INTEGRATED DESIGN AND PRODUCTION USING LEAN PRINCIPLES IN CONSTRUCTION PROJECTS

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Introduction

Despite its many specialized tools such as: Critical Path Method (CPM)/PERT schedules, Gantt charts, Functional Analysis Systems Test (FAST), Earned Value Analysis (EVA), and Budget-trackers, the construction industry is plagued with supply-chain deficiencies, high defect rates, wasted labour and materials, cost overruns, inefficiencies, mistakes, delays and poor communications. With higher levels of client's expectations on quality and productivity set every day, there calls for a corresponding dynamic approach to managing constructed facilities (Forbes et al, 2000). Ballard et al (2003) believe that the construction production system can be improved tremendously if lean thinking concepts and tools are applied to them. They affirm that systems can be designed to specific goals in terms of providing value, reducing waste, increasing throughput, reducing cycle times, reduce supply chain losses, reduce construction costs and shorten project delivery schedules.

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1 Lean Construction

Lean construction is based on lean manufacturing which is a concept that seeks to eliminate waste (Muda) from production processes. Lean has been defined differently by different scholars. According to Womack and Jones (2003), Lean is the journey to providing the customer with exactly what they want by specifying value, lining up value-adding activities in the best sequence, conducting these activities without interruption and performing them more and more effectively, with less and less human effort, less equipment, less time and less space, whenever a customer puts in an order. While Forbes et al, (2000) see Lean construction as a process that maximizes value and **reduces waste** using Supply Chain Management (SCM) and Just-In-Time (JIT) techniques as well as the open sharing of information between all the parties involved in the production process. Koskela et al (2002) put it more succinctly, by defining Lean as 'a way to design production systems to minimise waste of materials, time, and effort in order to generate the maximum possible amount of value'.

Lean Construction emerged as a new concept in the mid-1990s. It has since been gaining acceptance within different disciplines in the construction industry. Koskela et al (2002) view lean construction as a novel theory-based approach to construction which seeks to integrate three scientific theories of production: the transformation view, the flow view and the value view of production. The TFV theory of recognises that each of the views in isolation is inadequate and limited as an explicit theory of production but are complementary when they are integrated (Table 1).

Table 1: Integrated TFV theory of production (Koskela, 2000)

	Transformation view	Flow view	Value generation view
Conceptualisation of production	As in transformation of inputs into outputs	As a flow of materials composed of transformation, inspection, moving and waiting	As a process where value for the customer is created through fulfilment of his/her requirements

Main principle	Getting production realised efficiently	Elimination of waste (non-value-adding activities)	Elimination of value loss (achieved value in relation to best possible value)
Methods and practices	Work breakdown structure, MRP, organisational responsibility chart	Continuous flow, pull production control, continuous improvement	Methods for requirement capture, quality function deployment
Practical contribution	Taking care of what has to be done	Making sure that unnecessary things are done as little as possible	Taking care that customer requirements are met in the best possible manner
Suggested name of practical application of the view	Task management	Flow management	Value management

Each focuses on certain aspects of production: the transformation view on the value-adding transformation; the flow view on the non-value-adding activities; and the value generation concept on the control of production from the customer point of view. (Koskela, 2000; Koskela et al, 2002)

Conventional project management in construction is inadequate because its current practices attempts to manage activities by centrally applied scheduling and to control them using output measures. It fails in the area of managing workflow and the creation and delivery of value given that the schedules only portray the project as a series of activities and ignore the flow of work within and between them. According to Koskela et al (2002), a lean project delivery system (Lean Construction) is one that is structured, controlled, and improved in simultaneously pursuit of the three goals of transformation, flow and value.

The direct application of the lean construction concept in a construction project will bring a change to the manner in which things are done in an organization and will inevitably alter the traditional work practices normally undertaken by the construction firms according to the objectives and principles established in the lean construction concept (Abdullah, et al 2010).

2 Alamai Northern Construction Ltd

This is a large multinational construction company with loads of construction experience. The company has a systematic resource planning and management system for its construction projects, starting from a master schedule and related partial plans for plant, personnel, materials etc. ; plans for shorter term are derived from the master plan, extending to weekly plans, and the progress is monitored and fed back to management. The company is currently executing a complex PFI hospital project in Manchester and has one of its competent teams managing the project on and off the site.

