

Introduction to Lean Manufacturing for Vietnam

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Note: This report by [Mekong Capital](#) is a general introduction to Lean Manufacturing (“lean”). Lean Manufacturing is a group of methods, which are being increasingly implemented around the world, that aim to eliminate waste and inefficiency from the manufacturing process, leading to lower costs and greater competitiveness for manufacturers. In a recent survey, approximately 36% of U.S. based manufacturing companies have implemented lean or are in the process of implementing lean¹. Some of the changes required by Lean Manufacturing can be disruptive if not implemented correctly and some aspects of Lean Manufacturing are not appropriate for all companies.

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¹ <http://www.industryweek.com/CurrentArticles/asp/articles.asp?ArticleID=1589>

1. What is Lean Manufacturing?

1.1 Objectives of Lean Manufacturing

Lean Manufacturing, also called Lean Production, is a set of tools and methodologies that aims for the continuous elimination of all waste in the production process. The main benefits of this are lower production costs, increased output and shorter production lead times. More specifically, some of the goals include:

1. **Defects and wastage** - Reduce defects and unnecessary physical wastage, including excess use of raw material inputs, preventable defects, costs associated with reprocessing defective items, and unnecessary product characteristics which are not required by customers;
2. **Cycle Times** - Reduce manufacturing lead times and production cycle times by reducing waiting times between processing stages, as well as process preparation times and product/model conversion times;
3. **Inventory levels** - Minimize inventory levels at all stages of production, particularly works-in-progress between production stages. Lower inventories also mean lower working capital requirements;
4. **Labor productivity** - Improve labor productivity, both by reducing the idle time of workers and ensuring that when workers are working, they are using their effort as productively as possible (including not doing unnecessary tasks or unnecessary motions);
5. **Utilization of equipment and space** - Use equipment and manufacturing space more efficiently by eliminating bottlenecks and maximizing the rate of production through existing equipment, while minimizing machine downtime;
6. **Flexibility** - Have the ability to produce a more flexible range of products with minimum changeover costs and changeover time.
7. **Output** - Insofar as reduced cycle times, increased labor productivity and elimination of bottlenecks and machine downtime can be achieved, companies can generally significantly increase output from their existing facilities.

Most of these benefits lead to lower unit production costs – for example, more effective use of equipment and space leads to lower depreciation costs per unit produced, more effective use of labor results in lower labor costs per unit produced and lower defects lead to lower cost of goods sold.

In a 2004 survey by Industry Week Magazine, U.S. companies implementing lean manufacturing reported a median savings of 7% of Cost of Goods Sold (COGS) as a result of implementing lean². We believe that the savings may actually be higher for companies in Vietnam considering the higher levels of waste which they typically have compared to U.S. based manufacturers.

Another way of looking at Lean Manufacturing is that it aims to achieve the same output with less inputs – less time, less space, less human effort, less machinery, less materials, less costs.

When a U.S. equipment manufacturing company, Lantech, completed the implementation of lean in 1995, they reported the following improvements compared to their batch-based system in 1991³:

- Manufacturing space per machine was reduced by 45%;
- Defects were reduced by 90%
- Production cycle time was reduced from 16 weeks to 14 hours - 5 days; and
- Product delivery lead time was reduced from 4-20 weeks to 1-4 weeks.

² <http://www.industryweek.com/CurrentArticles/asp/articles.asp?ArticleID=1589>

³ James P. Womack & Daniel T. Jones: *Lean Thinking*. Simon & Schuster, 1996. P. 121.

1.2 Key Principles of Lean Manufacturing

Key principles behind Lean Manufacturing can be summarized as follows:

1. **Recognition of waste** – The first step is to recognize what does and does not create value from the customer’s⁴ perspective. Any material, process or feature which is not required for creating value from the customer’s perspective is waste and should be eliminated. For example, transporting materials between workstations is waste because it can potentially be eliminated.
2. **Standard processes** – Lean requires an the implementation of very detailed production guidelines, called Standard Work, which clearly state the content, sequence, timing and outcome of all actions by workers. This eliminates variation in the way that workers perform their tasks.
3. **Continuous flow** – Lean usually aims for the implementation of a continuous production flow free of bottlenecks, interruption, detours, backflows or waiting. When this is successfully implemented, the production cycle time can be reduced by as much as 90%.
4. **Pull-production** – Also called Just-in-Time (JIT), Pull-production aims to produce only what is needed, when it is needed. Production is pulled by the downstream workstation so that each workstation should only produce what is requested by the next workstation.
5. **Quality at the Source** – Lean aims for defects to be eliminated at the source and for quality inspection to be done by the workers as part of the in-line production process.
6. **Continuous improvement** – Lean requires striving for perfection by continually removing layers of waste as they are uncovered. This in turn requires a high level of worker involvement in the continuous improvement process.

1.3 History of Lean Manufacturing

Many of the concepts in Lean Manufacturing originate from the Toyota Production System (TPS) and have been implemented gradually throughout Toyota’s operations beginning in the 1950’s. By the 1980’s Toyota had increasingly become known for the effectiveness with which it had implemented Just-In-Time (JIT) manufacturing systems⁵. Today, Toyota is often considered one of the most efficient manufacturing companies in the world and the company that sets the standard for best practices in Lean Manufacturing. The term “Lean Manufacturing” or “Lean Production” first appeared in the 1990 book *The Machine that Changed the World*⁶.

Lean Manufacturing has increasingly been applied by leading manufacturing companies throughout the world, lead by the major automobile manufactures and their equipment suppliers. Lean Manufacturing is becoming an increasingly important topic for manufacturing companies in developed countries as they try to find ways to compete more effectively against competition from Asia.

1.4 Key implications of Lean Manufacturing

	Traditional batch manufacturing	Lean Manufacturing
Orientation	Supply driven	Customer driven
Planning	Orders are pushed through factory based on production plan/forecast	Orders are pulled through factory based on customer/downstream demand
Batch size	Large	Small
Quality inspection	Checking of samples by QC inspectors	In-line inspection by workers
Inventory	Buffer of work-in-progress between each production stage	Little or no work-in-progress between each production stage
Handoff of works-	Materials after each stage accumulate	Materials handed off directly from one

⁴ Note: In this report, the word “customer” refers to both outside companies which receive the finished product as well as internal customers such as the next stage in the production process which receive semi-finished products. Likewise, the word “supplier” refers to both outside companies which supply raw materials or services as well as internal suppliers which are the previous stage in the production process.

