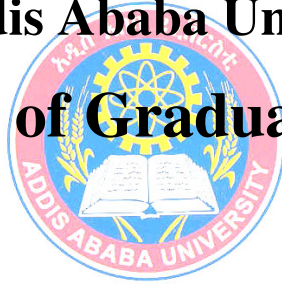


**Addis Ababa University**  
**School of Graduate studies**



**ASPECTS OF**  
**LEAN AND AGILE MANUFACTURING**  
**SYSTEMS**  
**AND THEIR**  
**APPROPRIATNESS**  
**IN ETHIOPIA**

**A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in  
partial fulfillment of the Degree of Masters of Science in Mechanical Engineering  
(INDUSTRIAL ENGINEERING STREAM)**

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**Addis Ababa**

**October 2004.**

## **Dedicated To My Son**

*To Fa'iz Idris* whose sincere love and affection was a means of relief to the stresses imposed by depressing learning atmosphere in AAU.

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*IDRIS ZEHRUDIN*

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## Abstracts

The thesis deals with the principles of *Lean and Agile Manufacturing Systems* and their appropriateness in Ethiopian context. Inflexible mass-production methods that produce voluminous of standardized products were inadequate for demands of increased variety. In pursuit of *greater flexibility* and elimination of manufacturing wastes, Lean Production System has been developed. More recently, demand for further responsiveness to the ever-changing customer demand and turbulent business environment, led to a formulation of Agile Manufacturing concept with the intention of *greater adaptability*. Thus, it is necessary to study their vital principles and adopt the appropriate system to improve the competitive capability of industries.

Using available literatures, Internet, industry survey and analyzing the gathered pertinent information, the thesis reviewed the main principles of lean production system. Taking authentic pilot cases, enhanced *value stream map is generated* and *lean Manufacturing Cell* for cutlery production is designed. The fundamental principles of agile manufacturing system and then, the comparison of the two systems are also discussed. Finally the suitability of these systems in Ethiopia context is analyzed.

It is found that **Lean Manufacturing** is a *collection of technical and operational systems* focused on productivity improvements with limited resources (44). LPS focuses on minimizing manufacturing wastes, continuously improving methods, utilizing flexible production system to produce variety of defect-free goods. *Agile manufacturing (AM)*, on

the other hand, is a comprehensive manufacturing system focused on thriving in unpredictable business environment. AM focuses on *enriching* customers, *reorganizing production system* for *greater flexibility*, cooperation to enhance market responsiveness and increased use of Information technology.

The comparison between these systems shows a difference in viewpoint and perhaps strategy with regard to change, but not in method or approach. Cases on the implementation of Lean techniques indicate that industries can enhance competitiveness by adapting Lean. The survey revealed that Industries are experiencing forces that lead to more responsiveness. More over, it is found that most industries believe that the Lean Production is more appealing in current Ethiopian Industries Situation.

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## Acronyms

AGV:	Automated Guided Vehicles
AMEF:	Agile Manufacturing Enterprise Forum
AMS:	Agile Manufacturing system
ASPSC:	Akaki Spare parts Share Company
BPR:	Business Process Reengineering
CAD/CAM:	Computer-Aided Design / Computer-Aided Manufacturing
CE:	Concurrent Engineering
CIM:	Computer Integrated Manufacturing
CM:	Cellular Manufacturing
CM:	Cellular Manufacturing
CNC:	Computer Numerical Control
CT:	Cycle Time
D&M:	Design and Method
FMS:	Flexible Manufacturing System
FWS:	Foundry Workshop
HCF:	Hand Tools and Cutlery
IQC:	Integrated Quality Control
IT:	Information Technology
JIT:	Just-in-Time
LPS:	Lean production system
MT:	Machining Time
MWS:	Mechanical Workshop
OT:	Operation Time
POK:	Production Order Kanban
PPC:	Production planning and Control
RRS:	Reconfigurable, reusable, Scalable
SMED:	Single Minute Exchange of Die
SQC:	Statistical quality Control

TPS:	Toyota Production system
TQM:	Total Quality Management
VA/VE:	Value Analysis /Engineering
VMS:	Value Stream Mapping
WIP:	Work-in-Process
WLK:	Withdrawal Kanban

# Chapter 1: INTRODUCTION

## ***1.1. Problem Formulation***

- Many manufacturing industries are increasingly requiring much greater flexibilities and timelines, due to market instability,
- Worldwide (global) competition among manufacturers has increased significantly that tend to force weak firms out of business,
- Need for better and promising production system approach became mandatory for the survival of industries in the ever-changing business environment.
- Ethiopian manufacturing industries are facing structural problems that hinder their competency.

## ***1.2. Analysis of Problem***

Major changes in the world of manufacturing have taken place. These are global competition, quick exchange of advanced technology, and development new manufacturing system structures, strategies, and management.

Worldwide (global) competition is now a fact of manufacturing life and this trend will continue in the future. Goods bought today may have been made any where in the world. The advanced manufacturing technology is usually referred to new processes. This new technology is often can be purchased from the companies who developed the machinery.

This approach is important but may not provide unique competitive advantage in that competitors who have the capital could buy it. (15)

The business of manufacturing is no longer a 'process only' activity. Traditional manufacturing process had a limited perspective of dealing with transformation of material. Manufacturers now proclaim that the process is no more or no less important than the system. For manufacturing to excel, it must include dramatic improvement in systems. (43)

Perhaps, the real key to success in manufacturing is to build a manufacturing system that can deliver on time to the customer superior-quality goods at the lowest possible costs in a flexible way. This reflects an effort to improve markedly the *methodology* by which goods are produced rather than simply upgrading the process technology. (15)

Even though the free market economy policy of Ethiopia ascertains the base for the growth of manufacturing and the implementation is going smooth, the manufacturing sector is still at its infant stage. Most of the industries are suffering from problem of structure, lack of focus on manufacturing wastes and product quality; low level of technological supply, and weak cooperation.

Most of the local industries have been established on the objective of import substitution. But, now a day, there is no such internally oriented market. Since the world is getting much closer and linked with business, focusing only on domestic markets is not viable. The market is open for neighbor countries, as well as for emerging continental and global trade. Manufacturers, regardless of their industries or the condition of their business, are forced to make major reductions in manufacturing costs using every conceivable means.

### **1.3. Objectives of the Study**

The **general objectives** are:

- To discuss the main principles of lean and agile manufacturing systems
- To analyze the conceptual differences and appropriateness of the two systems.

The **specific objectives** of the thesis are:

1. To give better view of Lean and Agile Manufacturing Systems principles, which are the competitive approaches of global production industries,
2. To clarify differences and similarities between Lean and Agile system approaches,
3. To show methods of improving the manufacturing performance,
4. To demonstrate the application of Lean using real manufacturing cases,
5. To assess current challenges of manufacturing industries in Ethiopia,
6. To examine the appropriateness of LPS and AMS in Ethiopian Context,
7. To recommend adaptation of the better system in Ethiopian context.

### **1.4. Research Methodology**

The methods of study used throughout this thesis comprise:

1. Literature survey and internet surf
2. Data and information gathering
3. Industry survey and questionnaire
4. Analysis and synthesis
5. Peer discussion, interview and personal observation

### ***1.5. Scope and Limitation of the Study***

It is clear that such a huge research topic demands long period of time to comprehend every detail of the subject matter. More over, the availability of material resources on the topic is scarce. As a result, the study is restricted to the main issues of the two production system based on the existing internet and library materials, and survey of limited nearby industries.

### ***1.6. Relevance of the Study***

Manufacturing is a transformation of inputs to usable outputs there by adding value to the input. It is the basis for the measure of prosperity of developed nations. In this context the reason for developing countries to be far behind industrialized nations can be partly attributed to lack of following appropriate manufacturing approaches. It is relevant then, to deal with the temporary production systems approaches to strengthen the manufacturing competency.

### ***1.7. Back Ground to Manufacturing Systems***

Manufacturing is the economic term for making goods and services to satisfy human wants. The manufacturing processes are collected together to form a manufacturing system (MS). The word system is used to define a relatively complex assembly (or arrangement) of physical elements characterized by measurable parameters that defines the boundary / constraint of the system and predict its behavior in response to excitation / disturbances.

The inputs to the manufacturing system include materials, information, and energy. The system is a complex set of elements that include machines, people, material handling equipment, and tooling. The materials are processed within the system and gain value. The manufacturing system outputs may be consumer goods or inputs to some other processes.

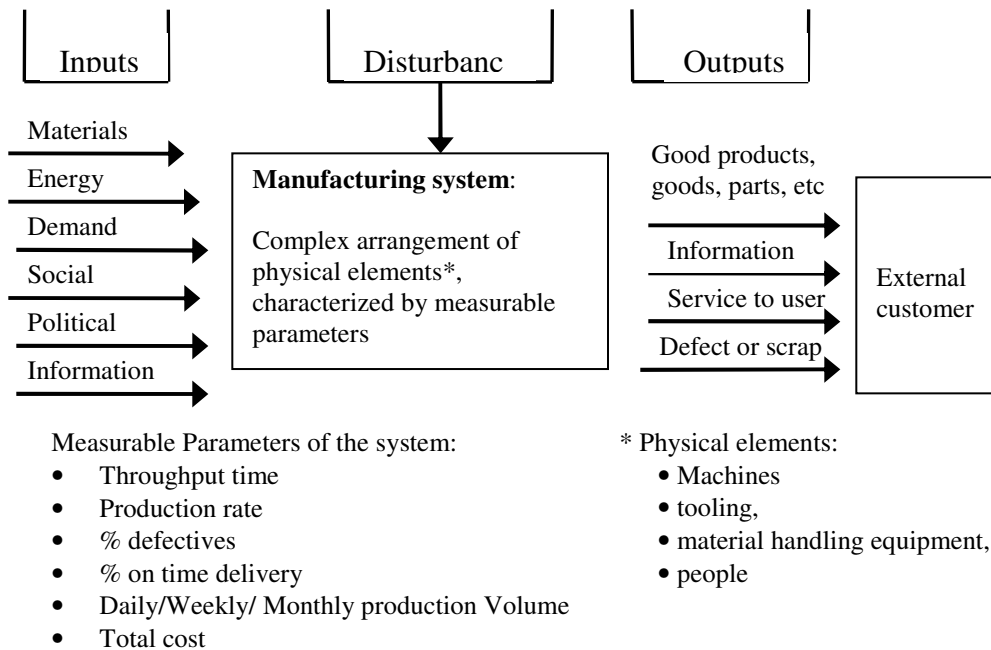
Fig 1 gives a general definition for any manufacturing system. It can be observed that many of the inputs can't be fully controlled, and the effect of the disturbance must be counteracted by manipulating the controllable inputs or the system it self. Controlling material availability or predicting demand fluctuations may be difficult. The business environment can cause change in any of these inputs. (15)

Since the mid-1970 the variety of manufacturing system types has grown considerably. Since that time, Flexible Manufacturing Systems, Agile Production Systems, and Lean Cellular Systems, have become accepted types of manufacturing systems. Prior to that, the main types of systems were limited to Job Shops, Disconnected Flow Lines, and Transfer Lines.

It is necessary to understand each type of manufacturing system and the advantages and disadvantages of each. Five production system types are briefed below. In reality, the line between the types is often hard to distinguish.

- i. **Automated Transfer Lines** – are Manufacturing systems that use dedicated automated machines that are specially designed with a particular model of product in mind. These systems tend to be expensive due to the engineering and custom development required. They generally support very few products or models. Due to the relative high cost to

retool, they are used for products with long life cycles. Therefore, these systems are most profitable only at the production level for which they were designed.



**Figure 1 View of a manufacturing system with its Input/output Condition**

ii. **Job Shop** – A Job Shop style manufacturing system uses standard flexible machines, which are not oriented or configured for any particular product. Instead, products flow from machine to machine in whichever order is necessary. Parts are not automatically transferred from one machine to another. Job Shops generally produce in batches. For instance, a batch of 100 parts of a particular type is processed at one machine, and then the batch is transported to the next machine. The machines in Job Shops generally have long changeover times, are labor intensive, and require complex scheduling. However, the Job Shop is the most flexible system type in terms of product variety for low volume products.

- iii. **Flexible Manufacturing System** – A Flexible Manufacturing System (FMS) is essentially an automated Job Shop. The machines are organized in a similar way and support a wide variety of products. Generally, material transport between machines is automated with robots or Automated Guided Vehicles (AGVs). Machine changeovers may be automated. An FMS requires less direct labor, but more investment than a Job Shop. As in Job Shops, machines are generally operated in parallel and are not designed or specified based on Takt time. This type of operation can increase system-wide changeover times and cause problems in the identification of quality problems.
  
- iv. **Agile Cells** – Agile Cells consist of clusters of modular machines which function in a similar manner to an FMS. Agile cells conform to the RRS Design Principles: Reusable, Reconfigurable, and Scalable. The modular machines are built around a common architecture. This facilitates quick exchanges of modules when one fails or a new product must be produced. This also supports capacity increases and decreases by adding or removing modules. To date, Agile Cells have been utilized primarily in electronics fabrication where high equipment cost, short product life cycles, and delicate part handling are necessary.
  
- v. **Lean Manufacturing Cells** – Cells tend to be flexible both in terms of volume and product mix. Cells give workers more control over the manufacturing system. The inherent flexibility of the worker is harnessed to build various products or models with zero changeover time. Workers also enable volume flexibility. If demand for a particular product family increases, more workers are assigned to the cell responsible for that product family. When demand decreases, workers are removed from the cell.

Attributes of the product that may dictate the type of system required include: the volume demanded, the certainty of that volume forecast, the mix of products to be produced, the expected product life, and physical attributes of the products. Some products have other requirements that limit the choices of a manufacturing system. Human hands cannot handle electronic devices; hence they must be manufactured in a system with automated material handling. Table 1 shows the characteristics of various manufacturing system types. (40)

**Table 1** Characteristics of various manufacturing system types

	<b>Volume Certainty</b>	<b>Product Mix</b>	<b>Product Life</b>
Automated Transfer Line	High	Low	Long
Job Shop	Low	High	Short
FMS	Medium	High	Short
Agile Cell	Medium	Medium	Medium
Lean Cell	Low	Medium	Medium

## Chapter 2 : LEAN PRODUCTION SYSTEM

### ***2.1. Lean Production Overview***

What is lean production? Perhaps to describe this innovative production system is to contrast it with craft production and mass production, the two other methods humans have devised to make things.

*The Craft producer* uses highly skilled workers and simple, but flexible tools to make exactly what the consumer asks for, one item at a time. Custom furniture, works of decorative art, and a few exotic sports cars provide current day examples. All love the idea of craft production, but goods produced by the craft method cost too much for most to afford.

*The mass producer* uses narrowly skilled professionals to design products made by unskilled or semiskilled workers tending expensive, single-purpose machines. These churn out standardized products in very high volume. Because the machinery costs so much and is so intolerant of disruption, the mass-producer adds many buffers - extra supplies, extra workers, and extra space – to assume smooth production. Because changing over to a new product costs even more, the mass producer keeps standard design in production for as long as possible. The result: the consumer gets lower costs but at the expense of variety and, by means of work methods that most employees find boring and dispiriting.

*The lean producer*, by contrast, combines the advantage of craft and mass production, while avoiding the high cost of the former and rigidity of the latter. Towards this end, lean producers employ teams of multi-skilled workers at all levels of the organization and use highly flexible, increasingly automated machine to produce volumes of products in enormous variety.

Lean production, a term coined by International Motor Vehicle Program (IMVP) is '*lean*' because it uses less of every thing 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. Also, it requires keeping far less than half the needed inventory.

Perhaps the most striking differences between mass-production and lean production lie in their ultimate objectives. Mass producers set a 'good enough' goal, which translates into an acceptable number of defects, a maximum acceptable level of inventories, a narrow range of standardized products. Lean producers, on the other hand, set their sights explicitly on perfection: continually declining costs, zero inventories, and endless product variety.

***The Rise of Lean Production:*** In 1950 a Japanese engineer Eiji Toyoda set out a three-month pilgrimage to Ford's Rouge plant. After carefully studying every inch of the vast Rouge, the then largest and most efficient manufacturing facility, he thought on the possibilities of improvement in the production system. Back at home, Eiji Toyoda and his production genius, Taiichi Ohno, concluded that mass production could never work in Japan. From this tentative beginning were born the 'Toyota Production System' and ultimately, Lean Production.

In 1937, Toyota entered the motor vehicle industry from textile by the urge of the government, specializing in trucks for military. It had barely gone beyond building few prototype cars. After the War Toyota was determined to go into full-scale car, but faced with a host of problems:

- The domestic market was tiny demanding wide range of vehicle,
- The native Japanese workforce was no longer willing to be treated as variable cost or as interchangeable parts.
- The economy was starved for capital to purchase massive production technology.
- The world was full of huge motor vehicle producers who were anxious to establish operations in Japan.

**Quick die change:** Bodies of vehicles are stamped from sheet steels in two ways: craft producers cut sheets, beat blanks by hand on a die to their final shape; mass producers use automated precision ‘blanking’ press. These efficient and expensive dies were not economical for Toyota. To overcome these problems, Ohno experimented the techniques of quick-change on used presses, which resulted in three minutes die-change. Since the new techniques were easy to master, the die change task was left for the production workers.

**Toyota Company as Community:** The employees in Toyota received a guarantee of lifetime employment. In return, they are expected to remain in the company for their working lives, to be flexible in work assignments, and be active in promoting the interests of the company by initiating improvements. The work force was a short-term and long-term fixed cost. To get the best out of the human resources over their working times, Toyota determined to continuously enhance the workers’ skills and gain the benefit of their knowledge and experiences.

**Final Assembly Plant:** Ohno's rethinking of final assembly shows just how this new approach to human resources paid enormous dividends. Assembly line workers in Ford would perform one or two simple tasks repetitively. There are different specialists with different tasks.

Ohno thought this whole system was rife full of *Muda*. He reasoned that none of the specialists beyond the assembly worker was actually adding any value. What is more, the assembly workers could probably do most of the functions of the specialists and do them much better because of their direct acquaintance with conditions on the line.

At first step, teams were formed with a Team Leader instead of Forman, and given a set of assembly steps. Next the team was given job of housekeeping, minor repair, and quality checking. After the teams were running smoothly, time was set aside to suggest way of improving the process – 'quality circles' or Kaizen in Japan – incremental improvement process.

With respect to rework, workers were instructed to stop the line if a problem is emerged that they couldn't fix. Further more, system of problem solving called '*five whys*' was instituted to trace errors back to their ultimate causes so that the problem would never occur again.

**The Supply Chain:** Final assembling the major components into a complete vehicle accounts for only 15% of the total manufacturing process. The bulk of the process involves engineering and fabricating more than 10,000 discrete parts and assembling these into perhaps 100 major components. Coordinating the process, so that every thing comes

together, at the right time with high quality and low cost has been a continuing challenge to assembler firms. Ohno and others at Toyota began to consider this issue. The real question was how the assemblers and suppliers could work smoothly together to reduce costs and improve quality. In mass-production, the approach was either to integrate the entire production system into one huge, bureaucratic command structure, or varying degree formal integration.

Toyota began to establish lean production approach to components supply. Suppliers were organized into functional tiers with different responsibilities assigned to firms in each tier. *First-tier suppliers* were responsible for working as an integral part of product-development team in developing a new product that would work in harmony with the other systems of given performance specification.

Then, each first-tier supplier formed a *second-tier* of suppliers under it self. Companies in the second-tier were assigned the job of fabricating individual parts. These were manufacturing specialists with less expertise in product engineering but with strong background in process engineering and plant operations.

Toyota shared personnel with its supplier firms in two ways: lending personnel to deal with workload surges, and transferring managers to senior positions in supplier firms. Finally, a way of coordinating the flow of parts within the supply system is developed on a day-to-day basis – just-in-time system. The idea was to convert a vast group of suppliers into one large ‘machine’ by dictating that parts would only be produced to supply the immediate demand. (30)

## ***2.2. Lean production system Principles***

Lean production is an adaptation of mass productions in which workers and work cells are made more flexible and efficient by adopting methods that reduce waste in all forms. According to Roos, D, the co-author of the book, 'The Machine that Changed the World', Lean Production is based on four principles:

1. Waste Minimization
2. Perfect First-time Quality
3. Flexible Production Lines
4. Continuous Improvement

### **2.2.1. Waste Minimization**

All the four principles of lean production are derived from the first principle - Waste Minimization. The various procedures used in lean production are developed to minimize manufacturing wastes. Waste elimination or minimization, there by increasing percentage of time devoted to value adding activities, is one of the most effective ways to increase profitability and competitiveness. As Toyota and other world-class organizations have come to realize, customers will pay for value added work, but never for waste. While products significantly differ between factories, the typical wastes found in manufacturing environments are quite similar. (44)

**The Seven Manufacturing Wastes:** “The seven wastes” is a tool to categorize wastes. To eliminate waste, it is important to understand exactly what waste is and where it exists. For each waste, there is a strategy to reduce or eliminate its effect on a company, thereby improving overall performance and quality. The seven manufacturing wastes identified by Taichi Ohno are:

**1. Overproduction;** is to manufacture an item before it is actually required. Overproduction is highly costly because it prohibits the smooth flow of materials and actually degrades quality and productivity. The Toyota Production System is also referred to as “Just in Time” (JIT) because every item is made just as it is needed. Overproduction manufacturing is referred to as “Just in Case.” This creates excessive lead times, results in high storage costs, and makes it difficult to detect defects. The simple solution to overproduction is turning off the tap. The concept is to schedule and produce only what can be immediately sold / shipped and improve machine changeover / set-up capability.

**2. Waiting;** Whenever goods are not moving or being processed, the waste of waiting occurs. Typically more than 99% of a product's life in traditional batch-and-queue manufacture is spent waiting to be processed. Much of a product's lead time is tied up in waiting for the next operation; this is usually because material flow is poor, production runs are too long, and distances between work centers are too great. One hour lost in a bottleneck process is one hour lost to the entire factory's output, which can never be recovered. Linking processes together, so that one feeds directly into the next can dramatically reduce waiting.

**3. Transporting;** Transporting products between processes is a cost incursion which adds no value to the product. Excessive movement and handling cause damage and are an opportunity for quality to deteriorate. Material handlers must be used to transport the materials, resulting in another organizational cost. Transportation can be difficult to reduce due to the perceived costs of moving equipment and processes closer together. Furthermore, it is often hard to determine which processes should be next to each other. Mapping product flows can make this easier to visualize.

**4. Inappropriate Processing;** Often termed as “using a sledgehammer to crack a nut,” many organizations use expensive high precision equipment where simpler tools would be sufficient. This often results in poor plant layout because preceding or subsequent operations are located far apart. In addition they encourage high asset utilization (overproduction with minimal changeovers) in order to recover the high cost of this equipment. Toyota is famous for their use of low-cost automation, combined with immaculately (flawlessly) maintained, often older machines. Investing in smaller, more flexible equipment where possible; creating manufacturing cells; and combining steps will greatly reduce the waste of inappropriate processing.

**5. Unnecessary Inventory;** Work in Progress (WIP) is a direct result of *overproduction* and *waiting*. Excess inventory tends to hide problems on the plant floor. Excess inventory increases lead times, consumes productive floor space, delays the identification of problems, and inhibits communication. By achieving a seamless flow between work centers, many manufacturers have been able to improve customer service and slash inventories and their associated costs.

**6. Unnecessary / Excess Motion;** This waste is related to ergonomics and is seen in all instances of bending, stretching, walking, lifting, and reaching. These are also health and safety issues. Jobs with excessive motion should be analyzed and redesigned for improvement with the involvement of plant personnel.

**7. Defects;** Having a direct impact to the bottom line, quality defects resulting in rework or scrap are a tremendous cost to organizations. In many organizations the total cost of defects is often a significant percentage of total manufacturing cost. Through employee involvement and Continuous Process Improvement (CPI), there is a huge opportunity to reduce defects at many facilities.

Lately, **Underutilization of Employees** has been added as an eighth waste. Organizations employ their staff for their nimble fingers and strong muscles but forget they come to work everyday with a free brain. It is only by capitalizing on employees' creativity that organizations can eliminate the other seven wastes and continuously improve their performance. (11)

### ***Value Stream and Value Stream Mapping***

Identifying the entire value stream for each product or product family in a Manufacturing is the first step toward eliminating waste. There are three things the manager will need to be understood before identifying value stream; *value*, *value stream* and their *significance*.

**VALUE:** Value is defined by the customer and is only meaningful when expressed in terms of a specific product, which meets the customers' needs at a specific price and at a specific time. Defining value internally is an error; instead rethinking value should be seen from the perspective of the customer.

**VALUE STREAM:** The value stream is all the steps and processes required to bring a specific product from raw materials to finished product in the hands of the customer. Analyzing the entire flow of a product will almost always reveal enormous amounts of waste and non value-added sequences.

Value stream analysis shows three types of actions: steps that create value; steps that create no value but are unavoidable due to current technologies or production methods or assets; and steps which create no value and are avoidable.

To begin a Lean journey, *Value Stream Mapping* (VSM) is a critical initial step in lean conversions. VSM is a method of visually mapping the flow of materials and information from the time products come in as raw material, through all manufacturing process steps, and off the loading dock as finished products. Mapping out the activities in the production process with cycle times, down times, in-process inventory, material moves, information flow paths, will help visualize the current state of the process activities and guide towards the future desired state. The process includes physically mapping the "*current state*" while also focusing on where to be next, or "*future state*" map, which can serve as the foundation for other Lean improvement purposes.

VSM can serve as a starting point to help management, engineers, production associates, schedulers, suppliers, and customers recognize waste and identify its causes. The goal is to identify and eliminate any activity that does not add value to the final product. VSM can be a communication tool, a business-planning tool, and a process change management tool.

Once a value stream map have been generated, problem areas stand out very clearly: inventory building up areas, long setup times, unplanned downtime, unbalanced labor or machine time, delays, how the rate of customer demand equates to rate of production and so on. In short, place(s) for starting waste elimination efforts, in the value stream, will easily be identified. It is possible to visualize how things could operate. This vision will be the basis of future value stream map, which is the true purpose of value stream mapping. There will be a chance to eliminate processes that add no value and combine or streamline those that do add value. Areas where suppliers can provide better services will be highlighted, redundant and unnecessary information flows will be eliminated. All of these changes will support an organization's goal of providing the highest level of service to customers. (10)

### **2.2.2. First-Time Quality**

When management and production workers trust each other, it is possible to implement an integrated quality control. Japan was started on the road to superior quality, when they readily accepted the statistical quality (SQC) techniques in the late 1940s and early 1950s. They taught the techniques and concepts to everyone, including top management and production workers. At Toyota, under the leadership of Ohno, quite different from the Known inspection philosophy, a new idea took hold. *Inspect to prevent* the defect from occurring rather than to *find* the defect after it has occurred. Ultimately the concept of *autonomation* evolved.

Autonomation means the autonomous control of quality and quantity: stop every thing immediately when some thing goes wrong; control the quality at the source instead of using inspectors to find the problem that some else may have created.

This is to make every worker an inspector and to give each person only one part to work on at a time, so that under no circumstance can a worker buries problems by working on alternative parts. Cells produce parts one at a time, just like assembly lines. In a nutshell, the idea is to ‘make one, check one, and move one’. Pull cords are installed on the assembly lines to stop the lines if any thing goes wrong. If workers find defective parts, if they can’t keep up with production, if production is going too fast according to the quantity required for the day or if a safety hazard is found, they are obligated to stop the lines. Then, problem is fixed immediately.

Mean while the other workers maintain their equipment, change tools, sweep the floor, or practice setups; but the line does not move until the problem is solved. Quite often, inspection devices are placed in the machines (inspection at the source) or in devices (called decouplers) between the machines, so the inspection is performed automatically. Inspection by a machine instead of a person is faster, easier, and more repeatable.

Inspection becomes part of the production process and does not involve a separate location or person to perform it. Parts are 100% inspected by devices which either stops the process if a defect is detected or correct the process before the defect can occur. The machine shuts off automatically when a problem arises. This prevents mass production of defective parts. The machine also may shut off automatically when the necessary parts have been made.

For manual work, another system for preventing defective work is called *Andon*, which is light board hanged high so that every one can see it. When a worker on a line needs help, he can turn on a yellow light. Nearby (multifunctional) workers who have finished their jobs with in the allotted times - with in the cycle time - move to assist workers having problems. If the problem can't be solved with in the cycle time, a red light comes on and the line stops automatically until the problem is solved. In most cases the red light goes-off within 10 seconds and the next cycle begins, a green light comes on with all processes beginning together. Such systems are built on teamwork and a cooperative spirit among the workers, fostered by a management philosophy based on harmony and trust.

