

**THESIS REPORT**

*On*

**STRATEGY DEVELOPMENT FOR LEAN MANUFACTURING  
IMPLEMENTATION IN PRODUCTION SHOP**

*Submitted in the partial fulfillment of requirement for the award of the degree of*

**Master of Engineering**

**IN**

**PRODUCTION AND INDUSTRIAL ENGINEERING**

*Submitted by*

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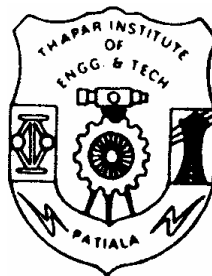
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**CERTIFICATE**

This is to certify that the Thesis report entitled **STRATEGY DEVELOPMENT FOR LEAN MANUFACTURING IMPLEMENTATION IN PRODUCTION SHOP** submitted by **Mr. DHARMENDER** in the partial fulfillment of the requirement for the award of the degree of **Master of Engineering in Mechanical (Production and Industrial) Engineering** to **Thapar Institute of Engineering and Technology (Deemed University), Patiala**, is a record of candidate's own work carried out by him under our supervision and guidance. The matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

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### **Abstract**

The technology during the 21<sup>st</sup> century offers a great promise to the people all over the world.

The latest advances in Engineering Science and technology have given engineers powerful tools for re-assessing and reorganizing the systems.

In the present business scenario, competitiveness of manufacturing companies is determined by their ability to meet and respond as swiftly as possible to the changing environment scenario and to produce and supply high-quality products at lower cost as per demand of the customer.

All the manufacturing companies are striving too hard to achieve their aims, objectives and their capabilities by proper planning and skillfulness, through application of automation and innovative concepts, e.g. lean manufacturing, just-in-time (JIT), and total quality management (TQM). Among these innovative concepts, lean manufacturing is recognized by the manufacturing companies as a major driver to achieve world-class capabilities. Many large and medium-size manufacturing companies have adopted lean manufacturing concepts, and experienced reduction in manufacturing lead time and material handling cost, and improvement in quality with other benefits.

It is generally agreed that for a lean manufacturing programme to be effective, it should include a set of tools and techniques or provisions to ensure management commitment, employee involvement, identification of wastes, development of controls for wastes and training and education for employees. These tools and techniques are said to be typical of any comprehensive lean manufacturing implementation programme. The implementation of lean manufacturing reduced the waste in the industry and enhances the profit and production.

The present study has been undertaken for analyzing different types of wastes in a Diesel Locomotive Plant's Light Machine Shop (camshaft section) with an aim to design strategies for developing and implementing a Lean Manufacturing Program in such machine shops. The study has been carried out in a phased manner. Various phases of the study have been: clarifying the context through a review of literature; understanding and assessing the current status of in the organization and identifying the areas which need to be taken up for further, detailed analysis of wastes and aligning them to Lean Manufacturing principles. The different types of wastes that have been identified for detailed analysis after the preliminary study are (1) Defects, (2) Inventory, (3) Excessive Material Movement, (4) Delay due to Waiting, (5) Overproduction and (6) Inappropriate processing. After the analysis, the job needing redesign to reduce the waste have been identified and then by using the cause and effect diagram, the root causes of problems

relating to wastes have been identified. Appropriate controls for the identified causes have been developed for each waste and its impact on implementation of Lean Manufacturing principles has been listed.

For the purpose of modeling for developing a strategy for implementation, the controls identified have been grouped into broad generalized categories. Expert opinion has been utilized to identify factors and parameters affecting development of a generalized approach for implementation. Generalized of various measures for developing an approach to be used by industry in future has been suggested using expert opinion. It has further been suggested that the implementation of the development approach be carried out in three phases.

## **INDEX**

### **TABLE OF CONTENTS**

1. Certificate	i
2. Acknowledgement	ii
3. Abstract	iii

<b>CHAPTER I: INTRODUCTION</b>	<b>(1-6)</b>
1.1 Introduction	1
1.2 Objectives Of Lean Manufacturing	1
1.3 Key Principles Of Lean Manufacturing	2
1.4 Lean Manufacturing Concepts	3
1.4.1 Value Creation and Waste	3
1.4.2 Main Kinds of Waste	4
1.5 Strategies of Implementation of Lean Manufacturing	4
1.6 Out Line of Study	5
1.7 Organization of the Thesis	6
<b>CHAPTER 2: LITERATURE REVIEW</b>	<b>( 7-21)</b>
2.1 Introduction	7
2.2 Categorization of Literature	7
2.3 Lean Manufacturing Principle and Techniques	7
2.4 Status of Lean Manufacturing Implementation in Various Classes of Industry and Benefits Accrued	10
2.4.1 Application of Lean in Discrete Industry	11
2.4.2 Continuous Process Industry and Lean	12
2.5 Approaches Adopted For Implementation Of Lean Manufacturing.	13
2.5.1 Unionization	13
2.5.2 Age of Plant	14
2.5.3 Size of Plant	14
2.6 Status of Various Tools and Techniques of Lean Manufacturing	14
2.6.1 Cellular Manufacturing (Cm)	14
2.6.2 Continuous Improvements	15
2.6.3 Just - In-Time	16
2.6.4 Production Smoothing	20

2.6.5 Standardization of Work	20
2.6.6 Total Productive Maintenance	21
<b>CHAPTER 3: DESIGN OF STUDY</b>	<b>(22-33)</b>
3.1 Introduction	22
3.2 Brief Description of the Industrial Unit	22
3.3 Methodology	24
3.3.1 Preliminary Study	24
3.3.2 Data Collection	32
3.3.3 Identification of Non-Value Added Activities and Their Quantum	32
3.3.4 Root Cause Analysis	33
3.3.5 Gap Analysis	33
3.3.6 Development of Implementation Plan	33
<b>CHAPTER 4: ANALYSIS AND RESULTS</b>	<b>(34-60)</b>
4.1 Introduction	34
4.2 Product Description	34
4.3 Analysis of Waste	35
4.3.1 Defects	35
4.3.2 Inventory Analysis	36
4.3.3 Waste Due to Unnecessary Material Movement	38
4.3.4 Delay Due to Waiting	39
4.3.5 Overproduction	44
4.3.6 Inappropriate Processing	44
4.4 Root Cause Analysis of Wastes	45
4.5 Gap Analysis	52
4.6 Development of Generalized Approach	53
4.7 Suggested Implementation Plan	58
<b>CHAPTER 5: CONCLUSIONS AND RESULTS</b>	<b>(61-66)</b>
5.1 Introduction	61

5.2 Summary of the Work	61
5.3 Results of the Study	61
5.4 Conclusion	62
5.5 Limitation of Study	65
5.6 Scope for Future Work	65
5.7 Concluding Remarks	66
<b>REFERENCES</b>	<b>(67-69)</b>

## **List of Figures**

<b>Figure no.</b>	<b>Figure title</b>	<b>Page number</b>
<b>Figure 2.1</b>	<b>Five Interdependent Principles of Lean Manufacturing.</b>	<b>10</b>
<b>Figure 3.1</b>	<b>Machine Layout of Machine Shop</b>	<b>25</b>

<b>Figure 3.2 Types of machine</b>	<b>26</b>
<b>Figure 3.3 Flow Chart of Cam Shaft</b>	<b>27</b>
<b>Figure 3.4 Flow Chart of Con Rod</b>	<b>28</b>
<b>Figure 3.5 Flow Chart of Equalizer</b>	<b>29</b>
<b>Figure 3.6 Flow Chart of Axle</b>	<b>30</b>
<b>Figure 3.7 Flow Chart of Gears</b>	<b>31</b>
<b>Figure 4.1 Existing Layout</b>	<b>40</b>
<b>Figure 4.2 Proposed Layout</b>	<b>41</b>
<b>Figure 4.3 Cause and Effect Diagram of Scrap</b>	<b>47</b>
<b>Figure 4.4 Cause and Effect Diagram of Rework</b>	<b>48</b>
<b>Figure 4.5 Cause and Effect Diagram of Inventory</b>	<b>49</b>
<b>Figure 4.6 Cause and Effect Diagram of Delays Due To Waiting</b>	<b>50</b>
<b>Figure 4.7 Cause and Effect Diagram of Excessive Material Movement</b>	<b>51</b>
<b>Figure 4.8 Cause and Effect Diagram Of Over Processing</b>	<b>51</b>

## **LIST OF TABLES**

<b>Table no.</b>	<b>Detail</b>	<b>Page Number</b>
<b>Table: 3.1</b>	<b>Data collection</b>	<b>32</b>
<b>Table: 4.1</b>	<b>Camshafts characteristics</b>	<b>34</b>

<b>Table: 4.2 Total camshafts produced in January2006</b>	<b>35</b>
<b>Table: 4.3 Raw material Inventories in Store.</b>	<b>36</b>
<b>Table: 4.4 Total in process inventory</b>	<b>37</b>
<b>Table: 4.5 Total finish product inventory in progress department</b>	<b>37</b>
<b>Table: 4.6 Distances between two stations</b>	<b>38</b>
<b>Table: 4.7 Waiting time</b>	<b>42</b>
<b>Table: 4.8 Reduction in delays</b>	<b>43</b>
<b>Table: 4.9 Rework in January</b>	<b>44</b>
<b>Table: 4.10 Differences in weights of raw material rod and finished cam shaft</b>	<b>45</b>
<b>Table: 4.11 Gap analysis</b>	<b>52</b>
<b>Table: 4.12 Scoring scale for state of parameter</b>	<b>54</b>
<b>Table: 4.13 Responses of experts</b>	<b>55</b>
<b>Table: 4.14 Suggested implementation plan</b>	<b>69</b>

## **CHAPTER-1 INTRODUCTION**

### **1.1 INTRODUCTION**

Lean manufacturing derives its name from the manufacturing systems and processes of the Toyota production system that are so effective at producing at low cost, and short cycle times. These

systems are highly flexible and responsive to customer requirements. Lean manufacturing is a multi-dimensional approach that encompasses a wide variety of management practices, including just-in-time, quality systems, work teams, cellular manufacturing, supplier management, etc. in an integrated system. The core thrust of lean production is that these practices can work synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste [Shah & Ward, (2003)].

## **1.2 OBJECTIVES OF LEAN MANUFACTURING**

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

*Defects and wastage* - Reduce defects and unnecessary physical wastage, including excess use of raw material inputs, preventable defects, and costs associated with reprocessing defective items and unnecessary product characteristics which are not required by customers.

*Cycle Times* - Reduce manufacturing lead times and production cycle times by reducing waiting times between processing stages, as well as process preparation times and product/model conversion times.

*Inventory levels* - Minimize inventory levels at all stages of production, particularly work-in-progress between production stages. Lower inventories also mean lower working capital requirements.

*Labor productivity* - Improve labor productivity, both by reducing the idle time of workers and ensuring that when workers are working, they are using their effort as productively as possible (including not doing unnecessary tasks or unnecessary motions).

*Utilization of equipment and space* - Use equipment and manufacturing space more efficiently by eliminating bottlenecks and maximizing the rate of production through existing equipment, while minimizing machine downtime

*Flexibility* - Have the ability to produce a more flexible range of products with minimum changeover costs and changeover time.

*Output* - Insofar as reduced cycle times, increased labor productivity and elimination of bottlenecks and machine downtime can be achieved, companies can, generally increase output

from their existing facilities.

In a 2004 survey by Industry Week Magazine, U.S. companies implementing lean manufacturing reported a savings of 7% of Cost of Goods Sold (COGS) as a result of implementing lean. Another way of looking at Lean Manufacturing is that it aims to achieve the same output with less input - less time, less space, less human effort, less machinery, less material, less cost.

When a U.S. equipment manufacturing company, Lantech, completed the implementation of lean in 1995, they reported the following improvements compared to their batch-based system in 1991. [Womack et. al., (1996)].

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

### 1.3 KEY PRINCIPLES OF LEAN MANUFACTURING

Key principles behind Lean Manufacturing can be summarized as follows:

**a) *Recognition of waste*** - The first step is to recognize what does and does not create value from the customer's perspective. Any material, process or feature, which is not required for creating value from the customer's perspective, is waste and should be eliminated. For example, transporting materials between workstations is waste because it can potentially be eliminated.

**b) *Standard processes*** - Lean requires the implementation of very detailed production guidelines, called Standard Work, which clearly states the content, sequence, timing and outcome of all actions by workers. This eliminates variation in the way that workers perform their tasks.

**c) *Continuous flow*** - Lean usually aims for the implementation of a continuous production flow free of bottlenecks, interruption, detours, backflows or waiting. When this is successfully implemented, the production cycle time can be reduced by as much as 90%.

**d) *Pull-production*** - Also called Just-in-Time (JIT), Pull-production aims to produce only what is needed, when it is needed. Production is pulled by the downstream workstation so that each workstation should only produce what is requested by the next workstation.

**e) *Quality at the Source*** - Lean aims for defects to be eliminated at the source and for quality inspection to be done by the workers as part of the in-line production process.

**f) *Continuous improvement*** - Lean requires striving for perfection by continually removing layers

of waste, as they are uncovered. This in turn requires a high level of worker involvement in the continuous improvement process.

## 1.4 LEAN MANUFACTURING CONCEPTS

### 1.4.1 Value Creation and Waste

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

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

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

Research at the Lean Enterprise Research Center (LERC) in the United Kingdom indicated that for a typical manufacturing company the ratio of activities could be broken down as follows [Hines P. et al, (2000)].

- Value –added activity 5%
- Non value –added activity 60%
- Necessary non value –added activity 35%
- Total activity 100%

### 1.4.2 Main Kinds of Waste

Originally seven main types of waste were identified as part of the Toyota Production System [Sullivan et al, (2002)].

**a) Over production** - Producing too soon, resulting in poor flow of information or goods and excess inventory.

**b) Defects** - Frequent errors in paperwork or material/ product quality problems resulting in scrap and / or rework, as well as poor delivery performance.

**c) Unnecessary inventory** - Excessive storage and delay of information or products, resulting in

excess inventory and cost, leading to poor customer service.

**d) Inappropriate processing** - Going about work processes using the wrong set of tools, procedures or systems, often when a simpler approach may be more effective.

**e) Excessive transportation** - Excessive movement of people, information or goods, resulting in wasted time and cost.

**f) Waiting** - Long periods of inactivity for people, information or goods, resulting in poor flow and long lead times.

**g) Unnecessary motion** - Poor workplace organization, resulting in poor ergonomics, e.g., excessive bending or stretching and frequently lost items.

## 1.5 STRATEGIES OF IMPLEMENTATION OF LEAN MANUFACTURING

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

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

Some simple first steps may include:

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

**c) Start Small** - It is recommended that companies try to implement lean as a test case at a small part of their operations before applying it through their entire operations, especially for the shift from a push-based to a pull based system since this can potentially be disruptive. For example, the test case may be a single production line or a small series of processes. This will help to minimize

the risk of disruption, help educate the staff on the principles of lean while also serving to convince others of the benefits of lean.

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

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

## **1.6 OUT LINE OF STUDY**

The study has been undertaken in an organization manufacturing engines for locomotives. A machine shop of the organization manufacturing cam shafts, connected rods, gears has been taken up for the detailed analysis. These components are made from the forging received from suppliers. Various machining and heat treatment operations are carried out on the material received from suppliers.

In the study, various operations have been carefully observed and the records of production have been analyzed to find out root cause of various types of wastes at different stages. Having determined the type and quantum of waste at every stage it was ascertained as to how far the company is from the concept of lean manufacturing. A root cause analysis of various types of waste has been carried out with an aim to design a strategy for implementation of lean manufacturing. Subsequently an action plan has been developed for step wise implementation of lean manufacturing which is primarily based on removing the root causes of various wastes.

## **1.7 ORGANIZATION OF THE THESIS**

The thesis has been divided into four chapters. Brief description of the contents of each chapter is as under:

**Chapter 1** introduces lean manufacturing and its objectives. This chapter focuses on key principles of lean manufacturing, and concepts of lean manufacturing. It also includes the strategies of implementation of lean manufacturing.