The project has been divided into work packages where all the building elements are executed by different subcontractors. This subcontractors have their different suppliers, different ways of working, different values and interests, and different schedules.

Among the many objectives of the project, one which the client stressed much was that the project coordinator must deliver a clean building. Not only should it be clean for hygiene purposes but also to look brand new with no dirt or stains around. Therefore, by the end of the project, all doors must be as new with no stains whatsoever.

After all designs were prepared, it was time for resource planning. The planning department developed and planned the resources across all work packages. All subcontractors sent in their work schedules and supplier's delivery schedule. This was incorporated within the master schedule so as to monitor progress of each subcontractor. The doors subcontractor was scheduled to start installation in six months. At this time, the prices of materials were unstable and the future of the market was quite unpredictable. Notwithstanding, Alamai Northern Construction proceeded with its construction activities.

But before the detail description of Alamai site construction and doors installation practices, an explanation of the 14 principles of the Toyota Production System (TPS) is given below.

3 Toyota Production System (TPS)

Today, Toyota is among the first three largest auto manufacturers in the world but by far the most profitable of the others (Liker, 2004). This made the author of the 'Toyota Way' Jeffery Liker to ask the question – what is the secret of Toyota's success? According to Liker Toyota's incredible and consistent success stems from mastering operational excellence within which it has vigorously implemented tools and quality improvement techniques such as Just-In-Time, Kaizen, One-piece flow, Jidoka and Hijunka. Liker advices that when applying TPS, the first step is to examine the production process (service or product) from the customer's perspective then identify both the value-adding and non-value-adding activities. This defines **value** and helps outline what is needed at each stage of the project with respect to internal and external customers.

Table 2: 14 Principles of TPS and the "4 P" (Liker, 2004)

Toyota terms	"4 P" Categories	14 Principles
Challenge	**Philosophy** (Long-term Thinking)	**Principle 1.** Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals

Kaizen		**Process** (Eliminate Waste)	**Principle 2.** Create continuous process flow to bring problems to the surface **Principle 3.** Use pull systems to avoid overproduction **Principle 4.** Level out the workload (heijunka). (Work like the tortoise, not the hare.) **Principle 5.** Build a culture of stopping to fix problems, to get quality right the first time **Principle 6.** Standardized tasks are the foundation for continuous improvement and employee empowerment **Principle 7.** Use visual control so no problems are hidden **Principle 8.** Use only reliable, thoroughly tested technology that serves your people and processes
	Respect and Teamwork	**People and Partners** (Respect, Challenges, and Grow Them)	**Principle 9.** Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others **Principle 10.** Develop exceptional people and teams who follow your company's philosophy **Principle 11.** Respect your extended network of partners and suppliers by challenging them and helping them improve
	Genchi Genbutsu	**Problem Solving** (Continuous Improvement and Learning)	**Principle 12.** Go and see for yourself to thoroughly understand the situation (genchi genbutsu) **Principle 13.** Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (nemawashi) **Principle 14.** Become a learning organization through relentless reflection (hansei) and continuous improvement (kaizen)

3.1 Wastes

The need for process improvement cannot be overemphasized. According to Koskela (2000), the West has neglected process improvement and embraced operations management through scheduling. He argues this point be citing Shingo (1988) who claims that in a transformation

model of production, there are activities that are transformation activities and those that are not. These non-transformation activities are unnecessary from the point of vies of the transformation and therefore, the less of them the better. Gilbreths (1922; cited by Koskela, 2000) categorised these non-transformation activities as **transfer, delay** and **inspection activities**.

