CHAPTER 1
INTRODUCTION AND BASICS OF LEAN MANUFACTURING

1.1 INTRODUCTION

One of the most important directions of research in contemporary times is the necessity, potentials and possibility of developing methodologies and applications tools and techniques aimed at improving machine tool manufacturing practices. This will focus primarily on cutting down wastes in operations as pioneered by Henry Ford and later practiced by the Toyota production system. The successful effort to reduce an initial assembly time of 728 minutes to 93-minutes output rate after five years of attempts by Henry Ford in his company in 1913 is the outcome of a lean effort. However, the lean drive in manufacturing has been relatively passive for many decades. Lean is usually achieved with the use of tools, including mistake proving, value stream mapping, visual management and pull-production, which are world-class tools and techniques successfully applied in other areas such as the automobile sector. This philosophy of improvement through waste reduction is referred to as lean approach. Unfortunately, despite the wide complexity of operations involved in the machine tool manufacturing industry, comprehensive experimental investigations on machine tool manufacturing using lean approaches are still not enough. The strong pursuit of such a goal to cut down wastes using lean philosophy would ensure sustainability and competitiveness of the machine tool manufacturing sector, which is
considered as a foremost sector in terms of technological innovation, particularly in India.

In the machine tool manufacturing industry, targeted wastes for reduction or elimination include defective processed parts, unnecessary transportation of worker and materials at the shop floor, excessive in-process inventories, waiting for instruction from the superior on the next action to take during operations processing, spare parts over-production and over-processing of parts and components. These wastes must be reduced or eliminated for better competitiveness of the industry. Certainly, more research is necessary in the lean manufacturing area as exemplified by the economic crisis worldwide, which has resulted in turbulent environmental conditions for machine tool manufacturing practices. Competition among the machine tool manufacturing industrial players is also keen, thus requiring a more judicious utilization of manufacturing resources and on the cautious waste-avoidance practices. Lean manufacturing, a foremost waste-cutting philosophy is therefore a potential and promising concept for the machine tool manufacturing industry. Till date, very sparse reports exist on lean manufacturing applications and the study of lean practices within the growing Indian economy with respect to machine tools industry.

Several benefits are envisaged from lean practices in the machine tool manufacturing industry (Yang et al 2011; Worley & Doolen 2006). These benefits have been mentioned as: increased flexibility, quality, customer satisfaction and communication, reduced inventory and manufacturing times.

In recent years, the machine tool industry in India has been attracting appreciable interests of researchers. By reviewing previous publications in the area, credits are given to Pullan (2011), who in his Ph.D thesis explored the machine tool industry on concurrent product and process design. Apart from Pullan (2011), researchers such as Gupta & Kundra (2012)
have added knowledge to the literature on lean manufacturing in the machine tool industry.

The Indian machine tools industry manufactures almost the complete range of metal-cutting and metal-forming machine tools. Customized in nature, the products from the Indian basket comprise conventional machine tools as well as computer numerically controlled (CNC) machines. There are other variants offered by Indian manufacturers too, including special purpose machines, robotics, handling systems, and TPM-friendly machines. Efforts within the industry are now underway to improve the features of CNC machines, and provide further value additions at lower costs, to meet specific requirements of users. In keeping with the current trends, and emerging demand, the CNC segment could be the driver of growth for the machine tools industry in India.

The hub of manufacturing activities is concentrated in Mumbai and Pune in Maharashtra, Jalandhar and Ludhiana in Punjab, Ahmadabad, Baroda, Jamnagar, and Rajkot in Gujarat, Coimbatore and Chennai in Tamil Nadu, Bangalore and Mysore in Karnataka, and some parts of eastern India.

All the global leaders namely Makino, DMG, Yamazaki, Haas, Trumpf, Daewoo, Agia Charmilles, Schuler etc. are present in India either through their marketing agents, technical centers, service centers or assembly centers. There are a number of issues of critical importance to the industry.

1.2 CHALLENGES FACED BY INDIAN MACHINE TOOL MANUFACTURERS

In recent slowdown the Indian economy had its impact on the prospects of Indian machine tools manufacturers. Stagnant demand, declining tariff barriers, pressures on margins, technology obsolescence have all put
‘fear’ in the minds of SMEs; fear of their very survival. Many SMEs’ fear is shrouded within the cloak of ‘uncertainty’ about the future. There is also lack of confidence; - they cannot face the future on their own. Such fear psychosis or uncertainty is maximum in this line of business and therefore differentiates this sector – on the very motivation behind its future progress.

Technological obsolescence in the machine tool business is extremely rapid. Product lifecycles are declining and currently the average life cycle is no more than six years. In the past, most of the products have been a result of ‘reverse engineering’. Unlike the Japanese and the Koreans, the Indian manufacturers have not graduated to the next level of ‘improving’ the technology of reverse engineered products. Thus, product technology obsolescence is a major issue facing the Indian machine tools industry today.

