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A Case Study on Implementing Lean Manufacturing

Introduction

Japanese manufacturing techniques have become a popular topic in most American manufacturing companies and their international subsidiaries. One of such popular techniques is Lean Manufacturing (LM), which provides for manufacturing the necessary quantity of the necessary item at the necessary time. The companies that implement LM employ some highly integrated systems that result in reduced lead times, just-in-time management, decreased costs, levelled production, continuous flow production, increased job satisfaction for employees, higher productivity, lower inventories, and higher quality levels. In Japan, this system is used to reduce the time line that begins with a customer order and ends with the delivery of the finished product. Many American companies are learning that, indeed, the time line shrinks when LM is implemented and thus they are better able to respond to changes in the market, keeping their companies viable during rough times and maintaining profitability during times of good or average business environments (Toyota Motor Corporation, 1992).

LM is a viable method for making products because it is an effective tool for producing the ultimate goal, profit. To achieve this purpose, the primary goal of LM is cost reduction, or improvement of productivity. Costs

Abstract

This paper presents a case of study of an application of the lean manufacturing (LM) in an organization. The authors discuss the most important elements of LM, the strategies used by the company for implementing LM, and the significant benefits that were accrued in manufacturing operations and total inventory values. The data for this study was obtained through interviews, a questionnaire survey and internal documents.

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are defined very broadly to include not only manufacturing costs, but also sales, administrative and even capital costs.

LM can work well in any country. That is evident at numerous plants around the world where Toyota and other companies have implemented the system successfully. The key is to adapt the system to local circumstances and values. As LM evolves into a global system, improvements will focus on further reductions in lead times, cost reductions and improvement of information technology for monitoring and managing the sequence of activity that begins in the design for new products and continues through the receipt of payment (Toyota Motor Corporation, 1992).

The purpose of this paper is to briefly discuss some of the most important elements of LM and to illustrate how a midwest company in the US was successful in implementing LM. This paper is written based on the authors' experiences using the visual systems in a LM manufacturing environment.

Case Study

In this section the methodology utilized for this LM case study is presented. First, the research method is explained. Next, a brief description of the company, the implementation strategy and the results are presented. Finally, future research recommendations are given.

Research Method

A case study approach was employed to conduct the research. Data was collected primarily through interviews, observations, and archival sources. Interviews were conducted, in person, with executives who were familiar with the manufacturing process. These included the director of operations, quality control manager, Kaizen team manager, materials manager, and the plant's general manager. The interview time varied from 40 minutes to two hours. Unstructured interviews were also conducted with other management and non-management personnel during periods of observations on the manufacturing floor.

Observations were made on the shop floor during 1994 and 1995 regarding the progress of implementation and tasks conducted to further the implementation progress. Internal documents and secondary sources were the third major source of data used in the research. Feasibility studies,

reports, memos, minutes of meetings, and proposals, that were available were reviewed and analyzed. These documents were collected and analyzed to identify and/or validate data.

During the data collection, special attention was given to ascertaining whether evidence from different sources converged on a similar set of facts. Guidelines in the existing literature on the enhancement of retrospective data accuracy were followed in the process of data collection. When all the evidence had been reviewed, and after an initial case study narrative was documented, the factual portion of the case study was reviewed by the major informants in the company. Such a review was not only a minimal procedure for validating the data collection process, but also a courtesy to those who had cooperated with the research.

Description of the Company

The field case study was conducted by the authors at a medium-size manufacturing corporation located in the Midwest region of the United States. The company is a tier one automotive supplier of electromechanical components. The plants comprising the manufacturing division of this company are organized around customer groups and are provided with considerable autonomy. All operations, with the exception of accounting and information systems, are decentralized. The largest plant has successfully implemented the LM in the manufacturing area. All budget appropriations are approved at the company level with final approval from the corporate office. Only general strategic guidance is provided from the corporate level.

