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LEAN MANUFACTURING

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Abstract—**Most all business managers agree that achieving low cost and high quality no longer guarantees a business its success. In the face of fierce global competition, companies are concentrating more than ever on reducing lead-times as a way of achieving operational flexibility. This is because as lead-times decrease, production times fall, quality improves and costs shrink.**
The methodology that an increasing number of companies are using to accomplish such a business strategy is the implementation of the Toyota Production System (TPS), also called lean manufacturing.
Lean Manufacturing is best defined as a management philosophy that focuses on reducing waste in all business processes. Although it originates from a time when the Toyota of today was a manufacturer of power looms, in its modern form, lean was pioneered by Toyota Motor Co. in the 1950's, when it dared compete with U.S. automakers who at the time dominated a seemingly impenetrable U.S. automobile market.

Keywords— Lean Manufacturing.

I. INTRODUCTION

Although Lean is a current business trend, it is not new. In fact, a major Japanese automobile manufacturer developed Lean in the 1940s. It quickly spread to other companies and industries within Japan, and finally the United States and West. Now, service, sales, governments, and other non-manufacturing sectors are jumping onto the Lean bandwagon.
The Lean Concept refers to a collection of tools used to promote long-term profitability, growth, and .doing more with less. In the past, increasing production efficiency required employees to work harder or longer, and machines to run faster. These methods work temporarily, but ultimately cause great problems. Accident rates increase, unions claim labor abuse, and overtaxed equipment breaks down. So, how do you increase efficiency without working harder or longer? The simple answer is by eliminating waste. Waste normally represents between 55 and 95% of the manufacturing process. All manufacturing processes are either value-added or non-value-added. Value-added processes mold, transform, or otherwise change raw materials into a finished product. Non-value-added activities include transporting material, conducting inspections, bar coding, and others. Implementing Lean Manufacturing involves streamlining the non-value-added processes as much as possible, because it represents as much as 75% of the total manufacturing process.
The need for Lean may be more easily understood by looking at financial models. Until thirty years ago, monopolies existed and large companies took their existing costs, added a profit, and the result was the sales price. This formula was especially fitting for new products. When VCRs were first introduced, they cost more than $1000 per machine. The same was true of cordless telephones, personal computers, and laptops. If consumers wanted the product, they were forced to pay the company's set price. In today's market, competition is more intense and consumers are more sophisticated. They demand more products, more features, better quality, higher availability, and competitive prices. Competition is also stronger due to the multiple numbers of companies producing each product.

NEW MODEL: PROFIT = SALES PRICE –COST

Current cost models assume the consumer sets the sales price. The manufacturer or service provider now determines its profit by subtracting cost from the sales price. As a result, the only strategy for increasing profitability in today's market is to reduce product cost by eliminating waste. Under the definition of Lean, manufacturers must meet consumer demand while applying fewer resources.

A. WHAT IS LEAN MANUFACTURING?

Lean manufacturing is a manufacturing system and philosophy that was originally developed by Toyota, Japan and is now used by many manufacturers throughout the world.
Lean Manufacturing can be 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 term lean manufacturing is a more generic term and refers to the general principles and further developments of becoming lean. The term lean is very apt because in lean manufacturing the emphasis is on cutting out "FAT" or wastes in manufacturing process. Waste is defined as anything that does not add any value to the product. It could be defined as anything the customer is not willing to pay for. Manufacturing philosophy is pivoted on designing a manufacturing system that perfectly blends together the fundamentals of minimizing costs and maximizing profit. These fundamentals are Man (labor), Materials and Machines (equipment) called the 3 M's of manufacturing. A well-balanced 3M is resulted through lean manufacturing.

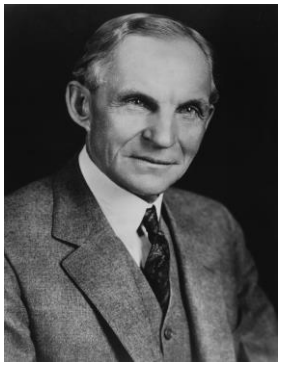
B. HISTORY

Lean Manufacturing is not especially new. It derives from the Toyota Production System or Just in Time Production, Henry Ford and other predecessors.
The lineage of Lean manufacturing and Just in Time (JIT) Production goes back to Eli Whitney and the concept of

interchangeable parts. This article traces the high points of that long history.

1) The Ford System

Starting about 1910, Ford and his right-hand-man, Charles E. Sorensen, fashioned the first comprehensive Manufacturing Strategy. They took all the elements of a manufacturing system- people, machines, tooling, and products- and arranged them in a continuous system for manufacturing the Model T automobile. Ford is considered by many to be the first practitioner of Just in Time and Lean Manufacturing.



Henry Ford

Ford's success inspired many others to copy his methods. But most of those who copied did not understand the fundamentals. Ford assembly lines were often employed for products and processes that were unsuitable for them.