**Chapter 2** an extensive review of the literature on the subject has been carried out. Literature review has been divided into the following categories:

1. Five Interdependent Principles of Lean Manufacturing.
2. Status of lean manufacturing implementation in various classes of industry and benefits accrued
3. Approaches adopted for implementation of lean manufacturing
4. Status of various tools and techniques of lean manufacturing.

**Chapter 3** covers the design of study, with overall methodology, detailed analysis carried out and tools and techniques employed for this analysis. It also contains the description of products and processes of the industrial unit where work has been carried out. Layout of the unit, flow charts of various processes and other process details are covered.

**Chapter 4** presents the main body of the work. It covers the complete step by step analysis carried out including data collection, calculation of various types of wastes, their root cause analysis and comparison with the requirements of lean manufacturing. A phased approach has then been developed for implementation of lean manufacturing in the organization.

**Chapter 5** concludes the work by presenting a summery of the whole work, results and conclusions and the scope for further research work.

## **CHAPTER -2 LITERATURE REVIEW**

### **2.1 INTRODUCTION**

It covers a detailed review of literature on various aspects of lean manufacturing. The literature review includes the status of lean manufacturing implementation in India and abroad, the studies carried out and the benefits accrued. It also includes the status of various techniques of lean manufacturing. Various approaches adopted for lean manufacturing have also been studied and presented in the Chapter.

### **2.2 CATEGORIZATION OF LITERATURE**

The literature has been categorized as under:

- Lean manufacturing principles.
- Status of lean manufacturing implementation in various classes of industry and benefits

accrued.

- Approaches adopted for implementation of lean manufacturing.
- Status of various tools and techniques of lean manufacturing

## **2.3 LEAN MANUFACTURING PRINCIPLE AND TECHNIQUES**

The five interdependent principles of Lean Manufacturing are:

### **1. Value Definition:**

This principle states that quality is what the customer wants. The principle entails specifying value from end customer's perspective, i.e., product cost, quality, variety, delivery and response time. The most important tool for defining the value from customer point of view is QFD: Quality Function Deployment (QFD) is a methodology for building the "Voice of the Customer" into product and service design. It is a team tool, which captures customer requirements and translates those needs into characteristics about a product or service [Besterfield et. al].

### **2. Value Stream Analysis:**

This principle focuses on identification of the sequence of processes from product concept to market [Davies.C et. al]. Value Stream Mapping is a pencil and paper tool that helps you to see and understand the flow of material and information as a product makes its way through the value stream. Kalsaas, (2002) limits the focus of value stream mapping to the "door-to-door" production flow inside a plant. Both the material and information flows have to be considered, and the mapping addresses one product family at time. The object of Lean manufacturing is to get one process to make only what the next process needs when it needs it.

In accordance with the "pull"-thinking the mapping start at the shipping end and proceed upstream. Each process on the material flow path is object of being mapped. The point is to uncover the value-adding time and the waste of non value adding time. A central point is to synchronize pace of production to that of sales, hence it is making efforts to design work processes with a balanced cycle time to that of customer takt time (available work time per Shift/customer demand rate per shift).

The future state is created by designing the physical material flow first using a Lean Manufacturing philosophy and applying the tools from the Lean Enterprise House that fit in this particular circumstance. After the material flow is complete, the information flow required to support the Lean operation is designed. The future state then becomes the “road map” or “blue print” for the activities that must take place for the future state to become reality [Harris, (2000)].

### **3. Flow:**

One piece production never delays a value adding step by a non –value adding step [Davies.C et. Al]. One-piece flow or continuous flow processing is a concept which means that items are processed and moved directly from one processing step to the next, one piece at a time. One-piece flow helps to maximum utilization of resources, shorten lead times, and identify problems and communication between operations. Single Minute Exchange of Dies (SMED) is a tool used for this principle. SMED is an approach to reduce output and quality losses due to changeovers. SMED is a system that allows the mixing of production without slowing output or creating higher costs from waste of setup [Czarnecki.H. et al, (2000)].

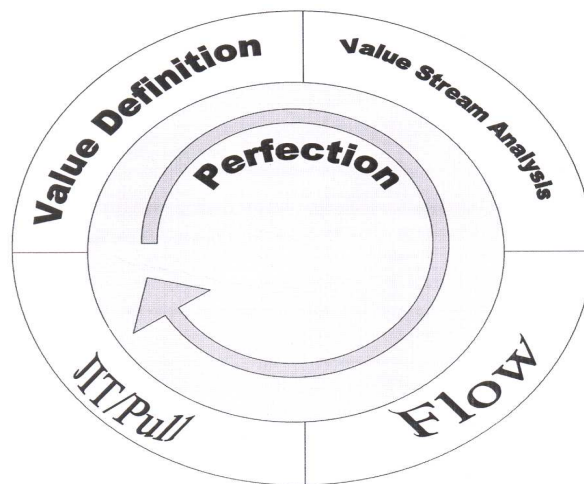
### **4. JIT/Pull:**

Closely associated with lean manufacturing is the principle of just-in-time, since it is a management idea that attempts to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. This addresses waste such as work-in-process material, defects, and poor scheduling of parts delivered [Nahmias, (1997)]. JIT can be considered as a method whereby the production lead time is shortened by ‘having all the processes produce the necessary parts at the needed time and have on hand only the minimum stock necessary to hold the processes together’ [Aytac, (2003)]. Inventory and material flow systems are typically classified as either push (traditional) or pull systems. Customer demand is the driving force behind both systems; the major difference is in how each system handles customer demand. Just-in-time is a tool that enables the internal process of a company to adapt to sudden changes in the demand pattern by producing the right product at the right time, and in the right quantities [Monden, (1998)]. Moreover, just-in-time is a critical tool to manage the external activities of a company such as purchasing and distribution. It can be thought of as consisting of three elements: JIT production, JIT distribution, and JIT purchasing.

The “pull system” is a basic principle of the kanban system. The pull system means the down stream processes fetch from upstream processes only the goods that are needed, only when they are needed, and only in the required amounts. Naturally, as an upstream process is depleted of its products it “pulls” more work pieces from the previous process, and this gets repeated all the way up the line. In the pull system, kanban are attached to in-process inventory, so that when goods are pulled from a process by the next process, the item indication on the kanban can serve as a work order for the previous process. Only make as needed [Davies.C et al].

**5. Perfection:**

This principle of Lean Manufacturing Approach involves using perfection in all the four principles explained so far. The techniques and approaches included here are New seven Q.C. Tools, Six sigma, Standard work and Preventive Maintenance. Fig. 2.1 pictorially represents the five principles of Lean Manufacturing and their interdependence.



**Fig. 2.1 Five Interdependent Principles of Lean Manufacturing.**

**2.4 STATUS OF LEAN MANUFACTURING IMPLEMENTATION IN VARIOUS CLASSES OF INDUSTRY AND BENEFITS ACCRUED**

Manufacturing systems are classified into two major classes; discrete manufacturing and continuous manufacturing (also referred to as the process industry). Discrete manufacturing refers to making discrete products such as an engine, an automobile, a drive shaft, a coffee maker, or a washing machine. On the other hand, continuous manufacturing includes making products that are measured or metered rather than being counted. Examples include paint, steel, textile, flat glass,

resin, oil, and flour [Needy and Bidanda, (2001)].

In manufacturing there are three different general classifications in term of production plants: job-shop production, batch production, and mass production. Job-shop production system is also known as intermittent production, and is characterized by low-volume, high variety products

The second type of production system is batch production. In batch production medium volume and medium variety of products are produced. Medium size lots of the same product may be produced once or at recurring intervals. General-purpose machines combined with specially designed jigs and fixtures designed for higher production rates are used in batch production.

The third type of production system is mass production. High volume low variety products characterize mass production. It requires expensive and special-purpose machines to satisfy the high demand rates for a product. Two types, quantity production and flow production can further distinguish mass production. In quantity production normally standard machines (e.g., injection molding and punch presses) are devoted for production of one type of product with high demand rate.

#### **2.4.1 Application of Lean in Discrete Industry**

Since the introduction of the Toyota production system, the lean concept has spread all over the world. The apparent success of Toyota in implementing a lean manufacturing system has led many of the world's automotive industries to try to implement this new idea of "lean" at their own companies. In this new era the application of lean manufacturing is seen in almost all companies in the automotive industry in Japan, Europe, North America and India. Most of the lean manufacturing ideas have been applied at the component assembly level, especially in discrete manufacturing. In the automotive industry the bulk of the work involved in making a car is carried out at the assembly level. This is due to the huge number of parts involved in building a car. These individual parts are first assembled at the component plants and then the final assembly of these parts is carried out at the assembly plant [Womack et al., (1990)].

The success of the Toyota production system has led the way for many companies in the discrete manufacturing industry to become lean in order to reduce cost through waste reduction and continuous improvement. The lean manufacturing concept is now being widely used in component assembly operations in a variety of industries, e.g., automotive, electronics, and cameras [Dimanancescu et al., (1997)]. In the United States many other companies particularly in the

discrete industry have adapted lean manufacturing tools and techniques. These include industries like shipbuilding, telecommunication equipment, office furniture, appliances, and computer part assembly. Other areas that have implemented lean manufacturing, particularly in Europe, include motorcycles and scooters, clothing, amusement park equipment, construction of vacuum pumps, air conditioning systems for cars, and bicycle components [panizzolo, (1998)].

In a study done in 2001, a survey was conducted on the adoption of lean manufacturing tools and techniques. The study included 313 telephone interviews and 2,511 responses from mail surveys [Stroznaik, (2001)]. The results of the survey illustrate that 32% of manufacturers use predictive or preventive maintenance, an increase from 28% in 2000 and 20% in 1999. also 23% of manufacturers are using continuous-flow production, up from 21% in 2000 and 18% in 1999, and 19% of manufacturing firms have adopted cellular manufacturing, an increase from 17% in 2000. Less than 20% of manufacturers adapted other lean tools such as lot-size reductions, bottleneck/constraint removal, and quick-changeover techniques [Stroznaik, (2001)]. Another lean manufacturing tool that has been widely used in the discrete industry is JIT. The automotive industry has been strongly influenced by the fundamental concept of JIT. Toyota for example led the way in using JIT where principles have been used with its suppliers [Womack et al., (1990)]. In the fifties, the Japanese shipyards implemented JIT in their steel deliveries from steel mills. [White, (1992)] states that JIT practices have been implemented in industries like electronic/electric, transportation equipment, health and medical components, and machinery.

#### **2.4.2 Continuous Process Industry and Lean**

A big part of the success of lean manufacturing has come from the automotive industry, especially in the assembly line type process. Other discrete manufacturing companies such as electronics followed the footsteps of the automotive industry by implementing lean concepts. Most of these companies have also succeeded in implementing lean. The challenge today is to adapt the ideas of lean and implement them in a continuous process manufacturing environment.

High volume, low variety products, and inflexible process characterize the continuous process manufacturing environment. Manufacturing environment managers have been slow to adapt the ideas of lean into these processes. The fear comes from the inflexibility of the process where it is more difficult to reduce the lot size. For example, in the continuous process industry set time are typically long and it is costly to shut down the process for changeover. The big confrontation

nonetheless, is not to be shaken off by these distinct characteristics of the process industry. [Sandras, (1992)] states that the differences that are distinctive to the process industry from the stand point of JIT (which is a lean tool) must be sorted out from those that are familiar in the discrete industry. He further stresses that those characteristics that are difficult to address must be sorted out from those that are not as hard. [Sandras, (1992)].

The process industry can be thought of as producing materials rather than producing items as in the discrete manufacturing industry. These two industries have features in common. However, the big difference is in the continuity of operation. In the process industry it can be so expensive to shut down a process that it creates a big challenge from the logistical standpoint. [White,(1996)]. Ultimately however, within a continuous process manufacturing environment, almost always, discrete parts are produced. The lean manufacturing concept can be applied to those processes where discrete parts are produced [Billesbach, (1994)]. The idea is to take those practices that are used to eliminate waste in discrete manufacturing and apply them to the constraints that are common to the process industry. ‘Some of the unique constraints, while difficult technically, may not be difficult from a JIT perspective (e.g. environmental issues)’ [Sandras, (1992)]. After those constraints are eliminated, one is left with the distinctive and difficult issues for each industry. One should then keep an eye on these by trying to minimize their impact while gradually trying to get rid of them.

## **2.5 APPROACHES ADOPTED FOR IMPLEMENTATION OF LEAN MANUFACTURING.**

In general, the success of implementation of any particular management practice frequently depends upon organizational characteristics, and not all organization can or should implement the same set of practice.

It describes three organizational context characteristics-unionization, plant age and plant size- that may influence the implementation of manufacturing practices. A limited number of empirical studies suggest that implementation or adoption of a manufacturing practice is contingent upon specific organizational characteristic [Shah and Ward, (2003)].

### **2.5.1 Unionization**

It is often assumed that because implementation of manufacturing practices require negotiating changes in work organization, unionized facilities will resist adopting lean practices and lag behind non-unionized facilities. Further, there are instances in which unions have been cooperative and helpful in implementation process. It is concluded that unionized plant are less likely to implement lean manufacturing practices than non-unionized or partially unionized plant [Shah & Ward, (2003)].

### **2.5.2 Age of plant**

Plant age may imply either a tendency toward resistance to change or a liability of newness. The “resistance to change” view is supported by the organizational sociology literature which suggests that the age of an establishment should inversely influence the rate of adoption of innovations, because organizational forms tends to be “Frozen” at birth. This implies that plant age has negative impact on the likelihood of implementation of lean manufacturing practices. It is concluded that older plants are less likely to implement lean manufacturing practices than newer plant [Shah & Ward, (2003)].

### **2.5.3 Size of plant**

Several authors have noted that since any administrative task tends to be more complicated in large firms, firm managers may not attempt to change; instead they may allow existing systems to linger. That is, large organizations suffer from structural inertial forces that negatively effect the lean implementation. It is concluded that large manufacturers are more likely to implement lean practices than small manufacturers [Shah & Ward, (2003)].

## **2.6 STATUS OF VARIOUS TOOLS AND TECHNIQUES OF LEAN MANUFACTURING**

### **2.6.1 Cellular Manufacturing (CM)**

Cellular manufacturing is a concept that increases the mix of products with the minimum waste possible. A cell consists of equipment and workstations that are arranged in an order that, maintains a smooth flow of materials and components through the process. An ideal, lean cell would have all machines needed to process a part located very close together, single –piece flow of parts between operations, and operators running multiple machine types [Cochran et al, (1998)].

Cellular manufacturing system is an application of lean manufacturing aims to partition manufacturing systems into manufacturing cells. Manufacturing companies that implemented CM systems improved their productivity level by increased output, increased rate of return on investment, increased profit, improved quality, decreased set up time, over due orders and work-in-process inventories, reduced material handling cost and reduced space requirements [Abduelmula et al, (2000)]. A manufacturing cell is composed of dissimilar processes grouped together and operated by multi-skilled workers who use the cell to process family parts. The manufacturing cells are typically laid out in a 'U' shape [Aytac, (2003)].

### **2.6.2 Continuous Improvements**

Continuous improvement is another fundamental principle of lean manufacturing. Kaizen, which is the Japanese word for a continuous endeavor for perfection, has become popular in the west as a paramount concept behind good management. Kaizen is a systematic approach to gradual, orderly, continuous improvement. In manufacturing settings improvements can take place in many forms such as reduction of inventory, and reduction of defective parts. One of the most effective tools of continuous improvement is 5S, which is the basis for an effective lean company. 5S is a first, modular step towards serious waste reduction. 5S consists of the Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Sweep and Clean), Seiketsu (Systemize), and Shitsuke (Standardize). The underlying concept behind 5S is to look for waste and then to try to eliminate it. Waste could be in the form of scrap, defects, excess raw material unneeded items, old broken tools, and obsolete jigs and fixtures [Monden, (1998)].