Another interesting technique is quality circles. The Japanese call them Small Group Improvement Activities (SGIA) and they are a key part of company wide quality control efforts (TQM). A quality circle is a group of employees who meet on a scheduled basis (daily, weekly) to discuss production and quality problems, to try to device a solution to the problems, and propose the solutions to their management. A foreman or a production worker may lead the group. It usually includes people from a given discipline or a given production area. Quality circles should be a natural entity within the manufacturing system and not artificially created. They are basically a technique to identify causes of problems and to generate ideas and suggestions to solve problems on the local level. (15, 44)

### 2.2.3. Flexible Production Lines

Customers demand variety and customization as well as specific quantities delivered at specific times; a lean producer must remain flexible enough to serve its customers' needs. Cellular manufacturing allows companies to provide their customers with the right product at the right time. It does this by grouping similar products into families that can be processed on the same equipment in the same sequence. To successfully maintain "one-piece-flow" in the manufacturing cells, quick changeover techniques are employed.

A cell is a group of workstations, machines or equipment arranged such that a product can be processed progressively from one workstation to another without having to wait for a batch to be completed and without additional handling between operations. Cells may be dedicated to a process, a sub-component, or an entire product. An ideal cell manufactures a narrow range of highly similar products. Such an ideal cell is self-contained with all necessary equipment and resources. The result is very fast throughput. Communication is easy since every operator is close to the others. This improves quality and coordination. Proximity and a common mission enhance teamwork.

Cellular manufacturing can help make companies more competitive by cutting out costly transport and delay, shortening the production lead time, saving factory space that can be used for other value-adding purposes, and promoting continuous improvement by forcing the company to address problems that block just-in-time (JIT) production. (10)

Cells have many features that make them unique and different from other manufacturing systems. Parts move from machine to machine *one at a time* within the cell. For material

processing, the machines are typically A (2)<sup>1</sup> or higher; capable of completing a machining cycle initiated by a worker. The U-shape puts the start and finish points of the cell next to each other. Every time the operator completes a walking trip around a cell, a part is completed. This time defines the cycle time (CT). The machining time (MT) for each machine needs only to be less than the time it takes for the operator to complete the walking trip around the cell. As shown in Fig 2a machining *processes are overlapping and need not be equal (balanced)* as long as no MT is greater than the CT. ***The cycle time is 150 seconds but the total machine time was 60+ 80+100+40+ 20 = 300 seconds.***

A numerical controlled (CN) machining center capable of performing the five operations could easily replace the cell. However, the cycle time for a part could jump from 150 seconds to over 300 seconds because combining the processes into one machine prevents *over lapping of the machine times*. More over, adding a portion of additional workers to the cell can readily alter the CT for the cell.

Manufacturing cell makes parts one at a time in a flexible design. Cell capacity (the cycle time) can be altered quickly to respond to changes in customer demand. The CT does not depend on the machining time.

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<sup>1</sup> Level of Automation

Level	Loading Machine	Machining	Unloading	Transferring Part
1	Manual	Manual	Manual	Manual
2	Manual	Automated	Manual	Manual
3	Manual	Automated	Automated	Manual
4	Automated	Automated	Automated	Manual
5	Automated	Automated	Automated	Automated

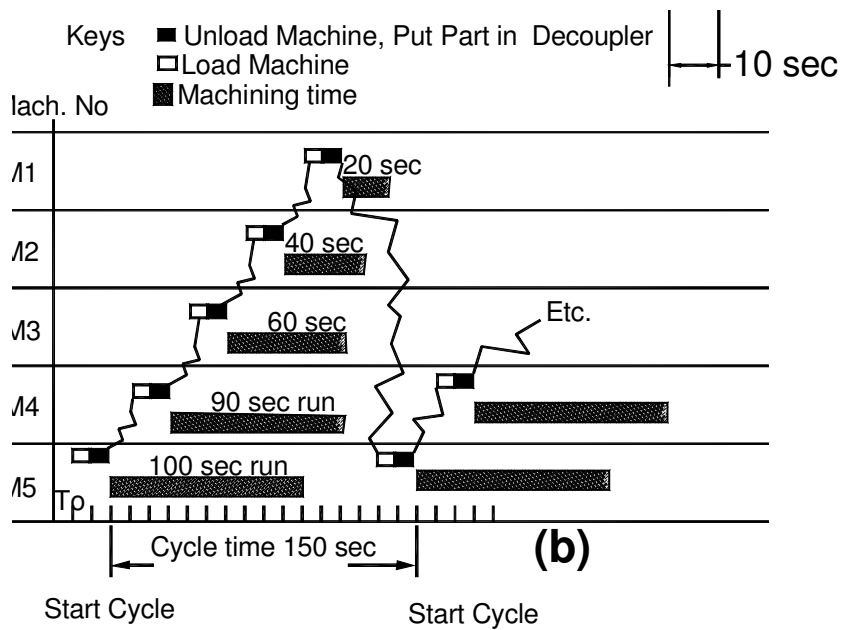
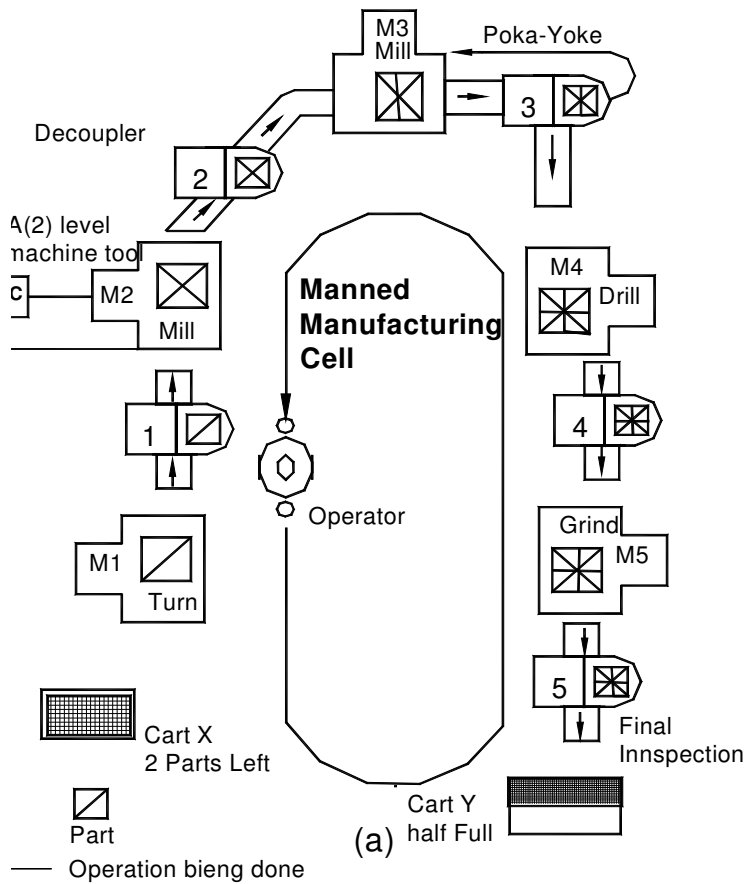


Figure 2 Layout and Time-bar Diagram of Five Machine U-shaped Cells

Fig 2b is a simple standard operations routine sheet, used to plan the manufacture of one of the parts in the family within the cell. The plan shows the relationship between the manual operation performed by the worker, the machining operations performed by the machine, and the time spent by the worker walking from machine to machine. The manual operations include loading and unloading the machine, checking quality, deburring, and taking chips out of fixtures.

The machining speeds and feeds can be relaxed to extend the life of the cutting tools and reduce the wear on the machines as long as the (MT) for a particular machine does not exceed (CT) for the cell. This increases the reliability of the process, by reducing the probability of breakdown. There is no mystery as to which process within the cell is the bottleneck - the machine with longest machine time. Every one in the manufacturing system can see and understand how the cell functions and, therefore, which process is the most likely to delay the cell's cycle time.

The cycle time is determined from the demand rate for the parts according to the following calculations:

$$\text{Daily demand for parts} = \frac{\text{Monthly demand (forecast plus customer orders)}}{\text{Number of days in month}}$$

$$CT = \frac{1}{PR} \quad \text{Where} \quad \text{Production Rate (PR)} = \frac{\text{daily demand (parts)}}{\text{hours in day (hr)}}$$

Workers in the cells are multifunctional; each worker can operate more than one kind of process (multiple versions of the same process) and also performs inspection and machine maintenance duties. Cells eliminate the job shop concept of one person / one machine and thereby greatly increase worker productivity and utilization. The restriction of the cell to a

parts family makes reduction of setup in the cell possible. This is often called flexible fixturing.

In some cells, Decouplers are placed between the processes, operations, or machines to provide flexibility, part transportation, and inspection for defect prevention (Pokeyoka) and quality control, and process delay for manufacturing cell. In Fig 2, the decoupler inspects part critical dimension and feeds back adjustments to the machine to prevent producing oversize parts as the cutter wears. A process delay decoupler will allow the part to cool down, heat up, cure, or whatever is necessary for a period of time greater than the cycle time for the cell. Decouplers and flexible fixtures are vital parts of unmanned cell.

Families of parts with similar designs, flexible work holding devices, and tool changers in programmable machines allow rapid changeover from one component to another. Rapid change over means, that quick one-touch setup is employed, often like flipping a light switch. A significant inventory reduction between the cells is possible, and the inventory level can be directly controlled. Quality is controlled with the cell and the equipment with in the cell is maintained routinely by the workers.

The product designer can easily see how parts are made in the cell, cell's process capability, since all processes are together and quality control techniques are integrated in the cell. The designer can easily configure the future designs to be made in the cell. This is truly Design for Manufacturing (DFM). (15)

## ***Designing Manufacturing Cells***

Conversion of functional system into a flexible, linked-cell system is a design task. There are different methods by which manufacturing cells can be formed. Most companies 'design' their first cell by one of the trial-and-error technique for expediency in gaining experience in cells. ***Digital simulation*** is gaining wider usage in designing and analyzing manufacturing systems with the advent of newer, more versatile languages.

Another technique being researched extensively is called ***Physical Simulation***. This approach uses small robots and scaled-down versions of machine tools (mini-machines) to emulate real world systems. The small machine employs essentially the same mini-computers and software as full-scale systems. Unmanned cells and FMSs can be simulated in the laboratory at quite reasonable cost. Generally speaking, the industrial robots and full-size machines are expensive.

***Group Technology*** offers a systems solution to the reorganization of the functional system, restructuring the job shop into manufacturing cells. The conversion presents system-level changes, which will create the potential for tremendous savings. But because of the magnitude of the changes, careful planning and full cooperation from everyone involved are absolutely required. The application of this concept to a manufacturing facility results in the grouping of units or components into families wherein the components have similar design or manufacturing sequences. Machines are then collected into groups or machine cells to process the family. By grouping similar components into families of parts, a group or set of processes can be collected together. This is a cell where order of machines in the cell defines the manufacturing sequence.

***Production Flow Analysis*** (PFA) uses the information available on the route sheets and groups them by a matrix analysis, using product-routing information. This method is more analytical than tacit judgment but not as comprehensive as coding / classification. PFA is a valuable tool in the systems reorganization problem. For example, it can be used as an up-front analysis, a sort of ‘before the fact’ analysis that will yield some cost/benefit information. Design makers will have some information on what the company could expect in terms of the percentage of their product that could be made by cellular methods, what would a good ‘first cell’ to under take, what coding/classification system would work best for them, how much money they might have to invest in new equipment and so on.

Many companies converting to cellular system have used a ***coding or classification method***. There are design codes, manufacturing codes, and codes that cover both design and manufacture. Classification sorts items into classes or families based on their similarities. It uses a code to accomplish this goal. Coding is the assignment of symbols (letters numbers, or both) to specific component elements based on differences in shape, function, material, size, processes, and so on.

A cellular manufacturing system composed of linked-cells is the newest manufacturing system. In cells, processes are grouped according to the sequence and operations needed to make a product. The linked-cell factory is composed of cells to fabricate components, subassembly lines, and final assembly lines. The cells are ‘linked’ by Kanban (or linked directly) to another nearby cell; the subassembly line is directly linked to a ‘point of use’ in the final assembly line. In the linked-cell system, the work-in-process inventory is between the cells and is controlled by Kanban.

To form a linked-cell manufacturing system, the first step is to restructure portions of the job shop, converting it in stages into manned cells. At the same time, the flow shop parts are reconfigured into U-shaped cells as well. To do this the long setup time of flow lines must be vigorously attacked and reduced so that the flow lines can be changed quickly from making one product to making another.

The formation of families of parts leads to the design of cells, but cell design is by no means automatic. It is the critical step in the reorganization and must be carefully planned. It can be begun with pilot cell so that every one can see how cells function. It will require time and effort to train the operators and they will need time to adjust to standing and walking. Nevertheless, the company should proceed with developing manned cells, not waiting until all parts have been coded. Only in this way will every one learn how cells operate and how to reduce setup time on each machine.

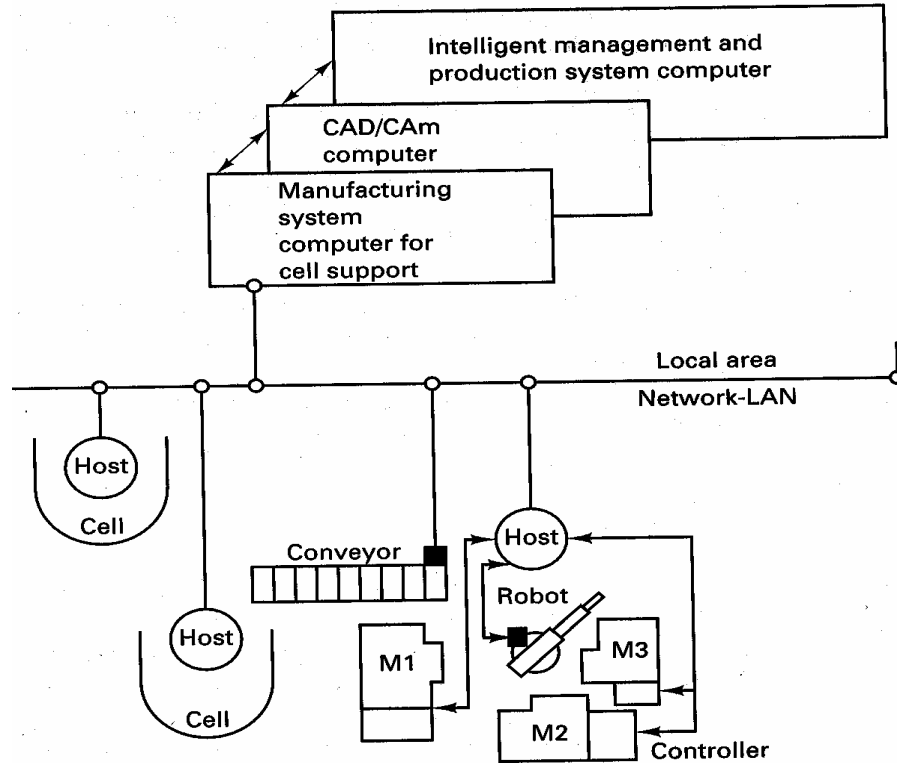
Machines will not be utilized 100%. Machine utilization rate usually improves but may not be what it was in the functional system. ***The objective in manned cellular manufacturing is to utilize the people fully***, enlarging and enriching their jobs by allowing them to become multifunctional. That is, the operators learn to operate many machines and / or perform tasks that include quality control, machine maintenance, and setup reduction. In unmanned cell systems, the utilization of equipment is more important because the most flexible element in the cell, the worker, has been removed and 'replaced' by a robot. (15)

## **Automating the Cell**

The need for automation simply reflects the gradual transition of the factory from manual to automated functions. Some people think this as CIM. Others recognize that people are the most important (and flexible) asset in the company and see the computer as just another tool that is used in the process, but is not the heart of the system. These companies are moving towards Human Integrated Manufacturing (HIM), where a creative, motivated workforce is seen as the key to lean production. Even though cells are typically manned, unmanned cells are beginning to merge with a robot replacing the worker. For the cell to operate autonomously, it must have adaptive control capability, that is A(5) level of automation.

For robotic (unmanned cells), the robot usually loads and unloads parts for one to five machine tools, (15) but this number can be increased if the robot can become mobile. A machining center can do the same sequence of steps but is not as flexible as a cell composed of multiple simple machines. Cellular layouts facilitate the integration of critical production functions while maintaining flexibility in producing superior quality products.

In robotic cells, the microcomputers of the CNC machine tools and a robot are networked together with a cell host computer. It is difficult, if not possible; to conceive of this kind of arrangement without resorting to some method that collects the work in to compatible families. All the machines in the cells are programmable, and therefore this kind of automation is very flexible. See Fig 3 for robotic cells. (15)



**Figure 3 Robotic Cells Connected by Computer Network**

### **2.2.4. Continuous Improvement**

Lean production supports the policy of continuous improvement. Called *Kaizen* by the Japanese, continuous improvement means constantly searching for and implementing ways to reduce cost, improve quality, and increase productivity. The scope of continuous improvement goes beyond factory operations and involves design improvements as well. Continuous improvement is carried out one project at a time. The projects may be concerned on the areas of the Quality improvement, Set up time reduction, Cost reduction, Work-in-process inventory reduction and others. (44)

### **2.2.4.1. Quality Improvement**

Quality problems are usually attacked on a project-by-project basis using teams. Team approach is one of the basic elements in quality improvement. This is because the issue usually requires the attention and expertise of more than one person to solve. It is difficult for one individual, acting alone, to make the necessary changes to solve a quality problem. Teams, whose members contribute a broad pool of knowledge and expertise in the problem area, are most effective.

The steps in each project will vary depending on the type of quality problem being addressed. The following logical sequence of steps is recommended approaches:

1. Selecting the project
2. Observing the process
3. Analyzing the process and conducting experiment if appropriate
4. Formulating corrective actions, and
5. Implementing the corrective action.

These steps and where each of the seven SPC tools might be utilized in quality improvement projects are discussed in Table-2. (44)

**Table 1 Applications of the Seven SPC Tools in Quality Improvement Projects**

<b>Steps</b>	<b>Quality Improvement Project steps</b>	<b>SPC Tools</b>
1	Select the Project	<ul style="list-style-type: none"><li>• Control charts</li><li>• Pareto charts</li></ul>
2	Observe the Process	<ul style="list-style-type: none"><li>• Check sheet</li></ul>
3	Analyze the Process	<ul style="list-style-type: none"><li>• Histogram</li><li>• Pareto chart</li><li>• Defect concentration diagram</li><li>• Scatter diagram</li><li>• Cause and effect diagram</li></ul>
4	Formulate Corrective action	<ul style="list-style-type: none"><li>• Scatter diagram</li><li>• Cause and effect diagram</li></ul>
5	Implement the Corrective Action	

#### **2.2.4.2. Setup Time Reduction**

Lean Production approach to manufacturing demands that small lots be run. This is impossible to do, if machine setups take hours. The setup operation is to change the manufacturing condition from those for producing a certain product to those for producing a different product, including *stopping the present job and preparing for the start of the next job*. Except for making one specific product in a dedicated line, it is periodically necessary to change the product produced on the line from a product to another. In this context, *single setup* means that it has been reduced to a single-digit number of minutes – less than 10 minutes. However, it means only the time when equipment is stopped for setup (so-called internal setup time) and does not include the times for incidental operations related to setup (external setup) that occur before and after equipment stoppage. (4, 15)

## **Shingo's Single Minute Exchange of Dies (SMED) Rules**

Large reduction in setup time can be achieved by applying Shingo's SMED rules for rapid exchange of dies. According to this rule, setup time reduction occurs in four stages:

The **Initial Stage** is *to determine* what currently is being done in the setup operation. The operation is usually video taped, then every one concerned gets together and reviews the tape to determine the elemental steps in the setup. In this stage, two issues are documented concurrently: a *walking diagram* illustrates the movement of a person being viewed in the layout – and *analysis chart* for detailed methodology of the workstation. The chronological time stamp from the video is used to determine the elemental time of each step.

**The Second Stage** is to separate all setup activities into two categories, *internal* and *external*. Internal setup can be done only when the machine is not running. These are:

- Installation and removal of cutting and similar tools,
- Centering and setting of dimensions and other parameters,
- Trial run and adjustments.

External elements can be done while the machining is running. This activity includes:

- Bringing in and positioning of new parts in the appropriate location,
- Getting any tools, parts, and dies ready in accessible position,
- Getting needed tools from the tool room and having them ready to install.

Without this distinction, all setup tasks may be treated like internal setup tasks and equipment may be stopped much longer than is necessary. Thus, simply by differentiating between internal and external setup, setup time requiring equipment stoppage can be reduced by 30% to 50%. (4)

**The Third Stage** focuses on converting internal setup to external setups. For example, a tool-centering operation had been done with the equipment stopped, but is found that presetting could be done. Likewise, procedures require the equipment to be stopped after setup until the quality of newly produced products could be verified. However, by increasing the reproducibility of manufacturing conditions for non-defective products, it is possible to restart the equipment immediately (without trial run).

**The Fourth Stage** of SMED concentrates on streamlining all aspects of the setup operation. It may be necessary to invest capital to drive the setup times below ten minutes. Automatic positioning of dies, bolster plates on rollers, intermediate jigs, and duplicate work holders represent the typical kinds of hardware needed. The basics for this stage include organizing activities before the setup, reducing the elements of the setup, and eliminating the adjustments after setup.

**Organizing before the setup** includes addressing all of the work that could be accomplished prior to setting the equipment down. Those internal tasks are scrutinized and each work evaluated as to when it had to be performed. Tools and fixtures are color coded for easy identification and control and kept on a tool cart to have them readily available when setup process began. The tools and dies are standardized so that they could run more than one type of job.

***Reducing the elements*** of the setup include reducing the time it take to perform the duties during the setup and eliminating activity during this process. By using simultaneous activities, two members work together to avoid having some one walk from one side of the machine to the other.

Improved clamping methods addresses the issue that fasteners slowdown the whole process. Replacement and installation include reviewing the fastening technique. The function of the bolt was to fasten or position things. Some fastening functions are accomplished through levers or pneumatic hold-downs instead of bolts. Using a one-turn fastening includes use of U-shaped washers, split threads, and clamps. There are also one-motion methods that include cam clamps, spring stops, and vacuum suctions.

***Eliminate the adjustments after setup*** includes finding methods and techniques to accomplish setting machinery correctly the first time. The objective is to set the machinery correctly and eradicate the need to adjust the equipment in latter steps. It is found that most adjustments were eliminated by calibrating the equipment on a scheduled basis and by being more accurate in setting tooling into the machinery.

Considering the result of setup improvement phases and activities, simply reducing setup time for one piece of equipment will not have that large an impact, because only labor-hours needed have been reduced. Besides, if setup time operation tasks have merely been changed to external tasks, the total labor-hour will not have been reduced at all. Therefore when a single setup have been successfully achieved, it is essential to think in terms of side ways expansion, so that single setups can be achieved throughout the entire line producing the product, and other lines as well.

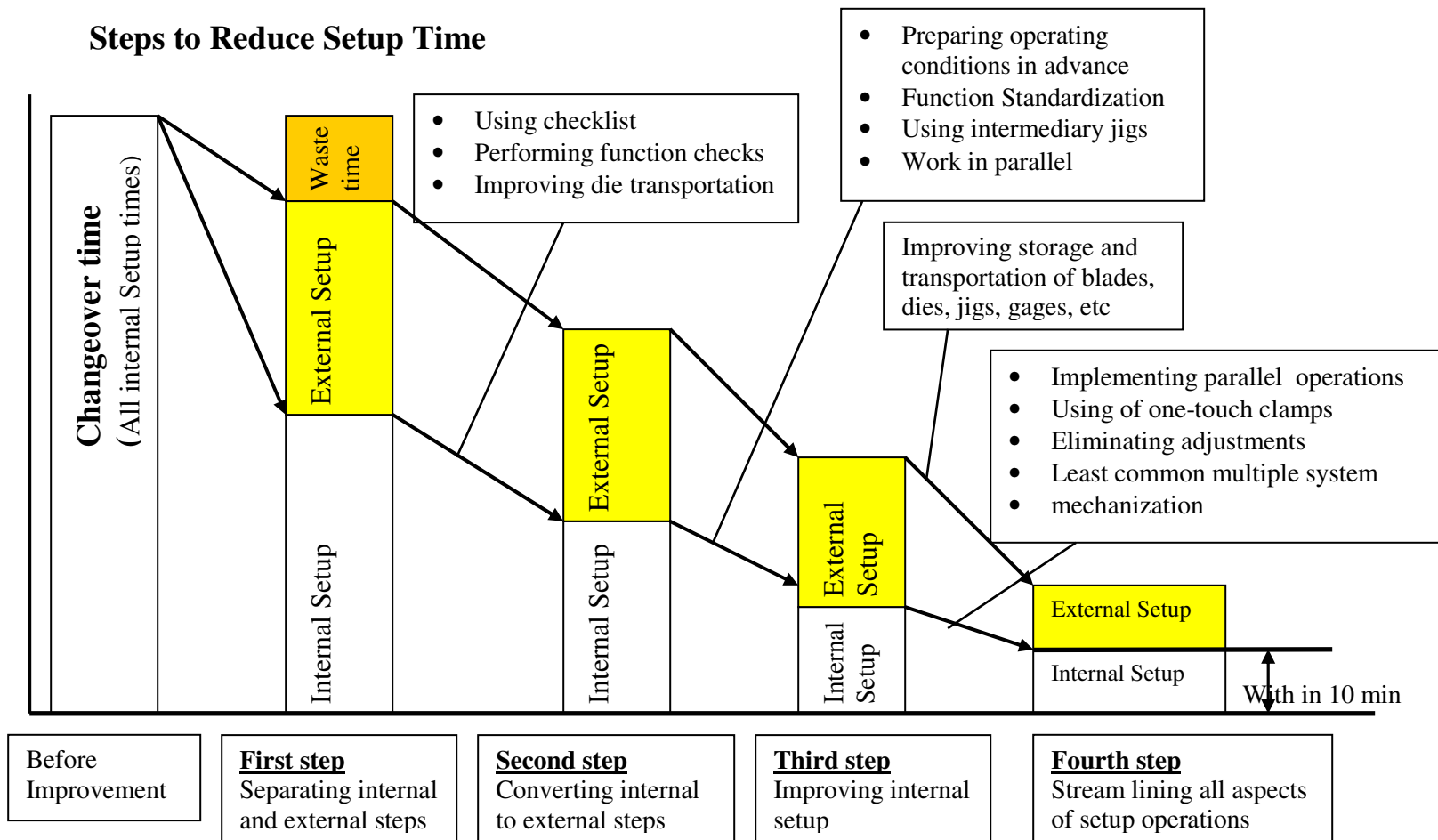
If the process described previously is viewed as progression of setup time reduction, it appears as in Fig 4, next page. This can be easily understood as a process of gradually 'digging deeper' through use of idea steps, while repeating the practical steps. (4, 5)

### **2.2.4.3. Cost Reduction**

The lean techniques and procedures are all tailored on effective utilization of resources that would result in minimizing manufacturing costs. So, the improvements in cost reduction can be obtained on cell formation, setup reduction, quality control and other methods.

Another important cost minimization method is accomplished jointly with suppliers. At the heart of lean supply lies a different system of establishing prices and jointly analyzing costs. First, the lean assembler establishes a target price of a product and then, with the suppliers, works backwards, figuring how the part can be made for this price while allowing a reasonable profit for both assembler and suppliers. In other words, it is a 'market price minus' system rather than 'supplier cost plus' system.

To achieve this target cost, both suppliers and assembler use Value Engineering techniques to breakdown costs of each stage of production, identifying the factors that would lower the cost of each part.



**Figure 4 Improvement Process for Setup Time Reduction**

Once the part is in production, a technique called Value Analysis is used to achieve further cost reduction. Value Analysis, which continues with the entire time the part is being produced, is, again, a technique for analyzing the costs of each production step in detail, so that cost-critical steps can be identified and targeted for further work to reduce costs still further. These savings can be achieved by incremental improvements, or *Kaizen*, or the introduction of new tooling, or redesign of the part.

Obviously, for the lean approach to work, the supplier must share information about costs and production techniques. Both go over every detail of the production process looking for ways to cut costs. Agreements made on sharing profits gives suppliers' the incentive to improve processes, because it guarantees that the supplier keeps all the profit derived from cost-saving innovations and *Kaizen* activities. (30)

#### **2.2.4.4. Work-in-Process Inventory Reduction**

The inventory held in the system is called the work-in-process (WIP). It has been analogized to the water in the river – high river level is equivalent to high level of inventory. The high river level covers the rocks in the riverbed that is equivalent to problems. Lowering the level (inventory) exposes the rocks (problems), and the problems receive immediate attention when exposed. When all the rocks are removed, the river can run very smoothly with very *little water*. While zero defects is a proper objective, zero inventories is misleading. The idea is to minimize the necessary WIP between cells. (With in the cell, parts are handled one at a time). The level of WIP between the stand-alone process, cells, subassembly, and assembly is controlled by the foremen. The control is integrated and performed at the point of use.