It is even doubtful that Henry Ford himself fully understood what he had done and why it was so successful. When the world began to change, the Ford system began to break down and Henry Ford refused to change the system.

For example, Ford production depended on a labor force that was so desperate for money and jobs that workers would sacrifice their dignity and self-esteem. The prosperity of the 1920's and the advent of labor unions produced conflict with the Ford system. Product proliferation also put strains on the Ford system. Annual model changes, multiple colors, and options did not fit well in Ford factories.

At General Motors, Alfred P. Sloan took a more pragmatic approach. He developed business and manufacturing strategies for managing very large enterprises and dealing with variety. By the mid 1930's General Motors had passed Ford in domination of the automotive market. Yet, many elements of Ford production were sound, even in the new age. Ford methods were a deciding factor in the Allied victory of World War II.

2) Toyota Production System

The Allied victory and the massive quantities of material behind it (see "A Bomber an Hour") caught the attention of Japanese industrialists. They studied American production methods with particular attention to Ford practices and the Statistical Quality Control practices of Ishikawa, Edwards Deming, and Joseph Juran.

At Toyota Motor Company, Taichii Ohno and Shigeo Shingo, began to incorporate Ford production and other techniques into an approach called Toyota Production System or Just in Time. They recognized the central role of inventory.

Taiichi Ohno
One of the originators of the Toyota Production System

The Toyota people also recognized that the Ford system had contradictions and shortcomings, particularly with respect to employees. With General Douglas MacAurthur actively promoting labor unions in the occupation years, Ford's harsh attitudes and demeaning job structures were unworkable in post-war Japan. They were also unworkable in the American context, but that would not be evident for some years. America's "Greatest Generation" carried over attitudes from the Great Depression that made the system work in spite of its defects.

Shigeo Shingo
Pioneer of TPS & Industrial Engineer extraordinaire

Toyota soon discovered that factory workers had far more to contribute than just muscle power. This discovery probably originated in the Quality Circle movement. Ishikawa, Deming, and Juran all made major contributions to the quality movement. It culminated in team development and cellular manufacturing.

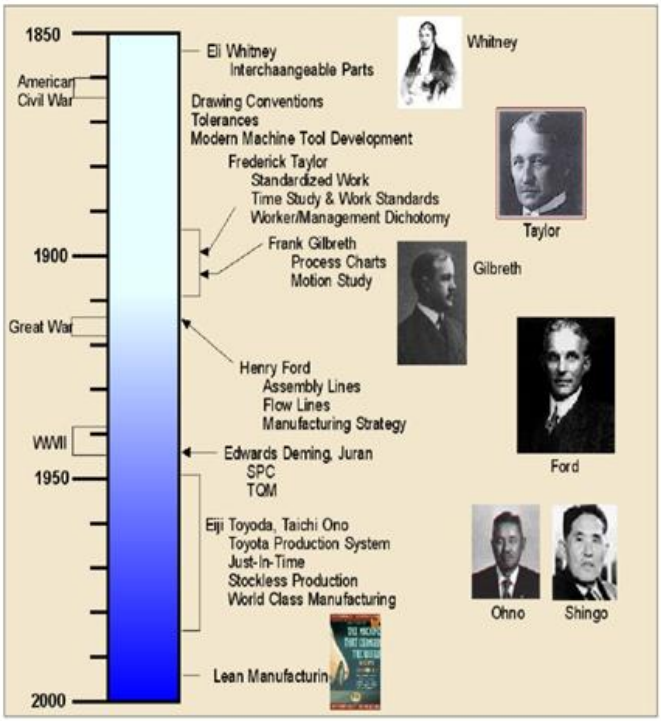
Another key discovery involved product variety. The Ford system was built around a single, never changing product. It did not cope well with multiple or new products.

Shingo, at Ohno's suggestion, went to work on the setup and changeover problem. Reducing setups to minutes and seconds allowed small batches and an almost continuous flow like the original Ford concept. It introduced a flexibility that Henry Ford thought he did not need.

All of this took place between about 1949 and 1975. To some extent it spread to other Japanese companies. When the productivity and quality gains became evident to the outside world, American executives traveled to Japan to study it.

They brought back, mostly, the superficial aspects like kanban cards and quality circles. Most early attempts to emulate Toyota failed because they were not integrated into a complete system and because few understood the underlying principles.

3) Lean Time Line



II. LITERATURE SURVEY

In 1900's U.S. manufacturers like Henry ford brought the concept of mass production. U.S. manufacturers have always searched for efficiency strategies that help reduce costs, improve output, establish competitive position, and increase market share. Early process oriented mass production manufacturing methods common before World War II shifted afterwards to the results-oriented, output-focused, production systems that control most of today's manufacturing businesses. Japanese manufacturers re-building after the Second World War were facing declining human, material, and financial resources. The problems they faced in manufacturing were vastly different from their Western counterparts. These circumstances led to the development of new, lower cost, manufacturing practices. Early Japanese leaders such as the Toyota Motor Company's Eiji Toyoda, Taiichi Ohno, and Shingeo Shingo developed a disciplined, process-focused production system now known as the "lean production." The objective of this system was to minimize the consumption of resources that added no value to a product.

