Simulation of Lean Assembly Line for High Volume Manufacturing

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ABSTRACT

Lean manufacturing is a systematic approach to identifying and eliminating waste (all non-value-added activities) through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection (NIST/MEP 1998). Global competition is forcing companies to improve quality, reduce delivery time and at the same time lower cost. The essence of lean is to compress time from the receipt of an order through receipt of payment. The results of compressing time are greater productivity, shorter delivery times, lower costs, improved quality and increased customer satisfaction. The objective of this paper is to provide background on lean manufacturing, present an overview of the seven manufacturing wastes and introduce tools and techniques used to develop a simulation to transform a company into a high-performing lean enterprise. An application of lean principles applied to a high volume manufacturing facility will be presented.

LEAN MANUFACTURING

Lean manufacturing has been defined as a systematic approach to identifying and eliminating waste (non-value-added activities) through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection. The essence of lean manufacturing is to compress time from receipt of an order through receipt of payment. Compressing time yields greater productivity, shorter delivery times, lower costs, improved quality, and increased customer satisfaction.

The origins of lean manufacturing are found in the Ford manufacturing system. In the early 1900's, Henry Ford introduced a new manufacturing system - mass production. Ford's philosophy was to build a small, strong and simple car at the lowest cost. The key elements of the Ford system were conveyors, division of labor, and an integrated supply chain (Imai, 1986). The conveyors moved cars through the assembly process with work coming to the worker rather than the worker going to the work. Through division of labor the assembly process was organized into simple, repetitive tasks. In this process each worker performed a single task. Prior to division of labor each worker had assembled an entire unit. The integrated supply chain provided parts and materials to the assembly line. Ford reduced deviation in parts, thus assuring that parts would fit together properly.

The Toyota production system evolved from the Ford manufacturing system. Managers and employees learned to question the need for every work sequence, every piece of in-process inventory, and every second that people, material and machines are idle. As a result, not only did production increase, but also quality increased when people learned to identify and eliminate waste (Ohno, 1988 and Monden, 1993).

Lean manufacturing has evolved from the Toyota production system. Lean manufacturing is a way of thinking; a culture where all employees continuously look for ways to improve the process with the philosophy of eliminating all non-value added activities.

SEVEN WASTES

The key to lean manufacturing is to compress time by eliminating waste and thus continually improving the process. Ohno defines waste as all elements of production that only increase cost without adding value the customer is willing to purchase.

The seven wastes of manufacturing are:
- Overproduction - producing more product than needed;
- Inventory - any supply in excess of required to produce product;
- Waiting - idle operator or machine time;
- Motion - movement of people or machines which does not add value;
- Transportation - any material movement that does not directly support value added operations;
- Defects - making defective parts; and
- Extra Processing - any process that does not add value to product.

LEAN MANUFACTURING TOOLS

The tools of lean manufacturing are provided in Figure 1. The foundation of lean manufacturing includes the following tools:

Standardized Work. Operations are organized in the safest, best-known sequence using the most effective combination of resources. Jobs are broken down into elements and examined to determine best and safest method for each. The standard is then established, taught, and sustained by attention and repetition. Finally the standard can be improved when better methods are found.

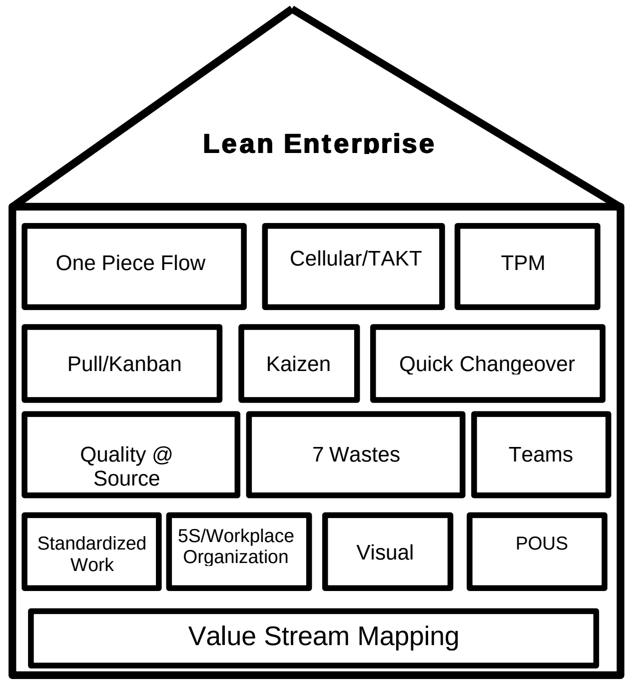

Figure 1: Lean Enterprise

- 5 S/Workplace Organization. Various housekeeping activities are often used first in adopting the continuous improvement way of life. Organization activities are:

Sort out what is unneeded;
Set-In-Order what must be kept;
Shine everything that remains and establish a cleaning schedule;
Standardize the system throughout the facility and provide employees with training
Sustain the effort with self-discipline and resources and time to improve their work areas.

Visual Factory. Information is made available and understandable at a glance for each operator to see and to use in achieving continuous improvements (Grief, 1991).

Point-of-use-storage (POUS). Locate all parts, raw materials, tools, and fixtures as close as possible to where they are being used.

Quality at the Source. Typical quality tools used are flow charts, frequency histograms, Pareto diagrams, cause and effect diagrams, control charts, 5 whys and poka yoke (error proofing) devices.

Teams. Process improvement teams are trained and responsible for detecting waste. Departmental barriers are eliminated and replaced with cross-functional teams that study a process and then immediately implement improvements.

Kanban. A kanban system is an information system that controls (pulls) the required parts in the required quantities at the required time (Schonberger, 1982).

Kaizen. Kaizen is a Japanese word for continuous improvement. Kaizen is the process of identifying and eliminating waste as quickly as possible at the lowest possible cost. Kaizen requires continuous, gradual, persistent improvement by all employees and management. Kaizen Blitzes utilize cross-functional teams, focused scopes, and aggressive goals to make rapid changes to processes.

Quick Changeover/Single Minute Exchange of Dies (SMED). SMED is a system that allows the mixing of production without slowing output or creating higher costs from waste of setup. (Shingo, 1983).

One Piece Flow. To minimize work-in-process, operators should focus on completing one part through the process before starting on the next part (Sekine, 1990).

Cells. Proper placement of machines is essential. Benefits of good cell layout are reduced inventory, balanced work, less walking time and an improved work area. Cells include work balancing, which maximizes operator efficiency by matching work content to TAKT time. TAKT time is the rate at which the customer requires the product and is computed as:

$$\text{TAKT time} = \frac{\text{Available work time per day}}{\text{Customer demand}}$$

Total Productive Maintenance (TPM). TPM consists of a company wide equipment maintenance program that covers the entire equipment life cycle and requires participation by every employee (Nakajima, 1988).

Value Stream Mapping (VSM). VSM serves as a starting point to help management, engineers, suppliers and customers recognize waste and identify its causes. VSM is a method of visually mapping a product's production path, including materials and information flow, from dock-to-stock. It takes a holistic look at the activity required (both value added and non-value added) to move a product from raw material to the customer. Data is collected to provide the information needed to develop the current state and the eventual future state. Ideas for the future state will be identified as information is gathered on the current process.

The result of VSM is a future state, which can serve as the foundation for other lean improvement strategies. These ideas are brought to the team and discussed for possible inclusion in the future state. The future state becomes the vision of how the operation will perform when the identified improvements have been made.

The future state is created by designing the physical material flow first using a lean manufacturing philosophy and using the tools from the Lean Enterprise House that apply to this particular circumstance. After the material flow is complete, the information flow required to support the lean operation is designed. The future state then becomes the "road map" or "blue print" for the activities that must take place for the future state to become reality.

LEAN SIMULATION

Manufacturing factory floor simulations are invaluable tools in the implementation of lean manufacturing. Many manufacturers will not make a change to the process before a simulation is performed to determine the impact of the change. Simulation can be considered as inexpensive insurance against costly mistakes.

A high volume manufacture was evaluating several alternative layouts for their proposed assembly facility. After an initial review, two alternatives were selected upon which to apply their limited simulation resources. These alternatives are illustrated in Figures 1 and 2.