If there are 10 carts with 20 parts holding capacity in the link, the maximum inventory becomes 200 parts. Going to the stock area the Forman picks up the kabana cards (one WLK, one POK), which puts a full cart out of commission. Now there are  $9 \times 20$  or 180 parts. When any problem appears the Kanban is immediately restored, which restores the inventory in its previous level. The condition is relaxed until a solution for identified problem is enacted. Once the problem is solved, the procedure repeats. If no other problem occurs, the inventory is made to drop to  $8 \times 20 = 160$  parts. This procedure is repeated daily all over the plant. After a few months, the Forman may make down to 5 carts of 20 parts. Over the weekend the system will be restored to 10 carts, but this time with each cart holding only 10 parts. If every thing works smoothly, with reduced WIP lot size, the Forman will then remove a cart to see what happens. More likely, setup time will need to be reduced. In this way the inventory in the linked-cell system is continually reduced, exposing problems. The problems are solved one by one working teams.

The minimum level of inventory that can be achieved is a function of, quality level, probability of machine breakdown, length of set-ups, variability in manual operations, number of workers in the cell, parts shortages, transportation distance, and so on. The significant point here is that inventory becomes a controllable independent variable rather than an uncontrollable variable dependent on cravings of users of the manufacturing system for more inventories. (15)

## **2.3. Lean Production Success Stories**

### **a) A Smarter Way to Make Smart Bombs**

#### **Boeing's new missile-making line showcases; Commitment to Lean Manufacturing**

For its older missiles, like the Harpoons, SLAMs and CALCMs, the missile assembly lines were look much like traditional batch and queue operations that depend on a trained workforce using manual assembly techniques. And there's a lot to assemble. These missiles consist of about 98 percent outsourced parts, and two percent Boeing-made parts.

Seated on stools, workers pick small parts from bins, then stretch and stick their hands inside tight compartments to assemble the missile's inner brains. Ticketed work-in-progress is visible in various stages of assembly; there is little automation, and the workers work in cells and mostly in isolation from one another.

When walking inside Boeing's new production facility for JDAM (Joint Direct Attack Munitions) line of missiles, a whole different world -- lean manufacturing is seen.

Starting from scratch, a group of lean manufacturing devotees within Boeing's missile division knew they had an opportunity to create the ideal lean assembly plant. They benchmarked with dozens of other facilities, studied best practices, conducted internal performance audits, attended lean manufacturing conferences, and did their homework. The result is a simple looking, but highly-efficient production line that can produce top quality missiles at a low cost - about US\$20,000 per missile. The line now makes about 1,000 missiles a year, but the system could crank out as many as 20,000.

On the assembly line, each munitions mechanic follows clearly outlined standardized work procedures, and spends the same time - 17 minutes - during each stage of the assembly process. There is no rework on the line, and parts are stored adjacent to where they are assembled. Each mechanic does every other job, from unloading raw goods from trucks, to assembly, to packing up the finished product in collapsible and reusable bar-coded containers with no packaging waste for shipping.

#### **b) North American Application lean production System**

Some of the approaches of lean are difficult to implement in North American. Life time employment, companies unions and subcontractor networks are not prevalent in US and Canada. Also, US and Canada companies traditionally use a top-down planning and management structure, which is counter to bottom- round management. In addition US and Canada companies are vulnerable to labor strikes. What have been adopted in the US and Canada is the Japans general philosophy and approach to lean

It is discovered that while it may take time to implement, reducing set up times, eliminating inventory, identifying problems, utilizing the expertise of workers are important, practical guidelines for all organizations. In deed, a survey on implementation of 1,035 US manufactures, 86.4% of respondents agreed that lean provided an over all net benefit for their organization less than 5% reported no overall benefit from their Implementation. Through put time decreased an average of 59.4%. The study found that organizations with 500 or more employees typically implement JIT practices more often. It was also practiced for a longer period of time for larger organizations. Regardless of size or type of process employed, lean manufacturing was beneficial for US manufacturers.

In Europe as well, many organizations have seen the benefits. In a study of 80 European plants, improvements included a 50% average reduction in inventory, a 50-70% reduction in through put time, a reduction in set up time by as much as 50% (with out major plant and equipment investments), 20-50% productivity increases, and pay back for the investment in less than nine months. (8, 20)

## **Chapter 3 : AGILE MANUFACTURING SYSTEMS**

### ***3.1. Agile Manufacturing Overview***

In 1991 a four-month long collaborative workshop was accomplished at Lehigh University that gave birth to the concept of the Agile Manufacturing Enterprise. The intention was to identify the competitive focus that could be successor to lean.

It was intended to develop a manufacturing competitiveness revitalization strategy to counteract competitive decline of American manufacturers. Decline occurred as large and unresponsive American mass-producers experienced market share erosion to foreign-based “lean” manufacturers. These smaller, more flexible and more responsive manufacturers took decisive control of global markets largely due to their ability to overcome inefficiencies associated with inflexible American-style mass-production. Lean manufacturers facilitated the shift in market dominance by systematically reevaluating and redefining the importance of all inputs to manufacturing processes. (2, 24, 26)

American response to the global market share erosion was unsuccessful exploitation of flexible but stand-alone technologies such as Computer-Numeric-Control machine tools, robotics, flexible manufacturing systems, computer-aided-design/drafting, and computer-integrated manufacturing, (2).

During the workshop discussion, the participants converged on the fact that most of the organization was feeling increasingly whipsawed by more frequent change in the business environments. The evidence was apparent that the pace of change was accelerating- and already outpacing the abilities of many established organizations.

To overcome reliance on stand-alone technologies and promote modular product designs, which evolve with the needs of consumers, the industry-led Agile Manufacturing Enterprise Forum (AMEF) took charge of the plan development. The purpose of the forum was to develop a methodology for creating *Reprogrammable, Reconfigurable, and continuously changeable* production systems.

Being agile means being a master of change, and allows one to seize opportunity as well as initiate innovations. How agile a company or any of its constituent elements is a function of both opportunity management and innovation management – one brings robust *viability* and the other brings is *preemptive leadership*. Having one without the other is insufficient in these times of quickening unpredictable change.

- **Viability:** seeks and responds to the voice of the customer, Says yes to opportunity, is reactive and resilient, has staying power and robustness.
- **Leadership:** introduces new approaches, makes existing approaches obsolete, changes the rules, Promotes out-of-box thinking, disrupt the market.

**Manufacturing Agility** is the ability to respond to, and create new windows of opportunities in a turbulent market environment driven by individualizing customer requirements cost effectively, rapidly and continuously. Essentially the customer, and more importantly the product requirements that they represent, are central to manufacturing

profitability. These requirements must be met at the right price, to the right quality, and at the right time. Nevertheless, these requirements are not static, and the customer's needs are in a state of permanent flux, which has an inevitable impact on a company, and requires greater flexibility of that company (4, 18). Moreover, the ability to fulfill these requirements is under permanent pressure from environmental turbulence. AM is, therefore, the enabling technologies that permit the drive towards manufacturing agility.

### **Tendencies in the Direction of Agile Manufacturing**

The basis for formulating the concept of Agile Manufacturing is an analysis of the development that is taking place in the management of companies. A number of market forces can be identified that drive the evolution of agility and agile manufacturing system in business. These trends include:

- 1) *Market fragmentation*
- 2) *Production to Order in Arbitrary Run Lengths*
- 3) *Information Technology, which makes it Possible to Service a Large Group of Customers Individually*
- 4) *Shorter Product Lifetimes*
- 5) *Global Production - Production Takes Place in Networks Covering the Globe*
- 6) *Companies Collaborate and Compete at the Same Time*
- 7) *Infra-structure for Marketing and Distribution of Mass Produced, Customer Specific Products*
- 8) *Companies Reorganise themselves at Shorter Intervals*
- 9) *Increasing Need to Build up a Special Company Culture with Well-defined Norms*

10) *Converge of Physical Products and Services*: The most important consequences of this development are:

1. Instead of a once-off sale of physical products, it is possible to adapt or upgrade products to build up a longer lasting relationship with customers.
2. Information has, as time goes by, become a product in itself.
3. The decisive competitive factor is changing from being incorporated in products, technology and processes, into being associated with the individual employee's knowledge, creativity and initiative.

### **3.2. Agile Manufacturing System PRINCIPLES**

The mass production system is undergoing major change. Companies today are able to cultivate ever more fragmented markets, to deliver customer specific products in arbitrary run sizes, to develop product families and rapidly change model, to make mass produced products customer specific and to market information. This development means that companies of today are moving away from the classical mass production to AM concept. **Agile Manufacturing** sets out to identify and apply practical tools, methodologies, and best practices that enable companies to achieve manufacturing agility within a *turbulent business environment*. (16, 26)

When the term *agile* is used in connection with the management of companies, it refers to the company's ability to perform in an ever more dynamic world in which markets, products, technologies that is rapidly changing. To be agile is not just a question of either

using the right technology, or of having the right organisational structure or of having employees with the right qualifications. There are many examples of companies who have worked with one or more of these elements. In general terms, the concept of Agile Manufacturing gives a new framework for how one can run a company in an open dynamic world.

Agile Manufacturing embodies an aggressive, growth-oriented company that is willing to change. It makes considerable demands on the individual employee's creativity and ability to change over to new tasks at work. Thus a movement in the direction of Agile Manufacturing puts big demands on how the individual employees are trained and on their access to relevant knowledge and information.

To get somewhat closer to the definition of Agile Manufacturing, researchers at Agility Forum have formulated four fundamental principles, which describe the agile company.

These Principles are:

1. Reorganization the production system for Agility,,
2. Enriching customers with total solution products
3. Leveraging people and information or Knowledge-driven enterprise.
4. Co-operating to enhance competitiveness (2, 26, 44)

### 3.2.1. Reorganizing Production System for Agility

Companies seeking to be agile must organize their production operations differently than the traditional organization. The changes required in this respect can be in two basic areas:

Product design and production operations:

- a) **Product Design:** Companies need to *design* or *develop* products that are focused specifically on an individual customer's requirement. Product design, in most cases, will need to be closely integrated with the production process. The need for fast and effective design means that the traditional approach of having all new products routed through a design area must be eliminated. The design process must be integrated with the manufacturing process. The manufacturing people on the production cell can be trained to do the majority of the design functions. Modularizing allows configuration of products rather than the separate design of each product; thus, simplifying the design process. Here, there is customer specific products or alternatively offer a wide spectrum of product variants which give the customer the possibility of assembling an individualised product.

The products may be designed to not only meet current needs but to be reconfigurable to meet the customers' future needs. Attention is paid to configurability, modularity, and design for the longer term satisfaction of customer requirements. Where the product contains software, it can be built to accept software updates over time. Where the product is mechanical, it can be designed for easy reconfiguration and upgrades as technologies change, as new features are added, and as the customers needs change over time.

It is noted that decision made in product design determine approximately 70% of the manufacturing cost of a product (44). For a company to be more agile, the design-engineering department must develop products that can be characterized as follows:

- ***Customizable***: for individual niche markets and in some cases, for individual customers.
- ***Upgradeable***: a product with base-model which fit subsequent additional options.
- ***Reconfigurable***: Through modest changes in design, the product is provided with unique features. A new model can be developed from the previous model without drastic and time-consuming design effort.
- ***Design Modularity***: The product design that consist several modules (i.e. subassembly). If a module needs redesign, the entire product dose not require redesign.
- ***Frequent Model Changes***: introducing new versions of the product every time.
- ***Plat-forms for Information Technology***

b) **Production Operations**: Agile production operations thrive under conditions that drive others out of business. When forecasts prove too optimistic, or markets run down, they throttle back on production rate with no effect on product margins. If product lifetime ends prematurely, they are quickly reconfigured and retooled for new or different products. Instead of loosing market opportunity, when product demand soars beyond capacity they expand to meet the market. Rather than postpone or shutdown periodically for major process changes, they evolve incrementally with continuous incorporation of new process technologies. In support of new product programs, they simply take prototypes in the workflow. For niche markets and special orders, they

accommodate small runs at large run margins. Irrespective of these changes, they maintain superior quality and a steady, loyal work force.

A substantial impact on the agility can be achieved by reorganizing operations, procedures, and systems that support them. Objectives in production operations and procedures are:

- ***Cost-effectiveness and Low-volume production***
- ***Producing to Customer Orders***
- ***Mass Customization***
- ***Reconfiguring and Reusing Processes and Resources;*** this include CNC machine tools, parametric part programming, robots, programmable logic controllers, mixed model production lines, and modular fixtures
- ***Involving Customers Closer in Production Process***
- ***Integrating Business and Production Procedures*** The production system should include business functions in a computer integrated production planning and control system, based on manufacturing resource planning (MRP II).
- ***Extended Production System from Suppliers through Customers;*** the companies' own factory is a component in a larger production system.

Some of the important enabling technologies and management practices to reorganize the production function for agile manufacturing are listed in Table 3. (44)

**Table 2 Enabling Technologies and Management Practices for AM.**

Enabling Technologies	Enabling Management Practices
<ul style="list-style-type: none"> <li>• Computer numerical control</li> <li>• Direct numerical control</li> <li>• Robotics</li> <li>• Program Logic Controllers</li> <li>• Group Technology Cellular Manufacturing</li> <li>• Flexible Manufacturing System</li> <li>• CAD/CAM and CIM</li> <li>• Rapid Prototyping</li> <li>• Computer Aided Process Planning CAPP</li> </ul>	<ul style="list-style-type: none"> <li>• Concurrent Engineering</li> <li>• Manufacturing Resource Planning</li> <li>• JIT production system</li> <li>• Reduced Set up and Change over time</li> <li>• Shorter product development times to increase responsiveness and flexibility</li> <li>• Pull production system</li> <li>• Lean Production</li> </ul>

### **3.2.1.1. Design Principles for Agile Production System**

Designing agile systems, whether they be entire enterprises or any of their critical elements like business practices, operating procedures, supply-chain strategies, and production processes, means designing a sustainable proficiency at change into the very nature of the system. A business engineer is interested in both the static (the fundamental system architecture) and the dynamics (the day-to-day reengineering that reconfigures as needed).

Sustaining a desired opportunistic/innovative profile is dependant upon the agility of these systems, which in turn is impeded or enabled by their underlying architectures: Reusable/Reconfigurable/Scalable (RRS) system. Fig 5 provides a set of design principles. These principles have emerged from observations of both natural and man-made systems that exhibit RRS characteristics.

The design of manufacturing enterprise systems, from production process to business procedure, can result in a more or less adaptable system to the extent that certain design principles are employed. The expression of RRS design principles explored in the three production systems is assembled in Appendix A, showing various applications.

<p>Any organization of interacting units is a 'system': an enterprise of business resources, a team of people, a cell of workstations, a contract of clauses, or a network of suppliers.</p>	
<p><b>Self-Contained Units</b> System composed of distinct, separable, self-sufficient units not intimately integrated.</p> <p><b>Plug Compatibility</b> System units share common interaction and interface standards, and are easily inserted or removed.</p> <p><b>Facilitated Re-Use</b> Unit inventory management, Modification tools, and designated maintenance responsibilities.</p> <p><b>Nonhierarchical Interaction</b> Nonhierarchical direct negotiation, communication, and interaction among system units.</p> <p><b>Deferred Commitment</b> Relationships are transient when possible; fixed binding is postponed until immediately necessary.</p>	<p><b>Distributed Control and Information</b> Units respond to objectives, decisions made at point of knowledge; data retained locally but accessible globally.</p> <p><b>Self-Organizing Relationships</b> Dynamic unit alliances and scheduling; open binding; and other self-adapting behaviors.</p> <p><b>Flexible Capacity</b> Unrestricted unit populations that permit large increases and decreases in total unit population.</p> <p><b>Unit Redundancy</b> Duplicate unit types or capabilities to provide capacity fluctuation options and fault tolerance.</p> <p><b>Evolving Standards</b> Evolving open system framework capable of accommodating legacy, common, or completely new units.</p>

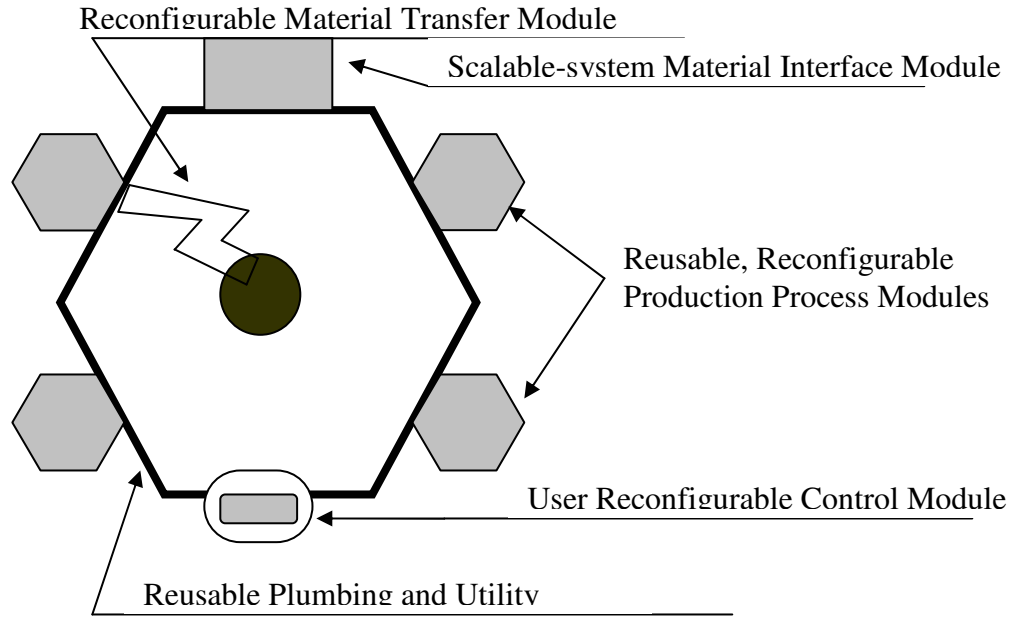
**Figure 5 Agile System Design Principles**

**3.2.1.2. Agile Machines**

Agile Machines Accommodate workflows of intermixed custom-configured products. US loss for semiconductor market in 1970s was due to noncompetitive process equipment- machine tools for semiconductor fabrication. In semiconductor, a high paced industry, production industries advance significantly every three years or so. With each new generation of equipment, semiconductor manufacturers build a completely new plant, investing a great deal of money, in equipment and twice that for environmentally conditioning the building. The machines are developed to deposit thinner layers of atoms, etch narrower channels, imprint denser patterns, test higher complexities, and sculpt materials with new accuracy and precision. Generally, each machine performs its work in a reaction vacuum chamber and sports a sizable supporting cast of controls, valves, pipes, plumping, material handling, and so fourth.

Because the technology in each generation is unique, market success with one generation of equipment has little to do with the next or the previous generation. The industry's history is littered with small vendors that brought a single product-generation to market: single-purpose, short lived, complex machines: long equipment development cycles; repeatability and reliability problems – all targeted for high volume, highly competitive production environment serving impatient, unforgiving markets.

In 1987 new machine architecture is brought to market – architecture based on *Reusable, Reconfigurable, and Scaleable* concepts for semiconductors, Fig 6. The machines decoupled the plumbing and utility infrastructure from the vacuum chamber, and introduced a multi-chamber architectural concept. Instead of one dedicated processing chamber, these machines contained up to four independent processing modules serviced by a shared programmed robotic arm. Attached like outboard motors, process modules are mixed and matched for custom configured process requirements. A centralized chamber under partial vacuum houses a robotic arm for moving work-in-process wafers among the various workstations. The arm also services the transfer of wafer cassette in and out of the machine's external material interface.

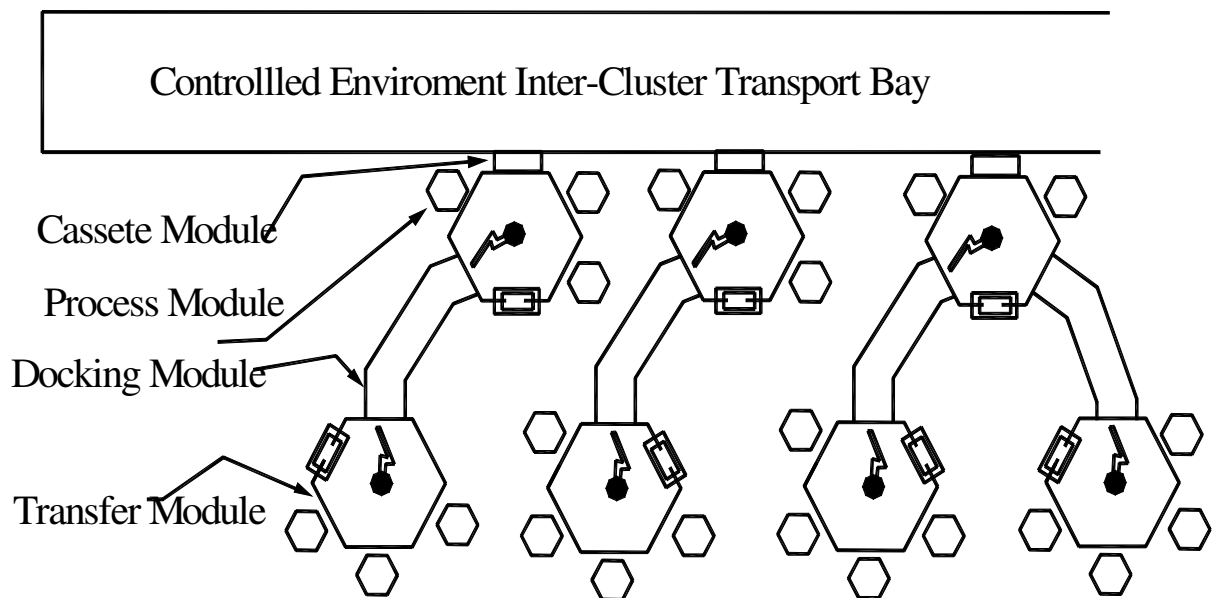


**Figure 6 Semiconductor Wafer –processing Cluster Machine**

**Architecture: Reusable, Reconfigurable, Scalable**

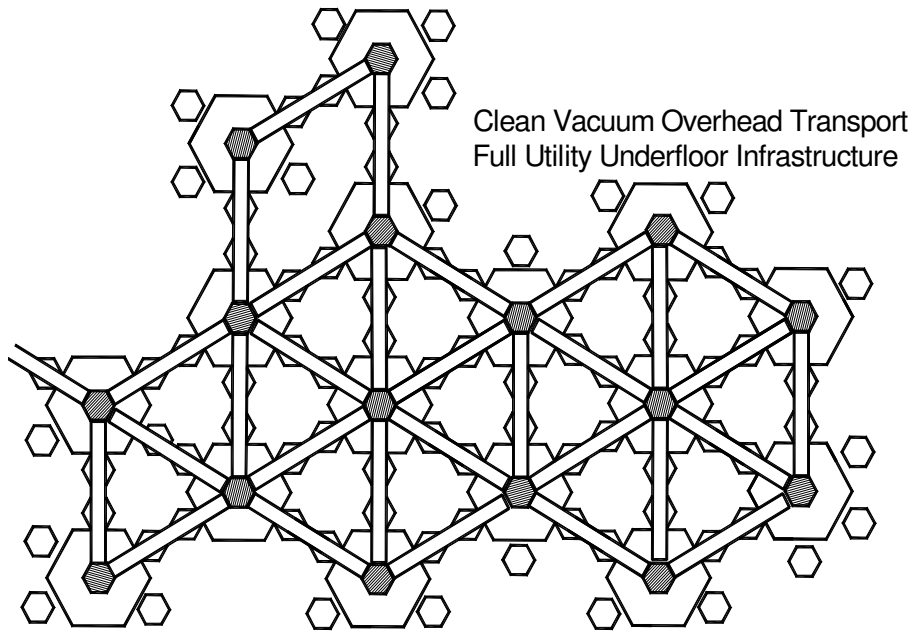
A single machine can integrate four sequential steps in semiconductor fabrication that decrease scrap caused by contamination during inter-machine material transfer. The equipment development time and cost is significantly shortened by separating the utility platform from the processing technology. Development resources are focused now on process technology and reusing a common utility base across technology generations, which accounts for 60% of the machine. More important, perhaps, is increased reliability that the customer's enjoy with a mature and stable machine foundation. A malfunction in a process module is isolated to that module alone. It can be taken off-line and repaired while the remaining modules stay in service.

Semiconductor Manufacturing is barraged with prototype run requests from product engineering. New product typically requires new process setups and often requires new process capability. When needed redundant process modules can be dedicated to prototyping for the period of test-analyze-adjust interactions required for process parameters to be understood. And if a new capability is required, a single new ‘outboard motor’ is delivered quicker. Cluster architecture also brings a very major savings in both time and cost for creating new fabrication facilities, as shown in Fig 7; these machines can be directly interconnected to increase the scale of integration.



**Figure 7 Scalable Machine Clusters**

Extending these concepts and combining them with a strategy for reconfigurable facilities might push the utility services below the floor and the clean transport above the machines. Though this ultimate configuration shown in Fig 8 does not yet exist in a production environment, the possibilities are obvious.



### Observed RRS Principles

#### Reusable

- Self-Contained
- Plug Compatibility
- Facilitated Re-Use

#### Reconfigurable

- Self Organizing
- Non-Hierarchical
- Deferred Commitment
- Distributed Control

#### Scalable

- Flexible Capacity
- Redundancy
- Evolving Standards

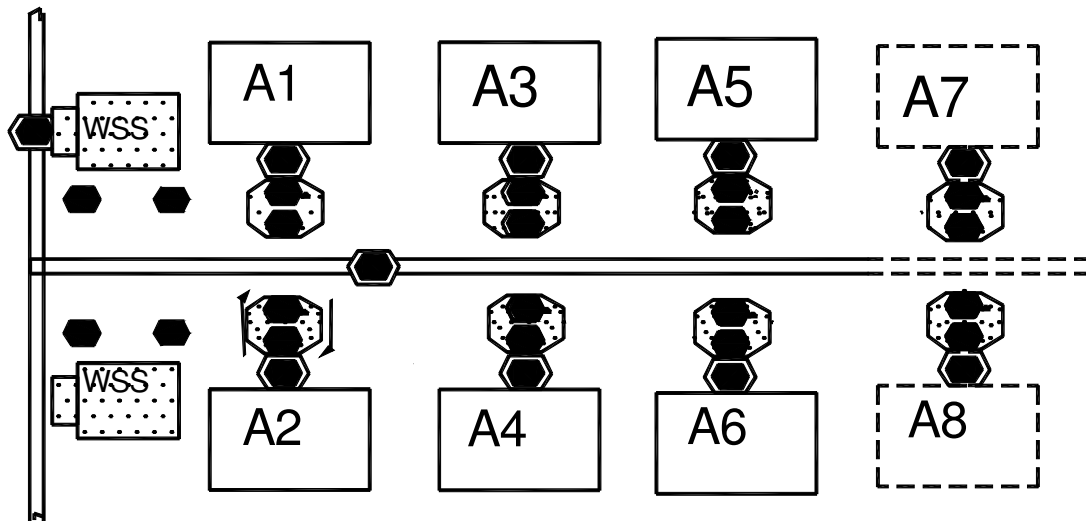
**Figure 8 Agile Machines in a Reconfigurable Plant Framework.**

### 3.2.1.3. Agile Cells

Manufacturing cells in general and flexible machining cells in particular, are not especially new concepts. Machining centers are expensive and building of cells from these multiple machines is still too costly for many manufacturers. It is typical to expect benefits from these flexible machining cells in production operations on high part variety and low volume runs. When justification and benefit values are based on flexible configuration and objective this is understandable.

Flexible machining cells have been implemented in many places, but the agile configuration here brings additional values, Fig 9 and Fig 10. The configuration and the specific modules were chosen to increase the responsiveness to identified types of change. The horizontal machining centers do not require pits or special foundations, so they are

(relatively speaking) easy to move. A cell can increase or decrease its machining capacity in the space of a day and never miss a lick in the process. This is facilitated by a plant infrastructure of common utility, coolant, mechanical, and human interfaces that provide a frame work for reconfiguring modules easily.



**Figure 9 Agile Machining Cells**

Replacement or massive retooling of a rigid production module is more expensive than transformation of a flexible production module. Agile system configuration can further change the economics to overcome an initial investment that has been higher. The price per performance ratio of the modular production units are, becoming better as cells increase their production quantities.