The "lean manufacturing" concept was popularized in American factories in large part by the Massachusetts Institute of Technology study of the movement from mass production toward production as described in The Machine That Changed the World, (Womack, Jones & Roos, 1990), which discussed the significant performance gap between Western and Japanese automotive industries. This book described the important elements accounting for superior performance as lean production. The term "lean" was used because Japanese business methods used less human effort, capital investment, floor space, materials, and time in all aspects of operations. The resulting competition among U.S. and Japanese automakers over the last 25 years has led to the adoption of these principles within all U.S. manufacturing businesses. Now it has got global acceptance and is adopted by industries world over to keep up with the fast moving and competing industrial field.

III. KEY TO LEAN SUCCESS

A. Commit to the lean program

It is beyond question that practitioners think that managerial commitment is the most important success factor—irrespective of differences in plant size, corporation, location and other factors. But it is not enough to just "lead from the office;" the managers must also participate personally on the shop-floor. This involves ongoing communication, listening to suggestions and questions from employees, and explaining why lean means change for the better.

B. Train the workforce

A second critical success factor is to provide training and education in lean production for the whole workforce. Without knowledge in lean, a plant is not likely to succeed with its implementation. Importantly, managers are the first who need training and education. Learning by doing is a superior way to learn, but requires local coaching by trained managers or staff. In the early stages of lean implementation, external consultancy firms or internal corporate resources can help build the needed knowledge. Another quick way to learn is to benchmark other organizations that have implemented lean. On the whole, accumulating local knowledge is considered much more important than the continued use of consultants.

C. Have a plan and follow it up

A third critical success factor is to have a plan and follow it up. Perhaps a good idea is to have a proper lean program in the first place, and a vision of where you want your organization to be. The plan should be broken down into defined steps. Clearly defined performance targets should be

set and monitored. Regular meetings must be held in order to follow-up the implementation of specific projects. Managers must seek to integrate lean in everyday business, rather than run it as a separate, temporary project on the side of operations.

D. Allocate resources and share the gains

Allocating the necessary resources to assist implementation and then share the gains with all employees is also critical for success. It is difficult for organizations to turn lean without a coaching and supporting local "lean team," or a distributed task force in the organization. It is also necessary to dedicate a budget for the transformation. Gains won through improvements should be shared. Reward and recognition schemes can be effective in the early stages, but managers should take care when designing reward and recognition schemes because the effects of such schemes seem particular sensitive to differences in cultural traits.

E. Use lean tools and methods

Finally, the application of lean tools and methods is important. The specific lean tools and methods most frequently mentioned in the survey were waste reduction, visualization, problem solving, team concept, continuous improvement, daily management, value stream mapping, and 5S. These are all well-known methods from the lean production philosophy. Tools and methods are effective and necessary for succeeding with the implementation of lean in a plant, but they are not sufficient on their own; the four other success factors must complement the tools and methods.

IV. PRINCIPLES OF LEAN

1. Identify value- Specify the value from the point of view of the end customer.
2. Map the Value Stream- Identify all the steps in the value stream, eliminating the steps that do not create any value
3. Create Flow- Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer
4. Establish Pull- Responding to customer demands as quickly as possible without creating excess inventory
5. Seek Perfection- begin the above processes again and continue it until a state of perfection is reached in which perfect value is created with no waste.

V. COMPARISON BETWEEN TRADITIONAL AND LEAN MANUFACTURING

For years manufacturers have created products in anticipation of having a market for them. Operations have traditionally been driven by sales forecasts and firms tended to stockpile inventories in case they were needed. A key difference in Lean Manufacturing is that it is based on the concept that production can and should be driven by real customer demand. Instead of producing what you hope to sell; Lean Manufacturing can produce what customer wants with shorter lead times. Instead of pushing product to market, it's pulled there through a system that's set up to quickly respond to customer demand.

Lean organizations are capable of producing high-quality products economically in lower volumes and bringing them to market faster than mass producers. A lean organization can make twice as much product with twice the quality and half the time and space, at half the cost, with a fraction of the normal work-in-process inventory. Lean management is about operating the most efficient and effective organization possible, with the least cost and zero waste.