The restricted availability and the inability to raise resources are common to all types of small businesses. However, the machine tools sector, by its very nature, is a high financial outlay driven business. Average product costs are greater, gestation period of investments –longer, time to market–higher and the purchasing system–not yet fully matured. All these demand, greater than most other businesses, financial resource requirement. This, in turn, puts the machine tool SMEs in a particular disadvantage. No other business requires such complex level of vendor linkages as the machine tools. For materials, electrical, electronics, hydraulics, pneumatics, metallurgy, tribology, measurement controls–the list of myriad technology linkages is endless. This requires exceptional networking capabilities and plenty of time to be spent by the owner of a company/CEO himself. The business has also a very large diversity. For example, it encompasses over 200 HSS codes! This further enhances the unique complexity of the business, which is more heterogeneous.
The growing competition and technological developments in this sector are having inevitable effects on the Indian machine tool industry as a whole. The typical problems faced by the Indian machine tool manufacturers in the emerging globalization are: lack of pace in innovation, lack of professionalism and poor communication on market developments, poor product design and after sales service, prices not being competitive, and devoid of well established R&D to redesign and develop products in line with the customer needs (www.onuperu.org/wto/wgttt/unido_2005.doc).

1.3 STATUS OF MACHINE TOOL INDUSTRY IN INDIA

Currently, there are about 160 units in the organized sector and another around 800 in the tiny and small - scale sector, producing machine tools and related products. Size - wise, the industry structure is very lop - sided. 31% of the value of production comes from a Government owned public sector company (HMT). Another 53% comes from 20 mid - sized private sector companies and balance 16% from small scale and unorganized sectors.

The top 21 companies in public and private sector account for 84% of the production. The most popular types of CNC machines produced are CNC lathes, vertical and horizontal machining centres, wire cut EDM, CNC external grinders and flexible CNC SPMs. In fact, in standalone CNC machine tools Indian machine tool industry is achieving a key advantage of the volume driven competitiveness. This substantial growth makes CNC machine tools a sunrise segment of the Industry. (www.onuperu.org/wto/wgttt/unido_2005.doc).
1.4 PERFORMANCE OF INDIAN MACHINE TOOL INDUSTRY

In the global scenario, Asia accounted for 37 - 38% of world production. Singapore, Hong Kong, Malaysia, the Republic of Korea, the Province of Taiwan & Thailand continue to act as major engines of world trade and economic growth. Studies had visualized an average growth rate of 7% to 8%. Crucial element in the high growth economies of Asia and the Pacific is the issue of price sensitiveness. This will force shift of the machine tool production from high cost areas to more competitively priced Asia and the Pacific (www.onuperu.org/wto/wgttt/unido_2005.doc).

The Indian machine tool industry is way behind the global majors in production, improving its ranking from 22nd in 2002 to 21st in 2003. Considering the growth prospects and investments planned by the local industry, it could jump several notches to about the 13th position in a short span. This is the golden chance for the Indian machine tool industry (IMTMA 2012).

The industry would inevitably require special support for meeting the emerging challenges of competition by addressing the following needs: High speed machining, Machine Tools for TPM, Lean, Cellular manufacturing, Exposure through outbound missions, Capacity expansion and International alliances in design, development, manufacture and marketing. These constraints will require institutional backup to facilitate upgrading the manufacturing enterprises in a WTO compatible manner. The manufacturing units do not have the option of ‘reverse engineering’ due to WTO obligations and necessarily have to opt for innovative developments to keep pace with the technology. The industry will need to be sensitized and updated regularly on the WTO provisions and the related opportunities.
Outright purchase of technology or licensing arrangements for sustainable upgrading have generally not proved economical or even viable. Technology exposure with appropriate in-house capacity building to absorb the modular technology procured from the technology provider is the best option for remaining competitive, based upon experience of the recent past. This will in turn promote better trade in technology and also facilitate more and more application of new developments in the field of machine tool manufacture. The expansion of the trading base for available technology as well as availability of machine tool components, accessories and sub-assemblies will also result in, reduction in cost and improve commercial viability of technology options. This will further open avenues for technology cooperation and technology marketing in developing and developed countries. The technology seekers will also become technology providers over a period of time in this chain of developments. Trading in technology thus is seen as a more effective and faster mechanism of addressing the technology obsolescence issue.