⁵ http://www.factorylogic.com/glossary_11.asp

⁶ James Womack, Daniel Jones and Daniel Roos: *The Machine that Changed the World*. Simon & Schuster, 1992.

in-progress	into works-in-progress storage areas before being retrieved by next production stage	production stage to the next
Production cycle time	Total production cycle takes significantly longer than actual time spent processing the materials.	Total production cycle shortens to approach time spent actually processing the materials.

1.5 What kinds of companies benefit most from lean?

Lean is most widely used in industries that are assembly-oriented or have a high amount of repetitive human processes. These are typically industries for which productivity is highly influenced by the efficiency and attention to detail of the people who are working manually with tools or operating equipment. For these kinds of companies, improved systems can eliminate significant levels of waste or inefficiency. Examples of this include wood-processing, garment manufacturing, automobile assembly, electronics assembly and equipment manufacturing.

Since Lean Manufacturing eliminates many of the problems associated with poor production scheduling and line balancing, Lean Manufacturing is particularly appropriate for companies that don't have ERP systems in place or don't have strong material requirements planning (MRP), production scheduling or production allocation systems in place. This is particularly significant in Vietnam where we believe that many private Vietnamese manufacturing companies are operating significantly below their potential capacity, or experiencing a high level of late-deliveries, due to problems with their current production scheduling and production management systems.

Lean Manufacturing is also appropriate in industries for which it is a strategic priority to shorten the production cycle time to the absolute minimum as a source of competitive advantage for the company.

Recently, some companies in Vietnam have actively conducted training and implemented lean methods to eliminate process inefficiencies. This resulted in an improvement to their production and service lead times. For example, Toyota Ben Thanh, a service center of Toyota in Vietnam, has implemented lean methods to significantly reduce the process time for its automobile maintenance service from 240 minutes to 45-50 minutes per car, and as a result, increased the total number of cars processed at each service center from 4-6 cars up to 16 cars per day. Toyota Ben Thanh achieved significant reductions in the process lead time by successfully eliminating unnecessary waiting time, inefficiencies of physical motions and process flow.⁷

⁷ For more details of the process improvement at Toyota Ben Thanh, please see Hoang Ly: [Co The Tang Nang Suat ma Khong Can Dau Tu \(Improving Productivity without Capital Investment\)](#). Thoi Bao Kinh Te Saigon, 27 May 2004.

2. Lean Manufacturing Concepts

2.1 Value Creation and Waste

In Lean Manufacturing, the **value** of a product is defined solely based on what the customer actually requires and is willing to pay for. Production operations can be grouped into following three types of activities:

Value-added activities are activities which transform the materials into the exact product that the customer requires.

Non value-added activities are activities which aren't required for transforming the materials into the product that the customer wants. Anything which is non-value-added may be defined as waste. Anything that adds unnecessary time, effort or cost is considered non value-added. Another way of looking at waste is that it is any material or activity for which the customer is not willing to pay. Testing or inspecting materials is also considered waste since this can be eliminated insofar as the production process can be improved to eliminate defects from occurring. For more on the kinds of waste, please see section 2.2.

Necessary non value-added activities are activities that don't add value from the perspective of the customer but are necessary to produce the product unless the existing supply or production process is radically changed. This kind of waste may be eliminated in the long-run but is unlikely to be eliminated in the near-term. For example, high levels of inventory may be required as buffer stock, although this could be gradually reduced as production becomes more stable.

Research at the Lean Enterprise Research Centre (LERC) in the United Kingdom indicated that for a typical manufacturing company the ratio of activities could be broken down as follows⁸:

Value-added activity	5%
Non value-added activity	60%
<u>Necessary non value-added activity</u>	<u>35%</u>
Total activities	100%

This implies that up to 60% of the activities at a typical manufacturing company could potentially be eliminated.

2.2 Main Kinds of Waste

Originally 7 main types of waste were identified as part of the Toyota Production System. However, this list has been modified and expanded by various practitioners of lean manufacturing and generally includes the following:

1. **Over-production** – Over-production is unnecessarily producing more than demanded or producing it too early before it is needed. This increases the risk of obsolescence, increases the risk of producing the wrong thing and increases the possibility of having to sell those items at a discount or discard them as scrap. However, there are some cases when an extra supply of semi-finished or finished products are intentionally maintained, even by lean manufacturers.
2. **Defects** – In addition to physical defects which directly add to the costs of goods sold, this may include errors in paperwork, provision of incorrect information about the product, late delivery, production to incorrect specifications, use of too much raw materials or generation of unnecessary scrap.
3. **Inventory** – Inventory waste means having unnecessarily high levels of raw materials, works-in-progress and finished products. Extra inventory leads to higher inventory financing costs, higher storage costs and higher defect rates. For more on this, please see section 2.5 below.
4. **Transportation** - Transportation includes any movement of materials that does not add any value to the product, such as moving materials between workstations. The idea is that transportation of materials between production stages should aim for the ideal that the output of one process is

⁸ Peter Hines & David Taylor: Going Lean. Lean Enterprise Research Centre, January 2000.

immediately used as the input for the next process. Transportation between processing stages results in prolonging production cycle times, the inefficient use of labor and space and can also be a source of minor production stoppages.

5. **Waiting** – Waiting is idle time for workers or machines due to bottlenecks or inefficient production flow on the factory floor. Waiting also includes small delays between processing of units. Waiting results in a significant cost insofar as it increases labor costs and depreciation costs per unit of output.
6. **Motion** – Motion includes any unnecessary physical motions or walking by workers which diverts them from actual processing work. For example, this might include walking around the factory floor to look for a tool, or even unnecessary or difficult physical movements, due to poorly designed ergonomics, which slow down the workers.
7. **Correction** – Correction, or reprocessing, is when something has to be re-done because it wasn't done correctly the first time. This not only results in inefficient use of labor and equipment but the act of re-processing often causes disruptions to the smooth flow of production and therefore generates bottlenecks and stoppages. Also, issues associated with reworking typically consume a significant amount of management time and therefore add to factory overhead costs.
8. **Over-processing** – Over-processing is unintentionally doing more processing work than the customer requires in terms of product quality or features – such as polishing or applying finishing on some areas of a product that won't be seen by the customer.
9. **Knowledge Disconnection** – This is when information or knowledge isn't available where or when it is needed. This might include information on correct procedures, specifications, ways to solve problems, etc. Lack of correct information often leads to defects and bottlenecks. For example, unavailability of a mixing formula may potentially suspend the entire process or create defective items due to time-consuming trial-and-error tests.

