Literature Review

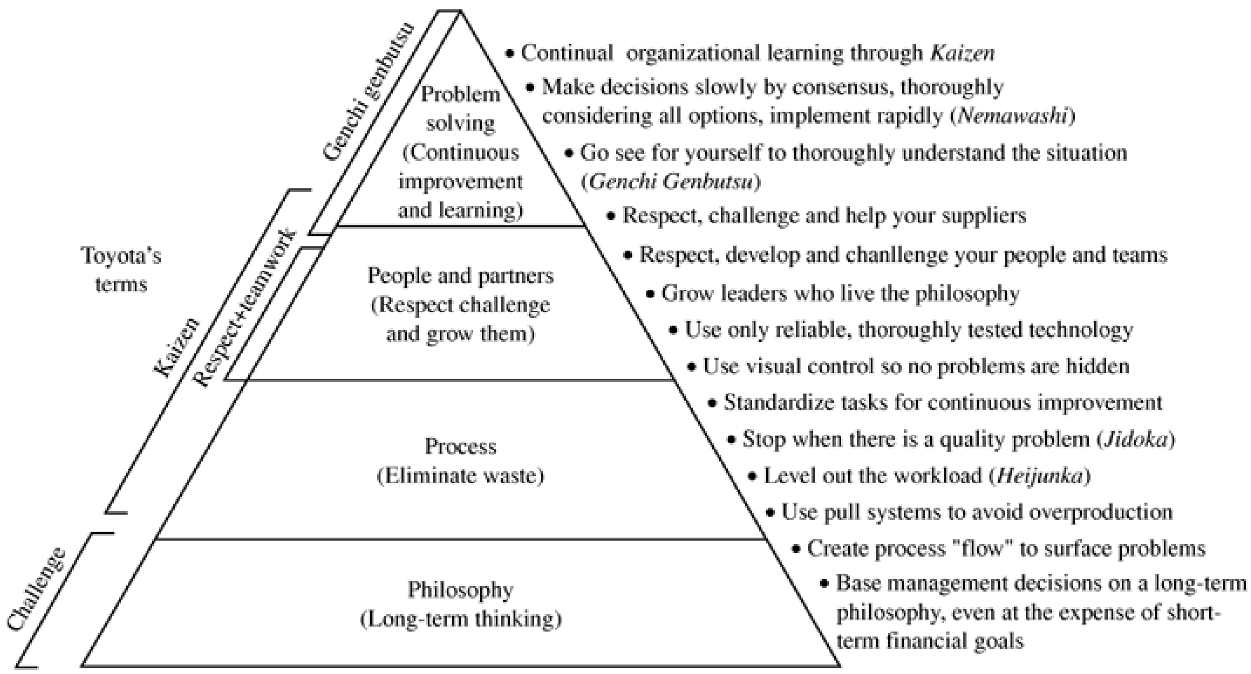
The literature review for lean construction focuses on three main parts. The first part discussed will be about where the idea of lean construction came from and the background of lean principles. The second part of the literature review will talk about how those lean principles worked their way into the construction industry. It will also review the lean construction tools and methods and how they help to improve the construction process. Some methods contain sub-methods, which are also discussed in greater detail. The third part briefly discusses where lean construction stands today and the challenges the construction industry faces in implementing not only the lean tools, but also thoroughly committing its practice to the lean philosophy.

Lean Background

Before defining lean construction, it is important to note that its roots come from lean production. Toyota invented lean production, which is also known as the Toyota Production System (Howell, 1999; Liker, 2004). Although Toyota Motor Corporation may have started implementing lean production in as early as the 1950s (Koskela, 1992; Tommelein, 1998), their supreme quality and efficiency became noticeable in the early 1990s. The Toyota Production System can best be described by its founder, Taiichi Ohno. “All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non-value-added wastes” (Liker, 2004, p. 7). Many of the lean construction methods come from some lean production philosophy, specifically from the Toyota Production System. The next few sections discuss some of the principles, tools, and models that led to effectively developing Toyota’s strong lean background.

14 Toyota Way Principles

In 2004, Jeffrey Liker wrote a book called *The Toyota Way*, which exemplifies the philosophy Toyota practices to achieve their lean status. Liker summarized the Toyota Way in 14 principles as shown in the model below, which provide a solid foundation to the methods developed in lean construction.



Source: Liker (2004)

Figure 1: 14 Principles of the Toyota Way (Liker, 2004)

The next several sections will discuss the Process (Eliminate waste) portion of the pyramid, looking more specifically at the tools and techniques that really help to eliminate waste.