The first S, **Seiri**, deals with moving those items that are not currently being used on a continuous basis (e.g., items that will not be used for the next month or so) away from those that are. Moving those items and tossing away needless items will make material flow smoothly, and workers move and work easily [Feld, (2000)].

**Seiton** has to do with having the right items in the right area. Items that do not belong to a given area must not be in that area. For a given workplace area tools must be marked and arranged as belonging in that area. This will make it easier to move those items that are not labeled from that area. Arranging items in the right place will make tools, jigs, fixtures, and resources noticeable, detectable, and easy to use [Feld, (2000)].

**Seiso** deals with cleaning and sweeping the work place methodically. The workplace should look

neat and clean and ready to use for the next shift. The work place should be maintained on a regular basis (e.g., daily). All tools and items should be in the right place and nothing should be missing. A well-maintained workplace creates a healthy environment to work with [Feld, (2000)].

**Seiketsu** is maintaining a high standard of housekeeping and workplace arrangement. A regular audit should be run and scores should be assigned for areas of responsibilities. If every area has people assigned to it then everyone has responsibility to maintain a high standard of housekeeping and cleaning [Feld, (2000)].

**Shitsuke** is management's accountability to train people to follow housekeeping rules. Management should implement the housekeeping rules in a practiced fashion so that their people can buy into it. Management should walk the shop floor, explain what they want from people, reward those who follow and instruct those who do not [Feld, (2000)].

Taken together, 5S means good housekeeping and better workplace organization. Kaizen tools such as 5S are not only a means to increase profitability of a firm but also allow companies to reveal potential strengths and capabilities that were hidden before [Hirai, (2001)]. [Sweeny, (2003)] and [Cox, (2002)] have reported good results implementing 5S.

### **2.6.3 Just - In-Time**

Closely associated with lean manufacturing is the principle of just-in-time, since it is a management idea that attempts to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. This addresses waste such as work-in-process material, defects, and poor scheduling of parts delivered (Nahmias, 1997). JIT can be considered as a method whereby the production lead time is shortened by 'having all the processes produce the necessary parts at the needed time and have on hand only the minimum stock necessary to hold the processes together' [Aytac, (2003)]. Inventory and material flow systems are typically classified as either push (traditional) or pull systems. Customer demand is the driving force behind both systems; the major difference is in how each system handles customer demand. Just-in-time is a tool that enables the internal process of a company to adapt to sudden changes in the demand pattern by producing the right product at the right time, and in the right quantities [Monden, (1998)]. Moreover, just-in-time is a critical tool to manage the external activities of a company such as purchasing and distribution. It can be thought of as consisting of three elements: JIT production, JIT distribution, and JIT purchasing. More details are given for each in the following

sections.

### **Just-In-Time Production**

Lean manufacturing is about eliminating waste wherever it is. One of the most important steps in the implementation of lean manufacturing is JIT. [Monden, (1998)] and [Levy, (1997)] both agree that JIT production is the backbone of lean manufacturing. Just-in-time production is about not having more raw materials,

Working process or products than what are required for smooth operation. JIT production is accomplished by a 'pull' system instead of a 'push' system, which is used in traditional production system. In traditional manufacturing system; the production schedule of the final product is exploded to determine the requirement of all subassemblies and parts that make up the final product. [Aytac, (2003)].

The process goes on as each process pulls the needed parts from the preceding process further up stream. The whole process is coordinated through the use of a Kanban system.

Shipments under JIT are in small, frequent lots. A Kanban is used to manage these shipments. Kanban is an information system that is used to control the number of parts to be produced in every process [Monden, (1998)]. The most common types of Kanban are the withdrawal Kanban, which specify the quantity that the succeeding process should pull from the preceding process, and the production kanban, which specifies the quantity to be produced by the preceding process [Monden, (1998)]. The withdrawal Kanban shows the parts, the subsequent machining process requests from the preceding process.

A supplier kanban is another type of kanban that is used between the supplier and the manufacturer under JIT. Lean manufacturing requires quick deliveries and in order to achieve this, many manufacturers require their suppliers to deliver items just in time. In order to achieve JIT delivery, suppliers have to adjust from the traditional run sizes to smaller lot sizes. The supplier kanbans circulate between the manufacturer and the supplier. The kanban is delivered at predefined times from the manufacturer to the supplier. For example, if parts were conveyed twice a day (8 a.m. and 10 p.m.), the truck driver would deliver the kanban at the supplier's store at 8 a.m. which is a signal to the supplier to produce the required quantity. At the same time the driver picks up the parts that are completed at 8 a.m. that morning along with the kanban attached to the boxes containing these parts. These are the kanbans that would have arrived the previous night at 10 p.m. signaling the production of the parts [Monden, (1998)].

By utilizing a kanban system under JIT, smaller lot sizes and huge inventory reductions can be achieved. Under JIT production, raw material, subassemblies and finished product inventory are kept to a minimum and the lean manufacturing principles are followed to eliminate inventory as a source of waste. Another type of waste that is eliminated under JIT production is overproduction. Since every process is producing at a pace no higher than that of the subsequent process's requirements, the need to produce more than what is needed is diminished.

### **Just-In-Time Distribution**

JIT effectiveness depends heavily on having a strategic alliance between buyers and suppliers. By having a third-party logistics distributor, companies can focus on their core competencies and areas of expertise leaving the logistics capability to logistics companies [Simchi, et al., (2000)], [Quinn and Hilmer, (1994)]. Third-party logistics (3PL) refers to the use of an outside company to perform all or part of the firm's materials management and product distribution functions [Simchi, et al, (2000)]. 3PL can support just-in-time distribution (JITD) by providing on time delivery to customers or distributors, technological flexibility such as EDI and flexibility in geographical locations. [Simchi, et al., (2000)], [Raia, (1992)].

JITD requires the exchange of frequent, small lots of items between suppliers and customers, and must have an effective transportation management system because the transportation of inbound and outbound material can have a great effect on production when there is no buffer inventory [Spencer, et. al. (1994)]. Under HTD having a full truckload sometimes is difficult due to the frequent delivery of smaller lots, which in turn will increase the transportation cost. However, to get over the problem [Monden (1998)] states that instead of having one part loading, using a mixed loading strategy makes it possible to have full truckloads and increase the number of deliveries.

Another important factor that is essential to JITD is EDI. In order to have effective product deliveries between suppliers and their distributors or customers, an EDI system must be in place. In traditional product delivery system suppliers always have to keep finished goods inventory or have to alter their production schedules to respond to demand surges. Under EDI, suppliers can look at all the shipment and inventory data and adjust their production schedule accordingly [Simichi, et. al., (2000)] .To stay competitive under JITD, it is very important to share information in the whole supply chain because suppliers can adjust their production schedule and narrow their delivery windows as more product data becomes available to them . Other benefits of EDI include cost reduction, cycle time reduction, stock out reduction, and inventory reduction.

### **Just-In-Time Purchasing.**

[Ansari and Mondarress (1986)] and [Gunasekaran, (1999)] define just-in-time purchasing (JITP) as the purchase of goods such that their delivery immediately precedes their demand, or as they are required for use. The idea of JITP runs counter to the Traditional purchasing practices where materials are brought well in advance before their use. Under JITP activities such as supplier selection, product development and production lot sizing become very critical.

Customer-supplier relationships are a very important part of JITP. Under JITP it is Necessary to have a small number of qualified suppliers. Having quality-certified suppliers shifts the inspection function of quality and piece-by-piece count of parts to the supplier's site where the supplier must make sure that parts are defect free before they are transported to the manufacturer's plant. Another important factor of JITP is product development. Buyers must have a "Black Box" relationship with the suppliers where suppliers participate heavily in design and development. The benefits of sharing new product development and, design innovation include a decrease in purchased material cost, increase in purchased material quality, a decrease in development time and cost and in manufacturing cost, and an increase in final product Technology levels [Simchi, et al., (2000)]. EDI is very important under JITP. The ultimate goal of JITP is to guarantee that production is as close as possible to a continuous process from the raw material reception until the distribution of the finished goods [Gunasekaran, (1999)]. EDI can support JITP by reducing the transaction processing time and meeting the specialized needs of buyers by helping them to synchronize their material movement with their suppliers. Although under JITP the carrying cost of materials is increased due to frequent small lots, this cost is offset by a decrease in the cost of processing a purchase order and by the decreased inventory holding cost. Some of the benefits of JIT [Nahmias, 1997]):

- Eliminating unnecessary work-in-process, which results in reduction of inventory costs?
- Since units are produced only when they are needed, quality problem can be detected early.
- Since inventory is reduced, the waste of storage space will be reduced.
- Preventing excess production can uncover hidden problems.

### **2.6.4 Production Smoothing**

In a lean manufacturing system it is important to move to a higher degree of process control in order to strive to reduce waste. Another tool to accomplish this is production smoothing. Heijunka, the Japanese word for production smoothing, is where the manufacturers try to keep the production level as constant as possible from day to day [Womack et al., (1990)]. Heijunka is a concept adapted from the Toyota production system, where in order to decrease production cost it was necessary to build no more cars and parts than the number that could be sold. To accomplish this, the production schedule should be smooth so as to effectively produce the right quantity of parts and efficiently utilize manpower. If the production level is not constant this leads to waste (such as work-in-process inventory) at the workplace.

### **2.6.5 Standardization of Work**

A very important principle of waste elimination is the standardization of worker actions. Standardized work basically ensures that each job is organized and is carried out in the most effective manner. No matter who is doing the job the same level of quality should be achieved. At Toyota every worker follows the same processing steps all the time. This includes the time needed to finish a job, the order of steps to follow for each job, and the parts on hand. By doing this one ensures that line balancing is achieved, unwarranted work-in-process inventory is minimized and non-value added activities are reduced. A tool that is used to standardize work is what called “takt” time. Takt (German for rhythm or beat) time refers to how often a part should be produced in a product family based on the actual customer demand. The target is produced at a pace not higher than the takt time (Mid-America Manufacturing Technology Center press release, 2000). Takt time is calculated based on the following formula [Feld, (2000)]:

$$\text{Takt Time (TT)} = \frac{\text{Available Work Time per Day}}{\text{Customer Demand per Day}}$$

### **2.6.6 Total Productive Maintenance**

Machine breakdown is one of the most important issues that concern the people on the shop floor. The reliability of the equipment on the shop floor is very important since if one machine breaks down the entire production line could go down. An important tool that is necessary to account for

sudden machine breakdowns is total productive maintenance. In almost any lean environment setting a total productive maintenance program is very important.

There are three main components of a total productive maintenance program: preventive maintenance, corrective maintenance, and maintenance prevention. Preventive maintenance has to do with regular planned maintenance on all equipment rather than random check ups. Workers have to carry out regular equipment maintenance to detect any anomalies as they occur. By doing so sudden machines breakdown can be prevented, which leads to improvement in the throughput of each machine [Feld,( 2000)].

Corrective maintenance deals with decisions such as whether to fix or buy new equipment. If a machine is always down and its components are always breaking down then it is better to replace those parts with newer ones. As a result the machine will last longer and its uptime will be higher. Maintenance prevention has to do with buying the right machine. If a machine is hard to maintain (e.g., hard to lubricate or bolts are hard to tighten) then workers will be reluctant to maintain the machine on a regular basis, which will result in a huge amount of lost money invested in that machine.

Researchers including [Nicholls (1994)], [Taylor (1996)], [Suehiro (1992)], [Ljungberg (1998)], [Nakajima (1989)] and others have reported good results implementing TPM.

## **CHAPTER- 3 DESIGN OF STUDY**

### **3.1 INTRODUCTION**

This chapter covers the overall methodology of the research work including the steps of analysis and tools and techniques employed. A brief description of the industrial unit where the study has been carried out is also given.

### **3.2 BRIEF DESCRIPTION OF THE INDUSTRIAL UNIT**

Diesel loco modernization works (DMW) was conceived for manufacturing sophisticated components to meet the maintenance need of diesel traction fleet of Indian railways. Diversity of technology involved under one roof at DMW is unmatched not in Indian railways but also in the

industrial set ups around the globe. Manufacture of carbon brushes on one hand and the traction gears on the others; remanufacture of traction generators to machine of engine blocks stretches the imagination of even well experienced engineers. To manage such a plant of diverse activities and to maintain the healthy and rhythmic throb of such complex system calls for paramount professional skills. Unlike other production units, DMW does not have an assured captive market for the products. For most of its products, DMW has to compete with other private and public sectors enterprises that have been supplying these items to zonal railways for decades.

DMW have two phases, phase-1 and phase-2.

Following shops are included in phase 1

Sr.no.	Shop	Activity
1.	Carbon brush shop	Manufacturing of brushers for traction machine.
2.	Light machine shop	Manufacture spare parts of diesel locomotive.
3.	Heavy machine shop	Remanufactures of engine blocks and traction motors
4.	Traction machine shop	Remanufacture of traction machine including manufacturing of coils.
5.	Cylinder liner shop	Remanufacture of cylinder liner by chrome plating.
6.	Heat treatment shop	Heat treatment of components
7.	Plant maintenance shop	Insulation and maintenance of machine tools and facilities including material handling.
8.	Central transport shop	Material handling and transportation.
9.	Tool room	Manufacture and maintenance of jigs and fixtures

Phase 2:- Facilities for rebuilding of power packs and diesel locomotives are distributed in the following shops.

Sr.no.	Shop	Activity.
1.	Power packs shop	Stripping, assembly and testing of diesel power packs.
2.	Bogie shops	Stripping, reconditioning and assembly of loco bogie.
3.	Traction repair shop	Rebuilding and testing of auxiliary machines and electric equipment.
4.	Loco rebuilding shop	Stripping and rebuilding of locomotives.

5.	Air brake shop	Reconditioning, testing and assembly of air brake equipment.
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### **Description of light machine shop**

Light machine shop is one of the most important shops of diesel locomotives modernization work, which is concerned, with the manufacturing of over 200 components for the diesel engine. The shop has got the most modern technology producing the components to highest accuracy.

The light machine shop has been divided into a few major sections as given below.

- CNC (turning): In this section CNC turning machines have been installed.
- Camshaft section: The section undertakes manufacturing of camshaft.
- Connecting rod section: This section undertakes manufacturing of connecting rod.
- Gear section: About 15 different types of gears are being produced in this section.
- Center less grinding section: It is used for grinding of thread of gear.
- CNC machining: In this section CNC machines, which are used, for various machining processes have been installed.
- Benching section: In this section light jobs like grinding / deburring of jobs by baby grinder are undertaken.
- Inspection and gauge room: In this section various gauging and inspection equipments are there for measurement and inspection of various components being manufactured in the LMS.
- Zero bay section: Here the initial processes of manufacturing of various important components such as the axle boxes, connecting rods etc. are undertaken since this is the starting point of various components hence its name. Refer figure 3.1 and 3.2.

## **3.3 METHODOLOGY**

### **3.3.1 Preliminary Study**

Cam shaft section has been chosen for the detailed study of status on lean manufacturing implementation. The steps of camshaft machining are as follows.