2.3 Pull Production

A core concept of Lean Manufacturing is Pull Production in which the flow on the factory floor is driven by demand from downstream pulling production upstream as opposed to traditional batch-based production in which production is pushed from upstream to downstream based on a production schedule. This means that no materials will be processed until there is a need (signal) from downstream. For example, in pull production a customer order creates demand for finished product, which in turn creates demand for final assembly, which in turn creates demand for sub-assemblies, and so on up the supply chain. The specific implications of this are as follows:

1. **Orders start at most downstream stage** - When an order is received from the customer and communicated to the factory floor, the production order is initially placed with the most downstream workstation (such as packaging or final assembly) as opposed to the most upstream workstations (such as initial processing of raw materials). This practice requires a very effective communication system that ensures that upstream suppliers are continuously aware of what is needed by their downstream customers. Please also see section 3.13 on Kanban for more information on this.
2. **Product is pulled through production based on demand from downstream process** - Each production stage or workstation is seen as a customer of the production stage or workstation immediately upstream of it. Nothing is produced by the upstream supplier until demanded by the downstream customer.
3. **Rate of production is driven by downstream consumption rates** – The rate of production at each production stage or workstation is equal to the rate of demand/consumption from its downstream customer.

Pull production is the same as Just-in-Time (JIT) which means that raw materials or works-in-progress are delivered with the exact amount and "just in time" for when the downstream workstation needs it.

The ideal of pull production is that the materials will be available from the supplier (upstream stage) exactly when the customer (downstream stage) needs them. This means that all inventory in the factory is being processed, as opposed to waiting to be processed, and that the customer usually must plan ahead by anticipating what it will require based on the turnaround time for the supplier. For

example, if it takes the supplier 2 hours to deliver materials when ordered by the customer, the customer will have to order ahead by 2 hours so that the materials will be ready when the customer needs it.

2.4 Different models of Pull Production

Many lean manufacturers intentionally maintain certain inventories of raw materials, semi-finished products and finished products in order to:

- protect against variations in customer demand;
- protect against unexpected late shipments from suppliers or production slow downs;
- smooth production flow by producing some items on a continuous basis even if not required by the customer;
- accommodate the fact that raw materials must be delivered in batches and that finished products must be shipped in batches;
- accommodate the fact that some processing must be done in batches due to the nature of the equipment or the process.

Generally speaking, the less predictable customer orders, the more unstable production (such as unintentional slowdowns and bottlenecks), or the less reliable the raw materials suppliers, the greater the inventory that will be required to buffer against sudden changes in customer demand, production instability or raw materials shortages. In such cases, lean manufacturers intentionally maintain inventories of raw materials, semi-finished products or finished products to buffer against such events.

In order to accommodate these situations, there are different models for implementing pull based production, including the following:

1. **Replenishment Pull System** – In a replenishment pull system, the company intentionally maintains inventories of each type of finished product and only when the inventory of a certain finished product falls below a certain level a replenishment order is issued to produce more of the product. Replenishment pull is more common when a company has a large number of small volume customers who order standardized products. In a replenishment pull system, production schedules are more predictable so low inventories of raw materials are required.
2. **Sequential Pull System** – In a sequential pull system, orders are placed on the factory floor only when demanded by an outside customer. All products are made on a made-to-order basis. Sequential pull is more common when a company has a small number of large volume customers who order customized products. Although companies using this system should have lower inventories of finished products, they will typically require larger inventories of raw materials or semi-finished materials due to less predictability in the production schedule (due to difficulty predicting exactly what customer orders will be placed and when).
3. **Mixed Pull System** – In a mixed pull system, certain elements of replenishment and sequential pull systems are used in conjunction with each other.

For example, a company may produce some products on a replenishment pull basis while producing other products on a sequential pull basis.

Alternatively, a company may use replenishment pull for part of the production process and sequential pull for a different part of the production process. An example of this would be a company that maintains a managed level of inventory of certain semi-finished items but only produces a finished product when ordered by the customer. In such a case, the company applies a replenishment pull system for producing the semi-finished items and applies a sequential pull process for the remainder of the production process. In the Toyota Production System, production is triggered to restock semi-finished items so that whenever an item is needed, it is available⁹.

2.5 Why high levels of inventory increase defects and wastage

Pull production results in the elimination of unnecessary inventory between processing stages. High levels of inventory between processing stages result in higher defect rates for the following reasons:

1. **Non-detection of defects in batch processing** – in batch processing, more defective units will be produced before being detected at the next processing stage. For example, if the batch size of a

⁹ <http://www.aug.edu/~sbajmg/quan6610/Lean%20Concepts/leanWP1.pdf>

bag printing process is three thousand pieces at a time before going to the next workstation and the quality controller doesn't identify the defect, it is likely that many defective bags will have been produced before the errors are discovered by the next workstation.

2. **Defects and wastage from storage and transportation** - some defects occur during transportation and storage. For example, in the furniture industry exposure to humidity during storage can contribute to high moisture content which may be considered a defect. Meanwhile, the act of storing inventory requires extra labor, energy and space.
3. **Direct accountability** - when there is an inventory queue between two production stages, there is no direct connection between the two production stages. The downstream stage may not even know which worker or team produced particular items. When there is less accountability by the upstream worker/team, it is more likely to make a defective product or not produce exactly to customer specifications. Conversely, a direct handoff and immediate usage by the downstream worker/team will help ensure that the upstream worker/team takes full responsibility to only produce items which will be accepted by the downstream worker/team.

However, as mentioned in the previous section, there are some cases inventory is essential for ensuring smooth production and therefore certain kinds of inventory should be maintained at a managed level to ensure that no disruption occurs.