Major Types of Waste

Toyota came up with seven major types of non-value-adding waste and Liker came up with one himself in the following list as stated in *The Toyota Way*: (1) Overproduction, (2) Waiting (time on hand), (3) Unnecessary transport or conveyance, (4) Overprocessing or incorrect processing, (5) Excess inventory, (6) Unnecessary movement, (7) Defects, (8) Unused employee creativity. The lean methods used by Toyota help eliminate or significantly reduce these major types of waste (Liker, 2004).

One-Piece Flow

The idea of one-piece flow revolves around the principle that continuity in a process will ultimately lead to the best quality, lowest cost, and shortest delivery time. With a continuous flow, many of the major types of waste can be eliminated. As stated in the Toyota Production System model, flow can surface problems. Continuous flow lowers the “water level” of production revealing any inefficiencies in a process, instead of inventory acting as a blanket hiding critical problems (Ballard, 2008; Liker, 2004).

Jidoka

The term, *jidoka*, essentially means to never let a defect pass through a system and freeing people from machines, or automation with a human touch. By implementing this principle, it stops production when a defect is recognized in order to bring everyone’s attention toward solving that problem. Instead of the traditional idea of producing as many products as possible in a given time, *jidoka* focuses on mistake-proofing and stopping automation when a problem needs to be resolved. This will increase problem visibility and help solve root cause of problems (Damiano & Devine, 2012; Howell, 1999; Liker, 2004; Tommelein, 1998).

Heijunka

This term means leveling out the production schedule in both volume and variety. *Heijunka* can also apply to scheduling since a leveled schedule keeps the process stable and minimizes inventory. If there are big spikes in production as opposed to the leveled production, there must be a lot of inventory in order to accommodate those spikes (Liker, 2004).

Just-In-Time (JIT)

As Liker (2004) simply put it in *The Toyota Way*, “JIT delivers the right items at the right time in the right amounts.” The concept treats both external and internal personnel as customers making JIT especially applicable within a company. This is also indicative of a pull-system, which means processes are triggered or start in accordance with their subsequent process.

Kanban

Kanban is a Japanese word basically meaning, “sign”, but it also represents a powerful lean technique. A *kanban* is a signal that alerts replenishment of something running low. A simple example of a *kanban* system is a gas-gauge in a car letting the driver know when to fill up the tank for more gas. This system exemplifies a pull-system where gas is retrieved only when supply is low. Toyota goes by this principle: “Flow where you can, pull where you must.” (Liker, 2004, p. 108) This means that whenever one-piece flow is impossible or impractical, a pull-system should be used as an alternative. It is considered an alternative because the pull-system does come with inventory. In a perfect one-piece flow, however, inventory is non-existent (Liker, 2004).

Kaizen

The Japanese term, *kaizen*, refers to making continual improvements in a process with the ultimate goal of eliminating all waste. A tool that uses *kaizen* is the Plan-Do-Check-Act (PDCA) Cycle. This cycle is used to achieve the ideal one-piece flow, which starts with surfacing problems with the first step, “Plan”. Once problems are surfaced, counter-measures are performed, which is the second step, “Do”. After implementing those counter-measures, the next step is to evaluate the results, “Check”. The last step in this cycle is to create flow with confirming results, “Act”. This cycle represents *kaizen* and it is practiced regularly in the Toyota Production System in order to continually improve.

5S

5S is another lean tool that Toyota uses to eliminate waste. The principle behind this method is visual control, which helps surface problems and improving the work environment. The idea was to clean and organize the work place to the point where problems would be visually obvious. Instead of a mess in a factory that could easily hide waste, 5S would clean out and organize that same factory to make problems stand out. The 5 S’s as stated in *The Toyota Way* by Liker are as follows:

1. Sort – Sort through items and keep only what is needed while disposing of what is not.
2. Straighten – “A place for everything and everything in its place.”
3. Shine – The cleaning process often acts as a form of inspection that exposes abnormal and pre-failure conditions that could hurt quality or cause machine failure.
4. Standardize – Develop systems and procedures to maintain and monitor the first three S’s.
5. Sustain – Maintaining a stabilized workplace is an ongoing process of continuous improvement.

Besides making problems more visible, 5S also helps sustain Toyota’s strive for continuous improvement, as the last of the 5 S’s indicates.