A. OVERALL ORGANIZATIONAL CHARACTERISTICS:

	TRADITIONAL MASS PRODUCTION	LEAN PRODUCTION
Business Strategy	Product-out strategy focused on exploiting economies of scale of stable product designs and non-unique technologies	Customer focused strategy focused on identifying and exploiting shifting competitive advantage.
Customer Satisfaction	Makes what engineers want in large quantities at statistically acceptable quality levels; dispose of unused inventory at sale prices	Makes what customers want with zero defect, when they want it, and only in the quantities they order
Leadership	Leadership by executive command	Leadership by vision and broad participation

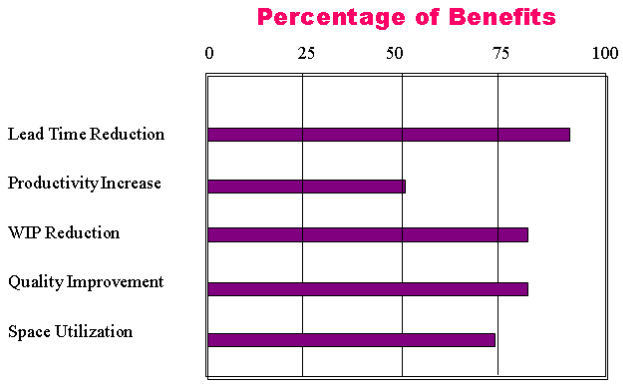
External Relations	Based on price	Based on long-term relationships
Production	Large-scale machines, functional layout, minimal skills, long production runs, massive inventories	Human-scale machines, cell-type layout, multi-skilling, one-piece flow, zero inventories
Operational capability	Dumb tools that assume an extreme division of labor, the following of orders, and no problem solving skills	Smart tools that assume standardized work, strength in problem identification, hypothesis generation, and experimentation
Maintenance	Maintenance by maintenance specialists	Equipment management by production, maintenance and engineering
Engineering	"Isolated genius" model, with little input from customers and little respect for production realities.	Team-based model, with high input from customers and concurrent development of product and production process design

B. MANUFACTURING METHODS:

	TRADITIONAL MASS PRODUCTION	LEAN PRODUCTON
Production schedules are based on…	Forecast — product is pushed through the facility	Customer Order — product is pulled through the facility
Products manufactured to…	Replenish finished goods inventory	Fill customer orders (immediate shipments)
Production cycle times	Weeks/months	Hours/days
Manufacturing lot size quantities are…	Large, with large batches moving between operations	Small, and based on one-piece flow between operations
Plant and equipment layout is…	By department function	By product flow, using cells or lines for product families
Quality is assured…	Through lot sampling	100% at the production source
Workers are typically assigned…	One person per machine	With one person handling several machines
Worker empowerment is…	Low — little input into how operation is performed	High — has responsibility for identifying and implementing improvements
Inventory levels are…	High — large warehouse of finished goods, and central storeroom for in-process staging	Low — small amounts between operations, ship often
Inventory turns are…	Low — 6-9 turns per year or less	High — 20+ turns per year
Flexibility in changing manufacturing schedules is…	Low — difficult to handle and adjust to	High — easy to adjust to and implement
Manufacturing costs are…	Rising and difficult to control	Stable/decreasing and under control

VI. BENEFITS OF LEAN MANUFACTURING

According to the study conducted in various industries world over the main benefits achieved by implementation of lean manufacturing is as shown below.



(From ERC staff meeting, march 20, 2002, Maryland University)

Establishment and mastering of a lean production system would allow you to achieve the following benefits:

- Lead time is reduced by 90%
- Productivity is increased by 50%
- Work in process is reduced by 80%
- Quality is improved by 80%
- Space utilization is increased by 75%

These are areas in an establishment that directly affects its survival. There are many other benefits also which directly or indirectly affects the performance of the industry.

OTHER BENEFITS

- Reduced scrap and waste
- Reduced inventory costs
- Cross-trained employees
- Reduced cycle time
- Reduced obsolescence
- Lower space/facility requirements
- High quality & reliability
- Lower overall costs
- Self-directed work teams
- Lead time reduction
- Fast market response
- Longer machine life
- Improved customer communication
- Lower inventories
- Improved vendor support and quality
- Higher labor efficiency and quality
- Improved flexibility in reacting to changes
- Allows more strategic management focus
- Increased shipping and billing frequencies

However, by continually focusing on waste reduction, there are truly no ends to the benefits that can be achieved.

VII. BARRIERS IN LEAN

There are so many benefits to be gained from going Lean that it can almost seem illogical for anyone to oppose Lean or for there to be any barriers to its successful implementation, but in reality there are many barriers that can be faced by any organisation that is implementing Lean.

The first barrier is undoubtedly related to staff and personnel. Without all the workforce behind Lean and without their commitment to Lean, it will be an uphill struggle to successfully implement it within the company. In particular senior management need to be committed to it as a philosophy, management strategy and as the overall framework in which they will do business.

Any organisation that implements Lean without the full commitment of the management team is almost doomed to fail, so management are vital to the process.