2.6 Impact of Pull-Production on Production Planning

Most private manufacturing companies in Vietnam are using a centrally planned system whereby the Production Planning Manager develops a production schedule and allocates orders to workstations in batches. This is a push-based system, meaning that inventory gets pushed through the production process based on the production schedule. The Materials Requirements Planning (MRP) module of most Enterprise Resource Planning (ERP) systems operates on this basis.

In a push-based system, if the production forecasting systems is not accurate (which is often the case for Vietnamese manufacturing companies) or the Production Planning Manager doesn't have perfect information about production status and demand at each stage of the production process or doesn't have effective tools for analyzing this (which is also often the case at Vietnamese manufacturing companies), he/she may allocate too much or too little work to different teams and workstations, thereby resulting in bottlenecks, excess inventory, low likelihood of being able to produce on a continuous flow basis, and inefficient use of resources in general.

In contrast, a key element of the pull-based system is that, with the exception of production leveling, the allocation and flow of work on the factory floor is determined based on demand on the factory floor and not based on a production schedule or centrally planned production allocation system.

Although lean manufacturing companies still have a production plan, the plan is primarily used for the following:

- planning capacity requirements, including changes to the configuration of production lines or cells;
- planning labor requirements;
- smoothing the flow of orders to the factory floor (see section 3.14 on Production leveling); and
- (in some cases) planning raw materials requirements.

2.7 Continuous Flow

Continuous flow is the linking of manual and machine operations into a perfectly smooth flow in which works-in-progress are continuously undergoing some form of processing and never become stagnant waiting to be processed. Continuous flow eliminates waiting time for works-in-progress, equipment or workers.

In Continuous Flow, the ideal is one-piece flow or small batches which can be processed with virtually no waiting time between production stages.

Continuous Flow may require a redesign of the production layout away from groups of similar workstations located near each other and towards highly integrated production lines in which semi-finished products can move as quickly and easily as possible from one production stage to the next.

Continuous flow can result in very substantial reductions in total cycle time. For example:

- When Simms Fishing Products, a U.S. based manufacturer of garments used by fishermen, implemented Lean Manufacturing, their production throughout (i.e. the total time from the start to the finish of the production process) fell from 17 days to 2-3 days¹⁰.
- When Woodland Furniture Company, a U.S. based manufacturer of high-end wood furniture, implemented lean manufacturing, lead times were reduced from 12 weeks to 1 week¹¹.

2.8 Mixing Continuous and Discontinuous Flow

Sometimes continuous flow isn't possible for some stages of the production process. In these cases, continuous flow can be implemented in some but not all of the production stages. Some examples of cases in which continuous flow is not appropriate for some stages of the process include:

- Cycle time mismatches in which some processes occur at very fast cycle times and must change over to serve multiple product types.
- Distance between processes may be unavoidable in some cases and may mean that transportation of materials must be done in relatively large batches.
- Some processes are too unreliable and therefore have unpredictable yields which can be disruptive to a continuous flow operation.
- Some processes must be done in large batches. For example, Kiln drying of wood is done in batches which means that when wood comes out of that process, it will likely need to be stored as inventory for a least some time because it can not all be processed at once.
- Sometimes the use of scrap should be maintained as inventory for future use in order to maximize yields. For example, some scrap which is generated in wood-cutting stages can be re-used at a later time when there is a requirement for a piece of wood with the dimensions of the scrap. This means that some works-in-progress inventory might be intentionally generated at stages where reusable scrap is produced. In a case like this, a truly continuous flow would result in a higher level of waste than a yield-maximizing approach in which some scrap is intentionally created for later use¹².
- In some cases, the company may intentionally maintain inventories of semi-finished products at some stages of the production process.

2.9 Continuous Improvement / Kaizen

A company can never be perfectly efficient. Lean Manufacturing requires a commitment to continuous improvement, and preferably a systematic process for ensuring continuous improvement, whereby the company constantly searches for non value-added activities and ways to eliminate those. The focus of continuous improvement should be on identifying the root causes of non value-added activities and eliminating those by improving the production process.

Kaizen is a Japanese term for "continuous improvement", with an emphasis on small incremental improvements. A main theme of Kaizen is to create a culture of continuous improvement, largely by assigning responsibility to workers, and encouraging them, to identify opportunities for improvement, as described in section 2.10 below.

2.10 Worker Involvement

In Lean Manufacturing, workers are assigned clear responsibility to identify sources of non value-added activities and to propose solutions to those. Lean Manufacturers typically believe that the majority of useful ideas for eliminating non value-added activities typically originate with workers involved in those processes. A significant body of research also substantiates this assertion¹³.

In order to ensure that ideas for eliminating non value-added activities are acted upon, the power to decide on changes to the production processes are pushed down to the lowest level possible (i.e. normal workers) but any such changes are required to meet certain requirements. For example, at Toyota workers are encouraged to implement improvements to the production processes but the improvement must have a clear logic which is in accordance with the scientific method, the improvement must be implemented under the supervision of an authorized manager and the new process must be documented in a high level of detail covering content, sequence, timing and

¹⁰ http://www.apparelmag.com/bobbin/search/search_display.jsp?vnu_content_id=2010873

¹¹ http://www.techhelp.org/about_success_details.asp?ID=37

¹² <http://woodpro.cas.psu.edu/WoodPro%20Word%20HTML%20files/WoodPro%20TechNotes%202003-1.htm>

¹³ <http://www.sme.org/cgi-bin/get-newsletter.pl?LEAN&20040309&1&>

outcome¹⁴. Toyota initially implements the proposed changes on a small scale on a trial basis and if the improvement is effective, Toyota will implement the change across its manufacturing operations.

Two common ways to encourage worker involvement in the continuous improvement process are:

1. **Kaizen Circles** - One way of increasing the levels of worker involvement is to implement Kaizen Circles in which groups of 6-8 workers are formed to generate ideas for solving particular problems. Typically a Kaizen Circle will meet for around one hour per week for 6-8 weeks and at the end of that period will present some proposals to their managers on how to solve particular problems. Active involvement/support by managers is critical to the success of Kaizen Circles.
2. **Suggestion Programs** - Another way of increasing worker involvement is having an active suggestion program where people are strongly encouraged to make suggestions and rewarded for suggestions that are successfully implemented. Often the cost of the reward is quite small relative to the value that is created for the company by implementing the improvement.

