A Physical Demonstration of Lean Concepts

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Abstract

A key component of lean is the creation of flow of value to the customer. Many have difficulty in understanding the practical differences between push and flow. Physical simulations are effective tools for teaching advanced manufacturing concepts to people of all ages. This paper presents a physical simulation where participants operate workstations along the assembly line in a mythical aircraft plant. Through a series of four scenarios, participants encounter supplier problems, labor skill issues, deadlines, quality control problems and other real life situations. As a result of participating in the simulation, people learn about cellular manufacturing, pull systems, small - batch flow, work - in - progress as a manageable asset, inventory risks, cross - training, empowerment and many other concepts considered to be best practices in today's manufacturing environment.

Keywords
Lean, Pull, Push, Flow

1. Introduction

In the book, “The Machine that changed the world,” Womack, Jones, and Roos [1] originated the term lean. Lean is defined as the elimination of waste (the frequently used Japanese term for waste is muda). They popularized it even more with their follow up book, “Lean Thinking” [2]. Many of the techniques used in lean are of the same tool set that industrial engineers have used for years. Rother and Shook [3] list the key principles of lean as:

1. Define Value from the Perspective of the Customer - This is the most vital of all the principles as many enterprises skip this step and improve the stream or flow of an inferior product. Everything done in a lean project should focus on the customer and consider the customer’s viewpoint. This principle does not imply simple verification of the acceptability of the current product offerings; rather it takes an aggressive approach in identifying additional ways to provide value to the customer. This principle is considered throughout the on-going process of becoming lean.

2. Identify the Value Streams – A fundamental problem with most improvement projects is that they tend toward a suboptimal solution. That is, an improvement is made that improves a local area, but there is no impact to the overall enterprise. Hammer and Champy [4] stated that the key aspect concerning business process reengineering was the lack of focus on a process view. Martin [5] defined a value stream as, “… an end-to-end collection of activities that creates a result for a ‘customer,’ who may be the ultimate customer or an internal ‘end user’ of the value stream. The value stream has a clear goal: to satisfy (or, better, to delight the customer.” A current state map is created to understand the current environment. A future state map is the tool used to plan actions to eliminate waste in the current environment. Value stream maps consider the entire loop, the material flow to the customer as well as the information flow from the customer back to all points in the value chain [6], [3], [7].
3. Flow – One of the seven original wastes is excess inventory [8]. Inventory typically accrues during handoffs. Rummler and Brache [9] stated that the, "greatest opportunities for performance improvement lie in functional interfaces." As shown by the time line at the bottom of the map in figure 1, the major contributing factor to the lead time is the delays in the crossing of functional barriers. The key benefits to flow are reduced lead time and work-in-process (WIP) inventory [10].

4. Pull – Making product efficiently is not the goal. Pull is a technique of only producing what is required when it is required. The first waste that Shingo [8] listed is that of overproduction. Pull reduces the tendency to overproduce based on improving efficiencies.

5. Perfection – Kaizen is the Japanese term for continuous improvement. Once the future state map is completed and implemented, it becomes the current state map. Additional improvements are identified and a new future state map is created. Lean is the relentless elimination of muda. The continued pursuit of perfection is this relentless elimination of muda.

In order to more clearly understand the impact of flow, a physical simulation has been created and the next section describes the scenarios used.

2. Simulation Scenarios
This presentation uses a physical simulation that has been an effective tool for teaching advanced manufacturing concepts to people of all ages. The simulation is a hands-on activity where participants operate workstations along the assembly line in a mythical aircraft plant. Through a series of four scenarios, participants encounter supplier problems, labor skill issues, deadlines, quality control problems and other real life situations. As a result of participating in the simulation, people learn about cellular manufacturing, pull systems, small-batch flow, work-in-progress as a manageable asset, inventory risks, cross-training, empowerment and many other concepts considered to be best practices in today's manufacturing environment.