1. The Shop floor and Lean

But Lean has to be adopted and believed in by all sections of the workforce, if management believes in it, but staff do not, then again, it will be difficult to successfully implement Lean. Staff can effectively put a clog in the wheels of production or manufacturing so they are vital links in the process.

2. Resistance To Change

Any organisation will have some staff who are resistant to change. No matter how beneficial the changes may be, they will oppose them almost on principle, so these staff have to be targeted specifically because their resistance can act as a significant barrier to Lean.

3. Roots And Branch Philosophy

Lean has to be a roots and branch philosophy. In a sense, people have to live and breathe Lean and it has to permeate all the activities and roles within the organisation. If it is implemented in a piecemeal fashion or in certain parts of an organisation only, then it will face barriers. All parts of the organisation, including the administrative and supportive sections need to adopt Lean. It is a radical approach and one that should be embraced fully, so that it can be a success.

4. Lack Of Planning

Lean has to be planned. If Lean is suggested on Monday and implemented on Tuesday, then this is not just a barrier, but it is a recipe for disaster. Planning is essential for it to be a structured process; it simply cannot be rushed in to or done in a way that has not been carefully thought out, or else it will simply falter and no one will actually understand the strategy or what is being done.

Training goes hand in hand with planning and if there is insufficient training then staff will not be behind the process and no one will fully understand it, so training really has to be undertaken; by everyone!

5. Unwillingness To Learn and See

Central to the philosophy of Lean is the need for those who are involved in the process to learn from things that go wrong, to see where waste exists and to keep looking, learning and improving continuously.

This sounds easy in theory, but in fact relies on those involved being able to learn, see and aim for continuous improvements. Yet it can be tempting to gloss over negative issues and to 'leave things be' when in fact, to do so will not lead to improvements and will not reduce any waste. So there has to be a culture created where mistakes can be recognised and rectified leading to improvements, as opposed to a culture where mistakes are simply identified in order to apportion blame!

Thus there are many barriers to Lean, but these need to be viewed in context; the benefits of Lean are immense, with the barriers actually being easily surmounted

VIII. WASTES IN MANUFACTURING

The aim of Lean Manufacturing is the elimination of waste in every area of production including customer relations, product design, supplier networks, and factory management. Its goal is to incorporate less human effort, less inventory, less time to develop products, and less space to become highly responsive to customer demand while producing top quality products in the most efficient and economical manner possible.

Essentially, a "waste" is anything that the customer is not willing to pay for.

Typically the types of waste considered in a lean manufacturing system include:

A. OVERPRODUCTION

To produce more than demanded or produce it before it is needed. It is visible as storage of material. It is the result of producing to speculative demand. Overproduction means making more than what is required by the next process, making earlier than is required by the next process.

Causes for overproduction waste include:

- Just-in-case logic
- Misuse of automation
- Long process setup
- Unbalanced work load
- Redundant inspections

B. WAITING

The principle is to maximize the utilization/efficiency of the worker instead of maximizing the utilization of the machines.
Causes of waiting waste include:
• Unbalanced work load
• Unplanned maintenance

• Long process set-up times
• Misuses of automation

C. INVENTORY OR WORK IN PROCESS (WIP)

This is material between operations due to large lot production or processes with long cycle times.
Causes of excess inventory include:
• Product complexity
• Poor market forecast
• Unbalanced workload
• Unreliable shipments by suppliers
• Misunderstood communications

D. PROCESSING WASTE

It should be minimized by asking why a specific processing step is needed and why a specific product is produced. All unnecessary processing steps should be eliminated.
Causes for processing waste include:
• Just-in-case logic
• True customer requirements undefined
• Over processing to accommodate downtime
• Lack of communications
• Extra copies/excessive information

E. TRANSPORTATION

This does not add any value to the product. Instead of improving the transportation, it should be minimized or eliminated (e.g. forming cells).
Causes of transportation waste include:
• Poor plant layout

• Poor understanding of the process flow for production
• Large batch sizes, long lead times, and large storage areas

F. MOTION

Motion of the workers, machines, and transport (e.g. due to the inappropriate location of tools and parts) is waste. Instead of automating wasted motion, the operation itself should be improved.
Causes of motion waste include:
• Poor people/machine effectiveness
• Inconsistent work methods
• Unfavorable facility or cell layout
• Poor workplace organization and housekeeping
• Extra "busy" movements while waiting

Motion

Unnecessary movements by people (e.g., walking).

G. MAKING DEFECTIVE PRODUCTS

This is pure waste. Prevent the occurrence of defects instead of finding and repairing defects.
Causes of defective products include:
• Poor quality
• Deficient planned maintenance
• Inadequate education/training/work instructions
• Product design
• Customer needs not understood

Defects

Efforts caused by rework, scrap, and incorrect information.