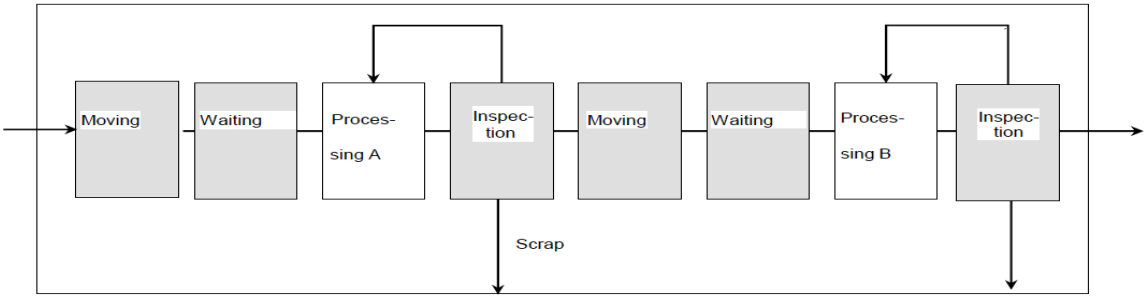

Figure 1: Production as a flow process: Shaded portion – non-value-added activities (Koskela, 2000)

Both transformation (value-adding) and non-transformation (non-value-adding) activities are embedded within the lead time of the product. In other words, the time needed to produce an item is shared by both activities. Koskela (2000) claims that in order to improve the production time, the unnecessary (non-value-adding) activities has to be eliminated or reduced as the share of the unnecessary time is generally dominant.

The 14 Toyota principles (see Figure 1) focuses on **minimizing waste** in all forms, continuous improvement of processes and systems, and maintaining respect for all workers. **Waste** in this case, or **Muda**, as the Japanese call it, is specifically any activity which absorbs resources but creates no value in other words – non-value-adding activity (Womack and Jones, 2003). According to Liker (2004), there are eight types non-value-adding waste in **any business or manufacturing processes**. Seven of which he adopted from the Toyota Company and the last he added. They are:

1. ***Overproduction*.** Producing items for which there are no orders, which generates such wastes as overstaffing and storage and transportation costs because of excess inventory.

2. ***Waiting (time on hand).*** Workers merely serving to watch an automated machine or having to stand around waiting for the next processing step, tool, supply, part, etc., or just plain having no work because of stock outs, lot processing delays, equipment downtime, and capacity bottlenecks.
3. ***Unnecessary transport or conveyance.*** Carrying work in process (WIP) long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes.
4. ***Over processing or incorrect processing.*** Taking unneeded steps to process the parts. Inefficiently processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing higher-quality products than is necessary.
5. ***Excess inventory.*** Excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.
6. ***Unnecessary movement.*** Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. In addition, walking is waste.
7. ***Defects.*** Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling, time, and effort.
8. ***Unused employee creativity***. Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees.

The ultimate goal of lean manufacturing (construction) is to apply the ideal one-piece-flow to all project process, i.e. setting up **cell** comprising of people, machine, and accessories in a sequential order to execute works within the process. However, it is interesting to note that, in a process cell, there could be mini-cells at each work stage. The idea of one-piece-flow is to make one unit at a time at the rate of customer demand (Liker, 2004).

3.2 The Toyota House

Toyota summarises its production system using a house-like diagram called the 'TPS house'. This house is made up of four parts, the foundation, pillars, roof and centre.