Agile production requires neither agile nor flexible machines—for agility is a function of how the modules of production are permitted to interact. An agile system must be readily reconfigurable, and may gain this characteristic by simply having a large variety of compatible but inconsistently or infrequently utilized production units. (4, 16, 17)

## Observed RRS Design Principles

### Reusable

- Self Contained – Machines, work setting stations, pallet changers, fixtures.
- Plug Compatibility – Common human, mechanical, electrical, and coolant frame work.
- Facilitated Re-Use – Machines do not require pits or special foundations, and are relatively light and easy to move.

### Reconfigurable

- Self Organizing – Cell control software dynamically changes work routing to accommodate module status changes and new or removed modules on the fly.
- Non-Hierarchical – Complete autonomous part machining, non-sequential.
- Deferred Commitment – Machines and material transfers are scheduled by cell control software in real time according to current cell status, part programs downloaded to accommodate individual work requirements when needed.
- Distributed Control – Part programs downloaded to machines, machine life history kept in machine controller, machines ask for appropriate work when ready.

### Scalable

- Flexible Capacity – cell can accommodate any number of machines and up to four work setting stations.
- Redundancy – All modules are standard and interchangeable with like modules, cells have multiple instances of each module in operation, machines capable of duplicate work functionality.
- Evolving Standards – utility services and vehicle tracks can be extended without restrictions imposed by the cell or its module.

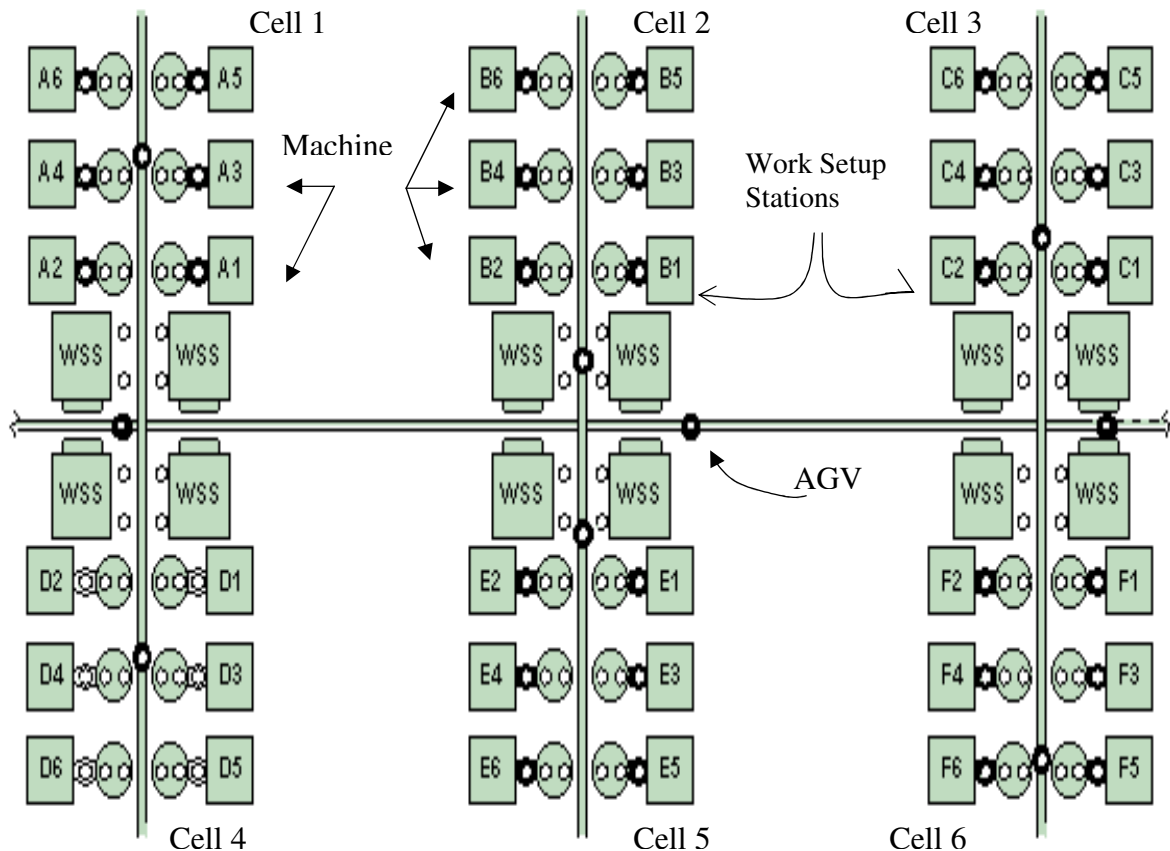


Figure 10 Agile Machining Cells in a Reconfigurable Framework

### **3.2.2.Enriching the Customer**

Enriching the Customer or Providing Solution to the customer refers to the company's ability to deliver customer-adapted products, including the ability to incorporate future services into a given product. An important aspect here is, the establishment of a "lifelong" connection to the customer, i.e. one must be able to continue to service the customer long after the product has been delivered.

The customary view of products is changed from solely focusing on a physical product to include information and services in relation to the product. In traditional mass production, the customer buys a product and uses it until it is worn out or out of date, after which a new standard product is bought from a supplier selected more or less at random. The agile company offers a complete solution to the customer, including both physical products and services.

An example is companies which deal in photo-copiers, from whom one can purchase a complete service. The photo-copier company guarantees to make facilities available, so that one as a customer will be able to produce a given quantity and quantity of photocopies. The suppliers, then autonomously look after all services and maintenances, delivers paper and toner, and replaces the copying machine when necessary and so on. Instead of buying a copying machine, the customer pays a monthly sum, which corresponds, to the current level of use of photocopying facilities.

Selling solutions to the customer means, amongst other things, is to support part of those processes, which are related to maintenance, use, and disposal of the product. For example, one might offer automatic upgrades of products, or perform all service and maintenance of

the product throughout its lifetime, or automatically replace the product, or arrange for disposal of the product when it has to be replaced etc. The key to customer prosperity is to look at the products and services in terms of how much value they add to the customers. World class manufacturers have placed great emphasis on being close to the customer; customer prosperity goes much further and examines how much value is put on the company's products and services.

To intimately recognize the customer's needs it requires understanding customer's use of the products more thoroughly than they know themselves. This requires a short, medium, and long term view. To address the customers' real needs one must sell solutions and not products. Providing solutions, in turn requires a detailed and thorough understanding of the customers needs there by pass together a package of products and services to fulfill those needs. Since products alone many not be enough, one may need to add extra services or technical support or special terms. Adding complementary products supplied by other companies - perhaps by competitors - to truly satisfy the customers' needs.

Automated design systems such as CAD (computer aided design) some times with Computer Aided Manufacturing (CAM) systems can remove much of the detailed skills from the design process so that the designs can be automatically fed into the computer controlled production machines. When more complex products are being sold, the customer is involved in the design, by directly taking part in the company's product development team, or by the customer being given access to facilities for specifying an individual product by design software. The design process can be significantly enhanced by having the customers fully participate. The two companies - customer and producer - work together cooperatively for mutual benefit. The customers bring their design skills to bear of the

project and manufacturer adds its production skills into the equation. In some cases the suppliers and outside process vendors can also be integrated into the design process so that the product is designed to meet the customers needs very effectively. This close cooperation allows for the development of service-rich products that can evolve over time, as the customer and the company work closely together, that may lead to the development of long term relationships. (26, 44)

### **3.2.3.Leveraging the Impact of People and Information**

Leveraging the impact of people and information refers to the company's ability to exploit and disseminate knowledge, both internally within the organisation and externally. An important aspect is the possibilities offered by information technology for modelling knowledge and information. Through the building up of such models, knowledge is made explicit and can thus be shared between different actors, - both internally within the organisation and externally, in a more operational manner.

The new information technology leads to a paradigm shift for the way in which engineers work. Instead of primarily working operationally on work-out specifications, related to concrete products and customer orders, engineers must in the future be able to build up a degree of preparation in the form of the intelligent IT systems. These systems can then support the task of working-out specifications in connection with concrete development projects, enquiries or orders from customers.

Increasingly, it becomes the company's information and the skill of the people that becomes a premium. The company ceases to sell products, as such. Rather sells its ability to fulfill the customers' needs. This knowledge and skill needs to be valued, protected, and shared. New information systems technology has made it possible for the company's personnel to be directly in contact with each other wherever they are in the world. This makes information, skills, and knowledge accessible to the people who are the primary providers of customer service. This can be a powerful tool linking people, customers, and other third parties closely together.

The skills and knowledge of the people within the company become a paramount consideration as a company develops solution-based selling. This knowledge includes product knowledge and experience, but it also includes a rich depth of knowledge of the customers' needs, anxieties, and service requirements. The relationships that develop between the customers and company's people when the company sells solutions instead of products become very much a part of the product itself. The customers need to be treated as individuals, with individual needs, and a history of experience with the company. This level of customer enrichment can only be achieved through the use of knowledge-based systems.

Increasingly, the best way to create close customer awareness is to provide the people within the company, and the customers themselves, a great deal of information. This may be product information, company information, education and training in the use of the companies' products, analysis and data, product upgrades, manuals, drawings, instructions, and specifications. These days, all this information can reside within the computer systems and be readily available to all authorized users including customers, suppliers, and other third party partners. This way, the sales representatives can be highly knowledgeable about

the customers' requirements, ordering pattern, payment history, use of the technical support or customer service facilities, and so forth. Available, complete, pertinent, and easy-to-access information is fast becoming a key competitive weapon that enables all customer contacts to be thorough and satisfactory.

Leading from this, of course, is the ability to closely link the customers' information systems into the producer's systems. Orders can be placed automatically from the customer and scheduled within the plant, yielding the customer accurate delivery promises. The design requirements can be automatically picked up in the customers' information systems without drawings or specification being printed and passed. This enables the company to address customer needs with great agility. Design, delivery information, history, accounts receivable, customer service contact can all be integrated and made available.

Some of the technologies required to achieve this level of information sharing and availability have only become accessible recently. The wide access to the Internet and the World Wide Web opens up a standard and direct method of access information and providing the customers with a standard link into a companies system. For the customers to be linked into a company's information systems in the past, direct link was required (usually through dialing). The Internet and other networks allow the customer to have a simple and standard link to place orders, make inquiries, send message, and specify their needs.

Another important aspect is that the individual employees are required to have the necessary abilities, at the same time they should show flexibility in performing changing

tasks. This last requirement, in particular makes it necessary to build up a culture in which the individual employee is constantly being trained to be able to deal with more tasks.

The individual employees' knowledge and ability, together with their ability to absorb new knowledge and to deal with more and more new tasks, are the crucial requirements if an organisation wants to be able to exploit the possibilities which are present on the ever more dynamic markets. It is also necessary for the employees to be innovative and able to take new initiatives. In this context it is essential that employees who, for example, participate in collaborative projects with external partners are empowered to make the necessary decisions on their own, and that they receive the necessary support for doing so. (26, 55)

### **3.2.4. Cooperation to Enhance Competitiveness**

The rapid change in technology and other skills added to the customers requiring highly specific, customized products has led to the need for far greater cooperation within and between firms. No company can have all the required skills and knowledge. It is just not possible for one firm to have everything, to fully meet a customer's needs. There may be additional services, information, or logistics required to meet the need. To achieve these diverse and ever-changing needs requires great cooperation. In the context of Agility, there are two types of relations - internal and external relationships.

**Internal Relationships:** are those that exist within the firm between workers and between supervisors and subordinates. Often traditional companies have very little flexibility and cooperation between departments. The various departments or areas must work together for the enrichment of the customer, irrespective of the department's short-term benefit.

Relationships inside the firm must be managed to promote agility. Some of the important objectives include:

- Make the work organization adaptive
- Provide cross-functional training
- Encourage rapid partnership formation ,and
- Provide effective electronic communication capability

**External Relationships:** are those that exist between the company and external suppliers, customers, and partners. The customers, suppliers, and other third parties can be brought into the cooperation to design a product or develop a value-added service. In some cases the company will need to seek out specific partners with special skills or attributes and create a virtual corporation from several parties to focus on meeting the needs of a customer. These virtual corporations are opportunistic alliances of core competencies across several firms to provide focused services and products to meet the customers' highly focused needs.

It is desirable to form and cultivate the external relationships for the following reasons:

1. to establish interactive, proactive relationships with customers;
2. to provide rapid identification and certification of suppliers;
3. to install effective electronic communication and commerce capability;
4. To encourage rapid partnership formation for mutual commercial advantage.

The fourth reason raises the issue of the *virtual enterprise*.

**Virtual Enterprise (VE)** refers to the company's ability to collaborate in a manner involving several internal functions, and its ability to collaborate with external partners. This is analogous with the concept of Concurrent Engineering. Where Concurrent Engineering describes concurrency in connection with product development, and Collaborative Operations refers to concurrency in connection with *all* the company's business processes.

Virtual enterprise (also 'virtual organization' and 'virtual corporation' are used) is defined as a temporary partnership (may be with competing firms) of independent resources (personnel, assets, and other resources) intended to exploit a temporary market opportunity. In such a partnership, resources and also benefits are shared among partners.

These cooperative partnerships are not the traditional joint ventures or mergers. They are informally created by companies dedicated to cooperation. Usually there is no complex legal structure. The cooperative arrangements are quickly made, written down so everyone understands their role and expectations, and then put into practice. Virtual Corporation require considerable trust, respect, and openness.

The formation of Virtual Enterprise has potential advantages:

- 1) It may provide access to resources and technologies not available in-house;
- 2) It may provide access to new markets and distribution channel;
- 3) It may reduce product development time, and;
- 4) It accelerates technology transfer.

The agile enterprise is adaptable enough to transform itself proficiency into whatever current trends require. At least, the corporate management understands that business is not just about making money; it is also about staying in business. Making money was all it took to stay in business, but now one can make money right up to the day he become irrelevant – then he is probably the last to know while he is ignored to death.

A corporation stays alive because the customers continue to pay more for goods than the ‘real’ cost of production. This excess payment is required to cover the cost of production inefficiencies (nothing is perfect) and the cost of preparing for new goods to replace ones that (eventually) lose favor. With increased competition, it is getting harder to fund these production inefficiencies; some one is always finding a better way to produce the same thing. With faster technological obsolescence, it is getting harder to fund the preparation for new goods; reduced life generates both less investment cash and a high risk of investing in the wrong thing.

*Downsizing* was the strategy to seek leaner operating modes, while *outsourcing* for increasing responsiveness. When business picks up or new products enjoy high demand, thus downsized corporation are not upsizing. *Contract Manufacturing* is providing new options for fluctuating production capacity, and outsourcing in general is broadening the capabilities and capacities available to a company on a quick notice.

Gaining new productive capacity and capability through outsourcing has several potential advantages: short-term requirement are not burdened with long-term costs, capital investment and its associated risk are both eliminated, the learning curve to develop new production competency is eliminated, and unit costs may well be lower. *Contract*

*manufacturers* and outsourcing firms are thriving by focusing on areas where they have a high degree of competency.

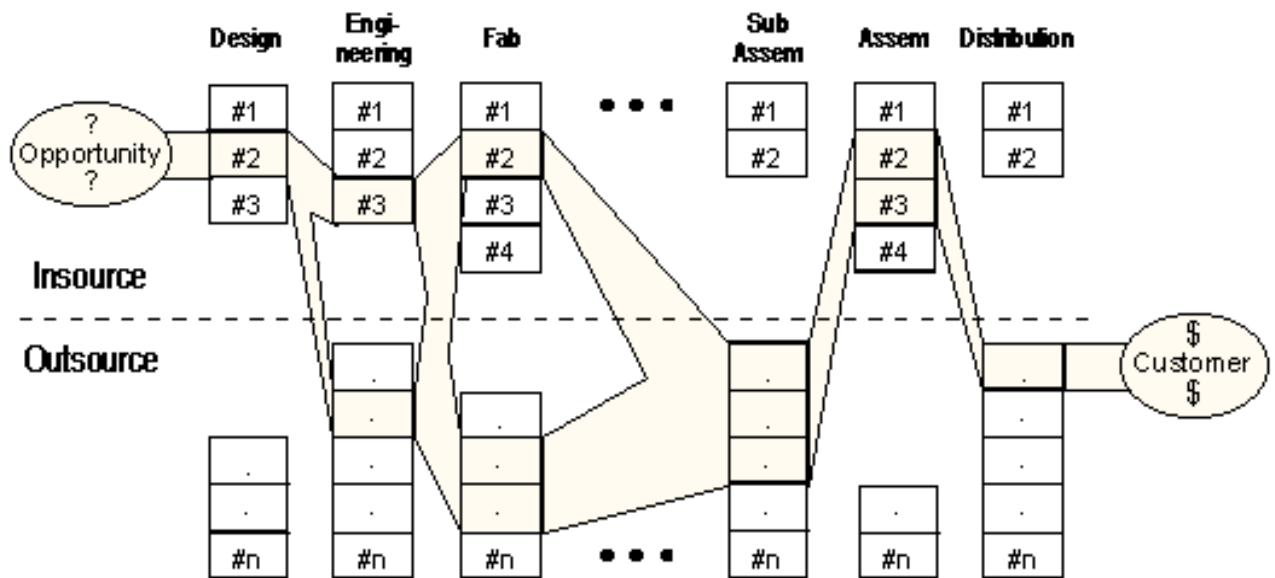
With the advent of the information revolution, companies can readily communicate and cooperate across long distances and provide products and services that are widely scattered geographically and politically. Information technologies, which allow groups of people to work together effectively even if they are geographically separated, are tools that enable these kinds of informal, cooperative endeavors to flourish.

A notable example of this kind of cooperation is the link that has been forged between IBM, Motorola, and Apple Corporation to develop the new PowerPC chip to compete with the Intel Pentium. The companies, in some aspects competitors with each other, have created a team to design, develop, and manufacture the PowerPC chip. None of them could have done this alone.

An Australian company that was experiencing high costs and problems with the replenishment of materials from their principle suppliers entered a cooperative relationship with a transportation company. The truck drivers were given keys to the company's production plants and trained to identify component parts that were in short supply or had kabana requirements. The driver enters a requirement message in the computer system and drives to the supplier for replenishment of the item. These transactions occur continuously throughout a 24 hour period, even when the plants are closed and empty. This significantly reduced costs, eliminated the purchasing/order entry role within the customer and the supplier, and solved many of the part shortages problems. Cooperation of this kind requires trust, training, and an openness to try unorthodox approaches. The difficult aspect of this

change was not the organization of the approach; it was the acceptance by company managers that this would even work.

From the enterprise point of view, agile production is achieved when the makeup and relationships of the enterprise's production resources are easily adapted to the precise needs of the moment, and a fleeting moment it is. *The internal strategy* breaks the company into independent functional resource units that look like one big job shop, Fig 11, when they bid on work, based on their performance capabilities. Good performance is rewarded with lots of jobs, bad performance is starved up to death, and the system is self-organizing. Some learn and improve; others get traded out, shutdown, simply ignored to death, Subsidies replaced with local profit responsibility and investment authority.

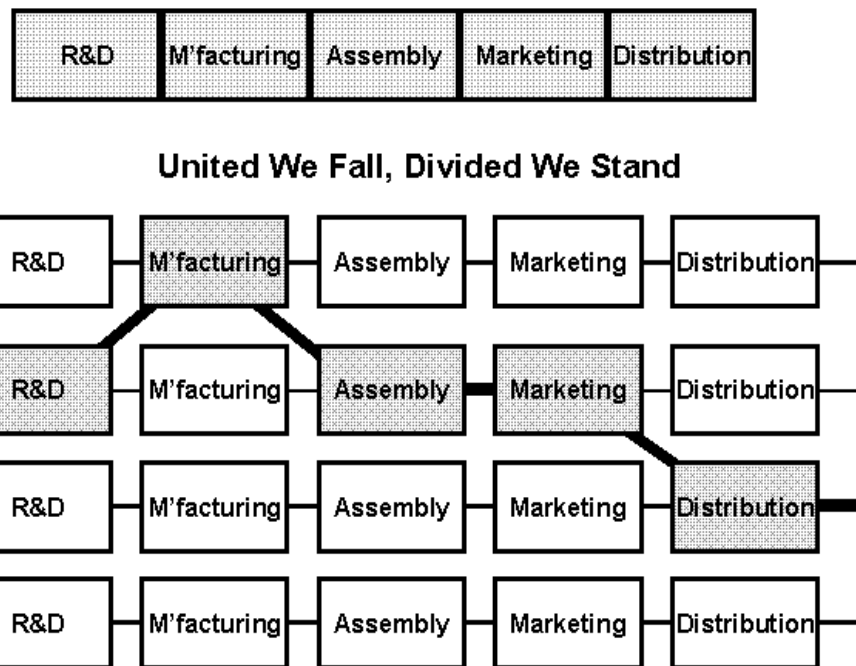


### Resources Bid on Opportunity Fulfillment

Figure 11 Enterprise Job Shop

The *external strategy* recognizes that resources do not necessarily have to be owned and captive; they only have to perform effectively when needed. Outsourcing and contract

manufacturing enters the corporate mix of possibilities here see Fig 12. When a good system is setup, these outside alternatives are not used as threats to distort internal costing, but rather as self-organizing influence that brings best-in-class to the table. The management values the retention of captive resources. It builds a system that levels that real difference over a reasonable time. Invariably, this leads back to responsibility and local authority. Internal units that must compete with best-in-class external alternatives are allowed to compete on an even basis. And by the same token, they are able to find other customers that will help maintain a balanced production rate, justify new capability investment, and inspire innovative leadership. (4, 26)



**Figure 12 Loosely Coupling the Enterprises**

### **3.3. Agile Success Stories**

#### **a) Motorola pagers: To Each his own**

In the early 1980s, the electronic pager industry in America was stormed by Japanese competitors selling high quality pagers for \$100, half the price charged by the half-dozen American manufacturers. By 1985, most domestic producers were out of the business. Motorola realized that, even if it streamlined its traditional production system, it could not hope for more than a 20 percent increase in productivity. A drastic transformation of the production process was necessary, but it had to be done quickly. Motorola therefore, decided to develop a fully automated production process using the best off-the-shelf technology in the world. The idea was not only to reduce production costs drastically and achieve very high quality but also to gain the flexibility to make different pager models faster than its competitors.

Motorola used many concepts and technologies, discussed here to achieve its ambitious goal of *mass customization*. It developed a completely automated, computer-integrated manufacturing processes and assembly line to produce its Brava line of pagers. The pager was designed to have only 134 parts assembled robotically. The electronic devices in the pager provided the customization necessary to allow 29 million possible variations.

The goal was not to transform just the manufacturing line, but rather to transform the entire order-to-delivery process. Instead of taking a month or so to process orders, Motorola transmits orders for customized pagers by computer to its plant at Boynton Beach, Florida, where pagers can be manufactured, tested, and ready for delivery in less than two hours. A

sales person obtains pager specifications from the customer and transmits them to the plant. Computers in the plant use the order information to determine the exact production schedule, plus the machines and robots that will produce the pager. The plant is a show case facility with automated, minimal set up time and flexible build-to-order manufacturing operations. The technology is so flexible that Motorola has been able to dismantle and use some of the equipment in other pager lines. This is an example of a firm that has used technology with ingenuity to dramatically improve all Hour Strategic Dimensions; Cost, Quality, Speed of Delivery, and Flexibility. (8)

## Chapter 4 : COMPARISON OF LEAN AND AGILE SYSTEMS

### 4.1. Comparison of Lean and Agile Systems

In the literature review section, the thesis has thoroughly discussed with the two trendy World-Class manufacturing systems, lean and agile. As both patterns of the systems coexist, there may be a tendency to view the latest system as a successor to the latter. There was a special focus and necessity to catch-up the lean manufacturing paradigm by several firms in the world; and nowadays manufacturers may possibly tend to become agile. This section compares the two systems by referring to their main attributes.

Agile and lean production systems use different statements to describe their core principles that probably emphasize the difference. In Table 4 the four principles of lean production with equal number of agile principles, are indicated. (44)

**Table 4 the Four Principles of Lean and Agile Production**

<b>Lean Production</b>	<b>Agile Manufacturing</b>
<ul style="list-style-type: none"><li>• Waste minimization</li><li>• Perfect First-time quality</li><li>• Flexible production lines</li><li>• Continuous improvement</li></ul>	<ul style="list-style-type: none"><li>• Enriching the customer</li><li>• Co-operating to enhance competitiveness</li><li>• Organize to master change</li><li>• Leverage the impact of people and information.</li></ul>

It is important to point out that agile production system is newer than its co-existing lean system. Though these four main principles with other attributes are mentioned and became a topic of discussion in a number of newer research articles, forums and a few books, the

idea of agility and its implementation remains on development stage. So agile manufacturing system principles and concepts are open for incorporating other matter as researcher and practitioners exploit the topic. More over, Agile System takes many of the developed management, and production approaches.

On the other hand, lean manufacturing is a relatively older system, sustained taking various names by different attracted researchers, authors and industries. Other names given to lean system are depicted below. Its birth goes back more than a half century in the vicinity of Toyota Company, Japan, where Taiichi Ohno and his colleagues begun to seek a better method of production that rescue the factory from the dominance of giant Western companies. Starting from 70s, the system has been given due attention by researchers, authors, consultants and practitioners. Hence, its management philosophy, application method, merits and demerits are explored and explained by many Western Authors and industry cases.

#### **Other Names that some times replace for Lean Manufacturing System**

Just-in-Time / Total Quality Control, name coined by Dick Schonberg  
ZIPS (Zero Inventory Production system), Omak Industries  
World-class manufacturing, also by Dick Schonberg  
MAN (Material as Needed), Harley Davidson  
MIPS (Minimum Inventory Production System), Westing House  
Ohno System, Many companies in Japan  
Toyota Production System, the model in Reality  
Stockless production, Hewlett Packard  
Kanban, many companies in US and Japan  
Modular Manufacturing; apparel industries. (15)

To compare the similarities and differences of lean and agile systems identifying the distinguishing attributes of each is necessary. The main features of the two systems are listed in Table-5 (44). Taking every attributes from lean and corresponding features of agile is more convenient.

**Table 5 Attributes of Lean and Agile Manufacturing Systems**

<b>Lean Production</b>	<b>Agile Manufacturing</b>
• Enhancement of mass production	• Break with mass production; emphasis on mass customization
• Flexible production system for product variety	• Greater flexibility for customized products
• Focus on factory operations	• Scope is enterprise wide
• Emphasis on supplier management	• Formation of virtual enterprises
• Emphasis on efficient use of resources	• Emphasis on thriving in environment marked by continuous unpredictable change
• Relies on smooth production schedule	• Acknowledges and attempts to be responsive for change.

#### **4.1.1. Enhancement of Mass Production Vs Mass Customization**

Lean is emerged during the 1940s, when mass production significantly dominated the world market by its highly standardized goods produced in automated factories that permit utilization of low labor skill and some experts. This efficient system of Fordism managed in a Taylorism fashion had been founded with firm base of experience, development and was enhanced for more than three decades. It was also built on lofty financial capacity that strengthens its capability to extend through North America and Europe.

Observing this seemingly untouchable deep rooted system, firms with limited capacity and small market segment, studied the system for prolonged time. This enthusiastic study revealed some promising opportunities for improvement. Some of potential points for improvement were:

- Time consuming setup for model change that hinder the flexibility,
- Quality problems resulted in high rework and defect sacrificed to smoothen the automated line, and
- Poor resource management. (30)

These rooms for improvement motivated the investigators to look at the enhancement of mass production by minimizing the manufacturing wastes. Consequently, the lean production system is born with focus on flexibility, waste elimination, quality enhancement and continuous improvement.

Agile manufacturing concept, on the other hand, was initiated during 1990s. The fierce global competition of the contemporary market, unpredictable change of business environment and customer demand for high diversity of goods worried industry analysts and researchers. These concerned bodies arranged a conference to investigate exiting challenges of the enterprises and develop a framework to face the challenge. After a thorough discussion, they come up with a set of principles for agility.

One of the important features of agility is to break with mass production and embrace the newly developed business philosophy 'mass customization'. Mass Customization emphasizes on providing customers with high variety of quality goods that are produced and delivered in time. In order to satisfy with this demand companies need to be responsive in design to the extent that each customer could be supplied the particular model he / she intends to purchase. Modularity of products, where by diversified models can be integrated to build up the final products as per the customer order, have of paramount importance. To realize this objective the system relies on recent advanced technologies such as FMS, information technology and loosely coupled enterprises.

In conclusion, these two features – enhancement of mass production and mass customization seems to focus on the same issue, but in different terminologies. At the heart of lean in attempting to enhance mass production; there is flexibility improvement in

production systems that are a prerequisite for responding individualized customer needs. What mass customization emphasizes is that the existing model variation by a firm is not sufficient and it should be further widened. Then, the enhancement of mass production by lean is a basement for mass customization.