The automotive market is fiercely competitive for the company under study. Price is often stated by the automotive customer and only the most efficient suppliers survive the quoting process. Although a program is frequently awarded to a supplier solely on price, quality issues frequently cause a customer to change suppliers. This company needed to improve its manufacturing operations performance to remain competitive in the automotive market.

The implementation of LM was begun in 1993 after an exhaustive interview process with the Toyota Supplier Support Center (TSSC). TSSC provides consulting and implementation support free of charge to those organizations found worthy of the total commitment required to implement the changes expected. This automotive supplier remains one of most successful examples of LM implementation in North America today.

Implementation Strategy

The TSSC begins with an evaluation of a client's manufacturing capability and prescribes the appropriate implementation strategy. To help ensure success, topics of discussion and task assignments are kept very focused. TSSC consultants spent about one week per month on site, answering questions and assigning new tasks. Based on the advice of the consultants, the management of the company being researched decided to focus on the following six critical elements of LM. These include: (1) one piece flow, (2) standard work/small lot production, (3) standard set-up, (4) Kanban, (5) Jidoka, and (6) Heijunka. A brief description of the critical elements, the appropriate measures, and the implementation strategy used at this company are discussed below.

1. One Piece Flow

One piece flow is defined as moving/making only what is needed, when it is needed, thus minimizing WIP inventory. Minimizing WIP inventory enhances efficiency, enables quick response time, eliminates build-up of defects and facilitates standardized work.

One of the most important tenets of the LM is never to vary the work pace. Therefore, as efficiencies are introduced in the factory or design shop, or as the rate of production falls, it is vital to remove unneeded workers from the system so that the same intensity of work is maintained. Otherwise the challenge of continual improvement will be lost (Womack et al. 1990). It's important to begin by observing the workplace firsthand and to keep in mind anything that doesn't add value is Muda or waste. Muda has seven main categories: overproduction, waiting, conveyance, processing, inventory, motion, and correction. LM considers overproduction to be the most serious since it frequently hides some other types of Muda.

The implementation strategy for this company involved: (1) Completing a line balance based on observed times. (2) Identifying the operations that may require buffers (i.e. cooling after weld operations, cure time for adhesives, etc.), and (3) Modifying work stations so only one part can be stored between them. This frequently involved major rearrangement when first attempted. The company decided to use a "U" shaped layout with operators inside the configuration. Design buffer hold areas were used so that a predetermined maximum number of parts could be stored. This maximum was equal to the buffer quantity that was calculated earlier.

(4) Putting flow racks in place which utilized standard totes. When new flow racks are built they are designed to hold either two totes or only enough material for about an hour. (5) Ensuring that each flow rack is assigned an "address" location for delivery by the material handler. Flow racks allowed for incoming material from the perimeter of the cell and empty totes to the perimeter of the cell.

2. Standard Work

The goal of LM is to create an efficient production sequence that emphasizes human motion and the elimination of waste. Focused around human movements, standardized work outlines efficient, safe work methods and helps eliminate waste while maintaining quality. Standardized work is the foundation for Kaizen, or process improvement, in production. It organizes and defines worker movements. This is important because when the work sequence is different each time and/or if the motions are disorganized, there is no base line for evaluation. The first step in Kaizen is standardization.

The expected results of implementing standardized work include: 1) maintaining quality, 2) providing safer and more efficient operations, 3) ensuring proper use of equipment and machinery, 4) facilitating problem solving, 5) assisting in the visual control of that cell, and 6) providing a tool for line balancing.

The implementation strategy that this company embraced involved: (1) establishing the work sequence, (2) measuring the cycle time for that work sequence, (3) calculating the task time (synchronized processing speed), and (4) comparing the cycle time against the required task time. The procedure used for measuring the cycle time at the work site included:

- 1) Drawing the work layout and work sequence: These drawings clearly depicted machine location, operator movement, safety hazards, standard inventory and process quality requirements.
- 2) Determining the work elements: This included the elements of transporting, loading, adding value and unloading parts in a process.
- 3) Achieving a consensus of grouping of the work elements.
- 4) Measuring total cycle time 10 times and finding the mean.
- 5) Measuring work element time, machine time, and walking time.
- 6) Preparing standardized work combination table. This ensures that improvements are made to reduce walk time and other non-value added elements.