Some experts in lean manufacturing maintain that high levels of worker involvement in continuously suggesting improvements is a critical success factor in the implementation of lean and is the key thing which differentiates Toyota from other companies in terms of its success at implementing lean manufacturing principles¹⁵.

2.11 Cellular Layout

In cellular production layouts, equipment and workstations are arranged into a large number of small tightly connected cells so that many stages or all stages of a production process can occur within a single cell or a series of cells. Cellular layouts are characterized by the following characteristics:

1. **Continuous flow** - There is a smooth flow of materials and components through the cell with virtually no transport or waiting time between production stages.
2. **One-piece flow** - Cellular manufacturing utilizes a one piece flow so that one product moves through the manufacturing process one piece at a time.
3. **Multi-purpose workers** - There is only one or several workers in each cell and unlike batch processing where workers are responsible for a single process, in cell manufacturing the cell workers are responsible for handling each of the different processes that occur in the cell. Therefore each worker is trained to handle each process which occurs within the cell.
4. **U-shape** - Cells are usually U-shaped, with the product moving from one end of the U to the other end of the U as it is processed by the worker(s). The purpose of this is to minimize the walking distance and movement of materials within a cell.

Cellular layout helps to achieve many of the objectives of Lean Manufacturing due to its ability to help eliminate many non value-added activities from the production process such as waiting times, bottlenecks, transport and works-in-progress. Another benefit of cellular manufacturing is that responsibility for quality is clearly assigned to the worker in a particular cell and he/she therefore can not blame workers at upstream stages for quality problems.

Many companies implement cellular layout for certain parts of the production process but not the entire production process. For example, processing stages involving lengthy heating or drying processes would not be appropriate for a cellular layout since it is difficult to connect those to a continuous flow which happens in a cell. Furniture companies typically implement cellular layout for some cutting, assembly and finishing stages but not for any kiln drying or paint drying stages.

A case study on implementing a cellular production layout for a series of intermediate production processes at Franklin Corp., a U.S. manufacturer of upholstered furniture, is available here: <http://www.ifmm.msstate.edu/doubled.pdf>. They reported a 36% increase in labor productivity as a result of implementing a lean manufacturing system.

¹⁴ Steven Spear and H. Kent Bowen: Decoding the DNA of the Toyota Production System. Harvard Business Review, September-October 1999.

¹⁵ Steven Spear: Learning to Lead at Toyota. Harvard Business Review, May 2004.

Cellular layouts are not appropriate for all companies and many companies successfully implement Lean Manufacturing without implementing cellular layouts. For example, some industries require large batch processing due to the nature of the equipment or significant waiting times between production stages and therefore these would not be suitable for cellular layouts. Please also see section 3.11 on Batch size reduction.

2.12 Administrative Lean

Administrative lean is the application of lean manufacturing concepts and tools to improve administrative processes other than factory floor production. This is particularly relevant for administrative processes which are repetitive and involve a high volume of transactions such as order entry, purchasing, accounting or various kinds of back office processing. However, the application of lean to administrative processes is less common than the application of lean to production processes.

3. Lean Manufacturing Tools & Methodologies

3.1 Standard Work

Standard work (also called “standardized work” or “standard process”) means that production processes and guidelines are very clearly defined and communicated, in a high level of detail, so as to eliminate variation and incorrect assumptions in the way that work is performed. The goal is that production operations should be performed the same way every time, except insofar as the production process is intentionally modified. When production procedures are not highly standardized, workers may have different ideas of what the correct operating procedure are and easily make incorrect assumptions. A high level of process standardization also makes it easier for the company to expand capacity without disruption.

The standard work guidelines used in Lean Manufacturing are typically defined in significantly greater detail than the minimum required for conformity with 7.5.1. of ISO9001:2000 on “Control of Production and Service Provision”¹⁶, particularly in terms of standardizing the movements and work sequences of particular workers.

In Lean Manufacturing, standard work has several main elements:

1. **Standard work sequence** - This is the order in which a worker must perform tasks, including motions and processes. This is clearly specified to ensure that all workers perform the tasks in the most similar ways possible so as to minimize variation and therefore defects. Ideally this is so detailed as to clearly describe every single hand movement by a worker. For example, in wood cutting, the standard work sequence would describe every specific cut and operating step from machine setup to materials handling, cutter adjustment, manual movements and processing time. In an assembly process, it would describe the exact sequential step-by step motions by which the item is assembled.
2. **Standard timing** – Takt time is the frequency with which a single piece is produced¹⁷. Takt time is used to clearly specify and monitor the rate at which a process should be occurring at various production stages. For lean manufacturers, the Takt time of each production process is actively managed and monitored so that a continuous flow can occur.
3. **Standard in-process inventory** – This is the minimum unit of materials, consisting primarily of units undergoing processing, which are required to keep a cell or process moving at the desired rate. This should be clearly determined since it is necessary to maintain this minimum amount of in-process inventory in order to not cause unnecessary downtime. This is used to calculate the volume and frequency of orders, or Kanban, to upstream suppliers.

3.2 Communication of Standard Work to employees

Standard work guidelines shouldn’t only be textual manuals but should include pictures, visual displays and even samples. Employees are unlikely to read boring textual production manuals so visual displays and actual samples, including pictures, should be used as much as possible. The guidelines should be clear and detailed, but at the same time be presented in such a way that is as easy as possible for employees to understand and relevant to what they need to know. This is particularly true in Vietnam since many of the workers may have low education levels and will find visual displays easier to understand than written materials. Some companies even apply video training for tasks which are more complicated or safety-related.

3.3 Standard work and flexibility

Some companies in Vietnam have expressed concern that having highly standardized/defined production procedures will lead to inflexibility. Although standard work requires a high level of detail, in Lean Manufacturing the standard work guidelines should be updated as frequently as necessary to

¹⁶ Requirement 7.5.1. states that “the organization shall have the following available: a) information concerning product characteristics; b) appropriate work instructions; c) suitable production equipment; d) measuring and monitoring devices and facilities; e) processes to cover the release, delivery and post-delivery activities.”

