbytes Viewpoint*, *4*(14), 2004.

U.S. Green Building Council. (2011). LEED Core Concepts and Strategies. Retrieved from www.usgbc.org

Walter, maggie. (2009). Participatory Action Research. *Social Research Methods*, *Chapter 21*.

Westney. (2013). Going, Going,Gone - Whatever Haappened to Productivity. Retrieved March 4, 2013, from http://www.westney.com/blog/?p=149

Womack, J.P., & Jones, D. T. (2003). *Lean thinking: banish waste and create wealth in your corporation*. Simon and Schuster.

Womack, James P., Jones, D. T., & Roos, D. (2007). *The Machine That Changed the World: The Story of Lean Production-- Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry*. Free Press.

CURRICULUM VITAE

Mohamed E. Hassan is a licensed Professional Engineer in the state of Texas and Virginia. He attended Cairo University, where he received his Bachelor of Civil Engineering in 1977. He went on to receive his Master of Science in Civil Engineering (Structure) from The City College School of Engineering, New York in 1982. He then received his Doctorate degree in Civil, Environmental, and Infrastructure Engineering from George Mason University in 2013. He is teaching project management and civil engineering courses in DeVry University and Northern Virginia Community College.