- Cut length of 46.7” of raw material (Alloy Steel) using a band saw.
- Face end center at both ends.
- Turn bearing dies. Also turn pilot, flanges and form grooves in the remaining length.
- Drill oil hole by a gun drill.
- Drill and ream indicating hole, on the flange end by a radial drilling machine bench and deburr. Drill three oil holes.
- Milling of the camshaft making exhaust, air, and fuel cam.
- Bench and deburr and relieve stresses by heat treatment.
- Harden the cam and bearing to required hardness by induction hardening process up to a case depth of about 4.5-5.5mm.
- Rough grind bearing diameters on a grinding machine.
- Lathe work
- Flange drilling on the radial drill.
- Finish grind bearing diameters on the cam grinding machine
- Inspection

# MACHINE LAYOUT OF LIGHT MACHINE SHOP

## SECTION

1. Centreless Section
2. Precision Section
3. Benching & Stud Section
4. Semi Precision Section
5. Gear Section
6. F.P. Support Section
7. CNC (M) Section
8. Axle Box Section
9. Equaliser Section
10. C.N.C. (T)
11. Conrod Section
12. Camshaft Section
13. Fire Exting. Location
14. First Aid Box



Figure: 3.1 layout of machine shop

Sr.	MW	Machine Name	Sr.	MW	Machine Name	Sr.	MW	Machine Name
1.	220	Centreless Grinder	45.	864	Vertical Milling Machine	89.	208	Horz. Milling
2.	233	Internal Grinder	46.	936	Horz. Milling Machine	90.	102	Copy Milling Machine
3.	428	Drill Machine	47.	1138	Twin Spindle CNC ATL	91.	118	Radial Drill (ELHA)
4.	122	Pillar Drill Machine	48.	1140	CNC Turning Centre	92.	263	Vertical Turret Lathe
5.	878	Radial Drill	49.	838	Gear Hobbing MIC	93.	748	Axle Grinder
6.	878	Radial Drill	50.	374	Vertical Turret Lathe	94.	443	Bar Straightening Machine
7.	874	Radial Drill	51.	807	Cylindrical Grinder	95.	189	Flame Cutting Machine
8.	877	Radial Drill	52.	581	Rotary Surface Grinder	96.	1088	Flame Cutting CNC Machine
9.	684	Surface Grinder	53.	232	Internal Grinder	97.		Heavy Duty Band Saw MIC
10.	151	Int. Grinder	54.	158	Horz. Milling Machine	98.	229	DOALL Band Saw MIC
11.	150	Int. Grinder	55.	800	Radial Drill	99.	208	Double Ended Facing & Centre
12.	265	Cylindrical Grinder	56.	263	Capstan Lathe	100.	437	Radial Drill
13.	264	Cylindrical Grinder	57.	234	CNC VHM	101.	1145	CNC Heavy Duty Turning MIC
14.	475	Horz. Milling Machine	58.	873	Radial Drill	102.	1109	SB-CNC-40
15.	438	Horz. Milling Machine	59.	1074	CNC TSC-20	103.	221	CNC ATL
16.	885	Centre Lathe	60.	215	Electrical Arc Drill MIC	104.	224	CNC ATL
17.	132	Monoclide Lathe	61.	1117	Horz. Milling Machine	105.	223	CNC ATL
18.	1138	Twin Spindle CNC ATL	62.	1118	Horz. Milling Machine	106.	222	CNC ATL
19.	1137	Twin Spindle CNC ATL	63.	1078	CNC TSC-20 Machine	107.	831	STC-25 CNC
20.	1123	Gun Drill Machine	64.	470	CNC HTC	108.	863	SB-CNC-35
21.	188	1 AC ATL Machine	65.	1142	CNC HMC (Praga)	109.	230	Cicum CNC
22.	1110	CNC STC-20	66.	988	WSU-12 CNC Chuckor	110.	231	Cicum CNC
23.	474	Capstan Lathe	67.	169	Gear Hobbing CNC	111.	172	U. Cylindrical Grinder
24.	749	Horz. Milling Machine	68.	562	Gear Grinder	112.	149	M.S.D.
25.	478	Horz. Milling Machine	69.	311	Tooth Profile Cutting MIC	113.	863	Vert. Milling Machine
26.	227	Bench Lathe	70.	834	Gear Testing Machine	114.	438	Radial Drill
27.	205	Pedestal Grinder	71.	500	CNC V.T.L.	115.	377	Rotary Surface Grinder
28.	193	Belt Grinder	72.	391	Gear Grinder	116.	348	Fine Boring Machine
29.	204	Pedestal Grinder	73.	226	WSU-12 Lathe	117.	390	Horz. Milling Machine
30.	1144	CNC Stud Turning MIC	74.	1155	CNC Gear Profile Grinder	118.	1115	CNC Cam Milling MIC
31.	1143	CNC Stud Turning MIC	75.	148	CNC VMC	119.	176	Horz. Milling Machine
32.	697	Copy Turning Lathe	76.	899	CNC G&L	120.	228	WSU-12 Lathe
33.	157	Centreless Grinder	77.	458	CNC Drill Machine	121.	923	Cylindrical Grinder
34.	891	Thread Rolling Grinder	78.	964	Cylindrical Grinder	122.	1027	Punching Press
35.	871	Thread Rolling Grinder	79.	138	Pipe Bending Machine	123.	189	Gun Drill Machine
36.	228	Centre Bore Grinder	80.	375	Vertical Turret Lathe	124.	875	Radial Drill
37.	424	Pillar Drill Machine	81.	119	Horz. Bore Machine	125.	128	Cam Milling Machine
38.	832	STC-25 CNC	82.	1141	Heavy Duty Boring Centre	126.	271	Cylindrical Grinder
39.	962	Facing and Centering MIC	83.	167	Vertical Milling Machine	127.	471	NH-26 Lathe
40.	182	HMT Lathe	84.	129	Bed Type Milling Machine	128.	451	NH-22 Lathe
41.	-	HMT VMC	85.	567	Vertical Turret Lathe	129.	178	Cylindrical Grinder
42.	203	Capstan Lathe	86.	827	Radial Drill Machine	130.	126	CAM Grinder
43.	185	1AC ATL	87.	142	Jump Drill Machine	131.	1116	CNC CAM Grinder
44.	888	HMT Milling Machine	88.	493	ELB. Grinder	132.	268	Magna Spray Equipment

### **Figure: 3.2 Types of Machines**

- Application of rust preventive material.

Flow charts of manufacture of cam shaft, connecting rod and equalizer, axle and gear are given in figures 3.3 to 3.7.

### **FLOW CHART OF CAM SHAFT**



**Figure 3.3**

**FLOW CHART OF CON ROD**

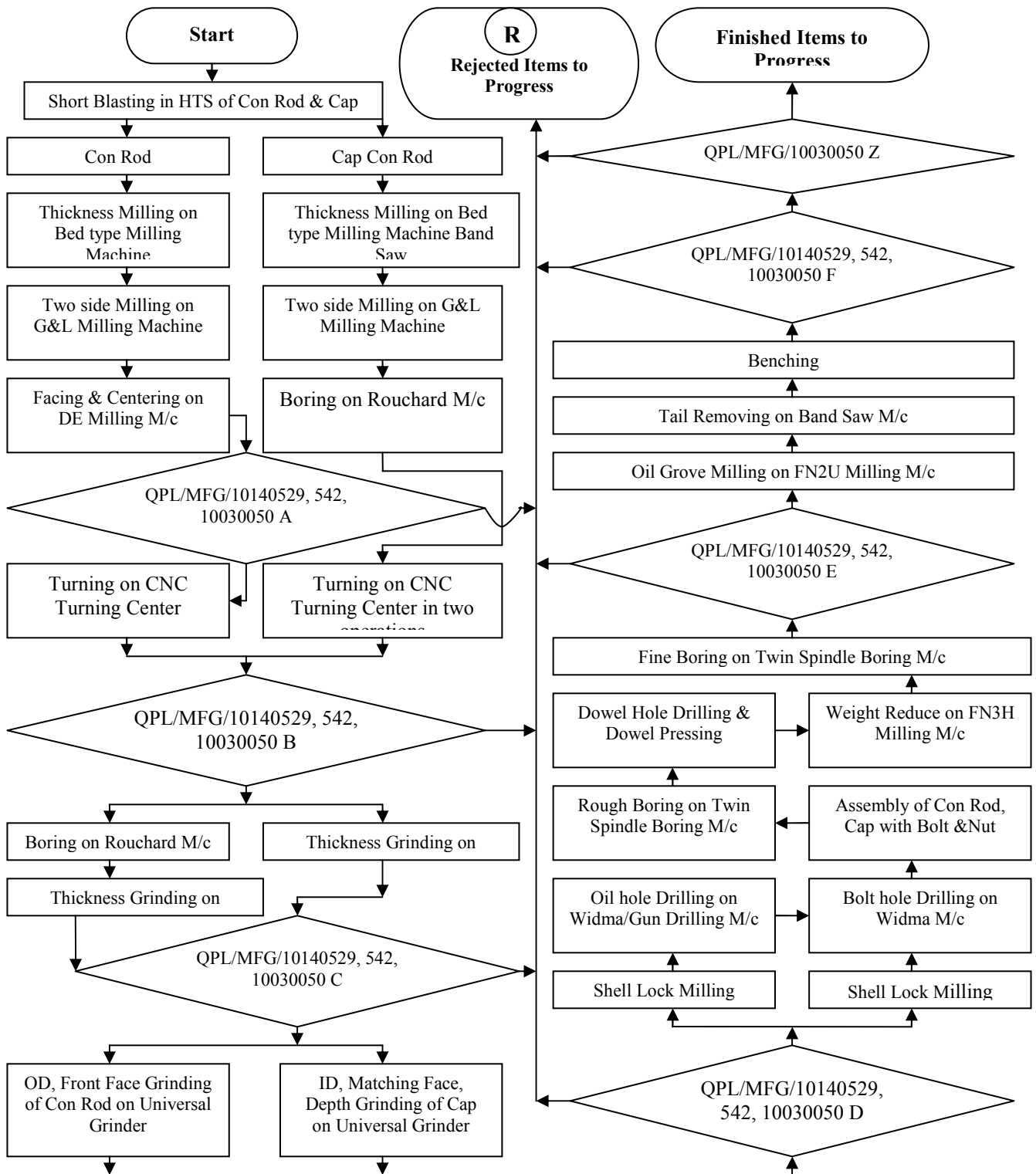
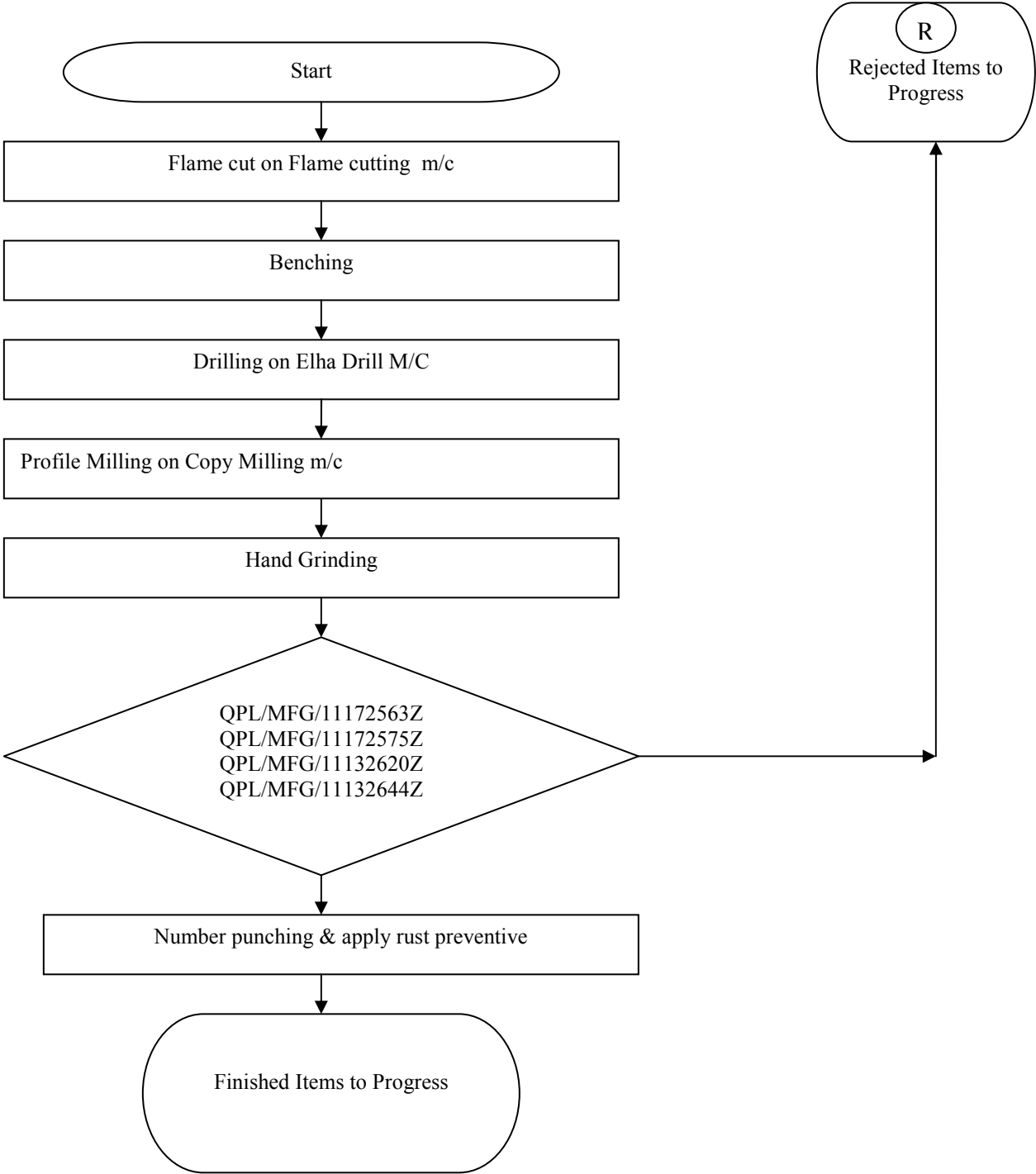