H. UNDER UTILISING PEOPLE

Not taking advantage of people's abilities.
Causes of people waste include:
• Old guard thinking, politics, the business culture
• Poor hiring practices
• Low or no investment in training
• Low pay, high turnover strategy

Talent

Underutilizing people's talents, skills, & knowledge.

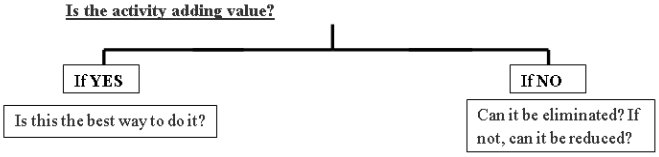
Old guard thinking, politics, the business culture
• Poor hiring practices
• Low or no investment in training
• Low pay, high turnover strategy

IX. LEAN TOOLS

Those concepts that lead to the implementation of lean manufacturing successfully are called Lean Tools. The basic elements of lean manufacturing are waste elimination, continuous improvement, pull system, one-piece workflow, cellular manufacturing and 5S's. When these elements are focused in the areas of cost, quality and delivery, this forms the basis for a lean production system.

A. ELIMINATION OF WASTE

Waste is anything that doesn't add value to the product. Checking whether the process is adding value to the product or not is the best way to identify wastes.

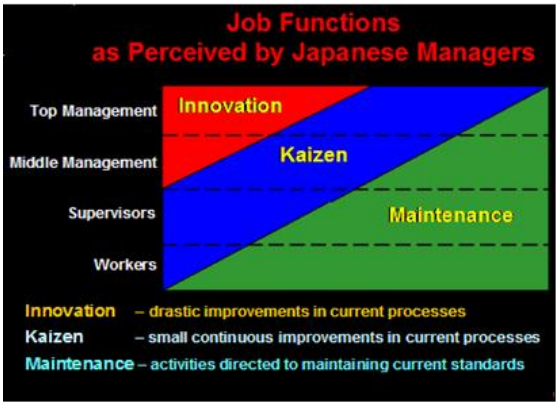


Out of the complete processes in an industry only about 5 % actually add value to the product. Rest of the process does not add any value. Rest 35% activities are such that even though this doesn't add any value but still it cannot be eliminated as it is necessary. For e.g. Inventory cannot be completely reduced, scrap materials cannot be made zero, it may take few minutes to load unload and load for next operation etc. So focus should be on complete elimination of waste activities and reducing the necessary non-value adding activities.

B. CONTINUOS IMPROVEMENT

Japanese looked at improving their work every time they do it. This lead to the development of concept called continuous improvement. Japanese rather than maintaining the improvement they have achieved they concentrated in continuously improving their work. This improvement can be in any field like quality, error proofing, lead-time reduction etc. So the focus should be on how you can improve your work than the same done last time.

Improvement is classified into innovations and kaizen. Innovations are those improvements which cause drastic changes. These occur due to huge technological advancements in the field of research and development. These are mostly done by high level engineers. Kaizen include small improvements done by lower order employees. According to the level of employees the type of improvements each should focus are as shown below:



C. PULL SYSTEM

Manufacturing system can be divided into two

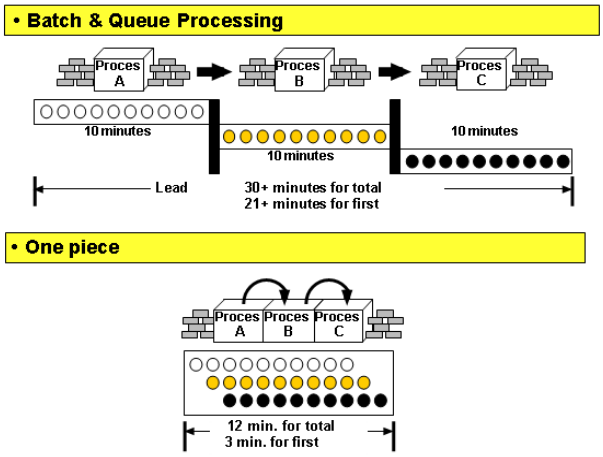
9.3.1 Push system- Here the products are made according to the market forecast and not according to the current demand. So here the information flow is in the same direction as the product flow. So there may chance of piling of finished goods as there are always fluctuation in demand. Thus the product is pushed through the production line.

9.3.2 Pull system- Here the product is made according to the customer demand. So the information of the quantity and type of product flow in the opposite direction to that of the product. Here no piling of finished products occurs as the production is according to the customer demand. Hence the customer pulls the product through the production line.

D. ONE PIECE FLOW

One piece flow is one of the important techniques in implementing lean manufacturing. Traditional batch production in mass production is replaced by one piece flow in lean manufacturing. Here batch size is reduced to almost one. This reduces the total lead time and also reduces waiting between operations or queuing.

Following figures show how effective is one piece flow over batch production.