1.5 RESEARCH PROBLEM

The machine tool manufacturing involves wide complexity of operations and comprehensive experimental investigations. Lean manufacturing, a foremost waste cutting philosophy is therefore a potential and promising concept for the machine tool manufacturing industry. The present problem is indentified while making a study in a medium sized machine tool factory called CLM. CLM has consistent order for 250-350 centre lathes in a year. During the detailed study it was found that on an average CLM is able to dispatch only 150-175 machines even though the resources available are much more than required. The study also revealed that the production method used was group technology and the processing was based on batch quantity. There were about 16 variants for the product and that
was one of the reasons for the delay in production. In addition the specific requirements of the customers, the design changes and other spares manufacturing etc are also contributing factors restricting smooth production. Moreover the cycle times at different workstations are not balanced and lot of time was wasted in the form of waiting, transportation and movement. The present study was taken up to address the existing production problems at CLM and to introduce an alternate method to batch quantity production in order to achieve the required production target. Lean manufacturing is considered as an alternative to mass production and was successfully implemented in many automobile industries. In line with this trend, an attempt was made in this research to introduce lean manufacturing in machine tool production. Machine tool production is considered as a low-volume high-variety production and the suitability of adopting lean manufacturing for this type of production environment is examined in this research. A well-structured questionnaire was developed as part of the study to collect the relevant data and information from the various machine tool enterprises. Machine tool manufacturers from different parts of the country participated in the survey. Medium-to-large scale manufacturers, which includes government undertakings, with significant market share for their products were approached for the survey. The survey was planned to understand the present managerial concepts in practice – how the enterprises looked at various disciplines of management, the extent of the lean manufacturing practice, and the general perception over how to impart lean in the system. The study highlighted the problems faced by the enterprises in managing the performance of the system and also focused on the current status of the various lean manufacturing tools used in lean implementation.
1.6 RESEARCH OBJECTIVES

The objectives of this research are:

- To investigate the current managerial controls and practices in medium and large scale industries with a specific reference to machine tool industry in a developing country, and to group the appropriate tools and techniques suitable for lean implementation.

- To develop a systematic procedure for implementing continuous improvement in the system through lean manufacturing principle.

- To define a generic model for lean implementation in machine tool industries and to study the adaptability of the proposed model in similar environment - low-volume, high-variety manufacturing environment.

- To systematically demonstrate how lean manufacturing tools when used appropriately can help the machine tool industry to eliminate waste, reduce inventory, lead time and finally customer satisfaction;

- To introduce value stream mapping for the existing batch production method to evaluate the lead time of manufacturing of a typical machine tool component, i.e., the bed of a centre lathe;

- To introduce cellular manufacturing and pull-type production method as an alternative to batch production;

- To develop a mathematical model for the machine tool component production to evaluate the production capability of a cellular manufacturing system for a production volume of 300 beds even before the physical implementation of the layout through simulation.
1.7 HISTORY OF LEAN MANUFACTURING

Toyota is credited with being the birthplace of lean production (Shah & Ward 2007). Figure 1.1, provides the time line of the development in the management philosophy in business as a whole.

The concept of transfer lines or assembly lines developed by Henry Ford revolutionized the automotive industry on mass production concepts. This was subsequently transferred to the other segments. After World War II, Toyota and other Japanese organizations suffered from the effects of the war. Their resources were strained and Japan needed to rebuild its industries. After the first oil shock in late 1973, the Toyota production system attracted the attention of Japanese industries. Facing unprecedented cost push inflation, most of the Japanese companies, except Toyota, faced losses. Toyota however showed high level profit. It was during this period that the Toyota production system (TPS) became popular in the manufacturing sectors, as a means of overcoming the depression caused by the oil shock.

Small lot production, frequent delivery of parts and components, leveling of production volume, reduction in set up time of dies, which were practiced under this system through multi-skill training of workers and concentrated efforts to improve the quality of products, enabled the Japanese to recover from the prolonged recession. This philosophy, along with an effort to induce flexibility in the system and with effective application of robots, manipulators, NC machine tools and machining centers gave the Japanese a worldwide competitive edge, particularly in automobile and consumer electronics industries. The Japanese products were cheaper and of higher quality when compared to their western counterparts in the American and the European market.
The Japanese companies achieved higher productivity and better quality using limited resources. The functioning of the TPS was not clear and was a black box to the western countries. Monden’s (1981) book entitled “Toyota production system – An integrated approach to just-in-time” was an
eye opener to the western world on the functioning of the Japanese manufacturing systems. The next section provides an insight into the fundamentals of Toyota production system (TPS).