¹⁷ This is different from cycle time which is the time it takes one particular piece to complete a process. For example, a furniture manufacturer may produce one sofa every 10 minutes (takt time) but it takes 3 days of work to actually produce the sofa (cycle time).

incorporate ongoing process improvements. In fact, companies are encouraged to maximize the rate of process improvement which means that the standard work guidelines are likely to change frequently. Also, standard work typically includes clear guidelines for workers to handle unusual situations, thereby empowering them to respond in flexible ways to unusual situations.

In order to implement this successfully, responsibility should be clearly delegated for preparing and distributing the necessary documentation and visual aids, as well as ensuring that any changes are clearly communicated to employees by their supervisors. As long as this responsibility is clearly delegated, the standard work procedures can be modified frequently. In fact, lean manufacturing companies such as Toyota are known for their flexibility, both in terms of product mix and their ability to make rapid improvements to their production processes, which also leads to quicker responses to customer's changing demands.

3.4 Visual Management

Visual Management systems enable factory workers to be well informed about production procedures, status and other important information for them to do their jobs as effectively as possible. Large visual displays are generally much more effective means of communication to workers on the factory floor than written reports and guidelines and therefore should be used as much as possible. When it comes to improving compliance with a process, visual presentation helps the team better understand a complicated process including the correct sequence of events, the correct way to perform each action, internal and external relationships between actions, and other factors. These visual tools may include the following:

1. **Visual Displays** - Charts, metrics, procedures and process documentation which are reference information for production workers. For example, trend chart of yield performance, % variation of defect rate, month-to-date shipping volume status, etc.
2. **Visual Controls** - Indicators intended to control or signal actions to group members. This may include production status information, quality tracking information, etc. For example, color-coded panel for temperature or speed setting control limits that help an operator quickly identify process is out of the control range. Kanban cards are another example of visual controls.
3. **Visual process indicators** - These communicate the correct production processes or flow of materials. For example, this would include the use of painted floor areas for non-defective stock and scrap or indicators for the correct flow of materials on the factory floor.

3.5 Quality at the Source (or "Do It Right the First Time")

Quality at the Source, also called "Do It Right the First Time", means that quality should be built into the production process in such a way that defects are unlikely to occur in the first place - or insofar as they do occur, they will be immediately detected. Lean Manufacturing systems often refer to the Japanese word "Jidoka" which means that problems should be identified and eliminated at the source.

Some of the key implications of this:

1. **In-line inspection** - The main responsibility for quality inspection is done in-line by workers, not by separate quality inspectors who inspect sample lots. Although some independent QC inspectors are often still used in lean companies, their role is minimized (ideally there are no QC inspectors because they also are considered a waste in Lean Manufacturing).
2. **Source inspections** - In source inspections, the quality inspectors don't inspect for defects themselves, but inspect for the causes of defects. For example, they may inspect if standard processes are being done correctly by workers, or in a case where defects have occurred, they may be responsible for identifying what was the source of those defects. From this perspective, the primary job of a quality control team is to troubleshoot the root cause of defects, implement preventive measures and provide training to workers to ensure the defects do not reoccur.
3. **Clear accountability among workers** - In Lean Manufacturing, unless there is an intentional inventory of semi-finished products, there is a direct handoff between each upstream stage and downstream stage, meaning that the workers at each upstream stage are fully responsible for the quality of the materials they deliver to the downstream stage and will be held personally accountable for any defects. On the other hand, if there is a large buffer of inventory between two

production stages, the workers at the upstream process are less likely to feel personally accountable for any defects.

4. **Poka Yoke** – Simple methods for in-line quality testing (not just visual inspection), sometimes referred to as “Poka Yoke”, are implemented so that defective materials do not get passed through the production process. In Poka-Yoke, 100% of the units are tested as part of the production process. These measures are performed in-line by the production workers (not the quality control team).
5. **Intentional shutdowns** – When defects are generated, production is shut down until the source of the defect can be solved. This helps ensure a culture of zero tolerance for defects and also prevents defective items from working their way downstream and causing bigger problems downstream. For example, at Toyota any worker can shut down the production line. This also helps ensure accountability by upstream workers.

3.6 Value Stream Mapping

Value stream mapping is a set of methods to visually display the flow of materials and information through the production process. The objective of value stream mapping is to identify value-added activities and non value-added activities. Value stream maps should reflect what actually happens rather than what is supposed to happen so that opportunities for improvement can be identified¹⁸.

Value Stream Mapping is often used in process cycle-time improvement projects since it demonstrates exactly how a process operates with detailed timing of step-by-step activities. It is also used for process analysis and improvement by identifying and eliminating time spent on non value-added activities.

3.7 The Five S’s

The Five S’s are some rules for workplace organization which aim to organize each worker’s work area for maximum efficiency.

1. **Sort** – Sort what is needed and what is not needed so that the things that are frequently needed are available nearby and as easy to find as possible. Things which are less often used or not needed should be relocated or discarded.
2. **Straighten (or “Set in order”)** – Arrange essential things in order for easy access. The objective is to minimize the amount of motion required in order for workers to do their jobs. For example, a tool box can be used by an operator or a maintenance staff who must use various tools. In the tool box, every tool is placed at a fixed spot that the user can quickly pick it up without spending time looking for it. This way of arrangement can also help the user be immediately aware of any missing tools.
3. **Scrub (or “Shine”)** – Keep machines and work areas clean so as to eliminate problems associated with un-cleanliness. In some industries, airborne dust is among the causes of poor product surface or color contamination. To be more aware of dust, some companies paint their working places in light colors and use a high level of lighting.
4. **Stabilize (or “Standardize”)** – Make the first 3 S’s a routine practice by implementing clear procedures for sorting, straightening and scrubbing.
5. **Sustain** – Promote, communicate and train in the 5 S’s to ensure that it is part of the company’s corporate culture. This might include assigning a team to be responsible for supervising compliance with the 5 S’s.

3.8 Preventative Maintenance

Preventative Maintenance is a series of routines, procedures and steps that are taken in order to try to identify and resolve potential problems before they happen. In Lean Manufacturing, there is a strong emphasis on preventative maintenance which is essential for minimizing machine downtime due to breakdowns and unavailability of spare parts.