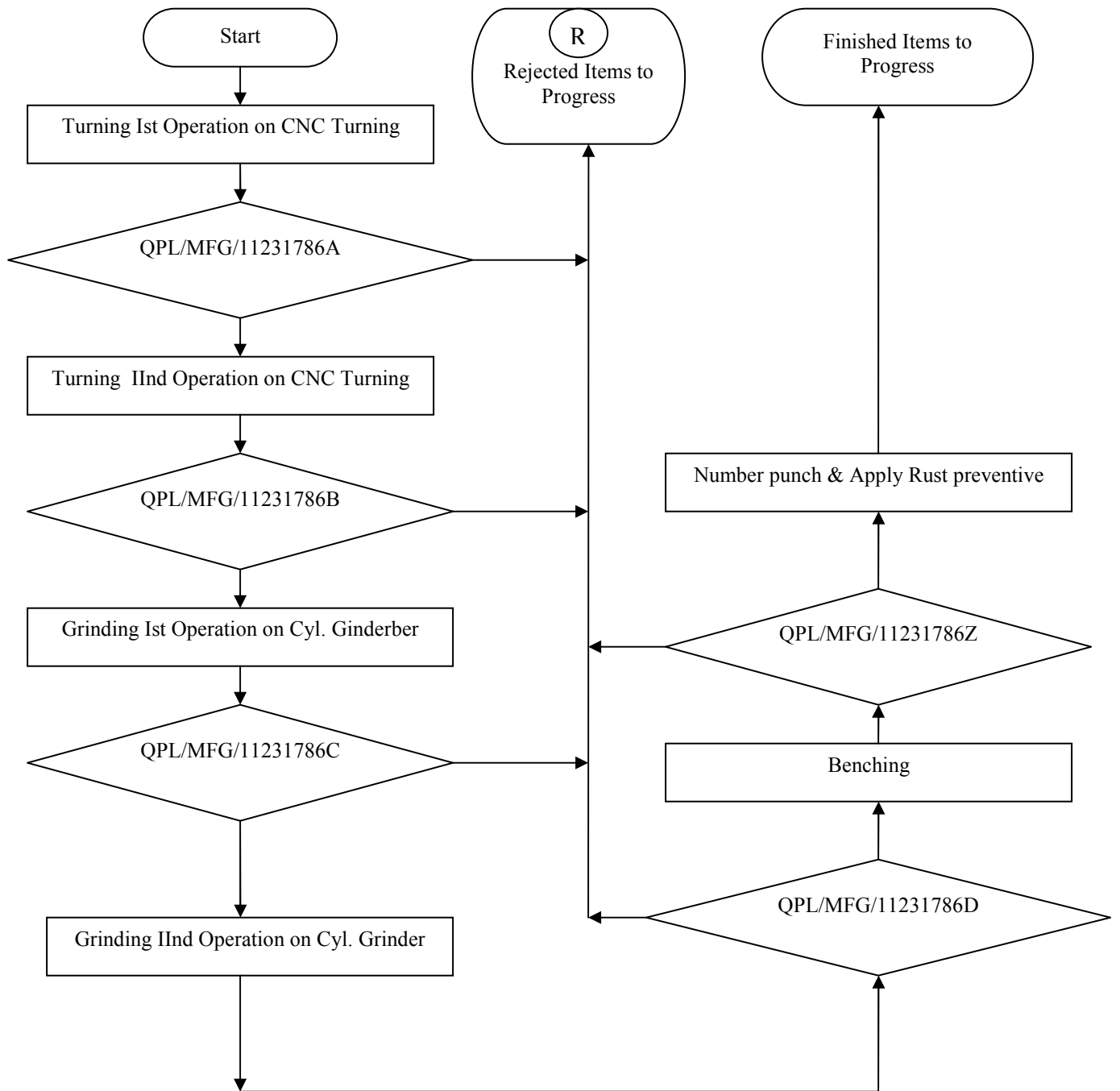
Figure 3.4

**FLOW CHART OF EQUALIZER**



**Figure 3.5**

### FLOW CHART OF AXLE



**Figure 3.6**

## **FLOW CHART OF GEARS**

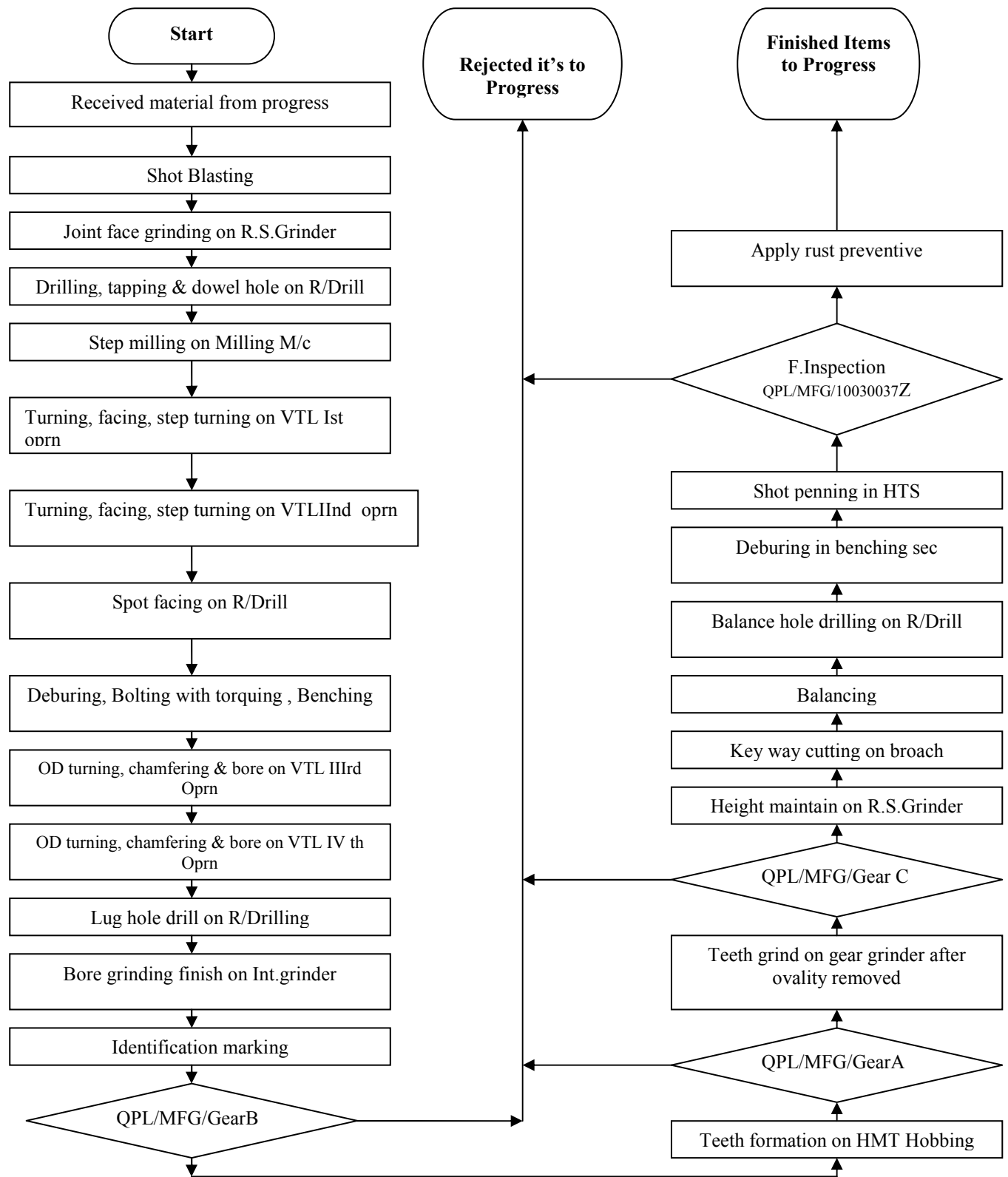


Figure 3.7

### 3.3.2 Data Collection

Data has been collected by the following methods:

- Observation of the performance of activities.
- Previous records: - Data from records include absenteeism, breakdown, inventories etc.
- Personal interaction: - It includes interviews of personnel directly related to the process.

### 3.3.3 Identification of Non-Value Added Activities and Their Quantum.

This involves collection and identification of various types of wastes as categorized in lean manufacturing. These are shown in following table.

**Table3.1  
Data collection**

S. no.	Type of waste	Data collection	Waste identification method
1.	Defects	Number of good parts made. Total number of products made. Scrap during processing. Rework during processing.	Difference of output and input. Difference of products made and products supplied.
2.	Inventory	Total raw material in store. WIP-work in process. Finished goods stock.	Data from records
3.	Transportation waste	Distance between machines.	Direct measurement on shop floor.
4.	Waiting	Cycle time, Setup time, Absenteeism Break down. Other Avoidable and Unavoidable delays.	From time study records. Number of absents per month. Number of break down per month.
5.	Overproduction	Total number of parts produced. Total requirement of parts.	Difference in total number of parts made and requirement.
6..	Inappropriate processing	Using wrong set of tools, procedures or systems	From records. Difference between the weight of raw material and weight of finished product.

**3.3.4**

**Root Cause Analysis**

An expert's teams of 12 persons comprising of 5 workers, 2

supervisors, and 1 engineer, 3 Store and Progress department personnel were chosen. Brainstorming was carried out to identify the area of waste and root causes of waste were identified.

### **3.3.5 Gap Analysis**

Following work has been carried out to identify gaps:

- a) Comparison of existing status in the shop with the requirement of lean manufacturing.
- b) Using expert opinion and clarify the gap as `HIGH` , `MEDIUM` or `LOW`

Where

HIGH- Very large gap, need immediate action.

MEDIUM-Large gaps, urgent action required.

LOW –Insufficient gap, doesnot require immediate action.

### **3.3.6 Development of Strategy for Implementation**

The steps employed in the qualitative modeling have been as under:

- a) Identification of experts.
- b) Dissemination of results of analysis to experts.
- c) Generalized of the provision/controls identified under each of the above area, by experts.
- d) Identification of factors and parameters influencing development of a generalized approach by brainstorming and idea generation.
- e) Collection of qualitative score to a quantitative score using the scoring scale and the number of responses to a choice.
- f) Listing the results of various generalized provision/controls in reducing order of their cumulative scores, separately for lean wastes.
- g) Using expert's opinion for implementation of these provisions and deciding an order of priority to the four major areas studied.
- h) Formulation of phased implementation approach by picking up the provisions which had higher weighted scores in the lean wastes.

## **CHAPTER -4**

### **ANALYSIS AND RESULTS**

#### **4.1 INTRODUCTION**

This chapter presents the main body of the work. It covers the complete step by step analysis carried out including data collection, calculation of various types of wastes, their root cause analysis and comparison with the requirements of lean manufacturing. A phased approach has then been developed for implementation of lean manufacturing in the organization.

## 4.2 PRODUCT DESCRIPTION

In the light machine shop, four type of camshaft are manufactured:

1. Conventional camshaft (broad gauge and meter gauge)
2. Modified camshaft (broad gauge)
3. Unit camshaft
4. Stiffer camshaft

Currently, only conventional (broad gauge) and modified (meter gauge) camshaft are manufactured. Cam shafts are made of alloy steel of 120 mm diameter weighing 106.5kg:

Various characteristics for camshafts are shown in Table 4.1

**Table: 4.1**

**Camshafts characteristics**

S.no.	Part no.	Length in inches.	Weight in kgs.	Cost in rupees.
1	10210933	33.898-33.914	53	17863
2	10210945	36.242-36.258	53	17863
3	10210957	36.242-36.258	52	17098
4	10210969	38.492-38.505	57	15470
5	10210970	33.954-36.671	58	18971
6	10210982	36.641-36.671	65	15898
7	10210994	46.117-46.133	71	17913
8	10211007	44.211-44.227	71	18523
9	10216534	44.211-44.227	51.5	18674
10	10216446	38.492-38.505	57	17611
11	10216558	36.242-36.258	52	17828
12	10216560	33.954-36.671	58	18719
13	10216571	33.898-33.914	52	17485
14	10216583	46.117-46.133	70	17082
15	10216601	36.641-36.671	64.5	17611
16	10216595	36.242-36.258	53	16906

## 4.3 ANALYSIS OF WASTE

For the purpose of analysis, the waste has been categorized into six different types:

1. Defects
2. Excessive inventory

3. Waste due to unnecessary material movement.
4. Delay due to waiting.
5. Overproduction.
6. Inappropriate processing.

The detailed analysis of each of above types has been presented in the next section.

#### 4.3.1 Defects:

Data of camshaft produced along with the number of defective camshafts, for different part numbers, has been compiled from the company records. Table 4.2 presents the data along with the percentage of defectives produced.

**Table 4.2**  
**Total camshafts produced in January 2006**

S.no	Part no.	Total quantity produced	Quantity good	Quantity Rejected
1	10210982	6	4	2
2	10211007	4	2	2
3	10216534	57	56	1
4	10216546	56	55	1
5	10216558	5	5	-----
6	10216560	50	47	3
7	10216571	51	51	-----
8	10216583	36	36	-----
9	10216595	53	49	4
10	10216601	45	45	-----
11	Total	363	350	13

Company reported a rejection of 3.6% during January 2006.

The high scrap percentage in the LMS reveals large amount of wastage in term of lost material, machine time, labour, energy and other resources.

#### 4.3.2 Inventory Analysis

The analysis of waste caused due to excess inventory levels has been categorized into Raw Material, Work In Process (WIP) and Finished Goods Inventory

a)

## Raw material

Table 4.3 shows the status of raw material inventory as on 31st January 2006. Typically the monthly customer requirement is about 350 camshafts. With an average rate of 106.5 kg per camshaft, a total of 37275 kg material is required to meet the customer's monthly requirement.

**Table: 4.3**  
**Raw material Inventories in Store**

Thus the material required by the customer is only 26% of the raw material (144971.5 kg) available in stock, which indicates that only about ¼th of the raw material inventory is utilized every month and the rest depreciate.

S.no	Material type on 31.01.2006 (alloy steel 120 mm)	Quantity in KGS
1	Raw material	144971.5

### b) Work In Progress (WIP)

In the present case, because of different setup and cycle times at various stations, WIP inventory of 50 pieces can be considered to be ideal. This is also due to the problems with line balancing where in there is large difference in setup/cycle times at various stations. The facility, however, has a WIP inventory of 398 parts (Refer table 4.4) which is very high.

**Table: 4.4**  
**Total WIP Inventory**

S. No.	Machine-station	Total WIP (no. of pieces)
4	Gun drill	118
5	CAM milling Band saw	171
6	Benching CNC turner	38
7	Cylindrical grinding (rough)	15
3	Radial drill	32

8	Lathe (1&2)	1
9	CAM grinding	1
10	Cylindrical grinding (finish)	3
11	Inspection	14
12	Total	398

The excessive WIP inventory in this case is 87%.

### C) Finished Goods Inventory

Table 4.5 shows that quantity of total finished product is 350 pieces which is as per customer's monthly requirement.

**Table: 4.5**  
**Total Finish Product Inventory in Progress Department**

<b>s.no</b>	<b>Part No.</b>	<b>Quantity (no. of parts)</b>	<b>Total weight</b>
1	10210982	4	14120.3
2	10211007	2	
3	10216534	56	
4	10216546	55	
5	10216558	5	
6	10216560	47	
7	10216571	51	
8	10216583	36	
9	102165 95	49	
10	10216601	45	
11	Total	350	

### 4.3.3 Waste Due to Unnecessary Material Movement

The unnecessary transportation of material is a common cause of waste in the factory. In this case, the material does not follow a specific line flow due to which material moves from one station to another in a haphazard manner. In order to reduce this waste, the layout of the Light Machine Shop (LMS) is proposed to be amended to facilitate single piece flow and also reduce unnecessary material movement in the shop. Some other reasons for excessive material movements are:-

- There are delays in movement of pieces in between stations.
- Some stations are hard to access.

The LMS layout has been re-designed to reduce unnecessary material movement. Refer figure 4.1(Existing layout) and Figure 4.2 (Proposed layout). Table 4.6 shows the current and proposed material movement distance between various stations.

**Table: 4.6**  
**Distances between Two Stations**

S.no	From	To	Existing distance in meters	Proposed distance in meters	Total reduction in meters
1	Progress	Band Saw	150	75	75
2	Band Saw	Basic Centering	3.05	3.05	Nil
3	Centering	CNC Turner	24.4	3.05	21.35
4	CNC Turner	Number Punching	36.6	3.05	33.55
5	Number Punching	Gun Drill	3.05	3.05	Nil
6	Gun Drill	Radial Drill	3.05	3.05	Nil
7	Radial Drill	CNC Cam Milling	74.08	3.5	70.58
8	CNC Cam Milling	Benching	3.05	3.05	Nil
9	Benching	H.T.S	105.8	3.05	102.75
10	H.T.S	Cylindrical Grinding (Rough)	25.3	9.15	16.15
11	Cylindrical Grinding	Lathe	3.05	3.05	Nil

12	Lathe	Radial Drill	19.82	3.05	16.77
13	Radial Drill	CAM Grinding	40.55	6.1	34.45
14	CAM Grinding	Cylindrical Grinding (Finish)	9.15	3.05	6.1
15	Cylinder Grinding	Inspection	21.35	3.05	18.3
16	Inspection	Progress	15.15	4	11.15
17	Total reducing in meters of material movement		537.45	131.3	406.15

Thus, it is observed that in the existing layout material movement is very high and will be reduced by at least 75% by changing to the new layout. In the new layout, the material movement distance has been reduced to 131.5 meters compared to 537.45 meters in the existing layout.

#### 4.3.4

##### **Delay Due to Waiting**

The study has been carried out in the LMS of DMW, Patiala. The office and store workplaces have not been studied since productivity is more directly measured in production shop floor and profitability of the whole organization depends primarily on the productivity of operations carried out on the shop floor.

The direct observation of the work was started in the LMS. The job was broken down into tasks, and further into observable elemental operations. These elemental operations were subsequently evaluated.

A breakdown of tasks needing immediate changes or an in-depth study was thus carried out.