1.8 TOYOTA PRODUCTION SYSTEM (TPS)

To understand the principles of lean manufacturing, it is imperative that one should understand the development and the underlying principle of the Toyota production system (TPS). TPS was evolved in the early 1973 at the Toyota motors, Japan as a tool to fight the recession faced by Toyota due to the oil Crisis. The credit of developing TPS goes to T. Ohno, Vice President Toyota motor company. In developing the system, he developed many unique ideas and implemented them, correcting them wherever necessary in the course of implementation. He gradually spread his original methods throughout the company and finally applied them to the Toyota group. His efforts were backed by the support of the top executives and the co-workers. According to (Ohno 1988), “The system was born through our various efforts to catch up with the automotive industries of the western advanced nations after the end of World War II, without the benefit of funds or splendid facilities. Above all, our most important purpose was increased productivity and reduced costs. To achieve this purpose, we put our emphasis on the notion of eliminating all kinds of unnecessary functions in the factories. Our approach has been to investigate one by one the causes of various unnecessary manufacturing operations and to devise methods for their solution, often by trial and error.” Emphasizing strongly the practical nature of the system, the TPS has been created from actual practices in the factories of Toyota; it has a strong feature of emphasizing practical effects, and actual practice and implementation over theoretical analysis.
The basic idea of the TPS is to maintain a continuous flow of products in factories in order to flexibly adapt to demand changes. The realization of such a production flow is called just-in-time production at Toyota, which means producing only necessary items in a necessary quantity at a necessary time. With the realization of this concept, waste in all forms will be eliminated, and turnover ratio of the capital (i.e., total sales / total assets) will be increased, thereby the net worth and the productivity of the company as a whole will be improved. Although cost reduction is the most important goal of this system, it must achieve three other sub-goals in order to achieve the primary objectives, which include:

- **Quantity control:** It enables the system to adapt to daily and monthly fluctuations in demand in terms of quantities and variety;

- **Quality assurance:** It assures that each process will supply only good units to subsequent processes;

- **Respect for humanity:** It must be cultivated while the system utilizes the human resources to attain its cost objectives.

In 1980, Toyota motor company’s inventory turnover ratio was 87. The average inventories (including materials) represented 4 days of sales. At the same time, Toyota motor sales company had a turnover ratio of 40 i.e., average inventories were 9 days of sales. Toyota motor company had a break-even point of 64 % in 1980, i.e., it could earn a profit even if its sales levels were to be reduced to 64 % of the volume achieved. Needless to say, this performance was made possible due to the TPS (Korgaonker MG 1999).
1.9 THE EVOLUTION OF LEAN PRODUCTION

The Western/European automotive industry realized that the Japanese way of manufacturing vehicles out-classed the European and American industries’ principles of manufacturing. A major resource project was therefore initiated at the end of 1980 by Womack et al (1990) at Massachusetts Institute of Technology. This project, called “The International Motor Vehicle Program (IMVP),” was aimed to investigate and compare the Japanese Automotive industry with the western automotive industries. The IMVP study showed a significant gap in productivity and the quality between the Japanese vehicle assemblers and the rest of the vehicle assemblers in the world. The “Lean Production” was coined in the report as a description for the success of Japanese production philosophy. The IMVP research states: “The lean production is lean because it uses less of everything compared with mass production -- half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects and produces a greater and ever growing variety of products.”

The IMVP report war was recognized all over the world and ended up in the famous book “The Machine That Changed the World”. The Americans and Europeans felt, if lean production is the key to the Japanese superiority, the reasonable consequence should be to try and understand how the Japanese companies managed to become lean and if it is possible for them to practice lean production outside Japan. With the publication of the book “The machine that changed the world (Womack et al 1990)”, lean manufacturing practices have found acceptance in many manufacturing operations over more traditional mass production techniques. Womack et al
(1990), studied the implementation of lean manufacturing practices in the automotive industry on a global scale.

Lean production does not confine its activities within the walls of the production system in an organization; it rather relates to activities ranging from product development, procurement and manufacturing over to distribution. Together these areas found a lean enterprise. The ultimate goal of implementing lean production in an organization is to have the customer in focus when improving productivity, enhancing quality, shortening lead times, reducing cost etc. There are factors indicating the performance of the lean production system. The determinants of lean production system are the action taken, the principles implemented and the changes made to the organization to achieve the desired performance.