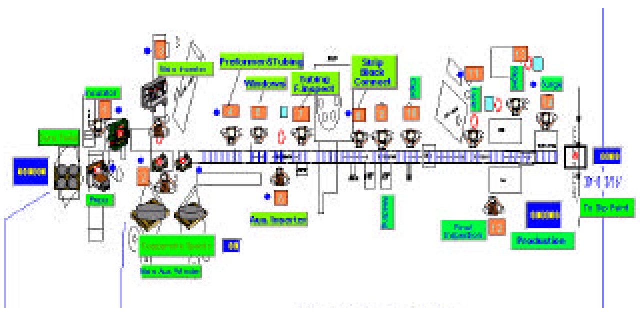

Figure 2: Alternative1 (traditional)

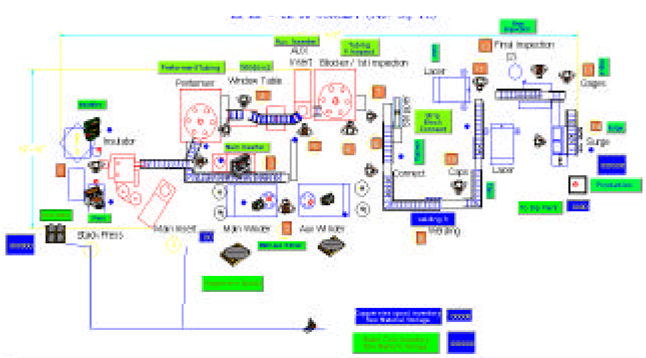

Figure 3: Alternative 2 (lean)

Alternative 1 was a more traditional layout, while Alternative 2 applied many lean principles. The lean alternative incorporated a kanban replenishment system, less work-in-process, compressed layout, visual management techniques standardized work and quicker changeover methods.

The two alternatives were compared on the metrics of throughput, work-in-process, square feet required and cost. The lean alternative showed an increase in throughput, lower work-in-process, less square feet required and a lower total cost.

CONCLUSIONS

Simulation can be used to support and evaluate lean manufacturing techniques and the value stream mapping process. Several of the obvious steps where simulation can support these process are:

- Current state assessment - One of the most obvious ways to use simulation in value stream mapping is as an assistant to the lean manufacturing champion in identifying problems in the manufacturing process. Several typical simulation metrics for identifying problems are large amounts of inventory, low machine and operator utilization, excessive waiting, machine breakdowns, defects, and long transportation distances or time. Armed with these problem areas, the champion can then prioritize the problems and select those with the greatest payoffs. As a result, the champion can provide the value stream mapping team with a specific goal.

- Train the value stream mapping team - It is well known that simulation is a valuable training tool. A model may be developed to show the current and future state to the team.

- Evaluate the future state - Simulation to evaluate the impact of various opportunities for improvement. Ideally the team can use the previous developed simulation model to evaluate the alternatives.

- Document opportunities for improvement - The results of the simulation can be used by the team in documenting opportunities for improvement.

- Measure impact of improvements - Once a suggestion for improvement has been made, the simulation model can be modified to include the suggestions and then run to measure the impact. The use of computer simulation of production operations in continuous improvement efforts allows the team to evaluate the effects of proposed changes while the production of product to meet customer demand is still underway. The application of simulation enhances the ability of the team to make incremental (or drastic) changes and observe the effects without disrupting the manufacturing process and causing unnecessary down time and costs.

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Nicholas Loyd is a Research Associate at the University of Alabama in Huntsville. He has a BS in Industrial and Systems Engineering. He has been active in providing lean manufacturing assistance to area companies such as Delphi Automotive Systems, SCI Electronics, ABCO Office Furniture, Atlas Cylinders, Cerro Wire, and Prestolite, Inc. and in the areas of: cellular manufacturing design, determination of TAKT time, work balancing, work standardization, and changeover reduction. He is a NIST certified lean manufacturing trainer and is an agent of change

Hank Czarnecki is on the staff of the UAH-ATN Center and has worked for the past four years performing lean training, facilitating Kaizen events and conducting other process improvement projects. He is a certified NIST Lean Manufacturing Trainer and has trained thousands of engineers, managers, and floor associates in lean manufacturing. He has conducted over seventy-five Kaizen events for manufacturers throughout the country. Mr. Czarnecki has BS in Industrial Engineering from the University of Pittsburgh, an MS in Industrial Engineering from Auburn University and is pursuing a PhD in Industrial Engineering at the University of Alabama in Huntsville. NIST has recognized Mr. Czarnecki as one of its most outstanding lean practitioners and he received the 2000 NIST/MEP National Practitioner of Year Award.