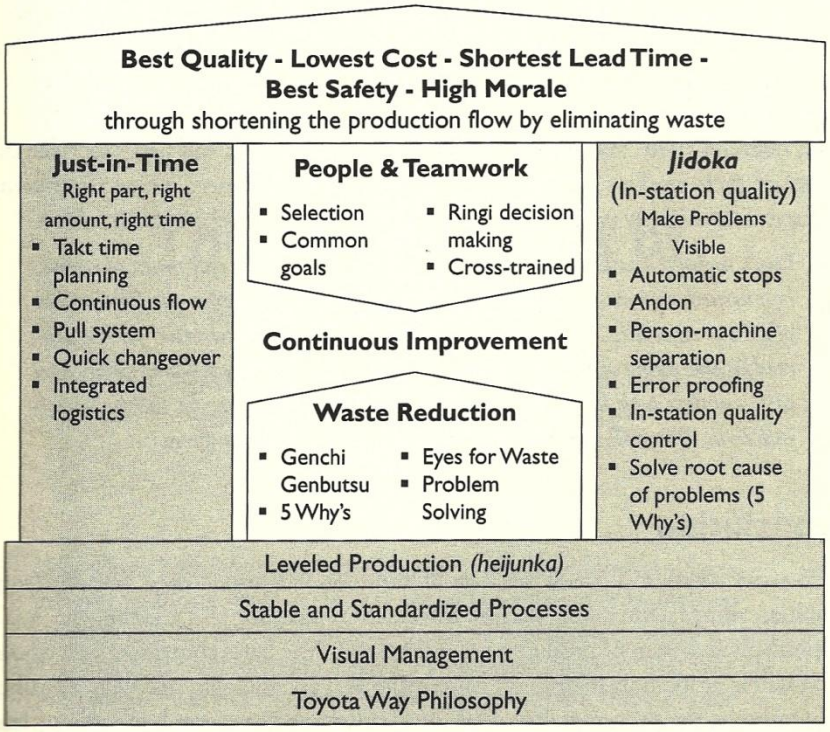

Figure 2: The Toyota House (Liker, 2004)

3.3 Foundations

3.3.1 Toyota Way Philosophy

Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals **(Principle 1).** A house built on a weak foundation awaits an impending dooms when faced by storms. In other words, a system based on weak principles or philosophies will crash when faced with problems. The principal mission of a company is to move to the next level where it always has a competitive advantage in the market it operates. Doing right for the company involves; doing right by employees, customers and society as a whole. According to Liker (2004), Toyota is never quick to fire its employees because of a downturn is company sales

but would rather apply the ***"hansei"*** which is a process of reflecting on problems and finding the way forward so that the mistake is not repeated again. ***Principle 14 –*** *Become a learning organization through relentless reflection (hansei) and continuous improvement (kaizen).* This instils a sense of belonging in the employees. They feel as part of the company – protected and secured. This keeps the company strong and ensures growth as one organism. ***Principle 9 –*** *Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others; and* ***Principle 10 –*** *Develop exceptional people and teams who follow your company's philosophy*

3.3.2 Visual Managament

'The accepted dysfunction of the day was to see no problems and hear no problems until the hidden problems jumped up and bit you in the face (Liker, 2004). Use visual control so no problems are hidden **(Principle 7)**. In order to do this, the Japanese advocate the use to their "5S programmes" that comprise a series of activities for eliminating wastes that contribute to errors, defects, and injuries in the workplace. They are;

- **Sort** – Sort through items and keep only what is needed while disposing of what is not.
- **Straighten** (orderliness) – A place for everything and everything in its place.
- **Shine** (cleanliness) – 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.
- **Standardize** (create rules) – Develop systems and procedures to maintain and monitor the first three Ss.
- **Sustain** (self-discipline) – Maintaining a stabilized workplace is an ongoing process of continuous improvement.

The five S's together create a cycle process for continuous improvement. Liker (2004) defined *visual control* as any communication device used in the work environment that tells us at a glance the standard being used to perform the task and whether it is deviating from the standard. The main essence is that the visual control system enhances flow. Examples of visual controls within the Toyota House are: *kanban* cards – used to signal the preceding step to produce more

items; the one-piece-flow cell; *andon* cord – used to signal a deviation from standards; and standardised work.

3.3.3 Stable and Standardized Processes

In everyday life, we find that some activities are not one-of. That is, we have to repeat this activity again and again within a process but producing different results. It is important that a standard be set for such a process so that the desired and consistent result is achieved whenever the activity is repeated. Standardized tasks are the foundation for continuous improvement (*kaizen)* and quality **(Principle 6)**. A Standard should not be seen as one-best way of doing a task but rather a step to stabilising the process and then improving on it. Henry Ford (1988) says it even more succinctly

"Today's standardization ... is the necessary foundation on which tomorrow's improvement will be based. If you think of standardization as the best you know today, but which is to be

The elimination of waste (*muda*) is the core objective of TPS. This can be done by using some of the tools explained above. Having an eye on waste will require going and seeing the process as it is done on the shop floor (*genchi genbutsu*) and then applying the four steps used by Toyota quality scientists explained above. Ask the 5 "WHYs", get to the root cause of problem and solve (Liker 2004).