Several researches investigated the content of lean production and the methods that are used to become ‘lean’. A number of models that describe the content of lean production have been evolved. The first fundamental principle is multifunctional teams. The team can be formed on different levels in the organization, above all among operators on the shop floor. The purpose of working in multifunctional teams is to develop multi-skilled employees who can compensate each other in the teams and achieve better solutions by taking advantage of different functional aspects when solving a specific problem. It also means that most of the problems can be solved within the group, without any external help. The second principle is the use of vertical information systems. This principle emphasizes the importance of information flow. Accurate information flow is inevitable to manage the organization, and is also a means for decentralizing responsibility. Employees who do not have information cannot take responsibility and employees who have information cannot avoid taking responsibility. An example on how information can be used in the company is the distribution of key performance indicators, such as
productivity and quality measures. The next principle is the elimination of buffers. This principle implies an ambition to reduce all kinds of buffers, especially time buffers and inventory. The buffers are considered to hide problems, such as process instability, lack of quality and uncontrolled variation. Instead of solving the problems, buffer hides them. The fourth fundamental principle is the lack of indirect resources. Instead of using specialists in problem solving, for example, quality control, the problem should be solved wherever it appears. The objective is to move the competence to where the work is done, to achieve problem solving at the source. And the last principle is the integration of networks. There are many kinds of networks, of which one of the most important is to integrate the supplier network. Grouping different shop floor operations together in cells or flows is another example of integrating networks. Figure 1.2 describes the model of lean manufacturing framework suggested by the IMVP study.

![Figure 1.2 Lean manufacturing framework (Karlsson and Ahlstrom 1996)](image-url)
Lean manufacturing evolved from Toyota Production System (TPS), and well defined by the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology, does not confine its activities to the manufacturing system but extend to all areas. A number of research models have been evolved to describe the lean production, namely: multifunctional teams, vertical information system, buffer elimination system and integration of networks among others.

1.10 LEAN MANUFACTURING PRINCIPLES

Traditional manufacturing systems are built on the principle of economies of scale. Here, the large fixed costs of production are depreciation-intensive because of huge capital investments made in high-volume operations.

These fixed costs are spread over large production batch sizes in an effort to minimize the total unit costs of owning and operating the manufacturing system. Large work-in-process inventories are also characteristic of traditional manufacturing. The resultant “batch and queue” operation produces large numbers of a particular product and then shifts sequentially to other mass-produced products.

As an alternative to batch-and-queue, high-volume, and inflexible operations, the principles of the Toyota Production System (TPS) have been widely adopted in recent years. Application of TPS principles have led to lean manufacturing (also called lean production, or lean thinking (Womack and Jones 1996) in which production and assembly cells consisting of product focused resources (workers, machines, floor space, etc.) are closely linked in terms of their throughput times and inventory control. These cells are typically U-shaped or rectangular and lend themselves to smooth (balanced)
workflow across a wide variety of products, elimination of waste, high quality output, flexible operation, and low total unit production costs.

Economic benefits attributable to lean manufacturing include reduced lead-time and higher throughput, smaller floor space requirements, and lower work-in process. Lean manufacturing can be understood at different contexts. Lean, as a philosophy drives the goals and culture, as foundational aspects of quality control on which it is built, as a business strategy to handle the customer needs and as skills which are utilized in the control to become Lean. Figure 1.3 is the house of Lean, a descriptive metaphor in graphic format that will assist in understanding how all these aspects work together to describe the mature Lean Manufacturing system.

![The Lean Production System](image)

**Figure 1.3 House of Lean (Wilson 2010)**

Lean as philosophy, which focuses on growth by generating value for the customer, society, and the economy with the objectives of reducing
costs, improving delivery times, and improving quality through the total elimination of waste. Wastes could occur in the management, clerical, sales, administration, and factory workers. The most common wastes are: Overproduction, Inventory, Transportation, Defects, Processing Waste, Operating Waste, and Idle Time Waste. Reduction of any wastes will increase productivity, reduce costs and make the company more competitive in the global markets. It will increase the desirability of the company’s products; the customer base will grow and require more workers to meet the demand.

As business model, it delivers superior performance to customers, employees, shareholders and the society at large; at the same time, it delivers the customers exactly to their requirements. This is done by freeing up capacity to deliver more value from existing resources with fewer additional costs. With the shortening of product lifecycles and increased product variety, the manufacturing industries today face enormous challenges concerning the satisfaction of the customer’s demands. Customers expect short lead time in the changing demand scenario. This means that a production system has to be able to adapt itself to the dynamic market changes. Increase in flexibility also results in higher cost. From an economic point of view, a lean production system should not be more flexible than absolutely necessary.

1.11 LEAN IMPLEMENTATION

Applying the philosophy of lean requires a fundamental shift in the way one thinks about business processes. Lean philosophy is all about eliminating waste. Any action or process that does not add value in the eyes of the customer is waste and should be prevented or eliminated. For example: View the activities in the processes from the perspective of the customer. Which activities in the process add value for the customer? Think from the perspective of the part, product, or service as it goes through the process. Walk the path that a part travels. Look for ways to reduce the distance
travelled and reduce the number of times the part is handled. View the process as end-to-end, not just as individual steps. Don’t optimize individual areas while sub-optimizing the whole. Look for ways to standardize processes across products. When the operations are lean, each remaining activity adds value from the customer’s perspective. Activities that do not add value represent wastes. Each type of waste adds cost and delay to the product or service but doesn’t add value for the customer. To stay ahead in today’s highly competitive global economy; waste in the enterprise must be identified and eliminated.