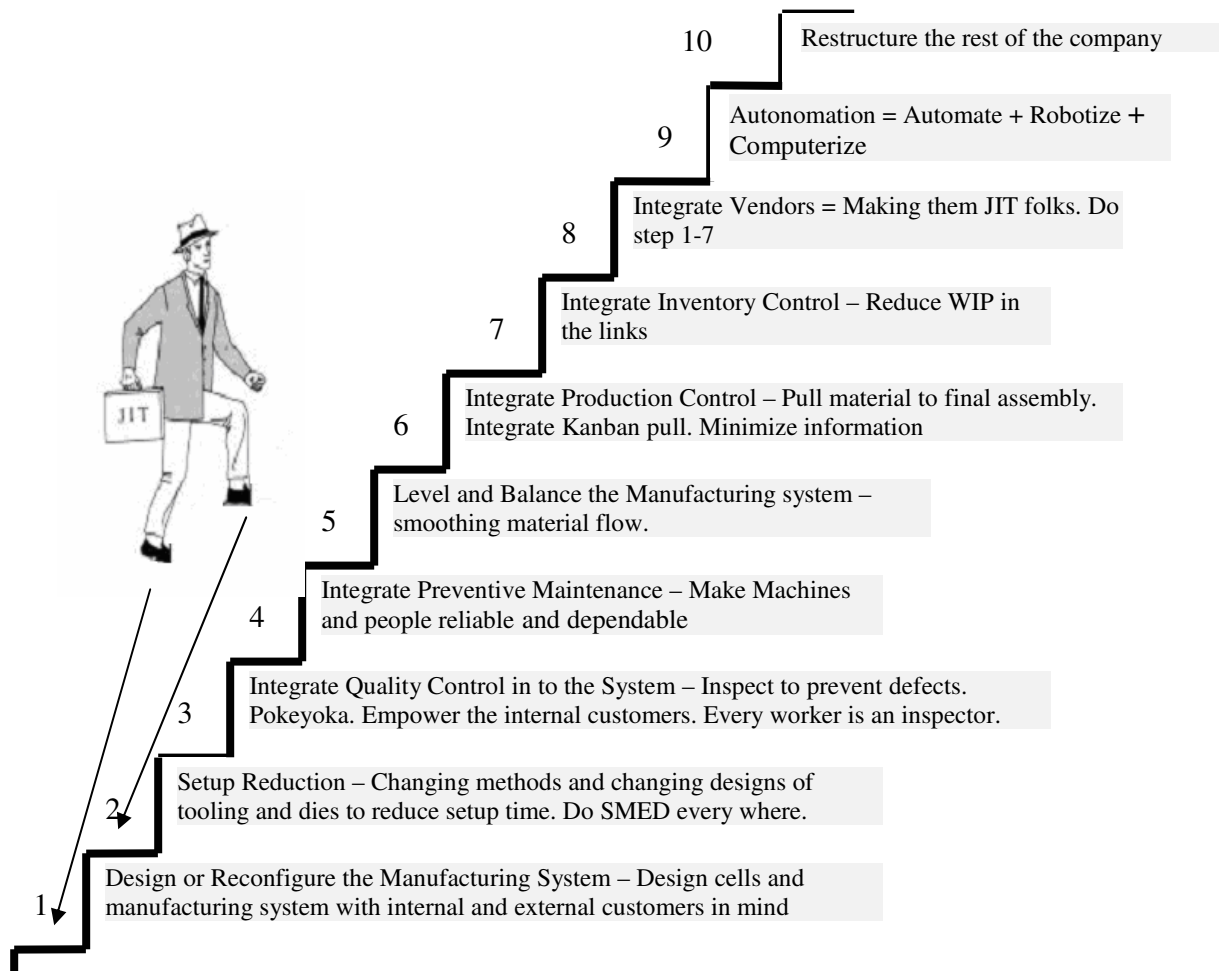
#### **4.1.2. Lean Flexibility Vs Agile Flexibility**

From flexibility perspective lean production thrives to enhance flexibility to alleviate limited resource constraints and competition. This was observed when experimenting on quick-change-over methods on used presses, to bring setup time from several days to few minutes. The traditional economic lot size practice to justify set up costs was broken through by the Shigeo Shingo (another accredited person for Lean system) when he introduced SDEM.

Lean production is not limited on reducing setup times, to flexibility. More importantly, it focuses on workforce flexibility, effective team work supported by cellular manufacturing system. Lean employees are trained to become flexible in handling multiple tasks, such as operation, maintenance, housekeeping and quality control.

Lean system follows methodical steps to build up from simple flexibility to more complex flexibility. The system starts from reconfiguration of simple manned machine cells, (A2), then gradually evolve to a highly autonomous system (unmanned cells), (A5). The steps to become lean are depicted in Fig 13, (15). From the steps, it can be observed that lean recognizes the importance of high tech tools to increase flexibility. This is currently implemented by lean practitioners that robotized cells become common, where economic justification and system requirements are apparent. Lean production is then open to

accommodate simple machines at A(2) level as well as the peak soft tools A (5), that recent and future technology edge brought about.



**Figure 13 Ten Steps to Lean Production or to Integrated Manufacturing Production Systems**

Agile flexibility enquires for greater adaptability on production systems that enable manufacturers respond proficiently for changes. The flexibility of agile system is supposed to be robust to withstand the wave of the market.

Such adaptability requires not only machine cell flexibility but also business practice flexibility. The agile machines, cells, and enterprises are characterized by

Reconfigurability, Reusability and Scalability. All should thrive to benefit or safely survive under either condition, responding reactively and proactively. Consequently, regardless of their cost, in Agile system, Flexible Machining Centers are justified to rapidly answer the multifaceted product demand. It advocates also on use of movable machines that facilitate reconfiguring the layout for mixed production requirements. In addition agile production strengthens flexibility by forming the loose coupling with enterprises.

Immense research is on progress to enhance existing soft automated machines to cop up with the vision of agility. Experiments on agile cells become a research concern. For example, Causey G. C. in 'Elements of Agility in Manufacturing' thoroughly discussed and analyzed Flexible part feeders, Modularity of work cells, Gripper design and other elements. As indicated in the literature part, the agile system enabling technologies are highly advanced, that is why it is called "Soft Manufacturing". Robot, CIM, PLC, and others are part of the requirements of the system. More over, the workforce should be knowledgeable that will react proficiently and initiate innovation.

In conclusion agile manufacturing means that production process must be capable to respond quickly to market change. There fore, the ability to rapidly reconfigure the production processes and systems is essential. In lean manufacturing, ability to reduce changeover time is a key, since long changeover time is a manufacturing waste. However, smooth production schedule may not justify change-over repeatedly. Thus, while it is highly desirable, and to be considered gradually (continuous improvement) to have rapid drastic reconfiguration it is not as essential as with agile manufacturing. (29)

### **4.1.3. Factory Operation Vs Enterprise Wide Scope**

The emphasis in lean seems to be more on technical and operational issues. Lean focus concentrates right down to the shop floor where much of the manufacturing potential opportunities and value adding tasks exist. This strategy is derived from the fact that lean, at the top of its priority, put emphasis on removing the manufacturing wastes, which are more or less located at operational and technical activities. The other principles - say flexible production lines, first-time-quality, and continuous improvement, are all directly or indirectly aligned to factory operations. The seven manufacturing wastes; over production, excess motion, unnecessary processing steps, transportation, inventory, waiting and production of defected parts are all issues of the factory.

Perfect first-time-quality is directed at elimination of defects, the Just-in-time philosophy is intended to produce no more than the minimum number of parts needed at the next work station – to reduce unnecessary inventories. Flexible production lines are again aimed at minimizing transportation, excess motion and waiting time synchronized with Kanban signal system. The continuous improvement approach seeks to pin point areas of improvement on company wide activities. All of these principles and other supportive techniques are core and periphery activities of the factory. Even the external suppliers of the lean factory are linked to the main factory and committed to deliver required amount of components and subassemblies just-in time. Hence, they are remote cells for the host factory. The demand in lean production is derived by market and the factory responds to satisfy the amount required with high level of agility at the right time.

Agility gives emphasizes more on organization and people issues. It's rather broader in scope, applicable to the enterprise level and even beyond, to the formation of virtual enterprises. Agility argues that existing circumstances of industries are difficult to tackle only with factory floor operations and traditional business procedures. In order to meet this uncontrollable challenge proficiently, companies focus should be on coordinating their respective available resource.

To react proactively, agile enterprises leverage knowledgeable workforce that is entrepreneurial in spirit and learner from the facts. Open communication, training and information technology enable the workforce, and the participative customer as well to a successful cooperation. Agile system acknowledges that individual firms of the current time may lack capability to meet agility objectives; unless they formed virtual enterprises that alleviate the limitation of single integrated organizations or small companies. Enterprises, regardless of their geographical location, are desired to be integrated loosely on mutually beneficial manufacturing tasks.

These two attributes of lean and agile - factory operation focus and enterprise wide scope - resembles in a different perspective. Focus of lean, though the factory considers all production functions, is at the factory level using predefined methods and techniques, supported by continuous improvement approach, while agile system focuses on the firm's boundary. The interest of agile on organizational and people issue tends to give less emphasis on factory floor procedural actions. Lean focuses on enhancement of physical tasks that are probably controllable, then solve existing immediate problems and react on realistic foundation. On the contrary, agility gives much attention to initiate change actions that are not in control, anticipating circumstances of disruption. The enabler of agile system

to apply knowledge management is to develop knowledge base system or intelligent manufacturing system. So, in these principles, lean and agile can be analogous to manufacturing resource planning and material requirements planning, that one complements the other in a better way.

#### **4.1.4. Supplier Management Vs Virtual Enterprise**

Lean manufacturing system supply management requires their component and sub-assembled components suppliers to develop lean mentality and practice. The main plant provides managerial and technical support to make them lean, and suppliers on their hand, contracted to supply quality products whenever the main plant just request. The contract is on relatively long-term basis that compensates the small batch production.

Suppliers of lean companies are not limited just on delivering required amount of parts. They play a role in product development activities and process improvement in collaboration with the assembly plant. This practice provides effective utilization of professional excellences in design and process from those tiers that are at real exposure to practical manufacturing situations. This approach cut down the life cycle of new product development. The suppliers of raw parts and receivers are tied closely with similar production philosophy mutual benefits and commitment. The suppliers are virtually remote linked-cells that tap parts as needed.

Outsourcing and contract manufacturing are, given much attention, in agile production system. The companies are not intimately united with each other in technical cooperation. They are partners or value exchanging groups just look for a benefit that an opportunity

brings. This can involve forming of partnership with competitive firms. Enhancing cooperation for competitiveness is the motto of agility. This objective helps bring required products to market as rapidly as possible by using independent resources. The partnership, may dissociate after the market opportunity is passed over.

While firms that practice lean focus on close tie of supply chain for timely delivery of raw parts, agile systems attempt this in a different way – it is a temporary partnership that may or may not be lasted for subsequent market opportunity. Agile system has doubt in the success of using limited number of suppliers that are seemingly permanent. This kind of supply chain as in a lean is fragile because problems encountered in one spot of the chain will disrupt the entire line.

On the other hand, Lean supply chain mutual cooperation creates an atmosphere of solving and handling problems together quickly. Furthermore, the lean supply system enjoys receiving of quality goods from trust-worthy sources participated in the product design. But agile supply system of virtuosity requires open communication, which provide new windows for markets and distribution channels, technology that are transfer and access to resources and technologies not available in-house. The same is also true in lean production, where main plant coordinates supplier of different tier to exchange information about manufacturing processes, and improve the weak one and enhance or replace inefficient production equipment.

#### **4.1.5. Efficient Use of Resources Vs Emphasis on Continuous Change**

Agile system is derived from ever changing business environments. Thus, the core principle is to thrive in the unpredictable market. All the strategies of agile concentrate on change proficiency. The feature of enterprises or part of it, are characterized by change attributes; reconfigurable, scalable and reusable design Principles. The mass customizations and valuing knowledge have also conceived an ultimate goal of being change agent.

Lean stresses on effective proficient use of existing resources to realize waste minimization objective. Human resources, (often cross-trained), carries out multiple tasks such as machine operation, quality inspection, maintenance and so on. Production systems organized in a cellular fashion assist the utilization of lean workforces, machines, and materials, in efficient way.

Machines need to be busy all the time the factory enjoys soaring demand. Breakdown and malfunction are taken care of, by operators, preventive maintenance crews. Material is pulled from the source as needed and flow one-piece-at a time to prevent accumulation of WIP inventory that hide problems. The whole steps are streamlined to minimize unnecessary transports; excess motions and waiting times there by optimize utilizing of equipment and other assets.

The stress of agile is on thriving in environment marked by continuous unpredictable change. According to Agile system, the resources of a particular firm may not be capable enough to respond effectively. The requirement is much more than utilization existing resources efficiently. Unlike lean, that uses resources up to last capability, agile system may

justify making inefficient resources obsolete and make contract with more efficient outsiders. Lean is known for its utilization of simple automation with cross-trained workers to produce low cost goods. But in agility cost it self is, some times, a relative matter, it pursues that speed to market and being change agent be introducing new models to market has a prime importance. This is why the agile system relies on highly advanced flexible manufacturing system, like flexible automation, robotics and computerization. Lean objective towards changing market is dependent flexible production system, continuous improvement and short product development time.

#### **4.1.6. Smooth Production Vs Responsiveness to Change**

If there is much difference between the two production paradigms, it is the area of change and change management. Lean tries to minimize change. It attempts to smooth or level out the ups and downs in production schedule in order to reduce the changeover on factory operations so that smaller batch sizes and lower inventories are feasible. Flexible productions that lean employs minimize disruptions caused by design changes. Production must flow as smoothly as possible which means reducing change from the fixed schedule. According to lean, changes that happen in downstream operations tend to be magnified by half in up stream operations due to extended working time, unplanned setups and procedure variation. Therefore, by maintaining constant schedule over a time, smooth workflow is achieved, and disruption in production fluctuation is minimized.

By contrast, the philosophy of agility is to embrace change in every aspect. The emphasis is on thriving in an environment marked by continuous and unpredictable change. It attempts to be responsive to change, even to be a change agent if that leads to competitive advantage. An agile company tries even to disturb a stable market opportunity if it perceives a window of better benefit in changing the ongoing business practice.

Groover M. 2000 argues that although there may be a difference in viewpoint and perhaps strategy with regard to change, there is no difference in method or approach. The capacity of an agile company to adopt to change or to be change agent depends on its ability to have a flexible production system, to minimize the time and cost of change over, to reduce on hand inventories of finished products, and to avoid other forms of waste. These capabilities belong to a lean production system. For a company to be agile, it must also be lean.

## Chapter 5: Case Studies

# APPLICATION OF LEAN MANUFACTURING SYSTEMS IN ETHIOPIAN INDUSTRY

### *5.1. The company's Background*

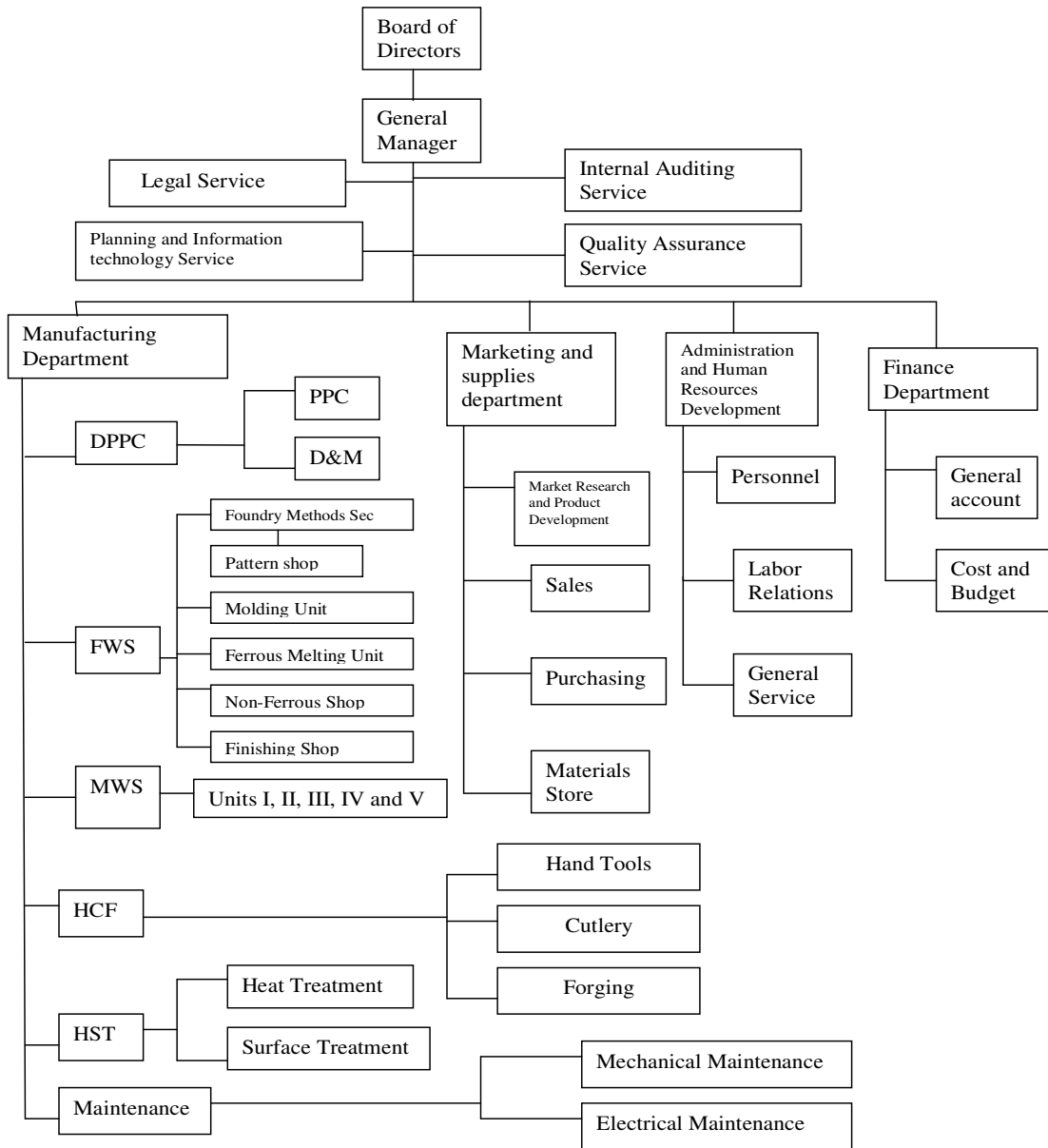
Akaki Spare Parts and Hand Tools Share Company (ASPSC) is probably the biggest job-order manufacturing company in Ethiopia. It is located at the periphery of the capital Addis Ababa (Akaki) adjacent to asphalt and railroad from the port. It is established in 1989, with main objectives of:

- Supplying local factories with spare parts,
- Saving foreign exchange and minimizing order lead-time,
- Enhancing the development of metal sector in the country.

The company has fixed capital of \$83,381,000, and about 600 workers, 300 employees less than its full capacity. Its electric power requirement is about 12MVA. The firm is established on a total area of 155,000m<sup>2</sup> of which 30,500m<sup>2</sup> in use. ASPSC produces various types of products. Its main manufacturing processes consist of: casting, forging, material removal, Sheet metal fabrication, repairing and surface treatment, assembling, and others. As the organizational structure depicted in Fig 14 shows, the direct production areas of the company are divided in to four main divisions. They are:

- 1. Foundry Workshop (FWS)**
- 2. Mechanical Workshop (MWS)**
- 3. Hand Tools, Cutlery and Forging (HCF)**
- 4. Heat and Surface Treatment (HST)**

All the four production divisions are supported by Design, Production Planning and Control and Maintenance section.



**Figure 14 Organizational Structure of ASPSC** (Mezgeu Aweke 2004)

**1. Foundry workshop (FWS):** - In this workshop finished or semi finished metal parts produced by casting. The workshop has four units:

- i. ***Foundry design and Methods section*** - prepares pattern and mold design for the part design. The pattern design is converted into required pattern sets in pattern making shop, and the mould design is sent either to mechanized or manual molding area where by mold cavity is constructed.
- ii. ***The molding unit*** consists of two sub-units: *mechanized molding* area makes light molds automatically, while the *manual molding area* is dedicated for heavy molds mostly by human effort.
- iii. ***Ferrous metal melting unit*** consists of three induction furnaces for melting ferrous metals and three resistance furnaces for non-ferrous alloys.
- iv. ***Finishing shop*** comprises areas for separating molds from castings and then cleaning automatically or manually.

**2. Mechanical Workshop (MWS):** - in this workshop parts are machined using Variety of Heavy and Light Machine tools arranged in Job shop layout fashion. Sheet metal products are also fabricated using different Sheet metal machines, welding operation and others.

**3. Hand Tools, Cutlery and Forging (HCF):** there are three units under HCF:

- i. ***Hand Tools Manufacturing unit:*** manufactures industrial hand tools.
- ii. ***Cutlery Manufacturing unit:*** manufactures household and restaurant items.
- iii. ***Forging unit:*** performs forging operations to give initial shapes to parts.

4. **Heat and Surface Treatment Shop:** consists of two units: *Heat treatment unit* that performs hardening, tempering and carburizing operations; and *Surface treatment unit* that performs Chrome, Nickel, Phosphate plating and Galvanizing.
5. **Design, Planning and Control (DPPC)** division consists of two sections: Design and Method (D&M) and Production Planning and Control (PPC) sections. The D&M section is responsible for preparing specifications, and manufacturing methods. The PPC mainly smooth out the progress of the production processes, by Planning, and controlling the progress of production activities.
6. **Maintenance section:** - this section is responsible to solve mechanical and electrical failures that occur during production operations, and to carry out scheduled preventive maintenances.

#### 5.1.1. Problem Identification

ASPSC is an ideal job shop production system with all characteristics of flexibility and inefficiency in utilizing machines and lack of meeting exact delivery date. It is a complex and highly integrated factory comprising wide manufacturing processes. The company's problems among others are:

1. About 60% of orders are delayed from the promised delivery date; (Appendix B)
2. The company's resources are underutilization while customers remain unsatisfied;
3. Manufacturing wastes that arise from waiting, inventory, unnecessary motion and others are hindering the overall performance of the plant.

Small to medium lots based on customer order and company's initiated commercial items are produced with the help of general purpose production equipment ranging from A0 up to A4 automation level mostly grouped in a functional layout fashion. In such shops parts spend much of the time waiting, or being transported and spend only few time on machines being positioned, loaded, measured or left idle, involving much less time for actual value adding tasks. High handling and transportation costs arise due to frequent movement of parts between departments and diversified flow of works complicate the planning and control tasks.

To over come such and other limitation of the factory considering various alternative solutions that may alleviate the problem becomes a mandatory.

### **5.1.2. Choice of Pilot Areas**

To insight the application of lean production system, two pilot areas are selected:

1. **The FWS, MWS and Order Processing Functions.** In these areas it is intended to identify non-value adding activities, (manufacturing wastes) by mapping the existing value stream and then, proposing alternative Future Value Stream to indicate potential improvement areas.
2. **Cutlery Manufacturing Unit.** In the cutlery unit, the objective is to redesign (reconfigure) the existing functional layout into lean cellular manufacturing layout, thereby enhance the performance of the shop.

The data collection on the manufacturing process flow, order and information flow, product characteristics are obtained from different sources that include: manufacturing process sheet and flow chart, interview, personal observation, existing shop layout, documents and operation manuals.

## ***5.2. Case -1 Value Stream Mapping (VSM)***

Value is determined by the customer and his desire to pay. Value added functions such as manufacturing processes; design, marketing, and service contribute to the performance that the customer desires. Some functions of the production system such as transport, storage, setup, planning, accounting and quality assurance, are among non-value adding functions but an obligatory. (12)

Minimizing actions that create no value has dramatic effect on end result. Value identification then mapping is an appropriate place to start the lean journey and understand the sources of waste in a factory's operation. There are many lean techniques that assist minimize waste. But to apply the tools, identifying existing value stream by walking-through all process steps is necessary.

Value stream mapping help visualize the flow of materials and information from the time products come in as raw material through all manufacturing process steps, and off the loading dock as finished products. This guides towards the future desired state, facilitate analysis and evaluation of the states, documentation of improvement areas, and assessment of the impact of proposed improvements. (3, 10)

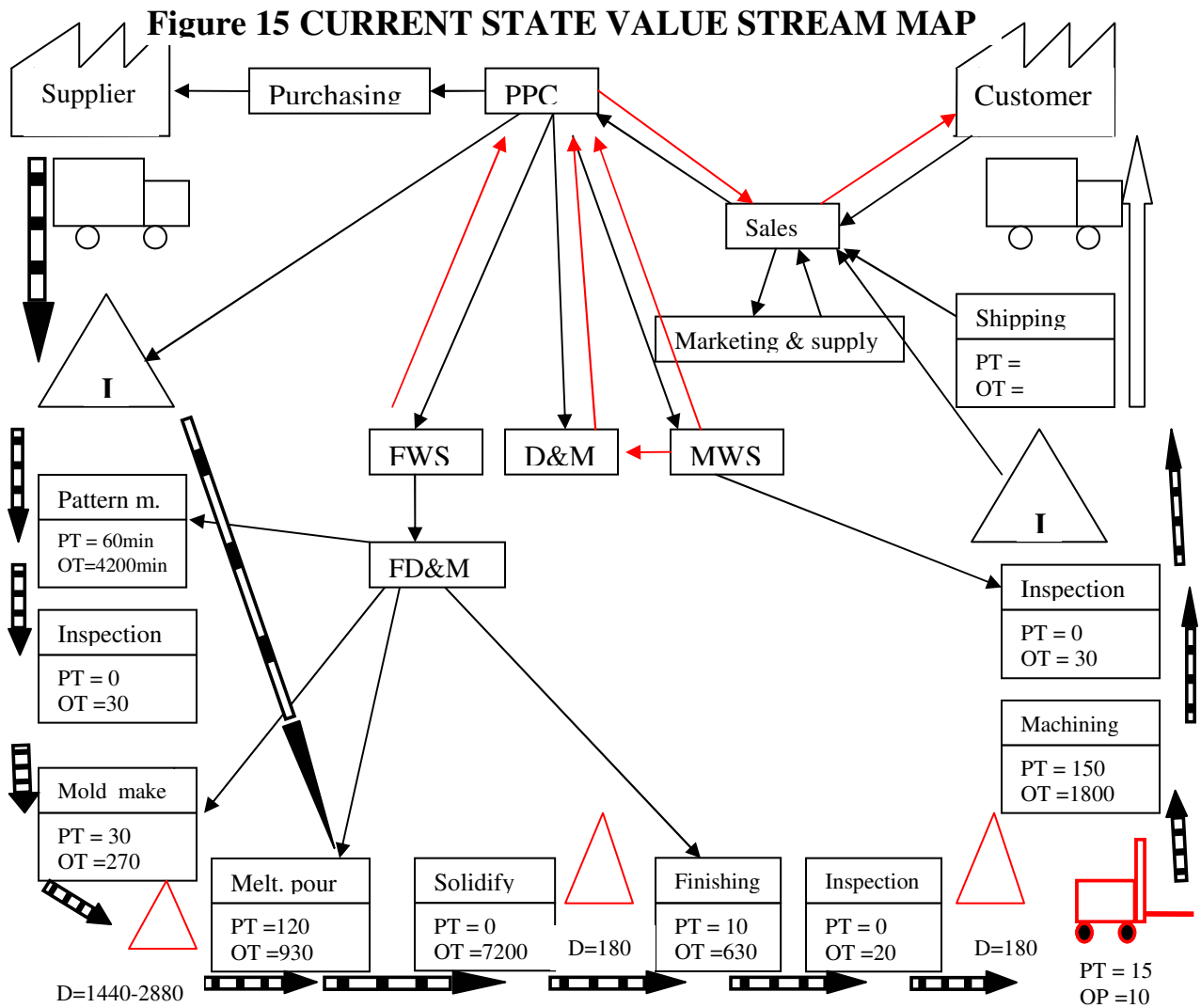
ASPSC manufactures products such as Trash plates, Sugar Mill Rollers, Gears, Scrapper plates, Sprockets, Rollers, Draw bars. Some of the products are spare parts of machineries that belong to selected customers. Among these spare parts '*Trash Plate*', which exists in four different models is selected. The product is chosen for analysis because:

- It is produced repeatedly every year,
- The production cost is high averaging Birr 9,800.00/unit,
- The product is spare part of Sugar Factories machinery, the preferred customers of the company, and
- The part passes through many operations that allow assessing various manufacturing processes in different workshops.

