AC 2007-2822: LAMPSHADE GAME FOR TEACHING LEAN MANUFACTURING

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Lampshade Game for Teaching Lean Manufacturing

Abstract

Implementing lean manufacturing concepts is essential for companies in the manufacturing and service industries to survive in the very competitive global marketplace. A key point is to eliminate waste while delivering value to the customers. Thus, graduates from engineering programs such as manufacturing, industrial and systems engineering and engineering management must be able to focus and apply lean principles as they transition to the industry.

The purpose of this paper is to present a new game named the "Lampshade Game" that can be beneficial for teaching lean manufacturing concepts to both undergraduate and graduate students. The Lampshade Game demonstrates the advantages and disadvantages of some of the key lean manufacturing principles (such as customer focus, quality focus, JIT, flexible manufacturing, setup and rework reduction) in comparison to craft and mass manufacturing by manually simulating the production of lampshades for each of the process types. The students form teams, and ideally each team should have a chance to manufacture lampshades using all three forms of manufacturing. The manufacturing performance is gauged and compared by different key performance indicators including inventory levels, total manufacturing cycle time, customer fill rate, and production yield. This paper will describe the game, its objectives and share experiences from a classroom implementation.

1. Introduction and Literature Review

Engineering graduates have to be educated in different production principles in order to be competitive as they transition to the industry. As Wang-Chavez et al.[10] highlights it, nowadays it is necessary to create "ready to execute" graduates from engineering programs. Production principles and strategies like "lean" can be taught using some of the traditional approaches such as industry projects, case studies, company visits or class projects. But it is possible to make the learning process even more efficient: using games. Many useful and interesting games exist in

the area of industrial engineering, manufacturing or supply chain management, highlighting and focusing on different concepts and principles. Games and simulation exercises can be a very important part of the curriculum as they are not only fun and interesting but also provide simulated hands-on experience in a subject area. Instead of reading about concepts, or watching them as an outsider, students can be part of the process, figure out how to manage processes and experience for themselves how things work in real life. This is also beneficial if there are students in the classroom whose learning styles are different from visual. So it should not be surprising at all that these games and simulation exercises have been very popular in recent years as an effective teaching approach.

Examples of lean manufacturing simulation exercises include the work of Stier et al.[8], who explain how simulation can help learning lean concepts, and how they are applied through project work. They also describe a Lean Manufacturing Workshop to help small to medium-sized manufacturers introduce lean manufacturing practices in their production facilities. Johnson et al.[5] describe lean laboratory exercises that combine two methods of discovery-based learning: learning by exploring and simulation-based learning, based on a physical simulation of a clock assembly. Other games available to highlight important points in lean manufacturing include: airplane manufacturing exercises (Billington[1]), the Lean Leap Logistics game (Holweg and Bicheno[4]), classroom simulations (Prusak[7], Verma[9], or production projects simulating an assembly production environment (Blust and Bates[2]).

Simulations can significantly increase students knowledge on lean, as Verma et al.[9] proves it using pre- and post-simulation surveys. A common important point for these games is, as Chaneski[3] emphasizes when describing a small manufacturing exercise with paper cuts, that they have to be simple. In the current paper, another simple yet useful game is described to illustrate three different manufacturing principles: craft, mass and lean production.

The rest of the paper is organized as follows: in the next section a brief description on craft, mass and lean production is provided. Description of the Lampshade Game is provided next, which is followed by the discussion of classroom implementation experiences and challenges, and final conclusions.

2. Craft vs. Mass vs. Lean

The method to produce goods before industrialization was craft production. This was a simple way to transform raw materials into goods in a job shop where a person had to have multiple skills to fulfill custom orders, and the objective is to produce a very high quality product. The production is triggered by customer demand (pull), and high flexibility and high variability can be achieved because the parts and materials used are non-standardized. This production method operates on a small economical scale producing low volume of the items with quality of the final product varying between low and high depending on the skill level of the worker. Very skilled workforce is required which usually tends to have high workforce morale. Since one person does all the phases in the production, it is a satisfying job, not that boring and monotone.

The next level in the evolution of production is mass production. Mass production operates on a big economical scale, and high volume of the products is achieved using moving assembly lines. Consequently, the flexibility and the variety of the products are low. Since perfection is not required, good performance is acceptable. Production is triggered by the demand forecast (push), and the quality of the final product is medium to high. The parts and materials are standardized and possibly interchangeable and the output is standardized as well, while the tools are specialized and require high setup times. The workforce does not need to be highly skilled or cross-trained, and employee morale can be low as it is a monotone, boring work.