Overproduction is the worst form of waste because it leads to many other types of waste. With overproduction there is a greater risk of damage to the product and also the requirement for additional investment in space, raw material, and people. Frequent product or engineering changes can also lead to rework or scrap. And for industries with volatile demand and frequent new product introductions, overproduction leads to obsolete inventory.

1.12 ELIMINATION OF WASTE

The critical starting point for lean thinking is value. Value can only be defined by the ultimate customer, and it is only meaningful when expressed in terms of a specific product which meets the customer’s needs at a specific price and at a specific time. Value is created by the producer. Everything that does not add value to the product is waste, and is something that the customer is not willing to pay for (Karlsson and Ahlstrom 1996). Identification and elimination of waste makes it easier to focus on value adding activities and become more cost efficient. Ohno (1988) described seven sources of waste commonly found in the industry. The sources of waste are given in Table 1.1.
<table>
<thead>
<tr>
<th>Types of wastes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over production</td>
<td>Supplying the customer, process with more than is needed, sooner than it is needed or faster than it is needed, causes almost all other types of waste.</td>
</tr>
<tr>
<td>Excess Inventory</td>
<td>Raw materials, work in process, finished goods.</td>
</tr>
<tr>
<td>Waiting</td>
<td>Watching machines run or cycle, waiting for parts, tools, instructions, information, approvals or decisions, waiting for the next operation. However, if in the process of waiting, the worker generates some useful (valuable) work, then the waiting activity is not a waste.</td>
</tr>
<tr>
<td>Motion</td>
<td>Walking without working, searching for tools, materials or information, reaching, bending, excess motion due to poor housekeeping, moving work from one fixture or position to another</td>
</tr>
<tr>
<td>Non value added</td>
<td>Repair or rework steps, extra setup steps, over specification of the process engineers, converting information in one form to another. This is especially wasteful when done manually and when measuring the wrong things. Examples of waste include manual processes to convert planning system output to a schedule that can be used by the lean factory.</td>
</tr>
<tr>
<td>Defects</td>
<td>Defective or scrap materials, out-of-statistical control processes, low yield, incorrect schedules, engineering documents, information.</td>
</tr>
<tr>
<td>People’s Skills</td>
<td>Treating employees only as a source of labor and not recognizing them as true process experts.</td>
</tr>
</tbody>
</table>
1.12.1 Waste – Overproduction

Waste from overproduction is a serious waste. There is no reason to produce items when it is not demanded. Traditionally “maximum resource utilization”, was the philosophy – leading to over production. Men and Machines should only be busy when they have useful tasks to accomplish. The production rate should be set by the customer’s demand and not by other factors. If more orders are released to the shop floor than demanded, the products must be handled, counted, stored and so on. Products stored as inventories increase the cost of production and the selling price.

Overproduction is more common when the forecast is inappropriate. It is often difficult to develop a forecast that exactly matches the customers’ demand. The system’s ambition is to produce to customer order only. This is not always possible if the customers’ demand on delivery speed is shorter than the lead time for producing the products. Forecasting must be used, and overproduction can only be avoided with accurate forecasts, which is not always easy to evolve. However the customer order point should be moved upstream the production flow as far as possible, which means that the products are dedicated as early as possible to a specific customer order.

1.12.2 Waste of Motion

Motion consumes time and energy. Eliminate motion that does not add value, such as searching for tools and moving material within the station, will reduce the energy spent. This objective should be guiding when designing workplaces, processes, operation procedures etc. Reducing waste of motions encompasses everything from describing detailed hand motions in assembly to selection of machines and design of fixtures to reduce the time for set-ups and material handling.
1.12.3 Transportation Waste

Waste due to transportation includes unwanted movements of material, work-in-process and components, which do not add any value to the system. It adds to the manufacturing lead time. In a well-designed system, work and storage areas are positioned to minimize the transportation work. For instance, if machines can be grouped together in a cell-based layout, the physical connection of the flow of products renders a faster truck useless. The layout in many factories is designed from a mass production perspective. Equipment and machines are often grouped together on a functional basis. In lean manufacturing, the layout is rather designed to create a smooth flow of products through the factory with less transportation between different workstations. Grouping products into product families and dedicate equipment to each family is sometimes necessary in order to achieve a flow with as little transportation as possible. The product families should be the basis when designing the factory and not the function of the equipment.