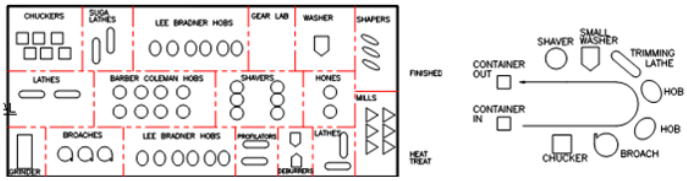


From the above example it is clear that the lead time can be reduced to almost 40% of the lead time when it was batch production. Also it can be noted that it takes about 85% less time for the first part to be produced. Thus product can be produced according to current demand quickly.

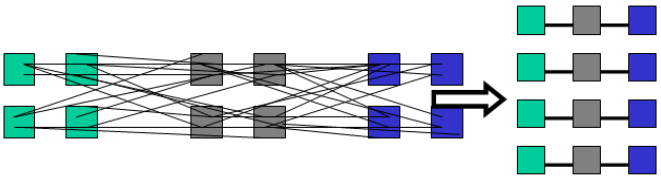
E. CELLULAR MANUFACTURING

In traditional mass production machines are arranged according to its functions. But in cellular manufacturing machines are arranged according to the processes involved in production. The plants layout is designed in such a way that transportation between machineries is reduced to minimum. For the implementation of such a good plant layout deep knowledge of processes as well as proper analysis of processes involved in production is necessary.

Following figures shows the diagrammatic representation of both forms of floor arrangement.



FUNCTIONAL CELLS



1) Cell advantages over functional departments

1. Shorter Lead Time
2. Improved Quality- Quicker problem identification & less potential rework or scrap
3. Less Material Handling
4. Improved Coordination
5. Reduced Inventory
6. Departmental conflicts eliminated
7. Less Space Required

F. THE 5S's

It is the Japanese method of keeping the work place clean and tidy. This helps in reducing many unnecessary movements.

1) The 5S's are:

•Sort (Seiri) - Perform "Sort Through and Sort Out," by placing a red tag on all unneeded items and moving them to a temporary holding area. Within a predetermined time the red tag items are disposed, sold, moved or given away.

•Set in Order (Seiton) - Identify the best location for remaining items, relocate out of place items, set inventory limits, and install temporary location indicators.
•Shine (Seiso) - Clean everything, inside and out.
•Standardize (Seiketsu) - Create the rules for maintaining and controlling the first 3S's and use visual controls.
•Sustain (Shitsuke) - Ensure adherence to the 5S standards through communication, training, and self-discipline.

G. JUST IN TIME

The notion of pushing materials in large quantities no longer makes sense. Both the financial cost and the required resources of doing otherwise are not smart. Just in Time simply promotes the concept, both internally and externally, that it is wise to deliver materials only just before they are needed and only in the quantity required.
In the past, suppliers would strive to ship as much product to the customer as possible in order to maximize sales and profits. This was a shortsighted strategy because customers' needs were disregarded. If a supplier pushed extra product to them at the end of the month or year, less would be required for the next period. This resulted in a slump as well as a continuation of the cycle. Many companies still either do not understand this concept or do not want to change.
Short-term goals and strategies still prevail in our business environment. Lean corporations strive to maximize long-term profitability and growth, often ignoring short-term wins.

H. TOTAL PRODUCTIVE MAINTENENCE

Total Productive Maintenance (TPM) is a Lean concept based on three simple ideas. The first is that preventive maintenance schedules must be developed and adhere to. Establishing a preventive maintenance schedule and placing it in a book is the easy part. Even when it is impossible to meet a preventive maintenance deadline, contingency plans and drop-dead dates should keep the system running smoothly.
The second idea is that extensive maintenance history exists in a database, and equipment failures may be predicted within reasonable timeframes. The database may be a manual maintenance logbook or a sophisticated software system. Predictive maintenance will allow the company to pinpoint failure intervals and required maintenance timeframes. This is especially relevant if the repair or replacement could have been easily scheduled when the equipment was not running, such as a weekend or night shift.
Last and most importantly, simpler maintenance tasks may be delegated to those who know the equipment the best. The normal temperature, sound, vibration, smell, feel, and look of a machine are clearly known by its operators. In turn, when the machine is not operating normally, the operators easily detect it. Rather than leaving a machine to beg for assistance, the operators may lubricate equipment and perform other basic or routine maintenance functions, either on schedule, or when vibrations, excessive temperatures, or other anomalies are observed. This creates a stronger bond between the operator and his equipment. This concept also adds to the multi-functionality of the operator.