- 7) Preparing standardized work analysis sheet. The goal of an effective line balance is to produce a cycle time capable of meeting the task requirements, normally within a two-shift operation.

Task time is the time required to produce a single component or entire product based on sold products. It is calculated by taking the total available production time divided by the total production requirements; that is, $\text{Task Time} = \text{Operable Time per Day (in seconds)} \div \text{Required Number of Pieces / Day}$, and $\text{Actual Manning} \times \text{Total Cycle Time} \div \text{Task Time}$. Task times are usually indicated at each work center and understood to mean an hourly requirement of parts to meet the shipping schedule. In assembly operations, where quality issues are frequently caused by human variation in the methods, standard work forms are also considered a quality assurance (process control) document. Standard work sheets determine the current capacity of a work centre.

3. Standard Setup

Standardized setup applies the principles of standardized work to the process of converting an operation currently producing one part number such that it produces a different part number. It is a series of steps determined to be the most efficient way to change over from one product to another. Considerations include the worker, machine and materials. It is measured from the last good piece to the first good piece. The target is always zero changeover time. Setup does not have a task time. Instead, the maximum allowable changeover time is calculated as follows:

- 1) Calculate theoretical run times for all jobs produced at that work centre over whatever rotation of days equates to the run sizes and usage rates.
Example: 12 jobs = 54.8 hours of run time required every 4 days rotation.
- 2) Subtract total theoretical run time from the total available time over the rotation period.
Example: 4 day rotation over 2 shifts = 15 hours / day \times 4 = 60 hours - 54.8 hours with 5.2 hours or 312 minutes.
- 3) Divide the remaining time by the number of changeovers required over the rotation period to calculate the average maximum (this

would be the maximum allowable, but you would continue to look for ways to minimize this changeover time) allowable time per changeover.

Example: 12 jobs every 4 days = 11 changeovers every 4 days and over 312 minutes = 28 minutes/changeover.

- 4) Plot average allowable changeover time on a combination table and document changeover elements (internal) on the combination table. Visually you can tell whether the actual changeover time meets/exceeds the average allowable time. You might also be able to see where elements could be eliminated (i.e. moved to external) or where time could be removed. To shorten the setup time, Monden (1993) recommends the following four major concepts which must first be recognized:

Concept 1) Separate the internal setup from the external setup and convert as much as possible of the internal setup to the external setup.

Concept 2) Operations improvement: For the internal setup which cannot be converted to external setup, emphasis is placed on shortening internal setup by continuously improving and monitoring operations.

Concept 3) Equipment improvement: Search for transport devices for dies, elimination of adjustments of settings, modify equipment so that a variety of setups can be selected with the touch of a button, and revise standard setup documents and provide training as equipment is improved.

Concept 4) Abolish the setup itself: Monden (1993) recommends using a uniform product design or to utilize alternative manufacturing methods and less expensive means to produce parts, usually in conjunction with the next assembly where they are needed.

Internal setup refers to those setup actions that inevitably require that the machine be stopped.

The worker should concentrate on changing over the dies, jig, tools, and materials according to the specs of the next order while the machine is stopped. External setup refers to actions that can be performed while the machine is operating. In the external setup, the dies, tools, and materials must be perfectly prepared beside the machine and any needed repairs to the dies should have been made in advance (Monden, 1993).

All of the following techniques recommended by Monden (1993), in varying degrees were implemented at this company. Of significant value was the advent of a decentralized die and tool storage area that allowed the operator visual access to the next set of dies and quality fixtures needed.

4. Kanban

Kanban is a scheduling system of production instructions that replaces what has been taken/used by the following process. It allows for minimal inventories and easily adjusts to changes in demand. Formal production instructions go only to one location (typically shipping) and the rest of the shop floor production is self-managed. The result is a short lead time from order to shipment. There are two kinds of Kanban typically used:

- 1) Withdrawal Kanban - which specifies the kind and quantity of product which the subsequent process should withdraw from the preceding process.
- 2) Production Kanban - which specifies the kind and quantity of product which the preceding process must produce.