3.3.4 Continuous Improvement

For a organisation to grow or have competitive advantage in its market, it needs to continually learn and improve. Most of the 14 principles mentioned above ensure continuous improvement. In order to continually improve you have to adopt **Principle 14** which states "*become a learning organization through relentless reflection (hansei) and continuous improvement (kaizen)"*. The right processes will produce the right result. This can be achieved only through standardisation, keeping an eye on the process to check for deviations, analyse problem (if they occur) and propose countermeasures to prevent them from happening again, empower employees and be receptive to new innovative ideas.

4 Installation of Doors Procedure in Alamai Northern Construction

Current practices of Alamai Northern Construction is dominated by contracts such that projects are broken down into work packages and contracted out to trades subcontractors who then execute/install the works separately. Alamai Northern has become complacent with its traditional practices as a result; they rarely consider alternatives for making the construction process more efficient. The project consists of two hospital blocks that covers 15,300m2. The buildings are 3storeys high with walls made of plasterboard. The client is Tameside County Council. The PFI contract with Alamai Northern Construction is supposed to last for 30 years. To construct this facility, Alamai Northern created a project team around the project who then prepared separate work packages and subcontracted them to trades contractors. Tameside County Council holds a PFI contract with Alamai Northern who in turn holds a contract with Pyramid Doors (to supply the doors and door frames including hinges and locks), Skanska Construction (floors subcontractor), and Bovis Ltd (walls subcontractor). Pyramid Doors is a doors manufacturer in Bamingham and have had a good working relationship in the past with Alamai Northern Construction.

As the work package for doors was prepared, the bid was won by Pyramid Doors who then will supply the doors and door frames. The Construction Manager passed the 'structural opening specification' to Pyramid Doors who then prepared for fabrication of doors. Upon the weekly schedule supplied by the Construction Manager, Pyramid prepared the delivery schedule which was then incorporated into the Master Schedule. The cross-functional team met and agreed to move on with the plan as scheduled. On the 18th month, the procurement department started preparing and giving order forms so that Pyramid Doors could start sending in batches of the doors, door frames, locks, hinges, and screws – the complete set. The doors were delivered in batches and stored on site under the supervision of the Site Manager.

In preparation, the joinery department installed sub-frames into walls while Bovis finished smooth with special grout. Doors were requested using the store requisition forms and were approved by the site manager and the procurement department. When approvals are given, the doors and door frames were moved together from storage to the desired point in the building. The door frame is put in place, then the door is fixed to the door frame and the floor level is

aligned. The Construction Manager and the Lead Section Manager for the given floor then inspect the doors and ascertain desired performance level. If approved, the doors are

Apply weekly JIT deliveries instead of maintaining high inventory levels of doors. JIT will free 25minutes of moving time, and 25minutes of returning time (see Figure 4). As the JIT deliveries are in little quantities, finding a temporary storage within the built structure will not be difficult. This will greatly reduce moving time by perhaps 100%.

Figure 6: Door Installation Process: Lean Thinking Way: Just-In-Time (JIT) concept

If all things remain equal, that is;

- 1hour lunch break
- 1hour contingency
- working hours per day

Productive time = (8 x 2) x 60mins = 6 x 60 = 360minutes

No. of doors to be installed/day = 360/90 = 4 doors/day

Therefore, when JIT is used 4doors could be installed/worker/day.

Daily Productivity = 4 x 10 = 40doors/day

Weekly Productivity = 40 x 5 = 200doors/week

Installation Duration = 830/200 = 4.15 approximately 4weeks

No. of JIT trips = 4 (208doors trip 1 & 2; then, 207doors trip 3 & 4)

Total Transportation Time = 18.5mins x 4weeks = 74mins (throughout the project)

A comparison between the current working process of Alamai Northern construction and the new Lean thinking Way is shown below.

Table 3: Comparison of Processes

Item	Current working process	Lean thinking process (JIT)
Productive time	310mins	360mins
No. of doors to be installed/day	3	4
Daily Productivity	30doors	40doors
Weekly Productivity	150doors	200doors
Installation Duration	6weeks	4weeks
No. of trips	4	4
Total Transportation Time	2hrs 30mins	1hr 14mins

It therefore means weekly productivity will be increased by 33% and Total installation duration will be reduced by 33% as well.