To manufacture one part of 'Trash Plate' a number of orders processing and manufacturing operations are carried out. Along the longest route, the part requires more than 30 order processing steps including revisions, and more than 25 main production operations that actually add value to the finished part.

Analyzing the critical processes leads to map the value stream. For convenience, complicated processes are simplified and grouped. Hence, the material and information flows in the factory for this representative family of product, is mapped as shown in Fig 15. Whenever information is obtained, preparation and operation time are included in the process box, Appendix D.

Job order is received from external customer through fax, via general manager office, letter through archive, sketch or purchase request or sample part directly to the sales Engineer. The order takes considerable time in between the divisions. That will definitely delay the response and delivery date.



The sales Engineer reviews the order and changes it to a preliminary design for cost estimation purpose. The estimation is made after checking the availability of raw material and other inputs on stock.

Manufacturing cost estimation sheet made by sales is transferred to production planning and control (PPC) section for further revision. The PPC evaluates the cost against the material, labor and other overhead requirements. Then approves the cost or sent it back to the Sales Engineer requesting amendments. After the approval, the order tracks back to sales so that price is quoted that will be approved by Marketing and Supplies head.

After all these processes, which take from 3 days (minimum order processing time with latest proposal) up to 20 days, the customer is notified about the price and often uncertain delivery date. If there is agreement on the proposed price, the client will put a purchase order after which the order is dispatched to PPC.

PPC sends the design order to D&M Section. The designers analyze the part requirement and prepare a specification, bill of raw material, operation method; and submit the detail to the PPC. However, the operation method or route sheet does not follow standard form of process sequences nor give detailed, accurate setup and machining time. It only indicates machine categories and production units. The trust is simply on the operator that is assumed knowledgeable enough on the route and machine selection. There is no value engineering or value analysis practice to reduce manufacturing cost or improve the existing manufacturing practices.

In case of problems of manufacturability and cost estimation, D&M Section, in its part, sends the order to PPC for further evaluation. Orders that pass the design stage are dispatched to the workshops. The sample product, 'Trash plate' order is dispatched to FWS and order waiting notice is sent to the subsequent MWS.

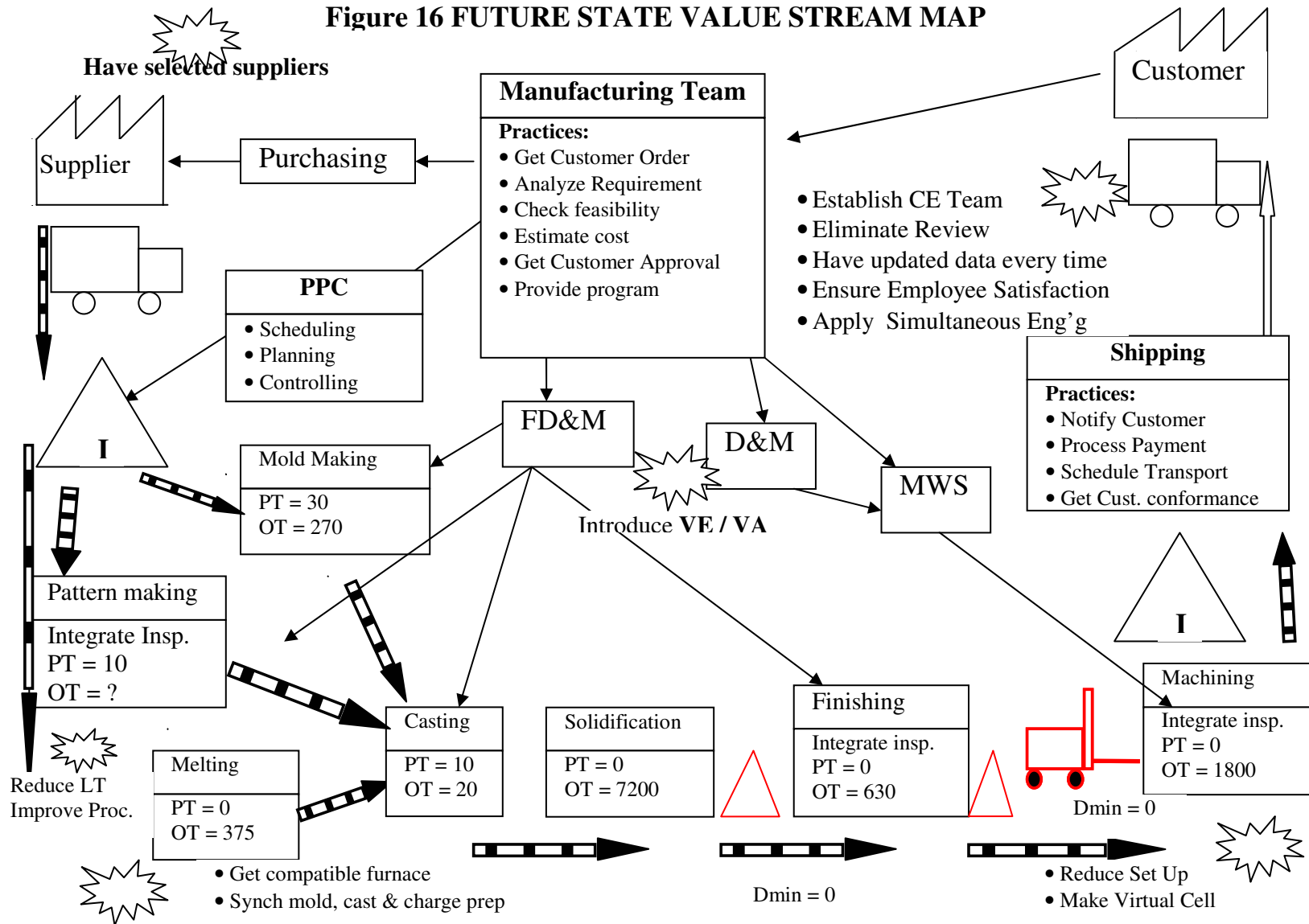
The main problems that can be visualized from the process flow, *current state value stream map* include:

1. Long order Processing time with many reversible actions;
2. Too long pattern making time (12 days);
3. Inflexible large capacity furnaces (minimum 3500 KG charge capacity);
4. Absence of scheduling operation that can be processed simultaneously;
5. Waiting time between operations;
6. Long setup time on machine tools and lack of parallel process.

As the current VSM, Fig 15, clearly shows, there are many manufacturing wastes and problems that can be avoided. Hence, analyzing the existing practices, and thinking the minimization of these wastes leads to the future value stream. The future value stream map developed in Fig 16, shows the possible methods and practices that enhance the overall performance of the factory and locate areas of further investigation. The future VSM indicates the situations in which the over all value stream should be. Based on the proposed VSM, the following activates are needed.

Strong *Concurrent Engineering* (CE) team is established from sales, marketing, accounting, PPC, design and workshops that perform all order processes in a time concurrently. CE refers to an approach in which the functions from all divisions and units are integrated to reduce the elapsed time required to bring new product from concept through production to market. (44)

**Figure 16 FUTURE STATE VALUE STREAM MAP**



The team analyzes the order requirements, and Estimate production cost immediately after receiving the order. Then, price quotation is approved by customer. In doing this, the customer shouldn't wait for long period of time. Depending on the order complexity, the customer is informed about the price within hour(s). After the approval, order is dispatched to different divisions. To be ready for any unpredictable customer order, updated information on material and shop floor status, and other information should be in the hands of the team every time.

This narrows the gap these functional divisions and sections; and give opportunities for manufacturing supervisors to offer advice on how the design might be more manufacturable. The involvement will also motivate and enhance sense of responsibility that will definitely result a remarkable effect in the operational effectiveness. Besides, CE shortens the overall product development process; because steps along the way are handled in parallel instead of sequentially.

In the current practice, the stock level is reported on a monthly basis, while many orders are entertained during a month period. The forces the sales engineer to check material availability every time the new order is initiated. It is more convenient to report the material and shop floor status on a daily basis.

**Suppliers Relationship Improvement:** Most of the approaches of lean production are straight forward and others are not easy to adapt, due to different classic business practices in different societies. The same thing holds true in Ethiopia. Lifetime time employment and Lean supply chain are not prevalent in ASPSC, perhaps a major barrier to achieve lean

significant benefit in terms of continuous improvement, reduced lead time, and inventory reduction.

Among the main problems of the company as well as others in the country is access of raw materials within short period of time. Most of the inputs of metal industries are ordered from abroad spending from weeks to months time. The job shop company such as ASPSC, which receives orders randomly, faces uncertainty of demand quantity, and variety to get ready by increasing the stock level on hand. Even if the demand is predictable, purchasing of inputs from foreign market either necessitates an “economic order quantity” (EOQ) or incurs high price.

In ASPSC, the raw material is purchased based on bid announcement and ‘Proforma’ collection from local and international suppliers. The bid takes up to three months while the local purchasing (proforma) take 3-15 days.

If due consideration is given to the supplier selection and relation, significant lead time can be reduced by local suppliers. There may be suppliers (importers) who have link with multinational reliable companies. Selecting some of these importers and negotiating as to the schedule requirements, may provide better opportunity to access inputs ‘Just-in-time’.

**Pattern Making:** In the production of the trash plate, pattern making processes take more than 50% of the manufacturing time, which account for about 12 days. Though the process is complex, the production time it takes is very high. This time may be reduced to some extent, if many operators are involved cooperatively on a particular pattern element. So, decomposing the pattern into manageable set of items there by distributing and then assembling to the final pattern set may reduce the lead time. It is necessary to improve this

preliminary foundry operation phase by applying every conceivable means. Subcontracting the pattern making or portion of it, to external shops help the company concentrates its efforts on core competitive operations – the actual Casting Process. Moreover, the inspection processes need to be integrated to production process and responsibility is given to pattern makers to eliminate waiting for inspector. The pattern making is a preceding process for molding and mould assembly operation. However, the melting process can be accomplished parallelly if proper schedule is given as to the finishing time of the given pattern.

The *melting process* is perhaps the most rigid operation and source of delay in the FWS. The existing functional furnaces are designed for high volume production while the firm mainly operates on order-based that mostly come randomly in low quantity.

The existing furnaces are operational for melt charge of 3300KG, below which ignition of the furnace is impossible. If received order(s) is/are below the minimum capacity of the furnace, waiting for new orders with compatible product mix is a must. This situation results in an idle time of days or weeks. On the other hand, orders may come as low as 40KG charge, with particular material composition.

In addition, the melting time is a function of charge volume; requiring 0.35min/KG and 0.75min/KG on big and small furnaces respectively. For the ‘trash plate’ of 500KG, the existing furnace requires an order of seven pieces, which may not be the quantity needed by the customer. And this amount of charge will take  $0.35\text{min/KG} \times 3300 \text{ KG} = 1155\text{min}$  or **19.25** hrs, which is approximately equivalent to three working days. In contrast, on a compatible small furnace that may handle the exact customer orders, a single piece order

can be manufactured with zero waiting, and less melting time. For example, a single piece of the part needs;  $0.75 \text{ min/KG} \times 500\text{KG} = 375\text{min}$  or **6.25hours** which is about 33 % of the time needed on the big furnace. Hence, the current melting furnace is the bottleneck point for all ferrous metal foundry processes.

To achieve greater flexibility, and then satisfy customers with reduced delivery time, the company needs to introduce a compatible and robust furnace, for order volume variation. Repairing the available gas furnace will help a lot, but will not solve the whole problem, since this furnace has a capacity of 250KG leaving orders in the range of 250-3300KG charge unresolved. Thus, it is strongly recommended either to introduce new furnaces or modify the existing one for volume flexibility.

Waiting line occurs in front of shot-blast or cleaning, before grinding, and before transfer to the MWS. Proper scheduling of machines and workers, developing a culture of time consciousness may minimize these manufacturing wastes.

In the *MWS*, the trash plate passes through machining processes of milling, grooving, drilling and manual threading after which the part is transferred to finished goods store. In this MWS two important improvement areas can be visualized. The first is **reducing setup time** the can be achieved by having the necessary tools, material handling and work holding devices ready before hand. The single minute exchange die method (SMED) discussed in the literature survey, is a useful approach in this regard. *Machining more than one surface* at a time using appropriate tools and operating more than one machine by an operator in a virtual cell fashion will significantly reduce operation time.

### **5.3. Case -2 Cell Formation**

The purpose of this second case study is to demonstrate how reconfiguring process layout to lean cellular layout improves performance of cutlery production in the company. The conversion to a lean cellular manufacturing (CM) system could help improve quality, minimize waste, and reduce total production costs.

Cutlery is a commercial product of the company to be sold both in both local and foreign markets. On domestic market level, it is mainly supplied to the Ethiopian Air Lines on demand and marketed through the Piazza Shop and factory gate distribution channels to various hotels, restaurants and households.

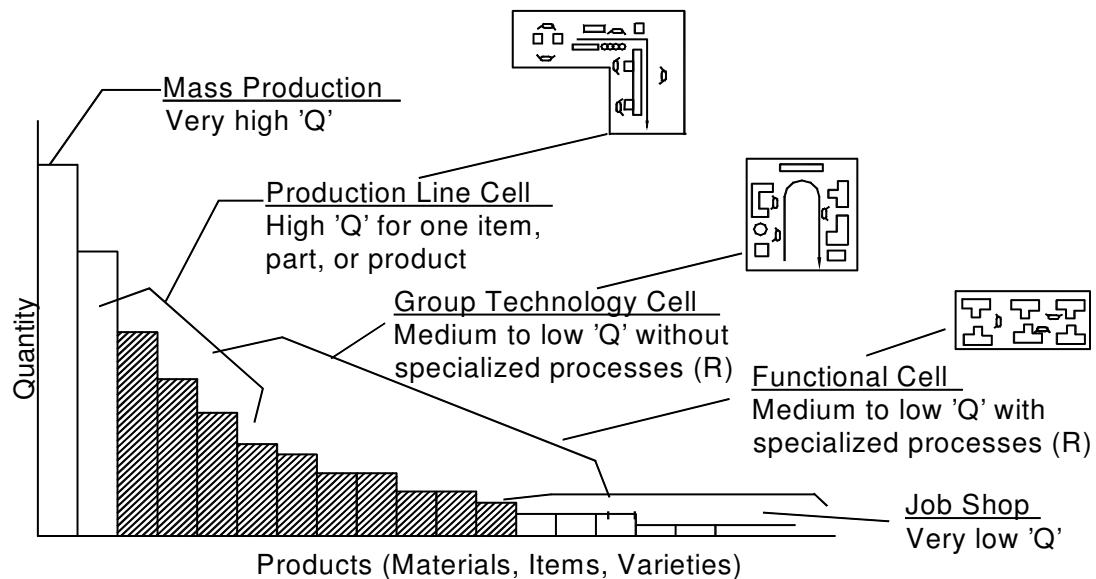
Cellular manufacturing is applicable in a wide variety of manufacturing situations. Survey conducted on industries show that manufacturing industries such as machining, machine tools, agricultural and construction equipment, medical equipment, weapons systems, diesel engines, and piece parts, has implemented CM. Hundreds of companies including such giants as Toyota and Dell Computer as well as small manufacturing entities have successfully implemented this technique and have realized dramatic improvements. In a study, published by the National Association of Manufactures, 1042 American Factories were surveyed and 56% of them were in the process of adopting a Cellular Manufacturing Approach.

CM is appropriately applied under the following circumstances:

- The plant currently uses traditional batch production and a process type layout.
- The parts produced can be grouped into part families.

Cells take different forms based on the product characteristics of parts (P) and quantities (Q) produced and the nature of the process sequence or routing (R) employed, see Fig 17.

Very high quantities lend themselves to dedicated mass production technique such as high-speed automation or transfer machines. At the other extreme very low quantities and intermittent production are best produced in a general-purpose job shop. In between these quantities are the many items, parts, or products that may be grouped or combined in some way to justify the formation of manufacturing cells. Within the middle range, a production line cell may be dedicated to one or few high volume items. This type of cell will have many of the attributes of a traditional transfer line.



**Figure 17 Effect of Q, P and R on manufacturing cells**

Medium and lower production quantities are typically manufactured in *group technology* cells. These are the most common types of cells. They exhibit progressive flow, but the variety of parts and the associated variety routings work differently.

If operations are specialized in some way, requiring special machinery and utilities or special enclosures of some kind, then a functional cell may be appropriate. Functional cells are often used for painting, plating, heat-treating, specialized cleaning, and similar batch or environmentally sensitive operation. (4, 44)

### **5.3.1. Identifying Part Families**

Part family is a collection of parts that are similar either because of geometric shape, size or because of similar processing steps in their production or both. The similarities must be close enough to merit their inclusion as members of the part families.

There are three ways of grouping similar parts: (1) *Design attributes* which are concerned with part characteristic such as geometry, size, and material; (2) *Manufacturing attributes*, which considers the *Production flow* or the sequences of processing steps required to make a part; and (3) the combination of the two.

*Production flow Analysis (PFA)* is a method for identifying part families and associated machine groupings using on production route sheets rather than part drawings. Work parts with identical or similar routing are classified into families, and used to form logical machine cells in a layout.

In this case study, PFA method is selected. Since PFA uses manufacturing data instead of design data, it can over come two possible anomalies. First, parts whose basic geometries are quite different may nevertheless require similar or even identical process routings. Second, parts whose geometries are quite similar may nevertheless require process routings that are quite different. (44)

**Product information:** The existing cutlery products range up to 25 line items and many other order-based items. The part families and varieties are presented in Table 6. Total production volume is estimated approximately 600,000 pieces annually. The batch size ranges from 5,000 to 10,000 units. Detailed parts name is included in the Appendix C. (9)

Table 6 Parts and present families

No	Parts	No, of models	Remark
1	Knives	8	Many others models can be added
2	Spoons	10	There exit other order-based items
3	Forks	7	There exit other order-based items

In the current system machines are grouped together by operation - process layout rather than by product flow as shown in Fig 18. Parts, during production, flow from section to another for subsequent processes.

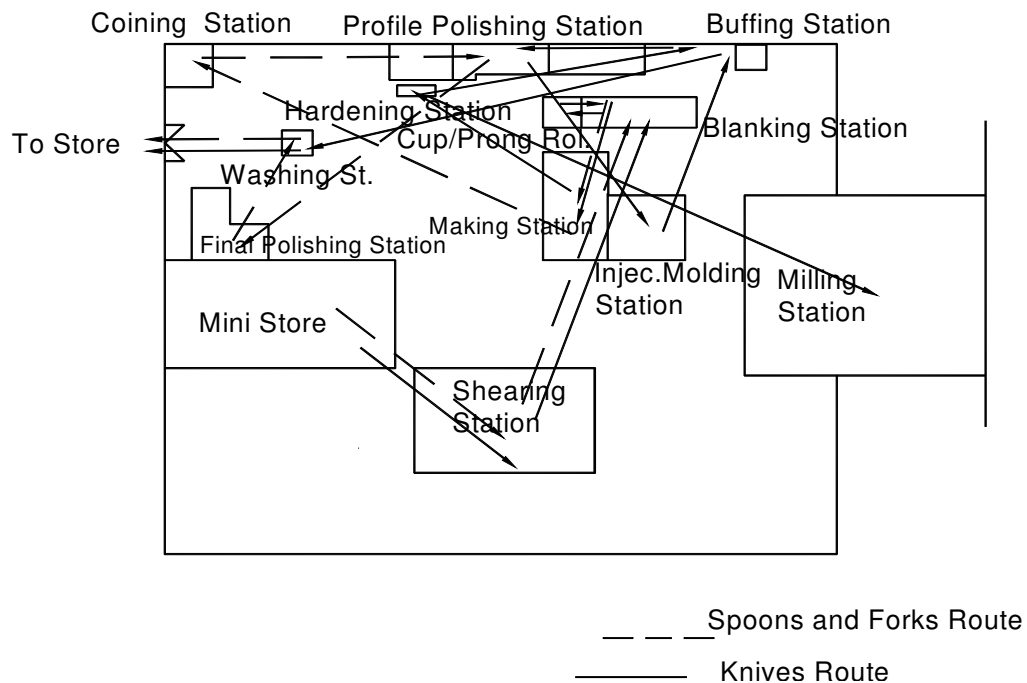


Figure 18 Existing block lay out and product route for cutlery

### 5.3.2. Analysis of processes

The part names and operation sequence are obtained from the manufacturing sheet of the factory. Each operation is associated with particular machine, estimated preparation (setup) and operation time. With reference to the operation sheet, the routine and cycle times (converted to seconds), with respective machines are sorted and presented in Table 7 for Forks & Spoons and Table 8 for Knives.

**Table 7 Operations, Cycle time and Corresponding Machines (Spoons and Forks)**

No	Description of operation	Machines	Cycle time (sec)	Setup time (sec)
1	Shearing	Shearing Machine	4.26	-
2	Blanking	Mechanical Press	12	2700
3	Cup / prong rolling	Cup rolling Machine	15	-
4	Cup / prong blanking	Mechanical Press	12	3600
5	Marking	Mechanical Press	8	600
6	Complete coining	Hydr. Coining Press	11	3600
7	Profile polishing	Polishing Machine	90	-
8	Buffing	Buffer	24	2700
9	Washing	Manual	11	
10	Packaging	Manual	30	

To visualize the routings of the family analysis of processes is done, and presented in operation process chart, see Fig 19.

**Table 8 Operations, Cycle time and Corresponding Machines (Knives)**

No	Description of operation	Machine	Cycle time (sec)	Setup time (sec)
1	Shearing	Shearing Machine	3-8	
2	Blanking	Mechanical Press	12-18	3000
3	Marking	Mechanical Press	10-15	600
4	Hardening and tempering	Harding furnace	8-18	3600
5	Sharpening	Sharpening Machine	28-35	-
6	Profile polishing	Polishing Machine	33-52	-
7	Injection Molding	Injection Molding Machine	13-56	3600
8	Buffing	Buffer	24-43	-
9	Washing	Manual	10-30	-
10	Packaging	Manual	11	

### 5.3.3. Design of Cell








































**Calculating Takt time:** Takt time (Takt meaning rhythm or beat) is the fastest cycle time that a cell, as unit of capacity is able to achieve. In a balanced cellular system, the demand of customer sets the pace of the cell. The Takt time is calculated by inverse of the forecasted demand over the available time for production.

$$TaktTime = \frac{Available\ time}{Average\ Demand}$$

However, the planned capacity of the system also has to meet customer demand while overcoming inevitable variations within the system such as machine down time. Therefore extra capacity that uplift the minimum Takt time is considered. In this cell system Overall Equipment Efficiency factor (OEE) of 85% is considered for both planned and unplanned down times. To give enough capacity, the peak demand is taken.

Hence,

$$TaktTime = \frac{AvailableWorkingTime / shift}{CustomerDemand / shift} * OEE$$

Seq. No.	Operation	Parts		
		Knives	Forks	Spoons
1	Shearing			
2	Blanking			
3	Cup / prong rolling			
4	Cup/prong blanking			
5	Marking			
6	Coining			
7	Hardening and Tempering			
8	Sharpening			
9	Profile polishing			
10	Injection molding			
11	Buffing			
12	Washing			
13	Packng			

**Figure 19 Operations Process chart for Knives, Forks and Spoons**

The annual demand for cutlery is about 600,000 pieces. Working hours per day is 8 hrs with 30 min break time. When the annual demand is distributed over the year working days it gives the daily demand. According to the information obtained from marketing department 360,000pcs are for domestic sale and the rest 240,000pcs for foreign markets.

Categorizing of products under consideration in to Table, Desert, Coffee/Tea, and Kitchen Cutlery, give reveal the following demand quantity for each category, (9).

**Table 9 Cutlery Products Category and Annual Quantity**

S.N	Cutlery Categories	Annual Quantity (Pcs)
1.	Table Cutlery	360,000
2.	Dessert Cutlery	90,000
3.	Coffee/Tea Cutlery	90,000
4.	Kitchen Cutlery	60,000
	Total	600,000

Further, regrouping of these products in to their families indicate that, they lie in to three families namely Spoons, Forks and Knives with annual demand of 200,000 units each. Thus, the market requires 200,000 units during 250 working days a year and manufacturing is planned to run on 8- hr shift.

Therefore the daily demand is:

$$Demand / shift ForEach Family = \frac{200,0000Units}{250day} = 800Units / day$$

Effective work hours per day (W) may vary from factory to factory due to differing policies for shift length, lunches, breaks, and other allowances that take away from available working hours. The scenario for ASPSC is an 8-hour shift with two 15-minute breaks

$$W = 8 * 60min - 2(15min break) \Rightarrow W = 480min - 30min$$

$$W = 450min (7.5EffectiveWwork hours per day)$$

The resulting Takt time would be:

$$TaktTime = \frac{Available\ WorkingTime\ / \ shift}{CustomerDemand\ / \ shift} * OEE$$

$$TaktTime = \frac{450\ min}{200,000} * OEE$$

$$TaktTime = 33.75 * 85\% \ sec\ onds$$

$$TaktTime = 29\ sec\ onds$$

This would mean that to satisfy the demand, a completed product would need to come off the end of the production line every 29 seconds in for one shift.

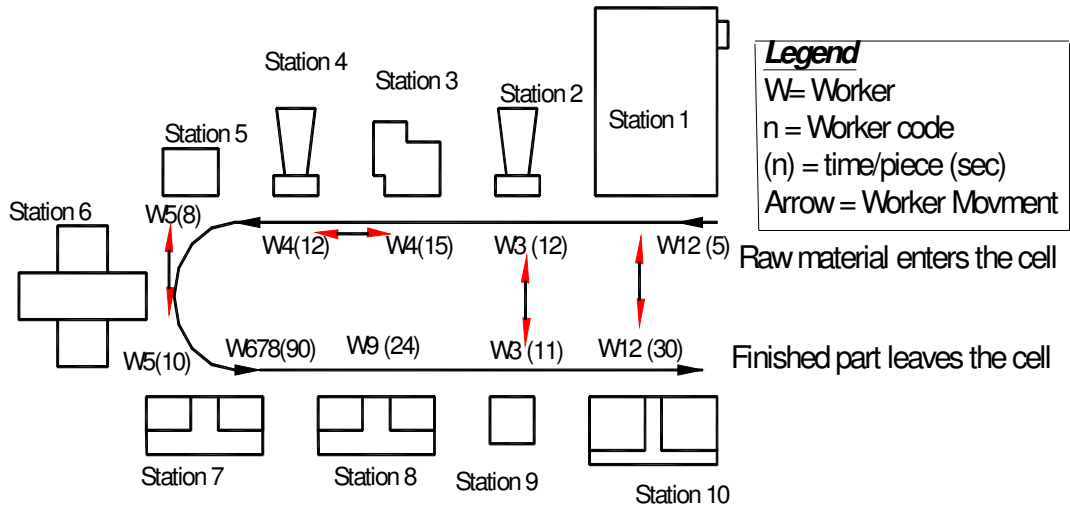
If the system is to operate at Takt time, the work content at each station should be in such a way that designed operation time is less than takt time, (11, 12). The total processing time of each station including loading and unloading parts and walking should be less than 29 seconds.

$$M_{CTi} \leq TT_{min} \quad \text{Where} \quad M_{CTi} = \text{cycle time of the machine } i$$

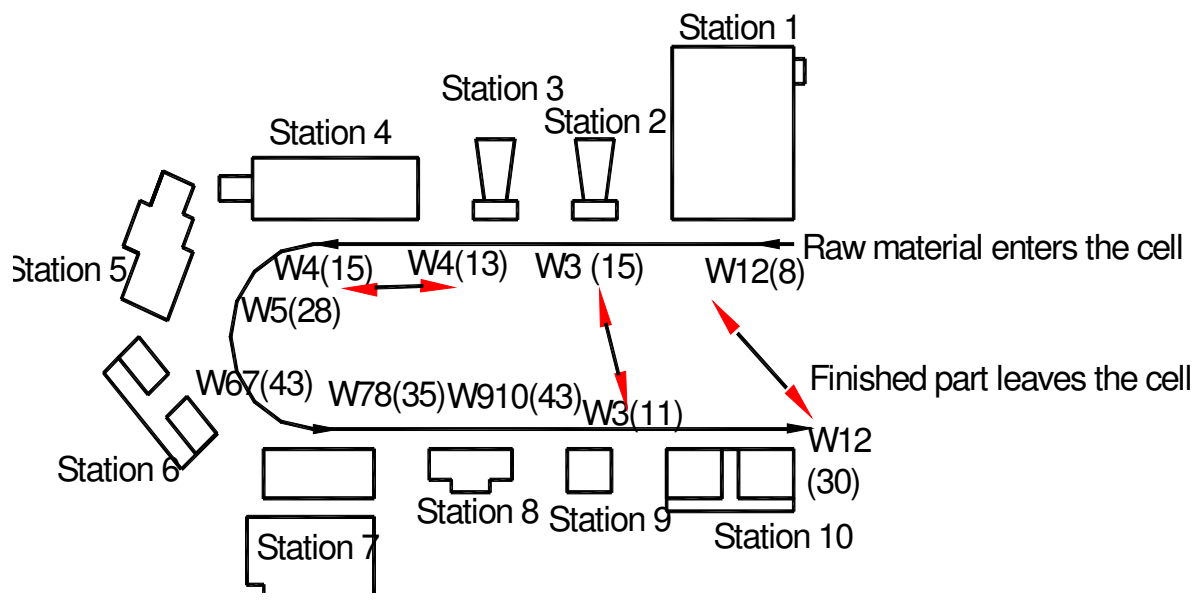
$$TT_{min} = \text{Takt time}$$

Since the products are small discrete items, manual loading and unloading, with carts for material handling is chosen. Besides, workers can operate more than one station with a little wasted motion possible.