Waiting time in the LMS can be classified into two categories:

- (i) Avoidable Delays
- (ii) Unavoidable Delays

Avoidable delays are due to excessive breakdowns, willful absenteeism, large setup/cycle times, and operators missing from workstations. Unavoidable delays are allowances given due to fatigue or rest on prescribed by the International Labour Organization. The emphasis in this work has been to reduce the avoidable delays .for this purpose a complete analysis of the existing data on

Figure 4.1 Existing Layout

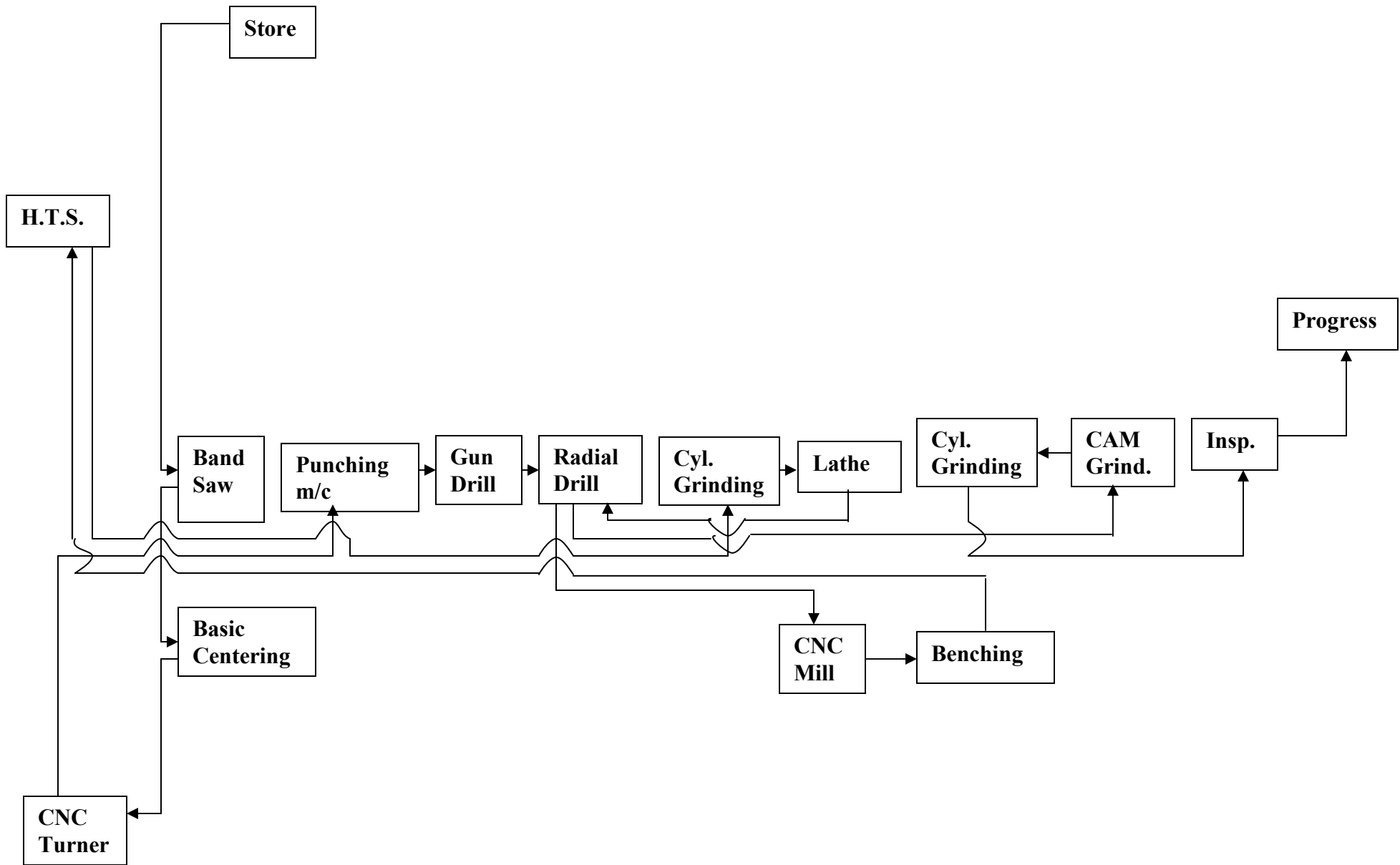
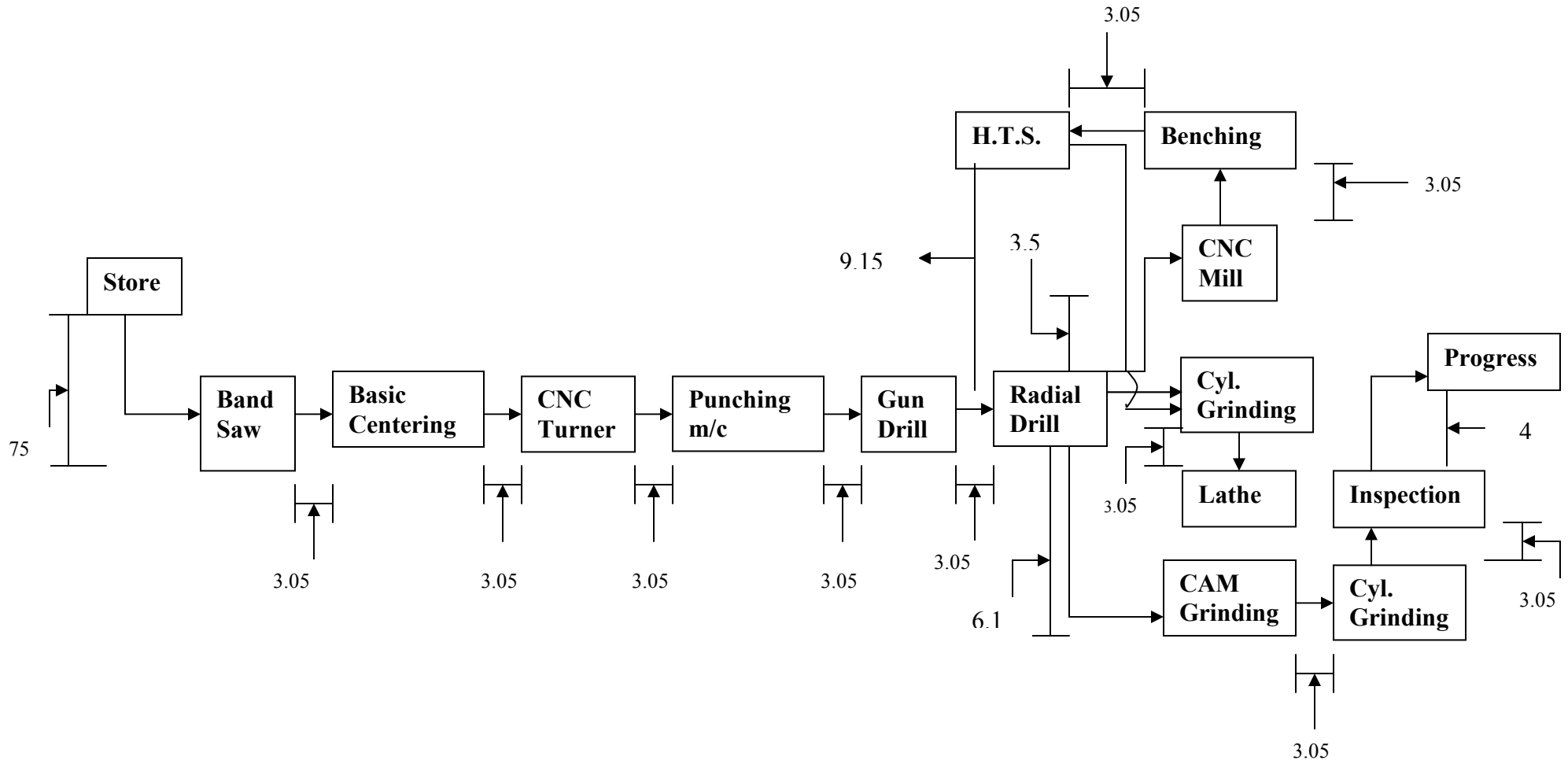


Figure 4.2 Proposed Layout (distances in meters)



Absenteeism, breakdown, setup times and cycle times was carried out for a period of three months. The data is presented in table 4.7. Once the existing situation was known, efforts were made to reduce these times to eliminate wasteful activities.

**Table 4.7**  
**Avoidable delays (January-March 2006)**

Sr.no	Machine number	Name	Avoidable delays				
			Cycle time (C <sub>t</sub> ) (Min)	Setup time (mm)	Breakdown %	Absenteeism%	Operator missing from work station (Number of min in 8 hr)
1	176	Band saw	26	40	4%	18%	20
2	--	Centering	43	66	7%	22%	42
3	1027	Punching press	0.08	22	1%	16%	21
4	--	CNC turning	123.3	15	6%	18%	16
5	189	Gun drill	36.16	20	5%	24%	27
6	75	Radial drill	79.9	22	10%	26%	21
7	1115	CNC cam milling	46.8	15	2%	21%	18
8	271	Cylindrical grinder	94.46	18	20%	19%	15
9	471	NH-26 lathe	133.92	28	5%	17%	25
10	451	NH-22 lathe	133.92	28	4%	12%	17
11	178	Cylindrical grinder	94.46	18	2%	18%	22
12	126	Cam grinder	105	15	2%	22%	24
13	1116	CNC cam grinder	119	15	3%	23%	30
Average					5.46	19.69	23

#### 4.3.4.1 Analysis and Development of Appropriate Controls for Problem Tasks

Efforts to develop appropriate controls included suggestions by employees performing the job in question and the researcher who performed the analysis. Engineering controls were generally preferred because they eliminate or reduce employee's exposure to potentially hazardous

conditions. These controls included changing the workstation layout or tool design, or changing the way the materials, parts, and products are transported to reduce setup & cycle time. However, wherever it was difficult to fix the problem using Engineering controls, Administrative controls or Work Place Modifications were also suggested.

Administrative controls include work practices, policies and providing instructions in work practices that can ease the task demands or burden.

Concurrent improvements to work practices ensure that employees understand the benefit of the changes and promote proper use of the equipment. Work practices modifications may include proper use of work procedures and training operators to allow them to understand the proper techniques to use while performing tasks. After training employees in any work practice, it is important to develop a method positively reinforce the practice. When operators learn a new work practice, it takes some time to develop the new habit. Therefore, management and supervisors must actively work with operators to ensure the compliance of work procedures and practices.

Table 4.8 shows the data for avoidable delays after implementation of some of the controls in April 2006. The data pertain to period April 15 to May 14, 2006.

The data has been analyzed and following improvements in reduction of delays due to unnecessary waiting time are seen:

**Table 4.8  
Reduction in delays**

S.no	operation	Cycle time ( min)			Setup time ( min)			Breakdown ( %)		Absenteeism ( %)		Operator missing from work station (Number of min in 8 hr)		
		Before	After	%age reduction	Before	After	%age reduction	Before	After	Before	After	Before	After	%age reduction
1	Centering	43.0	40	7%	66	40	39%	7%	5%	22%	15%	42	20	52.38%
2	Radial drill	79	52	37%	22	20	9%	10%	7%	26%	21%	21	17	19.04%
3	NH-lathe	133.92	100	25%	28	22	21.42%	4%	2%	17%	13%	25	15	40%

1. The cycle time will reduce by about 23% at each station.
2. The setup time will reduce by about 24% at each station.
3. The break down will reduce by about 3% at each station.
4. The absenteeism will reduce by about 5% at each station.

5. The operator missing from work station will reduce by about 24% at each station.

**4.3.5 Overproduction**

Overproduction is not that common in the factory, since all camshafts are made to customer order. A bigger problem is that some of the camshafts are not delivered to the customer in time. The delays are often caused by part shortages that have occurred because of supplier and delivery problem. Camshafts are sometimes produced when shortages exist and cannot be delivered until rework and missing parts arrive. This means those camshafts that are ready, except from the rework must be stored in yard. In some way this is overproduction, because the camshaft are produced before they actually can be delivered.

**4.3.6 Inappropriate Processing**

In DCW, there is high amount of the inappropriate processing. Incorrectly designed processes are a source of waste. The processes in the organization must continuously be reviewed and improved. Activities in processes can either add value to the customer, be necessary for the function of the process or non-value adding. The rework after the rejection is also the excessive processing.

**a) Rework**

Only part number 10210982 that is on heat treatment can be reworked. All other parts shown in the above table are ultimately scrapped

**Table: 4.9  
Rework in January**

S.NO	DEFECTS	PART NO.	Rework %age
1.	Dowel hole	10211007	25%
2.	Milling	10216595	1.8%
3.	Turning	10216534	1.7%
4.	Heat treatment	10210982	16%
5.	Grinding	10210982	16%
6.	Total		12.1%

**b) Wastage due to excessive material removal at machining operation:**

The organization uses raw material rods of alloy steel for cam shafts which have finished diameter of 110 mm. If the industry takes rods of 115 mm, it controls circularity and ovality of roots, and then the material removal at machining can be reduced.

**Table: 4.10**  
**Differences in weights of raw material rod and finished cam shaft**

S.no	Part no.	Quantity	Weight of the 120 rod in kgs	Length of finished cam shaft.	Weight of the finished cam shaft in kgs	Weight of 115 diameter rod.	Difference in weight of 120mm rod and finished rod. (kgs)	Difference in weight of 120 mm rod and 115 rod (kg)
1	10210982	4	106.5	36.68	65	73.00	41.5	33.5
2	10211007	2	106.5	44.20	71	90.05	35.5	16.5
3	10216534	56	106.5	44.20	51.500	90.05	55	16.5
4	10216546	55	106.5	38.00	57	77.42	49.5	29.08
5	10216558	5	106.5	36.20	52	75.10	54.5	31.4
6	10216560	47	106.5	33.90	58	69.06	48.5	37.44
7	10216571	51	106.5	33.80	52	68.80	54.5	37.7
8	10216583	36	106.5	46.10	70	93.92	36.5	12.58
	10216595	49	106.5	36.20	53	75.10	53.5	31.4
1	10216601	45	106.5	36.64	64.5	73.30	42	33.2
	Total	350	1065		594		471	279.3

If the raw material diameter is reduced from 120 mm to 115mm the saving in the raw material requirement is 59%.

#### **4.4 ROOT CAUSE ANALYSIS OF WASTES**

A Cause and Effect Diagram was developed to examine the factors that are contributing to the problem. The Cause -and-Effect Diagram was developed through four steps, namely:

1. Identify the problem's characteristics.
2. Brain storm the reasons why the problem is occurring using a causal table ( also known as the Why –because technique)
3. Group the causes by relationship
4. Create a Cause- and-Effect Diagram

The causes are grouped under the following headings: (1) Men, (2) Machine, (3) Material, (4) Method. The diagram makes it easy to see the many possible root causes of the issues that may be leading to defects.

## **1. Defects**

### **a) Scrap**

1. Improper machining and equipment due to:

- Poor upkeep and maintenance.
- Non-suitability of machines.
- Non-adherence of process parameters.

2. Poor quality of inputs like materials, tools etc due to:

- Poor selection.
- Inefficient incoming inspection.
- Non-availability of desired inputs.
- Using worn out tools etc.

3. Human error due to:

- Lack of planning.
- Too many bottlenecks.
- Faulty information and control system.
- Insufficient instructions or descriptions on the drawing.

4. Human error by workers due to:

- Deliberately not being careful in working and maintaining the laid down parameters.
- Not being suitable for the job.
- Not properly trained for the job.
- Chance variations.

5. Wrong setting and determination of parameters of temperature, pressure etc. and

inefficient control system to maintain them due to:

- Parameters set by initiation and approximations due to lack of initiative and/or R&D facilities.
- Controls are not automatic; lot of dependence on human beings as foolproof controls needs investment.
- Effects of variables like ambient conditions quality of inputs etc, not considered
- Controls even though automatic are not properly calibrated.

6. Scraping of product, this deviates from drawing specifications but can be used due to:

- Insufficient instructions on the drawing regarding acceptance of the product under special cases.
- Rigid attitude of inspection personnel.
- Lack of information contained in the drawing about allowances kept and final dimensions.

7. Use of processes, which are not suitable for the intended product due to:

- Lack of knowledge.
- Excess capacity available.