The increased productivity may be argued as overburdening the staff but it is not. Given that all things remained equal, lunch and contingency times – 2hours of non productive time is more than enough time for staffs to relax.

4.1 Push vs. Pull

Two counter intuitive truths exists within the TPS that state;

1. "Often it is best to build up an inventory of finished goods in order to level out the production schedule, rather than produce according to the actual fluctuation demand of customer order".

The TPS preaches operating under zero or minimum inventor to avoid overproduction and tying down capital where it could be used somewhere else. It supports and/or advocates production using the Pull system.

2. "It may not be a top priority to keep your workers busy making parts as fast as possible". You should produce parts at the rate of customer demand.

Hence, a need to decide which is best for the company processes at the point in time.

The Procurement Department should undertake market surveys to forecast the stability of market prices. This will help determine whether to purchase (push system) the doors early enough or wait until when needed on site before purchasing (pull system). As already been said, prices in the market are likely to go up. Therefore, Alamai construction should purchase the doors in advance at today's rate. This may require payment of a premium but as compared to the amount to be payed on a later date during construction, it is the better option. This generally will **save cost** in the end. Partner also with the supplier (Pyramid Doors) and agree that doors be stored with the suppliers until when needed on site.

4.2 Last Planner System (LPS)

As already discussed, the Lean Production delivery system supports a number of effective and efficient tools. One of the best tools in this practice is the Last Planner System (LPS) (Winch, 2006; cited in Ballard and Howell, 1998). The Last Planner refers to the person, individual or group that commits to near-term (often weekly) tasks. This is usually someone in the front lines such as a supervisor, foreman, team boss, section leaders etc (Koskela et al, 2002; Ballard and Howell 1994; cited in Ballard, 2000).The LPS is a tool used for buffering task execution by only allowing those quality assignments that are completely ready to be started. This is an important tool in managing cooperation and logistics during construction phases (Bertelsen and Koskela, 2004).

According to Ballard (2000), the LPS adds production control components to the traditional management system and can be understood as a mechanism for transforming what *Should* be

done into what *Can* be done, thus forming an inventory of ready work, from which *Weekly Work Plans* can be formed.

The Project Manager, Construction Manager, Site Manager and Pyramid Doors should hold a meeting and develop Weekly Work Plans through the use of the LPS. This action of weekly planning shows a commitment by the Last Planners to what they actually WILL do. The Last Planner System can be seen in Figure 5 below.