Considering all these points leads to a cell layout design for the spoons, forks and knives as presented in Fig 20 and Fig 21. AU-shape configuration is selected to accommodate operator work loops. Grouping of operations resulted in 10 stations for Spoons & Forks, and Knives each.



**Figure 20** Cell Layouts for Spoons & Forks



**Figure 21** Cell Layouts for Knives

## **Description of the Stations**

Station #1 consists of sheet metal shearing machine for preparing strips of required width from standard stainless steel sheet. Since the machine is bulky, the operation requires two workers. The second station, station 2 uses mechanical presses, to give the initial shape of the item (blanking) and prepare for the next operation. Station 3 is dedicated for rolling the cup/prong portion of spoons and forks respectively, by forcing blanked part to pass between the rollers. The rolled portion then is trimmed in station 4 (cup / prong blanking).

Station 5 marks patterns, letters, brands and or other special features on shanks of spoons, forks, and blades of knives using predefined dies. This gives a customized feature to order-based items, and attractive patterns and information for commercial parts. Coining (station 6) is an operation of making detailed designs and geometries (contour) on surface of the part using hydraulic coining presses, with die attachment.

Station 7, a polishing machine is the most laborious and time consuming bottleneck area. The operation is to give a clean and free surface from rusts and burrs. The polishing operation is carried out manually, by holding the part against the rotating abrasive belt. Considerable amount of time that account for nearly 50% of the total cycle time is needed. To level the production at the required takt time, two machines and three workers (W678) are assigned.

Station 8 is a polishing process that results in a shiny surface area by rubbing the part against a rotating fiber. Washing is carried out before packing so that the cutlery products get clean from any dirt, dust and hand prints. Station 9 cleans and wipes the part and then passes the part to Packing Station 10. The packing wraps in a plastic film and packs the utensil in a cartoon case, which carries information about the product.

Many of the machines for Knives are similar to the spoons and forks, with the exception of routing and some other stations. Stations that are special for Knives include: plastic molding machine, sharpening machine, hardening and tempering furnace.

The hardening and tempering furnace station 4 is dedicated for enhancement of mechanical properties of the knives, especially to give hardness. The knife sharpening machine Station 5 performs grinding operation on cutting edge of the knives to give a beveled sharp edge.

Station 7 moulds a plastic handle to knives. The operation consists of plasticizing raw material PVC, melting the material and then injecting it to the mold where handles of the cutlery is placed.

The operations and machines for forks and Spoons are similar, except for die change. If change over time is significantly reduced, one cell can handle both families, provided that additional shift is needed. Or else duplicating the cell allows meeting the demand.

### **Configuration of Operator Work Loops for Takt Time**

The workforce is used most effectively if the operators are able to run more than one stations at the same time. This separation of operators from machines is possible because workers operate multiple machines. Parallel or U-shaped configuration with minimized machine width, helps to reduce the operator walk time. Cellular productions are generally operated on the following schemes:

- **One-person scheme** – assigning one cell to one person,
- **Rotation scheme** – one cell is shared by several operators who move from station to station at approximately the same pace;
- **Allocation scheme** – the various process steps within the cell are divided up and work is accomplished through synchronized efforts. (4)

Accordingly Allocation Scheme is selected for these particular cells.

The ideal number of workers in a cell is given by the following equation, (33):

$$NOR = \sum_{i=1}^n \frac{OCT}{TT}$$

Where NOR is the number of operators in a cell; OCT is the operator cycle time, (station cycle time plus walking time to the next station); TT is the cell takt time.

$$NOR = \sum_{i=1}^{10} \frac{OCT}{TT}$$

For the fork and spoon,

$$NOR = \sum_{i=1}^{10} \frac{5 * 2 + 12 + 15 + 12 + 8 + 11 + 90 + 24 + 10 + 30 * 2}{29} = \frac{252}{29} = 8.69 = 9 \text{ worker s}$$

And for the Knife station,

$$NOR = \sum_{i=1}^{10} \frac{8 * 2 + 15 + 13 + 13 + 28 + 43 + 35 + 43 + 11 + 30 * 2}{29} = \frac{277}{29} = 9.55 = 10 \text{ worker s}$$

At minimum takt time 9 operators are needed in the cell for spoon, fork each; and 10 operators for knife. In a station requiring a cycle time of nearly equal to takt time, one operator is assigned. If the cycle time of the station is greater than takt time more than one worker are allocated. If the cycle time is far less than takt time, two close stations are handled by one operator. The number of operators is not a fixed value, as the takt time varies with customer demand, it changes as well. For example, for the demand case that requires more than 30 seconds of takt time, less number of operators is necessary to operate the cell.

In the layout, Fig 20 and 21, the workers are allocated on a one-piece-at-a time scheme. In dead, the result matches the theoretical concept of 'make-one-pass-one'. However, in these particular cases, the cycle time of most stations is so small that require repeated human touch. Thus, it is more convenient to produce the items in small batches, so that workers operate a particular station for the required batch and alternate to the other station to produce similar batch. This will result in a leveled production and allow the worker to be more efficient. Kanban Control system can readily be introduced.

#### ***5.4. Improvements Sought***

One of the important principles of lean manufacturing approach is its focus on continuous improvement. There is no limit for improvement, it should be thought every time endlessly. In this regard, the potential opportunities of ASPSC for incremental improvement exist in the skilled and well acquainted workers of the factory.

Technological improvement and innovation may demand expert and capital investment. These kinds of expertise and investment, though it is important, may be difficult to obtain. Moreover, technological innovations are replaced quickly, tending to make the today's

technology obsolete tomorrow. Thus, it is imperative to look for improvement on process innovation.

Lean cellular production system opens the door for process improvements, both before and after implementing the cell. At this stage, improvements can be considered on: Product development and Die design.

**Product development:** ASPSC has the technological capacity that makes it competitive. This is especially true with regard to the Hand tools and cutlery production. It is the only company that manufacture order-based and company's initiated commercial items in the country.

This competitive advantage of ASPSC should be given due consideration so that it cop up with domestic and foreign market requirement. The D & M section is expected to enhance the product development by cooperating with marketing and sales division.

This task requires collecting the brands that emanate from different parts of the world and learn about the product's quality feature, material, process and aesthetic appearance, there by develop market oriented attractive items. The selection of raw material design also matters the final part quality, manufacturability and cost. The Thickness of raw sheet shouldn't be more than the functional requirement of the part.

**Die Design:** Perhaps one prerequisite for the flexibility of the cell to process products is die design and changeover time reduction. The products require with special upper and lower dies attached to mechanical and hydraulic presses for every style. The changeover process in ASPSC takes from 10 min-to 60 min on some machine. While the changeover process is

an important task, the time is non-adding that should be minimized. Beside, it hinders the frequent changeovers among product variety, which leads to the rigidity of the system. Hence the change over time should vigorously be attacked by using Shigeo Shingo's setup time reduction rules discussed in chapter-2.

The physical die design also plays a great role in reducing process steps. In some cases, a die design can incorporate two or more process steps, like shearing and blanking at a time. If this approach works by some modification on the blanking machine so that it accommodates a standard sheet metal width, the shearing machine can be eliminated from the system. Or else, the imported raw material can be bought in the required width.

Moreover, accurate die sets that produce more than one piece at a time would double, or triple the production rate. This will also help reduce scrap rate; because the allowance left for one piece operation and two or more piece operation simultaneously, significantly differ in material utilization.

## **5.5. The Advantages of the Proposed Cellular System**

1) **Process Improvement:** One of the advantage of moving machines into cells and flow lines is that it opens the door to process improvement. A team, or perhaps an operator, can run more than processes and take ownership of a product. In the proposed cell system, several methods can be deployed to ensure predictable quality of output. First, inspection can be made after a station performing critical operations. This helps reduce the time it takes to find the source and correct problems that eventually contribute to better quality. Operators who move work in a cell are in an ideal position to see where simple improvements can be made. With operators generating ideas, factory engineers might equip conventional machines with automatic load and unload or with switches.

- 2) **Space Saving:** The proposed cell requires narrower aisles than the existing one. As the area is dedicated only for worker and small carts for WIP movement, the need for fork lift passage, large work transfer from station to station through these cells is avoided. More over, the gap between subsequent machines can be made closer as much as the technical and operational activities are not hindered.
- 3) **Reduced Motion in Distance Movement:** Instead of moving from one functional station to another, crossing long distant and encircling ways for subsequent processes, the movement of the operator and work in process is restricted in the cell's defined path way. Backtrack is completely eliminated. In deed, the distance moved in these cells is approximately 12.5% of the existing workshop.
- 4) **Time Reliability:** Predictable time output is a basic requirement for a Just-In-Time production and distribution. Time output is affected by all relevant processes involved in the production of a part. In a lean manufacturing system, all relevant processes are designed to meet takt time and operate in a periodic way. This periodicity gives room to absorb the variation of each cycle time. In other words, as long as machine operations are done within takt time, reliable time output is achieved. In addition, all operations have standardized steps to follow, so that reliable time outputs from workers are ensured. (33)

## **Chapter 6 : APPROPRIATENESS OF LEAN AND AGILE MANUFACTURING SYSTEMS IN ETHIOPIAN**

### ***6.1. Industries Survey***

In order to argue on the appropriateness of the lean and agile manufacturing system in Ethiopia, it is imperative to assess the industries situation and drive conclusions on the market forces that increasingly challenge the manufacturing sector. This assessment is done through structured questionnaire systematic interview, and discussion with companies' representatives. Whenever possible, tour to production areas has been done to observe, the physical states of manufacturing systems.

#### **6.1.1. Types of Industries Covered**

The kinds of industries taken in to consideration operate in various types of manufacturing sectors. Among these industries the governmental industries account for about 64 % while the private ones complement 36 %. From each category, some representative industries are taken randomly, that are located in Addis Ababa and the surrounding. A total of 25 sample industries are surveyed that may symbolize other industries in the country. The types of manufacturing industries surveyed are shown in Table 10.

The questionnaire is organized in such a way that companies' managers or their delegate may respond to the feedback form. In the questionnaire, lean and agile production systems were introduced with brief notes and further explanation was made as the need arises, see Appendix F.

The points emphasized in the questionnaire are intended to assess the attitudes of manufacturing industries towards the appropriateness of lean and Agile manufacturing systems to the Ethiopian industries and to check whether the existing market forces, drive companies towards more responsiveness. Towards this end, respondents reflected their attitude as to the appropriateness of the two systems (Lean & Agile) and the prevailing images of their respective companies.

From 25 questionnaires distributed 22 are returned that account for 88% of the total. See Appendix E for list of industries surveyed.

**Table 10 Types of Manufacturing Industries Surveyed**

<b>NO</b>	<b>Types of Manufacturing industries</b>	<b>Governmental</b>	<b>Private</b>	<b>Total</b>
1	Metal industries	7	2	9
2	Plastic industries and Glass	2	2	4
3	Food and Beverage industries	1	1	2
4	Shoe factories	1	1	2
5	Paper and printing industries	1	1	2
6	Textile and Garment industries	3		3
7	Electronics Assembly plant		1	1
8	Chemical industries	1	1	2
	<b>Total</b>	<b>16</b>	<b>9</b>	<b>25</b>

The reasons for the in proportionate of governmental and private industries stems from two reasons:

- i) The private industries, even though increasing in number tends to be reserved for visitors. Besides, the private industries are mostly on small enterprise level that may narrow the scope of the survey,

- ii) The abundant features of industries can be seen predominantly in the governmental companies. They are probably the best source for the purpose of the investigation this is because the government owned companies, have more capacity and long term experience compared to private companies. They are also with a host of problems.

### **6.1.2. Results of the Survey**

The significance of this analysis is to communicate the findings to concerned parties, readers, contribute to the topic and make the research more result will be reliable. This manifests that what ever said in this thesis can be supported using structured empirical data from local sources and its interpretation.

The method of analysis of the data is simple statistical percentiles and distribution. For easy visualization of results graphical representation of the data is given. The interpretation and lastly conclusion is made about the findings.

The core points of the questionnaire are:

1. Awareness to Lean and Agile Production Systems
2. Challenges of companies in existing business environment
3. Main problems of companies
4. Changes in customer behavior
5. Competitive strength of companies
6. Level of companies with regard to responsiveness
7. Appropriateness of Lean and Agile in Ethiopian context

## 1) Awareness to Lean and Agile Production System

As to the awareness of the respondents to Lean and Agile systems, around 90% of the respondents were new for the term lean and agile production System. During the discussion, it is found that some of respondents think that they are aware of the lean production principles. But the awareness is in its narrow sense, for example, the manufacturing wastes, were understood purely as rejects and improper utilization of raw materials. Even recycling of defective parts is taken as normal practice.

## 2) Challenges of Companies in existing business environment

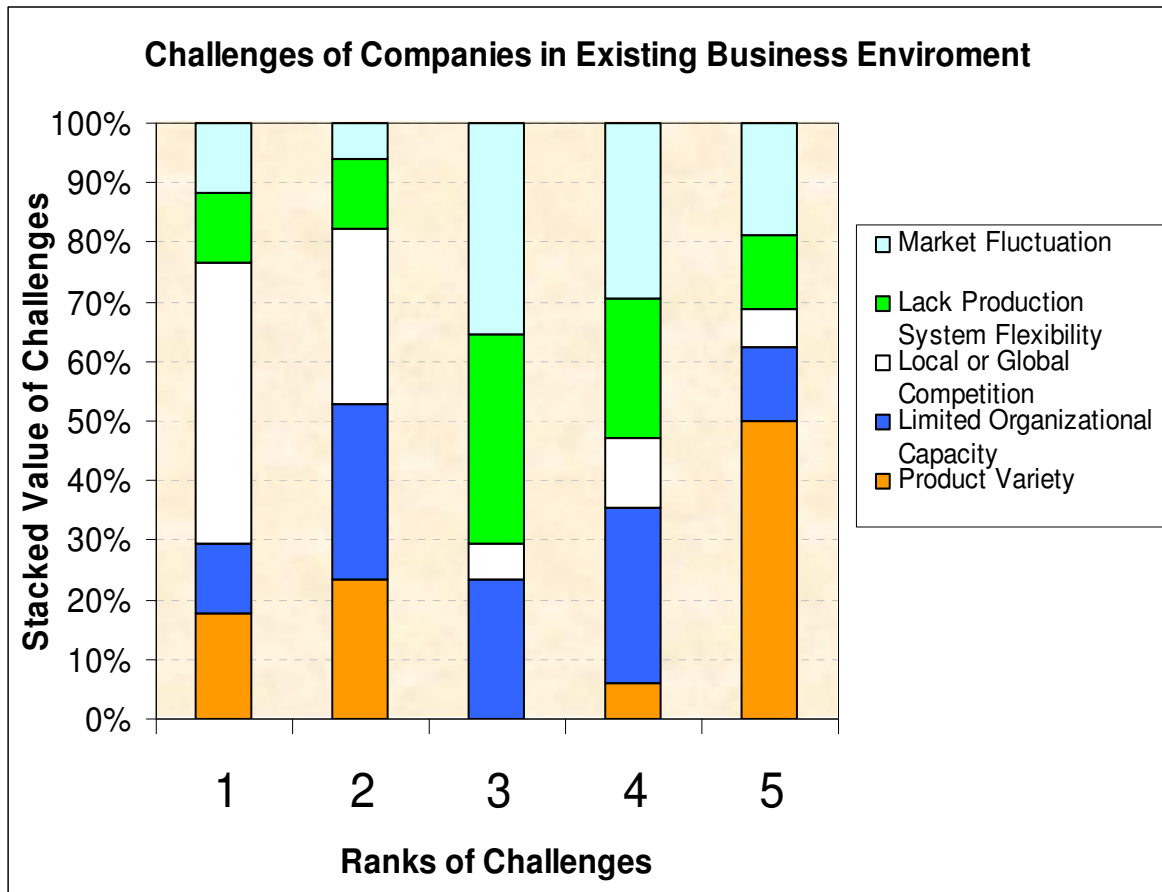
For the question raised to mark the challenges of industries in the current business environment, they sight different challenges to their respective companies. The response is summarized in Table 11.

**Table 11 Challenges of Companies in Existing Business Environment**

Challenges	Ranks				
	1st	2nd	3rd	4th	5th
Product Variety	4	4		4	8
Organizational Capacity	3	6	5	5	3
Local and Global Competition	8	7	3	3	1
Lack Production System Flexibility	3	4	6	4	2
Market Fluctuation	4	2	5	6	3

When industries are requested to rank the challenges that the company faces in the current business environment 8 respondents that account 36.36%, put global and local competition as a first challenge; 18.18% of them ranked the demand of market for increased product variety and unpredictable market fluctuation each on the first challenge; 13.64% refer to limited organizational capacity and lack of flexibility as the first challenge.

The challenge that is ranked second by 31.82% of respondents correspond to local or global competition; and lack of organizational capacity match to 27.27% of respondents. Lack of production system flexibility and increased demand for product variety accounted for 18.18 % each.



The third challenge is lack of production system flexibility which is reported by 27.27 % of companies; and 22.27% of them face market fluctuation and limited organizational capacity each; and only 13.64% for local or global competition.

On the fourth and fifth challenge, 36.36% and 22.27 % of companies reported increased demand for product variety and limited organizational capacity respectively.

It can be concluded from these findings that competition from local and global firms become the leading challenge for Ethiopian industries. The demand for product variety is also another challenge that industries are experiencing. This reflects that the drive for better and responsive production system exists.

### 3) Main Problems Faced by the Companies

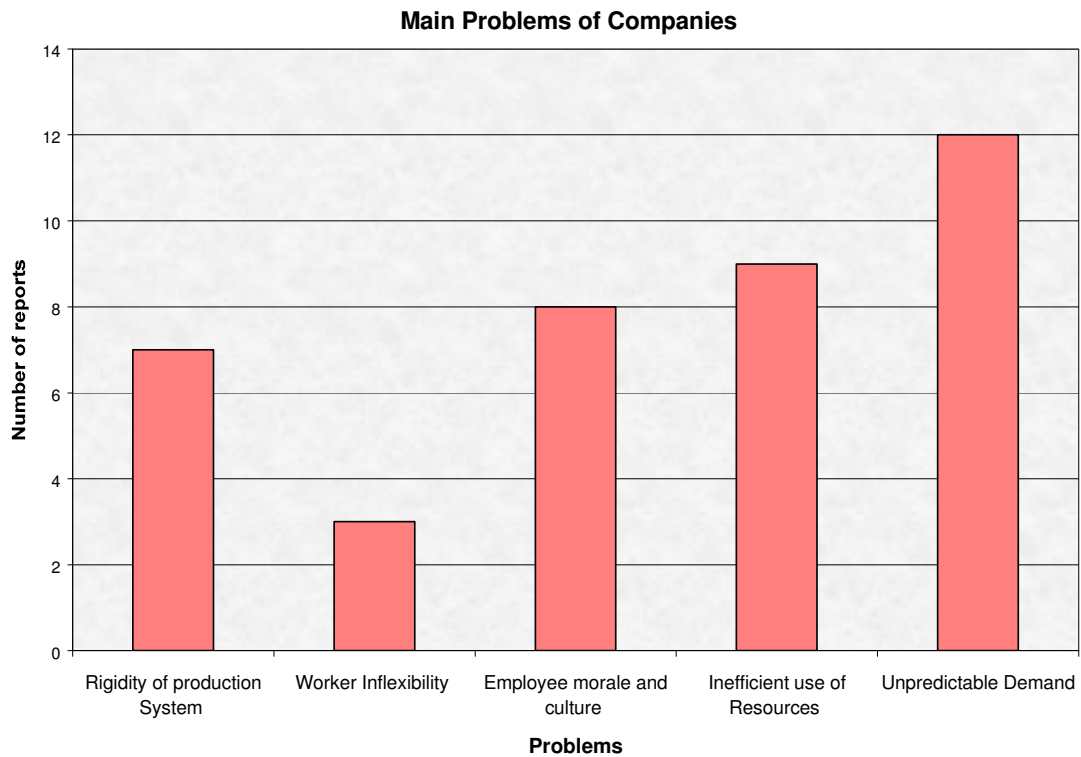
The industries were requested to mark main problems they face for selected issues and any other matter that may be considered as main problems. The report is summarized below.

**Table 12 Main problems faced by industries**

<b>Problems</b>	<b>Number of reports</b>	<b>Percentage</b>
Rigidity of production System	7	31.81
Worker Inflexibility	3	13.63
Employee morale and culture	8	36.36
Inefficient use of Resources	9	40.90
Unpredictable Demand	12	54.54

It is reported that many of the companies, 54.54%, faces problems of unpredictability in demand, where as the inefficient use of resources has been indicated by 40.09% of the companies. The employee morale and culture and rigidity of production system are pointed out as company's main problem by 36.36% and 31.82% of manufacturing industries respectively. Among the problems, which are indicated by the 13.63% of the industries is worker flexibility.

The other problem mentioned by the companies are, insufficient capital (two respondents), worker turnover (one respondent), old machinery and failure (three respondents), and foreign suppliers by one respondent.



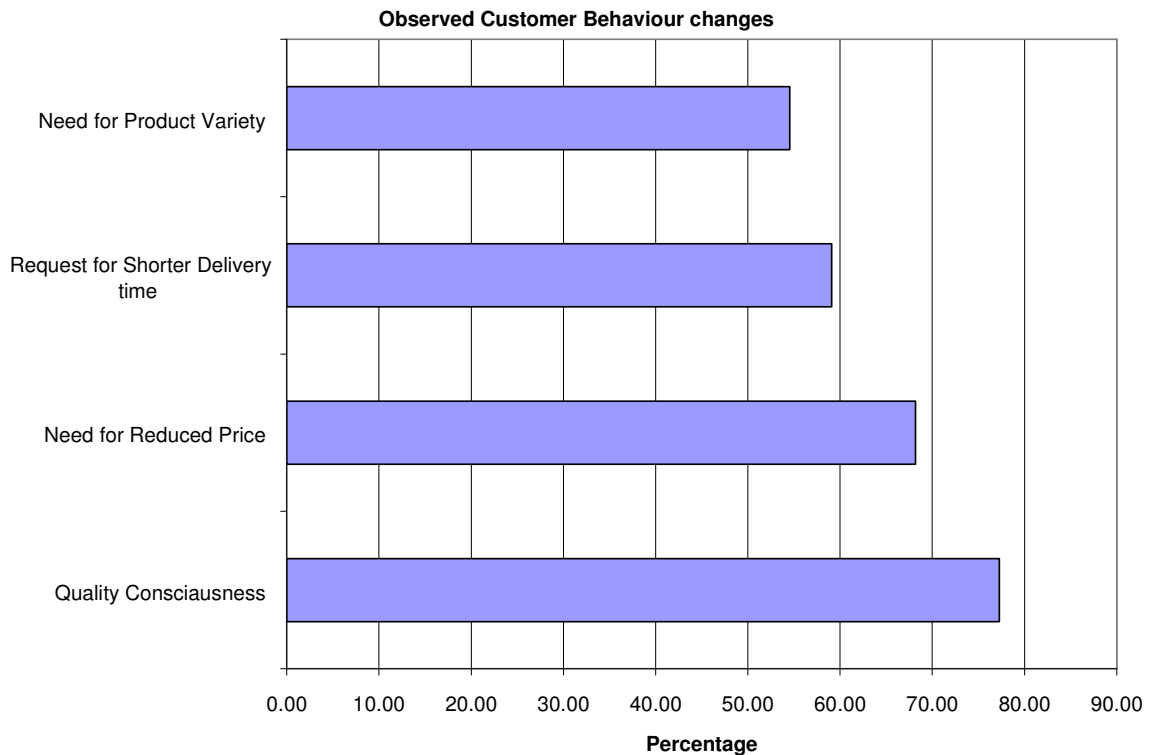
The analysis about the main problems of companies is proven to be unpredictability of demand. This result is in line with the current research findings on the topic. Moreover, the second problem, in efficient utilization of existing resources dictates for embracing lean principles. The reason for the problem of employee morale and culture arises from poor practice, inconvenient work environment, or low wage.

#### **4) Changes in Customer Behavior**

To assess the changing behavior of customers in recent years and its urge to the company's responsiveness, four behaviors that may possibly be reflected on industries are given. The responses on these points and the corresponding behaviors are presented here under.

**Table 13 Changes of Customer Behavior in Recent Years**

<b>Changes observed</b>	<b>No, of respondents</b>	<b>Percentage</b>
Quality Consciousness	17	77.27
Need for Reduced Price	15	68.18
Request for Shorter Delivery time	13	59.09
Need for Product Variety	12	54.55



From the information, it is found that most of the companies observed a change in customer behavior in recent years. Among these changes in behaviors, quality consciousness is reported by 77.27% of companies; need for reduced price due to the choices that the current market affords, was reported by 68.18%; and request for shorter delivery time is also experienced by 59.09 % of organizations surveyed. Customers need for variety and customized product is indicated by 54.55.09%;

Becoming more conscious about product quality, request for shorter delivery time, and reduced price, that is observed on customer, can be attributed to the on time availability of various products / services, which develop confidence to the customer on choosing whatever quality, style, he/she intends to buy on reasonable price. The implication reflects the global competitors' hand on the local industries.

### **5) Strength of Companies in Competitiveness**

For the open question asked about the main strength of companies with respect to competitiveness, 8 companies are found that their competitive strength is workers; 8 are consider their product quality as strength, organizational capacity and responsiveness is indicated by 4 factories.

The responsiveness of the companies to selected competitive factors is depicted here. From the graph, the level of responsiveness with respect to the factors given, the companies rate good level for 38.96%, Satisfactory for 33.77%; Very Good for 12.99%; Fair for 11.04%; and only 2.6% of the companies rated for poor.

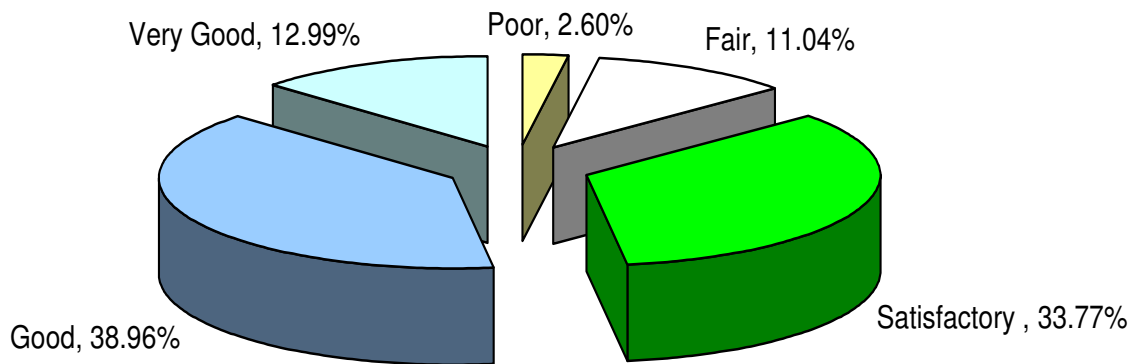
### **6) Level of responsiveness of companies to selected competitive factors**

The raw data and the average of the responses to the level of competitive factors is given in Table 14

Table 14 Level of Responsiveness to Competitive Factors

Score	Rates	Competitive Factors								
		Quality	Delivery Time	Inventory Reduction	Flexibility / Agility	Utilization of Resources	Productivity	Minimizing Waste	Average	%age
1	Poor	0	0	2	0	0	0	2	0.57	2.60
2	Fair	1	2	3	3	3	2	3	2.43	11.04
3	Satisfactory	6	9	9	7	7	6	8	7.43	33.77
4	Good	12	8	7	9	10	5	9	8.57	38.96
5	Very Good	3	3	1	3	2	8	0	2.86	12.99

Level of Responsiveness to Competitive Factors



The average result of this analysis for the level of responsiveness to selected competitive factors is on good level. This result may be a misleading. The bias here arises from benchmarking local industries, which are weak in structure and competitive attributes. In some industries boost for some given factors is observed, by claiming that they are unique in the country. But this will not be the true competitive strength as much as global firms are at every door step.