Lean Construction

By looking at the Toyota Production System, it is easy to say that manufacturing doesn’t apply to the construction industry because they were dealing with products instead of services. With a closer look, however, production management in construction today is derived from the same approach found in mass production and project management (Howell, 1999). Both of these non-lean approaches ignored the flow and value considerations (Howell, 1999; Koskela, 1992). They both have the same idea that if they reduce cost and duration for each individual activity in the process, it will lead to improvement. The lean construction approach focuses on the variation of the process as opposed to the speed of each step in that process. By focusing on reducing the variation in a construction project, predictability increases giving the project better flow (Ballard, 2008; Ballard & Howell, 1994; Gustafsson, Vessby, & Rask, 2012; Howell, 1999; Sacks, Treckmann, & Rozenfeld, 2009). "By first focusing on workflow, lean construction unplugs clogs in the project stream" (Pinch, 2005, p. 35). A better flow leads to the elimination of many types of waste, which are outlined in the first part of the literature review. In the next several sections, it will become evident how the lean principles of Toyota spilled into the construction industry to form lean construction (Gustafsson et al., 2012; Howell, 1999; Koskela 1992; Low & Teo, 2005).

Lean Project Delivery System (LPDS)

The LPDS is a philosophy that uses lean production principles from Toyota in order to develop better ways to design and build facilities. This philosophy includes five phases: (1) Project Definition, (2) Lean Design, (3) Lean Supply, (4) Lean Assembly, (5) Production Control (Ballard, 2000, 2008; Khanzode, Fischer, & Reed, 2005; Sacks et al., 2009; Salem, Solomon, Genaidy, & Minkarah, 2006). Implementing LPDS is not so much a tool or method, but rather a philosophy and research topic (Ballard, 2000). However, many of the lean construction techniques discussed in this literature review fall within the LPDS.

Increased Visualization

The purpose of increased visualization in construction is to effectively communicate important information to workers on the construction site. Using this lean tool can improve safety, timeliness, and quality (Salem, Solomon, Genaidy, & Luegring, 2005). Here are three examples from a case study of increased visualization at work.

A good way to maximize the safety on the construction site is to use commitment charts. In the case study, the General Contractor's Vice President addressed the importance of safety to project personnel in a meeting. The people attending the meeting were asked to give examples of proper safety techniques on the job site. At the conclusion of the presentation, all employees signed a commitment chart about their safety meeting and it was posted in the on-site trailer for the duration of the project.

In the same case study, mobile signs were also used to promote safety on the job site. These signs were designed to be colorful and humorous in order to attract the attention of the workers better.

Informing the construction workers about project milestones during a project was not regularly done previously, but in this particular case, signs were designed to show the target dates of each floor's completion. These signs were made visible so the workers would see these milestones. After the study, most workers felt that they were more involved in the project due to the visibility of the target milestones (Salem et al., 2006).

Huddle Meetings

These daily meetings come from the lean production principle about employee involvement and empowerment (Salem et al., 2005). There are two types of huddle meetings and both not only help get workers more involved, but it also increases communication and awareness of potential project problems that may arise. One type of huddle meeting is the all-foreman meetings, which focused on the completion of assignments for the next week. These meetings would help bring up the potential problems on a job site given the scheduling. This was also a meeting to keep record of what each foreman planned to do, which would later be reviewed the week after. There are also start-of-the-day meetings, which includes all personnel reviewing what work needs to get done that day. These are generally brief meetings that last about ten minutes, but help opening up communication between workers and foremen. In a case study, 67% of the workers found the meetings to be valuable and 42% gave feedback during the meetings (Salem et al., 2006).

First-Run Studies

This lean construction method is based off of the *kaizen* principle of continuous improvement. In first-run studies, a video, picture, or graphic may be used to illustrate some type of activity or work that is done in construction. With this data, a construction company can implement the PDCA cycle in order to make the activity more efficient. “Plan” refers to collaborating and coming up with a solution to make an activity better. “Do” refers to actually trying that solution. “Check” refers to assessing the results of the implementation. “Act” refers to collaborating again to see what the next step should be given the results of the planned solution (Ballard & Howell, 1994; Salem et al., 2005). In a construction case study using the PDCA cycle, bumper wall installation and joint installation activities were chosen. Bumper walls were chosen because it is a high-cost activity and the joint installation was chosen because it has high-variability. When the project manager, foreman, and crew used the PDCA cycle, their results included more than 38% cost reduction in crash walls and 73% cost reduction in joints (Salem et al., 2006).