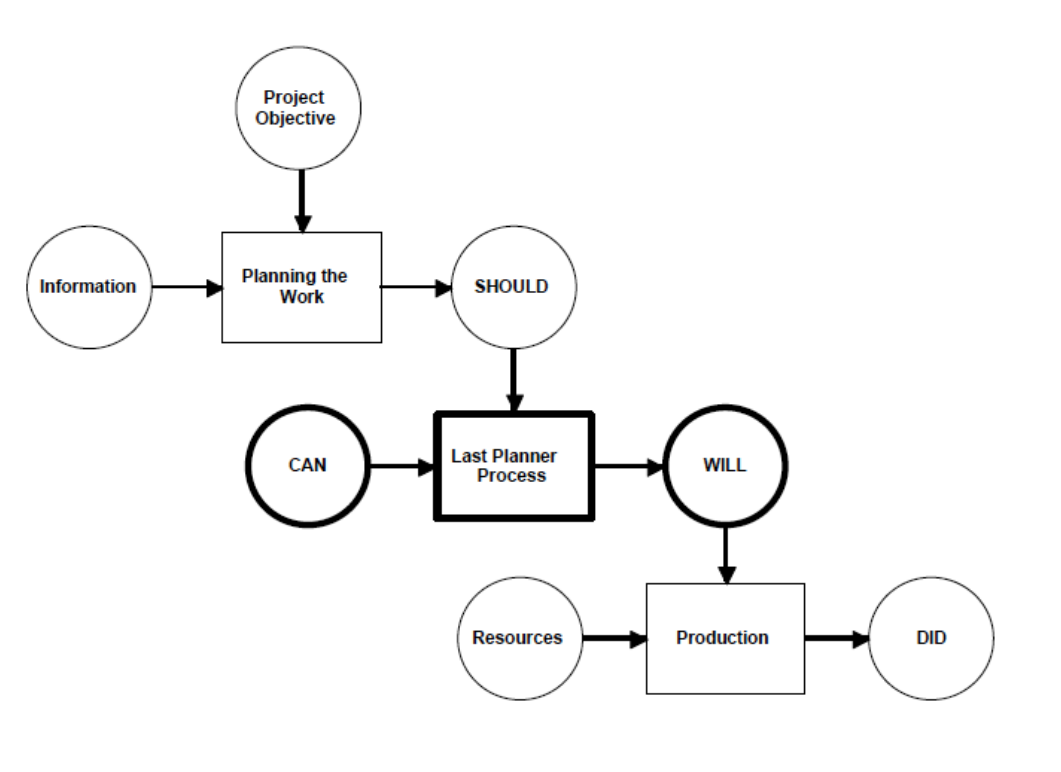

Figure 7: The Last Planner System (LPS) – (*source Ballard, 2000*)

Generally, companies who have applied the Last Planner System to planner their projects experienced a substantial level improvement in productivity and improved plan reliability to the 70%. Consequently, there is reason to hope for further improvement, possibly in all performance dimensions, especially with application across an entire project rather than limited to individual speciality firms (Ballard, 2000).

4.3 Benefits of Moving Towards a the Lean Way

- "A decision is only as good as its implementation". The company applied the cross functional decision making process which is very good. However the meeting did not include the Site Manager who can give input on site operations and accepting planned delivery.

- After the evaluation of progress of installation of doors, the decision could be to continue installation or to stop or suspend installation and correct/solve problem (if it exist) and then continue supply and installation. If the problem persists and can not be corrected, then this calls for a review of the contract. This is a form of ANDON.

- Develop master schedule through LPS

- When all major work packages that can cause damage to doors have been finished, then doors can be ordered from the subcontractor to deliver just in time in batches and according to floor section (ground, 1st and 2nd floors).

- Partner with subcontractor and encourage team relationship. This will in turn give value to the client.

- Eliminated risk of damage to doors during handling, moving and storage on site during the 4months interval between fixing frames and fixing back the doors. This gives better value for the client.

- Encourage RINGI decision making where most of the project team members meet and solve problems through consensus.

- Encouraged going to see for yourself as it's done on site (Genchi Genbutsu). Project Managers and Lead section Managers should move around the Hospital building to see how the joinery workers are installing the doors.

- Encouraged stopping or suspending or slowing down processes to correct mistakes/problems (kanban & Andon). At each completed floor level, the project team together with Pyramid Doors, the construction manger and the Lead section leader on that floor must meet and decide on the success of the installations on that floor before moving on to the next.

5 Implementation Plan

As was said earlier, Alamai Northern Construction has become complacent in its traditional way of doing things. Implementing Lean Construction concept requires the progressive application of a new way to design project-based production systems. Organisations are made up of strategy, structure, systems, people, style and culture. It is easy to change strategy, structures and systems but very difficult to change people and their own stereo-typed way of doing things – culture (Burnes, 1996). Changing long-held ways of thinking and acting is hard but the result is ultimately beneficial (Koskela et al, 2002).

5.1 Top-Down Commitment

A CEO once said, during an organisational change, managers should not make the mistake of focusing first on finding the right change management model but rather ensure that senior management is firm and passionately committed to the change. It's absolutely imperative that they recognise the need for major change and be the catalysts for making it happen. He observed that the best system or model in the world isn't going do any good to an organisation unless they have a top-down commitment to making it work (Carter et al. 2005 p.46). Alamai Northern need to be committed to change process in order to see success.