¹⁸ For a more detailed presentation of these, please see Peter Hines & David Taylor: Going Lean. Lean Enterprise Research Centre, January 2000. <http://www.cf.ac.uk/carbs/lom/lerc/centre/goinglean.pdf>

When equipment reliability is low, manufacturers are forced to maintain high inventories of works-in-progress as a buffer. However, high inventories are considered a major source of waste and defects in Lean Manufacturing.

3.9 Total Productive Maintenance

Total Productive Maintenance (TPM) assigns basic preventative maintenance work including inspection, cleaning, lubricating, tightening and calibration to the production workers who operate the equipment. TPM clearly assigns responsibility to workers to proactively identify, monitor and correct the causes of problems leading to unnecessary machine downtime. By allocating this responsibility to the machine operators, maintenance problems are less likely to occur and therefore machine downtime can be reduced. This also requires the operators to frequently update the maintenance team about the machine condition so that potential technical problems could be discovered on a timely basis and prevented.

In TPM, the maintenance team is responsible for the higher value-added maintenance activities such as improving the equipment, performing overhauls and improvements, fixing problems and providing training.

3.10 Changeover/setup time

Lean Manufacturing aims to reduce unnecessary downtime due to machine setup or product changeovers since machine downtime is a significant source of unnecessary waste. This requires a culture of continuous improvement in which the company is continuously trying to find ways to reduce changeover and setup times.

Often quicker changeover times can be achieved to some degree by having very standardized (and well-documented) configuration settings for the production of particular products so that there is no uncertainty about how to reconfigure the equipment during a changeover. Companies with a wide range of product mix, color and specifications often underestimate the conversion cost every time the production process is halted to replace molds, clean leftover materials with a different color or specification, adjust machine settings, etc.

Other ways to minimize the changeover/setup time include changing the physical layout of a process, having all materials and tools needed available, and using dual/spare storage bin to eliminate cleaning downtime.

3.11 Batch Size Reduction

Lean Manufacturing aims for materials to flow on the factory floor in the smallest batch sizes possible, with the ideal being one piece flow, so that works-in-progress between processing stages can be minimized. The smaller the batch size, the more likely that each upstream workstation will produce exactly what its customer needs, exactly when its customer needs it.

Therefore, instead a few large production lines with large batch sizes, Lean Manufacturing usually favors a larger number of small production lines with small batch sizes, with the cellular layout being one version of this. The main benefits of smaller production lines are:

- Smaller batch sizes mean less works-in-progress between processing stages and brings the company closer to the ideal of continuous flow;
- A larger number of production lines with smaller batch sizes allows for a bigger range of products to be made concurrently, therefore reducing downtime and disruptions due to changeovers.
- Smaller production lines have fewer workers and therefore lead to greater accountability among the workers at each line.

3.12 Production Layout and Point of Use Storage

Lean Manufacturing aims for the minimum amount of transportation and handling between any two processing stages. Likewise, works-in-progress should be stored as close as physically possible to the place where they will next be used. This is to reduce material handling requirements, reduce misplaced or inaccessible inventory, reduce damage to materials in transit, and to require the discipline of adhering to a pull based production system.

3.13 Kanban

“Kanban” is a pull-based material replenishment system that uses visual signals, such as color-coded cards, to signal to upstream workstations when inputs are required at a downstream workstation. In effect, Kanban is a communication tool for pull-based production. A Kanban could be an empty bin, a card, an electronic display or any suitable visual prompt.

Typically there are two main kinds of Kanban:

1. **Production Kanban** – A signal from the internal customer to the internal supplier that something is required from the internal supplier.
2. **Withdrawal Kanban** – A signal from the internal supplier to the internal customer that the supplier has produced something which is available to be withdrawn by the internal customer. In such case the internal supplier doesn’t produce more until the withdrawal is made by the internal customer.

There are many variations on the Kanban system and in fact there are many books dedicated to the topic of how to best apply Kanban.

3.14 Production Leveling

Production leveling, also called production smoothing, aims to distribute production volumes and product mix evenly over time so as to minimize peaks and valleys in the workload. Any changes to volumes should be smoothed so that they occur gradually and therefore in the most non-disruptive way possible. This will also allow the company to operate at higher average capacity utilization while also minimizing changeovers.

A key element of production leveling is that the person(s) responsible for placing orders to the factory floor should have a system for automatically smoothing out the orders so that any increases or decreases are gradual and not disruptive. This makes it easier to correctly allocate the necessary equipment and people. In order to apply this methodology, a company needs to know its true capacity as well as the rate of production at each production stage.

3.15 Pacemaker

In order to ensure the smooth functioning of continuous flow production in lean manufacturing, each workstation has to produce its product at the correct rate which is not too much or too little compared to what downstream workstations require. In order to achieve this, one workstation is often designated as the “pacemaker”. The pacemaker sets the pace of production for the whole production line and the production rates at other workstations are increased or decreased so as to match the rate of the pacemaker.

In a Replenishment Pull system, the pacemaker is usually the final workstation such as final assembly. In a Sequential Pull system, the pacemaker is often a workstation near the beginning of the value stream.

3.16 Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is a measure of the overall capacity utilization of particular pieces of equipment. OEE can be broken down into:

- **Availability** - how much time the equipment can be potentially operational after considering downtime; and
- **Performance efficiency** - the machine’s actual throughput when it is operating compared to its designed maximum capacity or the maximum it could produce based on continuous processing.

If, for example, availability is 80% and performance efficiency is 75%, then the OEE would be:

$$\begin{array}{rccccccc} \text{Availability} & & \times & & \text{Performance Efficiency} & & = & \text{OEE}^{19} \\ 80\% & & \times & & 75\% & & = & 60\% \end{array}$$

¹⁹ Sometimes quality yield percentages are also included in this equation.

When analyzing OEE, many companies may be surprised to find that there is significant room to increase the output of certain pieces of equipment. For example, they may be able to minimize:

- unnecessary equipment breakdowns;
- downtime due to set-up and adjustment;
- idling and minor stoppages due to lack of raw materials to process due to bottlenecks or poor production planning;
- Operation below maximum designed speed due to poor operator efficiency, maintenance constraints or other factors;
- defects that require re-processing;

Tracking OEE is helpful for identifying the sources of bottlenecks, for making capital spending decisions and for monitoring the effectiveness of programs to increase machine productivity.