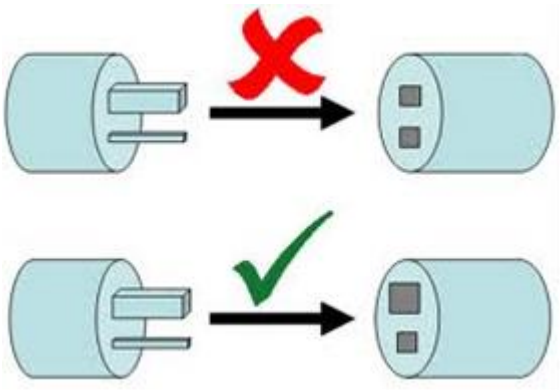
I. TOTAL SET-UP TIME REDUCTION

Manufacturing lead-time reduction is a primary focus in today's competitive environment. Many elements comprise manufacturing lead-time, such as material preparation, movement, and setup time. The goal is not to reduce the number of setups, but to reduce the required setup time that results in machine downtime for each occurrence of the setup. Simply reduce the amount of time tried to set up the process or machine when it is not running or in production. This is referred to as internal setup time.
Setup time that takes place when a process or machine is running is referred to as external setup time. The premise is that in many processes, the machinery is producing, not the operator. At the very least, the operator is not 100% utilized or occupied. As a result, the operator may, depending on the process and the machinery, perform some setup tasks during the time that the process or machine is running.

J. POKA YOKE

A poka-yoke is an error-proofing device, such as the connectors used on personal computers. The poka-yoke will not allow the connection of the cable in the wrong configuration. Likewise, a poka-yoke will not allow the operator to do something incorrectly. Each of these little bites allows us to eat an elephant. The elephant is a large block of wasted time. Most internal setup times may be reduced. Between 30 and 70% per discrete project, depending on the operation.

The key to Setup Time Reduction projects is to revisit the setup operation periodically to audit the results from the previous project, and to reduce the setup time again and again.



K. ROOT CAUSE ANALYSIS

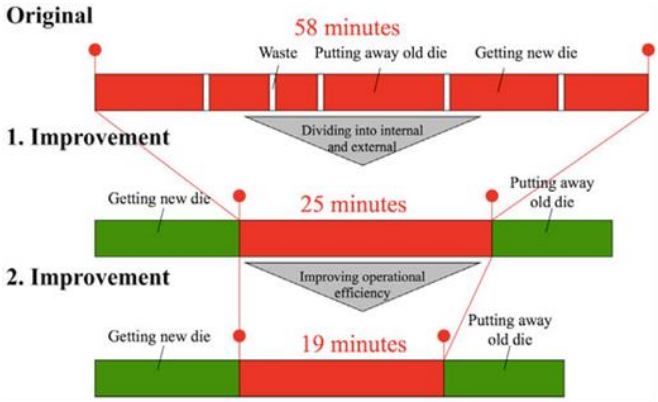
A problem solving methodology that focuses on resolving the underlying problem instead of applying quick fixes that only treat immediate symptoms of the problem. A common approach is to ask why five times – each time moving a step closer to discovering the true underlying problem.

L. TAKT TIME

The pace of production (e.g. manufacturing one piece every 34 seconds) that aligns production with customer demand. Calculated as Planned Production Time / Customer Demand. Provides a simple, consistent and intuitive method of pacing production.

M. SINGLE MINUTE EXCHANGE OF DIES (SMED)

Reduce setup (changeover) time to less than 10 minutes. Enables manufacturing in smaller lots, reduces inventory, and improves customer responsiveness.



N. KAIZEN (CONTINEOUS IMPROVEMENT)

A strategy where employees work together proactively to achieve regular, incremental improvements in the manufacturing process.

Combines the collective talents of a company to create an engine for continually eliminating waste from manufacturing processes.

O. OVERALL EQUIPMENT EFFECTIVENESS (OEE)

Framework for measuring productivity loss for a given manufacturing process. Three categories of loss are tracked:

- Availability (e.g. down time)
- Performance (e.g. slow cycles)
- Quality (e.g. rejects)

Provides a benchmark/baseline and a means to track progress in eliminating waste from a manufacturing process.

CONCLUSION

"LEAN" can be said as adding value by eliminating waste being responsive to change, focusing on quality and enhancing the effectiveness of the work force.

Although lean has its origin in the automobile industry it is being successfully used in other production industries. Lean manufacturing is now extended to fields like I.T, service etc. in order to reduce production cost and meet changing customer needs.

Since lean is completely customer oriented it is here to stay. It is also important as it emphasis customer satisfaction.

Lean has made its way into curriculum of major universities around the world. In universities like MIT, Maryland university etc. Lean manufacturing is included into the syllabus and it is given importance to new entrepreneurs. Many consulting firms are also functioning for proper guidance to those who are interested in lean.

Lean manufacturing cannot be attained in one day or one week or one month or in a year. It needs lot of commitment and hard work. Also there is no end in lean manufacturing. The more you eliminate waste the more you become lean. That is why it is said that:

"Lean is a journey".

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