1.12.4 Process Waste

Incorrectly designed processes are a source of waste. The processes in the organization must therefore be continuously reviewed and improved. Activities in processes can either add value to the customer, be necessary for the function of the process or non-value adding. Changing design of parts, limiting functionally unnecessary tolerances and rethinking process plans can often eliminate and simplify process activities in the manufacturing process. A tool for identifying and eliminating non value adding activities in processes is process mapping. A process map identifies each step in a process by using graphical symbols for different activities and links them together with arrows. For example an action of some sort is recorded in a box, and a decision is recorded with a diamond shape. The purpose of this is to ensure that all the different stages in a process are included before the process design is analyzed.
and improved. A detailed map of a process often reveals unnecessary stages and sequences, and can be used to improve the process design.

1.12.5 Defective Products

Poor quality parts and products are sources of wastes they need to be reworked on to bring in value to them. The level of wastage is especially significant in the scrapping of parts that obviously does not add value to the customer (Karlsson & Atilstrom 1996). Cost incurred, resource depletion and the negative impact of customer perception are some of the negative consequences of producing defective products (Kuruppalil 2007). Lean manufacturing emphasizes the importance of identifying the root-cause when a quality problem appears. The sources of the problem must be taken care of and not only the symptom. The possibility of quickly detecting a quality problem is closely related to the levels of inventory kept between operations. Using big lot sizes increases the time until the next downstream operator can detect the problem. This can cause an entire batch to be scrapped. A flow of one part at the time implies that a problem is detected when it occurs and the operator causing it can get instant feedback from his downstream ‘customer’.

1.12.6 Waste of Time

Waiting for correct information, products waiting to be processed, machines waiting for their operators and waiting for materials to arrive are examples of waste of times. One of the most common wastes of time is products waiting in inventory. An investigation of a product’s flow through the factory often shows that it is only being processed a few percent of the total throughput time. The rest of the time is waiting in inventory, which is pure waste. Reducing inventory is an important issue when reducing waiting time. A tool for identifying the products flow through the factory is value stream mapping. Value stream mapping is a variant of process mapping
adapted to the manufacturing process. Processing times, throughput times, set-up times, inventory levels etc. are mapped with standardized symbols. The map reveals the relationship between waiting and processing time. It is not uncommon to find that the value creating processing time is only few percent of the waiting time.

1.12.7 Excess Inventory

Inventory in the system helps to overcome fluctuations in the demand but also adds up to the overall production cost. It is imperative that the system operates with minimal inventory. In conventional manufacturing system, inventories were held to hide certain problems from being surfaced out during the production process. Inventory also hides other problems and prevents their solutions. Inventory in a system can be classified as Raw Part Inventory (RPI), Work In Progress (WIP) and Finished Goods Inventory (FGI). Excess inventory in the system is considered as waste and JIT philosophy aims to work with Zero inventories. WIP is the inventory held between operations.

Buffer inventory is held to absorb variations in supply and is a security towards the risk of running out of parts. WIP buffers are there because of variations in processing time, both in the supplying operation and in the demanding operation. The variation can be caused by:

- Variation in product models;
- Variation in skills between different operators;
- Defects in material or components;
- Problems that occur during assembly or processing.
Hopp & Spearman (2004) have empirically showed the relationship between WIP buffers, throughput time and production rate. Throughput time is the time for a specific product to go through the production flow, and the production rate at which the products leave the production. Instead of using WIP buffers, time buffers on each operation can be used.

Lean manufacturing emphasizes the importance of reducing inventory, since it is considered to hide productivity problems caused by unwanted variation and complicated set-up procedures. Inventory can be reduced by either reducing buffers or batch sizes. Buffer inventory is reduced by eliminating unwanted variation and cycle inventory, by decreasing set-up costs and batch sizes. The positive effects of reducing inventory are: Less capital tied up in inventory, shorter throughout times, lower cost for material handling and smoother production flow. The different causes and its effect on production of waste is shown in the Figure 1.4

![Figure 1.4 Different causes and its effect on production of waste](image-url)
1.13 PULL-TYPE CONTROL SYSTEMS

The pull-type production hinges on a make-to-order system that depends on actual customers’ demand. Pull production system is purely based on the customer demand. The information and the material flows are in the different directions in a push production system. The pull-system produces quantities purely depending upon the customer needs. In a pull-type production system, the process starts with literally receiving the customer orders. Once the customer orders are received, the order is converted into production order which triggers production. In many cases, Kanban is used to incorporate the customer needs. Kanban is used to give a clear idea of the number of parts to be produced, the preceding and the following process. Once the production order is received, the downstream operations request for parts from the upstream operations. Pull system is characterized by the practice of downstream work centers pulling products from previous work centers. When the work station receives production orders it starts production. The upstream work centers in turn requests the preceding station for product.