In comparison, the objective of lean production is achieving perfection through continuous improvement. Production is triggered by customer demand (pull) and moderate to high flexibility and variety can be achieved. While the word “lean production” was first used by Krafcik[6], it was the works of Womack et al.[12] and Womack and Jones[11] that popularized it. There are many slightly different definitions of what lean production is but a general way to define it is “Lean is doing more with less.” Thus lean production aims to eliminate all the “non-value-adding” activities (waste, or “muda”) in companies to fulfill customers’ needs while being profitable. Since the more traditional craft production seems to be limited in terms of speed, and mass production techniques are limited in terms of variety, the next natural step in the evolution of

manufacturing is lean production, which is capable of dealing with these demanding customer needs, combining the strengths of "craft" production that provides variety, and "mass" production, which provides economies of scale. Today, lean production strategies are a must-do to survive in the global economy, thus including "lean" courses in the curriculum is essential.

3. The Lampshade Game

The Lampshade Game is a simple yet powerful game that is easily available for the classroom use for interactive learning, possibly for both graduate and undergraduate students in areas such as industrial and systems engineering, engineering management and operations management programs. The purpose of the Lamp Shade Game is to demonstrate the advantages and disadvantages of the main lean manufacturing principles in comparison to craft and mass manufacturing, while simulating the three different manufacturing processes by producing lampshades according to a random demand. The main learning objective of the game is to contrast craft, mass and lean manufacturing based on various dimensions such as quality focus, production layout, skill level of the operator(s), setup times and flexibility of the system, product variety, production volume, production strategy (push vs. pull, built-to-order vs. built-to-stock), production trigger, production sales price, supply delivery (frequency and batch size), job satisfaction of operators, visuals used for communication, and division of labor. A way to measure the efficiency of the game in teaching the different manufacturing principles, a survey to test pre-game knowledge and post-game knowledge can be administered before and after the game.

Simple supplies such as paper cups, scissors, hole puncher and colored crayons are used as raw material and tools for production. Data recording sheets are also provided to track orders, order times, number of scraps, cycle time, inventory, scrap, material and labor costs.

During each production round, each team member plays a very specific role according to the manufacturing rules for each round. The manufacturing teams have to produce different lampshades from paper cups by first cutting the bottoms of the cups, then punching holes and

drawing different shapes on it by pencil, and finally, coloring the pre-drawn shapes, according to the specifications as the orders come in.

The ordering process is as follows: for craft, the customer draws any design in any color (that the operator has a corresponding colored crayon). The number of products to be manufactured by craft is determined by a roll of a die. For lean and mass, the orders are the same, and placed randomly by rolling a die twice: the first roll is the type of product to be produced (can be chosen from 3 different designs as shown in Figure 1, i.e. rolling 1 and 4 corresponds to Product 1, rolling 2 and 5 corresponds to Product 2 and rolling 3 and 6 corresponds to Product 3), and the second roll of the die represents the amount of the product to be produced (maximum 6). A "downtime" is also scheduled every 5 minutes for either one of the operators or one of the machines, when production is supposed to be stopped for 1 minute. This simulates real life events such as machine maintenance, or operator sickness.