5S in Construction

The 5S process is also a lean construction tool, which is pulled straight from Toyota. It is also sometimes referred to as the Visual Work Place. When applied to construction, “Sort” refers to separating tools, parts, and material from the unneeded ones (waste). “Straighten” refers to organizing those tools, parts, and materials in stacks or bundles making them easier to find and use. “Shine” refers to simply cleaning up the stacks of tools, parts, and materials. “Standardize” refers to maintaining the first three S’s. “Sustain” refers to making the 5S process habitual and consistently done (Salem et al., 2005).

Fail-Safe for Quality and Safety

This lean construction tool comes from the lean principles *jidoka*, which basically means to remove a defect from a process and stopping that process until the problem can be resolved. In construction, the fail-safe would be a crew member, foreman, or project manager indicating a potential problem in an activity involving some sort of installation. The activity would then stop until the process was resolved with no problems (Balle & Bouthillon, 2011). This can save the hassle, cost, and time of rework especially if an installation process needs to be done many times. The same fail-safe can be said for safety. If a worker or manager on site recognizes an unsafe practice, they would stop that process and implement the change to make the activity safer (Salem et al., 2005).

Last Planner System (LPS)

The LPS is a lean construction technique that focuses primarily on workflow and variability in construction. The physical definition of the Last Planner in construction is the person or group held accountable for production unit control, which means they are responsible for making sure that individual assignments at the operational level get completed (Salem et al., 2005; Koskela, Stratton, & Koskenvesa, 2010; Salem et al., 2006). This results in more accurate estimated durations of activities since the ones closest to the work are determining the schedule, not one project manager creating the entire schedule for all subcontractors (Cho & Ballard, 2011). In the Lean Project Delivery System, LPS would represent the fifth phase, production control (Ballard, 2000). The idea of LPS was influenced by the seemingly forgotten knowledge of short term and weekly planning for construction sites due to the growth of project planning software packages. The Last Planner System "is a philosophy, rules and procedures that can be implemented in practice" (Koskela et al., 2010, p. 539).

In LPS, there are five main elements: (1) Master Plan, (2) Reverse Phase Scheduling (RPS), (3) Six-Week Look-Ahead, (4) Weekly Work Plan (WWP), (5) Percent Plan Complete (PPC) (Cho & Ballard, 2011; Koskela et al., 2010; Mossman, 2009; Salem et al., 2005). These five elements will be explained in greater detail in the next several sections. LPS also determines what should, can, and will be done, which is contrary to traditional construction practices.

The LPS uses a variety of approaches with the ultimate goal of reducing flow variability and process-time variability. LPS implements a pull-system, which is what *kanban* does for lean production (Ballard & Howell, 2004). In construction, the construction site is pulling task execution and task inputs, as opposed to a customer pulling products. LPS still has elements in it that push towards a construction site, such as materials, but these are pushed due to the Master schedule and other lower level schedules. LPS's main target is to reduce the variability of those pulled tasks, which also reduces the need for buffers. Also, by reducing task variability, LPS increases productivity in those tasks, which also increases plan reliability (Cho & Ballard, 2011). When a plan is more reliable, more buffers can be eliminated and thus result in shortened duration (Koskela et al., 2010). This concept is apparent in the figures below.

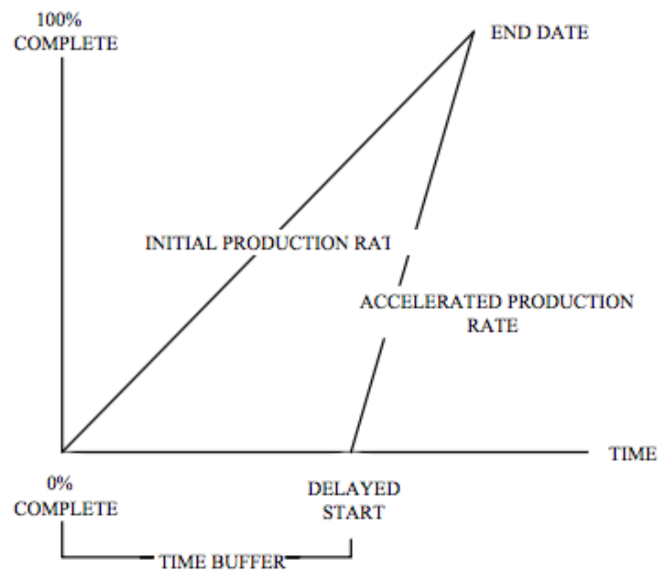


Figure 2: Wait to Start, then Go Faster (Ballard & Howell, 1994)