## **Conclusions**

From the industry survey it can be concluded that local industries are facing the global competition. This challenge and other findings on main problems of the companies, changing in customer behavior are evident that the drive for agility or more responsiveness is observed. This implies that it becomes necessary to observe and adopt appropriate production methodology.

### ***6.2. The Appropriate Manufacturing System to Ethiopia***

The overall situation of Ethiopian Industries as well as many other developing countries is far behind, when compared with other many nations. In fact, one of the main problems the country faces, of low living standard and proper utilization of artificial and natural resources emanate from lack of imitating and adopting the appropriate technology and method of production from the experience of successful nations.

Even though the free market economy policy of Ethiopia ascertains the base for the growth of manufacturing and the implementation is going smooth, the sector is still at its infant stage. Most of these industries are suffering from proper production system to response to market needs, low level of technological supply, Lack of focus on product quality, cost accounting, weak cooperation between firms and inefficiency to actively participate in export market. (54)

Most of the local industries have been established on the objective of import substitution. On the other hand, there is no such internally oriented market. Since the world is getting much closer and linked with business, focusing only on domestic markets is not viable. The

market is open for neighbor countries, as well as for emerging continental and global trade. Firms that do not earn profit will be forced to leave the way, (57). Manufacturers, regardless of their industries or the condition of their business, are forced to make major reductions in manufacturing costs using every conceivable means. The influence of globalization and the increased speed of technology development has become a challenge to industries. Competition among manufacturers has increased significantly and comes from all areas - industrialized and newly industrialized world.

Activities for Ethiopian industrial development should begin from local and global market perspectives in quality, price and on time delivery. Today, if products are not competitive in the global market, they will be out of business in the local market. To be competitive, the manufacturing strategy should be founded on aggressive propensity. The competition is with giant external companies that possess highly advanced technology, capital and management capability with strong market network, well-developed infrastructure, skilled professional workers, and effective governmental services.

When it is mentioned that the development strategy for Ethiopia is agricultural, it is not meant that industry remains as it is. It doesn't mean also that it grows slowly. When industries remain stagnant or the progress is below the need, the agriculture it self will be affected. The agricultural strategy does mean that, parallel to agricultural development, manufacturing industries should develop rapidly as much as circumstances permitted. (28)

In deed, many nations of developing world that currently established international competency pass through systematic transfer of technology and developing efficient manufacturing strategy parallel to the effort given to agricultural. Since the mid-1970 the variety of manufacturing system types has grown considerably. Since that time, Flexible

Manufacturing Systems, Agile Production Systems, and Lean Cellular Systems, have become accepted types of manufacturing systems.

### **6.2.1. Appropriateness Factors**

To see whether a particular production system is relevant and worth adapting, it is important first to set criteria that takes the current situation into account and perceive where to go next. The objective is to examine the adaptation of appropriate manufacturing system for Ethiopia.

To be appropriate:

- A system should be consistent with general Definition of the manufacturing system. The system should optimize the measurable parameters of quality, timeliness, quantity and total cost.
- The system should have a proven past experience and promising future.
- Preferably it is required to be implemented with less capital - the Feasibility
- More importantly, the system needs to be positively welcome by local industries - Attitude of Industries.

Manufacturing is the economic term for making goods and services to satisfy human wants. The manufacturing processes are collected together to form a manufacturing system (MS). The word system is used to define a relatively complex assembly (or arrangement) of physical elements characterized by measurable parameters that defines the boundary / constraint of the system and predict its behavior in response to excitation / disturbances.

The lean and agile manufacturing systems attracted the attention of many industries and researchers. Some of the reasons for this attention is the systems incorporate most of the contemporary production approaches. The prevailing slogans of today's manufacturing industries like TQM, JIT, FMS, BPR, Supply chain, and many others are intimately integrated into these systems. Hence, these the two systems are selected for alternative solutions. Manufacturing Systems in general, and Agile Production System and Lean Cellular System in particular, have become accepted types of manufacturing systems.

### **6.2.2. Consistency to the Manufacturing System Definition**

As indicated in Fig 1 the view of manufacturing system includes inputs to be fed into the system so that the system transforms it, in some way, to out put with increased value. The systems measurable parameters define the constraints of the system and predict its behavior to disturbances.

The parameters are in the shade of lean manufacturing system. Lean tools and techniques such as TQ, SMED, VSM, Flexible Production Lines, Continuous Improvement and others, are directly targeted on the enhancement of the parameters. So, it can be concluded that lean is appropriate enough to be adopted and implemented by industries who aim to optimize the throughput time, production rate and flexibility, percent defectives, percent on time delivery, periodical production volume and total cost.

Lean manufacturing approach can build sustained competitive advantage by starting with market requirements and focusing on a consistent doable set of manufacturing tasks. It is manufacturing 'without waste' that may be in any form, material, time, idle equipment,

inventory. The focus is not on a department, area or processes, but the optimization of the entire value stream - the series of processes between receipt of customer order and delivery of finished products.

Agile system, on the other hand, tends to concentrate on solving boundary problems that arise from the disturbances more sufficiently and robustly. The consistency of agile system to the definition of manufacturing system is reflected on their comprehensive frameworks which cover all business functions and the demand for increased use of information technology at every level of the enterprise.

### **6.2.3. Past experience of the two system**

Is the adaptation of these two systems proven to be useful? Perhaps essential criteria to agree on the systems suitability are to assess nations who tried to implement. Lean production system is probably the famous approach for its successes. Starting from its originators, Japanese, and adaptors from developed and less developed nations have gained the benefits of the implementation. A number of researchers, consultants and industrial practitioners in the world today are advocating for embracing lean.

Japan competed in mature technologies which is easier to acquire than newer industries. The industry competes with *process technologies*, such as Kanban, SMED, and SQC. Once these processes were reliable and flexible, Japan began to introduce innovation into the products. (32)

From the success stories on industries surveyed, it is evident that most of the industries that implemented lean production fully or partially have found the system helpful, regardless of type, size and location of the companies.

The agile system is emerged during the 90s as counteract for lean competitive strength. It has shown a splendid benefit and competitive guide lines for companies who possess the advanced technology. Using agile system, many western industries are working to overcome the competitive edges gained by the Eastern hemisphere. Thus, it seems less suitable to adapt agile system during this time. When advanced manufacturing and information technology becomes abundant, the system will be at the interest of industries.

#### **6.2.4. Feasibility of the Systems**

Womak et al (1990) pointed out that, currently or in immediate future, Lean production systems should form a promising strategy for developing countries that are characterized by poor performance in utilizing opportunities in a fiercely global market. Lean manufacturing represents a major breakthrough in production handling through a more efficient utilization of available resources. The focus on process improvements can incrementally added to the system.

The case studies that are carried out in realistic industrial scene on application of lean cellular system and identification of wastes, using value stream mapping have verified the feasibility and easiness of the system. It is clear that the proposed alternative improvements on ASPSC can be realized with little investment.

More over, it is the experience of the writer during the industry survey, that a huge amount of manufacturing wastes can be eliminated and significant performance improvement can be achieved by developing just a lean thinking mentality.

Agile seems to be more interesting for adaptation in developed nations. Some of the approaches of agile system are innovation and technology oriented, which is scarce for developing countries. Then, it can be said that agile principles can be philosophically good, as a business guide and strategy in today’s system as well as for manufacturing perspective in future.

### **6.2.5. Attitude of Industries to the Production Systems**

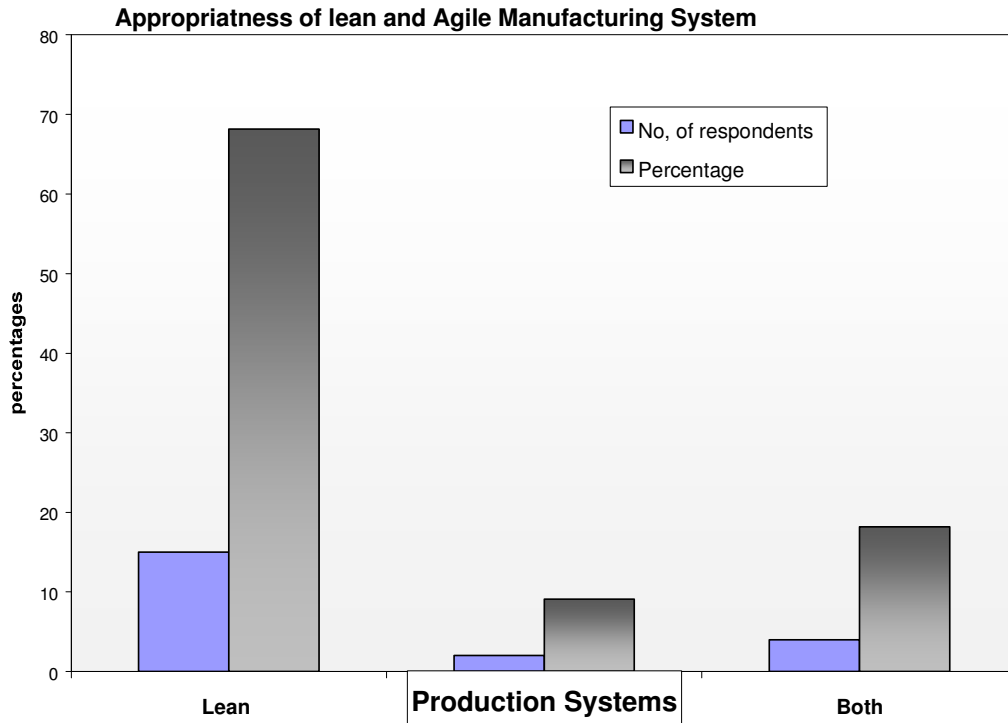
The attitude of industries towards Lean and Agile production System principles is assessed using questionnaire. The findings from the survey dictate that most industries show interest in lean production principles.

The data analysis for this criterion is discussed as follows:

For the question raised to select the appropriate production system with respect to current Ethiopian context, the respondents gave their response as follows:

**Table 15 Responses to the Appropriateness of Lean and Agile Systems in Ethiopian**

<b>Production systems</b>	<b>No, of respondents</b>	<b>Percentage</b>
Lean	15	68.18
Agile	3	13.64
Both	4	18.18



From the analysis of the data, it is evident that majority of the respondents, 68.18 %, indicated that Lean production approach is more appropriate in the current Ethiopian context. Some, among respondents who are interested in Lean, also pointed out that there are a lot of works to be done using Lean before going to Agile production system. They consider lean production system as a foundation for Agile. 18.18 % of the respondent chosen both Lean and Agile systems equally. The rest 13.64% of respondents show interest on Agile production systems in the country. Totally , 86.36% of respondents are attracted more towards lean production system approaches.

The attitudes of the industries personnel weighed more towards lean production approaches. All most all industries confirmed that Lean production system is more appropriate method of manufacturing. So, Lean is selected as promising and appropriate production system in Ethiopia. Thus, let's get lean.

## Chapter 7 : Conclusion and Recommendations

### 7.1. Conclusions

Inflexible mass-production methods that produce bulk of standardized products were inadequate for current demands of increased variety. In pursuit of *greater flexibility* to the production systems under resource constraints, and minimization of the manufacturing wastes, Lean Production System has come into play. More recently, demand for increased responsiveness to the ever-changing customer demand and fierce global competition has led to formulation of Agile Manufacturing framework with the intention of greater adaptability of production systems to satisfy the customers and reduce the delivery time.

The over all content of the literature survey, the case study and the industry survey have led to the following conclusions:

1. It is found that ***Lean Manufacturing*** is a response to competitive pressures with limited resources. It is a *collection of technical and operational systems* focused on productivity in relatively stable demand environment.
2. LPS focuses on minimizing manufacturing wastes, continuously improving methods, utilizing flexible production system and equipment organized to produce wide variety of defect-free goods.

3. **Agile manufacturing**, on the other hand, can be seen as a *response to the challenge of constant change*. It is an overall system focused on thriving in unpredictable business environment to overcome the global competition.
4. AM focuses on *providing solutions* to customers, **reorganizing production system** for *greater flexibility* with the emphasis on Reconfigurable, Reusable, and Scalable systems, and forming virtual enterprises to alleviate inadequacy of single firms. The agile system relies on increased use of Information Technology (IT) in production area and business functions.
5. The comparison between these systems shows that although there may be a difference in viewpoint and perhaps strategy with regard to change, there is no difference in method or approach. The capacity of one system depends on its ability to possess characteristics of the other.
6. Cases on the implementation of Lean techniques indicate that industries can enhance competitiveness by adapting Lean. The survey revealed that Industries are experiencing forces that lead to more responsiveness. More over, it is found most industries believe that the Lean Production is more appealing in current Ethiopian Industries Situation.

## **7.2. Recommendations**

- The Lean production system and its principle should be observed whenever performance improvement is intended.
- Industrial associations, managers and investment promotion bodies, need to focus on the implementation of lean, and give due attention to the fundamental approaches of Agile System.
- It is recommended that ASPSC pay due attention to the Value Stream developed, designed cells and take action to gain the benefits from lean system. Moreover, ASPSC need to further study other divisions and units using Lean thinking.
- The Ethiopian industries as a whole should be aware of such promising and competitive production systems to catch-up the world-class manufacturing practices.
- The established and newly establishing small and large manufacturing industries should concentrate on making their operation in line to the accepted competitive attributes that are *Quality, Cost, and On-time Delivery*.
- The industrial Engineers and other related professionals need to support industries by providing consultancy services as to the efficient method of production systems

## Appendix A: Applications of Agile Design Principles to Production System

RFS	Design Principles)	Production equipment (Cluster machines)	Production Process (Agile machining cell)	Production Enterprise (Enterprise job shop)
Reusable	<p><b>Self-Contained Units</b> System composed of distinct, separable, self-sufficient units not intimately integrated.</p>	Wafer-transfer module, various process module, docking module, cassette module, and utility base module.	Machine, work-setting stations, pallet changers, fixtures, rail guided vehicles	Design, engineering, fabrication, subassembly, and distribution resource modules.
	<p><b>Plug Compatibility</b> System units share common interaction and interface standards, and are easily inserted or removed.</p>	Common human, mechanical, electrical, vacuum, and control system interface	Common human, mechanical, electrical, and coolant system interfaces. Common inter-module mechanical interfaces.	Common information procedure among captured corporate resources, common interface in outsourcing contracts.
	<p><b>Facilitated Re-Use</b> Unit inventory management, Modification tools, and designated maintenance responsibilities</p>	Machine manufacturer extends / replicates module family for new capabilities. Fast module-swap maintenance is facilitated.	Machines do not require pits, or special foundations, and are relatively light and easy to move.	Corporate outsourcing department maintains pre-qualified pool of potential out sources.
Reconfigurable	<p><b>Nonhierarchical Interaction</b> Nonhierarchical direct negotiation, communication, and interaction among system units.</p>	Processing modules decide how to meet part production objectives with closed loop controls.	Complete autonomous part machining, direct machine-repository down load negotiation.	Business unit resources free to bid on internal jobs and external jobs.
	<p><b>Deferred Commitment</b> Relationships are transient when possible; fixed binding is postponed until immediately necessary.</p>	Machines custom-configured with processing modules at customer installation time.	Machines and materials scheduled in real time, down load part programs serve individual work requirements.	Individual business unit assigned to opportunity fulfillment at last possible moment.
	<p><b>Distributed Control and Information</b> Units respond to objectives, decisions made at point of knowledge; data retained locally but accessible globally.</p>	Intelligent process modules keep personal usage histories and evolving process characterization curves.	part programs down loaded to machines, machine history kept in machine controller, machines ask for work when ready	Enterprise integration information system queries databases local to the business unit.
	<p><b>Self-Organizing Relationships</b> Dynamic unit alliances and scheduling; open binding; and other self-adapting behaviors.</p>	Real-time controls system makes use of processing units available at any given time. Scheduling and rerouting as needed.	Cell-control software dynamically changes work routing for status changes and new or removed machines on the fly.	Bid-based production-flow alliances.
Scalable	<p><b>Flexible Capacity</b> Unrestricted unit populations that permit large increases and decreases in total unit population.</p>	Machines can be interconnected into larger constant-vacuum macro clusters.	Cell can accommodate any number of machines and up to four work-setting stations.	Outsourced resources can be easily added or deleted to increase the population of production modules with no size restrictions.
	<p><b>Unit Redundancy</b> Duplicate unit types or capabilities to provide capacity fluctuation options and fault tolerance.</p>	Machine utility bases are all identical; duplicate processing chambers can be mounted on same base or different bases.	Cells have multiples of each module; all cells made from same types of modules, machines have full work functionality.	Multiple duplicate production resources and second outsources.
	<p><b>Evolving Standards</b> Evolving open system framework capable of accommodating legacy, common, or completely new units</p>	Base framework becoming standard across vendors, and has accommodated processing technology across generations.	Utility services and vehicle tracks can be extended without restriction imposed by a cell or its modules.	Enterprise integration information system is open architecture, client/server based.

Appendix B: Delayed Works in 1994 and 1995

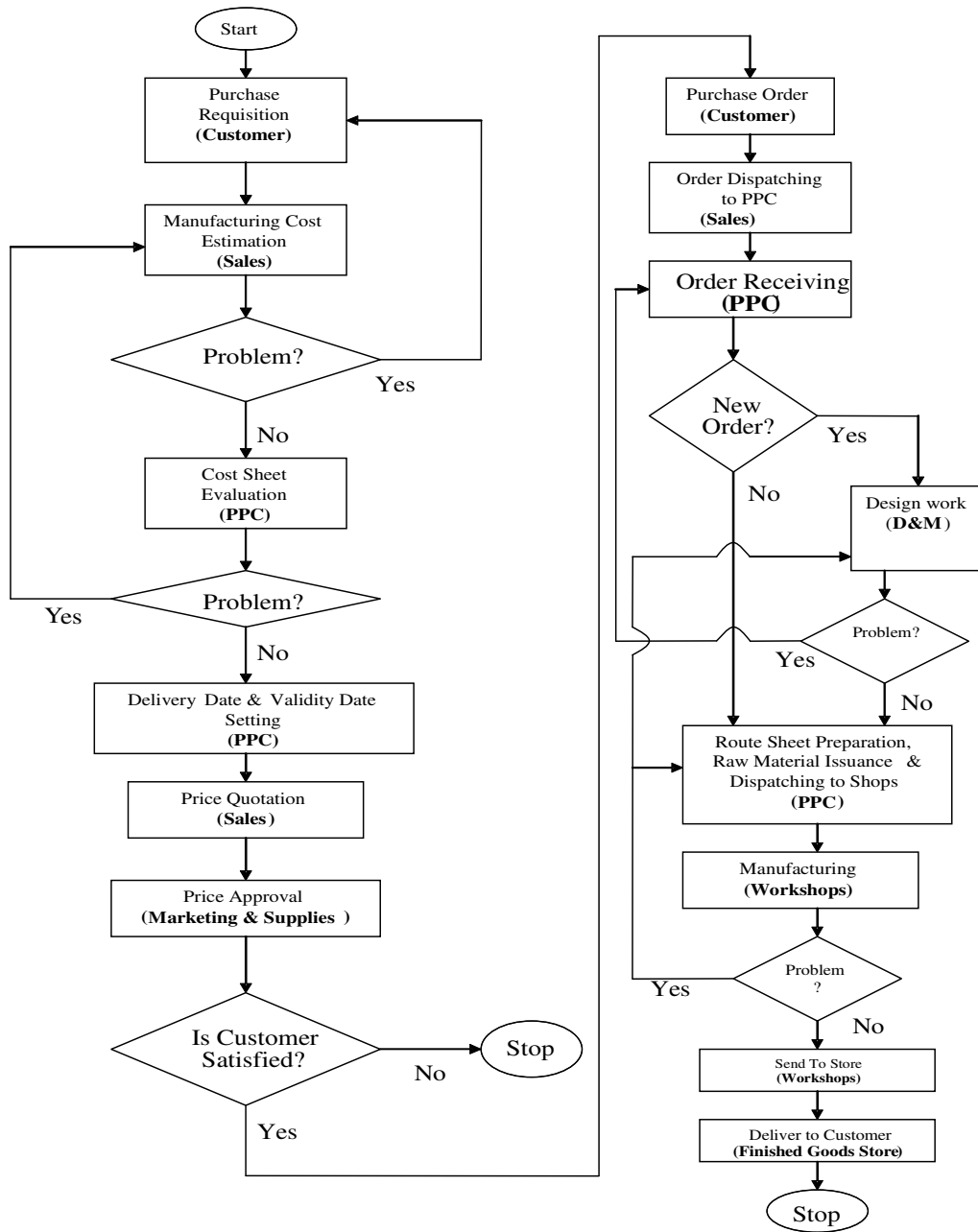
Month	No. of orders delayed (%)	
	1994	1995
July	57.94	60.48
August	58.80	28.74
September	52.40	74.31
October	71.96	47.40
November	81.28	72.09
December	68.12	68.57
January	49.42	63.48
February	67.57	75.66
March	69.68	63.81
April	58.61	64.92
May	62.81	65.78
June	51.35	45.79
<b>Average</b>	<b>62.26</b>	<b>58.56</b>

Source: Mezgebu Aweke, 2004

### Appendix C: Part Names and models of Cutlery

No.	Model	Description
1	100	Table Fork (W/o Flower)
2	100/L	Table Fork (Luxury)
3	100/N	Table Fork (Normal)
4	110	Desert Fork (W/o Flower)
5	110/L	Desert Fork (Luxury)
6	110/N	Desert Fork (Normal)
7	110/E	Fork 1 <sup>st</sup> Class
8	200/L	Table Spoon (Luxury)
9		Desert Spoon 1 <sup>st</sup> Class
10	210/L	Desert Spoon (W/o Flower)
11	210/N	Desert Spoon (Normal)
12		Tea Spoon 1 <sup>st</sup> Class
13	220	Tea Spoon
14	220/N	Tea Spoon
15	220/L	Tea Spoon (Luxury)
16	230/L	Big Spoon (Luxury)
17	230/N	Big Spoon (Normal)
18	300	Table Knife (W/o Flower)
19	300/L	Table Knife (Luxury)
20	300/N	Table Knife (Normal)
21	310	Plastic Handle Knife
22	320/4	Cooking Knife
23	320/6	Cooking Knife
24	330	Meat Knife
25	340	Sledge Knife
26	Eth. Air Line	Fork 1 <sup>st</sup> Class
27	Eth. Air Line	Dessert Spoon
28	Eth. Air Line	Tea Spoon 1 <sup>st</sup> Class
29	Eth. Air Line	Table Knife 1 <sup>st</sup> Class

### Appendix D: Flowchart of Job Ordering Sequence



Source: Mezgebu Aweke, 2004

**Appendix E: List of Industries Surveyed**

1. ADDIS ABABA BOTTLE AND GLASS S. Co.
2. ADDIS ABABA FOAM AND PLASTIC FACTORY
3. AKAKI GARMENT FACTORY
4. AKAKI SPARE PARTS AND HAND TOOLS S. Co.
5. AKAKI TEXTILE FACTORY S. Co.
6. ANBASSA SHOE FACTORY
7. AUTOMOTIVE MANUFACTURING COMPANY OF ETHIOPIA (AMCE)
8. BASIC METALS AND ENGINEERING INDUSTRIES AGENCY
9. BIRHANENNA SELAM PRINTING PRESS
10. EAST AFRICA BOTTLING S. Co.
11. EDGET YARN AND THREAD FACTORY
12. ETHIOPIAN CROWN CORK AND CAN MANUFACTURING INDUSTRIES S. Co.
13. ETHIOPIAN IRON AND STEEL FACTORY
14. ETHIOPIAN MANUFACTURING ASSOCIATIONS
15. FAFA FOOD S. Co.
16. IACONA ENGINEERING PLC
17. KADISCO CHEMICAL INDUSTRY PLC
18. KALITI METAL PRODUCTS FACTORY
19. KANGAROO SHOE FACTORY
20. KOLFE HOUSE HOLD UTENCILS
21. KOTEBE METAL TOOLS FACTORY
22. MA THERMO PLASTIC INDUSTRY PLC
23. MAMCO Pvt. Ltd. Co. PAPER PRODUCTS FACTORY
24. REPI SOAP FACTORY
25. ROTO PLC
26. UNITED NATION INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO)
27. UNITTED TEBAREK AND FAMILY (VESTEL TV Assembly plant)

**Appendix F:** Questionnaires to assess the challenges of industries in the current business environment

**Addis Ababa University**

**School of Graduate**

This questionnaire is prepared to assess the market forces that require companies to be more responsive to changing business environment. Your honest response is valuable to draw valid conclusion.

1. After reading the following brief notes on **LEAN and AGILE PRODUCTIONS**, comment on the appropriateness of the two production approaches in Ethiopian context.

**LEAN PRODUCTION**

Lean production is an adaptation of mass productions in which workers and work cells are made more flexible and efficient by adopting methods that reduce **production wastes** in all forms. It combines the advantage of craft and mass production, while avoiding the high cost of the former and rigidity of the latter.

Unlike a limited goal for an acceptable number of defects, high level of inventories, and narrow range of standardized products, lean aims on **perfection**: continually declining costs, zero inventories, and endless product variety. Lean Production is based on four principles:

- i. **Waste Minimization** – avoiding the %age of non-value adding activities.
- ii. **Perfect First-time Quality** – preventing defects at the source.
- iii. **Flexible Production Lines** – using cellular work stations and multi-skilled workers.
- iv. **Continuous Improvement** – ever-searching for performance enhancement.

**AGILE MANUFACTURING**

In recent decades, ever-more open markets, quick transport and use of Information Technology (IT) led to a number of changes and trends such as: partnership formation, use of IT, short Product lifetimes, fragmented market and markets arise and disappear faster.

In connection to these progresses, ‘Agile Manufacturing’ (AM) is emerged. **Manufacturing Agility** is the ability to respond to, and create new windows of opportunities rapidly and continuously in unstable market environment. It is a framework for how one can run a company in an open dynamic world in which markets, technologies and economic factors are constantly changing. Agile manufacturing is based on four principles:

5. **Reorganizing the production system for agility** – greater flexibility and responsiveness.
6. **Enriching customers with total solution products** – life long connection with customer.
7. **Leveraging people and information** – increased utilization of IT and knowledge worker.
8. **Co-operating to enhance competitiveness** – collaboration between firms to gain opportunities.

A. Have you ever heard of the two new production systems?

Yes \_\_\_\_\_ No. \_\_\_\_\_

B. Which production system is more appropriate in the current Ethiopian context?

2. Give additional relevant comments on these systems (if any).

3. **Rank the challenges** that the company faces in the current market.

Increased demand for product/service variety	Lack of production system flexibility
Limited organizational capacity	Market fluctuation
Global or local competition or both	

4. **Mark changes** that the company has experienced in the last 10-20 years.

Introducing new product / service	Closing / opening / merging departments
Using IT at office or production floor	Delegation of responsibility to lower organizational ladder
Dropping previous products / services	
Reducing production volume	

5. What are the **main problems** of the company with regard to market responsiveness?

Rigidity of production /service system	Inefficient use of resources
Inflexibility of workers	Unpredictable demand
Employee morale and culture	Others (if any)

6. Which **change in customer behavior** did the company experience in recent years?

Product/ service quality consciousness

Need for reduced price

Need for more products/ services variety

Request for shorter delivery time

7. Does the company subcontract or outsource a demand to other companies in order to gain temporary market opportunity?  
Yes \_\_\_\_\_ No. \_\_\_\_\_
8. Is the exiting organizational structure effective enough to meet today's organization requirements?  
Yes \_\_\_\_\_ No. \_\_\_\_\_
9. What is/are the main strength of the company with respect to competitiveness?
10. For the following questionnaire, **rate** the factors according to the scores given.

<b>Scores</b>	1	2	3	4	5
<b>Ratings</b>	Poor	Fair	Satisfactory	Good	Very good

<b>Factors</b>		<b>Scores</b>				
A	How responsive is the exiting production system of the company with regard to:					
	▪ Better quality	1	2	3	4	5
	▪ Delivery time	1	2	3	4	5
	▪ Inventory reduction	1	2	3	4	5
	▪ Flexibility / Agility	1	2	3	4	5
	▪ Space and equipment utilization	1	2	3	4	5
	▪ Productivity	1	2	3	4	5
B	To what extent IT (such as computers, networks and internet) favorably affects the organizational performance?	1	2	3	4	5
C	To what level the company minimizes non-value adding activities?	1	2	3	4	5
D	To what level suppliers and customers are involved in relevant activities of the company?	1	2	3	4	5

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