Some of the rules for Kanban are: defects are never sent to the following process, produce only the amount taken, no production or conveyance without a Kanban, Kanban should be attached to the actual parts, "first in, first out", and information on the Kanban must be consistent with the actual part.

This company implemented the typical Kanban system which starts with shipping when a shipment creates a need for parts which are withdrawn from the manufacturing location. This creates a need at the workcenter to produce more parts, which consumes components. As containers of components are emptied, instructions are sent to the area which produces that component and the consumed components are replenished. This withdrawal of components triggers the feeding process to produce more, thus withdrawing components from other feeding operations. This chain of withdrawal Kanbans and production Kanbans continues until raw material/purchased components are pulled into the plant.

5. Jidoka

Jidoka is defined as a system of ensuring that defect-free product is passed from one operation to the next. Quality is designed into the operation beginning at the product / equipment design phase utilizing prevention

techniques. Standard work supports tasks that involve exercising human judgment. Two common prevention techniques are Pokayoke and Andon.

A Pokayoke is an element of the process that senses a defect or non-conformance and will not allow the process to proceed. Examples of Pokayoke include fixture features that won't accept an out-of-spec part, sensing that checks for parts or features from previous operations, or sensing/clamping in the process that won't release a part if it is not properly processed. Pokayoke implementation should: 1) be based on firsthand experiences and observations, 2) ideally, ideas should come from team members, 3) have an emphasis on practical and inexpensive implementation, 4) the ideas should be durable, easily maintained and have lasting merit.

Andons are visual displays such as lights, flags, etc. which indicate the operating status of a workcentre. For example, a green light may indicate a cell is on schedule and is meeting task time, a yellow light may indicate a cell is behind schedule or that an operator is calling for help with a problem, and a red light may indicate a cell has been stopped. More important though, it provides identification of problems so that they may be solved. When problems and defects are eliminated, variability is reduced and the resource capacity is increased.

This element of LM has a lengthy implementation due to the equipment modifications needed for pokayokes. It requires a special skill to determine the appropriate type of fixture or machine modification needed to ensure defects were prevented. The other constraint that this company faced is that the necessary resources were often allocated to other maintenance projects. This company's implementation included the following elements, in varied degrees.

- 1) Fixture design was used to prevent defective parts from being used, to stop parts from being loaded incorrectly, and to prevent the wrong components from being used.
- 2) The equipment was programmed to stop at fixed positions between natural work steps and to stop automatically when problems occur to prevent equipment from cycling when components were missing.
- 3) Flag signal, downtime sheet, or Andon were used for ensuring that the state of production in the work centre is visible.
- 4) The separation between man and machine portions of the operation was made. However, automation was introduced only when it

is necessary to meet task time or the avoid/reduce repetitive trauma type injuries. Automation was never used merely for its own sake.

6. Heijunka

Heijunka is a production planning method which evenly distributes the production volume and production variety over the available production time. Heijunka prevents preceding operations from experiencing uneven workload and makes the planning process easier. Distributing the variety of parts produced prevents imbalances in inventory, having too many of one part and not enough of another.

Heijunka is the overall levelling in the production schedule of the variety and volume of items produced in a given time period. For example, if 80 of item A and 160 of item B were needed a day, production would be smoothed to manufacture 10 item As and 20 item Bs every hour. Heijunka (or pull) systems use a card or tag at the final work station to pull parts into shipping. Pull systems in a LM environment can move parts to shipping every 10 minutes or less. The implementation sequence for installing Heijunka at this company was as follows:

- 1) Determining the required finished good stores requirement in terms of both sales and floor space.
- 2) Allocating the shipping floor space as determined above and preparing and hanging location signs.
- 3) Determining the withdrawal frequency based on task time, conveyance manner and walk time and finished producer container size.
- 4) Ordering/producing a Heijunka box based on withdrawal frequency and product mix for the affected cell or work centre.
- 5) Designing/producing the appropriate Heijunka withdrawal tags (unless shipping labels are being used).
- 6) Assuring that completed product racking on the cell is designed to trigger a production Kanban based on the Heijunka withdrawal.
- 7) Training the Heijunka material operator.