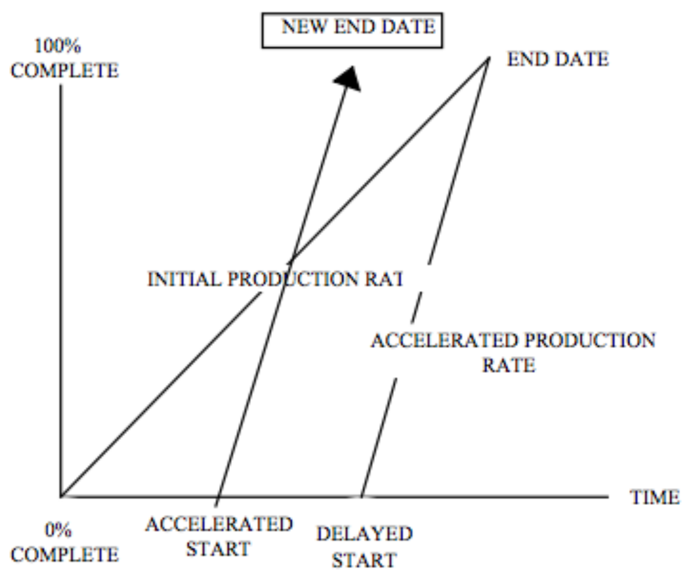


Figure 3: Reduce Flow Variation, then Start Sooner (Ballard & Howell, 1994)

LPS also tries to improve the commitment of the people responsible for the completion of tasks. It helps improve commitment through public promises, public checking of task completion, and statistics representing reasons for non-completed tasks. Through these statistics on non-completion, LPS uses an element of continuous improvement with the goal of decreasing the percentage of non-completed tasks (Koskela et al., 2010).

By reducing workflow variability and process-time variability, LPS can increase productivity, thus decreasing costs, increasing quality, and increasing safety. Also with this reduction in variability, the schedule can be compressed as shown in the figures above.

Master Schedule

Of the five elements of LPS, the master schedule might have the least to do with lean principles. The master schedule is like any other from traditional construction, which is an overall project schedule with milestones. The master schedule is mainly created in order to present in a bid package and to serve as the basis when implementing Reverse Phase Scheduling (Salem et al., 2005).

Reverse Phase Scheduling (RPS)

RPS is a scheduling technique that uses a pull-system working backwards starting at the completion date. By scheduling in phases, a plan is produced emphasizing integration and coordination of a variety of different specialties. By scheduling backwards, it ensures that all contractors take into account all work that must take place before any given activity. Working backwards also makes sure that late activities have an accurate estimated duration instead of trying to squeeze the late activities in the end to fit the master schedule (Messer, 2012; Salem et al., 2005).

For a case study, all subcontractors for a construction project displayed their schedule on a wall using Post-it notes. This allowed all subcontractors to see how their schedules affected the length of a certain phase. This case study found that after a few weeks, planners used RPS in their estimations of activity duration instead of the original master schedule (Salem et al., 2006).

Six-Week Look-Ahead

Look-ahead schedules, in general, are a tool used to improve workflow, and shows what work must be done in the future. They can provide an accurate picture of assignments that need to be completed farther down the road than what traditional construction schedules can provide. Looking farther in advance can make constraints easier to find before they happen, thus allowing the potential problems and conflicts to be solved before they actually have a chance to take place (Koskela et al., 2010). The Reverse Phase Schedule created beforehand shows the look-ahead durations and schedules for the activities. The look-ahead window varies, but in the Last Planner System, a six-week look-ahead is typically used. This lean tool helps reduce uncertainty and variability in the construction schedule (Salem et al., 2005).

Weekly Work Plan (WWP)

The WWP is created based on the look-ahead schedule, actual schedule, and the field condition before the weekly meeting. It is a collaborative agreement on what tasks will get done the next week. The meeting for the WWP takes into account the work being done in the present and as a result, determining what work will be made-ready to be done. The WWP meeting covers many things besides what will get done including: safety issues, quality issues, material needs, manpower, construction methods, backlog of ready work, and any problems that may occur in the field. Needless to say, this meeting promotes two-way communication resulting in important project information shared efficiently and accurately (Koskela et al., 2010; Salem et al., 2005).

The WWP looks more specifically at what "should" happen, what "can" happen, and what "will" happen. "Should" refers to work that must be done to keep up with the schedule requirements. "Can" refers to the work that can be done taking into account constraints. "Will" refers to the work that is committed or "promised" to get done after taking into account those constraints. Traditional construction practice ignores the differences between “should”, “can”, and “will”; they assume that pushing more tasks results in better results (Salem et al., 2005).