However, Lean Manufacturing typically prioritizes the maximum utilization of people instead of the maximum utilization of machines. One reason for this is that factories that produce multiple products will not be able to use all machines at all times since the requirements may differ depending on the product being produced.

4. Implementing Lean

4.1 Senior Management Involvement

As for any significant process improvement project, the total commitment and support of the most senior management is essential. Problems will almost certainly arise during the implementation of lean production systems and those problems will likely only be solved if the senior management is fully committed to the successful implementation of lean.

4.2 Start with a Partial Implementation of Lean

Some companies may initially implement only some of lean manufacturing and gradually shift towards a more complete implementation. In a 2004 survey of manufacturing companies in the U.S. by Industry Week Magazine, among companies which had commenced lean manufacturing programs, 39.1% reported implementing some aspects of lean, 55.0% reported implementing most aspects of lean and only 5.9% reported complete implementation of lean²⁰.

Some simple first steps may include:

- Measuring and monitoring machine capacity and output;
- Creating more clearly defined production procedures;
- Implementing the 5S system for shop floor housekeeping;
- Streamlining the production layout.

4.3 Start Small

We recommend that companies try to implement lean as a test case at a small part of their operations before applying it through their entire operations, especially for the shift from a push-based to a pull-based system since this can potentially be disruptive. For example, the test case may be a single production line or a small series of processes. This will help to minimize the risk of disruption, help educate the staff on the principles of lean while also serving to convince others of the benefits of lean.

4.4 Use an Expert

We recommend that for most private Vietnamese companies, it would be best to use the services of a lean manufacturing expert to help them implement lean manufacturing systems. In particular, the shift from a push-based to a pull-based production system can potentially be quite disruptive so it is best to be guided by someone who has significant experience in this.

4.5 Develop a plan

The company should develop a detailed and clear implementation plan before proceeding with the conversion to lean manufacturing. A list of issues to cover in the implementation plan can be downloaded from the article *Building the Lean Machine* from the September 2000 issue of Advanced Manufacturing Magazine²¹.

²⁰ <http://www.industryweek.com/CurrentArticles/asp/articles.asp?ArticleID=1589>

²¹ <http://www.advancedmanufacturing.com/pdfs/buildingthelean.pdf>

5. Reconciling Lean with other systems

5.1 Toyota Production System

Although Lean Manufacturing originated with the Toyota Production System (TPS), Lean Manufacturing has been adopted by many companies and has therefore become broader than what TPS encompasses. TPS can be seen as the way one particular company has implemented lean in a very pure form. In TPS, several key themes are emphasized²²:

1. **Standard Work** – All production processes are highly specified in terms of work content, sequence of events, timing and outcome. The objective is to eliminate any variation in the way that workers perform their responsibilities.
2. **Direct handoffs** – Every customer/supplier connection must be direct, and there always must be an unambiguous yes-or-no way to communicate production requests between suppliers and customers. This ensures maximum accountability by suppliers and ensures optimal communication flow.
3. **Production flow** - The pathway for every product and service must be simple and direct, with a predetermined flow. This means that goods do not flow to the next available person or machine but to a specific person or machine and that this person or machine is as close as possible to its supplier.
4. **Worker empowerment for process improvement** - All improvements must be made in accordance with the scientific method, under the supervision of an expert, but should originate at the lowest possible level in the organization. Toyota encourages workers to propose improvements to the production process which can be implemented on a trial basis, but any changes to the production process must be defined in detail in accordance with Toyota's standards for Standard Work, as described above.

5.2 Lean Six Sigma

Six Sigma is a systematic methodology for breakthrough improvement of business processes by identifying the causes of variation in the production process which lead to defects and then eliminating that variation to minimize defects. Since a key objective of Lean Manufacturing is also to eliminate defects, statistical and problem-solving tools of Six Sigma can be used in the implementation of Lean Manufacturing. Often they are implemented concurrently in what is referred to as "Lean Six Sigma". For more on Six Sigma, please see Mekong Capital's [Introduction to Six Sigma for Private Companies in Vietnam](#).

5.3 Lean and ERP

Enterprise Resource Planning (ERP) has its roots in Material Requirement Planning (MRP) systems for which production is typically scheduled based on a push-based production plan. The schedules are updated based on information on production status which is fed from the factory floor back into the MRP system. A frequent problem that emerges with MRP systems is that the data from the factory floor on production status and inventory levels may be inaccurate or not entered on a timely basis, causing the MRP system's production plan to use some incorrect assumptions which cause bottlenecks and/or cause the MRP system to intentionally produce more buffer inventory as a precaution. Most ERP packages are designed for push-based, centrally-planned production.

More recently some ERP systems have been optimized to support lean manufacturing. Companies should consider this carefully when selecting an ERP system. For more information on evaluating the suitability of ERP systems for Lean Manufacturing, please see Brian Nakashima's article *Can Lean and ERP Work Together?* from *Advanced Manufacturing Magazine*²³.

It should also be noted that ERP systems typically include a number of modules that don't specifically relate to production planning – such as accounting, financial analysis, human resource management,

²² Steven Spear and H. Kent Bowen: [Decoding the DNA of the Toyota Production System](#). Harvard Business Review, September-October 1999.

²³ <http://www.advancedmanufacturing.com/September00/informationtech.htm>

sales management, etc. These can often be very beneficial for the company and have no direct impact on the company's ability to implement lean manufacturing.

5.4 Lean with ISO9001:2000

ISO9001:2000 is a quality management system which aims to ensure that the company has basic systems in place to consistently meet the customer's quality requirements. Relative to ISO9001:2000, Lean Manufacturing may be seen as an efficiency management system which aims to reduce all waste and inefficiency from the production process. Although these goals are overlapping in some ways, particularly insofar as they both should result in minimizing the level of defective products delivered to customers, there are substantial differences. For example, a company could have 100% conformity with ISO9001:2000 but still have very high levels of waste and inefficiency. An important distinction is that ISO9001:2000 requires that the company's processes meet certain minimum criteria, whereas Lean aims for continuous improvement in the company's processes, and provides a set of methodologies to achieve that. In general, it is considered that ISO9001 provides a good foundation for Lean and that the two are complementary to each other.

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