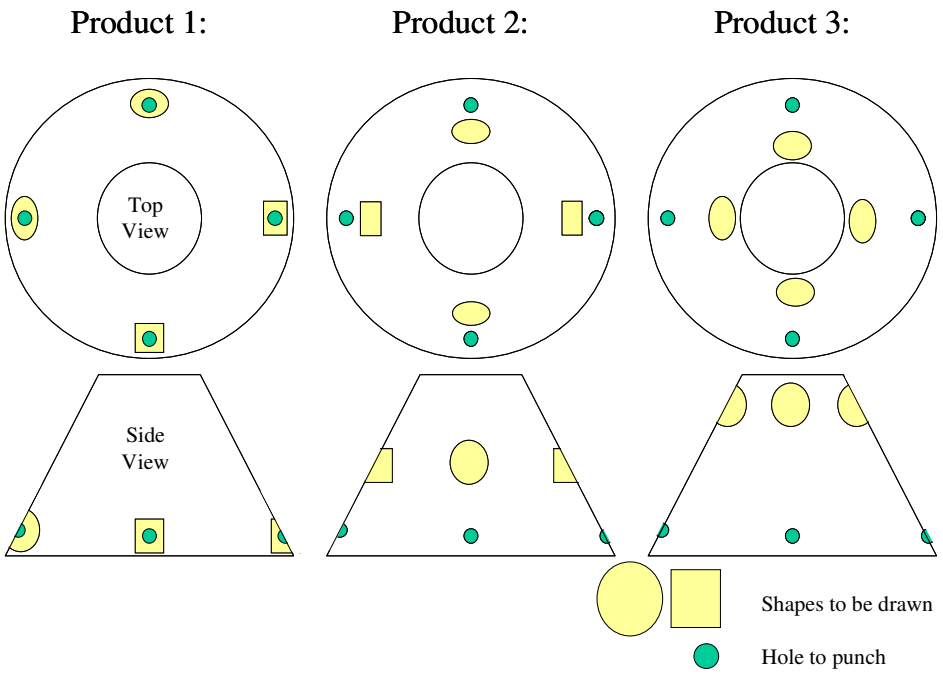

Figure 1: Product designs for mass and lean production

The objective of the game is to make the most profit within the same time by filling the orders, where profit is measured as the difference between revenue and cost. Also, at the setup of each production round, it has to be made sure that the raw material (the cups) has some defective built in to demonstrate the role of quality control and waste (e.g. lampshades are broken, the paper shapes are already with holes, etc.). One "warm-up" round, and a minimum of filling 5 orders is suggested while timing the minutes it takes to fill these orders.

Craft production is the simplest form of production. As described earlier, the customer can order any kind of design he/she wants (in terms of shapes drawn, colors and holes punched), and a die is rolled to determine the order quantity for that design. The supplier delivers raw material when needed in small batches. Then the operator starts producing and delivers whenever he is done. There is only a single operator who operates this job shop doing all the tasks by hand. The tasks are accomplished in the following order: inspection (free replacement of defective cups from the supplier), cut top of cup, draw shapes according to the customer's design by hand, punch holes according to the design, and color the pre-drawn shapes. This production method is supposed to demonstrate such key concepts in craft manufacturing as inspection at raw material, job shop layout, highly-skilled operator, high product variety (any type of product), low production volume, built-to-order (pull) system, high product sales price and high job satisfaction.

Mass manufacturing principles are illustrated by a linear assembly line layout, where every task requires a different operator (5 operators are needed). The supplier delivers raw material in large batches and no free replacement of defective raw material is possible, since inspection only happens at the end of the assembly line. To demonstrate inflexibility of high setup times between products, a template of cardboard shapes hanging on threads is used for drawing the different shapes according to the three pre-defined designs, and switching between products is possible only by retying the threads in different positions (this simulating high setup time between products). Since the assembly line produces only one product at a time, at the beginning of the mass round, a product number and color needs to be chosen as "forecast" of what product will be in demand. After the production completion, orders are fulfilled as they come in randomly by using a die rolled twice: first is the product number, second is the amount to be produced from that product (same order as for lean). The following manufacturing principles are demonstrated

in the mass round: inspection at the end of the process, linear assembly line, single-skilled operators, high setups (template for shapes needed to be setup for each product), low product variability, high production volume, Build To Stock (push) system, low product sales price, low job satisfaction.

Lean production layout is illustrated in Figure 2. The orders are the same as for mass production for comparison purposes. Production only starts when an actual order is placed, and products are delivered as soon as possible. The operators are cross trained and they use colored cards and kanbans for communication. Standard work and shadow boards help organize the place. During the lean round, the following lean manufacturing principles are illustrated: quality inspection at raw material, U-shaped cell, multi-skilled (cross-trained) operators, low setups (template for shapes in an flexible way), product variety is intermediate (3 product design but in many colors, built-to-order (pull) system, moderate sales price, delivery of raw material is as frequent as needed in small lots, job satisfaction is high, visuals (colored cards for downtime and kanban bins) are used for communication.