Another important part of the WWP is the variance analysis. In the variance analysis, the project manager looks at what assignments were not completed on time. Of those assignments, the project manager will then determine the immediate cause of those incomplete assignments. Below is a figure of constraints and variances created through variance analysis from a case study (Salem et al., 2006).

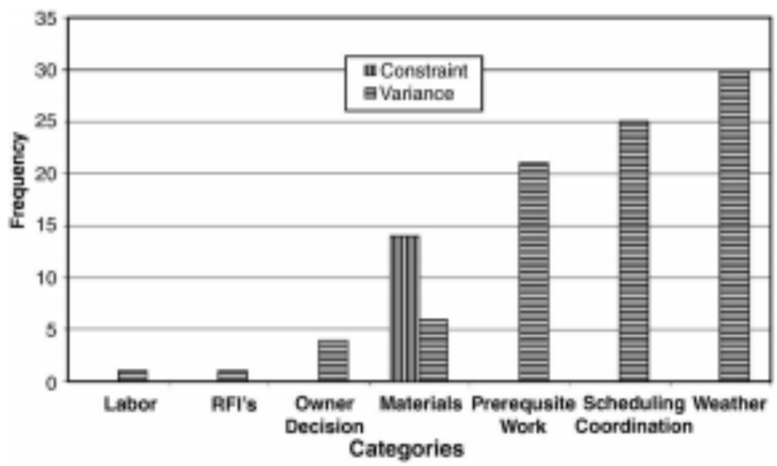


Figure 4: Constraints and Variances by Category (Salem et al., 2006)

This figure shows the causes of variances and their frequencies. This information allows the project manager to set better action plans to deal with delays in the future, instead of deciding what to do as delays happen. All of these analyses go into the WWP, which all help reduce the uncertainty and variability associated with construction.

Percent Plan Complete (PPC)

The PPC values represent the main source of measurement of the Last Planner System (Bortolazza, Costa, & Formoso, 2005). The PPC is simply the number of activities that are completed as planned divided by the total number of planned activities. PPC is actually used in the Weekly Work Plan variance analysis when computing the percentage of activities that get completed on time. When calculating multiple PPC values, an upward slope with respect to time means that production planning was reliable and vice versa. Traditional practices without lean implementation have highly variable PPC values ranging between 30% and 70%. With the implementation of several lean construction tools, PPC values can be greater than 70%, which is much less variability (Salem et al., 2005). To increase the effect of PPC, project staffs can post PPC charts for workers to see in an effort to improve the PPC values (Salem et al., 2006).

Integrated Project Delivery (IPD)

Another lean construction tool is Integrated Project Delivery (IPD), and it is an approach that aligns project objectives with the interests of key participants. In IPD, these key participants are called Primary Team Members (PTMs) and they usually include the architect, key technical consultants, general contractor, and key subcontractors. This is similar to the concept of cross-functional teams, which is discussed in *The Toyota Way*. Traditional construction practice would normally work under transactional contracts, where exchanges are made for goods and services. IPD works under relational contracts, where the relationships create one team working in harmony towards a common goal (Ballard, 2008; Cho & Ballard, 2011). By binding together as one team, everyone then has one price and one scope. The downside to this approach is that if one PTM makes a mistake, then each PTM will pay for it. The mindset in IPD is that a team doesn't point fingers, but rather helps each other pick up the slack. This only works because the team chooses PTMs with integrity, character, and competency. This plays right into the concept of IPD: working to create the right personnel able to effectively apply the principles and practices of the Lean Project Delivery System (Matthews & Howell, 2005). The next few sections will cover lean construction tools used in a construction project case study through IPD.

Building Information Modeling (BIM)

One of the lean construction tools used in the case study is based on the Industrial Engineering tool, simulation. The type of simulation used is BIM, which "is an integrated process for exploring a project's key physical and functional characteristics digitally – before it's built" (Cody, 2010, Project Conception section, para. 11). With BIM, a team can work collaboratively on one common model, instead of multiple teams coming up with different models and going through many iterations. Another advantage with BIM is that a model can show construction not only in 3D, but also in 4D and 5D. The fourth and fifth dimensions are time and cost. This allowed the Contractor of the project to extract material quantities from the BIM model, and provide a preliminary cost estimate.