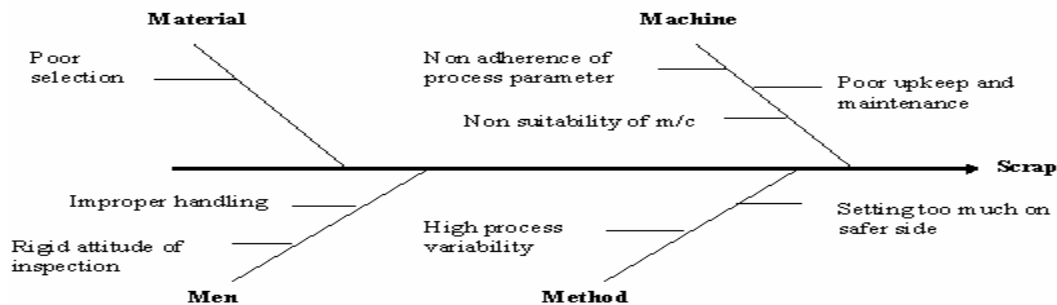
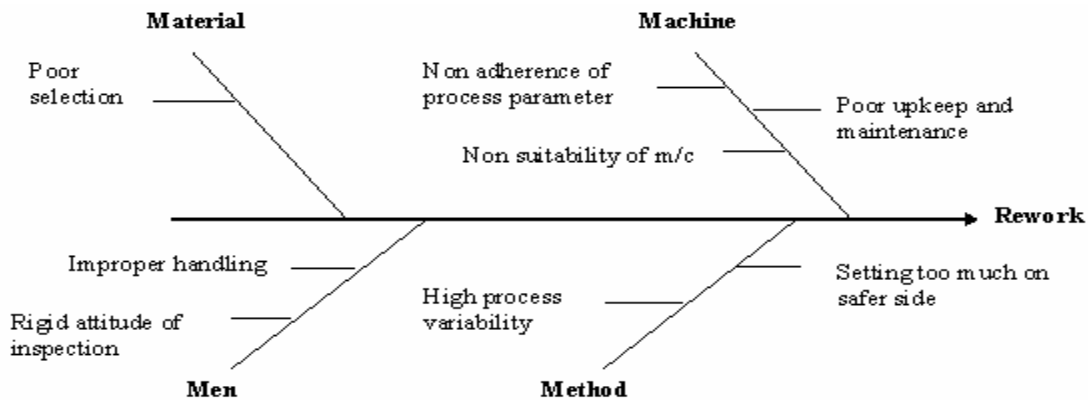


Figure 4.3 Cause and Effect Diagram of Scrap

## b) Rework

1. Burrs/extra material at places due to faulty setting, tool grindings etc.
2. Over sizes due to higher process variability and setting too much on the safer sides.

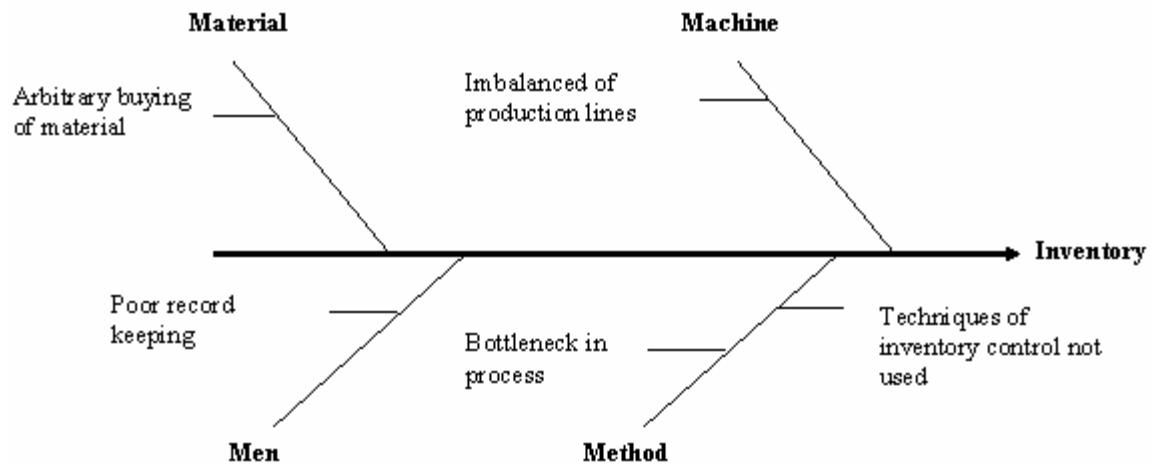
3. Scratches and other visual defects due to improper, handling and rigid attitude of inspection personnel.
4. Facilities for doing rework are generally not available through some rework is inevitable.
5. Decisions on “rework” material or disputed material is not taken immediately it gets deteriorated or damaged in storage.



**Figure 4.4 Cause and Effect Diagram of Rework**

## **2. Excess Inventory**

1. Arbitrary buying of material.
2. Buying gross requirement as per the matter production schedule, net requirement not calculated.
3. For regular items techniques of inventory control not used.
4. Poor record keeping and retrieval.
5. In balanced production lines.
6. Inventory levels between work centers not worked out.
7. Bottlenecks in the processes.

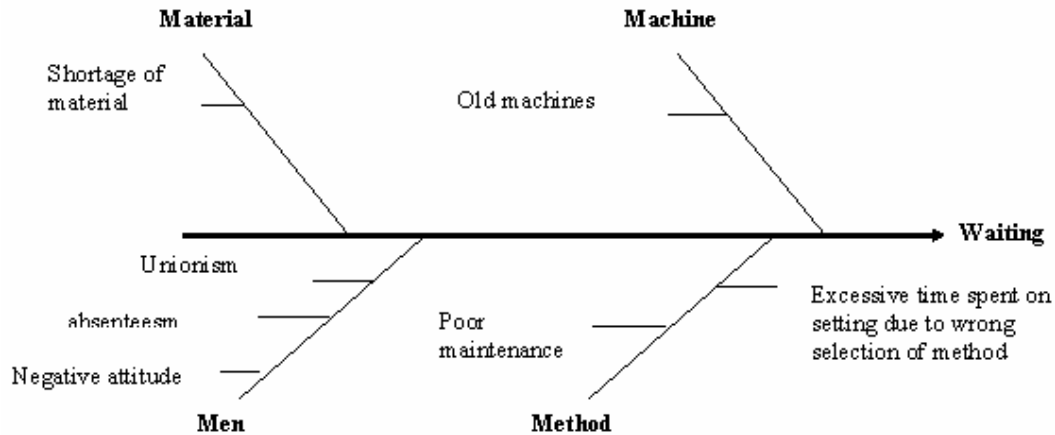


**Figure 4.5 Cause and Effect Diagram of Inventory**

### **3. Delay Due to Waiting**

1. Workers present but not working deliberately because of negative attitude, unionism, lack of motivation, low morale, no concern and lack of a accountability.
2. Un-avoidable delays due to:
  - Absence of proper drawing or instructions etc.
  - Time consuming inspection checks.
3. Shortages of materials due to:
  - Poor material planning.
  - Ineffective scheduling.
4. Break downs of machines and equipment due to:
  - Old machine.
  - Poor maintenance strategy adopted.
4. Excessive time spent on setting because proper jigs and fixture are not used.
5. Absenteeism
  - Without authorization.

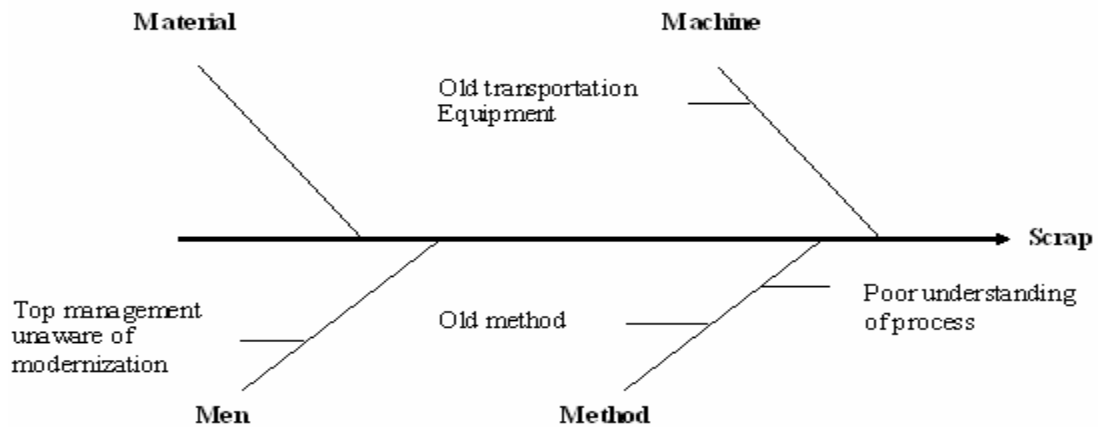
- Alienation from the place of work due to monotonous job and flaws in the working atmosphere.



**Figure 4.6 Cause and Effect Diagram of Delay Due to Waiting**

#### **4. Excessive Material Movement**

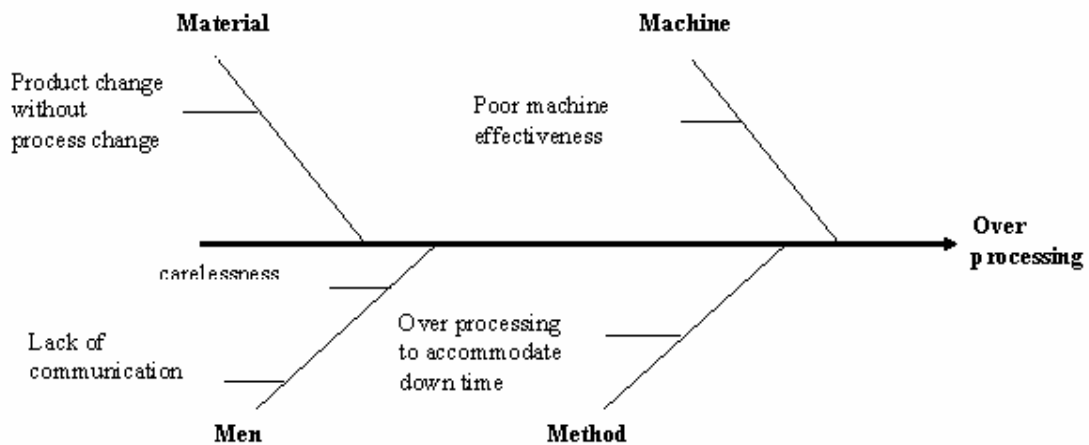
- 1.Improper layout.
- 2.Storage is away from the production shop.
- 3.Old method or manual transportation system.
- 4.Expansion of shops not properly planned resulting in excessive movement.
- 5.Unaware of extent of loss.
- 6.Inability of top management to plan modernization.
- 7.Poor understanding of process flow for production.
- 8.Large batch size, long lead-time and large storage area.



**Figure 4.7 Cause and Effect Diagram of Excessive Material Movement**

### 5. Over-processing

1. Product changes without process changes.
2. Poor machine effectiveness.
3. Customer requirement undefined.
4. Over processing to accommodate downtime.
5. Lack of communication.
6. Carelessness.



**Figure 4.8 Cause and Effect Diagram of Over Processing**

#### 4.5 GAP ANALYSIS

Following work has been carried out to identify gaps:

- c) Comparison of existing status in the shop with the requirement of lean manufacturing.
- d) Using expert opinion and clarify the gap as 'HIGH', 'MEDIUM' or 'LOW'

Where

HIGH - Very large gap, need immediate action.

MEDIUM - Large gaps, urgent action required.

LOW - Insufficient gap does not require immediate action.

Table 4.10 shows the gap between the existing status and requirements of lean manufacturing as per above classification.

**Table: 4.11**

#### **Gap analysis**

AREA	STATUS	LEAN MANUFACTURING REQUIREMENT	GAPS
Defects	MEDIUM	zero	MEDIUM
Inventory	HIGH	zero	HIGH
Excessive material movement waste	MEDIUM	zero	MEDIUM
Delays due to Waiting	HIGH	zero	HIGH
Overproduction	LOW	zero	LOW
Inappropriate processing	HIGH	zero	HIGH

#### 4.6 DEVELOPMENT OF GENERALIZED APPROACH

For developing a generalized approach, the cost associated with a provision has been taken as the most important input. In the development of approach experts play important role. Experts are employees of the organizations, in all, a total of ten experts consisting of two managers, three supervisors; three operators, one inspector and one mechanic were selected. The experts were

briefed about the findings of the root cause of wastes and the purpose of getting their feedback. All the experts who were selected had requisite amount of experience, education level and a realistic bent of mind. However, in the brain storming session the experts were requested, to first of all, identify factor and parameter, other than cost which must be considered for developing an implementation approach.

### **Factors and Parameters influencing Development of a Generalized Approach**

The experts after discussion and brain storming conversed on the following factors influencing development of a generalized approach.

#### **1. Cost associated with the removal of cause.**

- High (H)
- Medium (M)
- Low (L)

#### **2. Ease of removal**

- Easy (E)
- Not easy (N)
- Difficult (D)

#### **3. Effect on other areas (can be positive or negative)**

- High (H)
- Medium (M)
- Low (L)

After identifying these parameters a blank proforma was prepared (Appendix 1). In this proforma, all the generalized categories of provisions/ controls described in the previous section were listed in the first column. Expert provides the responses to each factor and parameter with regards to each general provision. These proformas were circulated to experts who filled up the information in the requisite columns in qualitative terms for e.g. High (H), Medium (M) or Low

(L). These qualitative scores were then converted into quantitative score using the scoring scale and the number of responses to a choice. The scoring scale is shown in table 4.11

**Table 4.12**

**Scoring scale for state of parameter.**

Sr. No.	Parameter	Constraint	Score
1.	Cost associated with the implementation of a provision.	<ul style="list-style-type: none"> <li>• High (H)</li> <li>• Medium (M)</li> <li>• Low (L)</li> </ul>	<p>1</p> <p>2</p> <p>3</p>
2.	Ease of removal	<ul style="list-style-type: none"> <li>• Easy (E)</li> <li>• Not Easy (N)</li> <li>• Difficult (D)</li> </ul>	<p>3</p> <p>2</p> <p>1</p>
3.	Effect on other areas	<ul style="list-style-type: none"> <li>• + High (H)</li> <li>• + Medium (M)</li> <li>• + Low (L)</li> <li>• - High (H)</li> <li>• -Medium (M)</li> <li>• -Low (L)</li> </ul>	<p>3</p> <p>2</p> <p>1</p> <p>-1</p> <p>-2</p> <p>-3</p>

Table 4.12 depicts the summary of the responses received from experts. In this table number of experts responding to a particular choice in a factor or parameter has been compiled from the individual responses of the experts. Number of responses to a particular choice has then been multiplied by the score of that choice in every factor as listed in Table 4.12. Those weighted

scores have been summed up against each generalized control or provision and have been listed in the last column of Table 4.14. The highest score of a provision in the column, depicts that considering all the above eight factors and parameters, this generalized provision should be taken up for implementation.