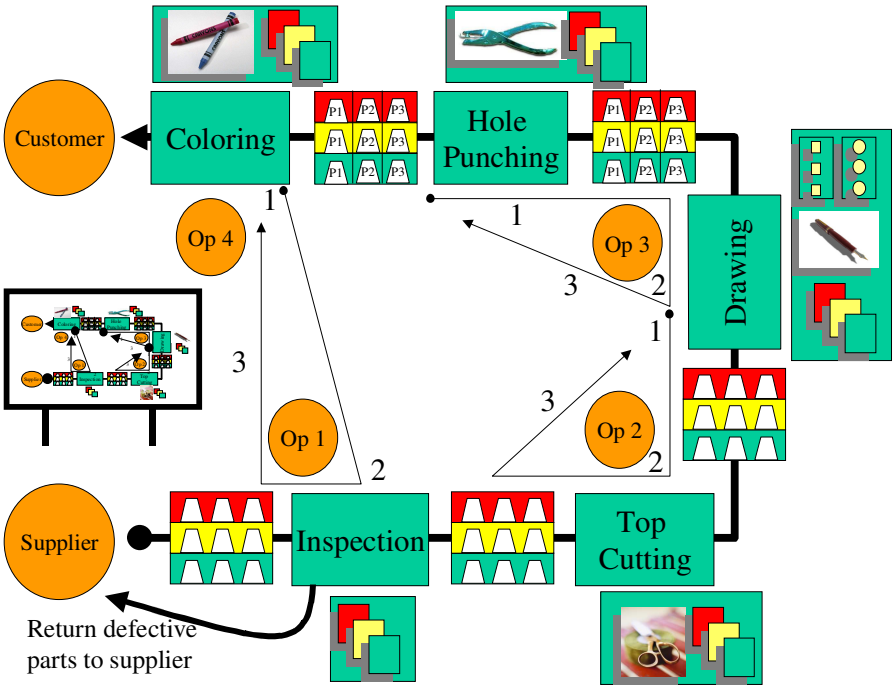

Figure 2: Production layout for lean manufacturing

The process flows described above are supposed to be simple enough to make it a game that can be learned and understood in a short time period, yet they demonstrate very important principles for the different ways of manufacturing. The following section shows the authors' classroom experiences based on two different classes.

4. Classroom Experience

One of the flexibilities of the game is the number of students participating in the game. The same benefits of hands-on learning can be achieved in both a smaller class and a larger class as well. The students play the role of operator(s), customer, supplier, data recorder, down-timer and observers. Depending on the manufacturing system the number of operators varies: 1 for craft, 5 for mass and 4 for lean. The other roles (customer, supplier, data recorder and down-timer) can be performed by using at least 1 student. When there are enough students, each student can play a single role in the manufacturing part, and the remaining students in the class are observers filling an observation form to deduct conclusions about the three manufacturing principles based on the game. In summary, the recommended minimum number of people for playing the game is 6 and the ideal number is 9 when each role is assigned to an individual player. When the number of students is not sufficient, the instructor may help out to play the role of supplier, "down-timer", and customer, and some of the consequent manufacturing stages in mass production can be assigned to 1 operator (e.g. inspection can be done by the coloring operator) which makes the game possible to play with 4 students with instructor participation.

The game takes about two hours to play from explaining the rules to playing and drawing brief conclusions at the end. Depending on the instructor participation, the required time may go up since the instructor needs to also coordinate the game and related discussions. On the other hand, the time allocated for the game could be probably reduced slightly by reducing the number of orders to be filled by each manufacturing method, however, it should definitely not be less than 3 orders per manufacturing method, in order to see the differences between the methods.

The Lampshade Game was implemented in both an undergraduate (Production Control Systems) and a graduate (Lean Supply Networks) course. To measure the efficiency of the game in teaching the different manufacturing principles, a survey was conducted to test pre-game knowledge and post-game knowledge. In general, the game seemed to be a success in both classes. Test scores significantly increased as a result of the game: from 48% to 63.3% success rate in the undergraduate class and from 32.5% to 70% in the graduate class. The pool of all surveys together shows an overall pre-game average of 42%, which significantly increased to 66% after the game. Positive student comments during and after the game also demonstrated that the game showed the differences between the manufacturing principles very well.

In practice, there were also some challenges: the game requires preparation before class, since the mass and lean systems have to have certain number of work-in-progress (WIP) lampshades in the system. If this is not prepared in advance, it could take valuable time from the actual game to set up everything. Also, when the number of students is 4-5 in the classroom, it is challenging for the instructor to take over multiple roles as supplier, customer, down-timer and game master.

In the post survey, there were also questions about the students' opinion of the Lampshade game. In the undergraduate class, it received an average score of 4.05/5, and in the graduate class this score is 4.96/5. This clearly shows that the Lampshade game was well-received among both undergraduate and graduate students.

5. Conclusions

A simple yet powerful game, the Lampshade Game was presented here to illustrate the differences of three different manufacturing methods: craft, mass and lean. The process is simple, yet seems to simulate main learning objectives well. Experience in testing the game in two different classroom settings (undergraduate and graduate) shows that the Lampshade Game was well-received among both undergraduate and graduate students, which proves it can be a useful tool for teaching manufacturing in a hands-on, interactive way. The teams have to learn to interact with each other, and work together as a team, just like in real life. Other advantages include flexibility in both the time allotted for the game, and the number of people can play.

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