In addition to cost estimates, the design phase of the project can save ample time and money through BIM models of the project. In a traditional design-bid-build construction project, the architect would develop drawings and send them to the structural engineer. These drawings would then get passed around in a circle through each discipline: mechanical engineer, electrical engineer, etc until it got back to the architect. Inevitably the design in the drawings changes many times and not all consultants even see all the changes. This leads to an inefficient circle of iterations and a lot of waste. With a BIM model, all disciplines can work on the same design simultaneously (Cody, 2010). A diagram representing the BIM relationship between all team members is on the following page.

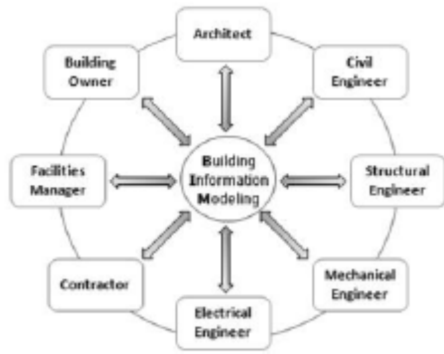


Figure 5: BIM Relationship Diagram (Cody, 2010)

This IPD approach is much more efficient when using the BIM model and offers many advantages (Khanzode et al., 2005). This can eliminate any rework on the design and allow for much quicker design updates. A BIM model also makes scheduling easier with its 4D capabilities. Anyone can see or review what a 3D CAD model might look like at any point in time over the scheduled life of the project. The contractor was able to build schedules into the BIM model, which meant that whenever the model was updated, the schedule was also updated (Fischer, 2000). An example of a 3D visualization of past, present, and future work status is on the following page.

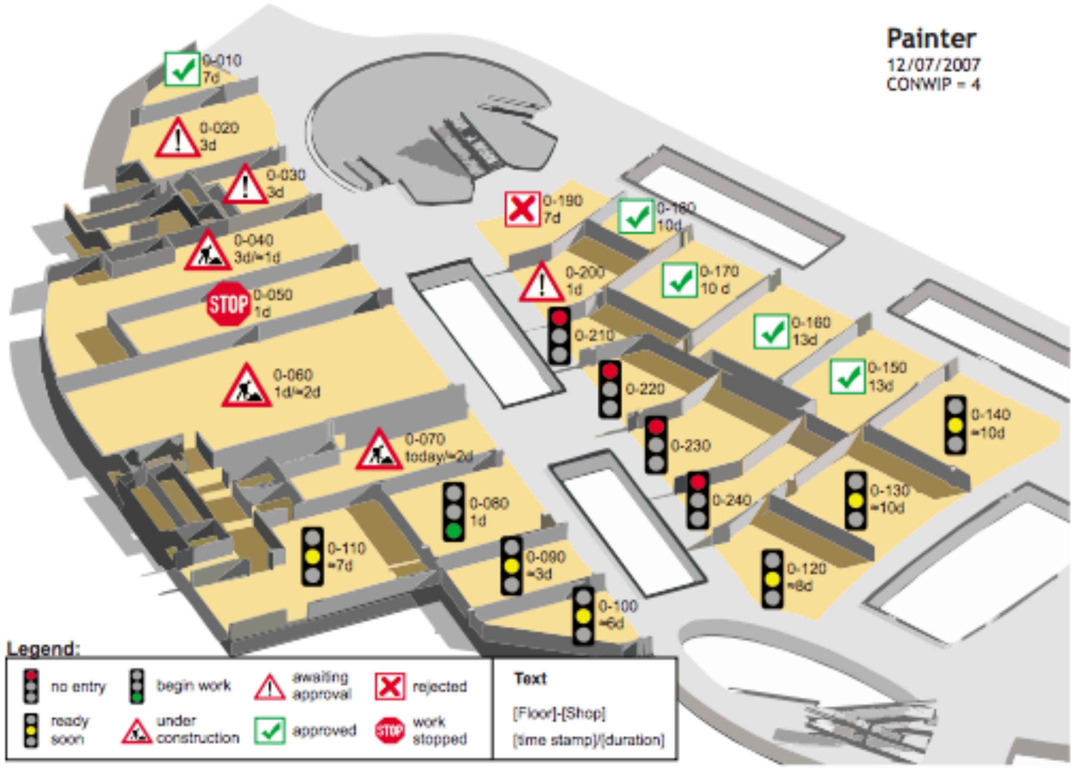


Figure 6: 3D Visualization of Past, Present, and Future Work Status (Sacks et al., 2009)

The BIM model also helped the contractor evaluate potential constructability issues long before they had a chance to happen. Naturally, this saved a lot of time for rework on the job site. (Cody, 2010; Pinch, 2005; Sacks et al., 2009)

Another important advantage with using BIM for a construction project, is its increasing value over three phases: design, construction, and operation. In the design phase, the BIM model is used to analyze different options and find the best fit design efficiently. In the second phase, construction, BIM is looked at as a Building Assembly Model (BAM), where benefits are considered to be 10 times greater than the design phase (Cody, 2010). In the third phase, operation, the BIM model is used as a Building Operation Optimization Model (BOOM). In the operation phase, energy savings and operational efficiency improve with the BIM model (Cody, 2010). Essentially, BIM from the design phase, turns into BAM in the assemble/construction phase, and finally turns into BOOM in the operation phase; BIM increases in value over time.