5.2 Change Management plan

Burnes (1996) argued that in order to cope with wide variety of types of change, there is a need for developing a corresponding change management plan. There are several change management models that Alamai Northern Construction can use to move towards Lean Construction. An example is that proposed by Kotter 1996 and the steps are as follows:

Establish a sense of Urgency

Form a powerful guiding coalition

Create a vision and strategy

Communicate the change vision

Empower others to act on the vision

Plan for and create short term wins

Consolidate gains and produce more change

Anchor new approaches in the culture

Another model for implementing Lean Construction is to follow the Toyota kaizen workshop (see figure 6). There are three ways to *kaizen* workshop; preparation, the actual workshop, and sustaining and continuous improvement after a workshop. It is one key tool to change in any organisation (Liker, 2004).

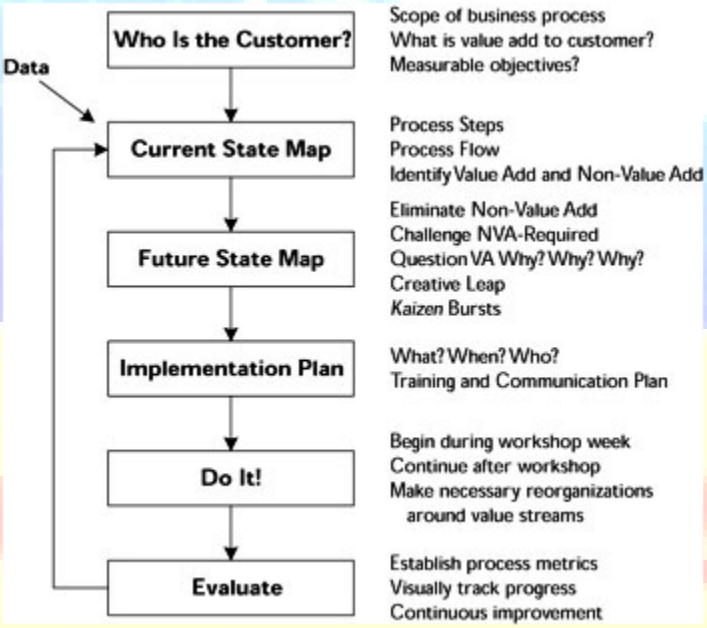

Figure 8: Kaizen workshop (source: Liker, 2004)

The first step for Alamai Northern Construction to implement this is to organise lean construction workshops and train people in the new process. Motivate them and create excitement for the new process. These training sessions could include some of the items listed by Liker (2004). They are:

- Re-layout of work areas to facilitate one-piece flow
- Workplace organization (5S and visual displays)
- Creation of standard work instructions
- Revision of corporate procedures
- Redesign forms and documents
- Problem-solving activities to uncover root causes of quality problems
- Specifications or even some changes for any information technology required to support the improved process
- Training people in the new process

In addition, Alamai Northern construction must not take too long to implement the concept. ***Principle 13.*** *Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (nemawash).* Too many long and repeated meetings which are not properly managed may lead to extension of the contract period.

6 Measuring performance

The only way to measure performance is if there is an existing benchmark. Alamai Northern should adopt the lean process map and establish it as the standard in the company. Upon this progress can be tracked and corrected. This tracking system could be in the form of a metrics like the analysis/comparison of the current processes table – Table 3. For example, the target everyday for the joinery department is to install 40doors/day instead of the usual 30doors/day. When this is not achieved, processes should be checked and corrected using the 5"Whys".

7 Continuous Improvement (*kaizen)*

In order to sustain the and drive the new adopted way of working continuously, the project team must continue to meet on a weekly basis to review the status of the open action items from the project plan, review process metrics to ensure improvements are being achieved, discuss additional opportunities for improvements, and continue to improve the process. Senior management should continue to use the metrics in Table 3 to continually monitor and improve.

8 Conclusions

Following the review of the current processes of installation of doors in Alamai Northern Construction on the PFI Hospital project, it was revealed within the process a couple of non-value activities such as; high level of doors inventory on site, long waiting times, damages to doors because of long transportation and long storage, too many unnecessary movements and approvals, under production, etc. These wastes have been cleaned out using the Lean construction principle and a new process map and implementation plan proposed. It's been proven that the adoption of the new process will bring a number of benefits to the company including an increase in the weekly productivity by 33% and a reduction of the Total installation duration by 33% as well. This means shortening Lead times and adding value to the client.

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