**Table 4.13**  
**Responses of Experts**

Wastes	Root cause of waste	Cost			Ease of removal			Effect of others						Cumulative score.
		H	M	L	E	N	D	H	M	L	H	M	L	
		1	2	3	3	2	1	+3	+2	+1	-1	-2	-3	
Defect	Improper machining and equipment	8	2	0	0	2	8	0	0	1	9	0	0	16
	Poor quality of inputs like materials, tools etc	0	8	2	7	3	0	0	0	1	1	1	7	26
	Human error on passing on instructions	1	1	8	8	2	0	0	1	2	7	0	0	52
	Human error by workers	1	8	1	2	7	1	0	1	2	5	1	0	38
	Wrong setting and determination of parameters of temp, pressure etc. and inefficient control system to maintain them	0	2	8	7	3	0	0	0	0	3	7	0	38
	Scraping of product, this deviates from drawing specifications but can be used.	0	3	7	8	2	0	0	2	7	1	0	0	65

Inventory	Arbitrary buying of material.	0	2	8	7	3	0	0	0	0	3	7	0	38
	Buying gross requirement as per the matter production schedule, net requirement not calculated.	0	3	7	8	2	0	0	0	1	7	2	0	34
	For regular items techniques of inventory control not used.	1	8	1	8	2	0	0	0	1	6	3	0	37
	Poor record keeping and retrieval.	0	3	7	9	1	0	0	0	2	5	3	0	47
	In balancing of production lines.	7	2	1	0	7	3	0	0	0	3	7	0	14
	Inventory levels between work centers not worked out.	8	2	0	0	2	8	0	8	0	0	2	0	36
	Bottlenecks in the processes.	7	3	0	1	2	7	0	0	0	1	1	8	16
	Deliberate attempt by production people to keep higher inventories.	0	7	3	1	2	7	0	0	0	4	5	1	18
Excessive material movement	Improper layout.	8	2	0	0	2	8	0	0	1	3	6	0	10
	Storage is away from the production shop.	2	7	1	2	7	1	0	1	7	2	0	0	47
	Old method or manual transportation system.	0	4	6	1	6	3	0	0	1	7	2	0	52
	Expansion of shops not properly planned resulting in too much excessive movement.	8	2	0	0	2	8	0	1	4	5	0	0	25

	Unaware of extent of loss.	2	7	1	0	8	2	0	4	2	4	0	0	43	
	Inability of top management to plan modernization.	8	2	0	8	2	0	0	0	0	3	7	0	36	
	Poor understanding of process flow for production.	0	3	7	1	7	2	0	0	2	7	1	0	39	
	Large batch size, long lead-time and large storage area	2	7	1	1	8	2	0	0	1	2	7	0	25	
Delay due Waiting	Workers present but not working deliberately because of negative attitude, union effects, lack of motivation, low morale, no concern and lack of a accountability.	7	3	0	0	2	8	0	0	0	1	1	8	2	
	Un-avoidable delays	4	5	1	0	4	5	0	2	1	7	0	0	32	
	Shortages of materials	0	4	6	4	6	0	0	0	1	3	7	0	22	
	Break downs of machines and equipment	8	2	0	2	8	0	0	0	1	2	7	0	19	
	Excessive time spent on setting because proper jigs and fixture are not used.	0	4	6	3	6	1	0	0	6	4	0	0	50	
	Absenteeism	7	3	0	4	6	0	0	0	0	4	6	0	21	
Inappropriate processing	Product changes without process changes.	0	6	4	2	7	1	0	0	4	5	1	0	42	
	Poor machine effectiveness.	1	7	2	3	7	0	0	0	3	6	1	0	39	

Trace customer requirement undefined.	0	4	6	4	6	0	0	0	2	7	1	0	43
Over processing to accommodate downtime.	3	7	0	3	7	0	0	0	1	8	1	0	31
Lack of communications.	1	6	3	4	6	0	0	0	3	7	0	0	42
Careless workers.	0	7	3	0	7	3	0	0	2	6	2	0	32
Extra copier/excessive information.	0	3	7	6	4	0	0	3	6	1	0	0	64

#### 4.7 SUGGESTED IMPLEMENTATION PLAN

It was then decided to formulate a phase wise implementation approach by picking up the provisions which had higher weighted scores in the above seven major areas. For deciding the number of provisions taken up for implementation in a phase, out of the total provisions under a major area, the proximity or differences of scores around the cutoff were considered i.e. there should be a considerable difference between the score of the last provision in a Phase 1 and the first provision of Phase 2 and so on. Based on all these considerations, the implementation of the provisions has been divided into three phases as an order of priority for implementation in any diesel locomotive industry. The three phases of the suggested approach are presented in Table 4.13.

**Table 4.13:  
Suggested Implementation Plan**

	<b>Defects</b>	<b>Inventory</b>	<b>Delays due to Waiting</b>	<b>Excessive material movements</b>	<b>Inappropriate Processing</b>
Phase 1	<ul style="list-style-type: none"> <li>• Scrapping of Product, this deviates from drawing specification but can be used</li> <li>• Human error on passing on instructions</li> </ul>	<ul style="list-style-type: none"> <li>• Poor record keeping and retrieval</li> <li>• Arbitrary buying of material</li> </ul>	<ul style="list-style-type: none"> <li>• Excessive time spent on setting because proper jigs and fixtures are not used.</li> <li>• Unavoidable delay</li> </ul>	<ul style="list-style-type: none"> <li>• Old method or manual transportation system.</li> <li>• Storage away from the production shop.</li> <li>• Unaware of extent of loss</li> </ul>	<ul style="list-style-type: none"> <li>• Extra copier/ excessive information</li> </ul>
Phase 2	<ul style="list-style-type: none"> <li>• Wrong setting and determination of parameters of temperature, pressure etc. and inefficient control system to maintain them</li> <li>• Human error by worker</li> </ul>	<ul style="list-style-type: none"> <li>• For regular items technique of inventory control not used.</li> <li>• Inventory level between work centre not worked out.</li> <li>• Buying gross requirement as per the matter production schedule, net requirement not calculated</li> </ul>	<ul style="list-style-type: none"> <li>• Shortage of materials</li> <li>• Absenteeism</li> <li>• Breakdowns of machines and equipments.</li> </ul>	<ul style="list-style-type: none"> <li>• Poor understanding of process flow for production.</li> <li>• Inability of top management to plan modernization..</li> </ul>	<ul style="list-style-type: none"> <li>• Trace customer requirement undefined</li> <li>• Product changes without process change</li> <li>• Lack of communication</li> </ul>
Phase 3	<ul style="list-style-type: none"> <li>• Improper machining and equipment</li> <li>• Poor quality of inputs like materials, tools etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Deliberate attempt by production people to keep higher inventory</li> <li>• Bottlenecks in the processes</li> <li>• Imbalancing of production line</li> </ul>	<ul style="list-style-type: none"> <li>• Workers present but not working deliberately, because of negative attitude, union, lack of motivation, low morale, no concern and lack of accountability.</li> </ul>	<ul style="list-style-type: none"> <li>• Large batch, long lead time and large storage area.</li> <li>• Improper layout</li> <li>• Expansion of shops, resulting excessive movement.</li> </ul>	<ul style="list-style-type: none"> <li>• Poor machine effectiveness</li> <li>• Careless workers</li> <li>• Over processing to accommodate downtime</li> </ul>

The provision or controls suggested to be implemented in Phase 1 will in general be less costly, easy to implement and would have positive or complementary effect on many other areas in the organization.

Phase 2 includes measures which are slightly more difficult to implement, involves reasonably higher cost, which may require some kind of budgetary provisions and approvals.

Phase 3 includes provisions, which are more related with hardcore technical changes, machinery, equipment and tooling. Implementation of these provisions will involve substantial capital investment and may require a number of iterations and trials for implementation.

## **CHAPTER- 5**

### **CONCLUSIONS AND RESULTS**

#### **5.1 INTRODUCTION**

This chapter covers the summary of the research work, its results and conclusions. Results of analysis and inferences drawn have been utilized to design a phased approach for implementation of lean manufacturing in a manufacturing industry. Conclusions have been drawn and recommendations are made for the use of industry in future. The limitations along with scope for future work are also covered in this chapter.

#### **5.2 SUMMARY OF THE WORK**

The research work was undertaken for analyzing manufacturing industry with an aim to design strategies. For developing and implementing lean manufacturing in manufacturing industry first of all, different type of wastes were identified using appropriate techniques. Then all wastes were reduced one by one according to the priority given to the waste by the implementation plan as well as improvement in performance was done . The study has been carried out in phased manner. Root cause analysis was also done using the Cause and Effect Diagram for the different type of wastes.

#### **5.3 RESULTS OF THE STUDY**

The following results were drawn from the study;

- Average monthly rejection of part before the conduct of study was 3.6%.
- The raw material usage is only 26% of the available inventory each month.
- The company has a high WIP inventory which is 87% of what is actually required.
- The finished goods stock inventory is as per requirement.
- In the existing layout material movement is very high and will be reduced by at least 75% by changing to the new layout. In the new layout, the material movement distance has been reduced to 131.5 meters compared to 537.45 meters in the existing layout.
- The cycle time will reduce by about 23% at each station.
- The setup time will reduce by about 24% at each station.

- The break down will reduce by about 3% at each station.
- The absenteeism will reduce by about 5% at each station.
- The operator missing from work station will reduce by about 24% at each station.
- Over production is not very common in this industry as the parts are made against actual order.
- If the raw material diameter is reduced from 120 mm to 115 mm the saving in the raw material requirement is 59%.
- 80% of the rework products are rejected.

#### **5.4 CONCLUSION**

1. Wastes identified after implementation of lean manufacturing principles serve as a starting point for bringing in improvements in any manufacturing facility.
2. the waste can be classified into the following categories
  1. Defects
  2. Inventory
  3. Waste due unnecessary material movement
  4. Delay due to waiting
  5. Over production
  6. Inappropriate processing
3. For bringing an overall improvement in the work particles and also to implement lean manufacturing principles, elimination of causes of the wastes as indicated above is necessary.
4. For reducing the wastes, the provisions or control to be evolved would be engineering controls related to equipment etc. in 80% to 100% of the cases. Administrative controls and work simplification would be of a very limited use.
5. The waste associated with defects and inappropriate processing can be reduced with a small effort in a short time frame with low cost.
6. Problem related to inventory can be solved by engineering controls. Most of the control can be implemented in a short period of time and with a small effort and low cost.

7. The excessive material movement and delay due to waiting can be reduced by higher cost and small effort in reducing breakdown, absenteeism.
8. The implementation plan of the provisions after the detailed analysis has been divided into three phases starting from less expensive, less effort involving, more productive and simpler provisions. This will facilitate feedback and correction, and will provide immediate and encouraging results for reducing waste for continuing with the implementation process of the subsequent phases.
9. The provisions or controls suggested in phase 1 are, in general, less expensive, easy to implement, results in immediate gains in productivity or other related parameters.
10. The provisions undertaken for implementation in phase 2 are slightly more difficult to implement, involves higher initial capital investment.
11. Phase 3 includes provisions, which are more related with hard-core technical changes in machinery or tooling. Large capital investment will be necessary, although it must be pointed out here that maximum productivity gains will come after implementation of these provisions.
12. following control and provision are suggested to be undertaken for implementation in each of the three phases:-

**Phase 1:**

Area	Provision or control
Defects	<ul style="list-style-type: none"> <li>• Scraping of products this deviate from drawing specification, but can be used.</li> <li>• Human error on passing on instructions.</li> </ul>
Inventory	<ul style="list-style-type: none"> <li>• Arbitrary buying of material.</li> <li>• Poor record keeping and retrieval</li> </ul>
Delay due to waiting	<ul style="list-style-type: none"> <li>• Excessive time spend in setting because proper jigs and fixtures are not used</li> <li>• Unavoidable delays.</li> </ul>
Excessive material movements	<ul style="list-style-type: none"> <li>• Old method and manual transportation.</li> <li>• Storage away from the production shop.</li> <li>• Unaware of extent of loss</li> </ul>
Inappropriate processing	<ul style="list-style-type: none"> <li>• Extra copier/excessive information.</li> </ul>

### Phase 2:

Area	Provision or control
Defects	<ul style="list-style-type: none"> <li>• Wrong setting and determination of parameter of temperature, pressure etc. in an inefficient control system to maintain them.</li> <li>• Human error by worker.</li> </ul>
Inventory	<ul style="list-style-type: none"> <li>• Inventory level work center not workout</li> <li>• For regular items technique of inventory control not used. Buying gross requirement as per the matter production schedule, net requirement not calculated</li> </ul>
Delay due to waiting	<ul style="list-style-type: none"> <li>• Shortage of materials</li> <li>• Absenteeism</li> <li>• Breakdowns of machines and equipments.</li> </ul>
Excessive material movements	<ul style="list-style-type: none"> <li>• Inability of top management to plan modernization..</li> <li>• Poor understanding of process flow for production.</li> </ul>
Inappropriate processing	<ul style="list-style-type: none"> <li>• Trace customer requirement undefined</li> <li>• Product changes without process change</li> <li>• Lack of communication</li> </ul>

### Phase 3:

Area	Provision or control
Defects	<ul style="list-style-type: none"> <li>• Improper machining and equipment</li> <li>• Poor quality of inputs like materials, tools etc.</li> <li>•</li> </ul>
Inventory	<ul style="list-style-type: none"> <li>• Deliberate attempt by production people to keep higher inventory</li> <li>• Bottlenecks in the processes</li> <li>• Imbalancing of production line</li> </ul>
Delay due to waiting	<ul style="list-style-type: none"> <li>• Workers present but not working deliberately, because of negative attitude, union, lack of motivation, low morale, no concern and lack of accountability.</li> </ul>
Excessive material movements	<ul style="list-style-type: none"> <li>• Large batch, long lead time and large storage area.</li> <li>• Improper layout</li> <li>• Expansion of shops, resulting excessive movement</li> </ul>
Inappropriate processing	<ul style="list-style-type: none"> <li>• Poor machine effectiveness</li> <li>• Careless workers</li> <li>• Over processing to accommodate downtime</li> </ul>

## **5.5 LIMITATION OF STUDY**

The main limitations of the study are as follows:

- The studies have been limited to large scale manufacturing industry in north India only.
- The studies have been carried out using observational and record techniques only.
- The study has been conducted, involving all major areas of lean manufacturing compliance. Separate studies taking one area at a time may be necessary for more detailed analysis of the deficiencies
- As such no mathematical model or equation has been derived to calculate the effect of lean manufacturing compliance.

## **5.6 SCOPE FOR FUTURE WORK**

Following are some of the areas where detailed research can be taken up.

- The present study has been concentrated on waste identification in large manufacturing unit in north India making camshaft for diesel loco motives. The work can be extended to carry out generalized studies covering all other categories of industries such as process industry, engineering industry, and service industry.
- The present study has suggested provisions and generalized approach for organizations operating in Indian working conditions and the work is fully in Indian context. The approach may be generalized for use in all types of work conditions.
- Present work is concentrated only on the waste identification and reduction. Further research work must be carried out on other compliance of lean manufacturing.

## **5.7 CONCLUDING REMARKS**

It is generally agreed that for a lean manufacturing programme to be effective, it should include a set of tools and techniques or provisions to ensure management commitment, employee involvement, identification of wastes, development of controls for wastes and training and education for employees. These tools and techniques are said to be typical of any comprehensive lean manufacturing implementation programme. The implementation of lean manufacturing reduced the waste in the industry and enhances the profit and production.

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APPENDIX 1  
Responses of Experts

Wastes	Root cause of waste	Cost			Ease of removal			Effect of others						Cumulative score.	
		H	M	L	E	N	D	H	M	L	H	M	L		
		1	2	3	3	2	1	+3	+2	+1	-1	-2	-3		
Defect	Improper machining and equipment														
	Poor quality of inputs like materials, tools etc														
	Human error on passing on instructions														
	Human error by workers														
	Wrong setting and determination of parameters of temp, pressure etc. and inefficient control system to maintain them														
	Scraping of product, this deviates from drawing specifications but can be used.														
Inventory	Arbitrary buying of material.														
	Buying gross requirement as per the matter production schedule, net requirement not calculated.														
	For regular items techniques of inventory control not used.														
	Poor record keeping and retrieval.														
	In balancing of production lines.														
	Inventory levels between work centers not worked out.														

	Bottlenecks in the processes.												
	Deliberate attempt by production people to keep higher inventories.												
Excessive material movement	Improper layout.												
	Storage is away from the production shop.												
	Old method or manual transportation system.												
	Expansion of shops not properly planned resulting in too much excessive movement.												
	Unaware of extent of loss.												
	Inability of top management to plan modernization.												
	Poor understanding of process flow for production.												
	Large batch size, long lead-time and large storage area												
Delay due to Waiting	Workers present but not working deliberately because of negative attitude, union effects, lack of motivation, low morale, no concern and lack of a accountability.												
	Un-avoidable delays												
	Shortages of materials												
	Break downs of machines and equipment												
	Excessive time spent on setting because proper jigs and fixture are not used.												
	Absenteeism												
Inappropriate	Product changes without process changes.												

processing	Poor machine effectiveness.													
	Trace customer requirement undefined.													
	Over processing to accommodate downtime.													
	Lack of communications.													
	Careless workers.													
	Extra copier/excessive information.													