Optimization

Another Industrial Engineering tool used in this case study is optimization. For this particular case, tunnel forms were used to optimize the construction process. Tunnel forms are basically place holders used for shaping concrete similar to the formwork used for a typical concrete structure. The benefits of tunnel forms over traditional formwork are that they can be reused ranging from 500 to 1,000 times, and can build the concrete structure with better precision (within 1/32" tolerance). Conversely, traditional formwork cannot be reused and is less precise. Since the tunnel forms could be reused, it also increased the repetition of that activity resulting in greater production and efficiency. Using tunnel forms led to the elimination of physical waste, saved time and money, and improved the quality. By using this optimization technique applied to construction, the contractor was able to propose a 13-month construction schedule, when a 21-month construction schedule was desired (Cody, 2010).

Lean Construction Today

As great as lean construction may sound, it definitely has its challenges. In 2012, a paper titled, "Exploring lean construction practice, research, and education" (Alves, Milberg, & Walsh, 2012), presented three main challenges according to authors writing about the implementation of lean construction today.

Challenge 1: "There are many meanings for Lean when applied to construction."

Challenge 2: "Academics should work closely with the industry in the translation of concepts from the manufacturing industry to construction and to promote the systemic use of concepts/systems and not only the use of tools."

Challenge 3: “Without a sustained effort to engage people in meaningful learning experiences which mix instruction, exchange of ideas and meanings, and guided practice, Lean Construction may be viewed as a fad in the construction industry.”

The recognition of these challenges is used to remind those aware of lean construction that it is still very much a work in progress in terms of both theory and implementation (Miletsky, 2010). These challenges also serve as a direction of where lean construction needs to go in order to keep from being a mere phase in the construction industry.

The first challenge implies that lean construction today stands in a growing situation. More research is needed to explain concepts in order to create uniform definitions. By tackling Challenge 1, hopefully the entire industry can be left with a common understanding of lean construction. Many companies believe that when they use a lean tool, they are being a lean company, which is not necessarily the case. Lean in the construction industry can vary in definition from person to person. By creating a solid foundation of lean principles throughout the industry uniformly, this challenge can be overcome with time.

Research on lean construction implementation is based on case studies and the quest for a theory of construction management (Alves et al., 2012). Challenge 2 presents an interesting point because all of the lean construction methods in this literature review are tools, and not so much concepts. The paper written by Alves et al. (2012) is accurate with this observation when it states Challenge 2. In an effort to overcome that challenge, this literature review attempts to draw the connections between concepts from the manufacturing industry and construction. Promoting the systemic use of concepts for lean in construction, however, is quite difficult. To support the difficulty of that challenge, Alves et al. (2012) state that lean construction is not widely implemented in the industry, thus making it difficult for researchers to work with large populations or make any statistical sense of much of the data collected across projects. As more construction companies begin to implement lean, better conclusions can be made on the lean concepts/systems in construction, and not just the tools (Miletsky, 2010).

Challenge 3 focuses on making lean construction sustainable. Due to the young age of lean thinking in construction, many companies and individuals are eager to learn about it. There are organizations that teach the topic quickly, but not many offer sustained and continuous learning of lean thinking. Liker (2004) explains in *The Toyota Way*, that many companies embrace the tools of lean, but not the principles they are designed to support. He goes on to say that people often misinterpret the Toyota Production System with the tools they see using at their Japanese plants, and failing to notice the principles behind those tools. Alves et al. (2012) recognize that a major step in learning lean construction, is unlearning old practices that have outlived their usefulness (Ballard & Howell, 1994).

In conclusion, making lean construction sustainable in the construction industry requires a consistent definition and a deeper understanding of lean as concepts. As more of the construction industry implements lean with continuous improvement, and not being afraid to make mistakes, "it will make us [the construction community] better, more efficient and probably more profitable" (Pinch, 2005, p. 37).