Discussion of Results

Obstacles

As a tier one automotive supplier, the company is rated by its response to customer complaints. External customer complaints are handled quickly

by the quality department and are reactive in nature. Engineering and quality control departments are relied upon to handle most problem definition and resolution within the process. At this plant, problem-solving teams search for root causes to defects, however, the solution is often slow in actual implementation on the shop floor. The plant is not currently organized into teams authorized to implement solutions and improvements. The Kaizen team, at present, is the primary group for implementing ideas, creating a considerable bottleneck of suggestions.

Operators are trained to perform first, last and intermittent inspections of parts during their run and record data. However, process control charting is completed by the quality department rather than by operators, thus removing process trend information from the operator.

The managers replied negatively to additional questions regarding the utilization of cost of quality data. The company is beginning the process of QS9000 compliance and as a result the management is confident that this factor will rate higher in the near future.

Interviews with purchasing personnel indicated that price, given a certain minimal level of quality, was the foremost criterion for selecting vendors.

Benefits

At this company, LM was fully implemented over a three-year period in manufacturing operations and total inventory values are approximately 16 days in 1996 as opposed to over 30 days in 1993. Manufacturing batch sizes have shrunk from a thirty day lot size to 30- days or less and they are continuing to shrink. Set up times in all areas of the plant have been reduced by half, on average.

Technology was used to reduce prototype lead time. Recently, five working prototypes were developed for a foreign customer in ten weeks, a few years ago this feat would have required ten months. In addition, premium transportation costs have been reduced from \$148,000 in 1993 to \$8,000 in 1995. This dramatic transition occurred through the introduction of the LM. The plant is now producing a two- to four- day supply with organized first in, first out storage.

While improvements have occurred internally, purchased parts account for over 60 per cent of the content of shipped product. JIT is fully endorsed and many suppliers (60-70 per cent) are Kanban scheduled. A local "milk run" provides deliveries on some parts with as little as 24 hours notice. Both raw materials (steel coil) and purchased parts are included in

the JIT implementation. Internal pull systems are effective with over 90 per cent of internally produced parts scheduled with a visual signal (only service work uses a traditional schedule). Most of the assembly work is organized in flexible cells scheduled by Heijunka.

Future Plans

A total productive maintenance program is scheduled to be instituted at this company in late 1997. Space reduction projects are underway throughout the plant facility, induced by moderate business growth.

Existing equipment is often difficult to move or maintain and expensive to duplicate. Plans are under way to incorporate new criteria into investment decision. The approach is changing to proactive flexible investment decisions that support the core competencies of the company.

A new information system is under consideration which should assist in reducing the time from order to payment. The company is developing an office version of LM internally with plans to install it in late 1997.

The interviews and discussion with top and middle managers within the manufacturing area of the company indicated a sincere desire to improve the organization's ability to embrace change. Visual systems are in place on the shopfloor and a yearly training day is scheduled to acquaint personnel with any visual system changes. The corporate focus, however, appeared to be more on the immediate financial impact of these changes than on the long-term benefits which many authors endorse.

Conclusion

Ferdows and De Meyer (1990) observed that the Japanese seem to follow a distinct sequence of improvement programs which aim at building one capability upon, and not instead of, another.

The essence of the case study is that excellence in manufacturing is built on a common set of manufacturing capabilities prioritized and staged for implementation. The sequence suggested in this article is one that puts a management commitment to the principles of LM at the base.

Perhaps because of their success, they now measure themselves against perfection instead of their competition. Recently, a visitor from a Toyota plant in Japan remarked that the plant "looked just like any other Toyota plant in Japan", an off-hand remark that conveyed a coveted benchmark.

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