The simulation was developed to demonstrate concepts that today would be considered an integral part of "lean manufacturing" to a company that refurbishes parts for aircraft engines. Concepts demonstrated included just-in-time, cellular manufacturing, pull systems of inventory control, teams, empowerment and standardization. The simulation is an effective tool in showing in a very simple way how to transform a company. It is a hands-on activity that produced numerical results in a very short period of time. The experience had a profound impact.

The simulation presents a mythical aircraft manufacturer. Participants assemble toy size airplanes from small plastic interlocking blocks. The goal of the participants is to build as many airplanes as possible within their six-minute working day. The factory consists of five workstations: four assembly workstations and one inspection workstation. The simulation consists of four different phases. During these phases, the simulation is changed to illustrate new concepts. Participants will experience supplier problems, deadlines, quality control issues, and other real life situations.

The simulation begins with the instructor describing a scenario of a company in turmoil. This mythical aircraft manufacturer has a high rate of late deliveries, a large number of customer complaints about quality, and a decreasing profit margin. The state of despair this company faces depends on the concepts the instructor wants to emphasize, but the central theme is to describe a company is grave trouble. Once the state of the company is known, the instructor then describes operational policies of the company. Participants are told not to communicate with their peers, not to break the chain of command with work related issues, not to work as a team and other rules that describe a traditional command and control work environment. These instructions are given to emphasize the importance of teamwork and communication later in the simulation.

With these instructions in mind, participants are ready to start the first phase on the simulation. The instructor specifies the rules in which the planes will be assembled. These rules reflect those commonly found in facilities that have a functional layout, a strict material control department, a traditional batch production flow, a central quality control function, and a workforce that does not work as a team. Participants are separated into five workstations that are spread across the room to simulate the long travel distances commonly found in functional layouts. Airplanes are assembled in batches of five. A value stream map of phase I is shown in figure 1. As participants deplete their raw material supply, they must travel a long distance to the raw material warehouse to emphasize the importance of travel distance
in manufacturing. An inspector examines the airplanes after they have been produced. Participants are not allowed to improve quality or correct problems. With these rules in place, participants practice making airplanes for a few minutes to reduce the learning curve effect. After everyone knows how to assemble their portion of the airplane, Phase 1 begins. Participants build airplanes for a while and a material problem is discovered that requires stations 1 and 2 to remove all work-in-process, thus illustrating a problem with poor suppliers. At the conclusion of Phase I, the results are recorded.

![Figure 1. Phase I Value Stream Map](image)

It becomes apparent that the distance traveled is a major concern. So, phase II begins with several improvements. First, the separated workstations are brought close together in a logical sequence. Second, raw material is brought to the individual workstations. Third, the quality control inspector can now announce where problems occur to the participants. Another six minutes of assembly follows with similar supplier problems. Results are recorded.

The results are still not pleasing. So, phase III introduces more improvements. Batches are reduced from 5 to 1 and inventory is moved in a continuous flow environment. Six minutes of production follows and results are recorded.

It now becomes apparent that workstation 2 is the bottleneck with workstation 4 also causing problems which should have been noticed on the current state map shown in figure 1. Therefore, phase IV introduces the concepts of teamwork and balances the line by leveling the workload. Figure 2 shows the value stream map for this phase.

At the conclusion of the fourth phase, the participants discuss the results they produced and how the changes in each phase influenced those results. At this point, participants are amazed at the dramatic increase in production over the four phases. Most participants quickly see the benefit of arranging the workstations into a cellular layout and building airplanes in batches of one rather than five. The value of teamwork and making everyone responsible for quality are also evident from the reduction of rework and scrap. At this point, the facilitator can emphasize other concepts that are not as obvious, such as the importance of communicating with team members, cross-training, sharing responsibilities and empowerment. The flexibility of this simulation begins to show its’ value as the facilitator emphasizes points vital to his/her teaching purposes. The value stream maps graphically present a significant reduction in lead time of close to 33% (the six hour lead time has been reduced to two hours). This is achieved as a result of single piece flow. Table 1 presents the typical results for both phase I and phase IV.
The simulation is extremely flexible in the level of teaching desired. Those who already have a working knowledge of the concepts find that their understanding is deepened. Those with little understanding quickly have a working knowledge of these concepts. The simulation would be an asset to the industrial engineering conference in providing a hands-on demonstration of several lean principles.