![Diagram of a typical pure pull production process]

**Figure 1.5 A typical pure pull production process**

The above process continues until the first work centre is reached. The downstream operation pulls products from the upstream operation. Once the material is pulled from the stores, the material passes through the production line. The product which is pulled through the production line is converted into a finished product and then supplied to the customer. Figure 1.5 illustrates the typical pure pull production processes (Selvaraj 2009). A
Kanban system is a common example of a pull production system that is extensively used in industry. The Toyota production system has made the word Kanban so synonymous with the pull system, which they practice, that pull systems are often referred to as Kanban systems. In Japanese, Kanban means display or a card. Kanban in a pull system is an authorization to produce. It is a signal from a downstream manufacturing process that prompts the upstream process to begin production of a component that has been consumed from inventory. The two things that have become integral to the pull type manufacturing system are: Kanban cards, standardized containers. The containers are used to standardize the production batch sizes, protect the material from damage and also assist in maintaining visual control of the WIP inventory. Production is usually triggered by a Kanban signal which usually comes from a customer order, then the signal flowing via each work centre. Each work-in-process container is attached with a Kanban specifying the details of the particulars such as product name, part code, due date, batch size, card number etc.

Though Kanban type pull-systems are most commonly used, there exist other pull systems, like POLCA (paired-cell overlapping loops of cards with authorization), CONWIP (Constant WIP), and DBR (Drum-buffer-rope). POLCA is a generic card system in which the cards are circulated immediately after a product exits the last of the two cells in a loop. With CONWIP, an authorization to produce the next batch is produced when another batch is removed from inventory, regardless of the product type. DBR is a system in which the master schedule sets the production rate according to the output rate of the bottleneck resource.

By implementing the pull-system, many manufacturers have achieved reduced inventory, increased productivity, smoother production flow, increased customer satisfaction, and reduced total costs, higher
production visibility. The prior aim of pull-system is zero or unit inventory. Pull-System will minimize work in process inventory. Pull easily respond to changing customer demands. Pull-system ignores future demand patterns.

1.14 MULTIFUNCTIONAL TEAMS

The creation of multifunctional teams among the shop-floor workers is one of the first and most important steps in the implementation process towards lean manufacturing. The implementation towards lean manufacturing does not have to start with the creation of teams but it will certainly help when implementing the other steps. Lean manufacturing demands creative workers who are interested in their work situation. This means that the individual worker has more demand and pressure on himself. Because lean is about making the production more efficient it may in a shorter cycle time with simpler assembly tasks.

1.15 DECENTRALIZED RESPONSIBILITIES

The decentralized responsibility to the shop floor workers is one of the key factors in the lean manufacturing philosophy. All work tasks that workers can handle on their own or in their teams, should be given to them. It is a waste of managers’ and supervisors’ time to handle duties that the workers can perform. To achieve this, the organization has to improve its vertical information system, as it is a critical factor to change in order to achieve sustainable effects in the organization. If there is a strict and bureaucratic channel in which the information is communicated, it will lead to a slow and inefficient organization. Improving the vertical information is supposed to make the organization more efficient in its way of exchanging information.
### 1.16 KAIZEN

A continuous improvement in lean manufacturing means that everyone in an organization is continuously working to improve the production process. Increasing demand from customers and harder competition makes continuous improvements necessary. Lack of quality is often a considerable cost in many organizations, which is another reason for working with improvements. In lean manufacturing the work with continuous improvements is often carried out within multifunctional teams on the shop floor and in the cross-functional groups. A cross-functional group consists of people from different areas in the organization. For example some specialists, a team leader and some operators form a group.

### 1.17 A ROADMAP TO LEAN MANUFACTURING

There is no well-defined procedure for lean implementation. The procedures adopted by different firms vary drastically. In general the implementation starts within the organization. Successful implementations involve active participations by players both inside and outside the system. A more generic procedure for adoption involves, determination of the value of the product or service from the customer’s point of view, Mapping of the end-to-end processes that takes the product from raw material to the customer, incorporate a pull control or partial pull control in the system, and elimination of waste in the system. This helps in reducing the inventory as well as lead time. Other potential benefits of lean include: Reduced labor costs, reduced storage costs, higher quality goods and improved cash flow. Realizing these benefits requires using the appropriate tools, at the appropriate time. The most important tool is value stream mapping.
1.18 CONCLUSION

This chapter provides a brief introduction to lean manufacturing, the status of Indian machine tool industry and the challenges faced by the industry. The problem identification and the research objectives are clearly spelt out in the first part of this chapter the second half describe on the history of the lean manufacturing, Toyota production system (TPS), the evolution of lean production, the lean manufacturing principles and their implementation in a broad perspectives. Elimination of non value addition activities brings forth leanness in the system. Lean is a continuous improvement process and there is no means to quantify the end to the implementation process. The system’s improvement increases multiple folds as the level of commitment increases in the system.