Figure 2. Phase IV Value Stream Map

Table 1. Phase I and Phase IV average results

<table>
<thead>
<tr>
<th></th>
<th>Number of good planes</th>
<th>Time at which a good plane is produced</th>
<th>Number of rework</th>
<th>Scrap</th>
<th>Work In Progress (WIP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>1</td>
<td>5.45</td>
<td>5</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Phase 4</td>
<td>23</td>
<td>0.55</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

3. Conclusion
Lean is a popular strategy to improve the enterprise. A critical component of lean is the creation of value that flows to the customer. Similar to other improvement methods over the years like MRP, JIT, TQM and others, a “one sized lean does not fit all.” Issues such as urban congestion, overseas suppliers, high product mix with low production volumes, company culture, and ensuring lasting change make a complete implementation of lean difficult in many enterprises [11][12][13], however the concept that flow is a goal to be achieved throughout the company is always appropriate. Rother and Shook [3] in their lean improvement steps have flow as the primary method for eliminating waste, but suggest measures when flow is not possible. It is clear that every enterprise is not able to completely switch to flow, but many enterprises that previously operated totally in a job-shop environment have found families of products or processes that can use flow in a ‘focused factory environment.'
Biographical Sketch

Larry Whitman is an Assistant Professor in the Industrial and Manufacturing Engineering department at Wichita State University. Dr. Whitman is the faculty advisor of the Wichita student APICS chapter. He also has over 12 years experience in the aerospace industry. He has led process modeling projects for various aerospace enterprises and developed multiple database-enabled web sites. He has taught lean classes to local industry. His research interests are in enterprise engineering, supply chain management, web-based simulation, and lean manufacturing.

Ryan Underdown is an Assistant Professor in the Industrial Engineering department at Lamar University in Beaumont, Texas. His research interests include Enterprise Engineering and process improvement issues of small businesses. Dr. Underdown is the faculty advisor of the Institute of Industrial Engineers (IIE) student chapter at Lamar. Professional affiliations include IIE and the Decision Sciences Institute. For six years prior to this assignment, he assisted small manufacturers in the Dallas/Fort Worth area to develop a competitive advantage through Enterprise Excellence, a comprehensive assistance program for small manufacturers funded in part by the Small Business Administration and the State of Texas. The Enterprise Excellence program, housed at the University of Texas at Arlington, provides assistance including strategic planning, cultural assessment and change, team development, process improvement and problem solving. In this role he has facilitated improvements with senior leadership and shop floor operators.

Michael Deese is the President/Owner of Santech Industries in Fort Worth, Texas. Other duties include Chairman of Institute Advisory Counsel of the Automation & Robotics Research Institute and Chairman of Texas Manufacturing Institute. Michael started with Santech as evening and weekend help at its founding (1971). He was warehouse manager from 1972 to 1974, and worked in sales and purchasing from 1978 to 1987 covering accounts in Military, Aerospace, Automotive Air Conditioning, Semiconductor, and Oilfield. In June of 1978 he became Vice President, and assisted in managing Santech until 1982 when he officially became General Manager. He computerized accounting in 1982, computerized inventory in 1983, and continued sales and purchasing duties until 1987 by which time all product areas had been delegated to sales managers. In 1987, he revamped the Quality Assurance System in order to expand customer base. Continued responsibilities include financial planning and negotiation, new product approval, sales assistance in new customer development, day-to-day decisions regarding company operations, accounting systems, and all computer information systems. Under his management, sales have grown from 1,300,000 to 6,600,000.

References:


