

ANALYSIS AND DESIGN OF WASTE MANAGEMENT SYSTEM FOR ENGINEERING INDUSTRY

**A THESIS SUBMITTED
IN FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF
DOCTOR OF PHILOSOPHY**

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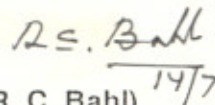
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Certified that the thesis entitled "ANALYSIS AND DESIGN OF WASTE MANAGEMENT SYSTEM FOR ENGINEERING INDUSTRY" which is being submitted by Mr. Tejinder Paul Singh, in fulfilment of the requirements for the award of the Degree of Doctor of Philosophy in Industrial Engineering, Thapar Institute of Engineering and Technology (Deemed University), Patiala, is a record of candidates' own work carried out by him under our supervision and guidance. The matter embodied in this thesis 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

Industry has been recognised to be the largest single consumer of finite natural resources. Rapid depletion of natural resources and consequential rise in their price has to be absorbed largely by the industry itself. High competition in the free market does not permit the transfer of resultant increase in the cost of production to consumers. Industry is, therefore, hard pressed to exploit all the engineering, technological and managerial skills to reduce manufacturing costs. Judicious selection of resources and their efficient utilisation should surely help a lot in achieving the defined objective through mitigation or atleast substantial reduction of wastages of all kinds. Waste is visualised as any unnecessary input to or any undesirable output from a system.

Waste can occur in variety of forms and at number of stages in an engineering industry. Besides the scrap produced and undesirable outcomes of the processes, there are other forms of waste such as using more expensive materials than required, consuming excessive energy, using old technology, keeping higher inventories, under-utilisation of machinery and manpower and so on. Concerted and sustained efforts alone using appropriate technology at every stage of production activity can check waste generation. In the given situation, waste management programme gains importance. For an effective management approach, it is prudent to deal with waste at a system level.

Despite the industry being alive to the prevailing dismal situation it is continuing with the old practices or have marginally improved. It is largely due to lack of awareness and familiarity on the part of the industry, with the tools and techniques of waste management and their application in the real life situations. Accordingly, industry is not in a position to precisely work out the amount of waste being generated and effectively mitigate it. To facilitate adoption of WM practices by an industry, it is desirable to make available in an easily useable form all the requisite information regarding tools and techniques, their applications and effects. This study has been undertaken with the objective of analysing all aspects of waste in the engineering industry and formulating a WM system for its use.

The study has been divided into two parts: Analysis and Design. The work has been carried out in four phases: Survey on waste management; case studies; mathematical modelling and formulation of the WM system.

A detailed survey on various aspects of waste management has been chosen as a means to analyse the industrial systems in general. For more detailed analysis, case

studies in each resource area of materials, energy, capital and manpower using mathematical modelling has been carried out.

The survey has been conducted through a specially designed questionnaire and status of various industries with regard to waste management as well as the state of various aspects of use of resources in various industries have been found out. Case studies have been conducted in an identified industry to find out areas and quantum of waste at various stages, their reasons and root causes and to generate alternate solutions.

The system has been divided into various identifiable sub-systems and input-output analysis of 'materials' conducted for each sub-system. The amount of waste generated at each stage has been identified along with the probable reasons causing waste. Methods to mitigate waste have been listed. In the 'case study' on 'energy' the difference of actual energy consumption and the ideal energy consumption of various sub-systems has been worked out to calculate waste. Reasons of waste caused and possible solutions for their mitigation are listed. Various areas analysed using appropriate techniques in 'capital' resource are : machine and plant utilisation; under-utilisation of machines with respect to sizes of the processed jobs; calculating waste due to difference between actual capacity and targeted capacity; inventory levels and state of automation. Case study on 'manpower' involves critical analysis to find out human error responsible for the wastage of resources of materials, energy and capital. Further, wastage of manpower itself due to overstaffing, overtimes, skill levels, and strikes, lockouts and disputes, etc. has been worked out.

Physical system theory model has been used for representing case situation in materials. For energy PST has been used in two phases. Due to multi-objectivity, involved, goal programming model has been used for capital. In manpower, a qualitative model using OFM (Options Field Methodology), AHP (Analytical Hierarchy Process) and FST (Fuzzy Set Theory) has been applied.

Broad outcomes of the survey, case studies and modelling have been listed, conclusions drawn and synthesised. Based on this information and the literature available, the WM system has been formulated. For deciding upon the format of the system, expert opinion of the industry has been sought and duly incorporated. The WM system is in the form of a manual and can be referred to for both general guidelines as well as specific problems at various stages of the plant life.

The system enlists various areas of waste in each resource, provides checklist

of reasons of waste and recommends a number of alternate solutions for waste management.

The study, by exposing areas of waste in each resource, their reasons and mitigation has served twin purposes of generating large data base on waste management practices and design of generalised guidelines, in the form of a WM system. Areas needing more detailed studies at micro level have been exposed. There is an ample scope to further explore these areas as well as extension of this study to process industry and also to other sectors like municipal, domestic and agricultural.

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NOMENCLATURE

AU_s	Weighted Average Percentage Under-Utilisation
CF_j	Cost of jth Fuel or Electricity Used
CS	Closing Stock
C_c	Inventory Carrying Cost
C_{ij}	Co-efficient Associated with Variables j in Goal Programming
Ed	Desired Energy Consumption
Ed_u	Desired Energy Consumption on Unit Product
Em	Average Energy Consumed on Productive Operations in a Month
H	No. of Heats (Charges)
H_L	Latent Heat
H_f	Number of First Heats
I	Input to the System
KB_j^i	Technological Coefficient of Input for Basic Process
KB_j^r	Technological Coefficient of Rework for Basic Process at Jth stage
KB_j^w	Technological Coefficient of Waste for Basic Process at jth Stage
KW	Technological Co-efficient of Waste in Simplified PST Model
Kd_1	Technological Co-efficient of Input at First Stage in Simplified Model
M	Mass
N	Number of Observations in Work Sampling Study
NI	Net Input to the System
Nb	Number of Blanks
Nb_{act}	Actual Number of Blanks
Nb_{max}	Maximum Possible Number of Blanks
N_p	Number of Products
O	Output from the System
OS	Opening Stock

P	Percentage Occurrence of Activity or Delay
Pe_i	Percentage of a Constituent Element i in the Powder
Pe_{mp}	Percentage of an Element in Mixed Powder
P_i	The Production Quantity of Product i
QB_{g_i}	Quantity of Good Blanks of Category i of the Product
QFC_j	Quantity of j th Fuel Converted to Energy Units MJ
QF_j	Quantity of j th Fuel or Electricity Used
Qe_s	Quantity Already Present in the Element Form
Q_j	Quantity of j th Job
Q_{mp}	Quantity of Mixed Powder
Q_p	Total Quantity of Powder Made
Q_{p_i}	Quantity of a Powder Type i
Q_{p_n}	Quantity of Powder Made in One Heat
RF_j	Rework Factor at j th Stage
S	Desired Accuracy Level
SH_c	Specific Heat of Copper
TM_c	Melting Temperature of Copper
TQ_e	Total Quantity of an Element CuPb or Sn.
T_a	Atmospheric Temperature
T_c	Total Inventory Cost
Us_j	Under-Utilisation in Category j of the Product
W	Waste in a System
WT	Wattage of the Equipment
W_t	Weight
W_{t_b}	Weight of a Blank
$W_{t_{bs}}$	Average Weight of a Blank after Sanding
W_{t_j}	Weight of j th Job
W_{t_m}	Weight of the Heaviest job
W_{t_p}	Powder Weight

Wt_{pi}	Average Weight of Category i of the Product
Wtr_{bmi}	Weight Removal at Blanking and Machining Operations
Wt_s	Weight of Strip
Wt_{st}	Weight of Steel Strip
X	Across Variable in PST Model i.e. Cost Variable
X_{01}	Cost at the First Stage in Simplified PST Model
X_d	Final Cost of the Product in PST Model
X_{d_i}	Cost of Input Material in Simplified PST Model
X_i	Decisions Variables for Quantity of Products in Goal Programming
Y	Through Variable in PST Model i.e. Flow Variable
YW_i	Waste at Stage i in Simplified PST Model
Y_d	Final Output from the Process in PST Model
Y_{d_i}	Quantity of Material at Stage i in Simplified PST Model
Y_i	Decision Variables for Number of Rounds in Goal Programming
b	Average Inventory at a Machine
fB_m	Unit Processing Cost at the Basic Process
fR_m	Unit Processing Cost at the Rework Stage
n	Number of Jobs
t	Time
t_{ij}	The Processing Time of Product i on Machine j
η	Negative Deviations from a Goal
ρ	Positive Deviations from a Goal

CHAPTER I

INTRODUCTION

For long our industry enjoyed monopoly and dictated prices of the products manufactured. Inefficient practices and techniques, loose control over operations, large amounts of overheads and extravagant use of resources were hardly cared. Easy availability of materials, energy, machinery and equipment, manpower, and practically no competition was mainly responsible for this attitude of the industry. Lately, scarcity of resources, increased competition, rapid technological advances and product innovations are posing a challenge to the very survival of the industry.

Rapid depletion of natural resources and resultant rise in their price are alarming issues for the manufacturing industry. To combat the situation efforts must be directed towards developing alternates to existing natural resource and ensuring most efficient use of the available ones. Industry is recognised to be the largest single consumer of resources and is accordingly most important in the context of utilisation and conservation of finite resources.

High competition in the free market does not permit the transfer of ills and inefficiency of the industry to the users. Industry is therefore hard pressed to exploit all possible means to mitigate or reduce wastages of all kinds resulting in reduced manufacturing costs. Judicious selection of resources and their efficient utilisation is thus a key to the problem.

1.1 PRESENT SCENARIO AND FUTURE OPTIONS

To avoid waste of any kind in today's complex manufacturing environment, a management with strong conviction and understanding is a must. Complexity of the production systems is owing to:

- Shorter production runs. This makes production planning and scheduling a specialised task and quite vulnerable to waste with the slightest error.
- Complex machinery and equipment requiring highly skilled operators and maintenance personnel.
- Products demanding closer tolerances and surface finish.
- Variety of materials used in a single production unit and consequent larger inventory.

- Rapid technological changes and product innovations.
- Poor work culture.

Manufacturing is thus rendered a specialised task demanding sound planning and control. Liberalisation policy aimed at reviving the economy has posed a serious challenge to the industry to bring in radical attitudinal changes together with upgradation of technology and management with a view to compete in the international market, for its survival.

To put up with this challenge, industry must be acquainted with the latest available tools, skills and methodologies that are crucial for efficient and cost effective production activity. A simple system needs to be devised which can be easily comprehended and appreciated by our engineering industry and which can suggest guidelines on efficient and effective utilisation of resources for manufacturing activity avoiding waste in all forms.

1.2 CONCEPT OF WASTE

Waste is defined as 'any unnecessary input to or any undesirable output from a system (Sushil, 1990a).' Any cost which does not enhance value is a waste (Robinson and Schroeder, 1992). The meaning of waste, particularly disposable waste, changes with change in conditions and the boundaries of the system. A waste of one industry may be an input to some other industry. Thus, something which is a waste at the level of one production unit may not be regarded so at the industry level. Ideally, if all outputs of one sector are taken as inputs by some other sectors there will not be any waste on the global level. This cannot be achieved in practice since some waste is inevitable in each sector and all types of waste cannot be recycled. In industry, particularly the engineering industry, there are a number of interrelated functions to be performed to transform raw materials to finished goods. There are so many stages of decision making : selection of materials and estimating their requirements and time periods for acquisition; selecting and acquiring equipment, processes, manpower and other inputs for production; and decisions regarding products and product mix. Thus there are high chances of erring at one place or the other resulting in to wastage of resources. Besides the scrap produced and other useless outcomes of the processes there are many wastes. Using costlier materials than required, producing more than required and keeping in stores, procuring materials much in advance, expenditure made on achieving higher levels of surface finish and closer tolerances than required, are all examples of waste. Any wastage of time due to poor planning and control results in the wastage of all the resources. Thus, waste in industry has a very wide meaning.

Further, use of various resources of materials, energy, manpower and capital is so

much interlinked that waste of one resource generally causes the wastages of other resources too. Material scrap while wasting the money spent on materials also wastes energy, man hours, machine hours and other inputs spent on its processing. Material waste can also occur in the form of excessive chips, damages, deterioration and obsolescence which has comparatively less effect on the wastage of other resources.

Energy is wasted in an industry in a variety of ways. Besides the energy spent on scrap, rework of products, and on producing excessive chips, the energy is also wasted in idle running of motors, heat wastages and use of unsuitable and inefficient equipment.

Under-utilisation of machinery, equipment, plant and buildings and higher levels of inventory form the major components of capital waste. Under-utilisation of machinery and equipment, in addition to wasting the invested capital, results in the wastage of manpower and energy too. Inventories waste money in the form of carrying cost, damages, deterioration and obsolescence of materials.

Manpower employed plays a major role towards resource utilisation or wastage, particularly in the industries where automation is in infancy. Any error at the planning or the execution stage results in wastage of materials, energy and capital. In addition, manpower wastage can occur in the form of over employment, overtime and useless expenditure done on manpower.

Various types of waste in industry and their interdependence dictate the need for evolving a system capable of suggesting ways and means to identify stages of waste occurrence and methods to avoid or reduce the same.

1.3 WASTE MANAGEMENT

Waste Management (WM) comprises of identification of waste generated/caused in a system, economic reduction, efficient collection and handling, optimal reuse and recycling and efficient disposal leaving no environmental problems (Sushil, 1990a). Of all the phases of waste management, the most important is waste reduction. Targetted efforts employing effective methods at the planning and execution stages of manufacturing activity in an industry bring down waste generation to a low level saving all subsequent efforts on collection, treatment, recycling and disposal. In case of capital, energy and manpower, the options of recycling are generally not available and waste reduction seems to be the only answer. For efficient and effective waste reduction, it is very important, in the first place, to identify waste. For this, the quantitative assessment of resources acceptable as inputs in various operations and processes and the actual amounts being consumed need to be

worked out. Similarly, in case of outputs, undesirable outputs which are a must, as a consequence of the process need be known with a view to mitigate waste. Thereafter, it is important to identify various factors responsible for waste at various stages besides knowing constraints of the processes and other parameters. These factors can then be suitably adjusted to effect waste reduction.

As some waste is inevitable with the working of a system, an efficient waste management system also provides for efficient and systematic collection of waste so that it can be subsequently made use of. Recycling of waste needs ingenuity on the part of the users, nevertheless a WM system must provide broad guidelines regarding the recycling of the material in the basic process or making an alternate use. Economic disposal of waste, in an environment friendly mode is an important function of waste management.

1.4 OBJECTIVES AND ISSUES

It is intended to formulate a WM system which can be easily used by the engineering industry to obtain detailed information on various stages of waste generation and order of their magnitudes, reasons of waste being caused, identification technique(s) to be used for determining wastes, possible solutions to mitigate waste with implications of each. For engineering industry the proposed system should be designed by taking into account the complexity of the concerned production systems, the interrelationships of various parameters, the effect of decision making in one area on the others, the financial implications of a particular decision, the general routine and responsibilities of the people in the industry and time availability with them to exercise and adopt various suggested guidelines. All these factors will decide on the information and its form that has to be provided.

It was decided that every detail contributing to the stated objective would be collected in two ways; firstly, a survey of engineering industry in a specified region and secondly, by conducting case studies in one of these industrial units. For survey, a suitable questionnaire needs to be designed and the mode of conducting survey decided. For case studies the main consideration is to select an industry which plays a willing host and encompasses almost all the operations, processes and other complexities of an engineering industry and represents engineering industry, in general.

1.5 SCOPE OF THE STUDY

The scope of the study has been limited to engineering industry. Further, industries with an invested capital above rupees one crore in the states of Punjab, Haryana, Himachal

Pradesh and union territories of Delhi and Chandigarh have been included for analysis. The generalised system has been designed to serve the needs of the industry in this region. Emphasis has been mainly on waste identification because industries, in general, are not aware of the quantum of waste being caused in their units. Quantitative information on the quantum of waste caused and improvements expected by adopting recommended techniques shall motivate industries, it is hoped, to step forward to know more about waste management techniques and its' benefits. General guidelines of various phases of WM i.e., collection, recycling, and disposal are also provided.

1.6 OVERALL METHODOLOGY OF THE STUDY

Figure 1.1 is a schematic representation of the study undertaken. Literature on the subject and its various aspects have been reviewed for deciding upon the contents of the questionnaire and those of the questions. Long standing industrial experience of the researcher particularly of the shop floor working, also served as a useful input for case studies and formulation of the WM system. The areas to be closely studied in case studies pertaining to waste in industry and its related aspects have been decided upon using the results of the survey, review of literature and industrial experience. In all, four case studies have been conducted, one each in the resources of materials, energy, capital and manpower. Wastage levels at various stages along with other relevant details of industrial working have been recorded. In each resource suitable mathematical models have been developed. The findings of the survey, results of the case studies and models have all been synthesised to draw inferences and a WM system has been designed.

1.7 ORGANISATION OF THE THESIS

The thesis has been organised in ten chapters:

Introduction to the subject of waste, need to avoid waste and techniques of waste management are covered in *Chapter I*. The need of a waste management system for engineering industry has been highlighted and objectives and issues connected with the design of such a system are briefly discussed. Further, the scope of study, brief methodology and scheme of the whole study is covered.

Extensive literature review of the subject involving waste, waste management and other closely related areas has been presented in *Chapter II*.

Chapter III deals with the details of the design of study. A brief methodology and explanation of the tools and techniques of analysis are covered in this chapter.

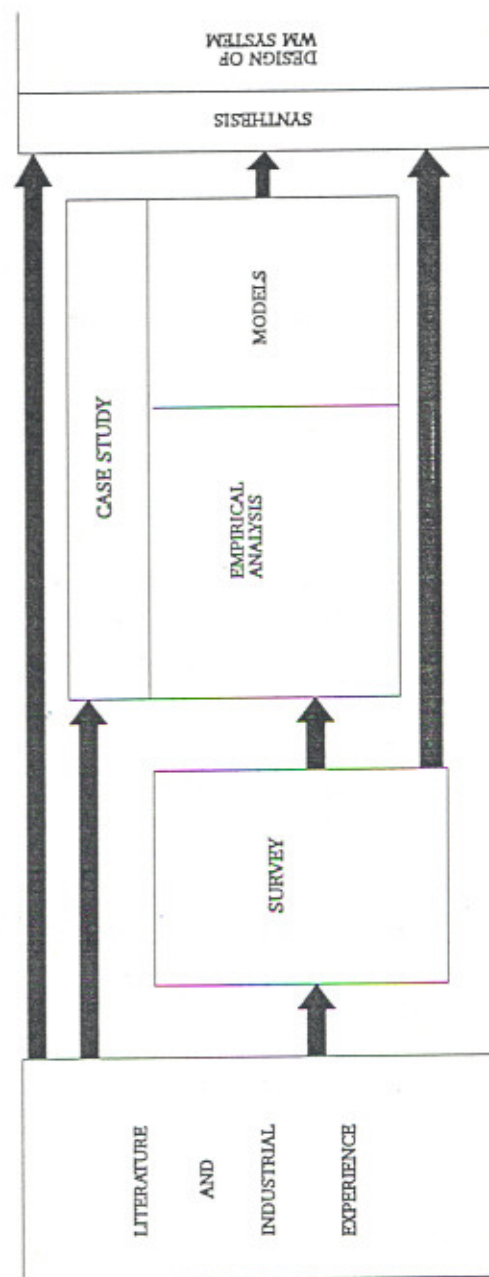


Fig 1.1 : Overall methodology of the study.

Chapter IV deals with the details regarding the methodology, analysis and results of survey on waste.

Chapter V to Chapter VIII deal with case studies on materials, energy, capital and manpower. Each case study encompasses two major parts: the empirical study and the model. The amounts of waste, reasons thereof and suggestions to reduce waste are all covered in each case study.

Synthesis of results and findings of survey and case studies are presented in *Chapter IX*. The inferences drawn from the survey and case studies and the detailed design of the WM system have also been covered here.

Conclusions and recommendations for future work are given in *Chapter X*.

CHAPTER II

LITERATURE REVIEW

A comprehensive review of the literature on diverse aspects of waste management with particular reference to the literature in Indian context is presented here. It helps to identify the areas to be explored in the study. Thrust areas of research and limitations of existing approaches are highlighted. Need for further research is explored.

2.1 REVIEW OF LITERATURE

In the past, the term waste was mistakenly held to be synonymous with solid waste, ignoring the broader perspective. It has not been possible to define the term waste accurately owing to the broad spectrum of waste and its heterogeneous character. However, from a system's point of view the term waste has been defined as: **any unnecessary input to or any undesirable output from any system** (Agrawal, 1984). This includes waste of all types of resources : materials, energy, manpower, capital, services, etc. Waste is a relative term which depends upon input requirements, prevailing technology and the definition of system boundaries. The waste for a sub-system may or may not be waste for the whole system; it may act as resource to other sub-systems. Considering the characteristics of waste this can be alternately visualised as follows:

Any lost, idle, overconsumed or unutilised (non-recoverable) resource available to the system, and the auxiliary output from the system which may or may not be directly usable or disposable, and may or may not create environmental pollution and other ecological disturbances is termed as waste (Sushil, 1990a). Robinson and Schroeder (1992) defined waste as: **waste is anything which adds cost without adding value**. The authors have also defined invisible waste as that waste which is not detected as it is and remains invisible.

Waste in industry may appear in a variety of forms. Scrap produced, rework, damages, deterioration, obsolescence, pilferage and spillage are the most common examples of material waste in industry. Energy waste can occur in the form of higher consumption on operations than required, wastages of heat, transmission losses, lower efficiency of equipment, non-suitability of equipment and so on. Under-utilisation of

machinery and equipment and higher levels of inventories along with lower automation levels, and bad state of technology are common examples of capital waste. There are two main heads under which manpower waste can be put: wastage of other resources due to manpower and wastage of manpower itself which may occur in the form of excessive manpower, extra expenditure done on manpower, overtimes, lack of automation and so on. A review of literature on waste management covers the literature on all these aspects which are directly or indirectly related to waste management.

Agrawal (1984), Sushil (1989a, 1989b) coined the term wastivity to emphasise on the finding out of waste generated by a system as a measure of its performance. Stating the practical difficulties in finding out the level of performance using productivity which is a more commonly used measure, the benefit of using wastivity which is a ratio of waste to input are highlighted. In terms of wastivity, waste management has been defined in its broader perspective as a multi-disciplinary activity involving engineering principles, urban and regional planning management techniques and social sciences to economically minimise the wastivity of the system under consideration (Sushil, 1989a, 1989b).

Complementary nature of waste management and resource management has been highlighted by Sushil (1990a). The main objective of WM is to minimise waste, while resource management aims to maximise utilisation of resources. The goals of waste and resource managements are the same: optimal utilisation of available resources for higher efficiency and growth of the system.

Considering the diverse nature of waste in industry as stated earlier, the areas covered in this literature review encompass, resource utilisation, energy management, environmental control, garbage disposal, manpower planning and utilisation, material conservation, productivity, and so on.

2.1.1 CATEGORISATION OF LITERATURE REVIEW

The review of literature has been divided into the following categories:

- Systems view of waste management
- Management of materials waste
 - Reduction of material waste
 - Collection, recycling, and reuse
 - Waste disposal
- Management of energy waste

- Management of capital waste
- Management of manpower waste

2.2 SYSTEMS VIEW OF WASTE MANAGEMENT

The subject of waste and its management has been of interest for the researchers for the past many years. Research work dealing with some aspects of the subject, related directly or indirectly, have been reported in the literature (Manian, 1974), (Kirov, 1975), (Bandopadhyay, 1977). A real beginning on the subject covering broad perspective of 'Unnecessary input to or undesirable output from a system' was made by Vrat (1979). The need for an organised approach towards management of waste in India was first highlighted by him. It was directed to minimise the wastage of materials, equipment supply and food grains, water, fuels and other utilities as well as the waste of space, capacity time, efforts and skills.

The earliest evidence of research in this direction is a survey of waste management practices (Agrawal and Vrat 1983a, 1983b). The entire national economy came under the purview of the survey comprising almost all sectors namely agriculture, irrigation, power and fuel, steel and mines, industry, transportation, education, society and community service etc. The analysis carried out to determine the relative weights of different resources has shown that materials constitute the most important resource in Indian context followed by energy, capital and manpower resources. The rationalised relative frequencies of various stages of waste generation indicated that the critical stages that needed immediate attention for waste control were design, planning, production and control. Further, the results of the survey revealed that agricultural and industrial sectors were critical requiring tight waste control, power and fuel, steel and mines were found to be semi-critical while others were non-critical.

This was followed by incorporation of the modelling of waste management in national planning by Agrawal (1984). It was here that the term wastivity came in. By this time the term waste management was very widely used in the developed countries. But the main emphasis was on the management of already generated waste i.e. collection, reuse and recycling, and disposal. There has been work reported on waste reduction too but even that pertains to tangible waste i.e. the undesirable output. A book on waste management by Curi (1985) deals the subject from this point of view only. Emphasis on unnecessary input has not been seen.

Sushil and Vrat (1986) carried out a comprehensive literature review on various

diverse aspects of Waste Management, with particular reference to the literature in Indian context. It has been observed that a lot of work has been reported on waste engineering while reviews and surveys have been little and case studies have been specific. Energy and environment interfaces have received attention only in the recent past. The work on waste management has been essentially towards materials waste. Manpower, capital and services wastes have rarely been modelled. Emphasis on waste recycling and disposal is observed while waste reduction is yet to be taken up.

Agrawal (1984) and Sushil and Vrat (1987, 1988, 1989) have proposed an I-O-W (Input-output-Waste) model as an extension of the input-output model to incorporate waste management aspects in national planning. It was visualised that in the economic structure waste parameter has a significant role to play and an I-O-W model is a closer representation of the economy than conventional input-output models. I-O-W model was generalised to apply to five basic resources i.e. materials, energy, manpower capital and services. The resource balance was established by treating input to be equal to output plus waste for each resource independently as well as for the overall flow. The scheme of integration has been presented for overall WM policy analysis and national planning. Subsequently, four models developed at different levels of aggregation namely the W-G model, I-O-W model GP model and B-C model have been reviewed with respect to their basic framework, special features and applications for the development of a methodology for the modelling and analysis of Waste Management in a growth oriented national planning. The basic technology used in these models has been simulation, input-output analysis, goal programming and physical system theory. A coordinated view of these models is presented in the form of a flow chart which may be used for planning and monitoring the economic growth profiles. Some broad guidelines to national policy on WM have been enumerated.

Shah and Jani, (1988) deal with the problem of determining the optimal use of resources for a production firm subject to different costs due to inventory, advertising, obsolescence and quantity discounts for bulk purchase. A production planning inventory model with the objective of maximising the net return to the producer and to determine the optimum level of output, optimum values of labour employed and capital invested and advertisement costs and obsolescence, has been formulated. Sensitivity analysis illustrated the application of the model. A case study by Meyer (1989) has highlighted the problems associated with material handling resources. Remedies and ways out to manage these resources are given.

Relationship of wastivity and productivity, the advantages of using wastivity as a measure of performance and various types of component wastivities have been covered by Sushil (1989b). Method of calculation of overall wastivity from the component wastivities has also been shown. The work done on various aspects of waste management, particularly on national planning, has been summarised in the form of a book by Sushil (1989a). Physical system theory frame work for modelling input, output and waste in multi-stage manufacturing system has been reported by Singh and Sushil (1990b). The model has proved to be a useful tool for representation, calculation of overall wastivity, management planning (materials or equipment planning) and doing sensitivity analysis.

A special issue of MCB university press by Sushil (1990) has covered all aspects of waste management from systems point of view. This complete journal is on waste management and treat waste in each resource and each sector. There has been an extensive coverage of waste generation, waste identification waste reduction, collection, reuse and recycling and disposal. Within each functional area even the minutest details have been covered. Integration of waste management with productivity improvement, resource conservation, energy management, nature conservation, environmental control and unemployment has been explicitly dealt with. Role of waste management in national planning has also been brought out.

Robinson and Schroeder (1992) have very clearly differentiated between the waste in the real sense and the common or derived meaning of waste in the following words.

"Eliminate Waste! This slogan is often shouted by management, yet we won't find much of what we imagine as waste lying around in the work place. Unfortunately, real waste lurks in forms and do not look like waste....We must always keep in mind that the greatest waste is the waste we do not see."

The author has named this type of waste as invisible waste and attributed two major reasons to this. First, to a person who knows no ways to eliminate it, waste becomes a normal and necessary part of the process. This is termed as knowledge based invisible waste. But waste can also be invisible even to someone who knows how to eliminate it, if that person views it from the wrong perspective. This is named as perspective based invisible waste. Examples have been cited from the production areas about these wastes and sources of invisible waste have been brought out. Principles and steps to eliminate the same have also been given.

Sharma (1992) has presented a multi-level futures research study to estimate the

present and future status of system waste and its management in the indian economy and some of its sectors using methodology sub-sets from consensus methodologies set. Further, policy analysis is done to reduce system waste in important sectors. The consensus methodologies have been subsequently modified to make them applicable to geographically dispersed group. Three aggregate level studies on system waste and its management in the indian economy have been conducted using a long scale Delphi technique. Scenario upto 2000 AD of waste management practices and interrelationships of the causes of system waste at the aggregate level have been generated and analysis carried out using ISM and MICMAC. This is followed by a consensus methodological study of the present and future objectives and actions of waste management at the aggregate and sectorial level. In the sectorial studies system waste and its management in education and research sector is followed by two detailed sectorial studies in the agricultural sector. The studies have dealt with policy analysis to reduce waste of inputs, development of a conceptual design for the utilisation and disposal of agricultural waste. In India National Waste Management Council has recently been set up in the ministry of environment and forests. The council constituted three subgroups to deal with municipal, industrial and rural wastes and suggest ways and means to utilise waste (Sharma 1992).

2.3 MANAGEMENT OF MATERIALS WASTE

Materials constitute the most important resource in the indian context and contribute to more than half the total cost of production. Waste management activities in the past have been restricted to material waste. Material waste may appear in any form: solid, liquid or gaseous. Industrial waste, which includes all unwanted materials from industry, may be organic/inorganic, metallic/non-metallic, hazardous/non-hazardous, salvable/non-salvable, etc. Waste is a consequence of all industrial activities. It may be overconsumed material, process scrap generated during production, rejections due to non compliance with design standards, damaged items and pilferage during handling, excessive storage resulting in surplus items, wholesale conversion of perishable items into scrap and junk as a result of corrosion, unserviceable machinery/equipment, obsolete items and machinery/equipment, industrial effluents, etc (Sushil, 1990a).

The management of material waste initiated the field of waste management, and even the thrust of latest literature is towards materials waste. However, most of the work appearing now deals with the reuse, recycling or disposal part of the already generated waste.

2.3.1 Reduction of Material Waste

Warren, (1962) stressed upon the improvement in material utilisation by managing scrap. The important steps for scrap reduction have been given. Shan and Bali (1974) brought out the areas of material waste in industry and suggested the ways and means for its control and management. Management of scrap and rejects by using careful working and appropriate tools, techniques and materials has also been stressed by Manian (1974). General steps to be undertaken for scrap reduction in small scale industry have been given by Pathak (1975). Statistical quality control techniques have been highlighted for process control and scrap reduction. Ekambaram (1981) brings out the use of SQC in the quality assurance and reliability of sub-contracted items. An optimal choice among several continuous sampling plans suggested by Dodge ensuring the specified AOQL value has been attempted by Mukherjee and Agrawal (1981), using different criteria for optimal decisions in the face of uncertainty.

Srinivasan and Malhotra (1978) have addressed the problem of conservation of zinc in the dry battery industry. Zinc consumption and wastage in dry battery industry in India which accounts for approximately 10% of total consumption of 7000-9000 tonnes of zinc was surveyed and discussed. Zinc losses in dry battery industry vary between 3% to 6% depending upon technology adopted. Thus 300 to 600 tonnes of zinc is wasted in the manufacture of dry battery. In another study, (Ramamurthy 1978), the stages at which material conservation can be applied are outlined dealing only with metallic materials. Current technology and commercial practices in this country for the manufacture and sale of non-ferrous castings have certain inherent characteristics that make material productivity (Kgs. of alloy used/saleable castings) the critical path in determining the profitability of the operation. The basic defects in the approach have also been discussed.

Need for concerted efforts on material conservation has been stressed upon by Poddar (1978). Standardisation techniques (Gupta, 1978) have been used for conserving material and other resources which subsequently improve productivity. Standards lead to simplification and variety reduction, thus eliminating avoidable waste during handling of materials, processing, packaging, transport and application. IS 1570-1961 has been used for reducing the variety of components. The impact of material conservation on productivity has been shown by Desai (1978).

Simulation modelling (Westwood, 1979) has been fruitfully applied to see the impact of the various waste control policies on the overall system. A case study of yarn waste in

carpet industry has been chosen to demonstrate the usefulness of simulation in developing a better understanding of the system and in carrying out various experiments with the simulated model. Sushil and Pankaj (1990) have applied extended physical theory and simulation to model cost and quality in a spinning unit producing medium count ranges of yarn. The approach aims at reducing quality related cost through reducing scrap.

The problem of overconsumption of materials for making products has been addressed. Cutting stock problems and trim loss problems have been very extensively covered, particularly in the recent literature. Seth (1987) has addressed the problem of wastage reduction in wood cutting, planks from sleepers. He applied linear programming modelling along with a special computer package which generates the cutting patterns. This study helped in reducing the avoidable wastage by 50%. Goulimis (1990) has also provided the solution of certain classes of cutting stock problems to optimality. The work is based on enumerating the possible cutting patterns and solving the associated integer programme by a combination of cutting planes and branch and bound. Usually optional solutions are obtained by the programme in trim loss terms. Subsequent post-solution optimisation minimises cutting patterns and reduces cutting tool set ups. Use of simulation is made by Farley (1990) for selection of stock plate characteristics and cutting styles for two dimensional cutting stock situations. Haessler and Sweeny (1991) have reviewed various types of one and two dimensional cutting stock problems, their basic formulation issues and solution procedures. Linear programming, sequential heuristic and hybrid solution procedures have been described. Agrawal (1993a) has proposed a method to minimise trim loss in cutting rectangular blanks of a single size from a rectangular sheet using orthogonal guillotine cuts. The problem is structured as a branch and bound technique and its optimal solution is guaranteed. Methods developed by an automobile press shop to determine stock sheet sizes to minimise total trim loss have been reported by Aggarwal (1993b).

The problem of leakages from pipes which is representative of spillage of material has been addressed by Hindi and Hamam (1991a,1991b) in their two papers dealing with single period models and multi-period models respectively. The problems considered are that of optimising the settings of the pressure control valves in order to minimise leakage losses in water supply network over single period or multiple periods. Two models one for the case of constant outlet pressure valves and the other for the case of flow modulated valves are formulated. Case studies have been discussed.

Over consumption of indirect materials in processes is also a very common problem.

Bindra (1991) has used the approach of statistical quality control to reduce the consumption of adhesive in a filter manufacturing concern. The assignable causes of variation in quantity of adhesive dispensed were removed, equipment was upgraded to reduce its natural variability and average quantity level was statistically set to achieve reduction in adhesive waste. Suggestions to reduce trim loss of impregnated filter paper have been made.

2.3.2 Collection, Recycling and Reuse

Keiseler (1978) worked on the segregation of recyclable solid waste using the expectancy theory. Cedroholm and Headenhag (1979) dealt with the possibility and potential of recovery of paper from municipal waste. Clifton and Brown (1980) suggested various uses of waste materials and by-products in construction. Reviews and efforts at materials conservation and recycling of waste in an iron and steel company are presented by Kharia and Iyer (1978). An elaborate system of collecting the waste arising from fabrication, erection and defectives produced during manufacturing; automatic grading and segregation according to a predetermined code of broad classification and direct transportation to points of consumption have been suggested. Recycling of scrap instead of disposing, designing of circuits for raw materials, processes and product improvements have also been discussed. Yeginbali (1985) looked into the possibilities of uses of soda industry wastes as construction materials. Dudenkov (1985) collected data on secondary raw materials including ferrous and non-ferrous scrap, waste paper, secondary textiles, worn out tyres and secondary plastic materials and discussed the potential of recycling the same.

Gottinger (1988) described a model for regional solid waste management as a network flow problem. Bio-gas generation from mill waste, fuel from refuse, electricity generation from the bio-gas derived from sanitary landfill are the possible uses of solid wastes discussed by Prasad (1988).

Robinson (1989) published a practical guide book dealing with generation, collection, recycling and reuse of waste materials. Khanna et al (1991) analysed informational, ecological, technological, managerial and socio-political constraints to waste utilisation and discussed appropriate strategies for minimisation and reclamation of waste. It served twin benefits of conserving materials and energy resources and circumventing environmental pollution. Kumar (1992) has listed various uses of flyash. Similarly the use of waste and sewage water on land has been highlighted. Power generation from waste material is also being accomplished (Briefs, 1992). Darrington (1992) has discussed economic aspects of recycling and the most common problems, including deficiencies in

product design that hamper recycling.

2.3.3 Waste Disposal

Treatment of waste before disposal to reduce its bad effects on environment and related issues have been extensively dealt by researchers. Fishelson (1977) emphasised apportioning allocation of capital between production and emission control to minimise adverse effects of industrial emissions on the environment. Virbhadrappa (1978) has discussed several schemes to utilise industrial wastes and lists the units set up. Effective recycling and alternate uses of a number of wastes, the resultant savings and environmental effects have been discussed. Srinivasan (1978) has dealt with solid waste disposal and recycling of domestic, commercial, industrial and agricultural refuse. Different material recovery techniques and use of material waste as raw materials for another source are also suggested.

Issues regarding hazardous chemical waste disposal have been discussed among other waste management problems by Curi (1985). Richards (1985) has discussed legislation of disposal in the U.K. The government has framed an act regarding disposal, called control of pollution Act 1974 (COPA). This act defines waste from disposal point of view and gives guide lines regarding various materials which are termed as waste. Further, a detailed procedure is laid down regarding the site, the working hours, the mode of disposal e.g. treatment before disposal (crushing, compression, thermal treatment), the name and address of the company disposing waste and so on. It has also put on time limits for keeping the wastes in-house before processing and disposal.

Srivastava et al (1990) discussed the problems of disposal of chemical and physical wastes from large pulp and paper mills. Incineration represents a treatment option for the destruction, safe transformation or reduction of waste. Cairnes (1990) has listed the types of wastes needing incineration, differentiated between hazardous wastes and industrial wastes, the treatment by high temperature industrial incineration, factors effecting incineration, optimal conditions for incineration, codes and standards and development of facilities. Chaurasia et al (1990) have also highlighted the problem of pollution created by the industries and strategies for pollution control.

Radioactive waste management involves the problems like financing of waste disposal, enormous time (decades) between electricity production and final disposal of materials in geographical formations, choice of a time scenario and disposal site, points of views of various sectors like electricity authorities, consumers, public bodies etc. Briggs et

al (1990) applied a multi-criteria analysis for nuclear waste management.

Goldstein (1990) has worked on the disposal of plastics. These materials are strong, light, durable, not soluble in water, and resist microbial degradation or the effects of sunlight and oxygen. Thus emphasis is being given on the design and manufacture of degradable plastics. Rosen (1990) has impressed upon the idea of enacting the rules and regulations and the legislations connected with the environmental effects of plastic wastes. Roysten (1991) has highlighted the need to look at the environment and industry as a single system. The author asserts that the true value of the environment is to be found out, not in its exploitation but in its preservation. Yacov (1992) has highlighted the importance of management of natural resources and the environment. Five essential principles have been suggested for the purpose including multi-objective analysis, risk analysis, impact analysis, consideration of multi-decision makers, and interaction of system.

2.4 MANAGEMENT OF ENERGY WASTE

Literature on this resource is divided into three broad categories.

- i) Energy being consumed and its projected demand. Stress is on its efficient use.
- ii) Development of alternate sources of energy.
- iii) Conservation of energy - strategies practised and proposed.

2.4.1 Energy Used and its Future Demands

Historical trends of energy consumption of some large energy consuming industries have been compiled and analysed by Singh (1986).

Nanda (1990) has compared energy consumption of various sectors of Indian industry with that of the developed nations. It is revealed that industries such as iron and steel, cement, aluminium and pulp and paper consume 50% to 100% more energy per unit output compared with corresponding industries in developed countries. Considering ever increasing demand and future projections, Natrajan (1990) has stressed that energy policy and planning for the future should aim at generation and resource allocation to energy and its conservation. Iyenger (1990) has explored upcoming coal based technological options to meet energy demands. Implications of current trends in energy use have been highlighted by Gill (1991). By 2020, India will spend 68% of the total outlay of the 13th plan on energy alone. Paulus (1991) has presented an energy policy perspective in India by highlighting the problems of inadequate supplies, under employment, balance of payments constraints,

energy crunch as well as environment crisis.

2.4.2 Alternate Sources of Energy Generation

Sen et al (1992) has discussed the possibility of conversion of hydrogen rich plant products from forest and agricultural waste to invaluable fuels. 'Briefs', (1992) has also reported a case of large amount of power generation from waste materials.

Kaushika (1992) has presented an overview of solar thermal power technologies such as the honey- comb solar pond, viable dish concentrators, light weight heliostats, semi-cavity absorbers and aeroderivative turbines which make the proposal cost effective for large scale grid connections.

Hangudu (1992) has projected bio-gas available from various waste treatment processes as a valuable energy source. Firing bio-gas directly in an industrial gas turbine to produce power and capture the hot exhaust gases to generate steam has been recommended as an efficient way of utilising bio-gas. Deambi (1992) has highlighted the need of education on renewable energy sources at all levels.

2.4.3 Energy Analysis, Management and Conservation

Anandlingham (1985) studied energy intensive industries of developing countries and suggested methods to enhance fuel efficiency and its conservation. David (1985) has presented energy analysis of transportation system of developing countries. A great scope for energy savings is indicated. Energy analysis has found its usefulness even in hospitals, Vineyard (1985). Energy consumption data of 41 hospitals has been analysed to identify wasteful operations.

Energy audit of an integrated aluminium complex using the energy usage diagram has been reported by Iyer (1986). Energy saving measures in refrigeration plant operations have been highlighted by Kumar (1986). Malathi (1986) conducted study to determine requirements of quantity and time taken by various commercial fuels used for cooking in utensils made from different materials and using different mediums of cooking. Energy conservation efforts for airport buildings using waste management systems approach have been reported by Vedi (1986). Energy usage by building systems, energy loads, annual and peak energy requirements were studied.

For a sulphuric acid plant, Nand (1987) determined waste of heat energy and impressed on heat recovery to boost energy efficiency. Parikh (1987) conducted detailed energy analysis for IFFCO, KALOL. Various areas were identified for energy efficiency

improvement and for reduction of specific energy consumption of different operations. Management of rural industrial systems has been reported by Sen and Nanda (1990). Srinivasan and Natrajan (1990) have presented a comparative analysis of energy conservation policies of different countries. Bhattacharya (1990) has suggested a basic approach for energy audit at enterprise level.

Bali and Singh (1990), while highlighting large amounts of energy waste in engineering industry due to non- suitability of equipment for the products made have stressed upon judicious selection of equipment to contain energy consumption and guidelines provided. Energy analysis of a non-ferrous piston foundry has been conducted by Singh and Bali (1991). Various areas of energy waste have been found out. A detailed energy analysis for one of the energy intensive sectors of small scale industry by Ramachandra and Subramaniam (1991) has shown that a wide disparity existed in specific energy consumption (SEC) among various units. It has also been shown that large amounts of savings can be effected by shifting the units from lower production ranges to high production ranges.

Saxena (1991) has developed energy conservation policy and strategy for indian cement industry by using qualitative techniques of system analysis. A scenario for energy conservation in indian cement industry has been projected and a methodology has been developed for building the scenario. Further, energy conservation options have been identified. National energy efficiency programme (1990) has been launched in the eighth plan that will take into account both macro-level as well as micro- level responses for different categories of users in the industry, agriculture, transport and domestic sector. The broad framework and contents of the national energy efficiency programme have been outlined and the eighth plan targets for energy conservation and their break-up have been given.

Arokiaswamy (1992) has presented the results of power audits of various industrial units. These reveal large number of faulty areas involving use of inferior equipment and fittings which result in huge wastage of power. Vij et al (1988) have examined energy issues of indian economy in a dynamic and multi-sectorial framework with prime focus on energy conservation and waste management. An application of the integrated energy model encompassing physical system theory and system dynamics has been described by using the published data of indian economy. The model has been used to study sensitivity of economy to energy constraints, changes in the capital productivity and capital utilisation in various sectors.

Some handbooks dealing with various aspects of energy analysis and conservation have been compiled. Bausted and Hancock (1979) have presented complete details of the subject of energy analysis. In addition, gross energy requirements of the products and materials ranging from metals, resins, fibres, metal casting and forgings to gases, salts, plastics, bricks, electrodes, cement, water, wood and a range of other articles have been tabulated. Different energy values are given for these products when these were produced from different raw materials using different methods. David (1983) has dealt with energy conservation.

2.5 MANAGEMENT OF CAPITAL WASTE

Capacity utilisation and inventories form the main components of capital. The available literature on these areas is presented here under the following broad categories:

- i) Concept of capacity, levels of capacity utilisation and reasons of under-utilisation.
- ii) Improving capacity utilisation using various techniques, models, studies etc.
- iii) Inventory levels and their reduction.

2.5.1 Capacity: Concept and Utilisation Level

Hari (1975) and Kale (1975) have attempted to define capacity, maximum capacity, rated capacity, licenced capacity, installed capacity, achievable capacity, agreed capacity targetted capacity etc. The importance of time in determining capacity utilisation has been explained. Stream factor and constraints influencing it have also been discussed. Singh (1975) has given figures for capacity utilisation in our industry for the years 1969 and 1973 and discussed various causes for poor utilisation. Rao and Kumar (1975) have reviewed literature on capacity utilisation from 1946 to 1975 and found it to be generally poor for want of raw materials and components. Karim and Bhinde (1975) have suggested capacity utilisation to be an important index of performance.

Venugopal (1975) while presenting figures of poor capacity utilisation in indian industry has drawn attention to the 'basis' used to calculate capacity utilisation.

A three point approach for using existing capacity effectively through technical innovations, change in product mix and utilising 'extras' has been suggested. Gupta and Thavaraj (1975) have highlighted the costs associated with capacity utilisation of fertiliser plants for the years 1963-64 and 1972-73. Under-utilisation of capacity in public sector steel plants along with fluctuations from plant to plant and from one product to another have been

compiled by Mathur (1981). The capacity utilisation ranged between 53% and 71%. Various reasons have been listed and impact of higher costs of production, lower profitability, higher prices, diminishing exports on future prospects have been discussed.

Kedia (1983) has cited capacity under-utilisation as the main reason of diminishing profits even in the wake of comfortable orders position of a plant. He, having determined capacity with a six stage model, has described several corrective measures to be used currently and at a later stage for improving capacity utilisation. Overtime payment has been found to be a damper on efficiency.

2.5.2 Improving Capacity Utilisation

Kumar (1975) has explained a systematic approach of capacity determination in mining industry while Khader (1975) has reflected the usefulness of linear programming in capacity determination, considering profit maximisation as the objective. Warner (1978) has brought out the role of operation control in increasing capacity utilisation and hence improving productivity. Maruchek and McClelland (1992) have demonstrated that planned level of capacity utilisation has a very significant effect on the performance of a firm. Mitra (1975) has highlighted the importance of adhering to maintenance schedules and smooth running of the plants to achieve higher levels of capacity utilisation. Sharma et al (1992) have provided a simulation based technique for maintenance planning to achieve higher levels of plant utilisation.

Narang and Batra (1981) have presented a goal programming approach to product - mix decisions. In addition to the objective of profit maximisation, the others have been minimisation of costs, meeting orders commitments, generation of a minimum stipulated revenue and maximum utilisation of plant capacity. Sushil et al (1988) have also illustrated the use of goal programming in capacity waste minimisation of a batch manufacturing industry. The authors have explained the model building involving various multiple objectives and constraints. The model involving objectives like maximising capacity utilisation, minimising inventories, maximising profits and so on has been solved in another paper, Sushil et al (1989). Priority of various goals has been varied to find out the product mix resulting in the achievement of goals. Porabhai (1990) has presented an analytical approach for the optimal utilisation of capacity of assembly systems.

Singh et al (1990) have used a minimax approach to strike a trade off between the conflicting criteria of cost, time and hamming distance involved in process planning of multi-parts on NC machines with multi-tools and fixtures. Rogers and Flanagan (1991) have

used on line simulation for real time scheduling of manufacturing systems by interfacing aggregate planning, manufacturing resource planning, production activity control, engineering, sales and marketing and purchasing. A combined input/output control system is presented by Fabrycky (1987) for periodically determining the set of jobs to be released (input variables) and the capacities of processing centres (output variables) in a dynamic job shop so that composite function is minimised. An interactive heuristic optimising algorithm incorporating a 0 - 1 linear mixed integer programming is formulated.

Angelmer (1990) has assessed overall contribution of product innovation to the competitive advantage, analysed the conditions under which such a contribution is likely, and discussed how this likelihood can be increased through company action. Babu (1990) has applied goal programming for decision making in the expansion of production capacity of a textile mill. By developing a model, suitable combination of new machines, old machines and partially modernised machines has been arrived at within the given constraints of total investment capacity and ratio of old to new machines. Klimberg et al (1991) have found out the optimal allocation of inspection resources by a two-objective zero-one programming model and solved it by a two stage decision support system. Rodrigues and Brady (1992) have highlighted the difficulties in allocating costs of various resources to the cost of manufacture in a multi-product environment. A solution to such problems is offered in unit of production effort method (UEP) which tries to unify production via the abstract notion of production effort including technical consumption and technical costs.

Gunasekaram et al (1992) have determined the profitability by changing the product mix in a production system with multiple products. A method for evaluating the potential of considering a new product using the available facilities is suggested. Adverse effects of not linking manufacturing investments with agreements on marketing have been brought out by Berry and Hill (1992). The need to link market and manufacturing strategy has been highlighted.

2.5.3 Inventory Levels and their Reduction

Menon and Sharma (1989) have highlighted that on March 31, 1988, total inventories in the public sector enterprises of Govt of India stood at Rs.17,962 crores which represented 91 days of output involving about Rs.5,400 crores of inventory carrying cost. Further, a direct relationship between the amount of inventories carried and the losses suffered has been reflected by the author. Menon and Sharma (1989) in another article have highlighted the need to tackle root cause of the problem of higher inventory rather than applying the

highflow inventory control techniques. The root causes have also been discussed.

Gunasekaran and Babu (1988) have presented an analytical model for determining economic order batch quantity for raw materials and production in a multi-stage production system considering the decay of raw materials and the in-process inventory. Viswambhram and Nair (1984) have proposed and demonstrated coverage analysis for reduction in the overall inventory level. Sunder (1989) has demonstrated application of on line computerisation in a public sector concern where varying types of products are manufactured with long lead times - variety of components required running into lacs. By designing a data base reflecting real world situation and using an appropriate software, average inventory was reduced to nearly less than half. Mayer (1991) has cautioned against the problems which inventory accuracy brings with it, such as, loss of worker productivity, manufacture of unneeded items, broken customer commitments, costly physical inventories, and - in general - frustration and presents an eight step approach which has been applied profitably at Leviton Manufacturing Company.

Grunwald and Fortuin (1992) have described how a large multinational company tried to reduce its stocks along the chain from raw materials to distribution outlets. Zero inventory has not been achieved, but neither was it aimed. A more realistic goal has been described as MRI, the minimum reasonable inventory. A mixed business strategy: cost leadership in one field, product differentiation through high tech innovation or global marketing in the other, have been applied. Different goals have been recoinced to find out MRI

2.6 MANAGEMENT OF MANPOWER WASTE

Manpower waste can occur due to variety of reasons ranging from manpower planning defects, wrong human resource development policies, turnover, absenteeism, skill levels, social background, motivation, working conditions, job content, employer-employee relationships and so on. On all these areas there has been an extensive amount of work done and papers keep appearing in the literature. The literature review has been divided into following categories here.

- i) Productivity, in particular, labour productivity, comparison of productivity of various countries, reasons of low productivity, human factors in low productivity, manpower waste and the reasons thereof.
- ii) Manpower planning, human resource development and other measures to reduce manpower waste.

- iii) Individual reason/aspect of skill, alienation, absenteeism etc.

2.6.1 Productivity : Levels and Reasons

Comparison of productivity of Asian countries in various sectors has been given by NPC research division (1991). It has been revealed that productivity in all sectors including manufacturing in India is very poor as compared to other Asian countries. As per the bureau of labour statistics, during the period 1983-88, the international manufacture labour productivity growth rates per year are as under (Smith (1989).

Japan	5.9%	Canada	3.3%
U.K.	4.7%	France	2.9%
Italy	4.3%	Germany	2.7%
U.S.A.	4.0%	India	1.2%

Clearly India's labour productivity growth rate is very poor as compared to the developed countries. An analysis has also been made about the growth of manpower productivity in various sectors of industries. It has been revealed that in certain types of industries, particularly sugar factories, non-ferrous basic metals, cement and a number of other sectors there has been a negative growth from 1970 to 1980. In others, there is a marginal growth.

Pestongee (1984) has opined that productivity can be conceptualised as the final outcome of interaction between performance and satisfaction whereas performance is the outcome of three major sets of variables; human (Individual), human (Social) and non-human. The author while outlining various factors like job satisfaction, performance, needs, job deficiencies, an environment effecting productivity has stressed on developing clearer insights into the human behaviour. Pratap and Srivastva (1984) have listed various causes for low productivity; faulty communication, formation of informal groups and complex human relations are the major ones. The author has visualised the industrial system as a socio-economic system and stressed on studying the total organisation and not merely some key individuals. He has suggested the setting up of behavioural sciences cell in each organisation to minimise the human problems.

Lakshman (1984) has suggested an approach using time study, work sampling and production study to assess the actual work content of a job, and fixing work for every individual in order to solve labour productivity problems. Das (1989) explained the concept of human resource accounting and discussed its need and importance in the present day

context along with methods of measuring the value of human assets. The effects of HRA on labour productivity and motivation have been discussed.

Ramjas (1989) has brought out that the attitude of the workers unions these days is neither positive nor, generally, aimed at increasing productivity and is only a means of collective bargaining- to dictate norms of shop floor working. Author has also discussed positive contribution which the unions can make. Robert (1983) has pointed out on the basis of studies conducted in Malaysia that the nature of work especially variety and autonomy has a strong effect on satisfaction. Author has stressed upon humanisation of work through better job design and participation of workers so that they are used well instead of treated well. Chatterjee (1989) has also stressed upon making the job worth doing by structuring it well. Sekar (1989) on the basis of a comparative study of two textile mills has argued that there is a direct relationship between the work environment and work alienation; suggestions for making work environment better are also made.

Rankin and Kleiner (1988) has reviewed various techniques of performance appraisal viz., rating scales, objective settings, critical incidents techniques, behaviourally anchored rating scales, and many others. Highlighting the imperfections of each technique the author has recommended the use of some important elements which are common to all the techniques. Elements of an effective performance appraisal system are also discussed. Fortuin (1988) has highlighted the importance of performance indicators and discussed how useful performance indicators are designed, how they should be employed and what pitfalls have to be avoided during implementation. An overview of the subject is offered. Blenkinsop and Burns (1992) have compared the systems of performance measurement adopted by Japanese and British Companies in order to get clues from the Japanese approach of using non- financial measures of the productivity of the company. Requirements of a good performance measurement system have been laid. Dass and Shikdar (1990) have highlighted the importance of applying production standards and feed back to improve worker productivity.

Malik and Bali (1991) have highlighted the problems of objectively setting the time standards in Indian industries. These are mainly due to unions' indifferent attitude and non-cooperation of workers and inability of shop floor personnel. Guidelines for setting time standards have been provided, the most important ones are the use of independent people, setting of time standards before handing over machine to the shop floor, use of MTM and work factor along with the time studies.

2.6.2 Manpower Planning and Human Resource Development

Hall (1986) has drawn graphs for the manpower requirements of seasonal company where demand varies a lot. Optimum manpower requirements have been calculated which satisfy various aggregate planning strategies. A similar work satisfying two strategies of aggregate manpower planning, i.e. constant work force size and increasing labour at constant time have been differently optimised by Singh (1991). Babu (1989) applied linear programming for evaluation of manpower requirements.

Usefulness of looking the manpower system as a whole, using a variety of methods such as Markov, Renewal theory and Semi Markov Models have been stressed upon by McClean (1991). Ramachandran (1992) has demonstrated the benefits of making future manpower assessments using past trends of the demand of the products and projecting it in the future. Mishra (1992) has highlighted the importance of manpower assessment, care to be taken while assessing manpower and the control of manpower towards the success of an organisation.

Parthasarathi (1987) has discussed a multi-disciplinary approach based on behavioural science methodologies for human resource optimisation, in the light of various reasons of accumulation of excess manpower. The author has also suggested short term and long term strategies and a system of manpower audits. Stages in the development of human resource development strategies including initiation, situation analysis, future scenario, linkages with MPP, HRD objectives, strategies and documentation have been discussed by Parthasarathi (1988). It is suggested that HRD strategies should be drawn keeping in view the dominant managerial ideologies and organisational climate. Jain and Sushil (1987) have enlisted various causes of manpower waste, the interfaces of manpower waste, Japanese style of waste management involving innovation, competition, centralised and soft management and respect for workers. Techniques for reduction of manpower wastivity including quality circles and productivity teams have also been suggested. The authors have further emphasised that there can be no single model or technique which can be blindly applied to indian industry. The real solution lies in deeply understanding various forces in a given situation.

2.6.3 Specific Areas

Education and training and skill levels have an important effect on the attitude of the people and thus affect their performance. Goh et al (1987) have given guidelines on the optimal planning of manpower training programmes by striking a trade off between training

costs and expected returns. Mathematical models which reflect the random nature of the manpower movements have been used to examine this planning problem. Chetty and Krishnaswamy (1988) have concluded from a survey that skills of human resources need a periodic review. Training programmes can be useful in enhancing the skills. Robert (1992) has reviewed literature showing effects of fragmented training development and has presented system theory and training system concepts. He has also provided a discussion of system oriented research issues in areas of training needs and goals analysis, training devices design and use, and training system evaluation. It is concluded that a system perspective will facilitate communication between individuals engaged in training system development, development and implementation of training systems, synthesis of these issues to the needs and goals of various groups that interact with their own needs, goals and decisions.

Sil (1986) has highlighted causes of absenteeism as seasonal, social, health factors, industrial relations, job satisfaction and accidents and suggested remedies such as good leadership qualities in the managers recognition and compensation system, care at the time of recruitment and selection, employee orientation and training performance appraisal, job satisfaction and improvement in health. Most of these reasons are cited for turnover too by Raghu (1988) who has opined that top industrial executives show lack of interest in labour turnover mainly due to lack of their knowledge of its costs and other effects on the industry.

Better employer-employee relationships and no conflicts can reduce problems due to manpower. Sharma (1984) has found out, through a survey of industries, that the factor which motivates people the most has been supervisory relationships followed by safety, security and monetary benefits. Spengler (1985) has addressed the problem of reducing conflict and increasing productivity in the operation area. A unique programme combining programmed learning and practical application and making use of principles of method study was launched which reduced conflicts and minimised resistance to change. Silverman (1992), while explaining the phenomenon of confirmation bias, has stressed on the need of being rational while dealing with problems related with human beings and not let any preconceived ideas or first hand informations influence the process and results.

2.7 CURRENT STATUS OF RESEARCH WORK

A comprehensive review of literature on related aspects of WM gives an indication of its infancy with few categories at intermediate stages of development. Scholarly research considering broader perspective of WM has been evidenced only occasionally.

Incorporation of WM in national planning in mid eighties and management of system waste in India dates in 1992. In between also some work is reported dealing with system perspective of waste and its management. In some developed countries the problem of WM has been taken seriously and some handbooks are compiled on solid waste, environmental control, energy management etc. In view of very little work done on the subject, the existing approaches suffer from many limitations.

The management of materials waste initiated work on waste management. Today, material waste is a thrust area. A good deal of work has been reported to develop waste engineering principles, new uses of waste materials, treatment and disposal techniques etc. Though the managerial aspects cover a wide spectrum of areas, particular emphasis has been given on the development of waste collection and disposal systems, and resource utilisation. Emphasis is on to study specific waste rather than overall waste in a system. Material waste reduction issues have also been addressed. Use of SQC and other techniques for scrap and rework reduction, overfill or excessive use of indirect materials, selection of suitable sized raw materials, leakages, damages during storage have all been covered individually. Reuse and recycling efforts being done are seemingly for disposal of waste materials rather than conservation of materials. Some efforts are made for saving fresh materials costs also. Disposal of waste and its environmental effects has attracted great interest. Legislations on disposal and pollution have also attracted research in this area.

Energy has become a crucial area for study in recent times. The main thrust in this resource has been to generate awareness for energy scarcity, rapidly increasing demand, projection of future demands and energy scenarios, and to impress upon people for proper and efficient use of energy and work for development of newer sources of supply. Producing energy from waste has gained momentum and some positive developments have been reported in this direction. Efforts are also being made to generate solar power economically. On making efficient use of available energy also, a lot of research work has been reported. Overall energy waste generation in a system and its reduction by proper management and careful working has been covered only for namesake. Some case studies on energy analysis and audit have been reported and the techniques of energy analysis, management energy audit etc. have emerged.

Capital, capacity utilisation and inventories have received little attention despite vast potential. Studies giving capacity utilisation figures have been reported. Research has also

been reported on various related areas of capacity utilisation viz. process planning, product innovations, materials planning, maintenance, scheduling and others but coordinated efforts and development of procedures for increasing capacity utilisation with other implications have not been reported. Regarding inventory levels and their reduction a lot of work is being done but the techniques used and suggested are based on many assumptions and do not apply to practical conditions. Some work has been reported on realistic situations also.

Manpower waste publications mostly deal with highlighting low labour productivity of Indian industries, reasons thereof and suggestions to improve. A lot is said about motivation, labour unions, time standards, labour laws, absenteeism and other aspects but an appropriate mix of all these techniques is sadly missing. Research on wastes of other resources due to manpower waste has not been evidenced. It is felt that approach of most of the researchers on manpower is quite conservative, particularly while dealing with union effects and labour laws etc.

2.7.1 Limitations of Existing Approaches

Some of the major limitations of the existing approaches towards management of waste are highlighted as follows:

- a) Studies treating overall waste generation of a resource, and its management have been few. The emphasis has been on studying waste at micro level and applying some techniques involving lot many assumptions resulting in little practical value.
- b) There has been a heavy emphasis on waste engineering principles, process for waste treatment, resource recovery techniques etc. while the managerial efforts have not been fully tapped.
- c) In materials, emphasis on scrap reduction and input - output - waste analysis has been seen to be quite less.
- d) Generalised guidelines giving information on various aspects of critical areas of waste generation, identification techniques, reasons of waste and alternative ways to reduce waste; have not been devised neither for any sector viz, industrial, agricultural, domestic, municipal or transport nor for any resource viz. materials, energy, manpower and capital.
- e) There have not been many surveys and reviews conducted in this area which may be one of the major causes for lack of appreciation of the status and potential of WM in diverse fields.

- f) The application of mathematical modelling to individual cases in WM has been conceptualised in a limited manner.
- g) In case of manpower various techniques have been suggested from time to time, but no model or methodology choosing an appropriate mix of options available in a given situation has been used.
- h) The WM research has been essentially concentrated to deal with process scrap, effluents etc. The interactions of different industries from the view point of WM has not been done.
- i) Lot of studies are evidenced in energy sector but the majority deal with energy policies, financial aspects and alternate sources of energy. There exists inadequacies in research on management of energy waste from system's point of view.
- j) In majority of the approaches waste recycling has been studied from engineering point of view while the application of system analysis techniques in this areas is yet to be taken seriously.
- k) The mathematical modelling of WM aspects has not been extensively treated in many papers. The input-output modelling does not give explicit consideration to waste parameters. The application of optimisation techniques is very rare in this field; in particular, the multi-objective optimisation of wastages have been left untouched. The casual relationship between various system parameters and wastes identifying possible feed backs are also not examined.

2.8 NEED FOR RESEARCH AND AREAS OF STUDY

On the basis of review some of the priority areas of study demanding immediate research attention are identified as follows:

- a) The term waste and waste management should be clearly defined so as to provide rational view regarding the boundries of the subject in order to motivate research efforts in proper direction.
- b) The conventional narrow approach giving consideration to materials wastes only needs a radical change to conceptualize the issue in a systems' framework. This will promote research on waste of all types of resources including materials, energy, manpower, capital and services etc.
- c) Research efforts are required to develop suitable data structures and information

flow systems on WM aspects.

- d) The waste reduction function that has received little attention in the past is identified as the most crucial and appropriate avenue for further WM research.
- e) Rigorous research work should continue on recycling and making alternate uses of waste materials and environmental effects.
- f) In view of severe energy crisis the WM of energy resources will continue to be a promising research area.
- g) Manpower, capital and service waste should receive immediate attention.
- h) Considering complexities of the present day industrial systems and systems in other sectors, there is a great need to devise waste management system which provides guidelines to manage waste in practical situations.

CHAPTER III

DESIGN OF THE STUDY

The chapter deals with the overall design of the study, its major parts and phases. Details of work done in each phase and tools and techniques used have also been covered here.

3.1 AN OVERVIEW

This study has been divided into two major parts namely Analysis and Design. 'Analysis' includes all collected relevant information and data regarding the status of the subject in engineering industry, reasons thereof and corrective measures which can be profitably applied. 'Design' deals with developing a waste management system using the information as collected and analysed in the first part. The work has been carried out in four phases:

Phase 1: Survey on Waste Management in Engineering Industry

Phase 2: Case Studies - Empirical Analysis

Phase 3: Modelling for the Case Situations

Phase 4: Design of Waste Management System

Figure 3.1 depicts the relevance and importance of each phase for meeting the objective of design of a generalised WM system. Details regarding the work undertaken in each phase and tools and techniques employed for analysis are also given in the figure.

By conducting a survey through a specially designed questionnaire, in the specified region, the information on the status of various aspects of resource waste and its management in engineering industry has been gathered. This information has reflected the potential areas requiring improvement and further investigation and thus served as a useful input for case studies. Case studies were then conducted in an identified unit. One case study in each resource has been carried out. The prominent areas of waste, problems encountered in their management and other constraints were found out during the exercise. The case situation in each resource has been represented by suitable mathematical model and analysis of the model has been undertaken.

The information derived from survey and case studies has been synthesised and in conjunction with the literature on the subject has been utilised for the design of the WM

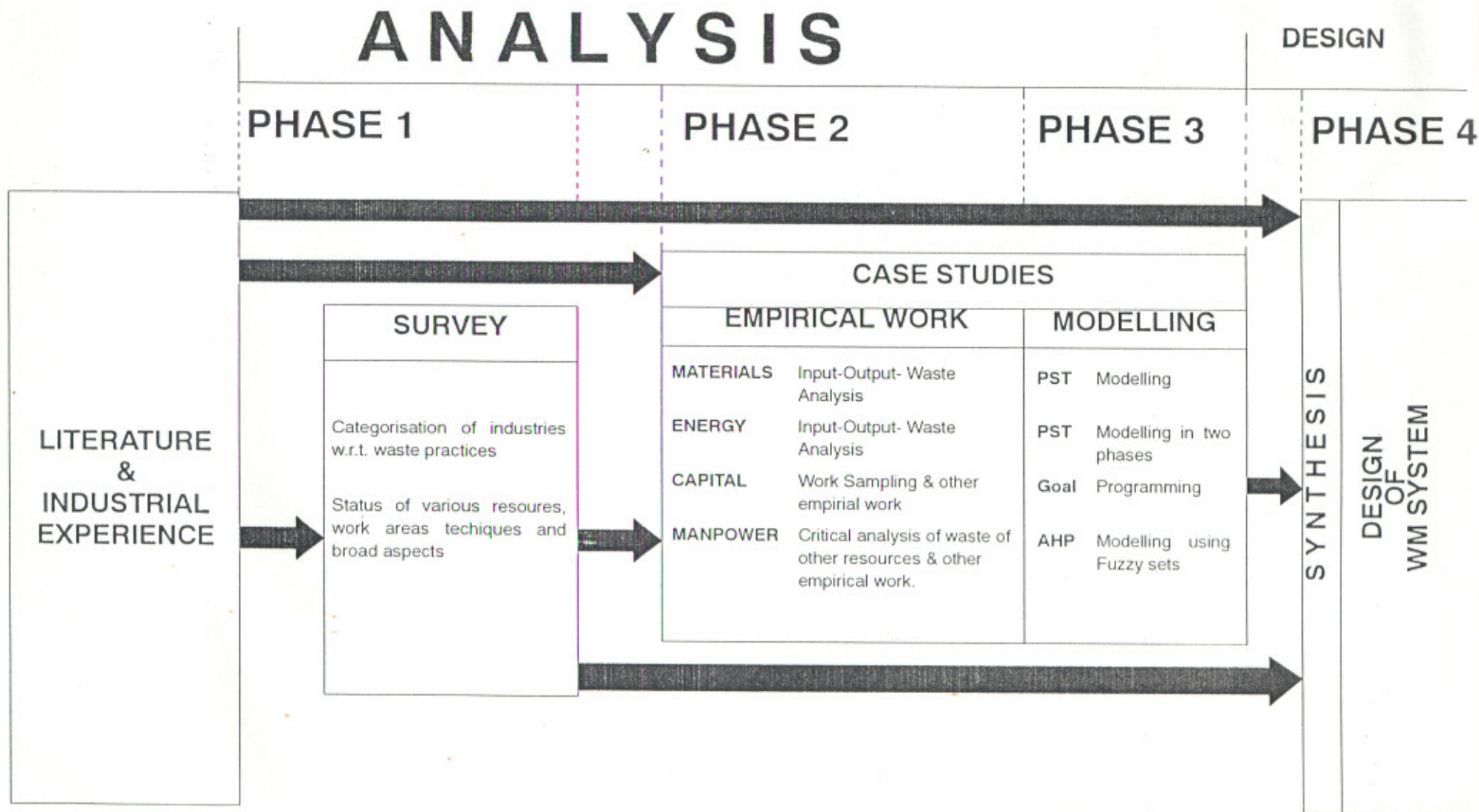


Fig. 3.1 Design of the Study

system.

3.1.1 Survey on Waste and Waste Management

Survey has been conducted using a specially designed questionnaire containing multiple choice questions. The steps involved in the survey are:

- a) Design of a suitable questionnaire.
- b) Standardisation of the questionnaire by pre-testing and incorporating the suggestions of the experts from industry.
- c) Conducting survey by mail and through personal visits.
- d) Compiling responses of the survey and doing the following analyses.
 - i) Categorisation of companies into various classes such as Very Good, Good, Fair, and Poor from waste management point of view. Total percentage score and standard deviation of each company is worked out and histograms plotted.
 - ii) Determining the status of various aspects of WM represented by individual question. Central tendency for the score of each question and standard deviation are worked out and scatter diagrams plotted.
 - iii) Determining the status of the broader aspects represented by set of questions. Central tendency and standard deviation of the broader aspects are worked out.

3.1.2 Case Studies

The case studies have been conducted at M/s Gabriels India Ltd, Parwanoo. This industry has varied types of processes which cover almost all types of human work i.e. manual work, working on machines with short cycle repetitive work and very long cycle repetitive work with the existence of unoccupied time. In addition, there is a large variety of products made which make the system complex. This unit was selected as it served best the objective of the study.

3.2. DESCRIPTION OF THE INDUSTRIAL UNIT

M/s Gabriels India Ltd., Anand Bearing division, the leading manufacturer of bi-metallic engine bearings in the country, was set up in 1978 in collaboration with M/s Federal Mogul of U.S.A.. In most of the engines manufactured in India, bearings manufactured by this company find their use as original equipment. As the company is

meeting the demands of a wide variety of engine and automobile manufacturers, a large variety of products are being made in this company. There are about 1600 types of bearings made here. Details of the products, processes employed and machinery used are presented below.

3.2.1 The Products

The products of the company are classified into four categories, i.e. straight bearings, flanged bearings, bushes and washers. They vary from one another with respect to their size and shape. Within each category, again, there is a large variation of size of the product.

The material used for the manufacture of all these categories of products is a bi-metallic strip. One side of this strip is made of steel which has the requisite strength and other mechanical properties commensurate with the fitment and location requirements of the bearings. The other side of the strip is made of a special alloy which has the bearing properties as required so as to cause least damage to the matching components and at the same time offer minimum of friction. Fig. 3.2 shows general construction of the product.

3.2.2 Material Flow and Layout Diagram

Powder metallurgy is used to produce bi-metallic strips. Firstly powder is made from its constituent elements by powder metallurgy. This powder is then sintered on one side of the steel strip. The bi-metallic strip thus made is cut into the required sizes. Subsequently various pressing and machining operations are carried out to make the finished product. Fig. 3.3 shows the flow of material through various sections of the factory.

Layout diagram of the factory, (Fig.3.4), shows the location of various departments. Materials coming from outside are received and kept in the stores after inspection. Powder plant is spread over three floors to suit the requirements of the operations to be carried out. Induction furnace, oil fired furnace and other equipment needed for melting operations are located on the first floor; the slurry tank and hydraulic equipment along with the powder grading equipment is located on the ground floor to take advantage of the gravity flow. The driers and related equipment like pumps and boilers are located on the second floor, thus making full use of the space available.

Sinter line is located on the extreme left side of the shop. The decoilers, sanders, first sintering apparatus, muffle furnaces, second sintering apparatus, slitting equipment are all located in the required sequence.

There are four lines of machines in the machine shop. In each line the first machine

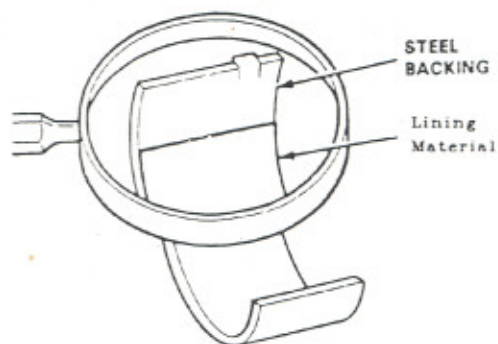


Fig. 3.2 : General construction of the product

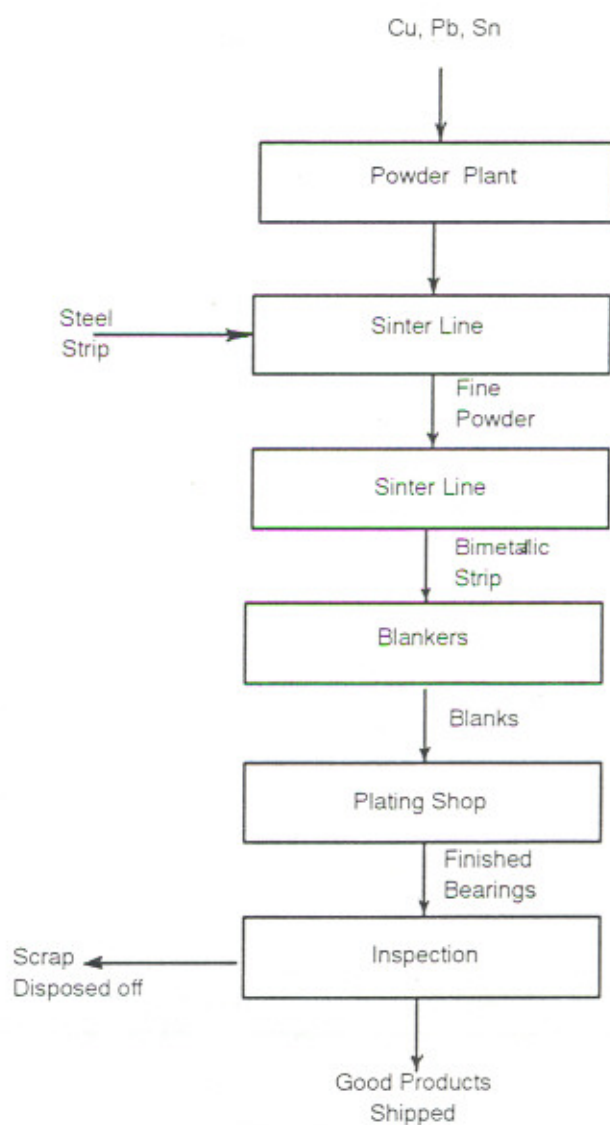


Fig. 3.3 : Material Flow

is a blanker and then subsequently machines for coining, facing and chamfering, broaching and other machining operations are located. Plating department is located just ahead of the final inspection and below the administrative block. Just adjacent to the plating plant is the laboratory. Ahead of the laboratory is the material receiving place. A store for keeping the steel strip and other materials is located near the receiving place. Packing department which is located on the other side of the plating department is another good example of efficient use of cubic space. This department is located on the first floor, above the accounts and administrative department. The shipment department is located alongside these departments and almost below packing. Thus gravity is again utilised in shipment here. The finished goods stores is located on one side of the packing department and ahead of the inspection department. Thus, it is found that the layout is well suited to the flow of material in the factory.

3.2.3 The Machinery

Almost all machinery and equipment used in powder plant and sinter line is imported machinery bought from the parent company, Federal Mogul of U.S.A.. In machine shop, though most of the machinery is again from Federal Mogul, but Indian machinery is also there, particularly the presses. But it is really sad to find that most of the imported machinery is outdated, particularly in the machine shop. Each machine does only a small single operation, where as just one look reveals that most of these operations can be combined and done on a single machine. Accordingly, material handling can also be automated.

3.2.4 Details of the Processes

As explained earlier, there are four different categories of products manufactured here viz; straight bearings, flange bearings, bushes and washers. A different set of machining operations are carried out on each of these categories. However, the operations of making powder and sintering remain the same for all types of the products. A brief description along with the flow chart of each section and of each category of products is given in the following sections.

3.2.4.1 Powder plant : Figure 3.5 shows flow of material through various operations in the powder plant. Various constituent elements of the alloy are heated until molten in the induction furnace. Just adjacent to the induction furnace, an oil fired furnace is heated all the time to maintain it at the required temperature. The crucible of this furnace has a hole in the bottom. When the alloy is made and it reaches the pouring temperature, the induction furnace is tilted and alloy is poured into the oil fired furnace. From the hole of the crucible

the alloy falls through a manifold. From another side of the manifold water at very high velocity strikes the molten metal and breaks it into powder. This powder, in the form of slurry falls into a slurry tank. From the slurry tank the slurry is pumped out and filled into rotating driers with the help of a pneumatic pump. After having been dried the powder is passed through a classifier where it is separated into fine and coarse powder. Fine powder is then passed to the blender and coarse powder is recycled. The output from the blender is finish powder ready to be used on the sinter line.

3.2.4.2 Sinter line : Rolls of steel strip in the required width and thickness are bought from outside parties. First operation to be done on the strip is its degreasing. For this purpose it is passed through alkaline solutions at elevated temperature followed by washings. Sanding is done to make the strip surface rough so that powder can be easily deposited on it. The steel strip is then passed through the rollers to straighten it. Requisite quantity of powder is then spread on the strip to make the desired thickness of the powder side. It is then passed through the muffle furnace in which high temperature is maintained. After passing through long length of the muffle furnace, the powder gets sintered on the strip. This bi-metallic strip is then passed through rollers for pressing. Second sintering is, then, done followed by rerolling. Fig. 3.6 shows the details of operations done on sinter line.

3.2.4.3 Machine shop and plating : Blanking is the first operation to be done in the machine shop. After that a different set of operations are done on different categories of products. The flow charts of the operations done on various products are given in Fig.3.7 to 3.10.

3.3 STEPS OF ANALYSIS IN CASE STUDIES

Before conducting studies, timing and duration of each study was decided to account for all fluctuations in the industrial working. It was observed that during a month there are a lot of fluctuations in the output and type of work, particularly between the beginning and end of the month. So one month was decided as the minimum period for any analysis. Care was also taken to select the timing in such a way so that it does not coincide with any abnormal happening in the factory, e.g. strike or settlement time etc.. Prior arrangements regarding the installations of equipments like energy meters were made and concerned people were requested to maintain data in the required form.

3.3.1 Case Study - Materials

An overview of analysis undertaken and tools and techniques used in this case

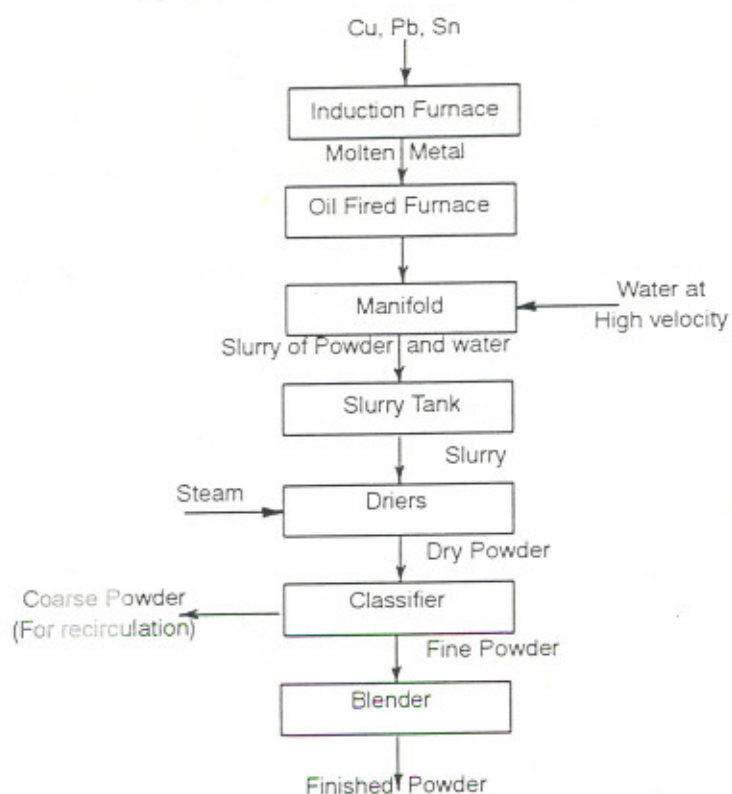


Fig. 3.5 : Operations on Powder Plant

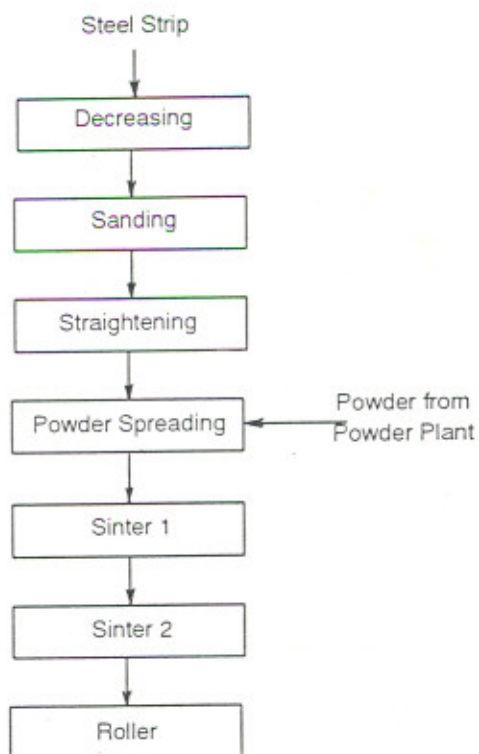


Fig. 3.6 : Operations on Sinter Line

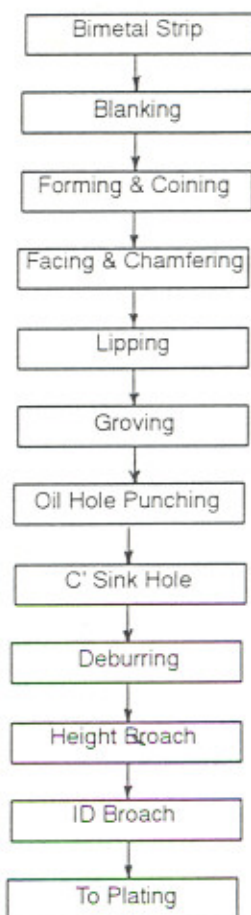


Fig. 3.7 : Flow chart Bearing Manufacture

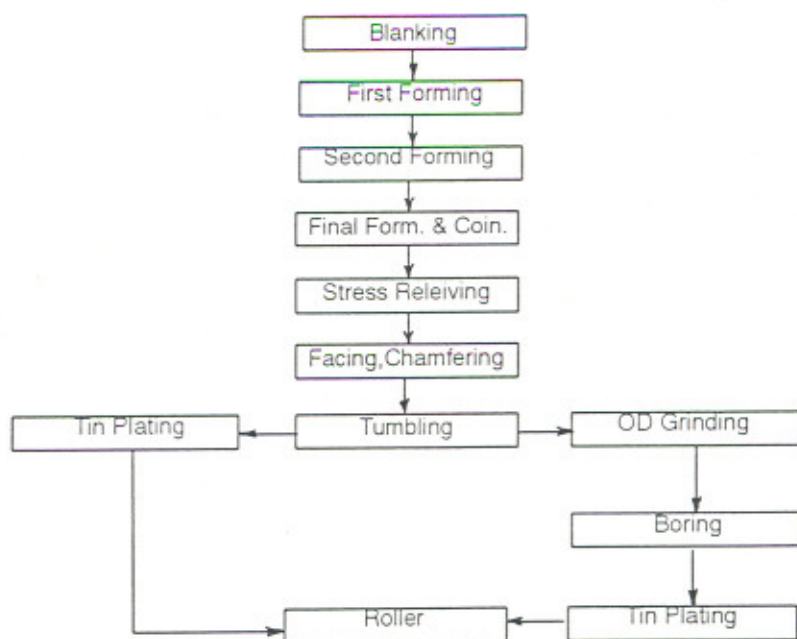


Fig. 3.8 : Flow chart Bush Manufacture

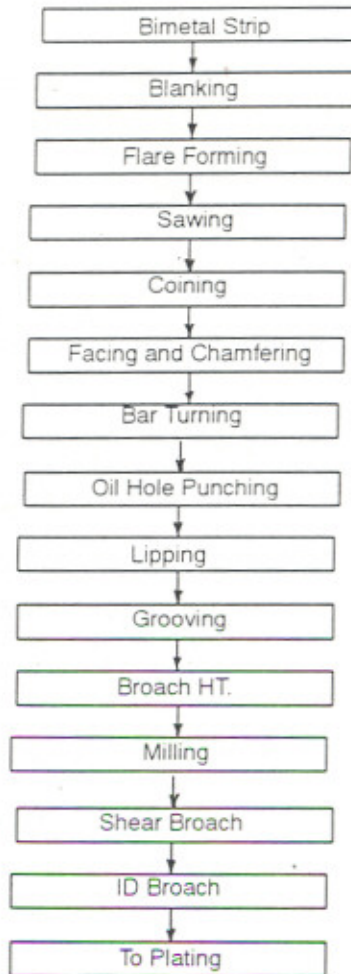


Fig. 3.9 : Flow chart Flange Bearing Manufacture

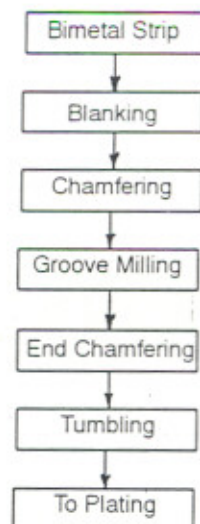


Fig. 3.10 : Flow chart Thrust Washer Manufacture

study are:

- a) Divided the overall system into identifiable sub-systems.
- b) Conducted empirical analysis of finding out areas and quantum of waste in each sub-system using Input - Output - Waste analysis.
- c) Listed probable reasons of these wastages and alternate solutions to reduce waste.
- d) Modelled the case situation using physical system theory model. This involved:
 - i) Calculation of waste percentages of each stage on output of that stage.
 - ii) Calculations of fixed costs and variable costs associated with the products.
 - iii) Representation of the case by system graph of the PST model.
 - iv) Calculations of input requirements at each stage for final output of 1000 kg. by using model equations of through variables.
 - v) Calculations of unit cost of the product at each stage by using model equations of across variables.
 - vi) Application of sensitivity analysis to find out the effect of wastes of various stages on the final cost.

3.3.2 Case Study - Energy

The steps of analysis and tools and techniques used in this case study are:

- a) Divided the system into identifiable sub-systems.
- b) Recorded the inputs of energy and output of materials from each sub-system during the study period.
- c) Calculated the energy consumed by each sub-system using energy meter readings directly or by using wattage and running time.
- d) Calculated the energy which should have been consumed by a sub-system, using number of operations done, wattage of the equipment and time taken to do one operation. These were found out as under:
 - i) Number of operations done were taken from actual production records.
 - ii) Wattage of equipment was noted from equipment itself or from the catalogues.
 - iii) Times for operations were recorded by conducting special studies under complete supervision.
- e) Found the difference of (c) and (d) and calculated waste.

- f) Listed probable reasons of waste. Alternate solutions have also been discussed.
- g) Modelled the case situation using PST model in two stages. Following steps were undertaken.
 - i) Calculated wastes of materials and energy of each stage on output of that stage.
 - ii) Represented the flow of materials and unit energy as through and across variables respectively in the first stage of PST and calculated input requirement of energy for 1000 kg. output of materials output.
 - iii) Represented the flow of energy and its cost as through and across variables respectively and calculated the requirements of energy at each stage taking all energy wastages into account. The actual energy content of the product at each stage has also been calculated by using model equations.
 - iv) Conducted sensitivity analysis and found out the effects of wastes of various stages on final energy cost.

3.3.3 Case study - Capital

Various analyses done and techniques used are:

- a) **Machine Utilisation Studies:** Standard work sampling technique has been employed to determine utilisation of both machines and plant as well as the under-utilisation due to various factors.
- b) **Machine utilisation with respect to its capacity to process size and weight of the job.** This has been done by finding out the difference of weights of each product with the weight of the heaviest product. This difference multiplied by the quantity of products has been taken to be a measure of under-utilisation.
- c) **Determination of plant capacity and checking line balancing.** This has been calculated considering standard times of operations for 25 working days, three shifts a days and six hours of effective working assuming a stream factor of 25%. Capacity of machines doing similar operations have been clubbed to find out:
 - i) Extent of non-balancing of lines.
 - ii) Actual capacities available for various categories of products.
- d) **Automation levels:** Data regarding the production rates, safety and labour requirements of the existing machines and that of some proposed machines has been compared. An approximate assessment of the loss suffered in the past few

years due to non- automation and non-modernization has been made.

- e) **Inventory levels:** Physical inventory exercises were conducted for a number of times in the beginning, middle or end of the month during the study period and average inventory levels worked out.
- f) **Modelling:** Due to multi-objectivity, goal programming model has been applied. Multiple objectives of maximisation of profits, utilisation levels, weight processed etc. have been selected and constraints defined. The model has been solved to determine the product mix meeting various priority structures of the goals.

3.3.4 Case Study - Manpower

The analyses undertaken and the tools and techniques used in this resource are:

3.3.4.1 Determining waste of other resources due to manpower : Areas of wast- ages of materials, energy and capital have been critically analysed and possibility and extent of human error at various levels causing these wastages have been found.

3.3.4.2 Determining wastage of manpower : In this regards following analyses have been done.

- a) **Waste due to overstaffing :** This has been found for each department as the difference of actual number of persons employed in a department and those required to carry out the desired operations. The latter has been determined using different techniques for different type of human involvement. Multiple activity charts have been drawn for powder plant which has very long cycle repetitive work. A similar approach has been used for sinter line. For machine shop which has a very short cycle repetitive work, standard times have been calculated and used.
- b) **Waste due to overtime:** The actual figures of overtime working in each department and its monetary value have been compiled for one month and waste worked out by comparing with installed capacity.
- c) **Waste due to strikes, lockouts and disputes:** All major strikes, lockouts and disputes in the past five years have been analysed and resulting waste assessed.
- d) **Waste of skill:** The nature of involvement of the workmen on their allotted work, their grades and skill levels have been critically analysed to assess this loss.

3.3.4.3 Analysis to assign reasons for waste : For this purpose every aspect of human working in the company has been studied e.g. HRD policy, motivational measures and benefits given to the workers, methods of selection, training and placement, incentive

scheme, organisational set up, PPC procedure, shop floor control system, absenteeism and turnover levels, opportunities for growth, unions, type of management and so on. An attempt has been made to identify the factors responsible for waste. A number of measures have been suggested for improvement.

3.3.4.4 Qualitative modelling : A qualitative model using OFM (Options Field Methodology) OPM (Options Profile Methodology), AHP (Analytic Hierarchy Process) and Fuzzy sets, has been applied to generate a number of alternate strategies to reduce manpower waste and choose the best strategy in the given situation. Due to the ambiguity present in the human activity systems and the complex problem of reduction in manpower waste, a qualitative model has proved to be quite suitable.

A number of experts were invited for creative thinking and modelling. A triggering question was asked (fired) and the process began. This involved.

Step 1 Options field methodology:

- i) Listing of various options as solutions and generation of a polystructure.
- ii) Making categories from options
- iii) Making dimensions from categories
- iv) Clustering of the dimensions
- v) Ordering of clusters
- vi) Ordering of dimensions within clusters.

Step II Options profile methodology:

- i) Making various profiles as a solution to the problem
- ii) Drawing tie line and allocating various options to the profiles.

Step III Analytic hierarchy process modelling (AHP):

- i) Listing various criterion (goals) or objectives.
- ii) Doing paired comparison of goals and assigning numerical values.
- iii) Calculating weighted sum of goals by Eugene Vector
- iv) Finding out the comparative contribution of each profile towards each goal and quantifying it.

Step IV Fuzzy set theory :

- i) Finding out of optimistic, pessimistic and average position matrix.
- ii) Making dominance matrix.

- iii) Ranking the profiles.
- iv) Making different plans to achieve goals with varying degrees of optimism.

3.3.5 Recording of other details of industrial working

Other details of the industrial working regarding maintenance of data and records, organisational set up, process rigidities and constraints, general responsibilities of the people and their routine, emphasised and neglected areas in the industry and so on were noted.

3.4 SYNTHESIS AND DESIGN OF WM SYSTEM

Broad outcomes of survey and case studies have been listed, conclusions drawn and synthesised. Based on this information and the literature available the WM system has been formulated. For deciding the format of the proposed system and the priority and criticality of various areas of waste and solution techniques, expert opinion of people from industry has been sought and appropriately incorporated.

CHAPTER IV

SURVEY FOR WASTE MANAGEMENT STATUS

A detailed survey has been conducted in engineering industries in the states of Punjab, Haryana, Himachal Pradesh and the Union Territories of Delhi and Chandigarh. The objective of the survey has been to assess the status of waste management in the specified industry, i.e. awareness regarding resource scarcity and wastage levels; knowledge of ways and means used for identification, reduction and management of resource waste; extent of use of these techniques and the level of interest shown by the industry for improvement. After analysis, this information has served as a useful input for case studies and for formulation of the WM system.

4.1 METHODOLOGY

For survey the first task has been to design a questionnaire which seeks information on all diverse aspects of waste and its management in engineering industry. The questionnaire was pre-tested and survey conducted in the industry. Survey is also carried by mail and by undertaking personal visits. The response was compiled and analysed to find the status of various companies with regard to waste and its management, the status of each aspect as represented by a question or a set of questions and the existence of departments or running of programmes by the industrial units aimed at managing waste. Statistical techniques of central tendency, standard deviation and frequency distribution or bar charting have been applied. Details of the analysis are presented in the subsequent sections.

4.2 DESIGN OF THE QUESTIONNAIRE

A comprehensive questionnaire covering important areas of resource waste has been specially designed. The questionnaire has been divided into three sections. Section 1 seeks information on the general aspects of the industrial units, e.g. authorised capital, products made, number of employees etc.. Section 2 contains four sub-sections: one each on materials, energy, manpower and capital. Each sub-section has been devoted to multiple choice questions on almost all areas of resource usage and its wastage. A scale of four has been provided for response. While designing the questionnaire time constraints for people in industry, reluctance to furnish information on a subject like waste and the actual form in

which this information would be available with the industry, were taken into consideration. Section 3 invites suggestions and feedback regarding any specific problem faced by the industry. (App.)

4.2.1 Pre-testing of the Questionnaire

The questions are framed to cover all stages of resource usage, i.e. its selection, acquisition, use and disposal. Backed by industrial experience, it helped evolve a simple, relevant and comprehensive questionnaire. To ensure the effectiveness and relevance of the questions to the industry, the suggestions given by senior executives from industry and academicians were incorporated. The questionnaire, thus made, was pre-tested on a random sample of the industry chosen on statistical basis covering every region, size and products of the industries to be surveyed (Appendix A1). In the light of the information received, the questionnaire was revised again.

4.3 INDUSTRIES COVERED

Engineering industries in the states of Punjab, Haryana, Himachal Pradesh and Union Territories of Delhi and Chandigarh, with an authorised capital of over rupees one crore were considered. A list was prepared by referring to the directories of industries (Kothari,1990). A total of 176 industries were selected.

4.4 CONDUCTING THE SURVEY

In the first place the questionnaire was mailed to all the 176 industrial units along with a write-up on the objective of the survey and its usefulness for the industries. A request to respond at the earliest was made and subsequently reminders were also sent. Personal visits were also undertaken to most of the industrial units. (65 units)

4.5 RESPONSE TO THE SURVEY

In spite of all efforts, the response of the industry, though satisfactory and adequate, was not upto the expected level. Table 4.1 shows the response of different categories of the industries.

In all 51 industries out of a total of 176 responded. 167 of the total industries were from private sector, out of which only 27% responded. As compared to this the public sector response was overwhelming with 67% of the industries responding to the questionnaire. This might be due to the hesitation of the private sector managers to furnish information on a subject like waste.

Table 4.1
Response of the Industry.

S.No	Classification	Questionnaire Sent To	Response	
			Number	Percent
1.	All units	176	51	29
2.	Private sector	167	45	27
3.	Public sector	9	6	67
4.	Large scale	43	16	37
5.	Medium scale	103	29	28
6.	Small scale	30	6	20

Analysing it scale-wise the maximum response received is from large scale (37 %) followed by medium scale (28%) and then small scale (20%). This indicates the unorganised way in which the small scale units work. Due to centralised control, the owner is either too hesitant or is not in a position to furnish information. Medium scale also has some of these reasons whereas the large scale industry looks to be more organised, keeps the records and appears to be open to furnish information.

4.6 SCORING AND STATISTICAL ANALYSIS

The list of industries along with other details was made in DBASE III PLUS . More fields were added to this file, one each for a question given in the survey form. The response received from the industry was then fed to this file after converting the choice ticked to its corresponding score in case of each question. This file was subsequently manipulated to carry out analysis of the response.

4.6.1 Scoring

In section 1 of the questionnaire most of the questions seek information in the form of 'Yes' or 'No'. This information has not been used to find out the total score of the company, rather it has been compiled to give some useful qualitative information. Some questions in section 1 and almost all questions in section 2 have a scale of 4. The score of 4 was assigned to the best choice, 3 to the second best, 2 to the next in order and 1 to the lowest choice.

The score of all the companies were fed to the computer and were analysed to derive useful information.

4.6.2 Analysis

The analysis of response was carried out from three view points:

- i) To determine percentage of the companies in various categories which have certain departments working for waste management or have conducted some programmes to manage waste;
- ii) To assess overall standing of each company leading to categorisation or classification of companies into very good, good, fair and poor classes.
- iii) To assess as to how each aspect as represented by a question or a group of questions is being looked after in industry.

The second part amounted to finding out total score of each company whereas the third part was concerned with total score of each question or a group of questions.

4.7 EXISTENCE OF DEPARTMENTS / PROGRAMMES

Based on response to section 1 of the questionnaire, information concerning the existence of departments or running of programmes for managing waste has been compiled. Table 4.2 shows status of existence of various departments in various companies in terms of the percentage of responding industries having that department.

Table 4.2
Existence of Departments and Programmes

S No	Department or Programme	Scale *			Sector *		Total %age
		L	M	S	PB	PR	
		%age			%age		
1.	WM Deptt.	19	48	33	38	33	37
2.	Industrial Engg. Deptt.	75	72	33	67	83	69
3.	Research and Development Deptt.	63	69	33	62	67	63
4.	Material Conservation Programme	56	52	17	49	50	49
5.	Energy conservation Programme	63	48	49	49	50	49
6.	Environment Conservation Programme	56	38	0	42	17	39
7.	Formal Work Study Programme	63	38	17	42	50	43

* L → Large, M → Medium, S → Small, PB → Public and PR → Private

A department entrusted with the task of managing resource waste exists in nearly one third of the industries. About two third of the responding industries have an Industrial

Engineering Department and a Research and Development Department. Regarding doing extensive exercises aiming at reducing waste nearly half of the industries have conducted materials conservation programme and a similar number have gone in for energy conservation programme. A little less than half of the industries have addressed the problem of setting time standards and improving methods of doing work through running a Work Study programme. Environmental conservation programme has been run by about 39% of the industries.

Scale-wise, sector-wise or even region-wise performance of industries with respect to these aspects is almost the same barring small scale which has the lowest percentage of these departments or programmes.

4.8 CLASSIFICATION OF COMPANIES

Total score of each company in individual resource of materials, energy, capital and manpower has been calculated from the raw scores. The gross total of each company has also been calculated. There were certain questions which were not applicable to some companies e.g. melting, casting or heat-treatment equipment may not be existing in every company. Therefore the total score of each company has been divided by its maximum possible score to arrive at the percentage score of each company. For categorisation of companies, following method was used.

While deciding upon the choice carrying highest marks in each question, the levels achievable by the Indian industry were taken into consideration. Requirements for the highest score are definitely lower than the best in the world, i.e. use of advanced packages, robots, FMS or TQM and so on. Thus, a score close to 100 will only be considered very good. Further, a company will score just 25% marks if all its answers to various questions fall at the lowest choice and will get 100% marks if all the boxes ticked are of the highest score. This way following scale has been finalised.

Based on above criteria companies have been classified into various categories as shown in Table 4.3 and histograms of Fig. 4.1. Here, classification of companies has been done in each resource as well as in all resources taken together. A comparison of standing of the companies in various resources has also been carried out.

Further, standard deviation and average of scores of the companies in individual resource area and of overall score has also been calculated to assess how much does a company differ from others with respect to its standing. The averages and standard deviations are shown in Table 4.4. The average score of various sectors, scales and regions

has also been calculated in order to compare performance of the companies amongst themselves and to derive out some useful information.

Catg. No.	Score	Inference	Grading
1.	25-30%	Industry at the lowest stage. Nearly all responses to the lowest choice box on an average.	V. Poor
2.	31-50%	Industry between lowest to the next stage. Nearly all responses to third or fourth choice on an average.	Poor
3.	51-75%	Nearly all the responses to second or third choice on an average.	Fair
4.	76-94%	Nearly all responses to first and second choice on an average.	Good
5.	95-100%	Nearly all responses to the highest choice	V. Good

Table 4.3

Range of Percentage Score of Companies

Range of score	No. of Companies				Total
	Materials	Energy	Manpower	Capital	
30-35		9			
35-40		6	1		
40-45		3	2		
45-50	1	4	7	2	4
50-55	3	2	4	2	7
55-60	10	5	3	2	7
60-65	6	3	3	2	5
65-70	8	6	7	4	6
70-75	8	7	6	7	10
75-80	6	2	5	10	4
80-85	6	2	7	11	6
85-90	1	2	5	2	2
90-95	2		1	4	
95-100				4	
Average	69%	59%	68%	77%	
SD	10.83	17.03	15.11	12.35	

From the histograms following important facts have emerged:

- i) A total of 8% of the companies fall in 'poor' grade. About two third of the companies are doing fairly well, only one fourth are at a good level. No

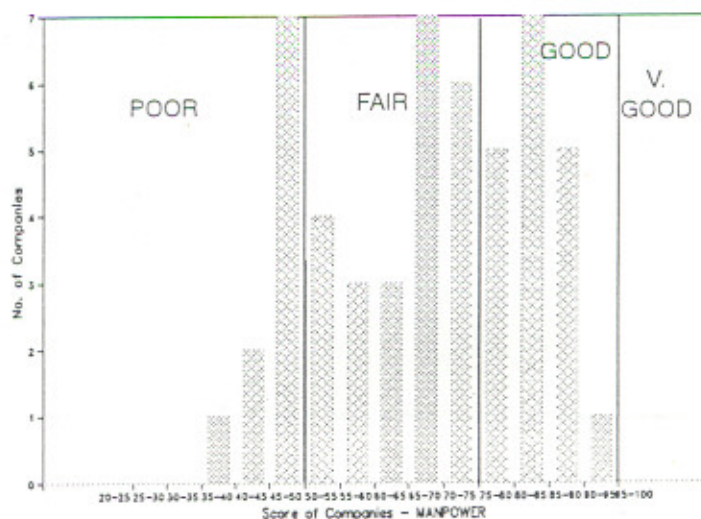
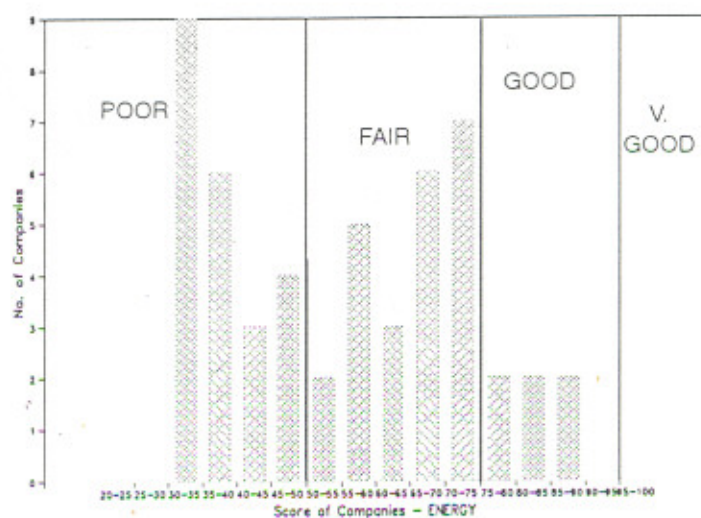
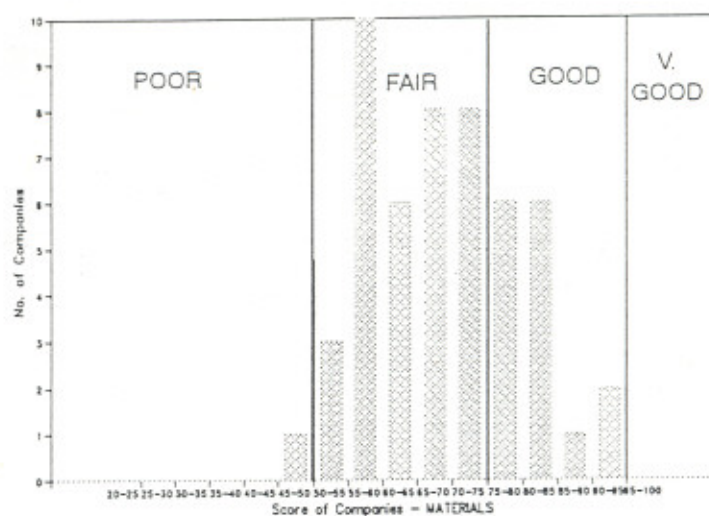


Fig 4.1 (a, b & c) : Status of Companies in Materials, Energy & Manpower

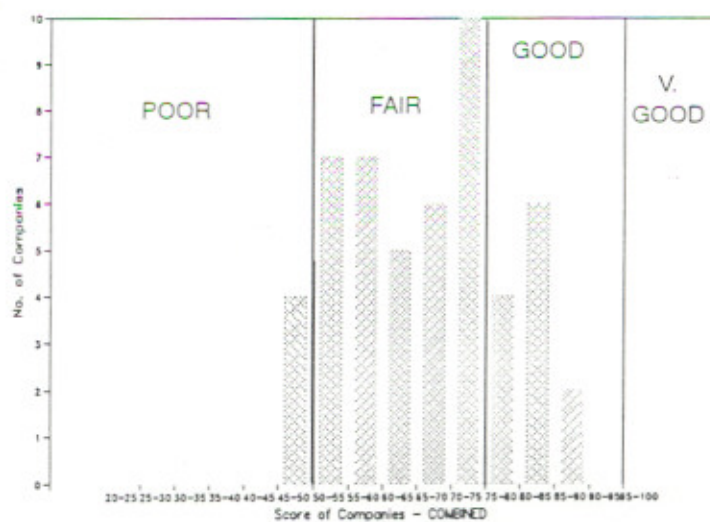
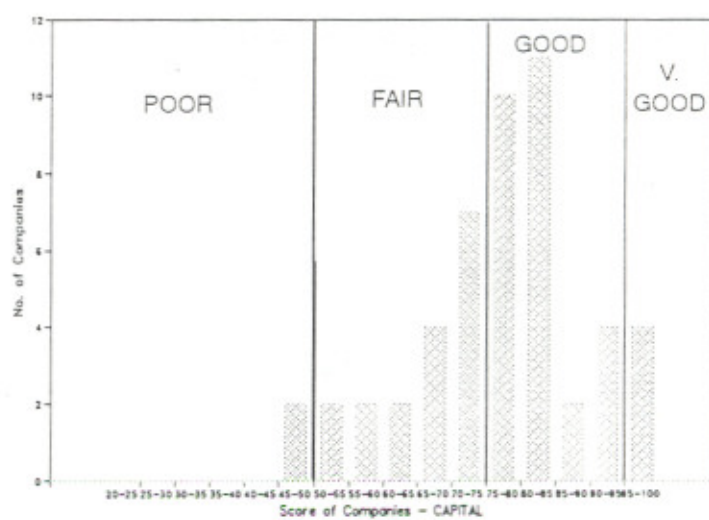


Fig 4.1 (d & e) : Status of Companies in Capital & Combined

company is at a level where each one should be.

- ii) Performance of the companies is the worst in 'Energy' where the average score is only 59%. A little less than half of the companies are in the poor range as far as energy waste management is concerned. Nearly 45% are doing fairly well and about 12% are at a good level. No company is doing very well in this resource.
- iii) Manpower with an average score of 68% becomes the next critical area. One fifth of the companies adopt those measures for management of manpower waste which render them a poor scorer. A little less than half of the companies get a fair grading, nearly one third are at a good level and no company is able to achieve a very good score.
- iv) Materials are the next in order of scoring having got an average score of 69%. A very low percentage (2%) of the industries are managing this resource very poorly indicating that most of the companies have put in efforts in this direction. A very large percentage (69%) of the companies fall in the fair class and 16% are at a good level. Even this resource is not being managed so well by any of the companies to achieve a very good rating.
- v) In case of capital which comprises of machine utilisations, inventory levels and other related aspects, a highest average score of 77% has been received. Only 14% of the companies get a poor rating, 34% are at a fairly good level. This resource has the highest number of companies at a good level (55%) and a fairly good percentage (16%) of the companies are doing very well.

From the above analysis it can be concluded that from the point of view of resource waste management, energy is the most critical area which requires more attention followed by manpower, materials, and capital. It is felt that materials, being a physical and tangible commodity attracts some measures itself and some attention is paid towards its management. Same can be said about capital, machinery, equipment and inventories. In case of energy, the basic problem, it looks, lies in the ignorance about energy to be spent on an operation and thus, unawareness of the amount of waste being caused. Manpower, though has been looked after fairly well has not responded to the measures adopted here to fore. Further it is seen that in all the resources most of the companies fall in poor and fair categories (materials 70%, energy 88%, manpower 64%, capital 37% and overall 76%).

It can be concluded from this that the industry is generally employing third level techniques and that they need two steps to come to an acceptable level.

Next, the average score of each category of companies and the standard deviation have been worked out for each resource (Table 4.4)

TABLE 4.4
Average and Standard Deviation of Scores.

S. No	Category	Average Score * / Standard Deviation *							
		Material		Energy		Manpower		Capital	
		Sc	Sd	Sc	Sd	Sc	Sd	Sc	Sd
1.	All Companies	69	10.83	59	17.03	68	15.11	77	12.35
2.	Private Sector	69	10.61	55	16.34	68	14.87	76	11.82
3.	Public Sector	72	9.74	53	20.22	64	16.29	79	14.27
4.	Large Scale	71	10.35	63	13.76	72	12.06	79	14.27
5.	Medium Scale	70	10.35	54	17.80	67	16.28	77	11.66
6.	Small Scale	62	12.47	44	11.90	59	12.34	72	11.56

* Sc → Score, Sd → Standard deviation

The average score and standard deviation of the various companies reveal the following -

- Energy has the lowest score followed by manpower, materials, and capital.
- Scale wise or sector wise there is marginal variation in the average score of the companies except in the case of small scale whose score in each resource is poorer than all other categories.
- Standard deviation is the highest in case of energy, depicting that in case of energy waste, and its management, large variations exist amongst the companies. In case of manpower also these variations are quite large followed by capital and materials.

4.9 STATUS OF VARIOUS ASPECTS

From the file of raw data, the sum of scores of each question in all the responding companies have been found out by considering the number of choices of each type ticked and the score of each choice. This score has been divided by the maximum score a question could have got considering that this question was not applicable to some companies. The fraction score, thus arrived at has been multiplied by 4 to find out the mean or central

tendency of each question. Standard deviation of these mean values has also been computed in order to compare how each of the areas represented by questions are being looked after in comparison to others.

This has been done separately for each resource. Table 4.5 gives a brief description of the area represented by each question on materials, number of responses to various choices carrying 1,2,3 or 4 marks, number of respondents to the question and calculations and values of average score achieved by various companies in materials. Tables 4.6, 4.7, and 4.8 depict the same for energy, manpower and capital respectively.

The average score of each question reflects as to how area represented by a question is being looked after. The results are discussed below.

The grand average of score of materials, energy, manpower and capital are 2.8, 2.3, 2.7 and 3.33 respectively as depicted by Fig. 4.2. Figure also depicts the status of each aspect contained in a question in comparison to other aspects. How many aspects are below or above average and how much is the total spread depicting the variation in care about an aspect by different companies has been revealed by the figure. Further, a score close to 1 shows that the status of the aspect is such that techniques listed at the fourth choice in the questionnaire are generally in use. Similarly a score near 2 reflects the use of third level techniques, score of 3 reflects the use of second level techniques and a score of 4 shows the use of the best techniques listed at choice number one. The above average scores depict that third level techniques are used in case of most of the aspects in energy, second level in materials and manpower and first and second level in case of capital.

4.9.1 Materials

Very little emphasis is laid on selection of suitable materials for making jobs. In some companies they are selected arbitrarily or conventionally. Majority of the companies are using materials as the trend is. But some, about 30%, have addressed themselves to this problem and have even gone in for value analysis. Nearly half the respondents do not go in for a long term policy regarding which part of the product should be made or bought. A cost benefit analysis is not done in such cases.

Use of computers for updating inventory records, making production schedules, calculating material requirements and storing and using standard data is reported to be very poor. Only 15% are using computers to advantage. Rest use manual cardex systems, scattered records or even memory of people.

TABLE 4.5
Score of various questions - Materials

Q. No.	Aspect	No. of Rps	Choice No. in questionnaire				CT
			1	2	3	4	
M1	Decision regarding materials	51	5	5	25	16	3.02
M2	Decision regarding buy or produce	50	1	14	9	26	3.20
M3	Making production schedules	51	2	29	13	7	2.49
M4	Materials requirements planning	49	9	17	19	4	2.37
M5	Emphasise the dates to vendors	51	1	5	24	21	3.27
M6	Establishing economic order quantity	51	7	16	18	10	2.61
M7	Establishing reorder point, lead time	49	4	14	19	12	2.80
M8	Incoming inspection	51	0	16	16	19	3.06
M9	Inspection procedure	51	2	28	14	7	2.51
M10	Updating of inventory	51	0	16	23	12	2.92
M11	Physical storage	50	4	13	9	24	3.06
M12	Handling from stores	51	5	30	15	1	2.24
M13	Physical inventory exercise	50	12	4	22	12	2.68
M14	Difference in physical inventory	50	3	5	11	31	3.40
M15	Establishing buffer stocks	47	6	11	23	7	2.66
M16	Investment to turnover ratio	43	7	9	11	16	2.84
M17	Classification into A, B, C items	51	12	13	14	12	2.51
M18	Money bound in obsolete items	50	6	7	16	21	3.04
M19	Money blocked in unrecognisable items	50	4	8	8	30	3.28
M20	Consumption of indirect materials	51	2	19	20	10	2.75
M21	Efforts to save indirect materials	51	3	24	18	6	2.53
M22	Inprocess scrap	49	1	11	11	26	3.27
M23	Using SQC techniques	51	13	12	19	7	2.39
M24	Raw material suitability	42	0	10	17	15	3.12
M25	Difference in chips collection	45	19	1	3	22	2.62
M26	Collection system	47	7	36	3	1	1.96
M27	Recycling status	51	7	9	17	18	2.90
M28	Reasons of not recycling	41	2	5	8	26	3.41

Q → Question Rps → Responses CT → Central Tendency

TABLE 4.6
Score of various questions - Energy

Q. No.	Aspect	No. of Rps	Choice No. in questionnaire				CT
			1	2	3	4	
E2	Awareness about energy consumed on each product	48	29	2	11	8	2.04
E3	Use of energy audit, energy analysis etc	51	20	11	14	6	2.12
E4	Awareness of energy consumed on each operation	51	19	11	14	7	2.18
E5	Awareness of theoretical amount of consumption	50	22	10	12	6	2.04
E6	Awareness of practically minimum consumption	51	24	11	10	6	1.96
E7	Awareness of energy consumption per unit weight	49	25	11	11	2	1.80
E8	Consideration of energy factor in purchasing M/C's	51	2	19	14	16	2.86
E9	Suitability of size of equipment to jobs	51	13	4	24	10	2.61
E10	Suitability of motors to machines	51	14	2	24	11	2.63
E11	Energy consideration in equipment installation	50	11	13	8	18	2.66
E12	Energy consideration in machine layouts	50	13	7	7	20	2.56
E13	Comparison of consumption of old and new machines	50	26	10	8	6	1.88
E14	Status of renovation or disposal of inefficient M/C's	51	28	14	9	0	1.63
E15	Establishing standards for energy consumption	49	16	18	12	3	2.04
E16	Awareness of operating efficiency of furnaces	45	8	15	16	6	2.44
E17	Awareness of rated efficiency of furnaces	44	6	13	21	4	2.52
E18	Awareness of waste of heat with flue gases	44	18	16	8	2	1.86
E19	Installation of heat exchangers	45	19	19	5	2	1.78
E20	Waste due to weak insulation	44	18	14	10	2	1.91
E21	Efforts to improve insulation	45	5	22	9	9	2.49
E22	Creating awareness about energy scarcity	51	3	25	13	10	2.59
E23	Selection of fuel	47	3	17	14	13	2.79
E24	Awareness of energy waste during breakdowns	48	7	19	18	4	2.40
E25	Awareness of energy waste during power failures etc.	44	1	2	33	8	3.09

Q → Question Rps → Responses CT → Central Tendency

TABLE 4.7
Score of various questions - Manpower

Q. No.	Aspect	No. of Qs	Choice No. in questionnaire				CT
			1	2	3	4	
H1	Calculations of manpower requirements	51	0	19	25	7	2.76
H2	Interviewing methods	51	0	22	20	9	2.75
H3	On the job training	51	4	18	14	5	2.00
H4	Job rotation and placement	51	17	11	17	6	2.24
H5	Facilities for welfare of employees	51	4	23	16	8	2.55
H6	Labour turnover levels	50	0	13	30	7	2.88
H7	Occurrence of strikes and lockouts	51	1	8	33	9	2.98
H8	Level of employee output	51	11	15	23	2	2.31
H9	Cooperation in time studies	50	13	9	23	5	2.40
H10	Implementation status of time study results	50	11	12	18	9	2.50
H11	Reactions to automation	51	8	15	8	19	2.71
H12	Reactions to change in jigs and fixtures	51	8	14	9	20	2.80
H13	Effective working hours	51	5	15	19	12	2.75
H14	Reactions to shifting workers to other machines	50	4	14	19	13	2.82
H15	Reactions to shifting Unskilled workers to other jobs	50	1	14	13	22	3.12
H16	Reactions to giving two machines to one operator	48	21	4	10	13	2.31
H17	Due punishment for indiscipline	50	6	18	11	15	2.70
H18	Actions taken against workers reporting in wrong shifts	50	6	19	8	17	2.72
H19	Absenteeism level	51	0	12	22	17	3.10
H20B	Type of incentive scheme	39	0	5	16	18	3.33

Q → Question Rps → Responses CT → Central Tendency

Only 20% of the companies have worked out economic order quantities, lead times and reorder points. Rest are using second line or adhoc approaches. Incoming inspection which generally should be very strict is looked after well only in about one fourth of the companies. Others use some inspection and in some cases it is sorted out at subsequent production stages.

TABLE 4.8
Score of various questions - Capital

Q. No.	Aspect	No. of Qs	Choice No. in questionnaire				CT
			1	2	3	4	
C3A	Utilisation of NC\CNC machines	18	2	0	0	16	3.67
C3B	Utilisation of SPM's	47	1	4	2	40	3.72
C3C	Utilisation of GPM's	46	1	1	9	35	3.70
C3D	Equipment utilisation	47	2	3	7	35	3.60
C4A	Loss of utilisation due to breakdowns	49	4	4	25	16	3.08
C4B	Loss of utilisation due to worker attitude	48	2	15	11	20	3.02
C4C	Loss of utilisation due to power shortages	49	4	3	9	33	3.45
C4D	Loss of utilisation due to material shortages	47	8	6	9	24	3.04
C4E	Loss of utilisation due to shortage of orders	45	7	1	9	28	3.29
C4F	Loss of utilisation due to other factors	14	5	2	2	5	2.50
C5	Selection of processes and operations	50	2	14	24	10	2.84
C6	Maintenance strategy	50	8	15	22	5	2.48
C7	Plant capacity decisions	50	7	10	18	15	2.82
C8	Orders position	50	3	7	12	28	3.30
C9	Aggregate planning	50	1	28	13	8	2.56
C10	Considering future expansions for plant size decisions	50	0	6	28	16	3.20
C11	Calculations of equipment requirements	50	1	15	13	21	3.08
C12	Procedure adopted for purchase of assets	50	0	8	21	21	3.26
C13	Upgradation in technology	50	5	8	19	18	3.00

Q → Question Rps → Responses CT → Central Tendency

Physical storage of materials, their proper handling, use of cubic space etc. is taken care of properly in about 30% of the companies. Rest have not given it as much importance as this area needs. Physical inventory of materials is not taken timely in three fourths of the industries. Large differences are found between physical inventory and material which should have been with the industry as per records. There are generally large inventories

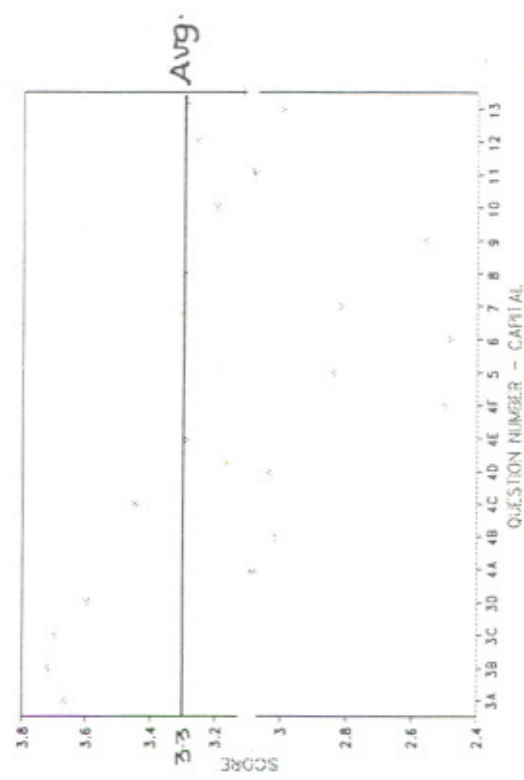
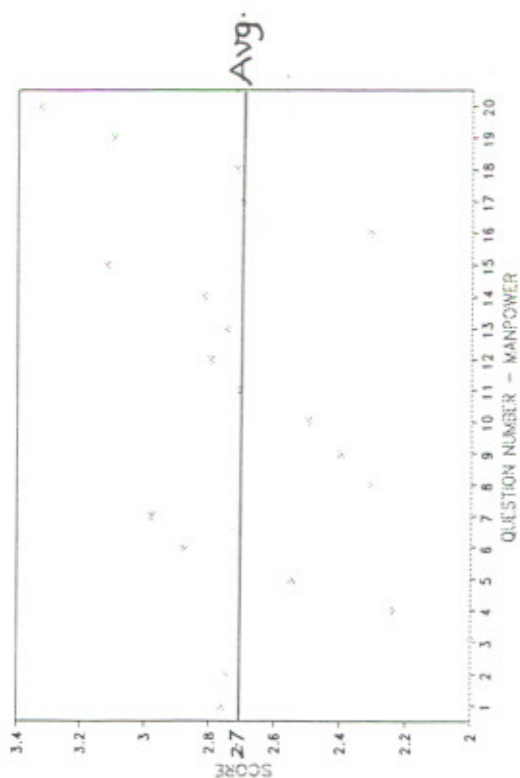
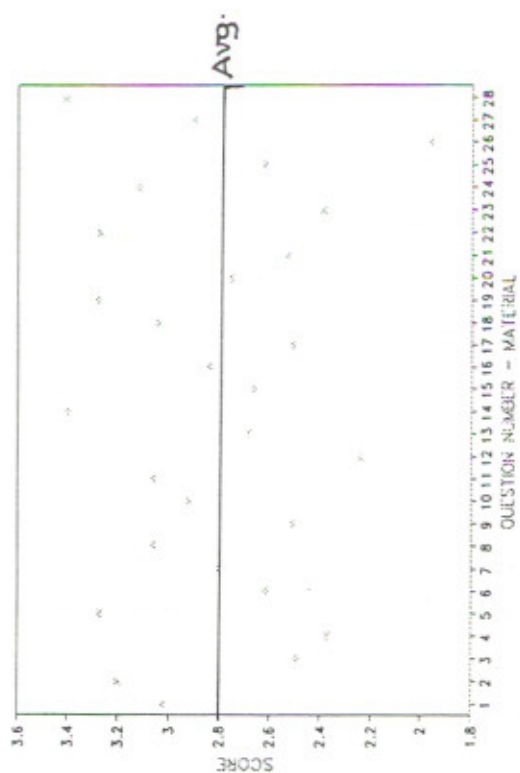


Fig 4.2 : Status of various aspects

kept in most of the industries. In 80% of the cases buffer stocks kept between work centres and other storing places have not been worked out at all. The considerations of the line balancing, probabilities of failures and consumption rates are generally absent. Only one fourth of the companies have classified the materials into A,B,C, items in order to focus their attention to the important few. As a result of poor inventory control, in nearly half of the companies, a large amount of money is blocked in obsolete, deteriorated or even unrecognisable materials.

The techniques used for reducing scrap, and rework, and reduction in consumption of indirect materials are substandard in most, (about 75%) of the companies. Indirect materials are generally used without any concern for their consumption. SQC techniques, in their proper form, are being used only by 14% of the companies. In 50% of the companies proper efforts are not put to segregate scrap at the processing stage, rather it is left to the final inspection stage. Sizes of raw materials used for further processing is kept appreciably on the higher sides in 60% of the industries. These 'safety margins' are kept to remain too much on the safer side.

Regarding collection, recycling and disposal of scrap the companies are generally not aware of the benefits of performing these functions in a systematic manner. Some companies (12%) do not know as to how much chips should have been produced and how much are actually there. It shows that they are not doing any Input-Output analysis of materials. Others find large differences between the quantities. It is revealed that collection system is of desired level in only one out of 47 industries. In 14% of the industries chips keep on piling up. They are collected only when they start hindering machining operations. In rest of the companies, though chips are regularly collected, collection system is much below the desired level. Scrap is not segregated at source which is the root cause of inability to recycle or properly dispose off material.

Recycling of materials is taking place in about 40% of the industries. Probably, the benefits of recycling are not known or improper collection system does not permit recycling. In about half of the cases it is reported that recycling is not being carried out due to technical reasons.

In conclusion the present state of various areas and aspects regarding materials waste and its management is that the status of only a few aspects is at the acceptable level.

4.9.2 Energy

Section 2 of the questionnaire seeks information on major areas of consumption,

wastage and management of energy as outlined below:

- i) Awareness regarding exact amount of energy being consumed on operations or products; acceptable levels of consumption and consequent waste; maximum energy consuming devices or products, actual efficiency of machinery and equipment vis-a-vis their rated efficiency; waste due to miscellaneous reasons, i.e the human error, efficiency of equipment, heat going waste with flue gases and so on.
- ii) Efforts towards building up awareness and reducing waste through conducting energy analysis, energy management and energy conservation studies, buying energy efficient machinery and equipment, matching machines with job sizes, installing motors of required capacity on machines, care in deciding upon layout and other factors of equipment, renovating old machines, setting standards of energy consumption for unit output, changing insulation of furnaces, installing heat exchangers, and decision making on the shop floor, etc.

The manner in which these areas of energy use are being looked after in the engineering industry is amply reflected by the data on responses to the questionnaire as given in Table 4.6.

In general, the state of this resource is reflected to be worse than that of materials. Awareness regarding energy being consumed and amount of energy being wasted is generally very poor. Only 13% industries know exactly the quantum of energy consumed for each product. Others have very little or no idea. Similarly, energy being consumed on each product, theoretically minimum amount of energy which should be consumed and figures achievable in practice are known only to 10% to 12% of industries. Others have not addressed themselves to this problem seriously and as a result do not know about these figures. Variation of energy per unit of weight of the product which provides a very useful information regarding suitability of equipment for varying size of products of the company is not at all known. Only 4% of the companies know this exactly.

A very few companies (6%) have set standards regarding quantity of fuel to be consumed for production of per unit of product for various operations.

Operating efficiency of furnaces, their rated efficiency, heat going out with flue gases, heat being wasted due to weak insulation; all these factors are very poorly looked after. Only 4% to 12% of the industries have a clear idea of loss due to above reasons. Others have

either approximate figures or nothing at all.

Again only 8% of the industries have reported that their managers have a clear knowledge about amount of heat energy wasted in case of breakdown of machinery and power failures. This knowledge is necessary for decision making (which operation to run and which to stop) in such circumstances.

Notwithstanding the fact that industries have generally poor knowledge about their own use of energy, a pinch is definitely felt of energy prices and energy scarcity. It is reflected by their efforts to create awareness to conserve energy. Only 6% of the industries have not put in any efforts. 20% of the industries are putting extensive efforts in this direction.

Another very important fact revealed by survey is that inspite of knowing about the need and importance of conservation of energy, industry in general is doing little to find areas and reasons of energy wastage. About 40% of the industries have not applied any diagnostic technique like Energy Analysis or Energy Audit. 45% are doing some efforts in this direction and only 15% of the industries have applied the exact diagnostic methods.

As awareness regarding reasons of wastage and amount of energy being wasted due to each reason is generally poor, decisions at planning and control stages in manufacturing units overlook the importance of energy consumption factor of machinery and equipment and operations. Only 32% of the industries give proper consideration to energy conservation factor while selecting machinery and equipment. As a result in most of the industries (about 60%) the equipment being used is capable of handling much bigger jobs than what are being made. Motors of appreciably higher power (HP) are being employed.

It is not only the size and type of the machinery vis-a-vis the intended job to be done but also the manner in which these are installed, which will reflect the amount being wasted. Installation of auxiliary equipment like compressors, water pumps is not considered important and accordingly due attention is not paid. The main objective kept in mind while selecting and installing these equipment, and their distribution, is that in no event they should become inadequate. The consideration that they should not waste energy in varying load conditions is generally absent. Only 35% of the industries are reported to have considered this factor. Similarly just 40% of the industries have taken care of energy consumption while deciding proximity and layout of various machines and equipment. Regarding selection of fuels the industries generally have not conducted detailed studies. About 30% of the industries have reported existence of proper fuel selection techniques.

It is a fact that most of the machines, after working for few years, start consuming more energy as compared to new machines. In addition, due to advancement in technology more efficient equipment has emerged. Most of the companies have not compared the energy consumption figures of new and old machines for similar operations. Again renovation of machinery and equipment or changing the insulation, etc. of furnaces are not carried out from energy point of view. The inefficient (from energy point of view) equipment is kept running till it finally breaks down. The repairs / renovations are carried out at this stage. About 10% of the industries are conscious of this energy wastage factor due to old machines.

4.9.3 Manpower

The questions on manpower contained in section 2 of the questionnaire aim at collecting information regarding the following -

- i) Management efforts to utilise this resource efficiently by realistically assessing the manpower requirements, their selection, training, job rotation, welfare measures including incentive schemes.
- ii) To know about response of the employees through the level of labour turnover, absenteeism, occurrence of lockouts, strikes etc; level of satisfaction about employee performance, their cooperation in time studies, reactions to upgradation of technology and automation; the quantitative assessment of effective working hours of employees etc.
- iii) To get information about working environment and prevailing level of discipline by knowing possibility of a machine operator or helper being shifted to other machines or one operator running two machines if need be, or capability of management to punish guilty and so on.

The response to individual question on this resource is presented in Table 4.7. This depicts a very interesting and revealing scenario. It is reflected that managements of the industries are trying reasonably hard to take care of this resource but the response to efforts is generally not very encouraging and as a result working environment is not very healthy and pleasing.

Most of the industries have addressed themselves to the problem of calculating the required number of manpower, though only 15% of the companies use proper time standards for this purpose, another 50% use the time standards set through experience.

About 35% leave it to the concerned officers.

About 60% of the companies have comprehensive type of interviews involving skill tests but about 40% depend upon formal interviews only. Nearly 10% of the industries do not provide any on the job training and put a person straight on job. Rest (90%) provide mild to extensive on the job training.

One factor which might be leading to disinterest or alienation is that the industries generally do not see interest of employees in specific jobs and instead give a job of their choice. About 35% of the industries do not rotate workers on various jobs and do not ask preferences at all. Rest 65% give some consideration to this area but only 16% out of these have properly implemented it to their benefit.

Most of the employers have provided facilities like housing, transport, school for children etc.. About 8% have not provided any facility. About 17% have provided almost everything. Incentive schemes of one type or the other exist in 76% of the industries. In 46% a clear incentive scheme with separate targets exist. 41% have one target for whole of the plant but a simple scheme, well understood by all. In 13% of the units a scheme having one target but involving complex calculations is running.

Employers generally put in efforts towards manpower and human resource factor, but these efforts have not yielded satisfactory results. This is amply reflected by the following:

- a) Strikes and lockouts do occur in the engineering industries. Only in 18% of the industries strikes etc have not occurred. In all others it has been a rare to frequent phenomenon. In about 20 % of the industries it is very frequent.
- b) Employers are generally not satisfied with level of output shown by workers. Only 4% have shown their full satisfaction. Satisfaction level of others vary from no satisfaction to mild level of satisfaction. About 23% are not at all satisfied.

Cooperation of workers, in general, and in conducting time studies, in particular, is poor. Only 10% have reported full cooperation from workers. About 45% have reported no to mild level of cooperation. Rest 45% have received a fair degree of cooperation.

Implementation status of results of time study is miserable. Only 18% of the industries have reported that they have been able to implement results of time studies. About 47% report a slight implementation. Rest 35% report partial implementation. This generally happens after negotiations with unions.

A strong opposition to the intentions of the management for bringing in automation

or newer technology has been reported. About 40% of the industries report that workers, in general, feel happy over such steps of the management. In all other cases there has been a mild to very strong reaction from work-force. About 18% report a mild reaction, 26% a very strong, but futile reaction. In remaining 16% of the industries the reaction is so strong that the management has to drop the idea of modernisation.

Other things reported by the survey which clearly point out towards the sad state of affairs on the manpower front are:

- a) Effective working hours of workmen are generally very less. Only 24% of the industries report more than 6 working hours out of an 8 hours shift. 38% report 5 to 6 hours, 30% report 4 to 5 hours and 10% report even below 4 hours.
- b) Absenteeism level is high. Only in 34% of the industries absenteeism is below prescribed limit of 10%. It is 10-15% in 44% of the industries and 15-20% in 22% of the industries. Future requirements of labour are generally calculated keeping about 10% absenteeism in mind.
- c) Attitude of workmen towards work is, generally, very poor. Due to general tendencies of unions to save even erring workmen, workers behave in an indifferent manner. They have framed their own rules:
 - i) In case of even pressing need it is very difficult to shift an operator from his machine to some other machine. While 26% have expressed no problem in shifting, 74% have reported mild reaction to a blank 'No'.
 - ii) Even in case of helpers or unskilled workers it has become difficult to put them on varying helping jobs. They have also earmarked their work and react if something else is demanded. This problem exist in 56% of the industries.
 - iii) Cycle times and other conditions permitting, it has become difficult to make an operator run two machines. About 70% of the industries have reported this problem in varying degrees. In about 40% of the cases a straight negative answer is given by workmen.

Indiscipline is increasing as reported by the industries and it is sad that it has become difficult to punish the guilty. Only 30% of the industries are in a position to give due punishment, 22% give mild punishment taking unions into confidence, 36% ignore indiscipline fearing trouble and 12% leave the matter to the unions to decide.

This is not all. Workers do whatever they want to do. It is not very uncommon to see

them reporting in shifts, other than in which they are supposed to. In most cases it is difficult for the management to send them back, only 34% of the industries send them back straight off. Rest 66% sometimes allow favouring or pleasing workers or only send back the repeaters. 12% have expressed their total inability to refuse such permission to workers.

4.9.4 Capital

In all 13 questions of multiple choice type on capital have been included in the questionnaire. Each resource in an organisation can be converted to and discussed in terms of capital, but it was decided to study it separately in view of its importance. There are many areas like overheads, administrative expenditure, depreciation of machinery and equipment, money blocked in inventories and other assests which can be covered under this head. Since the study is mainly concerned with the practices adopted within a production system it is decided to include only machinery and equipment, inventories and maintenance under this head.

First two questions in this resource invite information regarding percentages of various costs and investments made. Question 1 is regarding proportion of money blocked in fixed assets, machinery and equipment. Comparatively, less number of companies have furnished this information. The response varies from 72% to 82% of those industries which have otherwise responded. Question 2 seeks information regarding percentages of various costs of a product. Following tables show the proportions of various costs and investment and the companies reporting them.

Table 4.9
Investment in Various Areas

Invesment	%age of Reporting Industries					Do not Know
	Percentages of Total Investment					
	5-10	11-20	21-30	31-50	> 50	
Fixed Assets	8	13	11	21	36	11
Machinery & Equipment	2	13	23	38	13	11
Working Capital	6	36	21	11	13	13

Question 3 onwards relate to numerical marking from 1 to 4. The numerical score achieved by various questions in all the industries is as given in the Table 4.8.

Utilisation level of machinery has been reported to be generally above 70%. In case of NC/CNC machinery it is seen that only 36% of the surveyed industries have acquired

such machines. 89% of them have reported a utilisation level of above 70% but 11% have reported it even below 20%. In case of special purpose machines 94% of the companies are employing them with 86% reporting a utilisation level of above 70%, 4% a level of 50-70%, 8% a level of 20%-50% and 2% a level of below 20%.

Table 4.10
Percentage of Each Cost to the Total Cost

Cost	%age of Reporting Industries					Do not Know
	Percentages of Total Cost					
	5-10	11-20	21-30	31-50	> 50	
Direct Material	0	0	2	15	64	19
Labour	19	38	11	13	0	19
Overheads	8	45	26	2	0	19
Depreciation	62	11	8	0	0	19
Indirect Materials	54	11	15	0	0	20
Energy	46	24	8	2	0	20

In case of general purpose machines, 70% of the industries report a utilisation level of above 70%, 18% a level between 50-70%, and 12% below 50%. Equipment utilisation has been reported to be above 70% in 70% of the cases, between 50 - 70% in 14% cases, between 20 - 50% in 6% cases and below 20% in 4% cases.

Breakdown of machinery and equipment is responsible for below 5% non-utilisation in 32% cases, 5 - 10% in 50% cases; 10 - 20% in 8% cases and above 20% in the remaining 8% cases.

Labour attitude account for below 5% in 40% cases, between 5 - 10% in 22%, between 10 -20% in 30% cases and above 20% non-utilisation in 4% cases.

Power shortage is responsible for below 5% in 66% of cases, between 5 - 10% in 18%, between 10 -15% in 6% and above 20% in 8% cases respectively.

Material shortages account for below 5% in 48% of cases, 5 - 10% in 18% cases, 10 - 15% in 12%, and 15 - 20% in 16% cases.

56% of the industries lose below 5% on account of shortage of orders, 18% lose 5 - 10%, 2% between 10 - 15%, and 14% above 20%.

Only 20% of the companies go in for method study for selection of operations and methods of doing work. Rest depend upon experienced people, adopt conventional

practices or select them randomly.

Maintenance function is generally not looked after well. Only 10% companies have worked out efficient maintenance strategies including use of computers and IE techniques. About 75% use corrective maintenance with some preventive maintenance whereas 15% depend only on corrective maintenance.

Regarding establishing plant capacity, only a few companies (30%) have gone in for scientific technological forecasting. Others have taken these vital decisions based on guesses, intuitions and on the advice of others. As a result, orders position is satisfactory only in 55% of the cases. Rest 45% starve to a varying degree because of shortage of orders vis-a-vis the installed capacity. Aggregate planning aspect, where-in the plant capacity can be adjusted by adjusting some variables has also not been looked after well. Only 15% have used it properly, others have either made a partial plan or no planning at all has been done. Most of the companies (about 85%) keep future expansions also into consideration while deciding about size of the plant and machinery. In 40% of the companies a special department exists which works out and decides selection of the machinery. In others such care is not taken. Procedure for taking decision whether a particular department should be given more machines or not invites detailed capital proposals based on break-evens in only 40% of the companies. In others, procedure varies from deciding on immediate gains, verbal justification or is done arbitrarily. About 35% of the companies have taken care to keep pace with the technological developments. Others have lagged behind to a varying degree. About 25% have not improved at all.

4.10 STATUS OF VARIOUS BROAD ASPECTS

Various individual questions in each resource point towards and contribute to some broad area. These broad aspects and their average score has been given in Table 4.11. The average values have been arrived at from the average score of various questions. The details are given in Appendix A2.

The results listed in the above table depict that awareness regarding wastage levels is generally poor. In case of energy it is very poor, average score being 2.19 out of 4. A score close to 4 depicts that the aspect is being looked after very well and best available practices and techniques are in use. Similarly a score close to 3 shows that second line techniques are being employed. A score close to 2 and 1 reflects use of third line and fourth line techniques respectively. Thus a score close to 4 can be considered as very good, a score of 3 means good, a score below 3 depicts that the level of the aspect is between poor and

fair. It is seen that score of almost all aspects in case of energy is just above 2 depicting that level of these aspects is just above poor level. Manpower comes next followed by materials and capital. Level of almost all aspects is the same.

Table 4.11
Average Score of the Broad Aspects

S.No.	Aspects	Materials	Energy	Manpower	Capital	Overall
1.	Awareness regarding wastage levels and identification techniques.	2.98	2.19	2.71	3.29	2.79
2.	Efforts towards waste management at planning stage	2.68	2.61	2.74	2.95	2.74
3.	Efforts towards waste management at control stage	2.76	2.08	2.73	2.96	2.63
4.	Results of efforts	3.04	2.16	2.74	3.31	2.81
5.	Extent of use of appropriate techniques.	2.65	2.22	2.62	2.84	2.59
6.	Extent of use of computers.	2.58	-	-	-	2.58

Level of use of computers and appropriate techniques of WM are the lowest. There are more efforts put at planning stage than control stage towards waste management, however at both stages this level is not very satisfactory. Efforts are bringing in almost proportionate results. Need is to build up awareness for identifying waste. Once aware of wastage levels, industries would come forward to find out or devise ways and means to reduce wastage levels.

CHAPTER V

ANALYSIS OF MATERIALS WASTE

Materials, a basic resource, is processed in various stages and transformed into desired products consuming other resources such as energy, manpower effort, equipment time etc.. In order to determine consumption and wastages of any of these resources, it is necessary to have on hand results of materials analysis. Thus, it was decided to study first of all waste of materials. The analysis, as presented in the next sections, deals with recording inputs and outputs of materials for a specified period and finding out waste. Waste in different areas, due to different reasons and of different forms has been worked out. Probable reasons of waste have been listed and solutions proposed. The system has been modelled and analysed using Physical System Theory (PST).

5.1 METHODOLOGY

Following sequence of tasks was undertaken for analysis of materials waste.

5.1.1 Division of the System into Sub-systems

In the selected industrial unit, material undergoes transformations such as alloying, powder making, sintering, punching and pressing, and machining as explained in chapter three. These operations are generally carried out in different sections of the manufacturing unit. In various sections, form of the materials used and units employed for measurement vary. Therefore, it was necessary to divide the system into sub-systems and conduct input-output analysis for each sub-system separately. Thus, sub-systems were devised, depending upon the similarity of operations done within a sub-system and their difference from other sub-systems. Following sub-systems were made:

- i) Powder plant
- ii) Sanding and degreasing
- iii) Sinter line
- iv) Press shop
- v) Machine shop and plating

Machine shop and plating have been kept together because plating is done in between the machining operations.

5.1.2 Input-Output Analysis

In the case of all above sub-systems, input-output analysis has been carried out and waste W calculated as follows:

$$W = NI - O \quad (5.1)$$

Where NI is the net input and O , is the output of products from the sub-systems.

$$\text{Further, } NI = OS + I - CS \quad (5.2)$$

Where OS is the opening stock in the beginning of the study,

I is the input of raw materials to a sub-system during the study period and CS is the closing stock at the end of the study period.

As inputs and outputs are available in different forms of the materials, they are converted in a common form by

- i) using percentages of various elements in the material.
- ii) using weights of the products and in-process goods, transferring the numbers into weight.

In each sub-system the above input-output analysis approach has been adjusted to suit the requirements of a sub-system. Since unit weights of the products and in-process goods are not available they are calculated as under:

a) **Weight of blanks**

$$\text{Weight of a blank, } Wt_b = \frac{Wt_s / M}{N_b / M} \quad (5.3)$$

Where Wt_s is weight of strip and

N_b is number of blanks.

$$\text{Further } Wt_s / M = Wt_p / M + Wt_{st} / M \quad (5.4)$$

Where Wt_p / M is the powder weight per metre and

Wt_{st} / M is the steel weight per metre

Powder weight per metre and steel weight per metre are calculated from width, thickness and specific gravity of powder and steel.

$$\text{Blanks per metre} = \frac{\text{one metre of strip of certain width}}{\text{length of one blank of that width}} \quad (5.5)$$

- b) **Weight of in-process goods** : For a large variety of products involved it is neither possible to weigh all in-process goods nor calculate weight from standard data.

Considering that all the products have similar shape and only sizes vary, a new approach is applied with success. A few in-process goods are actually weighed before and after each operation and it is established that weight loss for an operation is almost a fixed percentage of the weight of the blank. From these percentages the weight of the product at every stage is worked out.

5.1.3 Representation and Analysis of the System using PST

The inputs, outputs and wastes of each sub-system are represented by Physical System Theory Model. This representation is useful for analysis and also for planning of capacity, materials and other resources. A brief discussion of PST and its applications in manufacturing system is given below:

5.1.3.1 Physical system theory model: The concepts of PST have been applied mainly to large scale systems, in particular to eco-systems (Koenig et al 1975, 1979, Koenig and Tummala 1972), and national economic systems (Satsangi and Ellis 1974, Aggarwal 1984, Sushil 1991a, Vij, et al 1988). At the micro level it has been applied to project systems (Kanda 1986), manufacturing systems (Sushil 1991b, Sushil 1992a, Sushil, et al 1988, Singh and Sushil 1990a), technology selection (Singh and Sushil 1990 b,c), organisational systems (Sushil 1991a), modeling of quality in extended framework of PST (Sushil 1990b) and information systems (Gupta and Sushil, 1989).

Physical system theory, a contribution of Koenig and his group (1967,1972) does not believe in the notion of analogies but in the concept of a linear graph. According to it, a linear oriented segment represents a two terminal component with a pair of complementary variables - an 'across' variable and a 'through' variable. The system model based on physical system theory is composed of component models, system graph and inter-connection or structural constraints. The performance characteristics of an N-terminal component can be completely and uniquely defined by a component terminal graph of (N-1) edges and a set of (N-1) equations relating (N-1) across variables and (N-1) through variables. On uniting component terminal graph in one to one correspondence with actual interrelations of components, system graph is obtained which is governed by laws of continuity, compatibility and the energy conservation.

Material flow is basic characteristic of manufacturing systems. The physical system theory can be applied to manufacturing systems as they obey the principles of conservation. Various production stages can be conceptualised as material transformation processes. In general every process converts inputs into outputs and generates some waste (scrap). In

some cases, scrap may be divided into disposable and reworkable categories. Therefore, each stage is conceptualised to have a basic transformation process and a rework transformation process (Singh and Sushil, 1990a).

Consider a multi-stage manufacturing system consisting of m stages ($j = 1, 2, 3 - m$).

In modelling the j th transformation process, unit cost of material is taken as across variable and flow of material as through variable. Figure 5.1 shows a system graph of a general manufacturing system.

Technological co-efficients

To calculate input requirements, quantities of waste generated and rework produced, technological co-efficients are used. These are found from working of the system using following equations:

Technological co-efficients of input for basic process at the j th stage,

$$KB_j^i = \frac{\text{Input to. the } j\text{th basic transformation process}}{\text{Output from. the } j\text{th transformation process}} \quad (5.6)$$

Technological co-efficients of waste for the j th basic transformation process.

$$KB_j^{w_i} = \frac{\text{Waste to. the } j\text{th basic transformation process}}{\text{Output from. the } j\text{th transformation process}} \quad (5.7)$$

Technological co-efficient of rework at the j th transformation process.

$$KB_j^r = \frac{\text{Rework at the } j\text{th transformation process}}{\text{Output from. the } j\text{th transformation process}} \quad (5.8)$$

Similarly, technological co-efficients of input and waste for the rework process are defined.

Applying the laws of continuity, compatibility and conservation following generalised equations are obtained at the l th stage ($J = 1, 2, 3, \dots, l, m$) when l to m stages are considered together using linking equations.

Input material required at the l th stage,

$$YB_l^i = \prod_{j=l}^m KB_j^i RF_j Y_d \quad (5.9a)$$

Waste generated by the basic process at the l th stage,

$$YB_l^{w_i} = KB_l^{w_i} RF_l \prod_{j=l+1}^m KB_j^i RF_j Y_d \quad l = 1, 2, \dots, m-1; \quad (5.9b)$$

$$YB_l^w = KB_l^w RF_l Y_d \quad l=m$$

Material for rework by the basic process at the l th stage

$$YB_l^r = KB_l^r RF_l \prod_{j=i+1}^m KB_j^j RF_j Y_d \quad l = 1, 2, \dots, m-1; \quad (5.9c)$$

$$YB_l^r = KB_l^r RF_l Y_d \quad l=m$$

Waste generated by the rework process at the l th stage

$$YR_l^w = KR_l^w (1 - RF_l) \prod_{j=i+1}^m KB_j^j RF_j Y_d \quad l = 1, 2, \dots, m-1; \quad (5.9d)$$

$$YR_l^w = KR_l^w (1 - RF_l) Y_d \quad l=m$$

The unit output cost at the m th stage (X_d) for a coupled multi-stage system ($J=1,2,\dots,m$) is

$$\begin{aligned} X_d = & \prod_{j=n}^m (KB_j^j RF_j) XB_j^j \\ & + \sum_{n=l+1}^m \prod_{j=n}^m [(KB_j^j RF_j) [(RF_{n-1}) (fB_{n-1} - KB_{n-1}^w XB_{n-1}^w) \\ & + (1 - RF_{n-1}) (fR_{n-1} - KR_{n-1}^w XR_{n-1}^w)]] \\ & + (RF_m) (fB_m - KB_m^w XB_m^w) \\ & + (1 - RF_m) (fR_m - KR_m^w XR_m^w) \end{aligned} \quad (5.10)$$

Where Y_d is the final output from the process

X_d is cost of final output

$$RF\text{'s are rework factors, } RF_j = (KR_j^j / (KR_j^j + KB_j^r)) \quad (5.11)$$

KB 's are technological coefficients.

YB 's are outputs from particular stages.

XB 's are unit output cost from particular stages.

fB_m and fR_m are unit processing costs at the basic processes and rework process.

Using above equations, input requirements at each stage can be found out keeping final requirements in mind. Cost of product at each stage can be comprehensively worked out, accounting for wastes and processing costs at all previous stages.

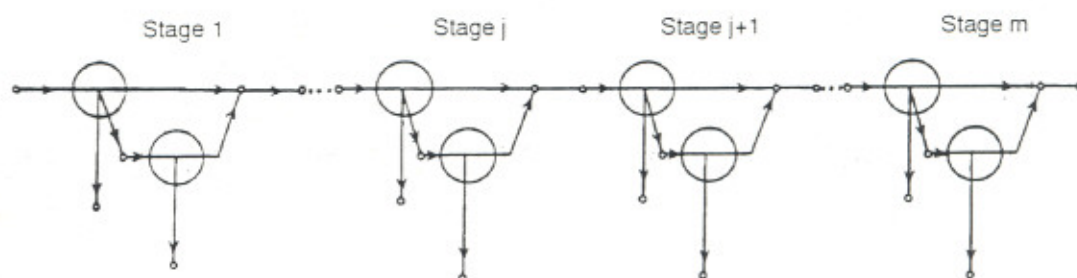


Fig 5.1 : System graph for m -stage manufacturing system.

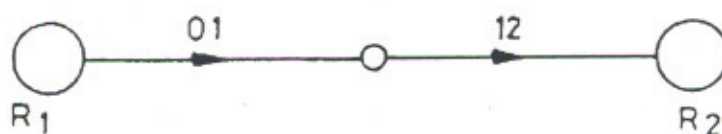


Fig 5.2 : A typical interconnection.

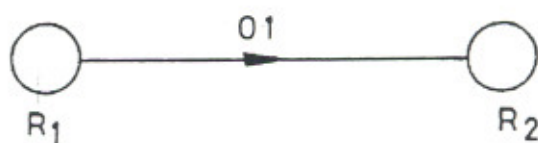


Fig 5.3 : Simplified interconnection.

With increase in size and complexity of system, complexity of system graph in PST model increases multiplicatively. Number of edges in system graph, and consequently, associated variables and equations pose a serious limitation on applicability to real life large systems. In order to make the frame work of PST more practical, it has been simplified by Sushil (1992b). Three significant features of PST models which facilitated simplification are:

- a) In most of interconnections of components there is one to one correspondence, i.e. output of one component is input to some other component, as shown in Fig. 5.2
- b) Further, it can be observed in a system model, where all the inter-connections are of the type shown in the Fig.5.2, that number of inter-connection nodes are equal to number of f-cutsets and number of circuits are equal to f-circuits. Hence, cutset equations at all nodes and circuit equations for all circuits can be written.
- c) A large class of these systems are forward flow or hierarchical in nature, i.e. input is processed in stages, one after the other.

First two features result in simplification in modelling whereas third feature results in simplification in solution of the model. Thus, two components as shown in Fig. 5.2 can be represented by a single component as shown in Fig. 5.3.

The simplified steps for obtaining values of across and through variables are as under:

a) **Through variables**

- i) Solve flow equations for the last process to determine values of flow of input/waste.
- ii) Repeat step (i) successively until values of the terminal input/waste are obtained.

b) **Across variables**

- i) Solve cost (across variable) equations for the first process(es) having only exogeneous input/wastes.
- ii) Solve cost (across variable) equations of the next process(es).
- iii) Repeat step (ii) successively until final cost (across variable) is calculated.

Equations for a stage are:

$$\text{Across variable, } X_{01} = Kd_1 Xd_1 - KW_1 XW_1 + f_1$$

$$\text{Through variable, } Yd_1 = Kd_1 Y_{01} \text{ and Waste } YW_1 = KW_1 Y_{01} \quad (5.12)$$

Where X 's are the costs, Y 's are the quantities, K 's are the technological co-efficients of input, YW 's are the waste, KW 's are the technological co-efficients of waste and F 's are the processing costs.

Similarly, equations for a system graph can be written and values of across variables and through variables found.

5.2 DETAILS OF EMPIRICAL ANALYSIS

In the following sections details of analysis done in each sub-system are presented.

5.2.1 Input-Output Analysis Powder Plant

As mentioned earlier, input to powder plant is copper, lead and tin and output is finished powder which is supplied to sinter line. Three different types of powders are manufactured here. Percentages of various elements in these powders are given in Table 5.1.

Table 5.1
Composition of Various Types of Powders

Powder Type	Percentage of		
	Copper(Cu)	Lead (Pb)	Tin (Sn)
HF2	80	10	10
HF16	74	23	3
H24	74.4	25	0.6

Data of inputs and outputs for a period of four months from 1.4.91 to 31.7.91 alongwith opening and closing stocks has been taken. Table 5.2 shows details of this data. Data has been taken from the daily production reports, daily material requisition slips and daily reports of material sent to sinter line.

As is evident from Table 5.2 these quantities were in different forms as below:

- Individual elements of the alloy, i.e. copper, lead and tin.
- Individual types of powder, i.e. HF2, HF16, and H24.
- Mixed powder or shavings of mixed powder received from machine shop.

Table 5.2
Input - Output Data of Powder Plant from 1-4-91 to 31-7-91

Description	Raw Material (In Kg)			Mixed Powder (Shavings) Kg.	Powder Type (In Kg.)		
	Cu	Pb	Sn		HF2	HF16	H24
OPENING STOCK	216	408	89.9	9999	-	-	-
INPUT	55274	12678	3688	5313	-	-	-
OUTPUT							
APRIL	-	-	-	-	6777	5954	7915
MAY	-	-	-	-	9791	3933	10316
JUNE	-	-	-	-	5139	4909	7561
JULY	-	-	-	-	5845	433	10717
CLOSING STOCK	-	-	-	-	1570	-	1733

It was necessary to convert all above quantities into their equivalent of some common form, i.e. either to powder or to individual elements of copper, lead and tin. The latter option was preferred because of its superiority over the former. Thus following course of action was followed:

- Most of the input materials and opening stocks were in the form of copper, lead and tin. These were kept as such.
- Quantities of individual types of powders were converted to their equivalent quantities of copper, lead and tin using composition details of each type of powder as given in Table 5.1.
- All quantities of mixed powder were converted to their equivalent of copper, lead and tin by using the 'weighted average percentages' of these elements in mixed powder. For working out these weighted average percentages, composition of each powder and its quantity as given in Table 5.2 were considered. This has been calculated as under:

$$\text{Weighted average percentage} = \sum \frac{Qp_i}{\sum Qp_i} \times Pe_i \quad (5.13)$$

where Qp_i is the quantity of a powder type, made in the months of April to July, 1991, Pe_i is percentage of an element copper, lead or tin in the powder i

$i = 1, 2, \text{ or } 3$ i.e HF2, HF16 or H24.

The average percentages found are copper = 77.10%,

lead = 19.42% and tin = 3.48%.

Conversions of various quantities to their equivalent of copper, lead and tin, using the above criteria are presented below:

5.2.1.1 Conversion of various quantities to individual elements

- a) **Opening Stock** The opening stock contained elements of copper, lead, and tin and mixed powder. Using percentage of copper, lead and tin in mixed powder as given above and figures of opening stock as given in Table 5.2, total opening stock in terms of copper, lead and tin has been calculated by using following equation.

$$TQ_e = Qe_s + Q_{MP} \times Pe_{MP} \quad (5.14)$$

Where TQ_e is total quantity of an element,

Qe_s is quantity already present in elemental form,

Q_{MP} is quantity of mixed powder and

Pe_{MP} is percentage of an element in mixed powder

The total quantity of copper, lead and tin comes out to be copper=7,925 Kg.,

lead= 2,350 Kg., tin= 438 Kg.

- b) **Input:** The inputs contained individual elements of copper, lead and tin and the shavings of mixed powder. Using percentages of mixed powder, and figures of opening stock as given in Table 5.2, total input in terms of copper, lead and tin has been calculated by employing equation 5.14. The quantities worked out are copper = 59,370 Kg., lead = 13,710 Kg. and tin = 3,873 Kg.
- c) **Output:** Output contained only individual type of powders. Table 5.3 shows details of conversion of outputs to copper, lead and tin using composition of each type of powder as given in Table 5.1 and quantities of each powder made as per Table 5.2.

Table 5.3

Calculations of Quantities of Individual Elements Used in Output

Powder Type		Total	Copper	Lead	Tin
HF2	%age	100	80	10	10
	Quantity (Kg.)	27552	22042	2755	2755
HF16	%age	100	74	23	3
	Quantity (Kg.)	15229	11269	3503	457
H24	%age	100	74.4	25	0.6
	Quantity (Kg.)	36529	27178	9132	219
Total Quantity (Kg.)		79310	60489	15390	3431

- d) **Closing stock:** Closing stock contained quantities of only two types of powders. Table 5.4 shows details of conversion of quantities of individual type of powder as given in Table 5.2 to their equivalent of copper, lead and tin.

Table 5.4

Calculations of Quantities of Individual Elements in Closing Stock

Powder Type		Total	Copper	Lead	Tin
HF2	%age	100	80	10	10
	Quantity (Kg.)	1570	1256	157	157
H24	%age	100	74.4	25	0.6
	Quantity (Kg.)	1733	1289	434	10
Total Quantity (Kg.)		3303	2544	591	167

5.2.1.2 Calculation of waste as the difference of input and output: After having converted all the quantities to copper, lead and tin, these quantities have been put together in Table 5.5 and the difference of input and output, i.e. the waste has been found as given below.

Table 5.5

Final Input - Output Powder Plant

DESCRIPTION	Cu (Kg.)	Pb (Kg.)	Sn (Kg.)	Total (Kg.)
Opening Stock (OS)	7925	2350	438	10713
Input (IP)	59370	13710	3873	76953
Output (O)	60489	15390	3431	78926
Closing Stock (CS)	2545	591	167	3303
Net Input, NI=(OS+I-CS)	64750	15469	4144	84363
Waste=NI-O	4261	79	713	5053
% age waste on input (material wastivity)	6.58	0.51	17.20	-
% age waste on output	7.04	0.51	20.78	-

Overall waste percentages

Total Waste = Waste as calculated in Table 5.5 + Waste of powder at sinter line.*

$$= 5053 + 384 = 5437 \text{ Kg.}$$

$$\text{Stage Wastivity} = \frac{\text{Waste}}{\text{Input}} = \frac{5437}{84363} = 6.44\%$$

$$\text{Waste on Output} = \frac{\text{Waste}}{\text{output}} = \frac{5437}{78926} = 6.88\%$$

* 384 Kg. is the waste of powder detected at sinter line for four months. For convenience it is being considered here. The details are shown under analysis of sinter line.

5.2.1.3 Waste due to excessive production of coarse powder: If temperature of alloy, water pressure and others parameters are not controlled properly on powder plant, higher percentage of coarse powder is produced. Producing coarse powder results in wastage of energy, manpower, equipment and other resources as the same has to be recycled. In addition, its separation and handling also involves effort and consumption of resources.

The company maintains a record, on daily basis, of quantity of coarse powder and finish powder collected from each drier during classifying operations. Data has been compiled from these reports for a period of three months to arrive at an average percentage of coarse powder produced and thus material recycled on powder plant. Table 5.6 shows the details.

Table 5.6
Ratio of Coarse to Fine Powder

Month	Powder Type	Total Powder	Fine Powder	Coarse Powder	% age of Coarse Powder
April	HF2	7996	6777	1219	
	HF16	7565	5954	1611	
	H24	10295	7915	2380	
	Total	25859	20646	5213	20.15
May	HF2	12562	9791	2771	
	HF16	4544	3933	611	
	H24	13030	10316	2714	
	Total	30136	24040	61096	20.22
June	HF2	6724	5139	1585	
	HF16	6120	4909	1211	
	H24	9495	7581	1914	
	Total	22339	17629	4710	21.08
Grand Total		78334	62315	16019	20.44

5.2.2 Input- Output Analysis - Sanding Operations

Sanding and degreasing operations are carried out prior to sintering. Here, waste can occur in two ways:

- Steel strip found defective and unsuitable for further operations.
- Material removed from steel strip during sanding operations to make it rough. Excessive loss can occur here due to large difference between thickness used and required for the steel strip.

Data of the material sintered and sanded was taken for the month of July, 1991. A total of 106 types of products were made in July in varying quantity. Along with various types of products and total length of strip made for each, details regarding width and thickness of the strip used, final width and thickness of the steel and thickness of powder layer required before and after sintering have been considered. From these details, total weight, powder weight and steel weight per metre of strip have been calculated for each product using specific weights of steel and powder as per equations 5.3 and 5.4. Finally, total weight of steel and powder for each type of strip made has been calculated. These values have also been summed up for all the products made in the month of July, 1991. The results are given in Table 5.7.

Table 5.7
Inputs and Outputs of Sinter Line

Description	Steel (Kg.)	Powder (Kg.)	Strip	
			Kg.	Metre
Quantity	66879	20684	87563	29464
Average Weight/metre of strip	2.269	0.702	2.971	
%age of strip weight	76.4	23.6		

5.2.2.1 Waste due to steel scrap: Opening stock and actual inputs of steel for July, 1991 were taken from the records of physical inventory as on 1.7.91 and from records of 'Material Requisition Reports' for material received from stores. Similarly, closing stock of steel was recorded as on 1.8.91. The output of steel as calculated from sintering record for July, 1991 has been taken. The analysis is given below:

Opening stock of steel as on 1.7.91 on Sanding,	OS	= Nil
Input during July	I	= 68382 Kg.

rejected during inspection was also noted. These quantities are given below.

5.2.3.1 Strip wastage :

Strip made, as listed in section 5.2.2,	= 29,464 metres.
Strip transferred, as per records	= 29,222 metres.
Opening stock, strip, (O.S)	= 13,244 Kg. = 4,458 metres.
Closing stock (C.S)	= 13627 Kg. = 4,587 metres.
Net Input of strip = Strip made + OS - CS	= 29464 + 4458 - 4587
	= 29,335 metres
Output of strip = Strip transferred	= 29222 Metres
Difference = Waste = 29335 - 29222	= 113 metres = 335 Kg.

This 335 kg. of strip wastage includes wastage of both powder and steel. Approximate quantities of powder and steel have been found out by using average ratio of powder to steel weight in the strip as calculated in section 5.2.2, (steel 76.4% and powder 23.6 %). The quantities are:

Steel	= 255 Kg.
Powder	= 80 Kg.

5.2.3.2 Rejection of strip : Strip rejected in July, 1991 as per records is equal to 782 kg. Using above percentages of 76.4% and 23.6% for steel and powder respectively the waste of steel and powder comes out to be:

Steel	= 597 Kg.
Powder	= 185 Kg.

5.2.3.3 Wastage in the form of Powder : Powder drawn from powder plant during July, 1991 is equal to 16,995 Kg.

Opening stock	= 4,512 Kg.
Powder consumed (O), as per section 5.2.2	= 20,684 Kg.
Closing stock (C.S)	= 727 Kg.
Net input (NI)	= 20780 Kg.
Waste = (NI-O)	= 96 Kg.

This 96 kg. of wastage per month has been shown on powder plant. Since powder plant analysis has been done for four months, this wastage has been worked out accordingly.

5.2.3.4 Total Waste, Wastivity and Waste on output

Total steel wastage = 255 + 597	= 852 Kg.
Total powder wastage = 80 + 185	= 265 Kg.
Total Waste = 1117 Kg.	
Net input of steel from sanding, (section 5.2.2.3)	= 62582 Kg.
Net input of powder = Os + I - CS	= 20780 Kg.
Total Net Input	= 83362 Kg.
Output = NI - Waste	= 82245 Kg.
Wastivity	= 1.33%
Waste on output	= 1.35%

5.2.4 Input-Output Analysis -Blankers

Input to press shop is rolls of bi-metallic strip of various widths. Here this strip is punched on presses and blanks, suiting various bearing sizes, are produced. Wastage of materials in press shop can occur in the following areas:

- i) Less number of blanks produced than that could be made out of the strip supplied.
 - ii) Weight loss due to oversize strip (i.e. width). In the following sections, losses in both these areas have been found out. Again, July 1991 figures of strips supplied to the press shop have been taken and details as worked out in section 5.2.2 have been used. To calculate above wastages following tasks were undertaken.
- a) Calculated the number of blanks made per metre of each type of strip and consequently total number of blanks to be made from total metrage of strip of each type received in the month of July, 1991. This has been done by comparing strip width and blank sizes. From the blank sizes and strip width, number of blanks which could be made per metre of strip have been calculated using equation 5.5. This, multiplied by the metrage of each type gives total number of blanks of each type which could be made. This has been done separately for bushes, bearings and washers.
 - b) Calculated blank weight of each type of product and average blank weight of each category of products, i.e. for bushes, bearings and washers. This has been done by

dividing total weight of the metrage of the strip made in case of each product by the number of blanks of each type as calculated at (a) above. Further, average weights have been calculated by dividing the summation of weight of all types by the total quantity of all types taken together. This has also been done separately for bushes, bearings and washers. The average blank weights are listed in Table 5.8.

- c) Recorded the actual number of blanks made from the strip made in July, 1991. Since these blanking operations got started in July itself but continued even in August so their production was very closely monitored and the record made in register was verified and counter checked everyday. After completion, these quantities were summed up individually for bushes, bearings and washers. These quantities are listed in column 3 of Table 5.9.
- d) Calculated material removal during blanking. The data of strip width and blank width from product mix of July, 1991 was critically analysed to find difference between the two. This material ultimately gets removed during blanking operations. The average weight removal came out to be about 10% in case of bushes and bearings and 65% in case of washers.

5.2.4.1 Waste due to less number of blanks (excessive scrap): From a product mix of 106 items made in July, 1991 as discussed in section 5.2.2, quantity of strip for various categories of products has been summed up, total number of blanks made as discussed at (a), and the average weight as calculated at (b) in section 5.2.4, have been listed in Table 5.8.

Table 5.8
Details of Number of Blanks and Average Weights

Item	Quantity of Strip Used (Kg.)	No. of Blanks which could have been made	Average weight (Kg.)
Bearing	52418.612	500165	.10480
Bushes	25987.025	279972	.09282
Washers	8102.155	94031	.08616
Strip sold	1055.66		
Total	87563.462		

As 1.4% of strip has been rejected as discussed in previous section on sintering the

number of blanks which could be produced as given in Table 5.8 have been brought down by the same percentage and are:

Bearings = 4,93,163

Bushes = 2,76,052.

Washers = 92,714

Table 5.9 shows details of calculations of wastage due to less number of blanks made on presses than expected. This has been calculated as under:

$$\text{Waste} = (Nb_{\max} - Nb_{\text{act}}) \times Wt_{bs} \quad (5.15)$$

where $Nb_{\max}$ is maximum possible number of blanks,

Nb_{act} is actual number of blanks and

Wt_{bs} is average weight of a blank after sanding

Table 5.9

Wastage Due to Less Number of Blanks Made

Product	Max. Possible no. of Blanks a	No. Blanks actually made b	Waste		
			Quantity C= (a-b)	%age $\frac{c}{a} \times 100$	Weight (Kg.) c × Blank Weight
Bushes	276052	263989	12063	4.36	1120
Bearings	493163	485503	7660	1.55	803
Washers	92714	92274	440	0.47	38
Total:	861929	841746	20163	2.05	1961

5.2.4.2 Waste due to material removal: It has been seen that, in general, strip width is nearly 10 % more than blank width. This 10% material is wasted either in slitting or in blanking.

Weight of strip blanked

= Total strip made × %age of strip accepted - Weight removal at sanding - Strip sold.

= (87564 × .986) - 4300 - 1055 = 80983Kg.

Thus weight loss due to over size is 10 % of 80983, i.e. 8098 Kg. In addition to this, there is excessive wastage in washers during blanking because washer is half round in shape.

$$\begin{aligned}\text{Wastage} &= \text{Number of washers} \times \text{Blank weight} \times \% \text{ wastage.} \\ &= 92274 \times .08616 \times .65 = 5170\text{Kg.}\end{aligned}$$

$$\text{Total wastage in blanks} = 1961 + 5170 + 8098 = 15229 \text{ Kg.}$$

This loss has been worked out considering original weight of blanks. Accounting for material wastage at sanding (6.4 percent of 1961+ 5170 equals 450 Kg), actual waste at blankers = 15229 - 450 = 14779 Kg.

5.2.4.3 Total waste, wastivity and waste on output

Net input (Section 5.2.4.2)	= 80983 Kg.
Total waste	= 14779 Kg.
Output = 80983 - 14779	= 66204 Kg.
Waste	= 14779
Stage Wastivity	= 18.24%
Waste on output	= 22.49%

5.2.5 Input- Output Analysis - Machine Shop

Input to machine shop is in the form of blanks of various types of bushes, bearings, flanged bearings and washers. Output is the finished products, both good and scrap. Scrap means the final inspection scrap as well as in-process scrap.

In this section, the input - output analysis of all categories of products taken together, of individual categories, and of individual products have been done separately.

The data of opening stock of in-process goods as on 1.4.91, input of blanks and output of good and scrap products for four months (1.4.91 to 1.8.91) and closing stock of in-process materials as on 1.8.91 was collected. This data was taken from the following records:

- Physical inventory done on 1.4.91 and 1.8.91.
- Blanking records maintained on the blankers and by the PPC department.
- Daily inspection reports of material checked and final inspection at the end of four months period.
- Daily in-process scrap reports made by the quality control department.

Daily inspection reports also contained information of rework declared, rework cleared, type of scrap and rework.

Since data of inputs and outputs were to be used for various types of analyses as explained earlier so it was fed to dbase III plus files. After feeding above varied data into their individual files, it was appended to a main file. The size of data in this file can be judged from the fact that there were more than 9000 records. Even after indexing and totalling, the records (types of products) came down to 1670 only. From this data it was very difficult to conduct input-output analysis on the basis of individual product. Following observations were made and steps taken to reduce the number of records while at the same time not adversely affecting results of the analysis.

- a) Same part number was written in a number of different ways e.g. a part number F0530530 was written as F0530530 or as 0530530 or as F530530 or as 530530. As there was no list of standard part numbers in the memory or records, part numbers could not be rectified automatically. This resulted into:
 - i) More part numbers than they actually were.
 - ii) Flaws in the input-output analysis as inputs were written against one form of the part numbers and outputs against some other version.

The main reason of this mistake has been that this data was maintained by shop floor people. They wrote incorrect numbers either by mistake or knowingly, thinking that it would be understood by people who are well conversant with the part numbers.

- b) Almost all part numbers are made in various sizes e.g. 10 oversize, 20 oversize and so on. In certain cases there are as many as 8 sizes. This fact resulted in excessive part numbers and also into flaws, as input was shown against one size and output against other sizes. This resulted into situations of 'no output from inputs' or 'output without inputs'.

To rectify the above mistakes following steps were taken:

- i) Against all sizes of products only standard sizes were written.
- ii) A list of standard part numbers was referred to substitute correct part number in place of many versions of the same.

These steps helped to reduce the flaws besides reducing the number of records to 218. The file now contained the following:

Total number of records = 218

No. of records for each type of product: Straight- Bearings = 84 Bushes = 100 Washers = 21 Flange Bearings = 13. Using this final file, input - output analysis has been

carried out as under:

5.2.5.1 Input-output analysis of all products taken together: This has been as under:

Difference in input and output,

$$\text{Diff} = \text{NI} - \text{O} = (\text{OS} + \text{I} - \text{CS}) - \text{O}$$

Where O, Output = Good + Rejected

$$\text{Reported Scrap} = \text{Rejected} / \text{NI}$$

$$\text{Actual Scrap} = (\text{Rejected} + \text{Difference}) / \text{NI}.$$

These calculations have been shown below.

Each category of the main file was summed up to give totals as per Table 5.10

Table 5.10

Input - Output of all Products (in numbers)

Opening Stock on 1.4.91	Quantity Blanked 1.4.91-31.7.91	Products		Closing Stock on 31.7.91
		Good	Rejected	
2,25,977	31,74,699	26,26,185	2,22,355	2,63,812

$$\begin{aligned} \text{Net Input} &= \text{OS} + \text{I} - \text{CS} = 2,25,977 + 31,74,699 - 2,63,862 \\ &= 31,36,864 \end{aligned}$$

$$\begin{aligned} \text{Total Output} &= \text{Good} + \text{Rejected} = 2,62,618 + 2,22,335 \\ &= 28,48,540 \end{aligned}$$

$$\text{Difference} = 2,88,324 = 9.20 \% \text{ of NI}.$$

Thus, the difference between input and output is of the order of 9.20% by number (not by weight). in other words 9.20% of the material could not be accounted for. Most likely actual scrap is higher by 9.20% than the reported percentage.

Reported scrap Rejected (Reported in the daily inspection reports)

$$= \frac{\text{Rejected}}{\text{NI}} = \frac{222355}{3136864} = 7.1\%$$

$$\text{Actual Scrap Rejected} = \frac{\text{Rejected} + \text{Diff.}}{\text{NI}} = \frac{222355 + 288324}{3136864} = 16.3\%$$

5.2.5.2 Input-output of individual category of products: Steps explained above were followed but the quantities considered were pertaining to only one category of products at a time e.g. for bushes.

This has been done by summing up various figures of good and scrap quantities etc. for individual category of products from the main file. The results are shown in Table 5.11.

Table 5.11
Input - Output of Each Category in Machine Shop

S. No.	Products	Opening Stock A	Quantity Blanked B	Good Products C	Rejected Producted D	Closing Stock E
1.	Bushes	43,669	9,45,657	7,75,724	43,967	63,806
2.	St. Bearings	1,52,591	17,93,043	15,30,190	1,56,389	1,51,172
3.	Washers	6,127	3,42,444	2,82,490	12,075	11,592
4.	Flanged Bearings	23,590	93,555	37,781	10,024	36,826

Table 5.12 gives the percentage of actual and reported scrap based on input and output values given in Table 5.11.

Table 5.12
Actual and Reported Scrap of Each Category

S. No.	Products	Net Input (NI) A+B-E	Output (O) C+D	Rejected		Unaccounted		Actual Scrap	
				D	%age D/NI	(F) NI-O	%age F/NI	(E) D+F	%age E/NI
1.	Bushes	9,25,520	8,19,691	43,967	4.8	1,05,829	11.4	1,49,796	16.2
2.	St. Bearings	17,94,462	16,86,479	1,56,389	8.7	1,07,983	6.0	2,64,272	14.7
3.	Washers	3,36,979	2,94,565	12,075	3.6	42,414	12.6	54,489	16.2
4.	Flanged Bearings	80,319	47,805	10,024	12.5	32,514	40.5	42,538	53.0

5.2.5.3 Calculations of total waste , wastivity and waste on output: Converted all quantities into weights we get

$$\text{Gross weight of output of good blanks} = \sum_{i=1}^4 QBg_i \times Wt_{pi} \quad (5.16)$$

Where QBg_i is the quantity of good blanks of each category of the product

Wt_{pi} is the average weight of each category and

i is the category of the product, i.e bushes, bearings, washers and flanged bearings

Using the quantities of good blanks of each category from Table 5.11 and the average weights as discussed in section 5.2.4 (a), the gross weight of the good blanks comes out

to be equal to 2,60,605 Kg.

Similarly weight of rejected blanks = 50,750 Kg.

$$\text{Weight of Chips of good blanks} = \sum_{i=1}^4 QBg_i \times Wtr_{bmi} \quad (5.17)$$

where Wtr_{bmi} is weight removal at blanking and machining operations.

Using figures of quantity blanked from Table 5.11 and the weight removal from Table 5.17, the weight of chips comes out to be 57,227 Kg.

$$\begin{aligned} \text{Net weight of output} &= \text{weight of good blanks} - \text{weight of chips} \\ &= 2,60,665 - 57,227 = 2,03,438 \text{ Kg.} \end{aligned}$$

$$\begin{aligned} \text{Total waste} &= \text{weight of rejected products} + \text{weight of chips} \\ &= 57,227 + 50,750 = 1,07,977 \text{ Kg.} \end{aligned}$$

$$\text{Weight of input} = \text{Output} + \text{Waste} = 3,11,415 \text{ Kg.}$$

$$\text{Stage wastivity} = 35\%$$

$$\text{Waste on Output} = 53\%$$

From the above results of the input-output analysis it is evident that the actual scrap percentage in almost all categories of products is much higher than the scrap percentage reported in the daily inspection reports. Flanges account for maximum scrap percentage of 53%. Further the company also compiles data of good and scrap products produced in various periods of time. These reports are made by production, inspection or quality control personnel. Table 5.13 shows the data regarding good, scrap and cost of quality on monthly basis for one year. This table also proves that the reported scrap percentage is generally very low. However in August and September, 1991 the reported scrap percentage is as high as 18% to 23%.

The compiled figures of reported scrap in the study period for various categories of products are as shown in Table 5.14. Flanges, again, lead with as high a scrap as 25% in May, 1991.

Using figures given in Tables 5.12 and 5.14 comparative figures of scrap have been obtained in Table 5.15. It may be noted here that figures of scrap reported in the monthly reports are generally higher than those calculated from the inspection reports. This is because the input is taken as, OS + I - CS, where as the input taken for monthly reports is, Good + Scrap.

Table 5.13
Data Regarding Good, Scrap, COQ etc.: 1990 - 1991.

Month	Good Quantity	Rejected %age	Sales Return (Lac Rs.)	COQ %age to Sale	Total Sales (Lac Rs.)
April	569849	10.46	3.60	23.80	51.00
May	651008	8.80	0.65	6.70	104.28
June	468685	8.23	0.43	-	95.00
July	131362	10.16	1.14	7.50	34.00
August	134085	18.23	0.41	26.81	16.60
September	137493	22.78	0.49	31.28	32.00
October	515994	10.62	0.21	18.20	47.50
November	665941	11.56	0.25	14.38	93.30
December	671099	8.89	0.90	12.00	86.10
January	673330	8.55	0.64	10.86	76.30
February	754257	7.11	0.33	9.91	72.60
March	785497	8.01	0.63	8.13	138.00
Total	6193200	9.75	12.02	13.25	848.08
1989-90	7090375	8.81	-	10.71	1036.00

* COQ is 'Cost of Quality'

Table 5.14
Reported Data Regarding Good and Scrap for the Study Period

Description	Scrap (Numbers/percentage)				
	April	May	June	July	Total/Average
Total Quantity	741661	672187	610493	721421	2745762
Rejection %age	6.31	8.93	7.31	7.93	7.62
Bearings (%)	8.31	12.50	10.27	10.67	10.46
Flanges (%)	23.26	24.86	10.86	9.59	17.13
Bush (%)	2.80	3.49	4.36	4.79	3.86
Washers (%)	4.61	3.43	1.59	1.74	2.84

Histograms shown in Fig. 5.4 give a pictorial view and highlight the difference in actual and reported figures.

Table 5.15
Comparison of Actual and Reported Figures

Type	Calculated from Daily Inspection Reports (%)	Reported in Monthly Reports (%)	Actual/Gross (%)	Unaccounted Material (%)
Combined	7.10	7.62	16.30	9.20
Bushes	4.80	3.86	16.20	11.40
Bearings	8.70	10.46	14.70	6.00
Washers	3.60	2.84	16.20	12.60
Flanges	12.50	17.13	53.00	40.50

5.2.5.4 Input- output analysis of individual product: Input-output analysis done here-to-fore serve the purpose of giving indications regarding broad areas of wastages alongwith quantities. But to pin point exact wastage along with reasons thereof, input output analysis of each type of product has been conducted.

Considering the variety of products, it is not an easy task to do this type of an analysis. Due to this reason the company has never conducted a detailed input-output analysis for individual part numbers. However, this analysis has been attempted here for the inputs and outputs of 4 months from April to July, 1991 as discussed earlier. All sizes of part numbers have been merged in an effort to reduce entries to manageable limits. Those part number for which blanking quantity was less than 2000 have not been considered. Appendix B1.1 shows prominent part numbers out of the total list. Fig.5.5 highlights the part numbers resulting in excessive scrap and requiring immediate attention.

5.2.5.5 Scrap analysis: To look into the reasons of higher scrap details of actual figures of rejected products due to various reasons have to be looked into. In any industry products are rejected either at the final inspection stage or during production, i.e. in-process stage. Both of these are discussed here.

- (a) **Scrap at final inspection stage:** For the month of July, 1991 scrap analysis has been done. Appendix B1.2 gives complete details regarding scrap produced at various stages. This data has been taken from daily inspection reports.

Appendix B1.2 and histograms as shown in Fig. 5.6 clearly show a higher percentage of total scrap in case of flanged bearings and straight bearings. Further, the flow charts of operations (chapter three) reveal that additional operations of height broach and I.D. broach

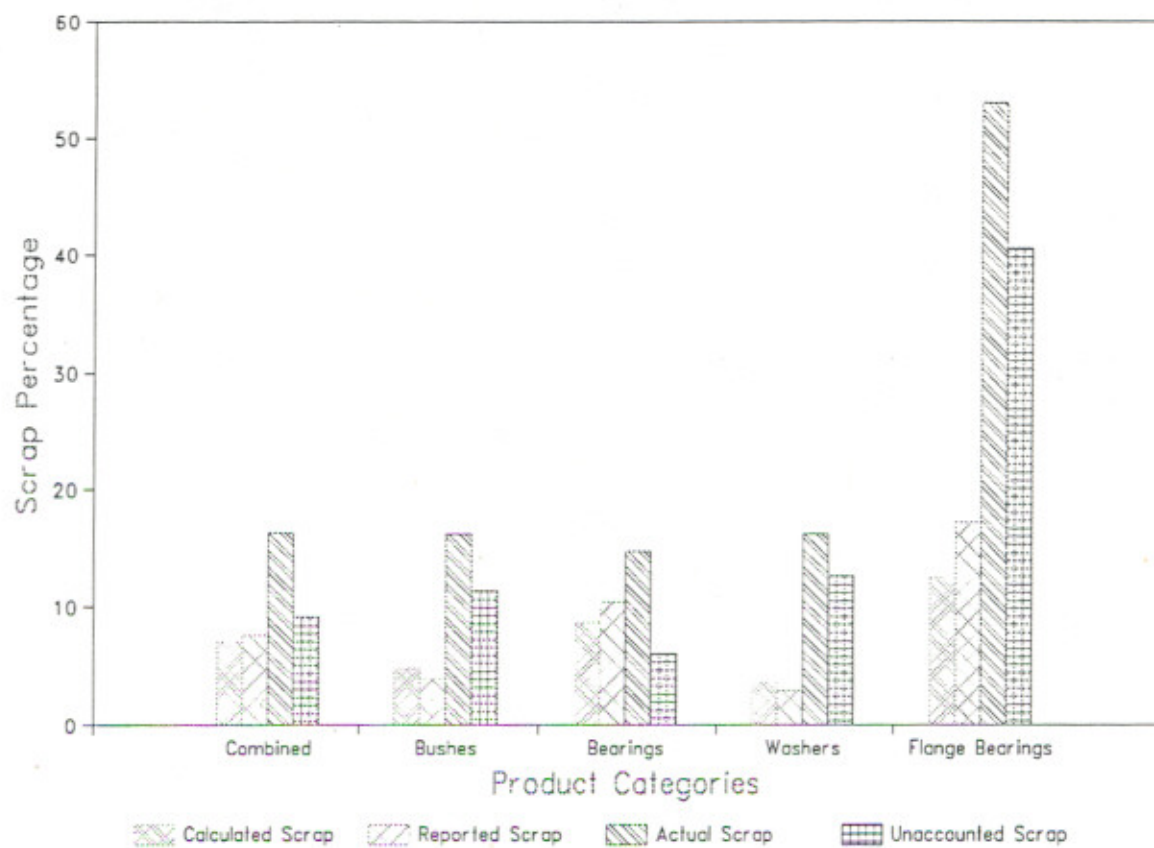


Fig. 5.4 : Actual & reported scrap - product categories

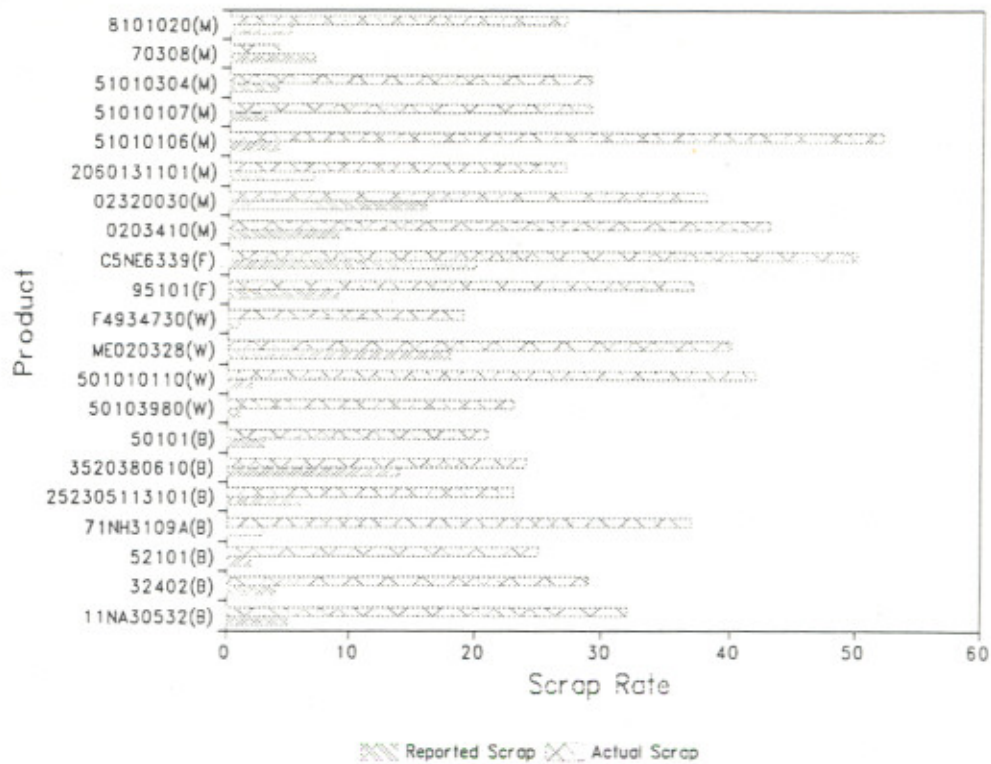


Fig. 5.5 : Actual & reported scrap - individual product

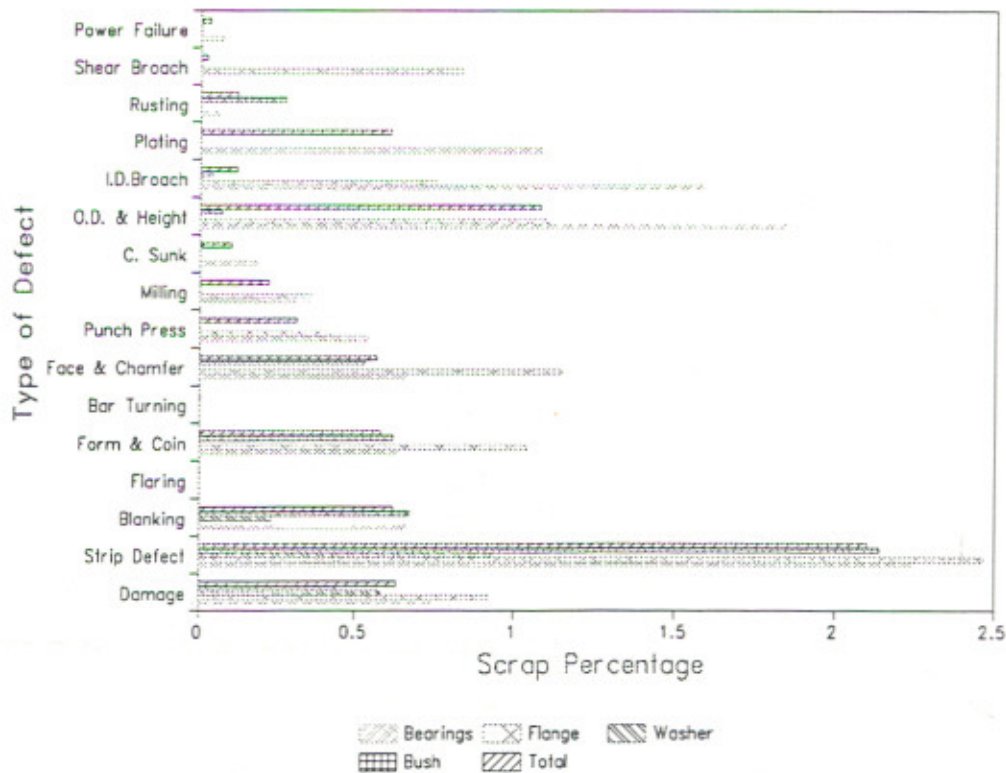


Fig. 5.6 : Scrap analysis

are done only on these two products. In case of flanged bearings, operation of shear broach is also carried out. A look into scrap due to individual reasons indicates that strip defects are the most prominent. But this defect is there in all categories of products viz. straight bearing (2.25%), flanges (2.47%), washers (0.93%) and bushes (2.14%). The lower percentage of 0.93% in case of washers can be attributed to the fact that in case of washers, bending or coining etc. are not done whereas in case of all other categories, these operations are carried out. Thus, reasons of higher scrap due to strip defect have to be looked into.

The other prominent area of scrap is height broaching and ID broaching. This is an area which is contributing maximum to the higher scrap percentages in case of flanges and straight bearings. To look into its reasons details of the operations, machine capability etc. have to be found out.

- b) **In-process scrap:** During the course of manufacturing, material having some defect which would ultimately render it scrap should be removed so that cost of further processing is saved. In this regard also, some efforts were made to segregate scrap at all the stages. The details of scrap picked up at various stages of the study period, and total scrap thus found out is given in Appendix B1.3. Important findings are presented here.

Total In-process Scrap	= 65,315
Total Scrap(In-process + Final Inspection)	= 2,22,355.
Thus final insp. scrap = 2,22,355 - 65,315	= 1,57,040.
Total Input	= 31,36,864 %age
In-process scrap	= 2.1% %age
final scrap	= 5.0%
In-process scrap as %age to total scrap	= $65315/222355 = 29.37\%$

Main type of in-process scrap as percentage of total in-process scrap

Strip Defect	= 42.72%
Blanking	= 19.58%
Forming & Coining	= 7.96%
Ht. Broach	= 7.78%
ID Broach	= 7.28%
Facing & Chamfer	= 4.89%

5.2.5.6 Rework analysis: This category has been included for detailed analysis because it is seen that a very little amount of rework material is generally salvaged and sent as good production. Only July, 1991 figures have been taken for the purpose of analysis.

Stage-wise rework generated for the month of July, 1991

Total Good	= 6,84,122 (From inspection reports)
Total Rejected	= 39,406 (reported figure)
Rework	= 33,588 (Compiled from inspection reports details in Appendix B1.4)
Percentage Rework	= $33,588 / (6,84,122 + 39,406 + 33,588) = 4.43\%$ of total.

Type of rework :

Appendix B1.4 gives details of the various types and stages of rework for the month of July, 1991. Prominent types are presented here.

Main types of rework:

Lip Milling	12,658	37.68%
Wall O.S.	6,440	19.17%
Height O.S.	2,229	6.63%
Parting Line Chip off to be removed	1,833	5.45%
Rebroaching	1,592	4.73%
Burr on Steel side	1,235	3.67%

Rework cleared in July, 1991:

The figures of rework material actually salvaged and sent as good production show a very interesting and revealing picture. It is as under:

Rework salvaged	= 6,672 (Taken from inspection reports)
Rework kept	= $33,588 - 6,672 = 26,916$
Percentage of rework cleared	= $6672 / 33588 = 19.86\% = 20\%$
Closing stock of rework on 31-7-91	= 26,749.

The closing stock of June 1991 was also in this range only. Thus, it implies that most of the rework lying earlier was thrown in scrap.

5.2.6 Input-Output Analysis by Weight

In the preceding sections, input-output analysis has been carried out on the basis of number of products. Large differences between inputs and outputs have been found out, i.e. the percentage of untraceable material is really very high. Now, if analysis is conducted on the following lines, a clear picture would emerge as to where has this material gone. If

weight of scrap material is more, then it would indicate that more number of scrap products (rejected products) were made than reported. Otherwise, it would indicate spillage, theft or anything of the like.

The analysis includes:

- a) Weight of blanks input in a specified period (1.4.91 to 31.7.91).
- b) Weight of the finished product sent out in this period.
- c) Weight of the material lying at various stages in the beginning of this period.
- d) Weight of the material lying at various stages at the end of this period.

Sources of data: The first task was to find out above weights. Blank weights were found out as explained in section 5.3.2. For finding out weights of in-process goods and finished goods, the material removed at each processing stage was required. To find out this, weight of a number of products before and after each operation was calculated and it was established that irrespective of size, weight removal percentage at an operation is the same for all types of products. The calculations for facing and chamfering are shown in Appendix B1.5. Similarly weight removal for all other operations have been calculated. Table 5.16 shows these values.

Table 5.16
Weight Removal at Each Stage

S.NO.	Operation	%age of Weight Remaining after Operation.
1.	Sanding	93.000
2.	Blanking	90.000
3.	Machine Shop	
	a) Facing & Chamfering	92.260
	b) Hole Chamfering	98.670
	c) Hole Punching	98.634
	d) Boring	86.150
	e) Height Broach	99.350
	f) I.D. Broach	92.070
	g) Lip Milling	99.507
	h) Grooving	94.561
	i) Sloting	98.890
	j) Notching	97.444
	k) Grinding	99.000

Based on percentage weight removals and average weights of products found out in section 5.2.4, weight of product at each stage has been calculated as shown in Table 5.17.

Table 5.17
Weight of Products at Each Processing Stage

S.No.	Bush (Initial Wt. 0.09282Kg.)		Bearing (Initial Wt. 0.1048Kg.)		Washer (Initial Wt. 0.08616Kg.)	
	Operation	Wt. After Operation	Operation	Wt. After Operation	Operation	Wt. After Operation
1.	Blanking	0.077	Blanking	0.087	Blanking	0.028
2.	First Forming	0.077	Form & Coining	0.087	Chamfering	0.0258
3.	Second Forming	0.077	Face & Chamfering	0.081	Grooving	0.0244
4.	Final Forming & Coining	0.077	Lipping	0.080	End Chamfering	0.0241
5.	Stress Relieving	0.077	Grooving	0.076	Tumbling	0.0241
6.	Facing & Chamfering	0.072	Oil Hole Punching	0.075	Plating	0.0241
7.	Tumbling	0.072	C.Sunk Hole	0.074		
8.	Tin Plating	0.072	Deburring	0.074		
9.	Grooving	0.068	I.D. Broach	0.068		
10.	Boring	0.058	Plating	0.068		
11.	Packing	0.058	Height Broach	0.068		
	Weight Loss in Blanking	0.01512		0.0171		0.06516
	Weight Loss in Machining	0.0199		0.02		0.0039

Using above weights of in-process goods of various stages, total weight of physical inventory as on 1.4.91 and as on 1.8.91 have been worked out as shown in Appendix B1.6 and B1.7. Weights of inputs and outputs are given in Appendix B1.8. Final input output has been shown below.

Table 5.18

Consolidated Figures of Input - Output by Weight

S.No.	Material	Quantity
1.	Input	
	a) Blanks	2,48,520.62 Kg.
	b) WIP	19,515.66 Kg.
	Total:	2,68,036.28 Kg.
2.	Outputs	
	a) Good Products	1,57,796.50 Kg.
	b) Rej.Products	5,808.86 Kg.
	c) Broach Shavings	18,903.69 Kg.
	d) Chips	
	i) Steel	15,000.00 Kg.
	ii) Bimetallic	17,000.00 Kg.
	iii) Combined	20,000.00 Kg.
	e) WIP	18,492.80 Kg.
	Total output	2,53,001.87 Kg.
3.	Net Input = 2,68,036 - 18492	= 2,49,543.00 Kg.
4.	Difference = (1) - (2)	= 15,034.41 Kg = 6.02%

The above difference between the inputs and outputs indicates that about 6% of material could not be accounted for. The most likely reason of this looks to be irregularities and misappropriations made in sale of scrap. It can be concluded that firstly, more rejected goods than reflected were produced and secondly, there was spillage or pilferage of the material.

5.2.7 Details of Collection, Recycling and Disposal

There is a wide variety of tangible wastes generated as under.

- i) Slag, i.e. material removed from surface of molten metal in the form of impurities.
- ii) Fine chips of steel generated at sanding.
- ii) Bi-metallic chips of quite big size or pieces of bi-metallic strip generated on blankers.
- iii) A large sized bi-metallic waste material in the form of continuous strip out of which blankings for washers have been taken.
- iv) Bi-metallic chips produced at various machining operations.
- v) Chips of only 'powder' material generated at broaching machines.

- vi) Chips of only steel, wet with cutting oil produced at bush grinding machine.
- vii) Rejected products.
- viii) Other wastes like, worn out machine components, used up indirect materials like blades, tools, brushes, steel parts like angle irons etc. and other such material.

5.2.7.1 Collection: All the above varied types of waste are produced at different places. So, as such there is no problem in segregating them at source. They are separately collected but as they are not sold separately, most of these materials are dumped at one place and get mixed up in the yard. Only chips from broaching machines are kept separately for their recycling. Even in this case shavings of different powder materials i.e. HF2, HF16 or H24 are not kept separately.

5.2.7.2 Recycling and disposal: Only broach shavings are recycled which are collected from broaching machines and put along with fresh material for alloy making at powder plant. As steel is bought from outside, steel scrap is not recycled. Bi-metallic scrap is not processed to separate powder material and steel.

The company's approach has been found to be quite casual for disposing off scrap. Various types of chips and pieces of steel or bi-metallic strip are sold at the same rate. Continuous strip, out of which blanks for washers have been taken is used for making partitions and racks etc.. Although this is good use of scrap material, yet keeping in mind the cost of powder on bi-metallic strip even this is not fully justified. No efforts have been made within the plant or through any ancillary unit to separate powder from steel by heating and selling of steel. If this becomes technologically viable, the company can save a lot.

Slag has been used as land-fills outside the building, thus making use of otherwise waste material.

5.3 PHYSICAL SYSTEM THEORY MODEL

The inputs, outputs and wastes of various sub-systems are represented by physical system theory model. The objectives of representing the case by model are:

- i) To facilitate calculations of materials requirements at various stages of production activity by taking into account waste at every stage.
- ii) To facilitate calculation of unit cost of product at every stage by considering wastage and processing costs at all previous stages.
- iii) To bring the case into a form which will facilitate production planning, capacity

planning and other management activities.

- iv) To conduct sensitivity analysis in order to find effects of wastes of various stages on the final cost of product. This would help choose areas needing more attention for waste reduction.

5.3.1 Development of the Model

In various sub-systems, material is measured in different units. In blanking, machine shop and plating the unit is number of products whereas in case of powder plant, sanding and sintering, material is expressed in terms of weight. Thus, for compatibility weight has been decided as the measure of material because number of products can also be converted to weight. Large variety of product did not permit use of number of products as the unit of measurement of material.

The model has been developed for an output of 1000 kg. The input requirements of material at every stage for 1000 kg output of material from the final stage have been calculated. In addition, the unit cost of product at every stage has been calculated. The system graph has been shown in Fig. 5.7 Rework has been shown at two subsystems, i.e. powder plant and machine shop. Equations 5.12 are used for calculations of through variables and across variables are:

5.3.1.1 Data required and parameters estimation

- a) **Material inputs, outputs and wastes on output at various stages of the production process.** Table 5.19 shows the values of waste percentage on output in various sub-sections.

Table 5.19

Waste Percentages on Output in Various Sub-Systems

S.No.	Department	Scrap Rate
1.	Powder Plant	6.88%
2.	Powder Plant(R)	6.88%
3.	Sanding	9.24%
4.	Sintering	1.30%
5.	Blanking	22.49%
6.	Machine shop & Plating	53.00%
7.	Machine shop & Plating(R)	400.00%

- b) **Initial Material cost of various ingredients, processing cost in various**

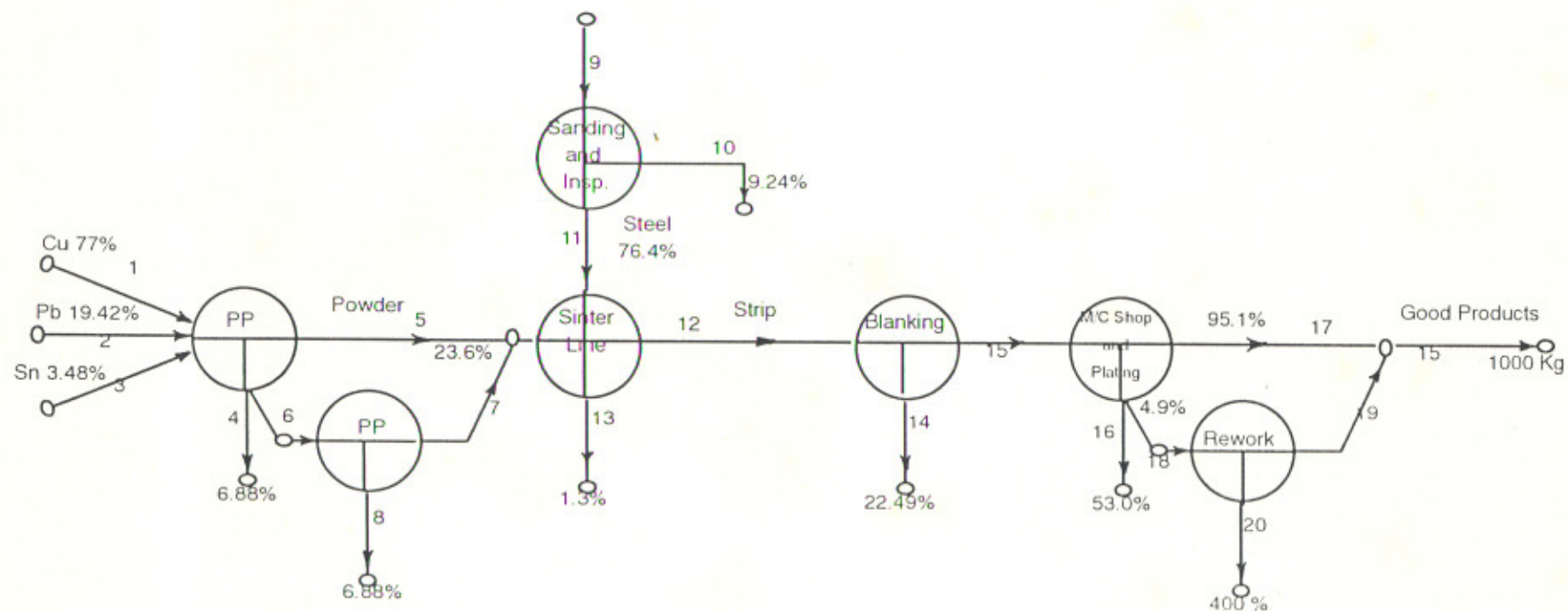


Fig 5.7 : Simplified System Graph of the Material Flow System

sub-systems, sale price of scrap material of various sub-sections. The costs are calculated as described below:

- i) **Processing cost:** Processing costs have been further divided into two components of fixed cost and variable cost. This has been done to account for the variation of processing cost with number of products made, i.e. economy of scale.

Fixed cost: Machinery and equipment cost and manpower cost have been included in fixed cost whereas energy cost has been included in variable cost. Table 5.20 shows the calculations of fixed cost. Machinery and equipment cost has been taken from records of the finance department of the company whereas manpower costs are actual costs incurred on manpower in the month of July, 1991. These manpower costs will be discussed in the case study on manpower in chapter eight. A flat depreciation rate of 10% has been assumed on machinery and equipment. Cost of utilities like compressed air etc. have been allocated to various sub-sections in the ratio of own costs of the sub-systems. From the total fixed costs of each sub-system as calculated in column 8 of the table, fixed cost for 1000 kg. material output has been calculated.

Table 5.20:
Calculation of Fixed Costs

S. No.	Area	Machinery & Equipment Cost (Rs) (a)	10% Depreciation Per Month (Rs) $b = \frac{10 \times a}{12 \times 100}$	Manpower Cost/ M (Rs) (c)	Total Fixed Cost (Rs) $d_i = b + c$	Utilities (e) (Rs) $224080 \times \frac{d_i}{\sum d_i}$	Final Cost (f) (Rs) $d_i + e$	Fixed Cost on 1000 Kg. (g) (Rs) $\frac{f \times 1000}{MP^*}$
1.	Powder Plant	23,68,607	19,738	39,600	59,340	+ 11,270	70,610	4,200
2.	Sanding	36,13,334	30,111	25,316	55,430	+ 10,530	65,960	760
3.	Sinter Line	1,08,40,002	90,333	75,948	1,66,280	+ 31,590	1,97,870	2,300
4.	Press Shop	35,00,000	29,166	69,242	98,410	+ 18,700	1,17,110	1,670
5.	Machine Shop	2,37,31,853	1,97,765	4,84,694	6,82,460	+ 1,29,670	8,12,130	15,600
6.	Plating	63,61,964	53,016	64,448	1,17,460	22,320	1,39,780	2,740
7.	Utilities	1,00,00,000	83,333	1,40,752	2,24,080			

* MP is material processed in a department.

Variable cost: Table 5.21 shows the calculations of variable costs. The total cost of energy has been computed for one month. This includes cost of fuels and electricity both. Details of costs have been explained in the case study on energy in chapter six. Energy

consumed per unit of the products on supporting equipment has been allocated to other sub-systems in the ratio of their energy costs.

Table 5.21

Calculation of Variable Cost

S.No.	Area	Total Energy Cost (Month) (a) (Rs.)	Total Material Produced (Kg.) (b)	Energy Cost per Product (Rs.) $c=a/b$	Energy Cost per product on supporting Equipment (Rs.) $d=2.60*c/dc$	Total (Rs.) $c+d$
1.	Powder Plant	65410	16995	3.85	1.27	5.12
2.	Sanding	33572	86000	0.40	0.13	0.53
3.	Sinter Line	100718	86000	1.21	0.40	1.61
4.	Press Shop	12000	69622	0.17	0.06	0.23
5.	Machine Shop	74500	50860	1.70	0.56	2.26
6.	Plating	28710	50860	0.56	0.18	0.74
7.	Supporting Equipment	132030	50860	2.60	-	-

Table 5.22 shows the fixed costs and variable costs of each sub-section.

Table 5.22

Fixed Costs and Variable Costs

S.No.	Sub-Section	Fixed Costs on 1000 kg (Rs.)	Variable Cost per Kg.(Rs.)
1.	Powder Plant	4200	5.12
2.	Sanding	760	0.53
3.	Sinter line	2300	1.61
4.	Press Shop	1670	0.23
5.	Machine Shop	15600	2.26
6.	Plating	2740	0.74

ii) Other costs: Table 5.23 gives the values of the other costs:

Table 5.23

Costs of Materials.

S.No.	Material	Cost per kg (Rs.)
1.	Copper	125.00
2.	Lead	38.00
3.	Tin	383.00
4.	Steel	22.00
5.	Sale Scrap	5.00

Technological co-efficients

Using values of wastes at every stage and inter-connection of the sub-system, graph of the model has been drawn as shown in Fig.5.7 Various segments have been numbered. Rework has been shown at powder plant and machine shop. Values of technological coefficients of input and waste have been calculated for each process in every sub-system. Rework factors, depicting the amount of material output through rework process have been calculated for powder plant and machine shop. These have been calculated using equations 5.6 to 5.11 in section 5.1. The values of technological co-efficients and the rework factors are shown in Table 5.24

Table 5.24
Values of Technological Coefficients

Sr.No.	Stage	Technological Coeff.of Input	Values	Technologic al Coeff.of Waste	Values
1.	Powder Plant (Basic)	K1	1.0688	KW4	0.0688
		K2	1.0688	KW8	0.0688
		K3	1.0688		
2.	Powder Plant (Rework)	K6	1.0688	KW13	0.013
3.	Sanding	K9	1.0924	KW10	0.0924
4.	Sinter Line	K5	1.013	KW14	0.2249
		K11	1.013		
		K7	1.013		
5.	Blanking	K12	1.249		
6.	M/C Shop	K15	1.53	KW16	0.53
		K18	5.0	KW20	4.0
	Rework Factors	RF17	$5/5.049 = 0.9902$		
		RF5	$1.0688/1.0688 + 0.257 = 0.806$		

5.3.1.2 Calculations of through and across variables: Using the equations for through variables and across variables and the values of technological co-efficients, these variables for each stage have been calculated. Table 5.25 shows the values.

Table 5.25
Values of Through and Across Variables.

Through Variable					
Input		Waste		Across Variable	
Variable	Value	Variable	Value	Variable	Value
Y19	10.00	YW20	40.00	X5	140.63
Y18	50.00	YW16	551.20	X11	25.02
Y17	990.00	YW14	357.86	X12	55.70
Y15	1591.20	YW13	25.33	X15	66.18
Y12	1949.06	YW10	139.37	X21	113.07
Y11	1508.44	YW8	6.21		
Y9	1647.81	YW4	32.48		
Y7	90.39				
Y6	96.60				
Y5	375.56				
Y3	17.54				
Y2	97.92				
Y1	388.28				

5.3.2 Sensitivity Analysis

Sensitivity analysis has been carried out to see the effect of slight increase in wastage level of each stage on the final cost and the effect of slight increase in fixed cost or variable cost on the final cost. This has been done by giving a small increment to wastage level or processing cost of each stage and calculating the final cost. The results are given below:

5.3.2.1 Effect of stage waste on final cost: Table 5.26 shows the values of final cost of the output with an increase of 1% in the wastage level.

The analysis reveals that final cost is most sensitive to the waste generation at sinter line followed by blankers. Thus, maximum efforts should be put to contain waste generation at these stages.

Table 5.26
Effects of Waste Percentage on Cost

S.No.	Sub-system	Technological co-efficients	Cost/kg (Rs)	Sensitivity
				$\frac{\Delta c}{\Delta \text{Scrap Rate}}$
1.	Powder Plant	K1, K2, K3	115.9627	2.56
2.	Powder Plant(R)	K6	115.4895	2.14
3.	Sanding	K9	115.7428	2.36
4.	Sinterline	K5, K7, K11	116.3106	2.87
5.	Blankers	K12	116.2023	2.77
6.	Machine shop	K15	115.9974	2.58
7.	Machine shop(R)	K18	115.4948	2.14

5.3.2.2 Effect of processing cost on final cost: Table 5.27 shows the effect of 10 paise per kg. increase in variable cost in each sub-section.

Table 5.27
Effect of Increase in Variable Cost on Final Cost

S.No.	Area	Cost	Sensitivity
			$\frac{\Delta c}{\Delta p}$
1.	Powder Plant	115.5559	2.19
2.	Sanding	115.6475	2.27
3.	Sinter line	115.6899	2.32
4.	Blankers	115.6555	2.29
5.	Machine Shop	115.6035	2.24

Above results show that the final cost is most sensitive to the variable cost on sinter line followed by blankers and sanding. Cost in these departments should not be allowed to increase as far as possible.

5.4 SUMMARY OF RESULTS, REASONS OF WASTE AND WAYS OUT

Table 5.28 presents summary of waste in various sub-systems, along with yearly loss due to waste.

Table 5.28
Summary Of The Material Wastages

S.N.	Area	Study Period (month)	Input (Kg.)	Waste (Kg.)	Annual waste (Kg.)	Cost per Unit (Rs.)	Annual Loss (Rs.)	Reasons
1a	Powder Plant	4	84363	5437 6.44%	16310	140.66	2294305	i Spillage ii Pilferage iii Process scrap iv Thrown out with slag. v Poor composition of inputs.
1b	Powder Plant recycling	3	78331	16016				i System parameters not properly maintained. ii Poor condition of machinery. iii Poor quality of inputs.
2	Sanding	1	68382	5800	69600	24.56	1709376	i Oversized raw material. ii Improper operations.
3	Sinter	1	83394	1117 1.3%	13404	55.34	741777	iii Poor quality of Steel. iv Process scrap
4	Blanking	1	80983	14779	177348	67.75	12015327	i Process scrap. ii Oversized raw material.
5A	Machine Shop by numbers	4	3136864	510679 16.3%	1532037	-	-	i Process scrap.
			Bushes	16.2%				
			St. Bearings	14.7%				
			Washers	16.2%				
			Flange Bearing	53%				
5B	By weight	4	311415	107977	323931	115.50	37414030	
Total Yearly Loss							54174815	

Total yearly loss in all the sub-systems has also been calculated which comes out to be Rs.5,41,74,815. Further, overall wastivity in case of materials is given by PST as under:

Input requirements for 1000 Kg. output have been worked out.

Steel 1,647.81 Kg.

Copper 388.28 Kg.

Lead 97.92 Kg.

Tin 17.52 Kg.

Total 2,151.55 Kg.

Thus waste = 2,151.55 - 1,000 = 1,151.55 Kg.

Overall wastivity = 53.56%

5.4.1 Probable Reasons of Wastage

A close look at Table 5.28 reveals the following main areas of waste:

5.4.1.1 Process scrap: Wastage in the industry has been largely due to process scrap. There has been 3.4% wastage due to process scrap on sinter line, 2.05% on blankers and

about 16% in machine shop. The reported process scrap in case of machine shop is nearly one half of the actual figures. Further, wastage on powder plant can also be due to process scrap or any other reasons.

5.4.1.2. Suitability of form of raw material: The size of raw material has been found to cause wastage particularly on blankers. It is seen in the analysis that difference in strip width and blank width is of the order of more than 10%. Thus, atleast 10% material goes waste if blank is made as per recommended strip size. If shortage or non-availability of this recommended strip size suggests some bigger strip size to be used, more waste is caused. Similarly, about 6.4% material goes as waste due to difference between required steel thickness and thickness of steel used.

Further, shape of the raw material vis-a-vis intended product has also caused considerable waste. This has occurred in the case of washers where 65% of the material goes as waste due to half round shape of washer blanked out of a rectangular continuous strip.

5.4.1.3. Untraceable material: There has been a large quantity of material which remains untraced. On powder plant about 8% of the total quantity of copper, lead and tin taken together is lost. Similarly, Input-Output analysis of machine shop shows that nearly 6% of the total input to machine shop could not be traced. This area again accounts for a large sum.

5.4.1.4. Production of coarse powder: On an average 20% of the powder produced on powder plant is coarse powder which has to be recycled. In addition to wastage of other resources of energy, capital and manpower, this also causes material loss, as with every heat slag is removed from the alloy. If proper care is not taken some material may go out with slag.

5.4.1.5 Rework: It is observed in practice that 90% of the rework produced, ultimately goes as scrap. It is seen that rework keeps piling up and is not salvaged for want of manpower. Ultimately it is thrown into scrap because of deterioration or other reasons.

5.4.2 Basic Causes

Having listed various apparent reasons of waste, next step is to find root causes responsible for the same. These are:

- a) **Process scrap or rework can be mainly due to:**
 - i) Negligence on the part of workers in maintaining process parameters and of

supervisors, inspectors and other people supplying drawings, toolings and giving instructions.

- ii) Inferior or sub-standard inputs of raw materials, indirect materials and toolings, etc.
- iii) Improper machinery and equipment.
- iv) Sudden interruption in power supply or other inputs.
- v) Environmental effects.
- i) **Human Error:** Machine capability studies were conducted for some machines which revealed that machine are generally capable. Scrap is caused mainly due to negligence on the part of workers in general, and due to non-adherence to system parameters, in particular. Scrap analysis reveals that sintering defects followed by broaching defects contribute maximum to scrap.
- ii) Higher humidity causes considerable scrap in sintering. The present heating system with LPG is not suitable for maintaining required reducing atmosphere.
- iii) Sudden interruptions in power supply have caused considerable scrap in plating.
- iv) Poor quality of steel has also caused scrap on sinter line.
- v) Scrap on broaching machines depends largely on the capability of these machines but some reduction is possible through proper care.

(b) Unaccounted material can be due to:

- i) Spillage
- ii) Pilferage or theft
- iii) Thrown out with slag

On powder plant it has been seen that the maximum wastage is of tin which is the most expensive of all, followed by copper and lead which are next in order in terms of their cost. This indicates, likelihood of pilferage of the material. Spillage on floor and in trenches etc. due to negligence can be other major reason. Thirdly, non-adherence of laid down system parameters can cause some of the useful material to go as waste with slag.

Similarly, unaccounted material in machine shop can be either due to pilferage or

due to irregularities in weight recording while selling scrap material.

- c) **Production of excessive coarse powder** can be attributed to both equipment and human error. About 10% production of coarse powder is inevitable with the existing process. Another 10% coarse powder is for not sticking to the laid down parameters of pouring temperature, pouring rate and water pressure.
- d) **Reasons for non-suitability of input material** for the intended product can be many. Prominent among them are:
 - i) Lack of ability on the part of planners of material to calculate and comprehend long term benefits of using exact materials instead of using some common material which is already being used on most of the products of the company.
 - ii) Lack of ability to have a suitable product mix to minimise losses on this account.
 - iii) Non-availability of exactly suitable material or lack of efforts to procure exact material.
 - iv) Excessive variety of products demanding different types, sizes and shapes of materials to be used, thereby increasing inventory and problems related with it.
 - v) Technological factors, particularly in case of washers where, with the present technology, sintering of powder on half round washer materials can not be done.

The study reveals that excessive variety of product is causing this waste.

- e) **Reasons for excessive rework** are the same as above. However, low salvage percentage of rework is due to non provision of manpower and facilities.

5.4.3 SUGGESTIONS

5.4.3.1 For reducing process scrap:

- a) Evolve an information system to make available information in the right form laying emphasis on vital areas so as to plan timely corrective actions. This definitely calls for computerisation of scheduling, material requirements planning, feed back and other related areas.
- b) Motivate and educate workmen to achieve production and quality targets. Educate and train supervisors. Involve them in sharing responsibility.

- c) Conduct machine capability studies of all available machines. Make realistic drawings assigning only achievable tolerances.
- d) Develop and provide systems to maintain temperature, pressure and other important parameters within desirable limits. Powder plant needs this immediately.
- e) Ensure quality control of inputs of materials, toolings, etc. Quality of steel needs to be properly inspected.
- f) Ensure uninterrupted supply of power and other facilities to critical areas which may result in excessive waste.
- g) Employ specialised equipment to meet environmental specifications.
- h) Provide manpower and facilities to salvage rework material.

5.4.3.2 To reduce quantity of unaccounted material:

- a) Tighten security check for one and all, on selected gates to contain pilferage.
- b) Modify containers in shape and size to receive material without any loss.
- c) Maintain pumps and pipe lines to ensure no spillage or leakage.
- d) Samples of slag to be checked to determine the percentage of useful materials going waste.
- e) Using suitable means for recording of correct weights of sold scrap material.

5.4.3.3 To reduce the production of excessive coarse powder

- a) Install suitable system to maintain system environment parameters.
- b) Install schedule of preventive maintenance of machinery and equipment on powder plant.

5.4.3.4 To reduce loss due to oversize of raw material

- a) Classify raw materials into fast, medium and slow moving types. Exact sizes for fast moving can be procured whereas for others, standardisation can be done for balancing resultant waste and inventory carrying cost.
- b) Establish combination(s) of parts for which waste is minimum. For future use a small software can be developed which can test all combinations with respect to available raw material sizes.
- c) On washers there is 65% wastage due to half round shape of the product. Possibility of procuring required size of half round washers and sintering of powder on these pieces must be explored. This calls for a lot of research and development work and

specialised equipment.

5.4.3.5 For effective and profitable disposal, following actions are suggested:

- a) Make efforts through advertisements in newspapers or by calling quotations to find industry and other users of scrap material.
- b) Explore possibility of doing some treatment on the bi-metallic scrap material to recover powder alloy from it. Remaining steel scrap can be sold. As melting temperatures of copper and other ingredients of the powder are considerably lower than steel, this proposal looks to be technologically viable. However, its economic viability considering equipment and other facilities needed for the purpose should be looked into. A separate ancillary unit can also be set up for the purpose.

CHAPTER VI

ANALYSIS OF ENERGY WASTE

The analysis deals with finding out waste of energy at various stages of manufacture, identifying reasons thereof and listing methods to reduce waste. Energy means electricity and all other types of fuels. The unit under study uses varied types of energy sources such as electricity, liquified petroleum gas and light diesel oil. Electricity is used the most. Unlike materials, energy is not a very tangible and physical quantity. Thus, a simple input - output analysis is not suitable to bring out quantities of waste. In this case, an approach involving recording of the actual input of energy and computing desired inputs has been used. The desired inputs have been calculated based on the amount of materials processed. The difference of actual and desired inputs have been worked out at various processing stages and wastes found out. Wastes in different areas and due to different reasons have been worked out and solutions suggested. The system has been modelled using physical system theory model in two phases. Sensitivity analysis of the PST model has been carried out.

6.1 METHODOLOGY

The general approach adopted and tools and techniques used for the analysis are described below:

6.1.1 Empirical Analysis

Following steps have been undertaken for empirical analysis:

- a) Recorded actual inputs of fuels and electricity to the system and to each department or section of the industry, from energy meters or from other records maintained by the industry.
- b) Divided the system into identifiable sub-systems depending upon the similarity of operations done within a system and their difference from the other sub-systems. Following sub- systems have been made.
 - i) Powder Plant
 - ii) Sinter Line
 - iii) Press and Machine Shop
 - iv) Plating

- v) Supporting Operations
- c) Worked out actual energy inputs to each of the above sub- systems. For some of these, the input figures were directly available from the energy meters while for others these have been calculated from wattage and running time. For press and machine shop it has been obtained as the difference of sum of energy values of all other sub-systems and total input to the system.
- d) Calculated the values of desired energy consumption for each sub-system as under:
Desired energy consumption,

$$Ed = Ed_u \times N_p \quad (6.1)$$

where Ed_u , is the desired amount of energy consumed on one product (operation) and

N_p , is the number of products (operations) made in the sub- system.

Further,

$$Ed_u = WT \times t \quad (6.2)$$

where WT is wattage of the equipment on which product is made and t is running time of the equipment for production of a unit product.

The details of wattage of the equipment and running time were collected as under:

i) **Wattage**

- By referring to machine catalogues or some scattered records maintained by the industry.
- By actually reading it from motor(s) provided with equipment.

ii) **Running time**

- In case of pressing and machining operations, a number of cycles were observed and average of their time was taken.
- In case of powder plant actual running time of equipment to produce one charge or batch of the product was noted through special studies.
- For sinter line, speeds at which sanding or sintering strip move during production were noted. Actual running time of heaters and other supporting equipment during production was also noted.
- In case of plating operations, details regarding production rates and actual running times of heaters and other equipment were noted.

A more accurate approach for calculating energy consumption (voltage $\times$ current $\times$ power factor) could not be used due to practical difficulties as given below:

- i) To note down current drawn and voltage of each machine, even by a tong tester is very tedious and impractical. This was also not permitted by the management as this would have caused interruptions in production process.
- ii) On machining operations, current drawn keep on varying during machining cycle. To note down times and voltages for each value of current is nearly impractical.

Thus, product of wattage and working time were used for this purpose. This amounts to assuming that the equipment kept running at full load. Accordingly, inputs worked out would be on higher side and wastes reflected would be on lower side. For a first diagnostic study in a plant, it was thought to be in order.

- e) Waste has been calculated to be the difference of (c) and (d) for each sub-system.
- f) Probable reasons have been listed and waste due to those has been calculated.
- g) Suggestions, which are a direct outcome of the analysis were made for reduction of waste.

6.1.2. Modelling

Physical system theory model has been used for representation of the case situation and its analysis. The model has been used in two phases - each phase used to analyse two major areas of waste of energy. In the first phase materials have been taken as through variable and unit processing energy as across variable. Wastages of energy due to material wastages have been reflected by this model. The second phase has quantity of energy as through variable and cost of energy as across variable. This reflected wastage of energy due to other reasons. Sensitivity analysis has been carried out on the lines of 'materials'. The model would help planning of energy requirements at each stage and doing costing. Theory and other details of the physical system theory model have been explained in chapter five.

6.2 DETAILS OF EMPIRICAL ANALYSIS

In this section, details of analysis of energy waste in each sub- section have been presented. The period of study has been chosen as one month, i.e. July 1991. Inputs of electricity and fuels and outputs of processed materials or products from each sub- system have been considered and analysis done to find waste.

6.2.1 Inputs and Outputs of the whole system

First of all energy inputs and materials outputs for whole of the industrial system and its natural departments and sections have been recorded. Table 6.1 lists the inputs of electricity and fuels to various sections/units of the industry.

Table - 6.1
Various Energy and Fuel inputs to the System.

S. No.	Section/Unit	Input to the System During Study Period		
		Electricity (Kwh)	LDO* (Lts)	LPG (Kg.)
1.	The whole of the Industry	3,66,800	5,654	8,645
2.	Sinter line	82,420		8,645
3.	Plating	28,710		
4.	Khosla compressor	18,900		
5.	Atlas compressor	55,920		
6.	Powder plant	37,140	5,654	
7.	Tool room	13,722		

* Light Diesel Oil

Values of electricity consumption have been taken from various energy meters installed for various sections. Fuels and LPG consumptions have been taken from the records of materials drawn by various departments.

Table 6.2 gives details of materials processed in each section.

Table 6.2
Material Output During the Study Period.

S.No.	Area	Powder(kg)	Strip(Metres)	Product (Numbers)
1.	Total	16,995	29,464	7,82,194
2.	Powder Plant	16,995	-	-
3.	Sinter Line	-	29,464	-
4.	Machine Shop	-	-	7,21,421(G) + 60,773(R) = 7,82,194
5.	Plating	-	-	7,92,574

G = Good, R = Rejected

This data has been taken from production records maintained in each department of the company. For carrying out analysis information on wattage of equipment and running time of various equipments is required. These details are presented here.

a) **Wattage of equipment and consumption rate of fuels**

Wattage of various pieces of equipment has been found from their catalogues or from the machines themselves. Appendix B2.1 carries details of consumption rates of fuels of various equipments in various sections. These consumption rates were observed through special studies. A number of readings were taken and their average worked out.

b) **Running times for unit production**

These times have been put into two broad categories: First category, long cycle equipment used on powder plant, sintering and plating. Appendix B2.2 presents details regarding running time of equipment of this category for the amount of output mentioned against them. The related equipment on these broad areas do not run for whole of the working time. For example, heaters on plating or sintering furnace keep switching on and off automatically to maintain the required temperatures. These fractional working times are not mentioned in this table. Second category includes short cycle repetitive work equipment. Appendix B2.3 gives details of cycle times, allowances added and times of operations on machines of press and machine shop. The standard times had to be calculated.

6.2.2 Division of System into Sub-Systems

The system has been divided into various sub-systems. Figure 6.1 shows the inter connection of various sub-systems.

6.2.3 Assigning Energy Values to Sub-systems

As can be seen from Table 6.1, energy values for some of the sub-systems are directly available from energy meter readings or other records of the company. For others these have to be calculated. The calculations of energy values are shown below for each sub-system.

- a) **Powder plant:** These are directly available from Table 6.1.
- b) **Sinter line:** Electricity consumption of different areas under this sub-system have been directly given in Table 6.1. L.P.G. consumption has also been given.
- c) **Plating:** Electricity consumption of the sub-system is also available from Table 6.1.
- d) **Supporting operations:** For compressed air and tool room the energy consumption

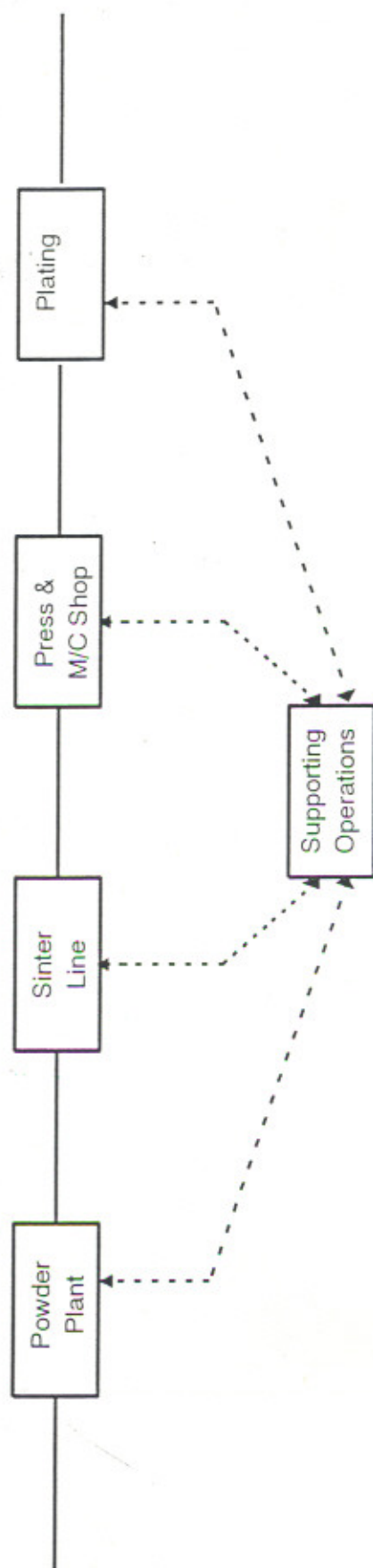


Fig 6.1 : Sub-systems

is directly available from table 6.1. For lighting load this is calculated from the wattage of the appliances and their working time. The calculations are shown in Table 6.3.

Table 6.3
Energy Consumption by Supporting Operations

S.No.	Appliance	Qty. (a)	Working Time (b)	Consumption		
				Kw (c)	Per Day $d = (a \times b \times c)$	Per Month Kwh. $d \times 25$
1.	HPMN Lamp	120	12 Hrs.	0.40	576.00	14,400
2.	Double Tube	90	12 Hrs.	0.08	86.40	2,160
3.	Double Tube	12	24 Hrs.	0.08	23.04	576
4.	Single Tube	50	24 Hrs.	0.04	48.00	1,200
5.	Single Tube	158	12 Hrs.	0.04	75.84	1,896
6.	Lamp	30	12 Hrs.	0.08	28.80	720
7.	Lamp	18	24 Hrs.	0.08	34.56	864
8.	Power Plug	54	8 Hrs.	2.00	864.00	21,600
9.	Tube 20W	6	24 Hrs.	0.02	2.88	72
Total						43488

Thus total consumption of supporting operations is calculated as under:

Energy consumption by compressor 1 = 55,920 Kwh.

Energy consumption by compressor 2 = 18,900 Kwh.

Energy consumption in tool room = 13,722 Kwh.

Energy consumption by lighting load = 43,488 Kwh

Total: = 132,030 Kwh.

- e) **Press and machine shop:** Since there is no separate energy meter installed for machine shop, the consumption of this sub-system has been calculated by adding up the consumption of all other sub-systems and subtracting from the total consumption (Table 6.4).

Total electricity consumption by all sub-systems leaving the machine shop is equal to the sum of energy consumption found at (a),(b),(c) and (d), which comes out to be 2,80,300 Kwh..

Total energy consumption as per Table 6.1 = 3,66,800 Kwh

Table 6.4
Consumption by Each Sub-System

S.No	Sub-System	Electricity(Kwh)	Fuel Oils	
			LDO.(litres)	LPG (Kg.)
1.	Powder Plant	37,140.0	5654	
2.	Sinter Line	82,420.0		8645
3.	Plating	28,710.0		
4.	Supporting Operations	1,32,030.5		
5.	Machine Shop	86,500.0		

6.2.4 Analysis of Powder Plant

Following steps are adopted:

- a) Calculate number of heats of induction furnace required to manufacture the quantity of powder made in July, 1991 (Table 6.2)

$$\text{Number of heats(charges), } H = \frac{Q_p}{Q_{p_h}} \quad (6.3)$$

Where Q_p is the total quantity of powder made and

Q_{p_h} is the quantity of powder made in one heat.

$$H = \frac{16,995}{150} = 114 \text{ heats}$$

- b) Calculate number of first heats and subsequent heats. For first heat, furnace is to be started from cold, therefore it takes more time and consumes more energy than subsequent heats.

$$\text{Number of first heats, } H_f = \frac{H}{H_{\text{day}}} \quad (6.4)$$

As powder plant runs on single shift per day basis number of first heats are,

$$= \frac{114}{8} = 15, \text{ and}$$

number of subsequent heats = $114 - 15 = 99$

- c) For powder metallurgy operations, times for first heat and subsequent heats were established. These times are given in Appendix B2.2.
- d) From times for one heat and number of heats, total running time of furnaces was

calculated (Table 6.5).

- e) Similarly, total running time of all the equipment on powder plant was calculated. From consumption rate and running time, energy consumption by each piece of equipment has been calculated (Table 6.5). Data in column(f) has been taken from Appendix B2.2.

Table 6.5

Calculation of Acceptable Amount of Energy Consumption on Powder Plant

S. No.	Equipment	No. of first heats	No. of Subsequent heats	Qty. of Powder made	Qty. per Hour	No. of Hours of Running (g) (e/f) or (c×1.5+d)×.5	Energy Consumption (Kwh)	Total Energy (Kwh) (i) (g×h)
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1.	Induction Furnace	15	99	-	-	72	150.0	10,800
2.	Reciprocating Pump	-	-	16995	750	23	37.5	863
3.	Pneumatic Pump	-	-	16995	110	155	3.75	582
4.	Cooling Pump	-	-	16995	75	227	3.75	852
5.	Drier	-	-	16995	120	142	3.75	533
6.	Pump Drier	-	-	16995	600	29	3.75	109
7.	Boiler	-	-	16995	120	142	1.5	213
8.	Boiler	-	-	-	-	142	7Lt	994Lt
9.	Classifier	-	-	16995	600	29	2.25	66
10.	Blender	-	-	16995	600	29	3.75	109
11.	Oil Fired Furnace	15	99	-	-	72	24Lt.	1728Lt
12.	Hydraulic Pump	15	99	16995	900	19	3.75	72
13.	Blower Motor	15	99	-	-	72	3.75	270
Total:								14,469Kwh
LDO Consumption								2,720Lts.

- f) Total consumption on powder plant is the sum of consumption of each piece of equipment - Electricity 14,469 Kwh and LDO 2,720 Litres
- g) Adding 10% allowance on account of some small equipments like hacksaws or small pumps etc., the total energy consumption is Electricity = 15,920 Kwh
LDO = 2,720 Litres

h) Calculating Waste

Waste of electricity is equal to energy input to the sub-system minus energy utilised on productive operations = $37,140 - 15,920 = 21,220$ Kwh. (= 57% on input).

Similarly, waste of L.D.O. = 2,934 Litres (=52% on input).

These figures have been calculated keeping in view ideal working. In practice, there is a large deviation from these ideal conditions.

6.2.4.1 Areas of waste. Following areas of energy waste were identified and waste calculated in each:

- i) Unnecessary holding of molten alloy
- ii) More starts of the furnace from cold.
- iii) Production of coarse powder.

Methods used for calculation of waste in each of these areas are approximate. The objective has been to have an assessment of amount of waste due to each reason.

- a) **Unnecessary holding of molten alloy:** It was observed that workers were taking out 8 charges of alloy in 8 hours whereas these can be comfortably made in 5 hours as given below.

$$\begin{aligned} \text{Time spent on 8 heats in a day} &= \text{Time of first heat} + 7 \times \text{Time of subsequent heats} \\ &= 1.50 + 7 \times 0.50 = 5.00 \text{ hours.} \end{aligned}$$

Thus, the furnace and supporting equipment keep running for 8 hours instead of 5 hours every day. As an approximation, this waste has been calculated as under:

Waste is equal to energy spent on running of equipment for 8 hour minus energy spent on running equipment for 5 hours. Energy spent on running of equipment for 8 hours

$$= \text{Energy spent on running the equipment for 5 hours} \times \frac{8}{5} \quad (6.5)$$

$$= 15920 \times \frac{8}{5} = 25472 \text{ Kwh of electricity, and } = 2720 \times \frac{8}{5} = 4352 \text{ litres of LDO}$$

Thus Waste = $25472 - 15920 = 9552$ Kwh of Electricity

and $4352 - 2720 = 1632$ litres of LDO

This wastage is due to holding of prepared alloy in the furnace.

- b) **More starts of the furnace from cold :** Breakdowns of any type of melting equipment will force a stoppage of the furnace resulting in cool down if the down

time is large. Actual data of each heat for the month of July has been shown in Appendix B2.4. There were ten occasions on which the furnace had to be started after a long halt. These have been marked on the table. Waste has been calculated as under.

$$\text{Waste} = \text{Extra time taken on a heat} \times \text{Number of extra heats} \times \text{Wattage of the equipment} \quad (6.6)$$

$$= 1.0 \text{ hour} \times 10 \text{ heats} \times 150 \text{ Kw} = 1500 \text{ Kwh of electricity}$$

$$\text{and LDO Wastage} = 1 \text{ Hour} \times 10 \text{ heats} \times 24 \text{ litres} = 240 \text{ litres}$$

- c) **Production of coarse powder:** Referring to Appendix B2.4, it is seen that the actual number of charges made in the month of July 1991 were 158 which are much more than the number of charges actually required (114), as calculated earlier. This difference is due to a large quantity of coarse powder made which has to be recycled. The approximate amount of waste has been calculated as under:

$$\text{Waste} = \text{Energy spent on 158 charges} - \text{Energy spent on 114 charges} \quad (6.7)$$

$$= \frac{\text{Energy spent on 114 charges} \times 158}{114} - \text{Energy spent on 114 charges}$$

$$= \frac{25472 \times 158}{114} - 25472 = 35303 - 25472 = 9821 \text{ Kwh}$$

$$\text{Similarly LDO Wastage} = 1049 \text{ litres}$$

6.2.4.2 Total waste: Table 6.6 gives the summary of wastes on powder plant.

Table 6.6

Summary of Wastages of Powder Plant

S.No.	Reason/Area of Waste	Amount of Waste	
		Electricity(Kwh)	LDO (Litres)
1.	Holding of molten alloy	9552	1632
2.	Breakdowns	1500	240
3.	Production of coarse powder	9831	1049
4.	Total	20833	2921
5.	Total wastage as calculated.	21220	2934
	Difference of (4) & (5)	387	13

These differences in two estimates given in Table 6.6 can be due to the approximations made in calculations.

6.2.4.3 Efficiency of induction furnace: The above wastes have been calculated considering the timings of 1.50 hours and 0.50 hours for making the alloy from first heat and subsequent heats as acceptable, since these times were established through special studies. But the efficiency at which furnace works would effect these times. Considering that furnace is already heated up it will take half an hour to make the alloy. Energy input in half an hour working at 150 Kw has been calculated. Heat required to convert elements of copper, lead and tin to alloy at the required pouring temperature of 1300°C has also been calculated and the efficiency of furnace has been worked out as under.

Efficiency of Induction Furnace

$$= \frac{\text{Heat required to convert 150 kg of a mixture of copper, lead and tin alloy at } 1300^{\circ}\text{C}}{\text{Actual quantity of heat input from 150 Kw for half an hour}} \quad (6.8)$$

For calculating heat required, melting temperature of copper and its specific heat has been used as it is the major constituent of the alloy.

$$\text{Heat required} = M[SH_c(TM_c - T_c) + H_f + SH_c(1300 - TM_c)] \quad (6.9)$$

Where M is mass of one heat, SH_c is specific heat of copper, TM_c is melting temperature of copper, T_a is atmospheric temperature and H_f is latent heat of copper

$$\text{Actual Input} = 150 \times 0.50 = 75 \text{ Kwh} = 75 \times 3600 = 2,70,000 \text{ KJ}$$

$$\text{Efficiency} = \frac{1,01,008}{2,70,000} \times 100 = 37.41\%$$

Similarly, efficiency of other equipment has been worked out.

6.2.5. Analysis of Sinter Line

On sinter line an approach similar to the one used in powder plant has been employed. In this section following equipment is employed.

- i) Degreasing and sanding equipment
- ii) Sinter lines 1 and 2.

Total running times of each of the above lines have been found out by dividing total quantity of strip processed by speed of the lines (The speeds were actually observed for a number of days and their mean was taken).

Strip made on sinter line (Table 6.2) = 29,464 metres.

- a) Working time of sanding line:

Average speed of sanding line (Appendix B2.2) = 12.192 metres/minute

$$\text{Total working time (hrs)} = \frac{\text{Total Strip made}}{\text{Strip made per hour}} \quad (6.10)$$

$$= \frac{29464}{12.192 \times 60} \approx 41 \text{ Hours}$$

b) **Working time of sintering line**

Average speed of Sinter line = 1.524 metres/min. (Appendix B2.2)

Using Eq. 6.10, working time of the sinter line for processing 29,464 metres of strip at the above speed has been worked out to be 322 hours.

Further, it was seen that the related equipment on these lines does not work for whole of the working time of the equipment. The equipment was closely watched and their actual working times as fraction of the total working time of these lines were noted.

$$\text{c) Working time of annealing furnace} = \frac{\text{Quantity annealed}}{\text{Quantity annealed per hour}} \quad (6.11)$$

Quantity annealed per minute, as per Appendix B2.2 is 2.2 metres. Thus working time is equal to $\frac{29464}{2.2 \times 60} = 223 \text{ Hours}$

6.2.5.1 Wastage of electricity: From the running times of equipment and its wattage, energy consumed by each of the equipment and consequently by whole of the sinter line has been calculated (Table 6.7).

Waste is the difference of these calculated figures and actual inputs to sinter line.

Thus, Waste = Actual Input - Calculated Consumption

$$= 82420 - 59692 = 22728 \text{ Kwh (= 28\% of input).}$$

6.2.5.2 Wastage of LPG: LPG is used to heat moving strip in the sintering furnace. LPG can be wasted due to leakages or improper adjustment of the mixture of air and LPG properly. The wastage is calculated as under:

LPG consumption per hour (Appendix B2.1) = 18.8 Kg.

Working time of Sinter Furnace = 322 Hours.

Thus total acceptable consumption = $18.8 \times 322 = 6,054 \text{ Kg.}$

Actual Consumption (Table 6.1) = 8645 Kg.

Wastage = LPG input to sinter line - Calculated Consumption.

$$= 8645 - 6,054 = 2591 \text{ Kg.}$$

Wastivity = 30% of input.

Table 6.7
Energy Consumption on Sintering Operations

Main Area	Equipment	Working Time of Main Area (Hr.) (a)	Fraction Working Time of Equipment (b)	Running Time of Equipment (Hours) (c)=(a)*(b)	Wattage (Kw) (d)	Consumption (Kwh) (e)=(c)*(d)
Sanding and Degreasing	Degreasing Equipment	41	Full	41	111	4551
	Babbitt Line	41	Full	41	143.87	5898
	Annealing Furnace	223	Full	223	40.50	9032
Sinter Line	Straightner Motor	322	Full	322	15.00	4830
	Rolling Mill	322	Full	322	9.00	2898
	Recoilers	322	Full	322	11.00	3542
	Blower Motor	322	Full	322	3.00	966
	Dryer Motor	322	Full	322	6.00	1932
	Fan Motor	322	Full	322	4.50	1449
	Sinter Furnace	322	3/8	120.75	180	21735
	Loop Hoist	322	1/4	80.5	1.50	1201
	Bryer Heater	322	1/2	161	6.00	966
	Return Water Pump	322	1/2	161	5.50	886
	Pump Motor of Cooling Tower	322	1/2	161	5.50	886
Total:						59692

6.2.5.3 Reasons of wastage: The main reason of wastage on sinter line is stoppage of the process due to poor or unacceptable quality of bonding of powder and steel layers. For effective bonding, along with other parameters of temperature etc., reducing atmosphere is also a necessity. LPG flame does not fully ensure the maintenance of a reducing atmosphere, particularly when the atmospheric humidity is very high. As the study was conducted in the month of July when atmospheric humidity was quite high, there were a number of stoppages due to this reason. As in such events the equipment is kept running

while efforts are made to achieve quality, a lot of energy is wasted.

6.2.6 Analysis of Machine Shop

In machine shop the energy which should have been consumed has been calculated using the figures of number of operations done on each machine, wattage of each machine and the time taken on each operation. Wattage of each machine has been taken from catalogues of machines and times of each operation have been taken from Appendix B2.3. Due to work-in-process present, both in the beginning and end of the month total production of good and scrap blanks was not representative of the actual number of operations done in the machine shop. For this purpose, daily shift production reports for the whole month were referred to and operations of each type carried on various machines were summed up.

Total operational time of each machine was then calculated from the standard times of operations and number of operations of each type. Wattage of each machine was multiplied with the time to find out the total electricity consumption of the machines. These calculations have been shown in Table 6.8.

In Table 6.8, only main operations done on machines have been considered. Supporting operations like running of inspection instruments or deburring equipment and others, which run quite intermittently and consume comparatively much smaller amounts of energy were not taken care of for want of their detailed operational timings. Thus, it was decided to give 5% allowance for such operations. The total consumption has been worked out as under.

Consumption on major operations = 71,271 Kwh.

Consumption for supporting operations = $0.05 \times 71,271$ = 3,564 Kwh.

Thus, total electricity utilised on productive operations,

= $71,271 + 3,564$ = 74,835 Kwh.

Waste = Energy input to the sub-system - Energy utilised on productive operations

Using the value of energy input to the sub-system from Table 6.4 and energy utilised on productive operations as calculated above, the wastage comes out to be 11,665 Kwh.

Wastivity = 13.5%

Table 6.8
Energy Consumption in M/c Shop

S.No.	Operation	No.of Operations (a)	Time of One Opn.(Min.) (b)	Total Time (c) (a*b) (Min)	KW of Machine (d) (Kw.)	Total Energy (e)(c*d) (KWh)
1.	Blanking					
	a) 200T	3,78,998	0.029	183	18.0	3294
	b) L2P01	1,89,800	0.087	275	17.25	4744
	c) L3P10	1,89,196	0.030	95	17.25	1639
2.	Drilling	7,60,524	0.065	823	0.75	618
3.	Forming					
	a) 63T	10,125	0.018	3	7.75	23.25
	b) L2P04	1,40,865	0.031	73	17.25	1260
	c) 40T	2,81,146	0.043	201	7.75	1558
	d) BL05	1,40,281	0.144	336	7.75	2604
4.	Coining					
	a) 225T	5,51,424	0.117	1075	11.77	12653
	b) L3P04	1,83,810	0.075	229	15.75	3606.75
5.	Bush Facing	2,75,560	0.20	918	15.00	13770
6.	Centreless Grinding	2,73,256	0.056	255	17.50	4462.50
7.	Bush Boring	2,66,112	0.023	102	15.00	1530
8.	Face & Chamfer	7,00,066	0.072	840	3.00	2520
9.	Lip Punching	4,25,860	0.044	312	3.75	1170
10.	Lip Milling	78,025	0.080	104	3.75	390
11.	I.D.Broach	4,85,083	0.065	526	3.75	1972.5
12.	HT Broach	4,74,842	0.070	554	5.50	3047
13.	Grooving	6,53,024	0.092	1001	9.75	9760
14.	Shear Broach	21,457	0.065	24	7.50	180
15.	Pocket Milling	81,152	0.092	125	3.75	169
Total:						71,271

6.2.6.1: Areas and reasons of waste: The probable reasons of waste in this sub-system are:

- i) More number of scrap bearings produced than were actually shown, i.e. more operations carried out than are actually shown in production report. This is generally done to conceal in- process scrap.
- ii) Idle running of machines i.e. machine motors kept running when the production was not going on. This can happen due to inspection checks, or other shortages, settings or due to carelessness on the part of the operators.

6.2.6.2 Wastage due to large variation in the sizes of the products:

Another area of wastage in machine shop is the processing of smaller jobs on machines which are capable of making bigger products. This was happening in this concern due to large variety of sizes of the products. An approximate quantity of waste due to this reason has been worked out for a normal product mix of one month. For this the data of material sintered in the month of July 1991 has been considered. Although this would have been processed in August in machine shop, yet it represented the product mix processed in machine shop in a month. Thus, a general figure of loss per month is attempted here and not an exact amount of loss for a particular month.

The waste has been worked out assuming that the power consumption by a machine is directly proportional to its size and that desired machine size is directly proportional to job size. Thus, waste has been calculated using following equation.

$$\text{Waste} = \frac{\sum_{j=1}^n (W_{tm} - W_j) Q_j}{W_{tm} \sum_{j=1}^n Q_j} \times Em \quad (6.12)$$

Where W_{tm} is the weight of the heaviest job,

n is the number of jobs in the month of July,

W_j is the weight of j th job $J=1,2,3,\dots,n$,

Q_j is the quantity of j th job and

Em is the average energy consumed on productive operations in a month.

Weight of every product in each of the categories of bushes, bearings and washers has been subtracted from the highest weight in each category. This has been separately done for bushes, bearings and washers for the product mix of July sintering production. The

difference multiplied by the quantity of the product reflects the under-utilisation with respect to size in case of each product. These values of under-utilisation have been summed up in case of each category of product. The summation divided by the product of maximum weight and the total quantity of all the products reflects percentage under-utilisation. The figures of under-utilisation, thus calculated are:

Bushes	77.08%
Bearings	76.55%
Washers	39.09%

Next, the weighted average of these figures of under- utilisation has been calculated as under.

$$AUs = \frac{\sum_{j=1}^n Us_j Q_j}{\sum_{j=1}^n Q_j} \quad (6.13)$$

Where, AUs is the weighted average percentage underutilisation, with respect to size of the product;

Us_j is the under-utilisation in each category of products,

Q_j is the quantity of each category of the product in July production and

j is each category of the product, from 1 to 3.

Quantities of bushes, bearings and washers sintered in the month of July, 1991 and the percentage under-utilisation of each category of products as calculated above have been put in the above equation and the weighted average percentage under- utilisation has been calculated to be 72.69%.

Energy Waste = Average Under-utilisation $\times$ Energy Consumption

Approximate energy consumption in a month = 70,000 Kwh.

Thus waste = $0.7269 \times 70,000$ = 50,883 Kwh.

Whole of this loss cannot be regarded as waste as it is not possible to have a separate machine for each size of the job. Still it should always be looked into. The possibility of dividing the whole range of products into smaller sub-ranges and acquiring suitable machines for each sub-range should be explored in the light of the related costs of inventory carrying of spares, initial investment, and working costs. Future demands also have to be kept in mind.

6.2.7 Analysis of Plating

Total time required to plate products in July has been calculated from the number of pieces per lot and time consumed on one lot. Plating is a continuous process. There are a number of stages through which a batch of products has to pass i.e. washing, plating, dipping in alkaline solution and so on. At a given instant each of these stage is in progress. There is a hanger on which as many racks move as the number of stages are. After completion of a stage the hanger moves the racks to next stage. After the last stage a worker replaces the rack of plated bearings with the one with fresh bearings and the process goes on.

Further, on bushes and washers, tin plating is done and on bearing LTC plating is carried out. The calculations of total time consumed on plating are given below.

a) **Plating time:**

As per Table 6.2, total number of products plated = 7,92,574
 Out of this bushes and washers are = 2,84,666
 and bearing are = 5,07,908.

b) **Time for tin plating:**

From Appendix B2.2, the times spent on tin plating are:

First lot = 41 minutes
 Cycle time for subsequent lots = 1.05 Minutes.
 Number of pieces per lot = 44.

$$\text{Thus number of lots} = \frac{\text{Number of bushes \& washers plated}}{\text{Pieces per lot}} \quad (6.14)$$

$$= \frac{2,84,666}{44} = 6,469.68 \text{ lots.}$$

$$\text{Time spent} = \text{Number of lots} \times \text{cycle time} \quad (6.15)$$

$$= \frac{6469.68 \times 1.05}{60} = 113.2 \text{ Hours}$$

On every first lot of the day 41 minutes of extra time will be spent. Number of first lot will be equal to the number of days the work has to be carried on. Thus considering an eight hour working day, the number of first lots are:

$$= \frac{\text{Total number of hours}}{\text{No. of working hours in a day}} \quad (6.16)$$

$$= \frac{113.2}{8} = 15 \text{ lots}$$

$$\begin{aligned}\text{Time spent on first lots} &= \text{No. of first lots} \times \text{Time spent on first lots} \\ &= \frac{15 \times 41}{60} = 10.25 \text{ hours.}\end{aligned}$$

$$\begin{aligned}\text{Total time} &= \text{Time on normal lots} + \text{Time on first lots} \\ &= 113.2 + 10.25 = 123.45 = 124 \text{ hours}\end{aligned}$$

c) **Time for LTC**

From Appendix B2.2, the details of time and number of pieces are:

$$\begin{aligned}\text{Time spent on first lot} &= 41 \text{ Minutes} \\ \text{Cycle time for subsequent lots} &= 1 \text{ Minute} \\ \text{Number of pieces per lot} &= 35\end{aligned}$$

Using the equations as in tin plating, the total plating time for LTC has been calculated as 263 hours.

d) **Total plating time:**

$$\begin{aligned}\text{Total plating Time} &= \text{Time spent on tin plating} + \text{time spent on LTC} \\ &= 124 + 263 = 387 \text{ hours.}\end{aligned}$$

e) **Actual running time of each piece of equipment:** Plating operations were observed for a sufficiently long time and noticed that the related equipment of pumps, heaters, mixers etc. do not run for whole of the plating time. Rather they automatically get switched on or off as per need. Thus their actual running time was a small fraction of the total working time of the plating process. These fraction working times were noted (Column 3 of Table 6.9). These fractions when multiplied by the total plating time as found out above give the actual running time of each equipment (Table 6.9).

f) **Energy consumption by plating:** The wattage of each piece of equipment has been found out and listed in column 4 of Table 6.9. The product of the wattage with the running time gives the energy consumed by each piece of equipment. The summation of these energy consumption values for all the equipment gives the total energy consumption by plating as depicted in Table 6.9.

g) **Waste:**

$$\text{Energy consumption by plating as given by Table 6.4} = 28710 \text{ Kwh}$$

$$\text{Energy Consumption as calculated in Table 6.9} = 23,277 \text{ Kwh.}$$

$$\text{Waste} = \text{Energy input to the sub-system} - \text{Energy actually utilised}$$

$$= 28,710 - 23,277$$

$$= 5,433 \text{ Kwh.}$$

$$\text{Wastivity} = 18.92\%$$

Table 6.9
Energy Consumption by Plating Operations

S.No.	Equipment	Running Time as Fraction of Total Time (a)	Total Running Time (b) = 387 × (a) (Hours)	KW (c) (Kw)	KWH (d) = (b) × (c) (Kwh)
1.	Water Pump Motor	2/8	96.75	5.50	532.125
2.	Hydraulic Motor	8/8	387	9.37	3626.19
3.	LTC Filter	2/8	96.75	1.68	162.54
4.	Agitator Motor	4/8	193.5	1.50	290.25
5.	Cathode Rectifier	8/8	387	3.00	1161.00
6.	Cathode Rectifier I	8/8	387	3.00	1161.00
7.	HCL Rectifier	8/8	387	3.00	1161.00
8.	Nickle Rectifier	8/8	387	2.00	774.00
9.	LTC Rectifier	8/8	387	3.00	1161.00
10.	Tin Rectifier I	8/8	387	2.00	774.00
11.	Tin Rectifier II	8/8	387	0.75	290.27
12.	Cathode Heater	5/8	72.56	18.0	1306.12
13.	Anodic Rectifier	5/8	72.56	18.0	1306.12
14.	Nickle Heater	1.5/8	72.56	30.0	2176.8
15.	Alkaline Heater	1.5/8	72.56	24.0	1741.44
16.	Tin Plating Heater	1.5/8	72.56	36.0	2612.00
17.	Hot Air Circulator	2/8	96.75	18.00	1741.5
18.	Hot Water Heater	2/8	96.15	18.0	1741.5
19.	Agitator heater	2/8	96.75	9.0	870.75
Total:					23,276.63

6.2.7.1 Probable reasons of waste:

- i) At the end of a cycle the plated rack is to be replaced by a rack of products to be plated. For this, the bearings have to be stacked properly in the rack and kept ready before hand. If due to any reason this is not done the rack goes empty, thereby causing waste.

- ii) Similarly, because of carelessness, less number of pieces are stacked, and waste is caused.
- iii) Power breakdowns cause the process to be started again resulting into waste.

All this type of waste was witnessed.

6.2.8 Analysis of Supporting Operations:

As given in section 6.2.3(d), the break up of energy consumption by supporting operations is as under:

i)	Compressed air	=	74,820.0 Kwh
ii)	Tool Room	=	9,822.5 Kwh
iii)	Lighting and ventilation	=	43,488.0 Kwh.
Total:		=	1,32,030.5 Kwh.

Combined they consume more energy than any sub-system taken individually. It is even higher than machine shop consumption. Looking at each of the individual area of supporting operations it is revealed that energy consumed by compressed air alone is 74,820 Kwh. Lighting and ventilation also account for 43,488 Kwh. For want of data on the requirements of compressed air of individual machine and of the whole shop a detailed analysis could not be conducted. But keeping in view the number of leakages observed during the study period, it can be safely concluded that there is a lot of wastage, here too.

In case of lighting and ventilation the total consumption is very high. Of this, HPMN lamps with 14,400 Kwh are the main consumers followed by power plugs for heaters and coolers etc. It is strongly felt that through proper care only, a lot of savings are possible.

6.3 PHYSICAL SYSTEM THEORY MODEL

Physical system theory (PST) model has been used for representation and analysis of the system. Empirical analysis has revealed wastages of energy in various sub-systems due to a number of reasons ranging from worker's carelessness and condition of equipment and so on. There is, however, another very important area of energy waste which has not been dealt with in the empirical analysis. This area is, energy waste due to material waste, i.e. the energy spent on the processing of the product which was ultimately rejected. As the figures of material waste were already available from analysis of material waste, it was preferred to calculate the wastage of energy due to this reason directly from the PST model. In addition, the PST modelling of the case has been done with the following objectives.

- i) To facilitate calculation of future energy requirements at various stages of production activity taking into account the waste at various stages.
- ii) To facilitate the calculation of the unit energy cost of the product by considering the wastages and processing energy at all the previous stages.
- iii) To conduct sensitivity analysis in order to find out the effect of waste of various stages on the final energy cost. This would help choose the areas needing more attention for energy waste reduction.

In this case the PST model has been applied in two phases as described below.

Phase 1: Materials have been taken as the through variable and the unit processing energy as the across variable.

Input requirements of materials at various stages and the final stage, considering only the material wastages have been calculated.

Phase 2: Quantity of energy as depicted by phase 1 of the model has been taken as the through variable and the cost of energy as the across variable. Input requirements of energy at the first processing stage and at all subsequent stages, considering both types of wastages, i.e. energy waste due to material waste and energy waste due to other reasons, have been calculated considering both types of wastages.

6.3.1 Development of the Model.

As in the case of materials, the quantity of materials has been represented in weight (Kg.). The model has been developed for an output of 1000 Kg.. In the first phase, considering the material wastages, the input requirements of energy for 1000 Kg. material output from the final stage have been worked out. In the second phase, the wastages of energy due to other reasons have been considered and input requirements of energy to meet the requirements as expressed by first phase have been worked out. The sub-systems made in the empirical study on energy are slightly different from those of materials. The energy values of the sub-systems have been broken up in the ratio of their consumption to have exactly same sub-systems in both energy and materials, e.g. 'sintering' has been divided into 'sintering' and 'sanding' by dividing the total energy consumption in the ratio of total wattage of these two areas, keeping the scrap rate same.

6.3.1.1 Waste percentages, values of technological co-efficients, processing energy and cost: Figure 6.2 and 6.3 show the simplified system graph of the two phases of the model. For the first model, considering materials as the through variable, the scrap rate and

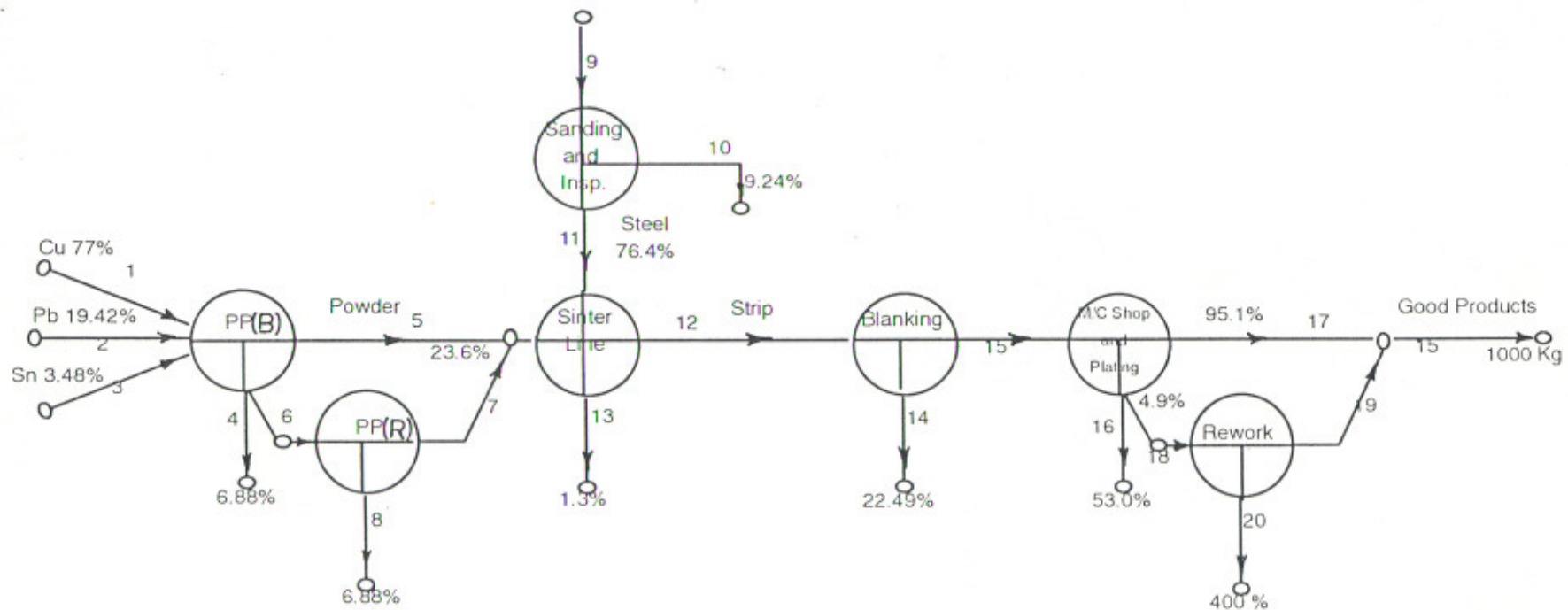


Fig 6.2 : PST Model - Energy — Phase 1

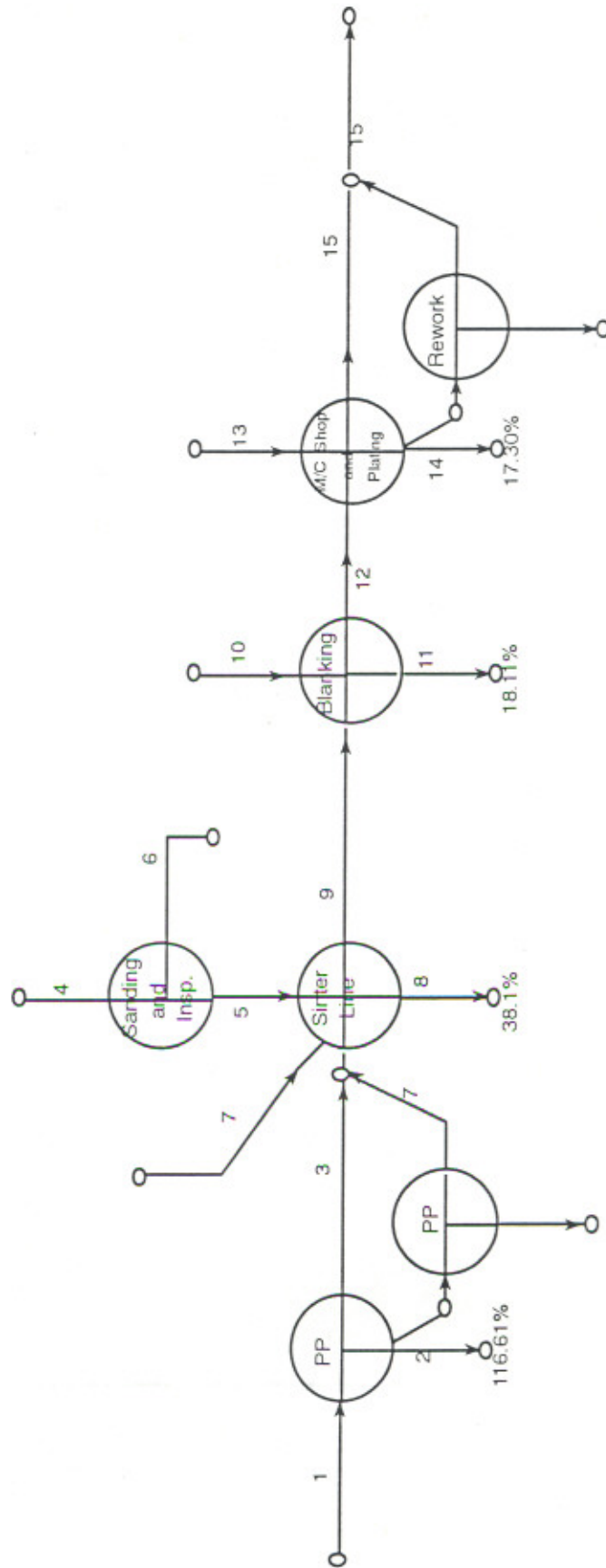


Fig 6.3 : PST Model - Energy — Phase 2

the values of technological co-efficients are exactly the same as listed in Table 5.24, under PST of materials in chapter five. These values are given in column 2 of Table 6.10. The values of across variables for first model, i.e. the unit processing energy and the values of waste percentages for the second model are also given in Table 6.10.

Table 6.10
Waste Percentages and Unit Processing Energy

S.No.	Sub-System	Waste Percentages		Processing Energy (Mj/Kg.)
		First Model	Second Model	
1	Powder Plant	6.88%	116.61%	12.76
2	Sanding	9.24%	38.10%	2.19
3	Sintering	1.33%	38.10%	6.57
4	Blanking	22.49%	18.10%	0.68
5	Machine Shop & Plating	53.00%	17.70%	8.10

The values of waste percentages for the second model and the processing energy for the first model as given in Table 6.10 have been calculated from the results of the empirical analysis. The calculations are shown in Appendix B2.5. Since the energy input has been in the form of different fuels and electricity, these have been converted to their equivalent energy values, i.e. MJ by using the following conversion values.

Electricity 1Kw	= 3600 KJ	= 3.6 MJ
L.D.O 1Litre	= 40180 KJ	= 40.18 MJ
L.P.G. 1Kg.	= 58190 KJ	= 58.19 MJ

- a) **Cost of energy:** In phase 2 of the model, unit cost of energy is taken as the across variable. The cost is calculated here specially for the product mix of the quantities of electricity and fuels being used in the present case. The calculations are shown below.

$$\text{Average cost of energy per MJ, CE} = \frac{\sum_{j=1}^n QF_j \times CF_j}{\sum_{j=1}^n QFC_j} \quad (6.17)$$

Where, QF_j is the quantity of j 'th fuel or electricity used,

CF_j is the cost of j 'th fuel or electricity,

QFC_j is the quantity of j 'th fuel converted to MJ, and

n is the number of fuels being used, $j = 1, 2, \dots, n$.

Putting the values in above equation from Appendix B2.5, the average cost of energy has been calculated as Rupees 0.22 per MJ.

6.3.2 Solution of Phase 1 of the Model

Using the equations 5.12 of through variables and across variables as given in section 5.3.1, putting the values of technological co-efficients and the processing energy as given in Table 6.11 and performing the successive steps for their calculation, the variables have been calculated. Table 6.11 shows the values.

Table 6.11
Values of Through and Across Variables.

Through Variable				Across Variable	
Input		Waste			
Variable	Value	Variable	Value	Variable	Value
YA1	388.28	YW4	32.48	X5	15.24
YA2	97.92	YW8	6.21	X11	2.19
YA3	17.54	YW10	139.37	X12	11.90
YA5	375.56	YW13	25.33	X15	15.25
YA6	96.60	YW14	357.86	X21	31.50
YA7	90.39	YW16	551.20		
YA9	1647.81	YW20	40.00		
YA11	1508.44				
YA12	1949.06				
YA15	1591.2				
YA17	990				
YA18	50				
YA19	10				

Thus 31.5 MJ of energy per kg. of the final product is spent in the unit. If 1,000 kg. of the products are to be made the energy required will be 31500 MJ.

6.3.3 Solution of Phase 2 of the Model.

In phase 2 of the model, the targetted output of 31500 MJ of energy has been fixed. The energy requirements at each stage are to be worked out considering the wastages of energy due to reasons other than the material wastages. Quantity of energy has been taken as the through variable and its cost as the across variable.

Technological co-efficients

Using the values of percentage waste of energy in various sub- systems, as shown in Table 6.10, the value of technological co- efficient for input and waste have been calculated. Table 6.12 shows these values.

Table 6.12
Technological Co-efficients - Phase 2.

S.No	Area	Technological Co-efficients of			
		Input		Waste	
		Co-efficient	Value	Co-efficient	Value
1	Powder Plant	KB1	2.1661	KWB2	1.661
2	Sanding	KB4	1.381	KWB6	0.381
3	Sintering	KB3,KB5,KB7	1.381	KWB8	0.381
4	Blanking	KB9,,KB10	1.1811	KWB11	0.181
5	Machine Shop and Plating	KB12,,KB13	1.730	KWB14	0.173

6.3.3.1 Values of through and across variables: For calculating values of the amount of energy input to be given to each sub-system for desired output of 1,000 kg. of materials or 31500 MJ of energy from the final stage and the unit cost of energy at every processing stage and the final stage, equations 5.12 have been used. For calculating through variables, the values of technological co-efficients as given in Table 6.12 have been used, whereas for calculating across variables, the technological co-efficients have been calculated again. These technological co-efficients take into consideration both types of wastages. The values are given in the Table 6.13.

6.3.4 Sensitivity Analysis

Sensitivity analysis has been carried out to see the effect of slight increase in the

wastage level of each stage on the final cost and the effect of slight increase in the processing energy of each stage on the final cost of per unit of energy. This has been done by giving a slight increment to the wastage level or processing cost of each stage. Table 6.15 shows the values of final cost of the output energy with an increase of 1% in the wastage level of materials in a sub-system.

Table 6.13
Values of Technological Co-efficients - Cost Calculations

S.No.	Area	Percentage Wastage due to			Technological Co-efficients	
		Materials	Others	Total	Coefficient	Value
1	Powder plant	6.88	116.61	123.50	KC1	2.2350
2	Sanding	9.24	38.1	47.34	KC4	1.4734
3	Sinter line	1.33	38.1	39.43	KC3,KC5,KC7	1.3933
4	Blankers	22.49	18.11	40.60	KC9,KC10	1.4060
5	Machine Shop and Plating	53.00	17.30	70.30	KC12,,KC13	1.7030

Values of across variables and through variables found out are presented in Table 6.14.

Table 6.14
Values of Through and Across Variables.

	Through Variable		Across Variable	
	Input		Variable	Value (Rs/MJ)
	Variable	Value (MJ)		
1	Y1	3300.00	X1	0.2200
2	Y4	3024.00	X3	0.4917
3	Y7	1271.90	X5	0.3241
4	Y10	6111.77	X9	0.5196
5	Y13	21699.50	X12	0.5875
			X15	0.6329

Table 6.15

Sensitivity of Cost of Output Energy to Wastage level of Materials.

S.No.	Sub-System	Increase of 1% in Technological Co-efficient	Output Energy Cost per MJ	Sensitivity
1	Powder Plant	KA1,KA2,KA3	0.6340	0.17
2	Powder plant(R)	KA6	0.6329	≈ 0
3	Sanding	KA7	0.6331	0.03
4	Sinter Line	KA5,KA3,KA11	0.6353	0.3
5	Blankers	KA12	0.6349	0.27
6	Machine Shop	KA15	0.6354	0.31

The results of the above table show that the final unit cost is most sensitive to the waste in the machine shop followed by sinter line.

Table 6.16 shows the values of final cost with an increase of 1% in the wastage level in the second stage of the model, i.e. wastage due to reasons other than the materials wastages.

Table 6.16

Sensitivity of Output Energy Cost to Waste
due to Reasons other than Material wastages.

S.No.	Sub-System	Increase of 1% in Technological Co-efficient	Output Energy Cost per MJ	Sensitivity
1	Powder Plant	KB1	0.6340	0.17
2	Sanding	KB4	0.6331	0.03
3	Sinter Line	KB3,KB5,KB7	0.6348	0.3
4	Blankers	KB9,KB10	0.6342	0.2
5	Machine Shop	KB12,KB13	0.6355	0.32

Table 6.16 reflects that there is no appreciable difference in the effect of waste of various stages on the unit energy output cost. Waste in sinter line has marginally higher effect than other stages.

In Table 6.17 is shown the values of unit output energy cost due to an increase of 0.1 MJ per kg. increase in the processing energy of various stages.

Table 6.17
Sensitivity of Unit Output Energy Cost
to Processing Energy at a Stage.

S.No.	Sub-System	Output Energy Cost per MJ	Sensitivity
1	Powder Plant	0.6335	0.09%
2	Sanding	0.6331	0.002
3	Sinter Line	0.6329	= 0
4	Blankers	0.6329	= ()
5	Machine Shop	0.6329	= ()

It is reflected by the analysis that there is a negligible effect of the increase of 0.1MJ per kg. of processing energy of a stage on the unit output cost of energy.

6.4 REASONS OF WASTE, BASIC CAUSES AND WAYS OUT

6.4.1 Summary of Results

Table 6.18 summarises wastages of energy at various locations in the system, approximate loss in monetary terms and the reasons of wastages. Total annual loss and overall wastivity has also been calculated.

Total annual monetary loss	= Rs.1377688	plus loss due to using bigger machines for smaller jobs.
Total Waste	= 61,026 + 39,609	= 1,00,635 Kwh of Electricity, 2,934 litres of LDO and 2,591 Kg. of LPG
Total Input		= 3,66,800 Kwh.of Electricity, 5,654 Litres of LDO and 8,645 Kg. of LPG.
Total yearly input of energy in monetary terms		= Rs.47,84,065
Wastivity	= $\frac{13,77,688}{47,84,065}$	= 28.79%

Table 6.18
Summary of Energy Waste

S. No.	Area/ Period	Source of Energy/ %age of Input*	Input	Waste	Annual Waste		Reasons
					Quantity	Monetary Loss (Rs.)	
1	Powder Plant/ One Month	E (Kw.)	37140	21200	254400	254400	i Machinery and equipment kept running Plant unnecessarily holding molten alloy at high temperature.
				57%			
		LDO (Ltr.)	5654	2934	35208	176040	ii Excessive production of coarse powder due to non- adherence to system parameters.
				52%			iii Breakdown of machinery and equipment and other shortages causing the equipment to be started from cold again and again.
							iv Scrap, pilferage, spillage of materials.
2.	Sinter Line	E	82420	22728		272736	i Non achievement of sintering quality because of which the process has to be stopped again and again for parameter adjustment.
				28%			
		LPG	8645	2591		155460	ii Process scrap and untraced material.
				30%			
3.	Machine Shop	E	86500	11665		139918	i Scrap and untraced material.
				14%			ii Running of machinery and equipment when production is not going on.
3a	Non suitability of machines to the jobs	E	86500	42000		5040000	i Due to large variety of products, small jobs are made on big machines.
				49%			
4.	Plating	E	28710	5433		65196	i Less production or less pieces loaded in a batch.
				19%			ii Stoppages of the process.
5.	Supp. Operations	E	132030	39690 approx.		475308	i Lights and other appliances kept switched on when not required
				30%			ii Air leakages.
							iii Flaws in compressed air and water supply generation and distribution.

* Electricity- E, Light Diesel oil- LDO, Liquified petroleum gas- LPG

6.4.2 Discussion of Results

Following important points come to light as a result of analysis of energy waste:

- a) The company is wasting over 60000 kwh. per month of electricity in four sub-systems

that is, powder plant, sinter line, machine shop and plating. For want of detailed data waste in supporting operations could not be calculated but it is expected that about 30% is going as waste which amounts to about 40,000 units. Thus, about one lac units or approximately 1 lac rupees are wasted only on account of energy per month. In addition, the loss due to processing of smaller jobs on bigger machines is estimated to be 42,000 Kwh, whole of which cannot be avoided but can certainly be reduced in future expansions. L.D.O. and L.P.G. wastages per month come to be around Rs.14,600 and Rs.13000 respectively.

- b) Supporting operations consume maximum energy. These account for nearly 36% of the total energy consumption and looks to be a potential area for waste reduction.
- c) Maximum waste has been found in powder plant. Nearly 57% of the total energy consumed in this sub-system is wasted. In addition the energy wastage due to low efficiency of induction furnace and other equipment is a waste- exact amount has not been found.
- d) The wastage of energy on sinter line has been calculated to be 28%, considering running of heaters of the furnace to maintain its temperature. In addition, LPG burners keep burning throughout the working time. A lot of heat energy is fed to the furnace but actual energy used on sintering of strip is quite less. Hence, energy is wasted due to weak insulation of the furnace.
- e) Similarly, the waste calculated in machine shop is 14%. The loss due to processing smaller jobs on bigger machines has not been added to this as this loss cannot be totally eliminated. This waste has been kept separately at an average of 42,000 Kwh.per month.

6.4.3 Reasons of Waste

By looking into the reasons of these wastages, it is found that human factor, both managerial error and workers' attitude and negligence, have been the primary causes. Condition of equipment and quality of controls to maintain parameters are also contributing to waste.

Most of the energy wastage on powder plant is due to attitude of people. Alloy is not poured even after it is prepared and has attained the pouring temperature. This is mainly to prove workers' view point to management that more than 8 heats in a day are not possible. Recycling of coarse powder is another prominent area of loss. Though some coarse powder

will always be produced but its excessive production can be attributed to non-adherence to laid down rules and parameters regarding pouring time, temperature, water pressure and so on. Equipment factor i.e. condition and functioning of equipment, is also responsible for this but personnel supervising operations are primarily to be blamed.

Breakdowns of machinery or equipment, among other losses, warrant the process to be started all over again. A lot of energy has been wasted due to breakdowns on powder plant. Present health of machinery and equipment and the maintenance policy of the industry are responsible for these.

On sinter line, wastage occurs when required quality of sintering is not attained. The main reasons for this are:

- i) Excessive humidity. Poor functioning of dehumidifiers and other equipment and fuels because of which reducing atmosphere is not maintained in the muffle furnace.
- ii) Human errors in maintaining the required parameters.

In machine shop, large quantity of scrap produced and unwanted running of the machines are the major wastages. Scrap is produced due to operators' negligence, errors in setting of machines and instruments, quality of inputs of materials, tools employed, capability of machines and so on.

6.4.4 Ways- Out

Having already identified the problem, following remedies are contemplated to reduce the wastage:

- a) Making all personnel namely managers, supervisors, workers and suppliers of materials etc. aware of these findings ensuring their emotional involvement in waste reduction.
- b) Powder Plant operators should be educated, convinced and motivated through special incentives to take out 8 heats in five hours.
- c) Introduction of appropriate incentive schemes for energy savings over the existing levels for each department. This will reduce unnecessary running of machinery and equipment.
- d) Installation of fool proof procedures and instruments in powder plant to monitor and maintain the system parameters. Operators should be educated about the maintenance of parameters and their effects. This will help reduce production of

- coarse powder. Equipment should be in healthy condition to ensure control of parameters.
- e) Preventive maintenance schedules should be adopted to eliminate breakdowns of machinery and equipment.
 - f) To enhance efficiency of induction furnace and oil fired furnace on powder plant, arrange to put a removable lid on crucible and also change/monitor its insulation.
 - g) For ensuring required sintering quality, proper dehumidifiers or a more effective alternate heating systems are to be installed.
 - h) To reduce scrap following steps should be adopted:
 - i) Train and educate workers.
 - ii) Conduct machine capability studies and update machinery.
 - iii) All inputs of materials, tools and indirect materials should be properly inspected and controlled.
 - iv) All system parameters should be properly maintained.
 - v) Incentives introduced to control scrap.
 - i) For future expansions or in case of replacement of machines buy machines of varying sizes to serve only a limited range of the total range of the products. This will reduce energy loss.
 - j) General incentive scheme for higher productivity levels should be replaced by a simple and effective incentive scheme which motivates the workers. Besides increasing productivity it will also save energy.
 - k) By plugging all air leakages, making the workers more aware and conscious and installing proper and fool proof equipment, compressed air requirements can be considerably brought down. Layout of compressed air supply line, varying demand requirements of compressed air and capacity of compressors should be scientifically worked out to plan and design a distribution system
 - e) Lights, heaters, fans and other appliances, as a matter of habit, should be switched off when not needed. Further, a study should be conducted to establish proper illumination level in shops at different times and alternative light sources should be compared to decide on the best and most economical.

CHAPTER VII

ANALYSIS OF CAPITAL WASTE

Machinery, equipment, plant, building and inventories of materials have been covered under the capital resource. The analysis deals with utilisation level of machinery and equipment, factors contributing to under-utilisation, waste caused by use of higher capacity machinery and equipment for processing of smaller jobs, waste due to flaws in determining targetted capacity and absence of line balancing, waste due to non-upgradation of technology and non-automation, inventory levels, usage of plant and buildings, etc. All these areas have been studied using appropriate techniques. The case situation has been represented by a linear goal programming model in view of multiple and conflicting objectives. Various priority structures of the objectives have been analysed and values of decision variables satisfying each priority structure have been found.

7.1 METHODOLOGY

The details of analysis undertaken, areas studied and tools and techniques employed are presented below:

7.1.1 Empirical Analysis

Following areas have been studied:

- i) Machine utilisation and plant utilisation.
- ii) Waste due to processing lighter jobs on heavier machines.
- iii) Determination of plant capacity, its comparison with declared or targetted capacity, and checking line balancing.
- iv) Waste due to non-automation or not bringing in new technology.
- v) Extent of use of plant and buildings etc.
- vi) Waste due to large inventories.

A brief description of the methodology and techniques used in each of these analysis is given below. Detailed description is taken up alongwith the analysis.

7.1.1.1. Machine utilisation study: Work sampling technique has been employed for determining utilisation level of machinery and equipment and the factors causing under-utilisation. The steps involved in this study are:

- a) **To decide scope of the study:** All machines in regular use are studied.
- b) **To decide total duration of the study:** The total duration of the study is decided to be one month in view of the following reasons:

In manufacturing industry, production generally is scheduled for a month, targets are set for a month, material is arranged for a month, and so on. This was so in this organisation too. Considerable fluctuations were seen in the output rate and working in the beginning, middle and end of a month. In the beginning of a month, the main activity related to procurement of raw materials and their processing whereas towards the end, efforts were directed to obtain finished goods to meet targets. Thus, to provide for all fluctuations, one month was considered as a satisfactory duration for study purposes.

- c) **To decide the accuracy level:**

Before initiating study, desired accuracy level and confidence level is decided. It was decided that a confidence level of 95% or 2σ deviations on the normal curve and an accuracy level of $\pm 5\%$ would give sufficiently good results for the study. A level higher than that would have drastically increased the required number of observations.

- d) Calculating the required number of observations using the following formula for 95% confidence limits.

$$S \times p = \sqrt{\frac{p(1-p)}{N}} \quad (7.1)$$

where S - desired accuracy level

p - percentage occurrence of the activity or delay. N - Number of observations.

To calculate value of p , a pilot study was conducted taking 100 observations at random. The value of p found from this study was used in Eq.7.1 to determine N .

- e) **To determine timings of observations:** To find timings of observations, following steps were undertaken:

- i) Calculate required number of observations per shift as under:

$$\text{Required number of observations per shift} = \frac{\text{Total number of observations required}}{\text{Number of shifts in a month}} \quad (7.2)$$

- ii) Find the random timings of observations by referring to random number tables and using the timings as found out in (e) above in chronological order.
- iii) Decide symbols of various activities e.g. W for working, S for setting, Tt for talking to supervisor, and so on.

- f) **Conducting study and presentation of results:** A work sampling study sheet was specially designed for the purpose. Activities going on at the time of observation were recorded. Every day one such sheet was used. Data from these sheets was compiled into two summary sheets; machine-wise summary sheet and date-wise summary sheet. Using these sheets, percentages of each activity have been calculated for each day and for each machine in the total period. From these percentages of individual small activities, utilisation level and under-utilisation due to various reasons have been calculated by combining percentages of more than one activities for a broader activity. Graphs have also been plotted for each of these categories. Daily variations, weekly variations and machine-wise variations have been found and analysed.

7.1.1.2. Waste due to processing lighter jobs on heavier machines: This waste has been calculated by using Eq.s 6.12 and 6.13 as explained in chapter six.

Data of product mix for a month has been taken to calculate waste. This has been individually done for various categories of products e.g. bushes, bearings and washers. Weighted percentage of waste has been worked out considering quantities of all categories of products to calculate combined waste.

7.1.1.3. Determination of plant capacity, its comparison with declared or targetted capacity and checking line balancing: Following procedure was adopted to analyse this area:

- a) Standard times of operations were determined by actually observing cycle time for a number of cycles and adding due allowances.
- b) Using standard times of operations on various machines, maximum possible products that can be worked on each machine per shift were calculated. Allowances for settings and other shortages were also given.
- c) Machines deployed for similar operations were grouped together and maximum capacity of the plant for individual operations was calculated.
- d) Some of these operations are common to all categories of products while some others are performed only on specific products. Considering this fact and using capacities calculated at (c) above, combined capacity of the plant for all products taken together, and capacities to produce each category of product have been worked out.

- e) Calculated capacities have been compared with targetted capacities to find their differences.
- f) The differences of calculated capacities for various operations have been found out to determine the extent of non- balancing of lines.

7.1.1.4 Waste due to non-automation or not bringing in new technology: To make a rough assessment of the extent of loss in this area, data regarding production rates, safety, and labour requirements of the existing machines have been compared with that of some machines proposed, ordered or even test run in some cases.

7.1.1.5.. Extent of use of plant and buildings: Use of cubic space, material flow and layout of machinery and equipment have been closely studied in the plant to make an assessment of waste in this area.

7.1.1.6. Waste due to large inventories: Inventories of raw materials, in-process materials, finished goods and rework materials lying at different locations were taken number of times during the study period and their average worked out. An approximate assessment of money locked in inventories as waste, has been made.

7.1.2. Modelling:

As this resource involves multiple areas of machine utilisation and inventory levels with multiple and conflicting objectives, it was decided to apply a multi-objective model to represent and analyse the case. Goal programming has been extensively used in similar situations. Kevin (1987) has used goal programming for solving optimal control problems and found this technique to be more general than other methods of multiple objectives optimisation. Singh and Panda (1989) have applied input-output goal programming for management planning of sericulture industry. Sushil et al (1988, 1989) have applied goal programming to problems of capacity waste minimisation in manufacturing industry. Narang and Batra (1981) have used this technique for product mix decisions in industry. It has also been applied to marketing distribution decisions (Kwak et al, 1991) and for the management of community storage systems.

The general mathematical formulation of this model is:

Find $X = (x_1, x_2, x_3, \dots, x_n)$ so as to lexicographically minimise.

$a = [g_1(\eta, \rho), \dots, g_k(\eta, \rho)]$,

subject to $f_i(x) + \eta_i - \rho_i = b_i$ for $i = 1, 2, \dots, m$. and $x, \eta, \rho \geq 0$

$$\text{Further } f_i(x) = \sum_{j=1}^m C_{ij} X_j \quad (7.3)$$

Where C_{ij} is the coefficient associated with variable j in goal or constraint i ,

$x_1, x_2, x_3, \dots, x_n$ are different variables and

$g_1(\eta, \rho), \dots, g_k(\eta, \rho)$ are different objectives written in order of priority and are the deviations from goals.

Multiple objectives of maximising utilisation levels, maximising profits and weights processed etc. have been selected, constraint equations written and the model has been solved to find product mix satisfying various priority structures of the goals.

7.2 EMPIRICAL ANALYSIS

The details of the analysis in each area as outlined in section 7.2 are presented below.

7.2.1. Machine and Plant Utilisation Studies

In this section utilisation level and underutilisation for each machine and for the plant, have been determined. Day-to-day variations in these levels have also been found out. Types of machines, under-utilised to the maximum extent have been found out. These studies are highly revealing and can be used to plan future corrective actions.

7.2.1.1. Required number of observations: The accuracy of results for percent working or idle time for an operator or a machine is a function of number of observations taken and their randomness. Eq. 7.1 is used to find number of observations required. A pilot study of 100 random observations was conducted and value of p , the percentage occurrence of working time was found to be 0.5. For this value of p , the number of observations required are 1600. Standard tables giving this information are available and have been used in the analysis.

For 27 working days running three shifts a day in the month under study, the number of observations required per shift were calculated to be 20.

7.2.1.2. Random times of observations: Random number tables were used for determining the timings of observations as per procedure given here under:

In random number tables the first random number was 950622. It was decided to use its first three digits for one timing and the next three digits for second timing. First of the three digits, represent hours, and the next two represent minutes. Accordingly, first timing

is 9.50 o'clock and the next is 6.22 o'clock. The timings determined by above procedure but falling out of the duration of a shift are discarded; for example, the timing 6.22 o'clock is not considered for the morning shift starting at 6.30 o'clock. Following the above procedure, number of applicable timings for each shift are determined for each day, put in the chronological order and recorded on work sampling study sheet.

7.2.1.3. Codes of activities: Codes of various activities have been decided. These codes are given in section 7.2.1.5 alongwith the categories in which these are put.

7.2.1.4. Work sampling study sheet: Sheet has as many columns as the number of random timings per shift. For each shift one such sheet is used. For the duration of the study 81 study sheets are prepared.

7.2.1.5. Study summary sheets: Data in work sampling study sheets were compiled into two study summary sheets. First summary sheet has data on number of occurrences of each activity for individual machines in 27 days alongwith number of actual observations. Second summary sheet carries compiled data of total number of observations of each activity on a day for all the machines taken together. From these summary sheets percentage occurrences of various activities have been calculated for individual machines for whole of the study period and for the whole plant on daily basis as well as entire study period.

Using this information, figures for machine utilisation and under-utilisation have been compiled for each machine (Appendix B 3.1). Individual small activities have been grouped into broader categories as under:

- a) **Utilisation includes**
 - i) Working W
 - ii) Setting S
 - iii) Operator talking to inspector Ti
 - iv) Operator talking to supervisor Ts
 - v) Operator cleaning the machine C
 - vi) Self inspection I
 - vii) Try out Try
- b) **Idle time includes:**
 - i) No material NM

- ii) Wait for tools T
 - iii) Others (Power B\D) OTH
- c) **Absenteeism includes:**
 - i) Operator absent A
- d) **Avoidable delays includes:**
 - i) Operator not working NW
 - ii) Operator away from machine O
 - iii) Operator talking to fellow worker TO
- e) **Unavoidable delay includes:**
 - i) Personal time P
- f) **Breakdowns includes:**
 - i) Breakdown of machines B
- a) **Machine utilisation:** From Appendix B3.1 it can be seen that utilisation level is as low as 12.43% in case of a drilling machine and as high as 67.30% in case of a facing and chamfering machine. The average utilisation level is 47.04%. Considering that settings, self inspections and taking instructions from supervisors have been already included in this, these figures are very low.

Among the reasons of under-utilisation, idle time accounts for 26.50%. Material shortages are the main component of idle time (24% of total time). In certain machines idle time has exceeded even 70%. Settings which have been included in the utilised time account for 11.78%. In certain machines settings have consumed as high as 35% of the time. Avoidable delays have wasted 11.84% time on an average on each machine. These were as high as 29.23% on a particular machine. Absenteeism is found to be of the order of 11.80% with highest as 21.51% on a broaching machine. Average breakdowns have been 2.52% with highest as 15.34% on a blanking press. Unavoidable delays have accounted for 1.31%. The highest has been 3.59% on a blanking press.

To know the types of machines that are contributing maximum to under-utilisation of the plant, average under-utilisation levels of various categories of machines have been determined (Table 7.1).

Table 7.1
Machine Utilisation - Group of Machines (%)

S. No.	Category of Machines	Utilisation Level	Idle Time	Absenteeism	Unavoidable Delay	Avoidable Delay	Break-downs	Settings	Material Shortage
1.	Blanking machines	59.25	11.52	12.64	2.80	2.15	11.63	29.21	8.82
2.	Forming and coining	52.12	13.47	10.25	1.46	20.66	2.04	19.58	9.99
3.	Drilling machines	21.41	57.82	5.98	0.83	12.91	1.05	2.55	56.18
4.	Centerless grinder	44.31	37.68	10.18	1.40	3.90	2.50	4.39	35.98
5.	Bush boring	17.27	64.38	8.72	0.30	5.21	4.12	1.94	62.99
6.	Facing and chamfering	57.99	9.11	17.71	1.06	10.87	3.25	14.16	6.93
7.	Broaching	52.36	24.05	13.56	1.19	6.98	1.86	12.82	21.26
8.	Punch press	50.93	23.77	7.72	2.24	11.29	4.08	17.02	21.07
9.	Grooving, notching etc	50.90	21.99	13.30	1.28	1.75	0.79	7.51	19.54

Table 7.1 depicts that machine utilisation is the lowest in case of bush boring with materials shortages contributing 63% towards the under-utilisation. Drilling machines are the next in order with 21.41%. Even in this case material shortages is the main factor contributing to under-utilisation. The utilisation level of all other categories fall almost in the same range with blankers recording the highest utilisation level of 59.25% followed by facing and chamfering machines (57.99%).

b) Plant Utilisation: From the percentage values of study summary sheet, the values of broad categories of activities for all the machines taken together have been calculated for each day and for whole of the study period (Appendix B3.2). The average daily utilisation of the plant including settings is 46%. On certain days utilisation level is as low as 22.96% with material shortages contributing 48.49% to the under-utilisation on that day. Fig 7.1 shows variation of utilisation level for each day. It depicts a clear trend of increase of utilisation level towards the end of the month. This phenomenon has been studied further by compiling figures for each week. The details are presented in the next section.

Average idle time is 26.10%. It was as high as 49% on a certain day. Fig 7.2 shows variation of idle time for each day. Absenteeism level per day comes out to be 11.71%. It reached as high as 22.21% once in the middle of the month. Fig 7.3 shows variation of level of absenteeism on various days. Avoidable delays are highest in the beginning as shown

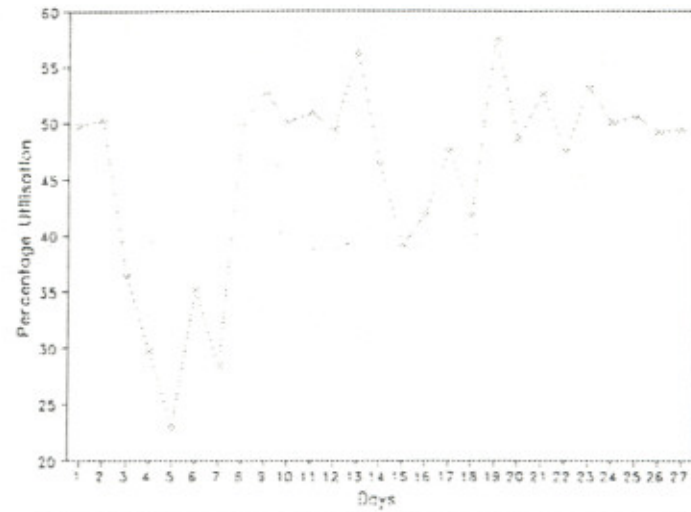


Fig. 7.1 Variation of utilisation level over a month

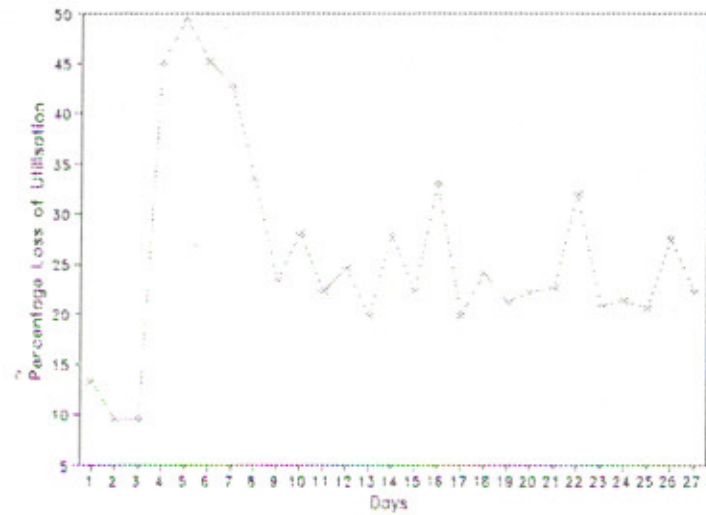


Fig. 7.2 Variation of ideal time over a month

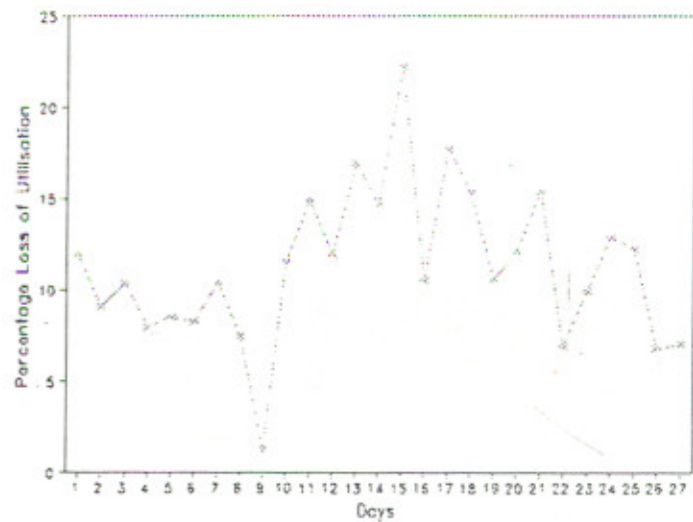


Fig. 7.3 Variation of absenteeism over a month

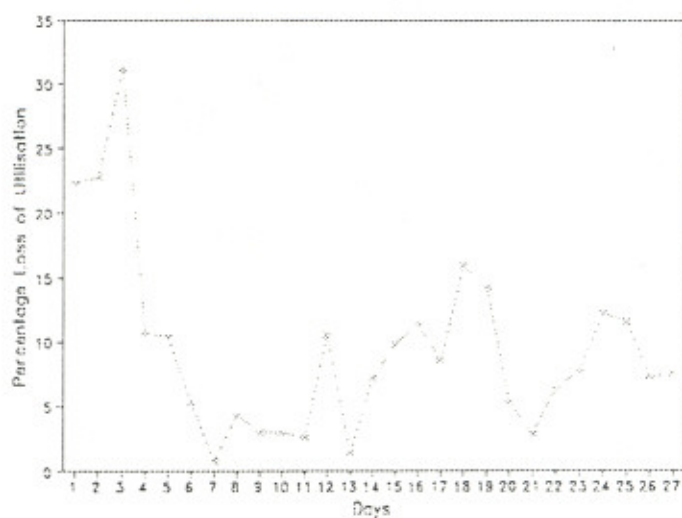


Fig. 7.4 Variation of avoidable delay over a month

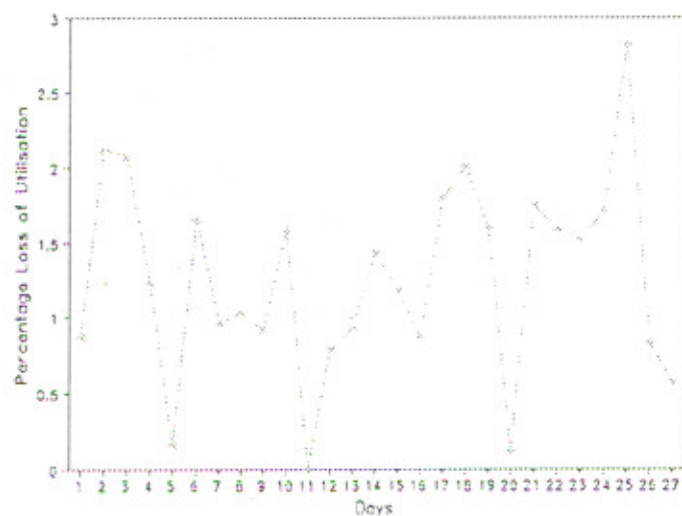


Fig. 7.5 Variation of unavoidable delay over a month

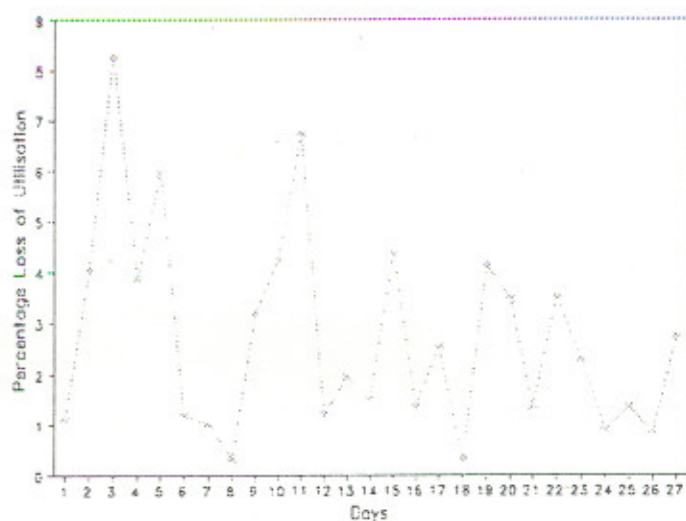


Fig. 7.6 Variation of break down over a month

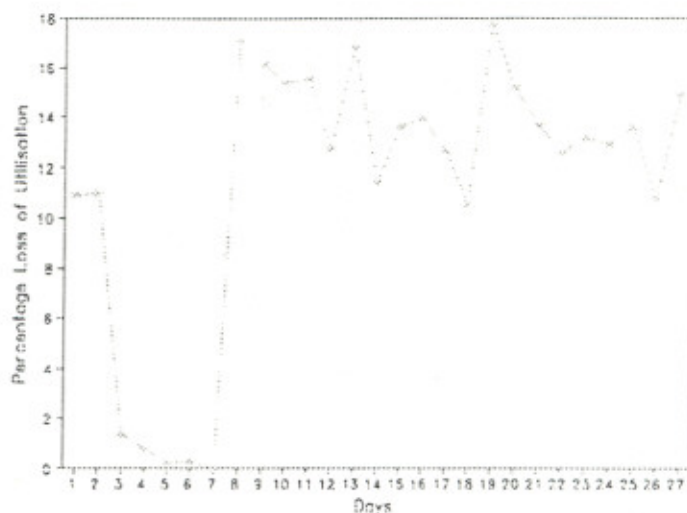


Fig. 7.7 Variation of setting time over a month

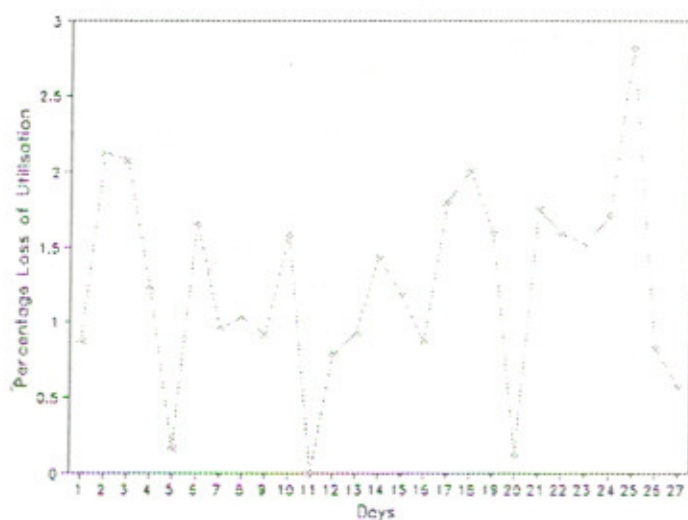


Fig. 7.8 Variation of material shortages over a month

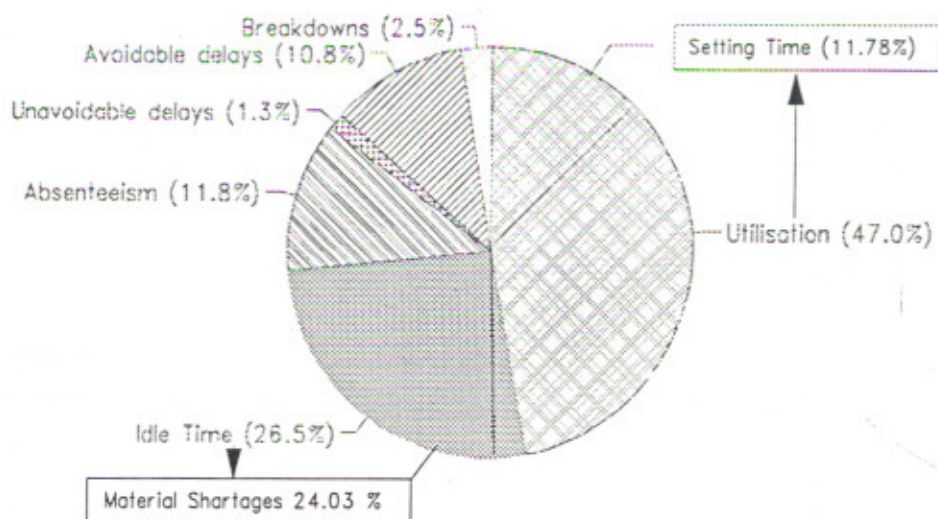


Fig. 7.9 Utilisation level and loss due to various factors

in Fig 7.4. These were as high as 31.14% on day 3. The average level comes out to be 9.10%.

Unavoidable delays comprise 1.26% of the total time. These were as high as 2.82% on a day towards the end of the month. Fig 7.5 shows the daily variation of unavoidable delays.

Because of breakdowns the average loss per day has been 2.70%. Fig 7.6 shows the daily variations in machine breakdowns. Highest level of breakdowns was observed as 8.28% on one day.

Settings have accounted for 11.31% of the total available time. These have been fairly stable between 10 to 18% with a few instances of very less percentage of setting times. Fig 7.7 shows the variations and this trend.

Material shortage is the largest single factor contributing to under-utilisation. Average level has been found to be 25.09% with 48.49% as the highest loss on day 5 (Fig 7.8).

Further, average figures of each week have been compiled to find their variations (Table 7.2).

Table 7.2
Weekly Variations of Utilisation Levels (%)

S. No.	Week	Utilisation Level	Idle Time	Absenteeism	Unavoidable Delay	Avoidable Delay	Break-downs	Settings	Material Shortage
1.	1	37.38	28.70	9.37	17.09	1.35	4.07	4.09	28.14
2.	2	46.84	29.09	11.42	4.02	0.88	2.62	12.83	28.43
3.	3	45.51	24.54	16.25	9.01	1.37	2.01	13.19	24.00
4.	4	51.51	23.38	11.32	6.43	1.38	2.61	14.23	21.14
5.	5	52.97	23.47	8.72	8.75	1.41	1.65	13.09	22.40

As shown in Table 7.2 the utilisation level has steadily increased from 37.38% in the first week to 52.97% in the last week. In the second and third week there has been a marginal change in the utilisation level. Idle time has been considerably high in the first two weeks, mainly because of material shortages, which are about 28%, in the first week and second week, as compared to about 22% in the fourth and fifth weeks.

7.2.1.6. Overall utilisation and under-utilisation levels: Pie chart (Fig 7.9) depicts the overall percentages of utilisation and under-utilisation due to various individual activities and broad categories.

7.2.1.7. Accuracy level of the study: Average utilisation level of each machine has been

found to be about 47%. Number of observations required for each machine are 1600. Utilisation levels of various machines have been found to be different. The percentages of under-utilisation due to each factor have also been different. Thus the accuracy levels of all these at 95% confidence level and using 1626 observations (actual average number of readings taken) would be different. In this regard following important points emerge:

- a) The average value of p (the utilisation level) has been found to be 0.47 instead of 0.5 as determined in the pilot study. The accuracy level of the study at 95% confidence limits and by using 1626 observations comes out to be nearly $\pm 5\%$. Thus the results are not affected much.
- b) Since the value of p in each case is different, the accuracy level of each has to be calculated a fresh. The lowest utilisation of a machine has been found to be about 12%. For this the accuracy level at 95% confidence limit using 1626 observations as obtained from tables is approximately $\pm 14\%$. The utilisation level of all other machines is above 22%. The accuracy level at a value of $p = 0.22$ and 1626 observations is about $\pm 10\%$. For all other machines the accuracy level is higher than this.
- c) The accuracy level of each activity included in under-utilisation for each machine at 1626 observations and 95% confidence level would be quite low because the value of p of each activity is quite low. For higher accuracy levels of each factor of under-utilisation on a specific machine, special and more detailed studies have to be undertaken. The present study serves as a beginning point.
- d) For a general figure of plant utilisation and under- utilisation due to various factors, the number of observations taken are 53,635. The accuracy level of these findings is thus quite high. For example, the working time has been found to be 32 percent. From tables, the accuracy level at a p value of 0.32 and 10,000 observations is $\pm 2.9\%$. At 53,635 readings, it would be even higher than this. Similarly even for smaller values of p in case of factors of under-utilisation, the accuracy level is quite good.

7.2.2. Waste due to Processing Lighter Jobs on Heavier Machines

As explained in section 7.2.1.2., this waste has been calculated by using Eq.s 6.12 and 6.13. The calculations of under- utilisation of machines with respect to job size and weight have been explained in chapter six.

Using Eq.6.11, under-utilisation has been found to be:

Bearings	77.80 %
Bushes	76.55 %
Washers	39.09 %

Calculations of waste:

For calculating waste, firstly, from the above percentages of under-utilisation of various categories of products, the weighted average percentage of all the categories taken together has been worked out using Eq.6.13. The average percentage comes out to be 72.69%.

Approximate cost of machinery and equipment in machine shop	= Rs 3 crores.
Approximate yearly cost	= Depreciation at the rate of 10% = Rs 30,00,000
Waste	= Rs 30,00,000 × 0.7269 = Rs 21,80,700

7.2.3. Determination of Plant Capacity, Its Comparison with Declared Capacity or Targetted Capacity and Checking Line Balancing

Capacity determination or facility design is an important task. Capacity of a plant is determined on the basis of production rates of machines and their expected availability for service.

$$\text{Availability factor or Stream factor} = \frac{\text{Time available for service}}{\text{Total time in the period}} \times 100 \quad (7.4)$$

The stream factor has to be chosen with care and includes expected delays, stoppages due to power failures, material shortages, servicing and so on.

The targetted capacity of the plant per month has been 7 lac products of all categories i.e. bearings, bushes and washers. Almost every month, the production has been more than this declared or targetted capacity. The machine utilisation studies, however, indicate that there has been a considerable loss of utilisation. All this suggests that excessive production capacity exists. Thus, the study was undertaken to determine actual capacity of the plant for all the categories of products taken together, and for individual categories of the products.

Monthly production capacity of the plant has been determined as under:

- As the standard times of the operations were not available with the company, the first task done was to determine the standard times. For this purpose, a complete

and formal exercise of time study could not be undertaken, however, the cycle times of all the operations on the machines were observed for a number of cycles. The averages of these cycle times are given in column 3 of Appendix B3.3, as observed times. For calculating standard times the following allowances were added:

- i) Ratings: While observing the times, readings of only those workers were recorded who looked to be working near a rating of 100.
 - ii) Relaxation allowance = 15% depending upon the type of work involved in the machine shop.
 - iii) Contingency allowance = 5%
- Thus total allowance = 20%.

Further a 10% allowance of the total available time was given for machine settings. Another 5% was given for breakdowns and shortages etc. i.e. the stream factor. Thus the total available time in an 8 hour shift was reduced by 15% or 1.2 hour on these two accounts. The useful time for production was left to be 6.8 hours.

Appendix B3.3 shows the standard times, and the possible number of products per shift and per month.

The monthly production has been calculated as shown in Table 7.3. All the machines doing similar operations are grouped together to arrive at the total capacity of the plant for each operation. For example, the total capacity of the plant to do blanking operations is 26,48,325. Similarly the capacity for drilling operations is 20,40,000 jobs per month.

By looking carefully into these figures it is revealed that line balancing is sadly absent. Some operations have a very large capacity while others are quite less in comparison.

Capacity of the Plant

Some of the operations listed in Table 7.3 are common to all categories of the products while others are used on specific products. Details of operations done on each category of products have been provided in chapter three. The lowest capacity of any operation among the common operations determines the plant capacity for the manufacture of all categories of products taken together. Lip milling with a capacity of 9,96,675 is the minimum of all the operations which are done on all categories of the products. This puts a limit on the plant capacity. Thus plant capacity is to produce about ten lac products.

A number of other operations like blanking, forming, drilling etc. have capacity much in excess to this determined level of ten lac products. Thus even if the company makes ten

lac products per month, there is lot of capacity waste due to the absence of line balancing.

Table 7.3
Monthly Production for Various Operations

S. No.	Operation	Name & Type of Each Machine	Total Monthly Output (No.)
1.	Blanking	BPO3(200T) L2PO1 L3P10	2648325
2.	Drilling	BDO1,DO2 EDO1,DO2	2040000
3.	Forming	BLPO4(63T) L2PO2 40T PRESS BLP05	3864900
4.	Coining	BLPO5(215T) L3PO4	718500
5.	Centerless Grinding	BCLO1	588450
6.	Bush Boring	B EXELD	1416675
7.	Facing & Chamfering	EFO1 L2FO2 L3FO4	1406250
8.	Lip Punching	EPO1,PO2 L2PO1,PO2	3000000
9.	Notching	EMO2,MO4 L3MO2,MO3	1342200
10.	Lip Milling	EMO3 EMO4	996675
11.	I.D. Broach	EID,L2IDI L3IDI	1530000
12.	Ht.Broach	EOHI L2HO1 LEHO2	1424775
13.	Grooving	EMO5 L2MO1 FN3 LEMO4	1102200
14.	Shear Broach	L3S01	510000
15.	Pocket Milling	L3MO3	359175

Capacity of some operations which are specifically done on some categories of the products, puts a limit to the plant capacity to produce that category of the product e.g. boring is done only in case of bushes, broaching only in case of bearings; grinding only in case of bushes; and pocket milling only in case of washers. Based on this fact, capacity to produce individual categories of products is:

		Remarks
Bushes	5,88,450	Limit put by centerless grinding
Flange bearings	5,10,000	Limit put by shear broach
Washers	3,59,000	Limit put by pocket milling

In conclusion, the company has a capacity to produce ten lac products per month with a limit on each category. This is much higher than the company's target of 7 lac products per month. Secondly, due to absence of line balancing, the wastage of capacity of certain

operations will always take place even if the company produces ten lac products.

7.2.4. Inventory Levels

In this area the inventory levels of the raw material, in-process goods and finished goods have been found out for a number of times and their averages worked to arrive at the average inventory level. While choosing the times of recording the inventories, care has been taken to include beginning, middle and end of the month inventory. After recording the average inventory, inventory equivalent of days of production lying with the company has been found. Inferences have been drawn and discussed.

Appendix B3.4 shows the inventory levels at various times, the average inventory level and the presence of inventory of how many days. Day's inventory as given in the last column of the table has been found out by considering the consumption rate of the concern for raw materials, of next departments for inventories in a section; and of next machines for inventory levels of various machines. The figures worked out are quite approximate with the aim of getting an assessment.

Appendix B3.4 highlights following important points:

- a) Average inventory levels of raw materials were not very high. Steel stock was for about two months which is higher, but considering the fact that the company always had problems in getting steel from various companies, it may not be regarded as very high.

Inventory of copper, lead and tin in the raw material stores was for about 20 to 25 days. At the time of conducting these studies a great scarcity of these items was observed. People in purchase and even in the production departments were seen making all out efforts to get copper from wherever possible. Even scrap wires were procured and used.

It was generally seen that on powder plant material is kept to meet daily needs only. Higher inventories are not kept. Powder stock collectively on powder plant and sinter line is enough for 15 days consumption on sinter line which is also not seen to be on a much higher side. Average stock of bi-metallic strip on sinter line is enough to feed the machine shop for 13 days. Similarly average stock of blanks and materials on the first few machines in the machine shop, collectively has been found to be sufficient for about 25 days production in machine shop. This is definitely on the higher side. On next few machines the material is generally insufficient. Only one or two hours production material, on an average, was recorded. This supports the findings of the machine utilisation studies that material

shortages are the main factor of under-utilisation. There is a large inventory of materials recorded in plating indicating towards the bottle necks in the process and non-balancing of the production rates in the concern. Rework material has an average inventory of 29,424 pieces. It indicates that rework material keeps piling up for want of men and facilities to carryout the salvaging. Finished goods stores also have a very large inventory of completed components. Most of these components were held up for want of their matching components and are called 'Mismatch'. These can be sent only if the set is complete. Obsolete items or items of those vehicles whose demand has almost vanished also form a considerable part of the material lying in finished articles stores.

It is concluded from the study of inventory levels that generally these levels have not been worked out. There is hardly any control over these. These have been seen to be very high at places where these are not required. At other places there have been shortages of materials. Lack of line balancing and market conditions have been the main factors contributing to this state.

7.2.5 Other Areas of Capital Waste

In addition to the detailed analysis undertaken in the previous sections, preliminary study of the following areas has also been conducted:

- a) Automation level and state of technology.
- b) Usage of plant, buildings etc.

A detailed analysis of the above areas could not be undertaken for want of data and also because these are complete studies in themselves and would have gone beyond the scope of the present study.

7.2.5.1. Automation level and state of technology: The machinery and equipment used in this plant generally employ old and outdated technology. On each machine only a small single operation is done e.g. drilling only or chamfering only. There is a lot of material handling in between and a large part of the total cycle time is spent on loading and unloading. Conveyors or other automated equipment for handling the material between the machines are not in use.

A careful look on the type of operations being done suggests that a lot of improvement is possible in machinery and equipment. More than one operations can be carried out on a single machine with some modifications of the present machines or designing new machines using hydraulic or pneumatic circuits and auto-feeding

mechanisms involving chutes and magazines. With these, allround improvement in production rates, safety, reduction in number of operators and inspectors and supporting staff for material handling etc, can be made possible.

The company has also realised it, though quite late and after incurring great loss for years, that it should upgrade its technology. A new department has been set up for designing or procuring new machines on which more than one operation can be done. A new production line has been conceptualised in which there would be lesser number of machines and material handling would be by a conveyor system. Some of the machines for this section have been designed and a few have been made too. The details of the machines which have been designed are:

Table 7.4
Details of New Automatic Machines

S. No.	Machine	Operations to be carried out by one machine in one setting
1.	100 Ton Blanker	Blanking, forming and coining
2.	Auto Grooving	Grooving with auto feed mechanism.
3.	Lip punch	Lip punch hole punch and counter sinking with auto feed mechanism.

These three machines were put on trial and were giving satisfactory results. But the real problem was to convince the workers. There was a strong initial reaction from the workers.

Some more machines have also been designed. Table 7.5 gives comparative figures of old and new machines.

In addition to the above benefits of production rate and saving of operators, the other benefits are:

- i) Fool proof safety.
- ii) Self inspection by operator because he has time to do so due to automatic loading and unloading.
- iii) Less fatigue on the part of the worker.
- iv) Less material handling and people required for it.

Thus the company would be saving a lot if these machines are successfully

made and put to use. The technology employed in the new machines is not something latest. This has been in-use, in India, for the past about 15 years. Thus, it can be concluded that the company over the past 15 years has lost a lot which is equivalent to the benefits expected from these machines. If all the new design machines are put to successful use the productivity is expected to increase 4 times. This gives an idea of the loss the company has suffered in the past.

Table 7.5
Comparison of old and new machines

S. No.	Machine	Present Production Rate per Shift (No.)	Production Rate of New Machine (No.)	Number of Workers required	
				Old	New
1.	Coining	7000	25000	1	1
2.	Blanking	7000	25000	1	
3.	Hole punching	6000	12000	1	
4.	Counter sinking	6000	12000	1	
5.	Lip punch	3000	12000	1	
6.	Face and chamfer	3400	8500	1	1
7.	ID Broach	3500	6500	1	1
8.	Height Broach	3000	6500	1	1

7.2.5.2. Usage of plant and buildings etc.: Generally speaking the company has utilised the available space in a nice manner. As can be seen from the layout diagram of Fig 3.4, powder plant is very well located on three floors making full use of the cubic space as well as getting the benefits of gravity feed wherever needed. Location of all offices above laboratory and other sections, is a good example of proper space utilisation. The locations of powder plant, sinter line, machine shop and other departments have been such that the flow of material in the plant is nearly unidirectional. Packing department, again, is located on two floors taking full use of gravity feed.

Some minor shortcomings have been observed. The layout of the machines, though almost systematic, does not fully ensure unidirectional flow of material. Further, higher levels of inventories on the machines occupy a lot of space. Delays in disposal of scrap material and salvaging from rework material also results in the wastage of a lot of space. For more

details a complete study of the layout and related aspects is needed.

7.3 GOAL PROGRAMMING MODEL

Empirical analysis has identified capacity utilisation and inventory mainly resulting in wastage. A goal programming model is formulated to determine a product mix minimising waste in the above areas. Aspects included in this model are:

- i) Capacity utilisation with respect to time.
- ii) Capacity utilisation with respect to size of the job.
- iii) In-process inventory.

For the goal programming model, objectives and constraints are outlined below:

a) Objectives

- i) Minimise idle time due to no job on the machine.
- ii) Minimise in-process inventory.
- iii) Minimise set-up time.
- iv) Maximise profit.
- v) Maximise total weight processed.

b) Constraints

- i) Maximum capacity available.
- ii) Minimum production levels.
- iii) Product mix.
- iv) Set up time.
- v) Number of rounds.
- vi) Continuity.
- vii) Non-negativity.

7.3.1 Model Construction

For the model, only machining operations have been considered. Further, due to large variety of products production carried out in the entire month has not been included. Rather the model is based on the production of two days (6 shifts) only. An effort has been made to represent faithfully the system through following measures.

- a) Quantity of each category of products taken for the model has been maintained in the same proportions as for the entire month.

- b) Number of types of products of each category taken for the model have also been maintained in the same proportions as for the entire month.
- c) Average weight of each category of products has been maintained for the model also.

Table 7.6 gives details of total quantity planned for July 1991, quantity of each category and average weight of each category of products. Calculations of these quantities for the model are also shown in the table.

Table 7.6
Requirements of the Model

Category	Details for the Month					Requirements for the Model	
	Quantity	%age	No. of Types	%age	Av. Weight	Quantity	No. of Types
	(A)	(B)	(C)	(D)	(E)	$\frac{C \times 6}{25 \times 3}$	$\frac{A \times 6}{25 \times 3}$
All Categories	8,74,168	100	64	100	-	69,933	6
Bushes	2,79,972	32	43	58.5	.093	22,380	3
Bearings	5,00,165	57	20	27	.105	39,860	2
Washers	94,031	11	11	11	.086	7,480	1

Following types of products have been chosen from each category in an effort to maintain the requirements.

Table 7.7
Details of the Products Considered

Category	Type	Assumed Name	Quantity	Weight Per Product
Bushes	33102	A	15,202	.0712 Kg.
	50402N	B	3,956	.0106 Kg.
	F05307	C	2,808	.107 Kg.
Bearings	70705	D	11,266	.063 Kg.
	80405	E	26,526	.136 Kg.
Washers	60102	F	7,124	.094 Kg.

Above categories, types, quantities and weights are an approximate representation of the system on a smaller scale. Table 7.8 gives the details of processing times and set-up

times of each product on various machines. Some minor operations have not been considered.

Table 7.8
Processing Times, Set-up Times and Unit Profit.

S. No.	Operation	Setting Time (Seconds)	Processing Time (Seconds)						No. of Machines
			Bushes		Bearings		Washers		
			A	B	C	D	E	F	
1	Blanking	7200	4.8	4.9	5.0	1.5	1.6	1.7	3
2	Drilling	1800	3.8	3.8	3.8	3.5	3.6	-	4
3	Forming	5400	2.5	6.5	6.5	1.0	1.8	-	4
4	Coining	5400	6.0	6.5	6.5	4.0	4.2	-	2
5	Grinding	1800	3.0	3.5	3.5	-	-	-	1
6	Boring	3600	1.2	1.3	1.3	-	-	-	1
7	Face and Chamfer	3600	2.5	2.7	2.7	3.0	3.1	5.4	3
8	Internal Broach	3600	-	-	-	3.6	3.6	-	3
9	Height Broach	3600	-	-	-	3.6	4.5	-	3
10	Pocket Milling	3600	-	-	-	-	-	5.2	1
	Profits(Rs.)		1.5	2.5	2.7	1.6	2.8	2.0	

7.3.2 Formulation

Let X_i , $i = 1$ to 6 be quantities of each type of the six products to be made. Further let Y_i , $i = 1$ to 6 be the decision variables for number of rounds or batches of each product. For big lot size there will be less number of set-ups resulting in less time spent on settings but resultant inventory levels will be higher. On the other hand, for smaller lots average level of inventory will be less but number of set-ups will increase. A balance has to be struck between the two costs.

7.3.2.1 Goals and constraints:

- a) **Effective capacity goals:** Left hand side of these goals are the time required for actual operation on each machine. Set-up times have not been considered in these goals. A goal is set as 80% of the available capacity to be utilised on actual operations and 20% is kept for settings. Accordingly, right hand side of the effective capacity goals is 80% of the available capacity. Negative deviations from the goals are to be minimised. Considering 6 shifts of 6.5 effective hours each the total available time comes out to be 1,40,400 seconds per machine. Goal for effective capacity, i.e. 80%

of available capacity is, thus 1,12,320 seconds and goal for settings is 28,080 seconds per machine. Table 7.9 gives the co-efficients of various variables of effective capacity goals.

Table 7.9
Effective Capacity Goals

Operation	Coefficients of Variables , Variables X_i , $i = 1$ to 6						Maximum Time Available on all Machines. (Sec.)
	1	2	3	4	5	6	
Blanking	4.8	4.9	5.0	1.5	1.6	1.7	336960
Drilling	3.8	3.8	3.8	3.5	3.6	-	449280
Forming	2.5	6.5	6.5	1.0	1.8	-	449280
Coining	6.0	6.5	6.5	4.0	4.2	-	224640
Grinding	3.0	3.5	3.5	-	-	-	112320
Boring	1.2	1.3	1.3	-	-	-	112320
Face and Chamfer	2.5	2.7	2.7	3.0	3.1	5.4	336960
Internal Broach	-	-	-	3.6	3.6	-	336960
Height Broach	-	-	-	3.6	4.5	-	336960
Pocket Milling	-	-	-	-	-	5.2	112320

- b) **Work-in-process inventory goals:** The expression for average inventory at a machine is :

$$b = \frac{P_i^2}{2Y_{ij}} \times \frac{t_{ij}}{TP} \quad (7.5)$$

where b is the average inventory carried,

Y_{ij} is the number of rounds of product i on machine j ,

t_{ij} is the processing time of product i on machine j and

P_i is the production quantity of product i in the time period TP .

Here $TP = 6$ shifts (in seconds)

Total inventory cost = Carrying cost + Set-up cost

$Tc = b \times Cc + \text{Set-up cost}$

Where Tc is the total inventory cost and

Cc is the inventory carrying cost.

As the expression for b is non-linear, it has to be linearised. Set-up time is considered

separately as an objective and so it has been removed from the equation. The value of X_i is assumed to be constant for a particular iteration. For first iteration it has been taken to be equal to current level of production. Hence the inventory goal is:

$$\text{Minimise } \frac{P_i \times t_{ij}}{2 Y_{ij} \times TP} \quad (7.6)$$

Where P_i is current production of product i , Which is assumed to be constant. The above is equal to:

$$\text{Maximise } \frac{2 Y_{ij} \times TP}{P_i \times t_{ij}} \quad (7.7)$$

This can be written in goal programming form as:

$$\frac{2TP}{P_i \times t_{ij}} \times Y_{ij} + \eta_i - \rho_i = RHS \quad (7.8)$$

The right hand side has been assumed to be the value obtained by putting $Y_{ij} = 5$. The objective is to minimise negative deviations. Table 7.10 shows the work-in-process inventory goals. These goals are six in number, one each for the number of rounds for each product and have been obtained from Eq.7.8.

Table 7.10
Work in Process Inventory Goals

Variables of Number of Rounds - $Y_i, i= 1$ to 6						RHS
1	2	3	4	5	6	
3.9	-	-	-	-	-	19.5
-	14.3	-	-	-	-	71.5
-	-	20	-	-	-	100.0
-	-	-	16.5	-	-	82.5
-	-	-	-	6.6	-	33.0
-	-	-	-	-	23	115.0

- c) **Set up time goals:** These goals are ten in number, one for each machine. Table 7.11 shows these goals. The right hand side of these goals is kept as 20% of the total available time.
- d) **Profit Goals:** Unit profit on each product has been listed in Table 7.8. The goal for profit has been set at Rs. 2,00,000 for the production of 6 shifts i.e two days. In this goal the negative deviations are to be minimised. The profit goal is:

$$1.5 X_1 + 2.5 X_2 + 2.7 X_3 + 1.6 X_4 + 2.8 X_5 + 2 X_6 \geq 2,00,000$$

Table 7.11

Set-up Time Goals

Variables of Number of Rounds - $Y_i, i=1$ to 6						RHS
1	2	3	4	5	6	(Sec.)
21600	21600	21600	21600	21600	21600	84240
7200	7200	7200	7200	7200	-	112320
21600	21600	21600	21600	21600	-	112320
10800	10800	10800	10800	10800	-	56160
1800	1800	1800	-	-	-	28080
3600	3600	3600	-	-	-	28080
10800	10800	10800	10800	10800	10800	84240
-	-	-	10800	10800	-	84240
-	-	-	10800	10800	-	84240
-	-	-	-	-	3600	28080

- e) **Goal for weight of products processed:** This goal is kept to maximise the use of machinery and equipment with respect to their capacity to process size and weight of the jobs. The goal for weight processed has been kept at a figure of 13750 kg, which is appreciably higher than the weight being processed at present. The goal is: $0.071 X_1 + 0.11 X_2 + 0.11 X_3 + 0.63 X_4 + 0.136 X_5 + 0.094 X_6 \geq 13750$
- f) **Capacity constraints:** The available capacity is based on planning period of 6 shifts of 8 hours each. Available machine hours of each machine are taken to be 6.5 hours, after allowing for idle time due to manpower, material shortages and breakdowns. The right hand side of these constraints have been worked out to be 140400 seconds multiplied by the number of machines. Capacity constraints take into account both setting times as well as the actual processing time. The constraints are given in Table 7.12.
- g) **Minimum production level constraints :** The right hand side value of these constraints are the current production level of each of the 6 machines. The constraints are given in Table 7.13. Negative deviations are to be minimised.
- h) **Product mix constraints:** These constraints ensure if the production level of the products are raised, it will be done in a fixed proportion for each product. The

constraints are worked out as under

$$2(X_1 + X_2 + X_3) = X_4 + X_5$$

$$2X_1 + 2X_2 + 2X_3 - X_4 - X_5 = 0$$

$$(X_1 + X_2 + X_3) = 3(X_6)$$

$$X_1 + X_2 + X_3 - 3X_6 = 0$$

- i) **Number of Rounds Constraints:** These constraints ensure that each machine will be set up atleast once. The constraints are

$$Y_i \geq 1 \text{ where } i = 1 \text{ to } 6$$

Table 7.12
Capacity Constraints

Variables of Production Levels, $X_i, i=1$ to 6						Number of Rounds - $Y_i, i=1$ to 6						RHS (Sec.)
1	2	3	4	5	6	1	2	3	4	5	6	
4.8	4.9	5.0	1.5	1.6	1.7	21600	21600	21600	21600	21600	21600	421200
3.8	3.8	3.8	3.5	3.6	-	7200	7200	7200	7200	7200	-	561600
2.5	6.5	6.5	1	1.8	-	21600	21600	21600	21600	21600	-	561600
6.0	6.5	6.5	4.0	4.2	-	10800	10800	10800	10800	10800	-	280800
3.0	3.5	3.5	-	-	-	1800	1800	1800	-	-	-	140400
1.2	1.3	1.3	-	-	-	3600	3600	3600	-	-	-	140400
2.5	2.7	2.7	3.0	3.1	5.4	10800	10800	10800	10800	10800	10800	421200
-	-	-	3.6	3.6	-	10800	10800	-	421200	-	-	-
-	-	-	3.6	4.5	-	-	-	-	10800	10800	-	421200
-	-	-	-	-	5.12	-	-	-	-	-	-	140400

- j) **Non-negativity Constraints:** These constraints ensure that the decision variables assume non-negative values only. The constraints are:

$$X_i \geq 0 \text{ and } Y_i \geq 0 \text{ where } i = 1 \text{ to } 6$$

7.3.3 Solution of the Model

The goal programming model has been solved using a computer package involving sequential goal programming technique. Number of trial runs of the programme were made involving various priority structures of goals. Details of priority structures of each trial are given in Table 7.14.

Table 7.13
Minimum Production Level Constraints

Variables of Production Levels - X_i , $i = 1$ to 6						RHS (No.)
1	2	3	4	5	6	
1	-	-	-	-	-	15000
-	1	-	-	-	-	4000
-	-	1	-	-	-	2800
-	-	-	1	-	-	11300
-	-	-	-	1	-	26500
-	-	-	-	-	1	7200

Table 7.14
Details of Priority Structures.

Objective	Priority Number				
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Maximise Profits	1	4	2	2	2
Minimise WIP Inventory	2	2	3	1	4
Maximise Effective Capacity	3	3	1	3	3
Minimise Set-up Time	4	5	4	5	1
Maximise Weight Processed	5	1	5	4	5

In the preliminary runs it was observed that on machine 1 the goal of 20% set up time cannot be met even with only one setting of each product. Due to this the setting time for machine 1 i.e the right hand side of goal was increased to 129600(38.46%). The results of each trial and corresponding value of the objective function are given in Table 7.15.

In addition to above values of decision variables and profit, the achieved values of other goals and their deviations are given in Appendix B3.5. It can be seen from Appendix B3.5 that in trial 1, goals of capacity utilisation have remained underachieved in case of most of the machines. Only in case of machine no 4, i.e, coining machines, the goal has been overachieved. The achievement has been 16% in case of machines M8, 30% in case of M3 and about 50% in case of most of other machines. Combined capacity utilisation of all the machines with the decision variables of trial 1 comes out to be about 63%. The set up time with this capacity utilisation is around 13%. Number of set-ups of each job have

been determined to be only 1. The set-up time with 1 set-up on each machine is as low as 3% on machine M10 to as high as 39% on machine 1. The profit goal and the goal for weight processed have been overachieved (Appendix B3.5).

Table 7.15
Results of each trial

Trial No.	Values of Decision Variables												Total Production (No.)	Profits (Rs.)
	Xi - i= 1 to 6						Yi - i= 1 to 6							
	1	2	3	4	5	6	1	2	3	4	5	6		
1	7233	4000	2800	11300	35237	27421	1	1	1	1	1	1	87991	1,99,995
2	15000	4000	1276	11300	26500	19935	1	1	1	1	1	1	78011	1,68,095
3	0	0	0	0	66857	27421	1	1	1	1	1	1	94278	2,27,069
4	15000	2476	0	11300	26499	23906	1	1	1	1	1	1	79181	1,68,779
5	0	0	0	0	66857	27421	1	1	1	1	1	1	94278	2,27,069

For trial 2, maximisation of weight processed has been kept at priority level 1 followed by other goals. The results are shown in Table 7.15. Effective capacity utilisation of all the machines taken together is of the order of 54%. Maximum utilisation is again of machine M4 and number of set-ups are one in case of each product. The total set-up time of all the machines is the same as in case of trial 1. The profit has considerably reduced in this trial.

Trial 3 has effective capacity utilisation at priority level 1 followed by others. Appendix B3.5 reveals that capacity utilisation has drastically increased in this trial to 70% but weight processed has reduced considerably to 12821 kg. The overall set-up time has reduced to about 12.4%. The goal of profit has also been overachieved in this trial as shown. Similar results have been obtained in trial 5 where the first priority has been given to reduction in set-up times.

In trial 4, the minimisation of in-process inventory occupies priority level 1. In this trial overall capacity utilisation has come down to nearly 54%, the profit has reduced to Rs 1,68,779 and weight processed to 14,307 kg.. There has been an increase in the number of set ups of product number 6 resulting in the increase of overall set-up time. This will bring down the average inventory of product 6.

7.3.4 Sensitivity Analysis

Sensitivity analysis has been carried out to identify the critical areas effecting the performance of the productive system. Priority structure of goals involving trial 1 only has been used for the sensitivity analysis. In this structure maximisation of profit is kept at first

priority and thus becomes very important for any company.

To carry out the sensitivity analysis, the right hand side of total capacity constraints were increased by 20% and 40% taking one machine at a time. This amounts to allowing overtime working of the order of 20% or 40% on a machine. Table 7.16 shows the details.

Table 7.16
Results of Sensitivity Analysis

Machine No.	Over-time	New Values of Decision Variables X_i						Total Production (No.)	Profits (Rs.)
		$i = 1$	2	3	4	5	6		
M1	20%	7233	4000	2800	11300	35237	27421	87991	1,99,995
M2	20%				No Change				
M3	20%				No Change				
M4	20%	15000	4000	2800	11300	31579	26718	91397	2,00,000
M4	40%	15000	4000	2800	23405	26500	26718	98423	2,05,144
M5	20%				No Change				
M6	20%				No Change				
M7	20%				No Change				
M8	20%				No Change				
M9	20%				No Change				
M10	20%	11620	4000	2800	11300	28969	32906	91595	2,00,000

The sensitivity analysis indicates that machines M4 and M10 are bottleneck machines. Giving overtime to these machines increases the overall output of the plant. It is suggested that capacity of these machines be increased. Similar results have been obtained by reducing the set-up times. Machine M4 becomes critical in this case.

The solution of goal programming model verifies the results of the empirical analysis regarding the level of capacity utilisation and existence of bottlenecks. It has also brought to light the areas which need strengthening to increase the output and the resultant profits of the plant.

7.4 SUMMARY OF RESULTS, REASONS OF WASTE AND WAYS-OUT

7.4.1 Areas of Waste

Table 7.17 provides the summary of results of various studies conducted in the previous sections.

Table 7.17
Summary of Results of Analysis

Sr.No.	Analysis	Results	Remarks
1.	Machine and Plant Utilisation Studies	Utilisation level = 47% Under-utilisation level = 53% <i>Major Areas of Under-utilisation</i> i) Idle Time = 26.50% ii) Avoidable delays = 10.80% iii) Unavoidable delays = 1.30% iv) Breakdowns = 2.60% v) Absenteeism = 11.80% <i>Individual Areas</i> i) Material shortages = 24% ii) Settings = 11.8% Further, considerable day to day and machine to machine variations in utilisation have been seen.	
2.	Waste due to Processing Smaller Jobs on Machines	Extent of Under-utilisation = 72.69% Approximate yearly waste = Rs.21,80,700	
3.	Determination of capacity and line balancing	Actual capacity of company against a target capacity = Combined Products 10,00,000 Bearings 5,10,000 Bushes 5,88,540 Washers 3,59,000	
4.	Level of Inventories	i) Normal Inventories of raw material ii) Higher Inventories of rework, plating material and material on presses. iii) Material shortages on most of the machines.	
5.	Automation levels	Old technology and lack of automation.	
6.	Use of Plant & Building	Generally efficient use, with minor improvements needed.	

7.4.2 Reasons of Waste and Ways-Out

Excessive variety of products, inefficient scheduling, poor material planning and gross inbalancing of lines have been found to be major reasons contributing to lower utilisation level of machinery and equipment and higher levels of inventories or shortages of materials. Material shortages alone have forced the machinery to remain idle for about

one quarter of the available time. To reduce this loss in future the following steps should be taken:

- a) More realistic and effective production schedules should be made which consider all relevant factors of availability of materials, machines and toolings etc.
- b) Material Planning needs an immediate attention. Desired inventory levels between work centres should be worked out.
- c) In future expansions, care should be taken to balance the lines.

Delays or carelessness on the part of workers has caused about 10% loss of utilisation. Workers have to be educated and motivated to give their best.

Breakdowns of machinery and equipment for about 3% of the total available time have also caused a considerable waste. Preventive maintenance should be undertaken to reduce this loss.

For waste due to using machinery and equipment on processing smaller jobs, large variety of products and inability of management to procure suitable varying sized machines are the main reasons. It is suggested that the whole range of products be divided into some smaller ranges and machinery suiting each range be procured. Related financial implications involving cost-benefit analysis and breakevens should be considered.

A tendency to keep too high and safe margins is a major reason of difference between the targetted and the actual capacity, as determined in the study. It is suggested that the company should review its target capacity and strive to attain that. Goals should be realistic and achievable. (A realistic figure could be 9 lac products in a month.)

Lack of farsightedness and knowledge on the part of top officials and their exceedingly high mobility have been the main reasons for not bringing in modernisation. The company should take a policy decision for acquiring machines using latest technology. Workers and their unions should be educated and taken into confidence to meet the goals of the company.

CHAPTER VIII

ANALYSIS OF MANPOWER WASTE

Manpower is the key resource in any organisation. Its performance level affects significantly the working of labour intensive organisations. This is true for all levels of activity. Resources of materials, energy, capital and manpower used, per unit of product depends largely on the skill, attitude and involvement of the human beings. Utilisation level of machinery and equipment directly affects usage of other resources. In turn, percentage utilisation of machinery and equipment depends mainly on human factor, be it the managerial skill and wisdom in an efficient production planning and control involving selection, determination and usage of factors of production or the involvement of people down the ladder to execute the plans.

Waste in this area can be put into two broad categories namely waste of other resources due to human error and waste of manpower itself. This study deals with identification of waste of both these categories and analysing every aspect of working of the organisation. The details of waste of materials, energy and capital as found in chapters five to seven are critically analysed to locate areas where human beings are directly or indirectly responsible for these wastages. To analyse other areas of waste of manpower itself, details of manpower actually employed in various departments, overtimes, skill levels, incidents of strikes, lockouts etc. have been collected and waste in each of these sub-areas have been found out. The reasons of waste due to manpower have been found by analysing the HRD policy of the company and functioning of other important areas.

As the factors related to human beings are largely intangible, a qualitative model was thought to be most appropriate. Thus a qualitative model using options field methodology (OFM), options profile methodology (OPM) , analytic hierarchy process (AHP) and fuzzy set theory (FST) has been applied. The best courses of actions to meet multiple objectives involved in the reduction of manpower waste have been found out . Different approaches with varying degrees of optimism have been tried and solutions found.

8.1 METHODOLOGY FOR EMPIRICAL ANALYSIS

The analysis has been carried out under two major heads:

- a) Waste of other resources due to human error,

- b) Waste of manpower itself.

Waste in both these areas has been identified as under:

8.1.1 Waste of Other Resources due to Human Error

Following steps have been undertaken in this area:

- a) Wastes of materials, energy and capital found in chapters five to seven have been critically examined to identify their root causes. Direct human error, equipment factor, quality of inputs or environmental factors have been found to be the apparent reasons of waste. Again, going a step further most of these areas have human error as the root cause in not maintaining the equipment properly or procuring substandard or unsuitable machinery and equipment.
- b) The possibility and extent of human error leading to above wastes has been then pin pointed.
- c) Wastes of resources due to human error have been compiled alongwith the level of manpower responsible for the same.

8.1.2 Waste of Manpower Itself

Following areas were studied:

8.1.2.1 Waste due to excessive manpower: The details of analysis undertaken in this area are:

- i) Figures of manpower actually employed in various departments are taken from records maintained by the personnel department.
- ii) Manpower required to carry out the work has been calculated for each department. To calculate these manpower requirments different approaches have been employed for different departments. This is done as the nature of work involved in various sections is different. The work under taken is briefly discussed here.

On powder plant and sinter line the working involves a very long cycle repetitive work. After loading the material on the equipment, the operator's job is to observe the process which goes on for a long time. Thus, on powder plant, multiple activity charts have been drawn for machine, worker and helper and the number of people required have been determined. On sinter line, although the worker remains free for a long time, yet he cannot be put to other jobs because of close observation of the process required. Thus, here multiple activity charts have not been plotted and only simple calculations carried out. Due

allowances for absenteeism etc. have been added.

In case of machine shop, using the standard times and the production to be made in the department including allowances for scrap, the percentage of time the machines remain occupied have been calculated. The number of operators have then been calculated assuming that the operator will not react to working on any machine. Due allowances have been added to arrive at the figures of the required manpower.

For other departments like tool room, maintenance inspection etc. the calculations have not been carried out as these would have gone beyond the scope of the present study. It is assumed that overstaffing in these departments would be equal to the average of the overstaffing in other departments where detailed studies have been carried out. The difference of actual number of people employed and the calculated figures have been found out which represent waste.

8.1.2.2 Waste due to overtime: Actual figures of overtime allowed in each department and their monetary values have been compiled for the month of July, 1991. Considering the excess capacity available with the company, no overtime is required. Thus, whole of the amount spent on overtime is a waste.

8.1.2.3 Waste due to strikes, lockouts and disputes: All major strikes, lockouts and disputes in the past five years have been listed and losses due to them discussed.

8.1.2.4 Waste of skill: Operations done by workers have been closely watched and considering their grades and skill levels, waste has been assessed.

8.1.3 Finding Causes of Waste

For this purpose details regarding HRD policy of the company and other aspects of working have been collected and analysed in the light of above wastes. Specifically the following areas have been closely looked into:

- a) Human resource development policy of the company.
 - i) Benefits extended to employees.
 - ii) Methods of selection, training, education and motivation.
 - iii) Details of incentive schemes.
 - iv) Opportunities for growth and advancement.
 - v) Extent of financial satisfaction of employees.
- b) Details of organisational set-up

- c) Production planning procedure.
- d) Shop floor control system.
- e) Absenteeism and labour turnover levels.
- f) Unions and their effects.
- g) Type of management i.e. open or secretive.

Most of the above information was collected by closely watching operations, going through records and reports and by interacting with people at all levels.

8.1.4 Reaching Root Causes of the Problem and Finding Ways-out

A thorough analysis of the above aspects brought out shortcomings in them. These were noted and ways-out or solutions were listed.

8.2. METHODOLOGY FOR MODELLING

The empirical analysis revealed a number of shortcomings in working, policies and systems of the industry. A number of solutions or ways out have also been suggested. To implement all the suggestions is very difficult and it is desired to establish priorities for action. Choice of method to reduce manpower waste, depends upon the conditions prevailing in the industrial unit. A need is felt for a technique which generates alternate solutions to the problem and helps in choosing a set of most effective solutions. Therefore, a qualitative model using Options Field Methodology (OFM), Options Profile Methodology (OPM), Analytical Hierarchy Process (AHP) and Fuzzy Set Theory (FST), was used to meet the above objectives, as shown in Fig. 8.1, in a flexible system methodology framework (Sushil 1993). A brief description of the model is given below:

The modelling began with a consensus methodological study in which modified idea writing was used to create a list of options as a solution to manpower waste problems. The list was converted into a conceptual design for the management of manpower waste. Options Field/Profile (Warfield, 1979, 1982, 1990) was largely used as a basis for this purpose. Finally, the alternative options profiles developed were got ranked using Analytical Hierarchy Process (Saaty, 1980) and Fuzzy Set Methodology (Zadeh, 1965).

8.2.1. Options Field/Options Profile Methodology

In order to adapt the method of idea writing (which Warfield termed 'idea management') to design, Warfield (1979) introduced a methodology for the conceptual design of systems which results into a portrayal on one page of the products of a conceptual

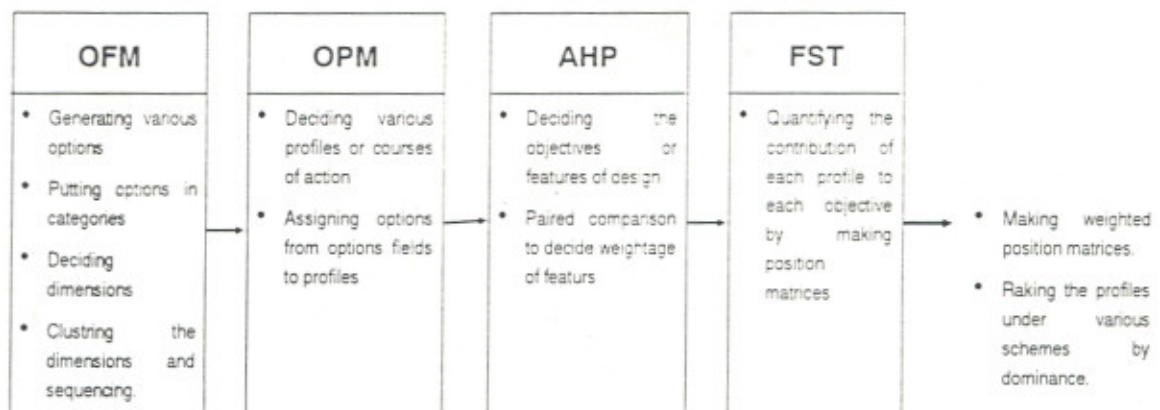


Fig. 8.1 : Qualitative modelling

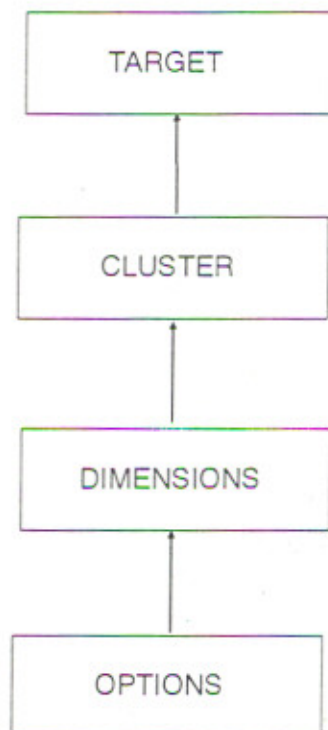


Fig. 8.2 : Four level structure quad.

design a foot. This portrayal shows not only what is accepted in the design but also what options are rejected. The Options Field Methodology and the Options Profile Methodology provide means for thorough development of design situation descriptions and design target description. They involve discovery and identification of dimensionality of the situation, and facilitate matching dimensionality of the target with dimensionality of the design situation. Various steps involved in these two methodologies are described below:

8.2.1.1 Options field methodology

- a) **Construction of a polystructure:** the completed options field is a polystructure. Its construction begins with the generation and classification of a set of options. This set may be generated using modified idea writing in response to a carefully formulated triggering question. This question defines the context and must, therefore, reflect substantial insight into the design situation. The question must neither be too broad nor too narrow. It must stimulate creative and productive responses that do not stray from the topic under consideration.
- b) **Initial structuring (placing options in categories :** Once a set is developed, the initial structuring begins. The initial structuring is for the purpose of placing options into categories. A relationship that may be used for this initial structuring is "in the same category as". Theory of dimensionality is used for placing the options into categories.

The structural theory of dimensionality of situations and processes introduces options field and options profile as by-products of design activity. Options field is a triply structured-quad, (Fig 8.2), since it is a four level structure, whose levels are named: Target, Cluster, Dimension and Options reading from the top to bottom. It is triply structured because its structure incorporates three distinct relationships, (Warfield 1990) described as 'membership in a dimension' for classifying options into dimensions, 'interdependence' for classifying dimensions into interdependent clusters and "time preference relationship" for relating dimensions to each other in clusters.

- c) **Naming the categories:** Following the placing of options into categories, options are displayed as sets, arrayed vertically in anticipation of developing a name for each category that will be placed at the head of the appropriate column of options.
- d) **Identifying design dimensions:** After the set of categories has been achieved, it is reasonable to believe that learning has occurred. At this point it is appropriate to ask whether every category should be taken as a dimension of the design. The criteria

for making this decision is to ask whether some option(s) in that category really must be specified in order to provide adequate definition of the alternative represented by choosing one or more options from each dimension, or whether any particular category is not essential to the definition of the target.

- e) **Discovering clusters of dependent dimensions:** Once the group has settled on the dimensions of the target, a second structuring occurs. Now it is the set of dimensions that is structured. The relationship used is "independent of". Two dimensions are defined to be independent if a choice of one or more options in one of the dimensions does not rule out any choices in the other dimension. If two dimensions are interdependent, the choice of options in one may be restricted by the choice of options in the other. Following this structuring, there is a defined set of clusters, each cluster consisting of a set of dimensions, and each dimension consisting of a set of similar options.
- f) **Establishing a choice-making sequence for clusters:** Now the third structuring begins. This structuring takes the clusters as elements to be structured. The structuring relationship involves the sequence in which choices of options should be made. A suitable relationship is "should be considered first in making choices of options".
- g) **Sequencing dimensions within clusters:** A fourth structuring is carried out now. In this, structuring is carried out separately for each cluster and initial decision-making sequence among dimensions in each cluster is defined.
- h) **Displaying the completed options field:** It is then appropriate to organise the options field by placing dimensions in the order determined with name of each dimension heading a list of the options therein and with the clusters clearly identified.

8.2.1.2 Options profile methodology (OPM): Options Profile is the visual representation of an alternative consisting of a set of chosen options with atleast one option coming from each dimension in the options field. Each option that has been selected is so designated by a line drawn from the bullet in front of the selected option down to the tie line. In applications, it is common to construct several options profiles for a given options field. Each options profile represent one design alternative. In choosing options, choices are made in the sequence determined in formulating the way the options field is represented.

Having made the profiles, next task is to list various objectives of the design or targets. Following this, contribution of each profile to each objective is determined by paired

comparison. Analytical Hierarchy process is employed for the purpose. A brief description of the AHP is given below.

8.2.2 Analytical Hierarchy Process (AHP)

Saaty (1980, 1982, 1986, 1990), Saaty and Vergas (1982), Saaty and Kearns (1985) describe and elaborate on the process.

- a) Paired Comparison: Paired comparison is based on the idea that a complex issue can be effectively examined if it is hierarchically decomposed into its parts. The elements are compared with each other, thus providing an opportunity for a pair-wise comparison for evolving the structure into a $n \times n$ reciprocal judgement matrix. In the matrix, one begins with an element on the left and compares how much more important it is than an element on top. When compared with itself, the ratio is one. When compared with another element, if it is more important than that element, an integer value, as discussed below, is used. If, however, it is less important, then reciprocal of the previous integer value is used. In either case, reciprocal value is entered in the transpose position of the matrix. Thus, only $n(n-1)/2$ judgements are considered where n is the total number. The respondent is to concentrate on only two elements at a time. A scale of 1 to 9 is used for giving judgement value according to the following guide lines:

- $a_{(ij)}$ = 1 if i and j are equally important.
- = 3 if i is weakly more important than j .
- = 5 if i is strongly more important than j
- = 7 if i is very strongly more important than j
- = 9 if i is absolutely more important than j .

Values of 2, 4, 6 and 8 are used to compromise between two judgements.

The weightages of the features are obtained by calculating the Eigen Vector weights for the judgement matrix. An index of consistency is calculated to provide information on how serious are violations of numerical and transitive consistency. The results could be used to seek additional information and re-examine the data used in constructing the scale in order to improve consistency. The consistency index (CI) is $= (X_{\max} - n)/(n-1)$ where n is the number of elements being compared and $X_{\max}$ is the largest eigen value of the judgement matrix. Dividing CI by the random consistency number for the same size matrix,

consistency ratio CR can be obtained. The value of CR should be around 10% or less to be acceptable. In some cases a maximum value of 20% may be tolerated. If CR is not within this range, participants should study the problem and revise their judgement. The average consistencies for different order random matrices are given below (Saaty and Kearns, 1985).

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

8.2.3 Fuzzy Set Theory

- a) Fuzzy Set Methodology (FST) developed by Zadeh (1965) is based on a recognition that certain sets have imprecise boundaries. Fuzzy sets and sub-sets are those ill specified and non-distinct collection of objects with unsharp boundaries in which transition from membership to non-membership is gradual rather than abrupt. A fuzzy set is characterised by a membership function, defined as a real number in the interval (0,1). For example, a membership measure $(X) = 0.5$ suggests that X is a member of set A to a degree 0.5 on a scale where 0 is no membership at all, and one is complete membership. Thus, a fuzzy set can be reduced to a crisp set by transforming memberships to extremes of the range zero or one. Fuzzy Set Theory by Zadeh (1965) has been successfully applied to automata theory, system analysis, decision theory, man-machine systems, modelling of industrial processes etc. In this study, it has been used for the purpose of ranking of options profiles in an integrated form with analytical hierarchy.
- b) Ranking of Alternatives Using Fuzzy Set Theory: The fuzzy set methodology for multi-criteria decision making is used to analyse various options. The fuzzy set techniques are designed such that quantitative and non-quantitative factors, and the view points of the interest groups can be readily incorporated into the decision making process. Ranks of the options in a group process are achieved through a dominance matrix designed for the purpose.

In order to represent the views of each of the interest group, a position matrix is prepared from the responses of all the experts in the group by giving numerical values to the qualitative assessment. Average value of each element representing the group response is worked out by multiplying membership function value of each alternative as given by the respondents with assigned weight i.e. the eigen vector weight as determined by AHP. This way some of the bias in the matrix can be eliminated. The weighted matrices for each of the interest group are thus, prepared. There are three ways to aggregate the weighted matrix

viz. optimistic, average and pessimistic aggregation. The highest value among various group responses represents the optimistic value, the lowest value represents the pessimistic value and the average of all the values represent the mean value.

An $n \times n$ matrix 'D' called dominance matrix is prepared to display the dominance structure between all possible pairs of options. The element d_{ij} is the number of features for which membership value of option j dominates or is greater than option i . A dash is entered for the diagonal d_{ii} element. If the K th column is summed, the total number of dominances of option K over all options is obtained. Similarly, if the K th row is summed, the number of times the K th option is being dominated by all other options is determined. More favourable outcomes have higher column sums and lower row sums. In cases where an option is very close to another option on the basis of aggregate weighted position matrix, the dominance among the options exists only if the membership value of the second option is outside the specified limit. The options can be considered equivalent with respect to that feature. This range may be set for each problem (for example ± 5 percent of the membership value) but should not be too large, otherwise lot of information is likely to be lost. As in the case of weighted position matrices, three dominance matrices namely optimistic dominance matrix, pessimistic dominance matrix and mean dominance matrix are prepared. The ranks of options are normally decided by examining ranks obtained from extent of dominance and also extent of being dominated by other options. Although any of the optimistic, pessimistic and average approaches can be used but there are shortcomings in each. The best course of action for a decision maker in such a situation may be to use the Hadley's criteria of cautious optimism (Hadley, 1967). The decision maker may choose different co-efficients of optimism (α). If 'A' is the dominance weight of the option as determined from optimistic matrix and B that of the pessimistic dominance matrix, weight of the option according to Hadley criterion is determined by the relationship: $W = \alpha \times A + (1 - \alpha) \times B$

Since the process of choosing the coefficient of optimism (α) in the Hadley criterion of 'Cautious Optimism' is a judgement based approach, ranks of the options from the dominance matrix is considered on the basis of dominance and ignoring the considerations of being dominated.

8.2.4 Model Building

A group of persons from the following fields were invited for model building. These were from industry and academics and were very closely connected with problems related with manpower and manpower waste.

- i) One person each from production department and personnel department of the company of the rank of a manager.
- ii) Two persons from junior management grade from production department and one from personnel department of the company.
- iii) Two personnel managers and two supervisors from the companies situated in the same town.
- iv) Two enterprenuers having industrial unit, one in Punjab and the other in Chandigarh.
- v) Three persons from academics closely in touch with management subjects, in general, and personnel management in particular.
- vi) Research worker himself.

Thus, a total of 15 experts participated in idea writing and model building. These people were selected by interviewing them. The questions put to them were concerning manpower and human resource development. A total of 21 persons were selected and invited, however 15 of them participated as listed above.

8.3 Empirical Analysis

The analysis has been divided into two major categories as under:

- i) Wastage of other resources due to human error.
- ii) Wastage of manpower itself.

Both these areas have been discussed here.

8.3.1. Wastage of Other Resources Due to Human Error

The analysis conducted in the resource areas of materials, energy and capital have reflected large amounts of wastages of these resources. Table 5.28, chapter five, Table 6.18, chapter six and Table 7.17, chapter seven show the summary of wastes of materials, energy and capital respectively. Some of these reasons point out directly at the human error while others reflect an indirect hand of the human beings. The waste and their reasons are critically studied and analysed here to find out the errors of human beings directly or indirectly contributing to waste. It is very difficult to assess the waste due to each error or each cause, quantitatively, as a number of factors contribute to the wastages in an area. Thus, quantities of wastes have not been attributed to the errors. Table 8.1 shows the areas of waste under each resource of materials, energy and capital, apparent reasons of waste and the human

error leading to these wastes. Whole of the wastes cannot be attributed to human errors as there are some environmental and chance factors also present which cannot be fully controlled. However, largely actions of human beings are responsible for this state of affairs.

Table 8.1
Wastage of Resources and Human Error

S.No	Areas of Waste	Apparent reasons	Areas of Human Error Leading to wastage		Level* Respon- sible
			Direct	Indirect	
1. Materials					
a) Process Scrap and Rework	i)	Negligence on the part of the worker in machine operation or of supervisor in giving instructions	Direct human error leading to waste		W
	ii)	Inferior and sub-standard inputs of materials and others like toolings etc.		Human error in selection or incoming inspection of inputs.	M,S
	iii)	Condition and incapability of machinery and equipment		Human error in selection and maintenance of machinery	M,S
	iv)	Interruptions in power supply and other inputs		Human error in not planning adequate own generation capacity not maintaining electrical equipment properly and in-adequate liason with the electricity boards.	M,S
	v)	Environmental effects of high humidity and temperature.		Not determining the system parameters considering environmental factors and not taking decisions as to stop production in the wake of un-favofable environment.	M,S
	vi)	Not salvaging from rework	Throwing the rework to scrap	Not providing facilities and labour for salvaging operations.	M,S,W
b) Unaccounted Material	i)	Spillage	Not being careful at the time of operation of the equipment.	Not maintaining the equipment,i.e. pipes,pumps etc. properly	M,S,W
			Deliberate throwing of the material into scrap	Not providing guards etc on the machines	M,S,W
				Not doing chemical analysis of scrap etc.	M,S

	ii) Pilferage	Theft of material	Not providing adequate security on gates Not keeping exact procedures, systems and records.	M M,S
c) Production of Coarse Powder	System parameters not properly maintained	Carelessness on the part of the operators	Non provision of fool proof controls	M,S,W
d) Large difference between the required size and actual size of raw material	Large quantities of chips produced		Not selecting raw materials properly	M,S
e) Damages etc.	Damage of the material during handling	Carelessness on the the part of the worker	Not designing a proper material handling system	M,S,W
2. Energy				
a) Holding of prepared alloy	Running of equipment for longer time than required	Negative attitude and lack of involvement of the workers	Not designing proper incentive schemes Not educating the workers Improper labour control	M,W M M,S
b) Production of coarse powder	Not maintaining the system parameters	Carelessness on the part of the workers	Not making fool-proof controls of the system parameters	M,W
c) Stoppages of machinery and equipment	Breakdowns of machinery and equipment Power breakdowns Environmental Effects	Negligent running of the machines Overloading etc of the equipment Explained under materials.	Not designing a proper maintenance strategy Not ensuring uninterrupted supply to vital areas and not providing safety equipment	M,S,W M,S,W
d) Idle Running of machines	Machines kept running when the production is not being made	Negative attitude or carelessness on the part of the worker	Ineffective labour control Non provision of clear instructions like drawings etc. Flaws in materials planning causing shortages Not making people aware regarding energy scarcity	M,S,W M M M
e) Making smaller jobs on bigger machines	Large variety of products	Improper job scheduling	Improper selection of machinery and equipment	M,S

f) Waste in lighting, Ventilation and other supporting areas	i) Air leakages and running of appliances when not required	carelessness in not switching off the appliances when not required	Improper selection of compressors appliances and other equipment	M,S,W
	ii) Improper distribution of compressed air supply and selection of equipment	Careless working causing leakages of compressed air etc.	Improper design of the distribution system.	M
g) Wastage of energy due to material wastage	Discussed under materials			
3. Capital				
a) Under-utilisation of machines	i) Large setting times	Deliberately taking more time or incompetence	Not designing proper jigs and fixtures	M,S,W
	ii) Material shortages.		Not doing material planning properly and inbalancing of machine capacities	M
	iii) Idle time and avoidable delays	Worker deliberately not working	Lack of supervision	M,S
			Shortages of inputs	M,S
	iv) Breakdown of machines	Already explained.,		
b) Waste due to making smaller jobs on bigger machines		Already explained under energy.		
c) Waste due to improper capacity determination and lack of line balancing	i) Actual capacity is more than the target capacity		Deliberate attempt by the production managers to keep margins	M
	ii) Imbalancing of the lines		Unjudicious selection of machinery and equipment	M
d) Automation Level	Use of outdated machinery and equipment	Reactions to automation	Not being farsighted in procuring proper machinery and equipment	M,W

* M → Manager, S → Supervisor and W → Worker

8.3.2 Waste Due to Manpower Itself

Following analysis has been carried out in this area.

8.3.2.1. Waste due to excessive manpower: To calculate waste due to this reason the following have been worked out:

- a) **Manpower actually employed in various sections:** Table 8.2 shows the details of the manpower actually employed in various sections of the company.

Table 8.2
Manpower Employed in Various Sections.

S.No	Department	Manpower employed
1.	Powder Plant	11
2.	Sinter Line	23
3.	Production	91
4.	Plating	16
5.	Tool Room	21
6.	Maintenance	14
7.	Quality Control	25
8.	Packing	13
9.	Materials	2
10.	Merchandising	2
11.	Production Planning and Control	2

- b) **Manpower required to carry out the needed operations and waste:** As the work involved in various sections is of different nature, calculations of manpower requirements involve the use of different techniques for different sections. The details have been given below under each section:

Powder plant: Powder is made from its constituent elements of copper, lead and tin by the powder metallurgy process. The details of the operations are given in chapter three alongwith the flow charts. The total manual work involved and the approximate time taken were established by observing a number of cycles of the process.

As the varied operations carried on the powder plant require the services of both operator and helper so atleast one operator and helper has to be employed. To find the required number alongwith their working time and idle time, multiple activity charts have been drawn separately for melting operations and drying, classifying and blending operations.

Melting area: Fig 8.3 shows the multiple activity chart of the operations in this area. It is revealed that only one operator and one helper are needed for the operation of induction furnace and supporting equipment. The charts, in addition, brought out the following facts:

- i) All allied work like making reports or filling slips for drawing or delivering materials and arranging drawings etc. can be entrusted to these two persons. This has been shown in the charts by a different pattern of hatching.
- ii) Even after doing these activities the manpower will be free for most of the time as calculated at the end of the chart.
- iii) In addition to the above idle time, they will be free after 5 hours of working every day, if there are no stoppages. Again in a month, only 17 days working (July production of 17000 kg.) are required out of an average of 25 working days. Thus workers will be free for about 35% of the working days too.

Operation of drier, classifier and blender: Molten alloy, after pouring, is struck by high velocity water in the manifold and falls into a tank in the form of slurry. A pneumatic pump operates for the whole duration of the functioning of the furnace and even two hours after that to pump all the slurry into the drier. The capacity of the drier tank is equivalent to the slurry made out of material of 8 heats. The drying process involves passing of steam through the slurry and rotation of the drier, which takes 12 hours.

Classifying operations are carried out to segregate fine and coarse powder. Coarse powder is recycled. Blending involves proper mixing of the powder. Times of drying, classifying and blending operations were established after recording a number of cycles. The operator's job is mainly to start, observe and stop the operations which have a very long cycle. Multiple activity charts for the operations of drier, classifier and blender are shown in Fig 8.4.

The multiple activity chart reveals that one operator each in the morning, afternoon and night shifts are required. Helper is required only in the morning shift, but the work involved is so less that a separate person is not justified. The helper in the melting area can comfortably do the jobs in these areas too. The actual occupied time of the operators, recorded at the end of the chart is also very less. The operators can be given some additional light jobs to be done in the free time or they can be used in the adjoining sections like sinter line. Total manpower required on powder plant has been summarised in Table 8.3.

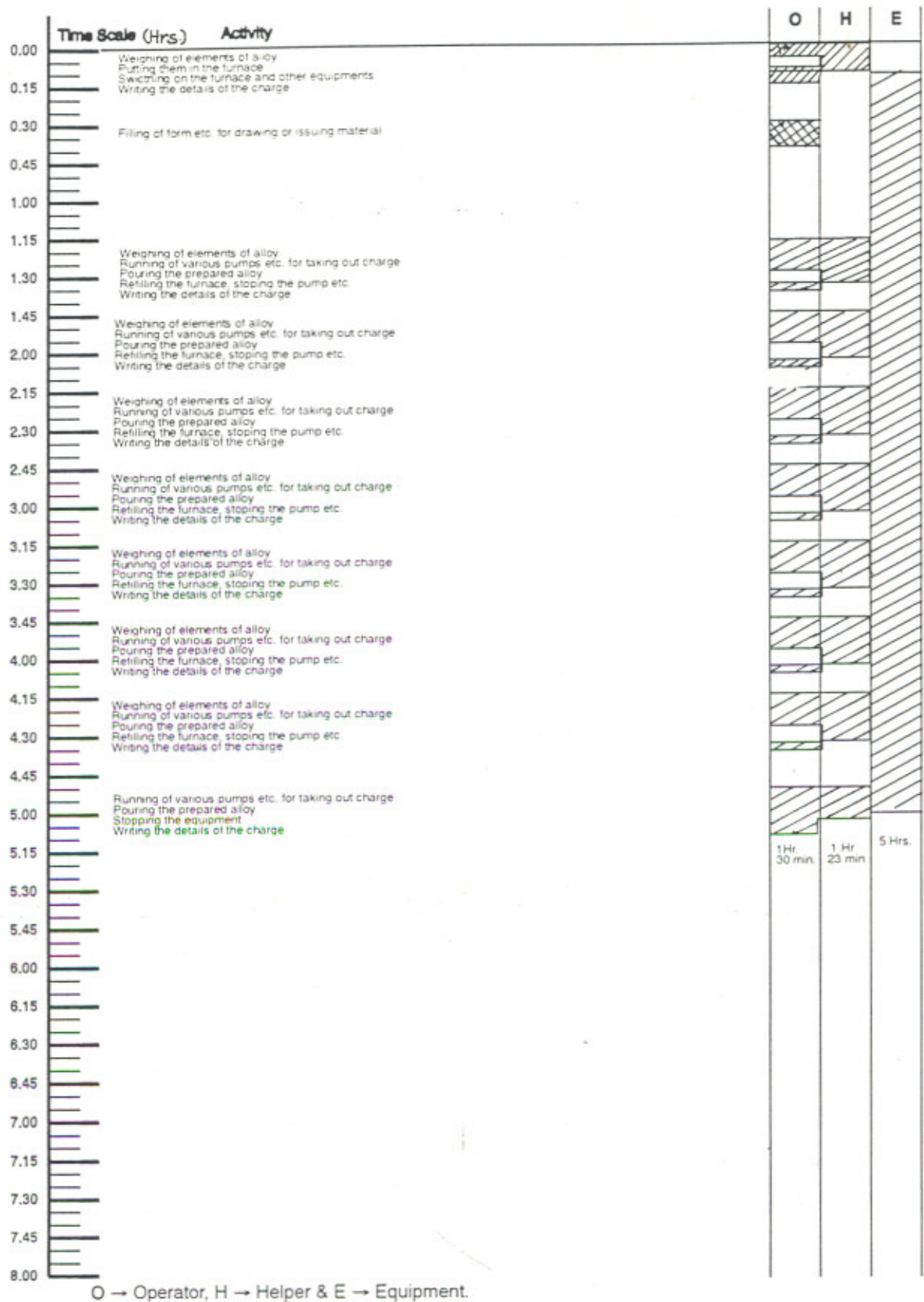


Fig. 8.3 : Multiple activity chart - melting area

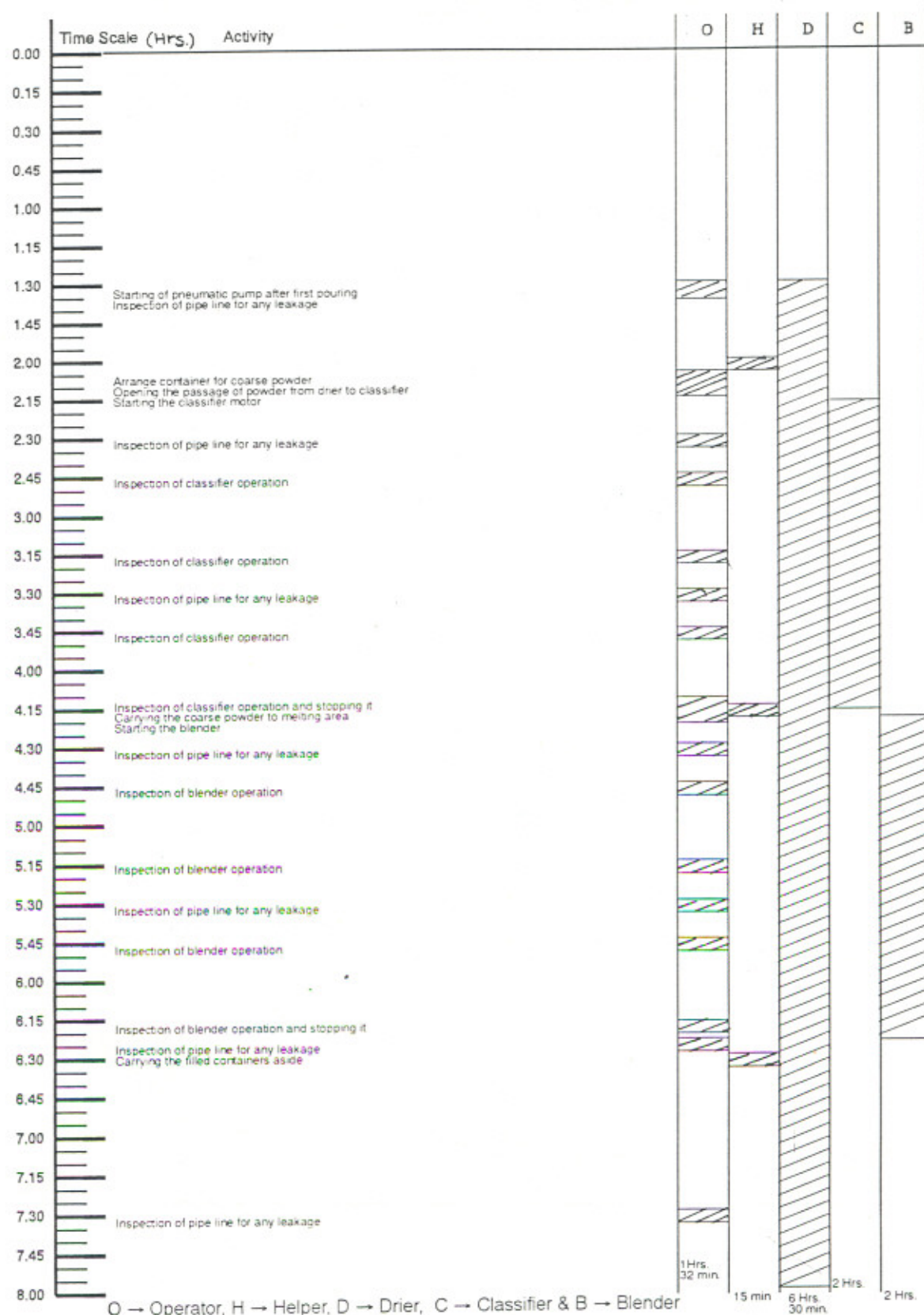


Fig. 8.4a : Multiple activity chart - Drier, Classifier & Blender (Shift-1)

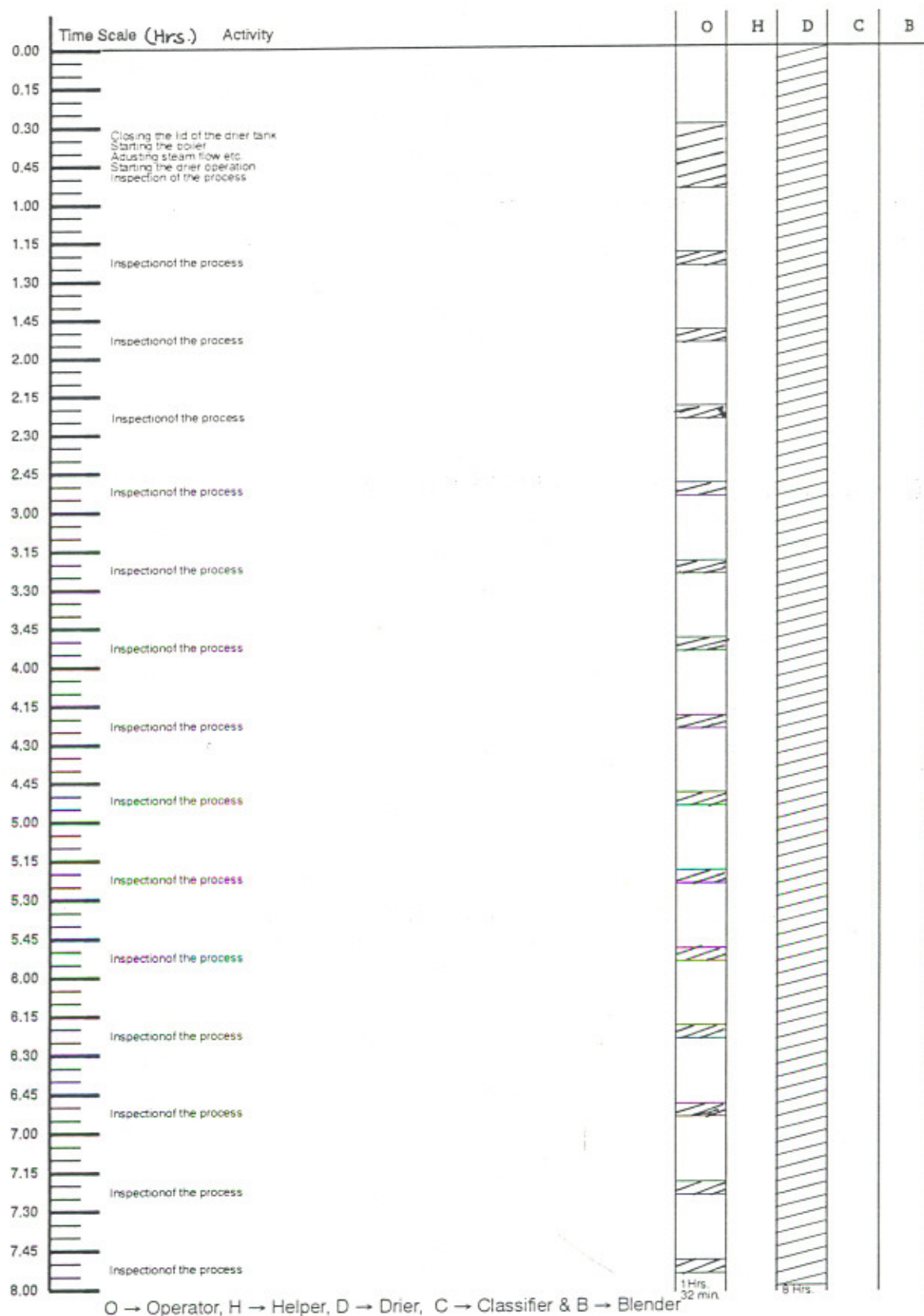


Fig. 8.4b : Multiple activity chart - Drier, Classifier & Blender (Shift-2)

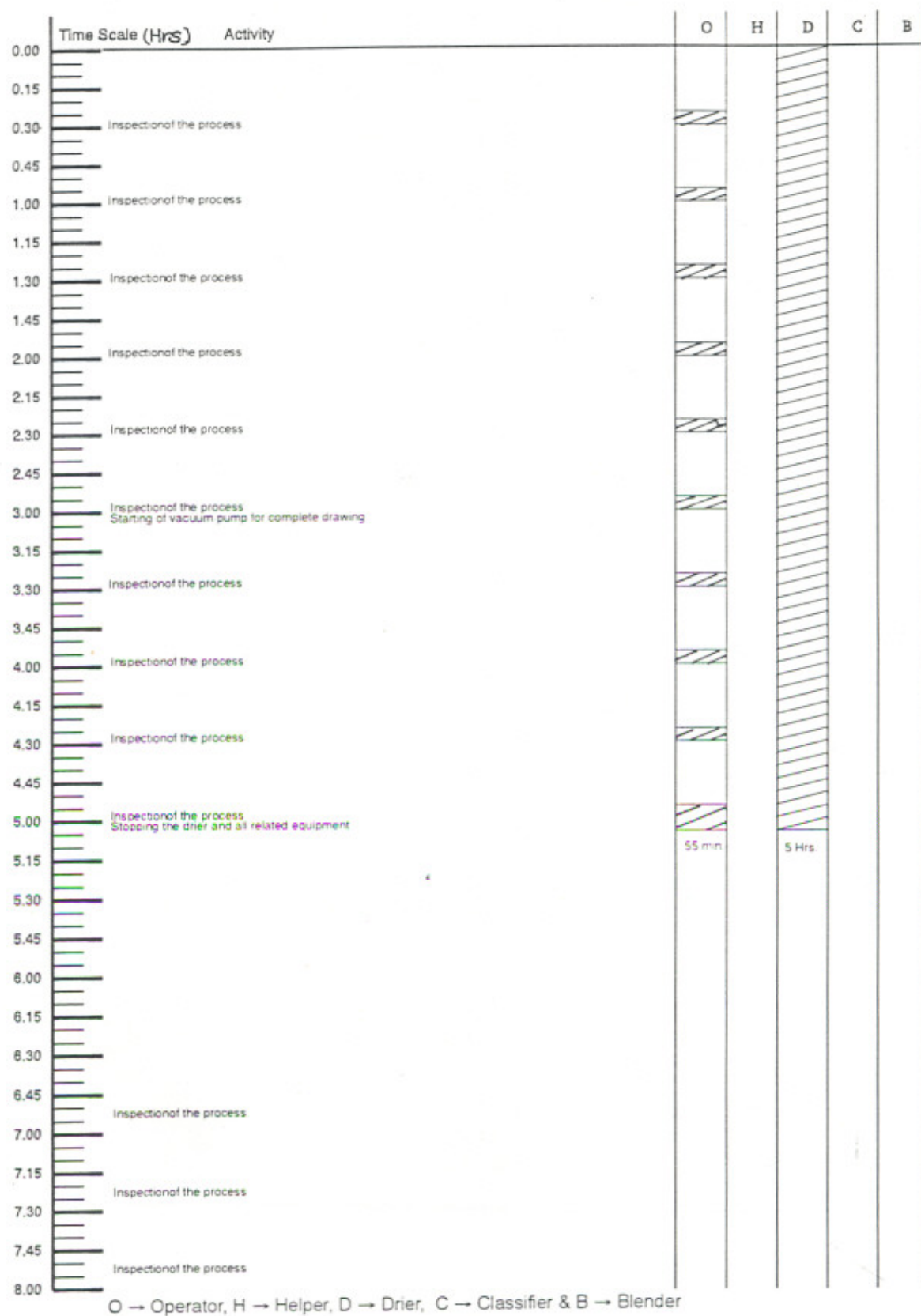


Fig. 8.4c : Multiple activity chart - Drier, Classifier & Blender (Shift-3)

Table 8.3
Total Manpower Required on Powder Plant

S.No.	Shift	Work Area	Manpower Required	
			Operators	Helpers
1	Morning	Melting	1	1
		Drier, Classifier and Blender.	1	
2	Afternoon	Drier, Classifier and Blender	1	
3	Night	Drier, Classifier and Blender	1	
Total			4	1

Thus, if there are no breakdowns and shortages, only 5 people are required on powder plant. But shortages and breakdowns do occur occasionally, because of which the melting work might have to be carried out in shifts, other than morning shift. This may require much more number of people who would sit idle for most of the days. Thus, while 10% allowance is being given for these mishaps and another 10% for absenteeism, but alongside it is recommended too, that free transfer of people, in case of need, from sinter line should be possible instead of making each small department self sufficient. Thus the gross requirements are $5 \times 1.2 = 6$ Men

Sinter line: The details of the manual work involved on sinter line are presented in Table 8.4.

Manpower required: As the operator has to continuously observe and adjust the process, he cannot be put to do other allied jobs simultaneously. For this reason, multiple activity charts have not been drawn. Sanding and degreasing operations need to be run only for one shift whereas sintering has to be carried out on two shifts basis. Thus, number of persons required on sinter line for operation of lines and other allied work are given in Table 8.5.

Machine shop: In machine shop the operations involve very short cycle repetitive work. The manpower requirements have been calculated using the standard times of these operations. As the capacity of the plant is much higher than the production levels achieved, the manpower requirements have not been calculated for 100% capacity utilisation. Rather, it has been based on the expected level of capacity utilisation considering the maximum production level achieved in the past. The calculations are explained below:

Maximum production level achieved in the past per month = 7,85,000

Thus targetted production for manpower calculations	= 8,00,000
Giving 15% allowance for scrap	= 1,20,000
Total	= 9,20,000

This 9,20,000 of targetted production has been further divided into the production level of individual category of products by using their average percentages in a month's production. These come out to be:

1.	Straight bearings	= 5,17,500
2.	Bushes	= 2,70,250
3.	Washers	= 86,250
4.	Flanged bearings	= 46,000

Table 8.4
Manual Operations on Sinter Line

S. No.	Major Area	Activity	Time (Minutes)	Operator(O), Supervisor(H)
1.	Sanding Line			
		1. Loading the strip coil on the line	10	(O,H)
		2. Fixing the strip	5	(O,H)
		3. Starting the sanding and degreasing equipment	5	O
		4. Observing and adjusting the process throughout, if needed	10	O
		5. Unloading the strip	10	O,H
		6. Carrying the strip to sinter line	10	H
2	Sinter Line 1			
		1. Loading the strip coils	10	O,H
		2. Fixing the strip	10	O,H
		3. Starting the sintering equipment	5	O
		4. Observing and adjusting the process if needed	*	O
		5. Removing the coil and loading another	10	O
		6. Carrying the coil to sinter line 2	10	H
3	Sinter Line 2			
		Same as Sinter Line 1		

*Throughout the shift

Table 8.5
Manpower Requirements of Sinter Line

S.No.	Work Done	Manpower Required	
		Operators	Helpers
Morning Shift			
1.	Sanding and Sintering	3	1
2.	Operation of fork lift and others material handling	1	1
3.	Observing and controlling LPG unit and burners	1	-
Afternoon Shift			
4.	Sanding and Sintering	2	1
5.	Operation of fork lift and other material handling	1	1
6.	Observing and controlling LPG units and burners	1	-
Total:		9	4
Grand Total:		13	
Allowance for absenteeism = 10% = 2 persons			
Gross Requirements = 13 + 2 = 15 persons			

Standard times of operations were taken from Appendix B3.3, discussed in chapter seven. From these standard times, maximum monthly output at full capacity utilisation and by giving due allowances for settings and stream factor have been calculated as discussed in chapter seven and given in Appendix B3.3. Total monthly capacities for various operations at full capacity utilisation are also shown in Table 7.3. From this table and by using the required production levels as written above the required percentage capacity utilisation of each machine has been calculated as given in Table 8.6. Total man days are calculated from this percentage utilisation.

Table 8.6
Manpower Requirements - Machine Shop

S. No.	Operation	Required Production	No. of M/cs	Production at 100% Capacity use	%age Utilisation	Required Mandays (e) (b × a ₁₀₀) × 25
		(a)	(b)	(c)	(d)	
1.	Blanking	9,20000	3	2648325	35	26.25
2.	Drilling	9,20000	4	2040000	45	45.00
3.	Forming	9,20000	4	3864900	24	24
4.	Coining	2,70250	2	718500	38	19
5.	Centerless grinding	2,70250	1	588450	46	11.50
6.	Bush Boring	2,70250	1	1416675	19	4.75
7.	Face and Chamfer	8,33750	3	1406250	59	44.25
8.	Lip Punch	9,20,000	4	3000000	31	31.00
9.	Notching	920000	2	1342200	69	34.50
10.	Lip Mill	920000	2	996675	92	46.00
11.	ID Broach	5,63,500	2	1530000	37	18.50
12.	Ht Broach	5,63,500	3	1424775	40	30.00
13.	Grooving	920,000	4	1102200	83	83.00
14.	Shear Broach	46,000	1	510000	9	2.25
15.	Pocket Mill	86,250	1	359175	24	6.00
Total:						426.00

$$\text{Number of persons required} = \frac{426}{25} = 17$$

Thus 17 workers are required in each shift for the operation of machines only. This will be possible only if the management is able to shift workers from one machine to another machine.

Manpower Required for other Jobs: The operations and people required for these are:

Running the belt grinder	= 2 each shift
For doing rework	= 2 each shift
Material handling (only in general shift)	= 4

These people are required for special material handling jobs. For general work like material handling between machines etc., contracted labour is employed.

Total manpower required:

In one shift		= 21 persons
In three shifts	= 21×3	= 63 persons
Additional people in general shift		= 4
Total		= 67

A 10% allowance for shortages and another 10% for absenteeism is given. Thus gross requirements are = $67 \times 1.20 = 80$ persons.

Other departments: Required strength of manpower in other departments has not been calculated because the calculations of manpower requirements in the departments like tool room and maintenance require the use of specialised techniques like simulation or queuing theory. These would become complete and detailed studies in themselves and would have gone beyond the scope of the present study. Similarly the calculations of requirements for quality control demands the system to be streamlined first. In other departments the number of people employed are quite less. To calculate over staffing, it has been assumed that the over staffing in these departments will be almost as much as in the departments for which detailed calculations have been carried out.

Table 8.7 shows the details of the loss due to overstaffing.

Table 8.7

Details of Overstaffing in Various Departments.

S.No.	Department	Number of employees	Number of men needed	Excessive men	Loss in monetary terms @ Rs.3200 per person per month (Rs.)
1.	Powder Plant	11	6	5	16,000
2.	Sinter Line	23	15	8	25,600
3.	Production	91	80	11	35,200
4.	Plating	16	11	5	16,000
5.	Tool Room	21	14	7	22,400
6.	Maintenance	14	9	5	16,000
7.	Quality Control	25	17	8	25,600
8.	Packing	13	9	4	12,800
9.	Materials	2	2	-	-
10.	Merchandising	2	2	-	-
11.	PPC	2	2	-	-
Total:		220	167	53	1,69,600

8.3.2.2. Waste due to overtime: Inspite of the fact that the company has appreciably excess capacity, overtime working worth over rupees one lac was there in the month of July 1991 for the production of 7 lac bearings. The details of overtime in various departments are shown in Table 8.8

Table 8.8
Details of Overtime Working in July 1991

S.No.	Department	Total Hours	Overtime Hours	%age Overtime	Loss in Monetary Terms @ Rs.32/Hour
1.	Sinter Line	4752	577	12.2	18464
2.	Machine Shop	20304	1517	7.5	48544
3.	Plating	3456	214	6.2	6848
4.	Tool Room	4536	283	6.3	9056
5.	Maintenance	3024	178	5.9	5696
6.	Quality Control	4968	365	6.1	9760
7.	Packing	2808	164	5.9	5248
8.	Materials	432	04	1.10	128
9.	Merchandising	432	59	13.7	1888
10.	PPC	432	78	18.1	2496
Total:					1,08,128
Annual Loss:					12,97,536

The table reveals that in machine shop alone where machine capacity is far more than required, Rs.48,000 worth of overtime was undertaken. In respect of percentage, maximum overtime working has been recorded in PPC department which has just two employees on the rolls. These employees had to sit extra time to make schedules and to calculate the requirements for factors of production. High percentage of overtime working in merchandising is attributed to the fact that most of the shipment is done in the last days of the month for which the employees have to stay back for extra time. Sinter line, due to lot of quality problems in the month of July, owing to higher humidity could not be smoothly run and as a result, overtime had to be resorted to.

8.3.2.3 Loss incurred due to strikes, lockouts and disputes :The details of strikes, lockouts and disputes occurred in the past five years are as under:

a) **Lockout from July 16, 1990 to September 6, 1990 for nearly two months:** The

reason of the lockout was a 'slow down' followed by a complete strike by the workers on non-acceptance of their demand for provision of a house to every individual. The workers, whose every demand had been met in the past, did not yield in the beginning but after two months apologised and resumed their duties unconditionally. But all this time the company lost two months of production, goodwill and some orders too.

- b) **Strike from 8th August to 23rd October 1986:** The workers demanded steep rise in salary and allowances at the time of settlement which falls due every three years. On the refusal of the management the workers went on strike.
- c) Go slow adopted by the workers in Dec. 1989. This happened, again, at the time of the next settlement. The workers demanded appreciable rise. On the 'not so promising' response of the management, the workers resorted to go slow.

In addition to above main instances, smaller incidents of deliberate going slow, indiscipline in some form and other acts of misconduct were reported from time to time. Obviously, all this results into loss of production.

A number of cases are pending in the courts, particularly, regarding those leaders which were instrumental and responsible for previous strikes etc. and inciting the workers to react and oppose the management policies. Litigation does cost the company. Thus there has been a considerable loss on this account.

8.3.2.4. Waste of skill: Responsibilities and duties of workers of various levels, supervisors and managers were closely studied and found that waste of this type generally did not exist. Responsibilities of machine operators vary from setting of machine to its operation, cleaning, minor maintenance and product inspection. Similarly the supervisors are used to their full potential. Managers are given responsibilities of sections or departments commensurate with their levels but they were seen doing smaller jobs like following up for machine maintenance or for products on the shop floor. On the whole the loss has not been very appreciable.

8.3.3 Analysis To Find Out Reasons Of Waste

After having identified the areas and quantities of manpower waste, the next step has been to find out the reasons of waste. To do this the details of company's HRD policy and other aspects of working have been closely studied. The details are given below.

8.3.3.1. Company's HRD policy

- a) **Selection, training and placement:** Generally, people are selected on merit. No workers with qualifications less than matric are selected.. The selection is made through interviews and skill tests. The company, as far as possible, does not scumb to the outside pressures in the matter of selection of the people. The workers are provided on the job training to develop necessary skills and are also educated regarding the measurement and other aspect of the job. Regarding placement, no special efforts are made to find out the interest of a new employee for a job and place him accordingly. However in press and machine shop the worker's job is rotated to match the people with the jobs.
- b) **Educational programmes:** Educational programmes for the workers are regularly run by the company. Managers from within the company are asked to speak on chosen topics such as safety; personal development; engineering drawings, limits, fits etc.; Jigs, fixture and product appreciation; nitrogen-hydrogen system of heating; ways to reduce set up times; developments in plating section; description of new machinery; and personal hygiene. These programmes are run during working hours and are very well received by the workers. Sometimes, special lectures by outside experts are also arranged for workers, supervisors and managers. In addition, people are sponsored to attend special programmes/training in the areas of technological advancement and personnel management.
- c) **Goodwill measures/benefits provided by the company :** Transportation by hired buses for 'A' shift employees, by vans for women employees in all the three shifts, travel allowance of Rs.1.50 per day for employees in B and C shifts; subsidised food and excellent canteen facilities for employees; uniform and shoes costing Rs.655 per annum per employee; leave travel allowance of Rs.750 per annum; reimbursement of medical expenses to the tune of Rs.250 per annum, if not covered by ESI; a new year gift of Rs.101; Rs.101 on the marriage of the employee; welfare loans with a ceiling of Rs.2000; coverage under group insurance and accident insurance schemes; excellent arrangement for sports; facilities of a welfare centre, creche, school, and library; hostel accommodation to all women employees and some other employees at nominal charges; overtime payment at double the normal rate and bonus payment of 20% of the salary.

Observations: Selection and training are being very well looked after by the

company. 'Placement', is lacking as the interest of the employee is not properly watched. Education and training programmes have definitely improved the skill, confidence level and involvement of the workers. Although the company is providing many goodwill measures/benefits, a number of them are not adequate and effective to serve the intended purposes.

The provision of houses to women employees, overtime at double the normal rate and payment of 20% bonus are all welcome steps but most of them are mandatory requirements.

8.3.3.2 Incentive scheme: The company is running an incentive scheme with the following details:

- a) Incentive is paid on the basis of:

$$\text{Index} = \text{Pieces per man hour} = \frac{\text{Good production}}{\text{Total reported man-hours}}$$

Incentive will be paid only if value of this index is above 21.90. For higher values of the index incentive is determined by the procedure given in Appendix B4.1.

- b) Incentive, as listed above, will be paid to a worker who works for atleast 188 hours. For others, it will be paid on pro- rata basis.
- c) If a worker works in a department other than his own, man-hours spent there are not counted giving an increased value of the index. As a result, management loses and worker gains by working in other departments. An advantage, however, is that workers generally do not resent working in other departments.
- d) Man-hours are calculated from job cards.
- e) Production of following sections is taken into account.
 Production, PPC, Packing, Plating 100%
 All other departments 80%
- f) Equal incentive is paid to all employees irrespective of their pay scales and basic pay.
- g) If production exceeds 7 lac bearings, a bonus of Rs. 125 is paid.
- h) Average incentive per month works out to be about Rs.625.

Observations: In general, incentive scheme being operated is good. Higher increment for reaching higher levels of production and a bonus on reaching a level of 7 lac bearings do have some motivational effect to reach higher production levels. But there are

some glaring short comings such as:

- a) Single basis for whole of the plant instead of separate targets for separate teams.
- b) Equal incentive to people of all grades instead of giving higher incentive to people with higher skills.
- c) Non-inclusion of overtime working in man-hours. This unnecessarily increases payment of incentive.
- d) Non-inclusion of time spent in other departments.
- e) Complex calculations which keep worker guessing as to what will be the incentive payment.

8.3.3.3 Organisational set up: Organisational chart is shown in Figure 8.5. It is representative of the adhoc and unplanned way of working. A large number of persons are reporting directly to the general manager. It appears that the head of the plant does not have complete faith in his team and involves himself into almost everything instead of leaving it to a few of his deputies. There are persons like assistant manager powder plant, assistant manager PPC, and engineer PPC who are directly reporting to him. Similarly, down the ladder, senior engineer QC, and manager QC are directly reporting to DGM QC. All this is an ample indication of deficiencies in the system. This type of organisation creates short circuiting of lower rank persons and top officials, by-passing the inbetween officers. Lower rank persons like supervisors and workers also get frustrated as there are too many officers giving them instructions directly. The GM and other top officials cannot plan the working properly as they have involved themselves in too many small tasks.

8.3.3.4. State of production planning: There are two officers and two clerks in this department. For the orders received by the company, requirements for components and raw materials are worked out manually and orders placed. Schedules are prepared and sent to production departments. These schedules are just the listing of the parts to be made. Timings, machine capacity requirements and loadings are not worked out and rather these are left to the production department. Considerations like the optimum sequence of products to minimise some function like set-up time and the availability of toolings etc. are nearly absent.

Observations: This area has been found to be very poor. For a production system where such a large variety of production are made, use of computer for materials and tooling requirements and for making realistic and effective production schedules is a must. The

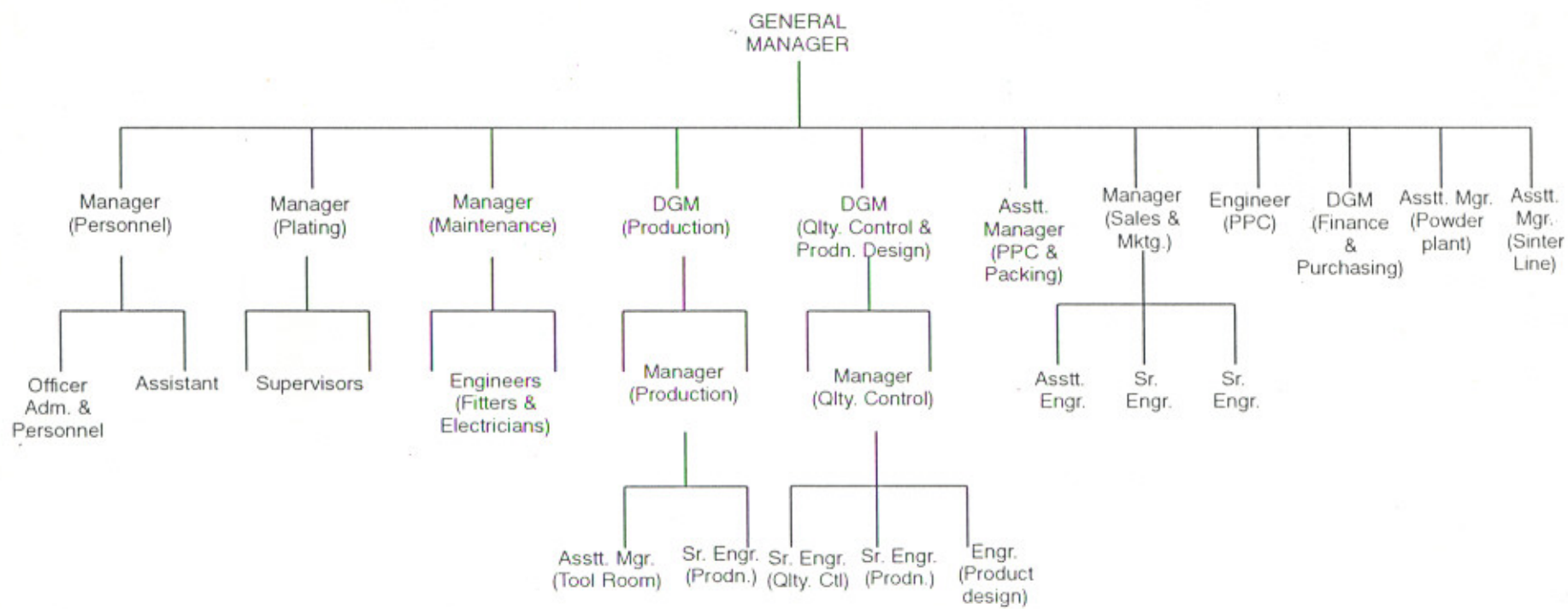


Fig. 8.5 : Organisational Structure

ad hoc approach adopted in this department, as explained above, has following detrimental effects.

- i) More time is spent on settings and resets.
- ii) Material shortages force workers to remain idle.
- iii) More stoppages, as preplanning for making a particular product is not done by toolings department or maintenance section.

8.3.3.5 Shop floor control system: A number of reports are made to pass information from management to the shop floor people and receiving feed back. These reports are:

- i) Production schedules made by PPC.
- ii) Steel supplied and number of blanks made, made by PPC.
- iii) Daily production report.
- iv) Downtime report, daily and monthly.
- v) Machine utilisation report - daily and monthly.
- vi) Worker's performance level - monthly.
- vii) Material plated - daily and monthly.
- viii) Inputs and outputs of powder plant - daily and monthly.
- ix) Inputs and outputs of sinter line - monthly.
- x) Inspection report - daily and monthly.
- xi) In-process scrap report - daily and monthly.
- xii) Cost of quality - monthly.

Observations: It is observed that these reports are too detailed and lengthy that referring them is a very tedious job. Important information is not highlighted or smaller reports for vital areas are not made separately. Further, the reports have to be specially made consuming a lot of time. As complete computerisation of procedures and systems have not been carried out, reports are not automatically made. Above all, these are generally not available at a time when a corrective action is possible and thus lose their significance and usefulness to a great extent.

8.3.3.6 Absenteeism and labour turnover: The absenteeism level generally varies between 15% to 20%. This is causing a great loss to the company. Turnover, in case of workers is generally low. They leave the organisation only if they get married or get government jobs. But turnover, in case of managers and supervisors is high. It is

exceptionally high in case of managers.

Observations: No specific reasons can be attributed to high absenteeism rates of workers. Most of them are not doing any part time jobs. Extreme cold climate in some months is to some extent responsible for absenteeism of workers.

Very high turnover of managers appears to be the main reason for this concern not doing so well. Every new manager starts some new systems and procedures but he generally leaves before the systems become fully operational. As a result long range planning involving technology upgradation and automation have been grossly neglected. Most prominent reasons of higher turn over appear to be:

- i) Generally very competent people are selected who have other avenues too. They leave at the first opportunity.
- ii) Factory is situated at a remote place.
- iii) Organisational set up is not clear and there is confusion.
- iv) Salary and perks are not comparable with the best in the market.
- v) Some of the top people are not considered to be very competent and people do not want to work under them and leave when they get a chance.

8.3.3.7. Financial satisfaction of the workers: In July 1991, salaries and other emoluments applicable to the workers are given in Table 8.9.

Table 8.9

Emoluments of the Workers

Grade	OG2	OG3	OG4	OG5	OG6,TG
Scale of Pay (Rs)	325-613	435-842	560-1045	670-1240	840-1500
D.A. (Rs)	450 - 610 Depending upon the grade				
Conveyance allowance (Rs)	31				
H.R.A. (Rs)	62 -87				
Bonus, LTA, Medical	Already Covered				
Wages on the minimum of the scale	Rs.2500 p.m.				
Wagess on the maximum of the scale	Rs.4000 p.m.				

Observations: Salaries and total emoluments as listed above are definitely

comparable with the best in the industry in this area. However certain allowances, particularly conveyance allowance and house rent allowance look to be too meagre and inadequate. However this should not be a cause for dissatisfaction.

8.3.3.8. Opportunity for growth: There are good opportunities for growth. An operator in OG2 grade can rise to management grade. The criteria for promotion is mainly performance. The performance levels are worked out on daily and monthly basis and a sincere worker cannot be neglected. In the management grade too, a competent and sincere person can get his promotions very fast. In about 8 years time, an engineer can expect to become a manager.

In addition, opportunities for professional growth are many. Programmes of education and training run by the company are quite helpful in this regards. Further, competent people are given important assignments, even in the beginning. In about 5 years time engineers are given complete responsibilities of their departments and good opportunities to learn more.

Observations: The growth opportunities as described above, both for managers and workers are excellent and should give satisfaction to the people.

8.3.3.9. Unions: Parwanoo being an industrial town, is a strong hold of the unions. Every worker of this company is a member of some union and most of them are quite active. These unions have their affiliation to larger unions who have the political backing also. To meet their own political ends, these union leaders incite workers and troubles are created. As such, there is quite an unrest seen in workers. However at the time of study workers were a bit quiet and subdued, may be it was a 'post lock-out' situation.

Observations: It was observed that due to fear of union leaders no worker, even if he wants to, can increase his production beyond a stipulated level. There is a sort of 'work to rule' system prevalent here. It is like two different sets of people working for different goals in an organisation; management to get maximum from workers and workers not to give beyond a particular level even if it is feasible. A general mutual distrust has been seen. It is only the previous negotiations and settlements which were binding the workers to achieve the minimum production level as decided upon. Infact, the production level is much below than what can easily be made.

8.3.3.10 Type of management: The management, as such, is quite open on almost all matters, may it be the benefits to be given to the workers or other aspects of working like resource waste, energy usage and conservation, pollution and effluents and so on. Most of

the matters are openly discussed and are not kept closely guarded secrets before their implementation.

Observations: The management is open in its approach; but this message has not gone to workers. There is a need to convince the workers about this through education and actions.

8.3.4. Reasons of Waste

Based on the preceding analysis of various aspects of working of the company, following reasons of waste have been pin pointed.

- a) Lack of long range planning, technology upgradation and automation mainly due to high turnover of managers and their short-sightedness.
- b) Non existence of laid down procedures and systems leading to confusion at various stages, duplication of work and eleventh hour running for the accomplishment of the tasks.
- c) Shortcomings in production planning and control of not making proper schedules and planning tools, machines and materials alongside. This leads to shortages and excessive time spent on settings and processing. People have to sit idle because of this.
- d) High turn over of officers leading to waste in the areas of long range planning and setting of systems and procedures of doing work.
- e) Faults in organisational set-up and lack of job clarity leading to confusion at all levels, curtailing the powers of the officers, interference by one officer in the affairs of other and short circuiting between a lower rank officer and the top officials by-passing the functional managers. This is unhealthy and affects dedication of people.
- f) Shortcomings in the incentive scheme as already discussed.
- g) Inadequacy of some financial motivators.
- h) Lack of faith of the employees in the management.
- i) Effect of unions leading to indifferent behaviour, lack of concern and sub-standard performance by the workers.

8.3.5. Solutions and Ways Out

- a) Every effort should be made to make systems for doing everything and they should be clearly defined and properly laid down. This particularly pertains to materials

requirements planning, scheduling and other production areas.

- b) PPC department should be strengthened. The function should be largely computerised because with such a large variety of products manual systems cannot yield efficient and economical results. Further, schedules should be made realistically taking into account the availability of all factors of production viz. machines, tools and materials etc. The production of various types should be so sequenced so as to minimise the setting time and elapsed time for a month's product mix.
- c) Responsibilities and authorities should be clearly defined. Faults outlined in the organisational structure should be removed and the top man should instill self confidence into his immediate juniors and in turn should have faith in them.
- d) The problem of high turnover of the managers needs to be looked into immediately. The ways out to reduce turnover, in the light of the reasons listed earlier, can be:
 - i) Remove confusion about the job content and organisational set up.
 - ii) Give more financial and other benefits to make the job more attractive.
 - iii) Make some special arrangements, by joining hands with other industries of the town, to make the town more attractive. This may counter the negative effects of the remoteness of the town.
 - iv) Give more opportunities for growth to the officers.
- e) Shop floor control system should be redesigned and computerised. Instead of doing it in parts, it should be done once for all. Some outside computer software expert should be hired who by coordinating with a capable and knowledgeable person from within the organisation would work for the generation of a new information system which will:
 - Have all standard data regarding product, process operations, raw material, tools and other related things already fed.
 - Facilitate updating and use even by office personnel.
 - Generates all relevant reports, highlighting the critical and important areas.
- f) Incentive scheme should be redesigned preferably, separate target for separate sections or teams should be set. In addition, shortcoming of equal incentive to all, non- inclusion of work done in other departments and overtime should be removed.
- g) Some financial motivators as discussed earlier are too meagre in today's context.

These should be revised upwards.

- h) Management should try its level best to carry along workers in all matters. They should generate a feeling of mutual faith and trust for each other. A pre-requisite for this is that the management should be totally sincere and impartial in the matters of elevating and rewarding the people. In addition, general get togethers should be arranged to give the employees a feeling that they all belong to one family.

To reduce the ill effects of unions following should be done.

- i) Keep the people satisfied by giving them their due without delays.
- ii) Do not ignore or overlook any act of indiscipline to avoid immediate trouble. Take action there and then. This will help in the long run.
- iii) Educate the workers and enlighten them so that they become wiser.

8.4 QUALITATIVE MODELLING USING OFM, OPM, AHP AND FST

The experts were made aware of the findings of the empirical analysis and a triggering question was asked. "In the present case how can manpower waste be reduced?" A total of 186 solutions were proposed out of which some were overlapping. After scrutinising and combining them 60 independent options were made and the polystructure was completed. These options are shown in the completed options profiles in Fig.8.6

8.4.1. Putting the Options into Categories

The options were then put into various categories and the categories were named too. The categories are:

- a) Reduction of idle time
- b) Selection and placement
- c) Education and training
- d) Effective production planning and scheduling
- e) Effective shop floor control system, production control, information feed back and effective inspection.
- f) Motivation
- g) Special care of human beings
- h) Financial satisfaction
- i) Application of method study, work measurement and ergonomic considerations.
- f) Incentive scheme

1. Effective Production Planning and Control

- Proper production planning, scheduling, materials planning and tools planning etc.
- Select system parameters of speed, feed, time etc. realistically
- Give clear cut instructions.
- Clear cut shop floor control system and information system.
- Ensuring quality of materials and other resources.
- Ensuring upkeep of machinery and equipment.

2. Work Study and Incentive Schemes

- Fixation of day's work rationally, on the basis of work measurement.
- Designing the job and work place for maximum efficiency and minimum fatigue.
- Provision of safety on the work place.
- Set time standards before handing over the machine to the shop floor for production
- Monitor employee performance.
- Differentiate between good and bad workers and reward them accordingly.
- Design an effective incentive scheme.

3. Education and Training Schemes

- Provide on the job training
- Educate and enlighten employees.
- Educate and train officers about job aspects.

4. Motivation

- Motivation through financial and other measures.
- Provision of good working conditions
- Provision of goodwill measures like transport, games, school etc.
- Provision of opportunities for growth.
- Utilise employee skill to the maximum to satisfy them.
- Make the work place attractive
- Give adequate freedom and responsibility to workers on work place.
- Give due allowances commensurate with the type of work.
- Provide special allowances for working at odd times and on difficult or hazardous jobs.
- Give patient hearing to employees regarding their personal or job related problems.
- Take care of old and sick employees and give them light jobs.
- Run a suggestion scheme and reward the employees giving good suggestions.

Fig. 8.6 : Options profiles

5. Stable, Open, Scientific and Strong Management

- Maintain discipline as far as possible and do not ignore serious acts of indiscipline and insubordination fearing immediate trouble. Keep long term implications in mind.
- Do not yield to in-genuine demands of the employees as far as possible.
- Use unions in a constructive manner.
- Get the participation of workers.
- Instil in the workers a sense of belongingness by arranging common parties, common eating place, mixing up with the employees and attending their functions.
- Provision of clear organisational set-up with responsibility, authority and delegation clearly defined.
- No exploitation of workers, keep a human touch.
- Do not be unduly secretive, discuss the things openly.
- Efforts to reduce absenteeism and turnover by bringing in clarity at all levels and keeping the people satisfied.
- Encourage employees to acquire multiskills, give incentives for it.
- Reduction in bad effects of unions by mature and straight forward dealing, no suppression or efforts to break them.
- Proper systems and procedures for doing work.
- Get service bond etc. filled to reduce turnover.
- Be fair and impartial in rewarding and elevating the employees.
- No delay in decisions on employee problems.
- Develop mutual faith.
- Encourage managers, supervisors, to develop personal rapport with the workers.

6. Reduction in Idle Time

- Give more than one m/cs to a worker in case of long cycles.
- Reduction in unoccupied time by readjusting the cycle of operation.
- Give additional light jobs in case of long cycle work.
- Arrange comparators on the work place instead of instruments to check absolute reading.
- Arrange sufficient orders through efficient marketing & producing high quality goods.
- Do systematic exercise of aggregate planning for efficient use of manpower.
- Reduce breakdowns of machinery and equipment.
- Ensure smooth (uninterrupted) supply of electricity and other services.

7. Selection and Placement

- Conduct fair and judicious selections.
- Give job of choice to workers as far as possible.
- Exercise job rotation, enrichment and enlargement.
- Calculate manpower requirements realistically and scientifically.

8. Technology Upgradation.

- Automation and improvement in general working.
- Bring in computerisation and reduce manual work.
- Reduce set-up times.
- Bring in automation and improvement in the methods of doing work but not at the cost of making the workers redundant.

Technology based

Employee based

Management based

Environment based

Mixed approach

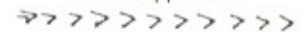


Fig. 8.6 : Options profiles (Cont.)

- k) Stable, open, scientific and strong management.
- l) Improvement in working
- m) Rewarding the employees

8.4.2 Dimensions of the Design

The above categories were scrutinised to include them or exclude any of them for the design. All of these have been included and considered as the dimensions of the design.

8.4.3 Clustering

The dimensions were put into broader categories called clusters. The principles have already been explained. These are shown in the next section.

8.4.4. Sequencing of clusters and dimensions within clusters.

Following the clustering of dimensions the clusters were put into the sequence as per the importance of an area. The sequencing of dimensions within clusters was then carried out. The resultant clusters with sequenced dimensions are given below:

I. Effective production planning and control:

- a) Effective production planning and scheduling.
- b) Shop floor control system, production control, information system and inspection.

II. Work study and incentive schemes:

- a) Application of method study, work measurement and ergonomics.
- b) Incentive schemes.

III. Education and training

IV. Motivation:

- a) Financial satisfaction
- b) Motivation
- c) Special care of human beings
- d) Rewarding the employees

V. Stable, open, scientific and strong management.

VI. Reduction in idle time

VII. Selection and placement

VIII. Improvement in technology, automation and general working of the organisation.

8.4.5. Options Profile Methodology

Various profiles or courses of action planned for reduction in manpower waste were decided to be:

- a) Technology based approach to manpower waste management i.e. more emphasis to be given to PPC, automation and upgradation of technology.
- b) Employee based approach in which more emphasis is to be given to motivation mainly on the basis of theory Y (Currie and Faraday, 1983).
- c) Management based approach in which more emphasis is to be given to maintain discipline and being tough i.e. mainly on the basis of theory X (Currie and Faraday, 1983).
- d) Environmental approach in which more emphasis is to be given to ergonomics, working conditions, etc.
- e) A mixed approach.

After deciding upon various profiles the next task performed has been to find out the options from each cluster contributing to each profile. For this purpose completed options fields have been displayed. A tie line has been drawn on the bottom. Each option contributing to a profile have been joined to the tie line through its bullet. This has been shown in Fig.

8.4.6 Analytical Hierarchy Process Modelling

Various objectives, features or characteristics were then decided. These objectives have been:

- a) Reduction in manpower wastivity
- b) Reduction in expenditure on manpower
- c) Reduction in strikes, lockouts and disputes
- d) Reduction in overtime
- e) Reduction in wastage of other resources due to manpower
- f) To have healthy inter-personal relationships

Next, paired comparison method of analytical hierarchy process has been applied to find out the weightage of each criteria or objective. Each criteria was compared with each other, independently by three respondents. These were: production manager of the unit, personnel manager of the unit and the researcher himself. The respondents compared the objectives on a qualitative scale of Very Low, Low, Medium, High and Very High as the

difference between the importance of two criteria. They however, wrote the response in quantitative terms by converting the qualitative response using the following scale.

V. Low	Low	Medium	High	V. High
0.1	0.3	0.5	0.7	0.9

The matrices of these values as filled by the respondents are given in Appendix B4.2 to B4.4. The matrices also show the calculations of the eigen vector and the weights of criteria.

A matrix containing the weights of all criteria as decided by various respondents are given in Table 8.10.

Table 8.10
Weights of Various Criteria

Criteria ⇒ Respondant ↓	Reduction of manpower wastivity	Reduction in expenditure on manpower	Reduction in strikes, lockouts, disputes	Reduction in overtime	Reduction in wastage of resources due to manpower	To have healthy inter- personal relations.
Production Manager	0.75000	0.00002	0.22070	0.00008	0.02440	0.00348
Personel Manager	0.04900	0.00213	0.77300	0.00028	0.03200	0.09320
Researcher	0.73000	0.00197	0.12400	0.00050	0.12400	0.01500

After determining the weights of the objectives the next step has been to make position matrix. In these matrices the quantitative value of contribution of each profile or course of action to each objective has to be decided. Again, this exercise has been done by the three respondents. The position matrices along with the weights determined earlier are given in Appendix B4.5 to B4.7

From the position matrices, weighted position matrices have been determined. This has also been done individually for the matrix from each respondent. The weight of the criteria as determined earlier has been multiplied by value of each position of the position matrix and weighted values have been obtained. Appendix B4.8 to B4.10 show the weighted position matrices.

From these weighted position matrices optimistic, average and pessimistic weighted position matrices have been made using Fuzzy Set Theory. For optimistic matrix the highest value for each position has been selected, for pessimistic the lowest values and

for average matrix, the average values have been selected. Tables 8.11 to 8.13 show these matrices.

Table 8.11
Optimistic Weighted Position Matrix

Profile ⇒ Criteria ↓	Technology based approach	Employee based approach	Management based approach	Environ- ment based approach	Mixed approach
Reduction in manpower wastivity	0.657	0.375	0.511	0.365	0.36500
Reduction in expenditure on manpower	0.00106	0.00149	0.00137	0.00106	0.00149
Reduction in strikes, lockouts, disputes	0.25509	0.5411	0.25509	0.5411	0.54110
Reduction in overtime	0.00084	0.00147	0.00140	0.00084	0.00084
Reduction in wastage of resources due to manpower	0.11160	0.062	0.0868	0.041	0.06200
To have healthy interpersonal relations	0.2796	0.06524	0.02796	0.0466	0.70000

Table 8.12
Pessimistic Weighted Position Matrix

Profile ⇒ Criteria ↓	Technology based approach	Employee based approach	Management based approach	Environ- ment based approach	Mixed approach
Reduction in manpower wastivity	0.0245	0.0345	0.0245	0.245	0.0245
Reduction in expenditure on manpower	0.0001	0.00002	0.0001	0.00006	0.0001
Reduction in strikes, lockouts, disputes	0.06621	0.0372	0.0868	0.0372	0.01544
Reduction in overtime	0.00005	0.000008	0.0004	0.00002	0.00002
Reduction in wastage of resources due to manpower	0.02196	0.01708	0.01220	0.01220	0.01220
To have healthy interpersonal relations	0.00104	0.00174	0.00174	0.00174	0.00243

Table 8.13
Average Weighted - Position Matrix

Profile ⇒ Criteria ↓	Technology based approach	Employee based approach	Management based approach	Environ- ment based approach	Mixed approach
Reduction in manpower wastivity	0.40216	0.2586	0.3035	0.20483	0.30483
Reduction in expenditure on manpower	0.000713	0.0007	0.00084	0.00057	0.000856
Reduction in strikes, lockouts, disputes	0.13603	0.2295	0.16559	0.21483	0.20618
Reduction in overtime	0.000413	0.00054	0.00059	0.00033	0.00037
Reduction in wastage of resources due to manpower	0.0581	0.0549	0.04318	0.03013	0.04386
To have healthy inter-personal relations	0.01316	0.02482	0.0124	0.01861	0.01884

Following this, dominance matrices have been prepared. In these matrices, the dominance of each course of action over the others has been tabulated. The cell value denotes that a course of action dominates other courses of action in how many criteria and it is dominated by another course of action in how many criteria. In the matrix the profile written on the top dominates the profile written on the left. Thus row sum depicts the number by which a criteria is dominated and the column sum depicts the number by which the profile dominates all other profiles. The matrices are presented in Table 8.14 to 8.16.

Table 8.14
Dominance Matrix - Optimistic

Profile	Dominates					Row Sum	Rank
	I	II	III	IV	V		
I	-	3	1	2	2	8	III
II	2	-	2	0	1	5	I
III	2	2	-	2	3	9	IV
IV	2	4	3	-	2	11	V
V	2	2	2	0	-	6	II
SUM	8	11	8	4	8		

Table 8.15
Dominance Matrix - Pessimistic

Profile	Dominates					Row Sum	Rank
	I	II	III	IV	V		
I	-	1	1	0	1	3	I
II	2	-	1	0	1	4	II
III	1	2	-	1	1	4	II
IV	2	1	1	-	1	6	IV
V	2	3	1	1	-	7	
SUM	7	8	4	1	4		

Table 8.16
Dominance Matrix - Average

Profile	Dominates					Row Sum	Rank
	I	II	III	IV	V		
I	-	2	1	2	2	7	III
II	2	-	1	0	1	2	I
III	3	3	-	2	3	11	V
IV	2	4	2	-	2	10	IV
V	2	3	0	1	-	6	II
SUM	9	12	4	5	8		

Table 8.17
Hadley's Matrix of Cautious Optimism

Scheme ⇒ Profile ↓	100% Optimistic	80% Optimistic	50% Optimistic	20% Optimistic	100% Pessimistic	Average
I	3	2	2	2	2	2
II	1	1	1	1	1	1
III	4	4	4	4	3	5
IV	5	5	5	5	5	4
V	2	3	3	3	4	3

All three dominance matrices, i.e. the optimistic, the pessimistic and the average, show that in the present circumstances, employee based approach is preferred by all experts. Further, in optimistic dominance matrix, a mixed approach occupies second place whereas in both pessimistic and average dominance matrices, technology based approach has emerged at second place. Hadley's cautious optimism (Table 8.17) worked out at different optimism levels also depict the same trend. Thus it is suggested that various strategies to reduce manpower waste should be applied in the above order in the present case.

CHAPTER IX

SYNTHESIS AND FORMULATION OF WASTE MANAGEMENT SYSTEM

This chapter deals with synthesising information from survey and case studies for the formulation of a WM system.

9.1 SYNTHESIS

Analysis of survey conducted and case studies generated a large data base on various aspects of waste and their management. Major findings of analysis presented in chapters four to eight are:

- a) Waste has been found at almost all stages of processing in the identified engineering industry. Generally, industries are poorly managed with regard to waste. Energy, by far, has emerged to be the most critical resource followed by manpower, materials and capital. For each resource, stages and areas alongwith quantum of waste in each area have been found and listed.
- b) Many reasons have emerged for the poor state of waste management. Each type of waste is caused by specific reasons. However, in general, following main reasons contribute to waste:
 - i) Lack of awareness regarding existing wastage levels and the tools and techniques of waste management and their applications.
 - ii) Inability of the middle and top management to appreciate long term benefits of suggested measures and lack of knowledge of proper economic analysis.

Non-availability of sufficient time with managers to properly plan activities and work for improvement. This is due to their too much involvement in routine activities.

Specific reasons of waste in each resource at each stage of processing have been outlined in the analysis. However, some basic causes are found to be responsible for the apparent reasons of waste e.g. poor quality of inputs, carelessness or incompetence of persons involved, lack of interest and indifferent attitude of human beings at various levels, flaws in the organisational set up, poor production planning and an inefficient shop floor control system, and so on.

- c) Mathematical modelling of case situations in each resource has been found to be more convenient and effective. Qualitative modelling of manpower has been found to be very useful in the selection of most appropriate and effective measures, out of a large number of available measures, to reduce waste.
- d) A number of alternative measures for mitigating waste are proposed in the case studies. It has been seen that choice of a particular solution is influenced by the financial and labour conditions, cost benefit effects and implications of decision in one area on the other areas. The solutions proposed are: motivating or pressurising people, setting-up of time standards; ensuring suitability and quality of inputs; effective production planning and control; and so on.

9.2 FORMULATION OF WASTE MANAGEMENT SYSTEM

Information and data regarding areas of wastages, wastage levels, reasons and basic causes of waste and alternative remedies generated in the analysis phase have been used for the formulation of WM system. Following tasks have been undertaken in this regard:

- a) Decided basic format of the system based on information and data collected. Suggestions of people from engineering industry are duly incorporated. Appendix C1 gives details of participants from industry and academics.
- b) Decided criticality of various wastes, likelihood of various reasons of waste and remedies based on
 - i) Quantum of waste of each type.
 - ii) Details of reasons and remedies.
 - iii) Suggestions of the people from industry.
 - iv) Literature on waste and its management and other closely related areas of planning and control.
 - v) Industrial experience and case studies conducted by researchers in the related areas.

9.3 WASTE MANAGEMENT SYSTEM FOR ENGINEERING INDUSTRIES

The system enlists common areas of waste generation in the order of their criticality, provides checklists of probable reasons of wastage of each type, suggests methodology to identify extent of wastage in each area and provides alternative solutions for waste management.

The system can be used at various stages of life of the plant, i.e. at the inception stage when machinery and equipment, materials, manpower, plant and buildings are to be acquired; during expansions or review stages; and for day-to-day working. Further, this system can be referred to both for general guidelines and for solutions to specific problems.

The system has been divided into following seven sections:

Section 1 provides information on 'how to use the system'.

Section 2 lists various areas of waste under each resource. These areas have been listed in the order of their criticality i.e. the importance and amount of waste in each area.

Section 3 contains general measures which every concern should adopt to manage waste. This pertains to the manner in which data and records should be maintained for conducting certain essential exercises.

Section 4 provides complete information on causes of waste in each area, identification techniques to find amount of waste and guidelines on what should be done to reduce or avoid waste. Causes of waste are listed in the order of their probability, i.e. the most likely cause is given first of all. Similarly, solutions are also given in the order of their likelihood for a problem of waste in a particular area.

Section 5 carries details of the identification techniques listed in Section 4.

Section 6 contains details of the guidelines or solution techniques suggested in Section 4.

A brief description of the standard techniques suggested under various guidelines is given in **section 7** (Appendix C2).

SECTION 1 : HOW TO USE THE SYSTEM

A user may be interested either in reducing overall waste in the industry or may have a specific problem. In the former case, it is recommended that user starts with the first area of waste in each resource as these areas are arranged in the order of their criticality resulting in maximum savings.

In case of waste in a specific area, user can select area of interest from SECTION 2 by reading number in the square bracket[]. This area can then be looked for in SECTION 4 using this number. Once the area of waste generation has been selected user can refer checklist of reasons of waste. For a specific waste, if a separate detailed identification technique is required to be used its reference number is given in the square brackets [] under column three in SECTION 4. The details of identification technique can be referred to from SECTION 5 using this number. If, however, steps for identification are simple and a few, these are given in column three itself.

The guidelines for managing waste in each area are provided in SECTION 4 itself. Along with the guidelines reference number is provided in square bracket [] to reach details of the techniques given in SECTION 6. A brief description of standard techniques as provided in SECTION 7 (Appendix C2) can also be approached by these reference numbers.

SECTION 2 : AREAS OF WASTE

MATERIALS

- Use of more expensive materials than required [1]
- Process scrap (rejected goods) [2]
- Rework. [3]
- Extra amount of chips produced because of non suitability of size and shape of raw material for the intended product. [4]
- Inaccurate weights and measures. [5]
- Not recycling or reusing the material which can be reused. [6]
- Pilferage. [7]
- Spillage. [8]
- Overconsumption of indirect materials like lubricants, additives, crucibles, hydraulic oil and others. [9]
- Damage during handling or movement of materials. [10]
- Producing that component of the product which can be economically bought or vice versa. [11]
- Damage, deterioration or obsolescence during storage. [12]
- Sale of scrap material (disposal) below its potential cost. [13]
- Unrecognisable, unidentifiable components in storage. [14]

ENERGY

- More energy consumption on operations than required. [1]
- Use of bigger machines and equipment on smaller jobs. [2]
- Running of machinery and equipment for longer time than required. [3]
- Use of bigger motors than required. [4]
- Scrap and rework material i.e. wastage due to processing of these materials. [5]
- Wastage due to flaws in compressed air and water supply generation and distribution system. [6]
- Starting of furnaces etc. from cold again and again. [7]
- Losses in lighting and ventilation system. [8]
- Use of old technology and inefficient equipment from energy point of view. [9]
- Use of unsuitable or wrong processes. [10]
- Heat loss from the uncovered furnaces. [11]
- Heat waste because of weak insulation of furnaces. [12]
- Heat waste with flue gases or hot water. [13]
- Decisions in the wake of electrical breakdowns, load sheddings, power cuts etc. [14]
- Interruptions in power supply. [15]
- Use of wrong fuel [16]
- Wrong layout of machinery and equipment, particularly furnaces. [17]
- Use of worn out or old technology. [18]
- Energy loss in transmission. [19]

CAPITAL

- Underutilisation of machinery and equipment with respect to time. [1]
- Underutilisation of machinery and equipment with respect to capacity of the machine to process size and weight of job. [2]
- Higher levels of inventories of raw materials and inprocess goods. [3]
- Waste due to less declared capacity and lack of line balancing. [4]
- Waste due to lack of capacity planning i.e. having more or less capacity than required. [5]
- Waste due to inadequate aggregate planning. [6]
- Waste due to lack of automation and non modernisation. [7]
- Losses due to using inefficient processes, operations and methods of doing work. [8]
- Higher levels of inventories of indirect materials. [9]
- Higher level of inventories of spare parts. [10]

MANPOWER

- Employing more people than required. [1]
- Wastage of other resources due to manpower. [2]
- Less output by the employees. [3]
- Lack of modernisation due to non co-operation of the workers. [4]
- Extra expenditure on manpower. [5]
- Loss due to strikes and lockouts. [6]
- Excessive overtime. [7]
- Using people of higher skills than required. [8]
- Absenteeism. [9]
- Labour turnover. [10]

* No. in [] corresponds to respected serial no. in section 4 in each resource.

SECTION 3 : GENERAL SUGGESTIONS/GUIDELINES

This section gives some general suggestions and recommendations aimed at managing waste. These have been divided into two parts:

Part 1: Recommendations regarding routine working of the industry are given here.

These are:

- i) Maintain Standard Data regarding products, tools, jigs, fixtures etc. in an easily retrievable form and use it for production planning and control purposes.
- ii) Maintain a record of materials received and materials used/sent and use it for material planning and production scheduling.
- iii) Take physical inventory of products every month and compare it with the material in stock as per the records.
- iv) Fix a day's work for every individual on the basis of realistic time standards.
- v) Maintain records of production of each shift and each day. Make a daily report containing production scheduled and production left to emphasise on the criticality of jobs. Also make reports regarding days left and scrap of each type produced every day. These records and reports should be neatly made. Printed forms should be used for this purpose.
- vi) Maintain records of time of use of tools, dies, jigs, fixtures etc. and the life left before renovation or replacement.
- vii) Have a clear, transparent, sincere, capable, caring and a truly professional management with clearly defined responsibilities and authority. Set procedures for doing each operation. Maintain discipline as far as possible. Adopt a tough and impartial approach. Do not exploit the workers.

Part 2 : This part contains information regarding how to conduct special studies as are recommended in the next sections. Keeping in mind the fact that executives in any industry devote most of their time in solving day to day problems, it is recommended :

- i) Create a special department or cell called Waste Management Department which will conduct special studies recommended in this system. This department can have experts in the area of Waste Management or persons from within exposure and aptitude may be drawn within the organisation. These persons should not be given any other work. Further, following

important points should be considered in this regards:

- Number of persons for conducting studies should be atleast two. They can be more, if need be, but expenditure on their salaries etc. should be justified.
 - These persons should have an easy access to records and data. All departments and personnel should be asked to extend full cooperation.
 - Any special equipment or arrangements needed by this team should be provided promptly.
 - Involve all employees in the task of managing waste, in developing a culture of waste consciousness. Work groups and quality circles may be developed.
- ii) Entrust responsibility of conducting these studies to outside agencies, consultants, technical institutes and universities. In this case also cost-benefit analysis is a must.
- iii) **Use of a model:** For special studies to be conducted in a company for identification and reduction of waste of resources at all stages, mathematical model is recommended. It helps in directing studies to the set objectives and deciding boundaries of the work to be undertaken. Further, modelling helps in performing some experiments on the collected data and choosing the best alternative in a given situation. Its application is recommended in a flexible system methodology framework to select one or a group of techniques , depending upon the purpose. Physical system theory models are recommended for materials and energy as they are very well suited for flow condition. All input-output analysis in material and energy can be best represented by models. A goal programming model is recommended for capital to take care of multi-objectivity. This model can help choose the products and product mix to reduce waste due to setting times, inventories and under-utilisation. A qualitative model using OPM, OFM, AHP and FST has been found to be most appropriate in choosing effective measures in a given environment for controlling manpower waste.

SECTION 4 CAUSES AND MITIGATION OF WASTE

A) MATERIALS

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
1	Use of more expensive materials than required. Example: Using better grades of steel than required or using steel or copper where Aluminium can work.	• Knowingly using better materials to cover up some flaws or shortcomings in processes, machinery or equipment, toolings or skill of people. • A material being used for a number of products is used for some other product also for which it is not an exact material. • No efforts made to find exact material due to: - Arbitrary selection. - Materials are suggested by experts, parent company or traditionally used practices. • Exact materials not used due to: - Less supply in the market. - Materials not available commercially.	Value analysis. [S7.1] Machine capability studies. [S7.2]	• Select suitable factors of production and conduct rigorous inspection for their acceptance. [S7.1,S7.7] • Conduct process capability studies involving normal materials and remove causes of variation. [S7.2,S7.6] • List all alternate materials which can be used and select the best using value analysis. [S7.1] • Develop new, more suitable and cheaper materials through R and D. • Plan materials in advance and acquire them considering market conditions and fluctuations. • Educate officers about these aspects. • Conduct cost-benefit studies regarding use of commonly used material on a new product also. [S7.4]
2.	Process scrap (Rejected goods)	• Improper machinery and equipment due to: - Poor upkeep and maintenance. - Non-suitability of machines. - Non adherence of process parameters. • Poor quality of inputs like materials, tools etc. due to: - Poor selection. - Inefficient incoming inspection. - Non-availability of desired inputs. - Using worn out toolings etc	Input - Output analysis of materials. [S5.1] PST model for materials. Machine Capability Studies. [S7.2]	• Conduct machine capability studies, remove assignable causes of variation and upgrade machines to make them suitable for the product. [S7.2] • Use SQC techniques to have better checks on the process. [S7.6] • Remove chance variations by making processes and controls fool proof. [S6.3] • Keep machines in good condition by preventive maintenance. [S6.1]

*No. in [] refers to details in section 5, 6 or 7. Section 7 is in Appendix C2.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
	In higher humidity conditions, the sintering process or the casting of aluminium alloy gets effected.	- Human error on passing on instructions due to: - Incompetent officers. - Lack of planning. - Too many bottlenecks. - Faulty information and control system. - Insufficient instructions or descriptions on the drawings. - 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. - Environmental effects of temperature and humidity influence quality of the product by effecting efficiency of workers. - Sudden interruptions in power supply or other inputs due to: - Frequent electrical breakdowns due to poor equipment, upkeep or overloading. - Unreliable supply from electricity boards due to inadequate liason or lower intake voltage. - No provision made for alternate supply to vital areas due to insufficient captive power or faulty distribution. - Breakdowns in services like compressed air supply etc due to wrong design or poor upkeep.		- Set the system parameters properly considering all variables and combining well both theory and practical. [S6.2] - Design an effective shop floor control system and information feedback system. [S6.4] - Make realistic schedules with requisite instructions to all concerened departments so that every-thing is available at the right time in the right shape. [S7.10] - Select materials, tools and other inputs properly. [S7.1] - Inspect incoming goods extensively. [S7.7]. - Select workers to match their skills with the job requirements. Give training and place them as per their choice and interest. [S7.9] - Motivate workers to give out their best.[S7.11]. - Keep complete records of the toolings. [S7.10,6.4]. - Educate officers on various aspects of scrap reduction. - Plan, arrange and acquire desired inputs in time. [S7.8,S7.10]. - Contain more information in the drawings regarding acceptance of product under special circumstances and materials and allowances still left after each operation. Make detailed drawing for each processing stage. - Reduce bad effects of environment on product quality. [6.2].

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
		- Wrong setting and determination of parameters of temperature, pressure, cooling rates etc. and inefficient control system to maintain them due to: - Parameters set by intuition and approximations due to lack of initiative or R and D facilities. - Effects of variables like ambient conditions, quality of inputs etc. not considered. - Controls are not automatic; lot of dependence on human beings as foolproof controls need investment. - Controls even though automatic are not properly calibrated. - Scraping of product which 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. - Use of processes which are not suitable for the intended product due to: - Lack of knowledge. - Excess capacity available.		- Ensure uninterrupted power supply to vital areas through own generation. . - Keep liason with electricity board to ensure uninterrupted supply. - Minimise electrical breakdowns by effective preventive maintenance. [S6.1]. - Ensure uninterrupted compressed air, water supply. [S6.5] - Determine system parameters considering all variables. [S6.2]. - Provide effective controls to maintain system parameters and calibrate them regularly. [S6.3]. - Build flexible attitude of inspection personnel so that something which can work should not be scrapped. Take prompt decisions in this regards. - Conduct cost benefit analysis of using excess capacity of non suitable processes vs. acquiring exactly suitable machinery and equipment for a new product. [S7.4]
3.	Rework	Example: Casting of long rods by gravity die casting instead of continuous casting, dependence on carefulness of human beings as fool proof controls need investment. - Same as for scrap. - Burrs/extra material at some places due to faulty settings, tool grindings etc. - Oversizes due to higher process variability and settings too much on the safer sides. - Size variations due to initial pieces on forging, casting or similar operations.	Input - Output Analysis. [S5.1] Rework Analysis. [S5.5]	- Same as for scrap. - Reduce process variability through machine capability studies. [S7.2]. - Draw SQC charts and set nominal value properly.[S7.6].
		It is seen that 80% of the rework material is ultimately scrapped.		

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
		- Scratches and other visual defects due to improper handling and rigid attitude of inspection personnel. - Facilities for doing rework are generally not available though some rework is inevitable. - Decision on 'Rework' material or disputed material is not taken immediately. It gets deteriorated or damaged in storage.		- Make provisions like undercuts etc. in toolings and fixtures of subsequent processes so that pieces with burr etc. can be accommodated. - Provide facilities and people for doing rework. - Take immediate and prompt decision on rework. - Design proper bins and material handling equipment etc. to avoid damages. [S7.12]
4	Extra amount of chips etc. produced because of non suitability of size and shape of raw material for the intended job. Example: i) Oversize material. ii) From long continuous sintered strip, half round pieces as shown are made.	- Tendency to be too much on the safer side due to - Poor quality of materials. - Inefficient processes, equipment or people. - Large variety of products resulting in increased. - Non-availability of required size and shape of material. - Required size and shape, though be available, is not suitable for preprocessing e.g. sintering.	Input - Output Analysis. [S5.1] PST Model. [Chapter 5]	- Divide whole range of products into 'Fast moving', 'Medium moving' and 'Slow moving' depending upon their frequency of production runs and quantity produced. [S7.19]. - Try to get exact sizes and shapes of raw materials for 'Fast moving' and nearest sizes for all others. - Strike a balance between costs of keeping higher inventory of exact sizes vs standardisation by conducting a cost-benefit analysis. [S7.4] - Try to make some changes in methods of processing the required size and shape of raw material. - In case of components to be made from sheets, plates etc. try to adjust more than one component to minimise loss. - Do not play too safe; rather: - Upkeep and maintain machines and give only required allowances. - Ensure quality of input materials. [S7.7].

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
5	Inaccurate weights and measures. Example: i) A pneumatic adhesive dispenser was seen dispensing inconsistent quantity every time because of assignable causes of variation. ii) Inaccuracy of the weighing instruments.	- Non-calibration at regular intervals. - High variability of the process and equipment dispensing the material. - Irregularities, inaccuracies in the methods adopted for weighing e.g. variations in weights of empty cans or containers.	Process capability studies. [S7.2]. Calibration of weighing instruments. [S6.3].	- Keep instruments in good condition. - Calibrate instruments regularly. [S6.3]. - Reduce process variability in case of dispensing instruments. Do settings keeping average dispensed quantity at a level so as to minimise loss. [S7.2,S7.6] - In case of actual weighing of cans and materials together, weigh empty cans individually even if they are of the same size and shape or ensure that empty cans are of reasonably same weights. (Singh, 1991). - Ensure that no irregularities are committed and no short cuts observed during weighing.
6	Not recycling or reusing the material which can be used.	- Different types of materials e.g. wet and dry chips of all sizes, oil, scrap products and different metals get mixed up making their recycling and reprocessing difficult. - Not aware of the worth (chemical composition) of some scrap materials e.g. slag etc. - Special efforts and treatment is needed for recycling which is not thought worth the expected benefits. - Special equipment is needed which involves huge investment. Cost-benefit analysis not done.	Cost -benefit Analysis. [S7.4] Checking of chemical composition of scrap materials.	- Source segregation of scrap and waste materials. [S6.7]. - Check chemical composition of scrap materials like slag. - Conduct cost-benefit analysis of making initial investment in special equipment for processing and recycling. [S7.4]. - Update knowledge of the officials about what alternate uses various scrap materials. - Use of scrap material as fuel to burn oils etc. from scrap chips. - Recover more expensive materials from waste with minor processing and sell the rest e.g. recovering copper from steel-copper alloy sintered strips.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
7	Pilferage Example : At petrol pumps input, output and evaporation losses are standardised to keep check on the salesmen.	- Incoming materials not checked and weighed properly due to: - Carelessness on the part of people. - Deliberate action to make money. - Some mis-appropriations which can be done if people from purchase, stores, and incoming inspection join hands. - Theft by the employees due to lack of security on the gates. - Mis-appropriation in the sale of scrap material due to casual attitude towards this area and absence of a laid down procedure.	Input-Output Analysis. [S5.1]	- Tighten the security on gates. - Check everyone, be it a manager or a worker. - Check one person thoroughly every day. Choose this person at random. - Check documents of each incoming and outgoing consignment of materials on the gate. No leniency to be shown to any one e.g. the managers etc.. - Make a system so that documents and actual materials are checked on random sampling basis by top officials. - Make a system for the sale of scrap. Build in counter checking in this system. Also compare the sale figures with the theoretical quantity of scrap produced. Standardise input and scrap ratios and balance it at regular intervals.
8	Spillage	- During production and processing, material like powder etc flies out due to: - Carelessness on the part of the people. - Gaurds are not provided on machines to stop material from falling. - Deliberate throwing of excessive scrap into trenches or into scrap yards. - Throwing of 'rework' material into the scrap. - Useful material goes with waste e.g. slag. - Leakages from pipes and other equipment.	Input-Output Analysis.[S5.1] Careful search of trenches, scrap yards and even shop floors.	- Provide shields and guards around the equipment. - Be careful during processing. - Be vigilant to avoid throwing of scrap into trenches or scrap yards etc. - Cover the trenches properly. - Conduct chemical analysis of the wastes like slag etc. to detect the presence of useful material in it. - Do preventive maintenance to avoid leakages. [S6.1]. - Design the equipment properly so that material does not fall out. - Material to be checked at random by a responsible person before being declared scrap.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
9	Over-consumption of Indirect materials like lubricants, additives, crucibles, hydraulic oil etc.	- Carelessness on the part of users. - Large variety of indirect materials making the control over them difficult and complex. - Casual attitude in the past due to comparatively lower costs involved. - Not taking care of material like crucibles etc. resulting into higher consumption. - Excessive spillage e.g. leakages of hydraulic or lubricating oils. - Badly maintained equipment consuming more of indirect materials like blades, tools etc.. - Exceeding the required or desired limits of use e.g. using blunt tools or blades etc.	Keeping records and consolidating the figures of expenditure done on indirect materials.	- Select most appropriate materials, e.g. better quality lubricants instead of the cheaper brands. - Divide the indirect materials into A,B,C, classes. Put maximum efforts on 'A' items. [S7.19] - Set targets for reduced consumption of indirect materials and put efforts to achieve them. - Quantities of such materials to be issued in proportion to finish production i.e. rationing. - Make people aware by posters, notes and boards and encourage them, through incentives, to reduce consumption. - Reduce variety by standardisation. - Keep machinery and equipment in good condition to reduce consumption of dependent indirect materials like tools, blades, hydraulic oil etc.. - Sharpen tools, blades, and cutters after recommended use. - Use only desired speeds and feeds and do not subject tools to loads beyond their capacity. - In case of lubricating oils try to detect and rectify the leakages. Record as to how much oil is filled on periodic checkings and draw inferences.
10	Damage during handling and movement of materials.	- Improper design of bins. - Ill designed and unsuitable material handling system. - Carelessness on part of the people handling or transferring material. - Too many transfers from one bin to another. - One type of bins used for all types of products.	Scrap and Rework Analysis. [S5.3, S5.5]	Detailed guidelines as to how to prevent damage to material during handling, transfer, and transportation. [S6.12].

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
11	Producing that component of the product which can be economically bought and vice versa. Example: Due to non-standardisation, producing special types of common components like nuts, bolts.	- Lack of standardisation. - Extra available capacity of machinery and equipment. - Lack of knowledge as to what is available in the market. - Lack of knowledge of analytical techniques like Cost-benefit analysis. - Thinking that a slight difference in the design from those available in the market might give the product an edge over others.	Cost-Benefit Analysis.[S7.4].	- Conduct cost benefit analysis of various available alternatives. [S7.4] - Educate officers about the latest techniques available for decision making in this regards. - Give more exposure to officers to keep them abreast with markets and facilities available.
12	Damage, deterioration or obsolescence during storage.	- Improper storage and stacking of material. - Improper handling. - Bulk buying of some raw materials or bulk production of some parts and keeping in stores. - Long storage. - No system as to which material would be used first. - Material exposed to damaging atmosphere. - Sudden drawing-change not communicated to stores in time to help consume all the material of old design.	Physical Inventory Exercise. [S5.4]	- Store the material properly. [S7.12] - Use a properly designed handling system commensurate with storage design. [S7.12] - Conduct physical inventory exercise regularly. [S5.4] - Use a practice like FIFO (first in first out) to avoid long stay of the materials in stores. - Communicate any drawing change or sudden variation in demand to the stores promptly. Before making such a change the inventory of the effected material should be checked and exhausted. - Regularly review optimum stock levels.
13	Sale of scrap material (disposal) below its potential.	- Wastes of various types get mixed up so these can not be sold separately at their respective costs. - Absence or lack of efforts to find out industry which can use scrap material as input. - Not advertising or calling offers; selling the scrap casually.	Working out the sale price of each type of waste material assuming it to be sold separately or used as an input by the industry.	- Source segregation of scrap and waste material. Separate scrap yards to be properly managed.[S6.7]. - Put efforts to find out users for different types of waste materials. - Recover some expensive material from waste with minor processing and sell the rest.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
14	Un-recognisable, un-identifiable components in storage.	- Absence of a proper system for physical storage and withdrawal from stores. - Component parts of products to be assembled or spares of machinery not kept with their tags on. - Places, boxes or bins for storing various types of components not fixed.	Physical Inventory Exercise.[S5.4]	Guidelines for physical storage, recognition, ordering and handling. [S7.12]

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
B) ENERGY				
1	More energy consumption on operations than required.	- Running machinery and equipment for longer time than required. - Use of bigger machines than required. - Use of bigger motors than required. - Lower efficiency of the equipment.	Explained for individual area in next sections.	Given for individual area in next sections.
2	Use of bigger machines and equipment than required i.e. non — suitability of machines to jobs.	- Poor selection of machines. - Large variety of products involving varying sizes. - Trying to accommodate whole range of products for processing on same machines. - Financial factors, risk factors, orders position etc. at the time of inception of the plant do not permit acquisition of different machines for different sizes of jobs. - At the time of expansions, machinery and equipment of the same design and capacity are bought as before to avoid risks and efforts. - While making selection remaining too much on safer side and giving too many allowances. - Lack of knowledge and ability to procure exactly suitable machines.	Input-Output Analysis of Energy.[S5.2] Finding out variation of energy per unit weight with the weight of the product.[S5.2] PST model of Energy (Chapter 6)	Selection of industrial machinery and equipment from energy point of view.[S6.6].
3	Running of machinery and equipment for longer times than required.	- Carelessness on part of workers and supervisors. - Material planning defects-material ready at previous stage but not required at the next stage e.g. molten alloy. - Low efficiency of machinery and equipment e.g. furnaces etc.. - Breakdown of machinery at the next stage. - Improper displays and controls.	Establishing time taken to do a job i.e. having standard or process times under varying parameters. [S5.7] Recording actual timings and finding differences.	- Solutions as to how the energy loss due to running machinery and equipment for longer time can be minimised. [S6.9] - Educate the workmen not to waste scarce energy.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
4	Use of bigger motors than required or recommended on machines.	• Arbitrary selection, no concern for energy wastage. • Motors kept for replacement are of higher sizes or power. • Playing safe and giving too many allowances. • Lower capacity motors get burnt due to overloading and the absence of overloading relays.	By finding out the difference between the required HP, the HP of the motor in use and the time of use.	• Working out the required HP of motors and the inventory of replacement motors.[S6.8]. • Keeping the motors in perfect working order, bearings etc.and insulation are to be checked at regular intervals.
5	Wastage due to processing of Scrap and rework material.	• Given at '2' and '3' under materials in section 4.		
6	Wastage due to flaws in compressed air and water supply generation and distribution systems.	• Leakages of compressed air and water at many points on the shop floor. • Poor selection of compressors etc. not considering all loading conditions. • Distribution system is such that if one small area needs supply it has to be given to whole of the shop. • High pressure supply is given to the whole shop although only few machines require that. • Sizes of compressors are such that even if a small area needs supply big compressors are to be run. • Poor choice of connectors, nozzles and coupling devices etc.. • Too many bends or change in diameters of the pipes. • Long distances of the central compressed air supply unit from the use points.	Detailed study to find out actual requirements of compressed air and water for a shop and the quantity actually being supplied. Finding out the leakages and loss due to them. Finding other flaws like distribution system and calculating loss in each area.	• Guidelines on reduction of loss in the area of compressed air and water generation and distribution system. [S6.5]

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
7	Starting of furnaces etc. from cold again and again.	• Cooling of dies etc towards the end of the shift. • Material not kept ready to be put in immediately upon taking out the previously processed charge from furnaces. • Excess capacity which does not require the equipment to run continuously for three shifts so it runs for only one or two shifts and gets cooled down. • Breakdown of machinery and equipment or interruptions due to other reasons. • Too many scattered off days.	Look into actual production records and find out how many times the equipment has been started from cold in a specified period. Also find out and establish how much is the difference in energy input in the first running from cold and subsequent use of already heated equipment. Calculate loss from above.	• Instead of running equipment for one or two shifts every day run it continuously. Do a cost-benefit study of such a proposal considering the increased cost of carrying inventories, variable manpower requirements, reduced feedback on quality, better maintenance opportunities and less energy expenditure. [S7.4] • Make next charges ready to be put in immediately on processing of previous charges. • Try to overlap working towards end of shifts on dies, furnaces etc.. • Do proper maintenance of machinery and equipment.[S6.1]. • Instead of scattered holidays give block holidays.
8	Waste in lighting and ventilation system.	• Improper design of buildings etc which effect natural light and ventilation. • Use of general lights where lighting specific areas can be sufficient. • In-efficient lighting, ventilation, air cooling or heating system. • Being careless in not switching off the appliances when not required.	A detailed study of present lighting and ventilation system to find shortcomings. Comparing alternate sources of light.	• Design and construct buildings in such a way so that they have natural light and ventilation. • Conduct a study to find the required illumination levels at various locations in the factory, particularly on shop floor. • Use localised light as far as possible. • Compare various sources of light and select the best suited. Make arrangements for automatic switching off the lights at dawn when natural illumination level reaches a pre-determined value. • .Bring in awareness among people about energy scarcity and rising cost and motivate them to be more careful • Set an example by being careful yourself first and cutting down the energy consumption for personal use.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
9	Use of old technology and energy inefficient equipment. Example: Use of motors of old design which have exceedingly low efficiency as compared to the motors of the latest design.	• Less depreciation cost of the old machinery and equipment. • Carrying on with the old machinery putting off the investment to be made for buying a new machine, not able to do cost-benefit analysis. • Poor financial position of the company. • Inability of top management to plan modernisation. • Less concern for energy consumption by machinery and equipment. • Lack of knowledge about the extent of loss. Only immediate gains are considered.	Conduct machine replacement studies considering the cost of energy also. [S7.13]	• Conduct machine replacement studies and take a decision. [S7.13]
10	Use of unsuitable or wrong processes. Example : 1) Use of casting where fabrication can be economically carried out and vice versa. 2) Use of gravity die casting for casting long rods instead of continuous casting.	• No concern for energy wastage, only goal is to make products by any means. • Processes recommended by parent company or experts. The company does not want to change or modify them or even do research to change them. • Trying to accommodate some additional product in the existing processes, plant and machinery.	Scan the literature and latest developments to find the exact process. Compare the scrap rate and energy consumption of the process in use with that of the recommended process and find the difference. Calculate the loss in monetary terms.	• Select exact processes by R&D and looking into latest developments. • If any additional new product is intended to be accommodated within existing processes go in for Cost- Benefit analysis. • Go in for extensive R&D to develop an alternate process in place of a wasteful process being used on the recommendations of the experts.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
11	Heat loss from uncovered furnaces.	- Unaware of the extent of loss. - If known, do not know how to reduce it. - Unable to design moveable covers etc which save heat and at the same time do not hinder the normal working. - If something is made, unable to get the co-operation of the shop floor people in putting it to use.	The loss can be worked out by considering the temperature difference between the molten metal and that of the atmosphere and the crosssectional area losing heat. [S5.6]	- Design moveable covers of heat resistant materials which automatically operate when material is to be transferred. [S6.10]. - Convince and motivate people to use these covers.
12	Heat waste because of weak insulation of furnaces.	- Insulation material has a certain life particularly at high temperatures - not changing insulation at this stage. - Unable to find out loss due to weak insulation. - Tendency to keep running the equipment even with lot of heat wastage till it finally stops doing its intended job.	Heat loss determination. [S5.6]	- Change insulation when temperature attainment or outside steady state temperature deviates beyond the acceptable limits. - From the previous record establish the life of insulation under prevailing working conditions and change insulation before that period in future.
13	Heat waste with flue gases or hot water.	- No concern for heat going as waste. - Not aware of the ways this heat can be recovered. - Not aware of the places this heat can be used at. - Lack of initiative or knowledge about cost-benefit if some initial expenditure is involved.	Find out flow rate and temperature of outgoing gases and water and calculate the amount of heat going waste.	- Preheat water, air or input material to be used in boilers, burners and other places by laying their pipes in the form of coils through the flue gases or water. Burner oils etc. can also be preheated. - Provide heat exchangers to recover heat and use it in other processes including general heating. - Conduct cost-benefit analysis if initial investment is substantial.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
14	Decisions in the wake of electrical breakdowns, load sheddings, and power cuts etc. as to which equipment is to be stopped or continued.	- Only production is considered to be the objective, may be at whatever cost. People are made accountable for production targets and not for energy consumption. - As proper planning is not done in advance regarding production, some items become vital whose production has to be carried out at whatever costs. In these circumstances decisions involving extensive waste of energy have to be taken on the spot. - People, unaware of the extent of loss in such cases.	Keep a record of such decisions in shift production reports of the days when power cuts etc. are in force. Compile these records and calculate the extent of loss.	- Exercise effective planning, scheduling and control so that items do not run behind schedules. If this is ensured more independent decisions can be taken in case of power cuts etc. and a lot of energy can be saved. - In case of load restrictions, stop that equipment which does not work at elevated temperature and will not cool down if stopped. - As far as possible foundaries should be kept running at the cost of the other shops till they exhaust the prepared materials etc.
15	Interruptions in power supply.	- Faulty distribution system prone to breakdowns. - Overloading, and absence of overload tripping devices. - Erratic power supply by the electricity board. - In-adequacy of own generation to vital areas.	Keep a record of electrical breakdowns, down times and reasons thereof.	- Make a good distribution system with suitable materials used at all places and requisite number of pannels to avoid breakdowns. Ensure no overloading of equipment or cables. - Provide overload tripping relays and other devices. - Ensure immediate supply to vital areas from own generation may be for a very small time in case of breakdowns. - Keep good liasion with electricity boards.
16	Use of wrong fuel. Example : Oil, where electricity should be used, H.S.D. for L.D.O., L.P.G. for N_2H_2 and so on.	- Using equipment of old design. - As the fuel is already in use on so many other operations in the company so it is made use of even on that operation for which it is not recommended. - Poor availability of exact fuel. - Special facilities needed for the use of the recommended fuel.	Make comparison of different fuels, their costs, quantities to be used, calorific value and the supporting equipment and facilities needed.	- Select exact fuel considering the following. - The form of energy needed i.e. heat, electricity, mechanical etc. - Calorific value of the fuel. - Cost-benefit analysis of use of a fuel involving: - Comparison with other fuels. - Equipment which would be needed for using each fuel. - Inventories which might have to be carried if a number of different types of fuels are to be used. - Design of present and proposed equipment.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
17	Wrong layout of machinery and equipment particularly the furnaces	- Arbitrary layout or layout decided considering only material handling, ignoring energy wastage. - Expansions of shops not properly planned resulting in too much centralisation of feeding equipment. - Centralised installation of induction furnaces etc. of very high capacity. - Unaware of extent of loss. - Tapping temperatures are generally kept very high and the phenomenon of loss does not come to the surface.	Find temperature drop of alloy during transportation. Find weight of material handled between each work centre by travel charting. From above, calculate the loss.	- Guidelines on the layout of machinery, equipment specially the furnaces. [S7.14]. - Use of insulated ladders with lids for transportation of molten alloys to avoid loss of temperature.
18	Use of worn out or old machines.	- Repairing or renovating a machine only when it stops performing its intended job; no concern for energy consumption. - Unaware of the difference between the energy consumption of an old and new machine.	Compare energy consumption of old and new machines Compare energy consumption of machines with some standards e.g. mileage per litre of fuel in case of vehicles.	Compare energy consumption of old and new machines or compare the consumption with some standards and renovate machines if needed, provided cost-benefit analysis permits.
19	Energy loss in transmission.	- Transmission of electricity at low voltage and high current due to: - Non-provision of proper transformers. - Incoming supply received at low voltage. - Technical constraints. - Inability to properly plan, select and install the transmission equipment. - Lack of awareness and concern for such wastage.	Note down the transmission current, voltage, time of use and the size of the conductors etc..	- Following important points are recommended to reduce the loss in transmission. - Install your own step down transformer at the entry to the unit. - Properly plan step down transformers for giving supply at various levels of voltages to different areas and instal suitable equipment. - Instead of stepping down in the centralised control rooms, the final stepping down can be done in the shops itself.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
C) CAPITAL				
1	Under-utilisation of machinery and equipment with respect to time.	- Workers present but not working deliberately because of negative attitude, union effects, lack of motivation, low morale, no concern and lack of accountability. - Un-avoidable delays due to: - Absence of proper drawings or instructions etc.. - Time consuming inspection checks. - Shortages of materials due to: - Poor material planning. - In-effective scheduling. - Power cuts due to erratic supply from electricity board and in-sufficiency of own generation - Breakdowns of machinery and equipment due to: - Old machines. - Poor maintenance strategy adopted. - Excessive time spent on settings because proper jigs and fixtures are not used. - Absenteeism.	Conduct a detailed Work Sampling study.[S7.3].	- Do effective production planning, scheduling and material planning. [S7.10,S7.8]. - Have a comprehensive and effective shop floor control system and an information feedback system.[S6.4]. - Ensure uninterrupted supply of electricity. - Give precise instructions and a drawing for each stage of processing. - Use comparators on the machines instead of instruments to check absolute dimensions. - Do effective preventive maintenance. [S6.1]. - Reduce time spent on settings. [S6.12]. - Make the worker do a fair day's work. - Reduce absenteeism and provide incentive for regular work. - Apply goal programming to find out the product mix resulting into minimum idle time. (Chapter 7)
2	Under-utilisation of machinery and equipment with respect to capacity of machines to process size and weight of jobs.	- Processing of smaller jobs on bigger machines because of large variety of products. - Not acquiring separate size and type of machinery to processes sub-ranges of the total variety of the products due to: - Lack of interest taken or awareness. - Taking no risks and buying the whole machinery and equipment of the same and established design,size, capacity and make. - Savings on the inventory of spares of machines and skill and expertise of people to run and repair different kinds of machines. - Playing safe by giving too many allowances for working out required size and capacity of machines.	Calculations of loss due to under-utilisation of machinery and equipment with respect to its capacity to process size and weight of the job. [S5.9].	Guidelines for reduction of waste.[S6.6].

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
3	Higher levels of inventories of raw materials and in-process goods.	• Arbitrary buying of materials. • Buying gross requirement as per the master production schedule. Net requirements 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. • Breakdowns of machinery and equipment. • Deliberate attempt by production people to keep higher inventories.	Physical inventory exercise at various times: [S5.4] -Beginning or end of the month. -Middle of the month.	• Do ABC classification of materials. [S7.19]. • Adopt techniques of inventory control viz. EOQ, reorder point and lead time; keeping in view market conditions, reliability of the suppliers, consumption rates, discounts and other factors. • Exercise physical control of inventory by one bin/ two bin system. • Use computer or a good cardex system for record keeping. • Conduct physical inventory exercise regularly. [S5.4]. • Use proper MRP system.[S7.8]. • Work out inventory levels between work centres and departments. [S6.14].
4	Loss due to less declared capacity and lack of line balancing.	• More capacity exists but less is utilised. Even goals set are lower. • Production personnel, even the managers keep some margins with them so that their mistakes are not fully exposed. • Due to lack of line balancing, low capacity machines put a limit to the utilisation of other high capacity machines. • Casualness in machinery selection and over capacity of the plant are generally responsible for errors in line balancing. • Complacency on the part of the personnel as they feel that every time they achieve and exceed the set targets. But, in fact they achieve much lower than the actual potential.	To find out the loss proceed as follows; -Work out actual capacity of the plant using standard times and stream factor. -Compare with the existing target capacity and find out waste by difference.[S6.13].	• Work out actual capacity of the plant. • Remove flaws in line balancing. • Convince shop floor managers about the actual capacity and revise targets.[S6.13].

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
5	Waste due to lack of capacity planning i.e. having less or more capacity than required to complete the orders.	- Forecasting figures are not got or are not correct. - Flaws in working out the required capacity levels from demand forecasting which is generally not stable throughout the year. - Not adopting good aggregate planning strategies. - Not phasing out capacity of those products whose demand is declining and not diversifying into other areas.	Find out the differences of number of orders available or processed and actual capacity available for all periods.	Guidelines on capacity planning. [S7.20].
6	Losses due to inadequate aggregate planning.	- Lack of knowledge about aggregate planning exercise. - Lack of analytical skills and ability to balance variable demand. - Prevailing labour scenario which may stop the management from adopting a particular strategy.	Find out the extent of extra production levels which could have been achieved only by adjusting capacity through aggregate planning and the loss of not having done so in the past.	Guidelines on aggregate planning. [S7.21]
7	Loss due to lack of automation and non-modernisation.	- Paucity of funds. - Not having gone in for cost-benefit analysis of bringing in automation and modernisation. - Reactions from employees on modernisation. - Not updating knowledge of managers about the latest in the field of manufacturing. - Felt no need for modernisation as the company was making profits.	Calculations of loss due to not modernising. [S6.15].	Guidelines as to how can the waste be minimised. [S6.15].

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
8	Losses due to using inefficient processes, operations and methods of doing work.	• Unnecessary additional costs, bottlenecks, excessive scrap and rework, higher production fatigue and low production rate due to: - Workers and supervisors or managers insist to continue with the old processes, methods of doing work and so on. - Lack of awareness regarding Method Study.	Detailed Method Study. [S7.22].	• Guidelines as to how can the approach of Method Study be applied. [S7.22].
9	Higher levels of inventory of indirect materials.	• Less emphasis paid to indirect materials. • Indirect materials are generally kept at so many places in an industry that their management becomes a difficult and a specialised task. • Same as for other materials, as above.	Working out the quantity of various categories of indirect materials used and their cost. Compiling the total figures.	• Steps as given at '3' above. • The demands and consumption rates of all user departments can be clubbed and material kept at a centralised place instead of maintaining inventory at so many user departments. Cost benefit analysis of such a proposal can be made. [S7.4].
10	Higher level of inventory of spare parts.	• Same as at '3' and '9' above. • Buying even those expensive spares which may not be used for many years. • Buying higher quantities than required to be on the safer sides.	Same as at '3' and '9' above.	• Same as at '3' and '9' above. • Work out the quantity of spares to be kept in stocks considering the: - Probabilities of their failure, - Probability of use of a particular spare, - Loss of production if a spare is not in stock at the time of a breakdown, - Cost and inventory carrying cost of a spare. • Standardise machinery, equipment and spares. • Keep repaired sub-assemblies in stock instead of keeping so many small items. • Exercise effective preventive maintenance instead of keeping more spares in stock because of higher expected probabilities of breakdowns. [S6.1]

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
D) MANPOWER				
1	Employing more people than required.	• Poor production planning and scheduling resulting in shortages which force workers to sit idle. • Effective work put in by the people is less due to: - Time standards not properly worked out. - Incentive schemes are not effective. - Labour control is lacking. - Absence of performance monitoring. - Union effects. - Weak and giving-in management. - People are not properly motivated. - Indiscipline and insubordination etc., - People not properly skilled, trained or placed. • High absenteeism levels. • Too much division of work and inability of the management to get varied kind of work done by the workers. • Exact procedures for working out manpower requirements for various categories are not known to the people and are not followed.	Calculation of number of people actually required in each department after considering all allowances and finding out difference between actual number of people employed and those calculated. [S7.18]	• Set time standards realistically. [S7.15] • Have effective labour control. The management should be firm, sound and open. [S7.16]. • Exercise effective production planning, scheduling and control. [S7.10]. • Monitor performance of workers and reward or punish them accordingly. [S7.16]. • Run an effective incentive scheme which really motivates people. [S7.17]. • Calculate manpower requirements realistically for various processes. [S7.18]. • Develop multi-skills in workers and encourage them to do varied jobs. Give incentives for this. • Do fair selections, give due training, place as per the interest shown by the employees and rotate them to reduce monotony. • Reduce absenteeism.
2	Wastage of other resources due to manpower.	• Wastage of machine time, energy and overheads due to workmen remaining idle. • Wastage of machine time, energy, overheads etc. due to shortages which are a result of poor planning and force the machines to remain idle. • Wastage of materials, energy, machine time and processing costs due to negligence on the part of the workers or incompetence of officers in planning and passing on instructions properly which results into excessive scrap and rework. • Wastage of capital, energy, overheads and other processing costs by acquiring wrong, inadequate or excess factors of production. • Wastages of materials and processing costs due to deterioration in storage, damage in handling, spillage, pilferage and excessive quantity of chips etc.,	Finding out the wastage of all the resources individually by conducting Input-Output analysis and then finding out reasons of waste and their primary causes. Waste due to manpower can then be found out by compiling wastes pointing towards human error.	• See individual resource area. (Materials, Energy and Capital in section 4)

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
3	Less output by employees.	• People not made accountable for day's work. • Shortages of materials and other inputs due to poor planning and control. • Lack of motivation because of poor knowledge about motivational aspects and techniques • People not suitable for jobs due to poor selection, training and placement. • Breakdowns, power cuts and other such problems. • Absence of effective performance monitoring. • People alienated because of monotony, working conditions, management dealings and policies.	Keeping a record of output shown by each worker every day, comparing with the desired output, finding difference and compiling these figures for a specified period e.g a month or a year to calculate waste.	• Fix a day's work for each employee and make him accountable for that. [S7.15]. • Monitor his performance and reward or punish him accordingly. [S7.16]. • Motivate people, give them adequate salaries and benefits, provide a good working environment and make their job interesting. [S. 7.11] • Have effective labour control with firm handling. [S7.9,S7.16] • Select, train and place employees adopting good practices and techniques. [S7.9] • Have an effective preventive maintenance strategy. [S6.1]. • Adopt effective production planning, control and resource planning to avoid shortages. [S7.10]. • Have a sound information and control system. [S6.4].
4	Lack of modernisation due to non cooperation of workers.	• Fears and misconception of workers that they will be made redundant as a result of modernisation and automation. • Fear that the stronghold and monopolies of employees in performing certain operations will be lost as in the case of automated equipment lesser skills would be needed and that even unskilled or semiskilled workers would be able to perform equally well. • Union effects.	Compare the present technology with what is available and bring out differences pertaining to the following in monetary terms. - Production rates - Safety - Number of people required. - Number of operations done at one work centre. - Quality and its consistency.	• Have a clear cut redundancy policy involving absorption of extra people on other jobs or in expansions and educate employees about this. • Educate workers and impress upon them the benefits of automation and that rather than retrenching people the industry will diversify and become more prosperous.. • Go ahead with the policy of modernisation. Resist the workers and unions as far as possible. • Continuously go in for modernisation by updating knowledge of officers by giving them more exposure.

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
5	Extra expenditure on manpower.	• Benefits like schools for children, transportation, loans and other benefits due to: - Motivational measures. - Pleasing the employees. - Union pressures. - Giving-in to the demands of the workers. • Training and education of employees. • Housing. • Canteen facility. • Tea, snacks etc. on the shop floors.	Calculate the total expenditure on this account for a specified period.	• Give all those benefits which are necessary as per the law. • Have a clear understanding of the motivational measures, satisfiers and hygiene factors and wisely decide as to which benefits are to be given. [S7.11]. • As far as possible do not yield to any unguenuine demand of the workers. Resist it. [S7.9] • Have a firm and sound management. Always keep in mind long term implications of decisions. [S7.9]
6	Loss due to strikes and lockouts etc.	• Unionism. • Increase in demands of employees as in the past almost all demands were accepted by the management. • Tolerating, ignoring or overlooking the acts of indiscipline, insubordination etc. fearing immediate trouble thereby making workers pampered, more indisciplined and insubordinate in future. • Exploitation of workmen, inhuman and indifferent behaviour by the management. • Biased labour laws which protect even erring workmen. • Lower salaries, benefits and lack of hygiene factors.	Compile figures of strikes, lockouts, slowdowns and other disputes over a period of, say 5 years and calculate: -Loss of production -Lost customer orders -Expenditure made on litigation etc..	• Have a firm, stable and sound management which keeps long term objectives in mind. • Always follow a slightly tough line of action; do not be too lenient or too tough at times. • Always accept genuine demands of the workers. Resist and refuse unreasonable demands as far as possible. • Have a human touch for the employees and reflect it in your actions. Create a spirit of belongingness. • Have an open management, do not conceal too much from the employees. • Use work study for performance appraisal, incentive scheme, labour control, deciding a day's work and motivation of workers.
7	Excessive Overtime.	• Machine capacities are adequate but people do not work or because of some other reason production does not go on in the normal time. Hence overtime. • Because of higher payments workers insist and force overtime because:	Compile figures of actual overtime worked in each section in a specified period, say a month.	• Fix a day's work for every individual. [S7.15] • Monitor performance of the workers. [S7.17].

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
		- Workers feel that because of their strong hold they can dictate and stay for overtime which is their right. - Lack of labour control and performance monitoring. - Weak management, biased labour laws etc., • Inadequacy of machinery and equipment. • Overtime working planned as a strategy in aggregate planning itself to match varying demand with available capacity.	Also calculate capacity requirements of the production quantities made in the above period. See if the actual capacity is more or less than the required capacity. Calculate the unnecessary amount of overtime worked which is a waste.	• Run an effective incentive scheme which ensures almost equal amount of payment as the workers would have got by overtime working. Educate workers about this and motivate them. [S7.17]. • Overtime production should not be included for the purpose of working out the incentive payment. • Same as at '1' above.
8	Using people of higher skills than required.	• No clear cut policy regarding giving higher level posts on promotions. • Workers do not take responsibilities of settings, quality control and inspection on their machines due to: - Lack of education and enlightenment. - Lack of motivation. - Union effects.	Note down skill levels and grades of people and calculate how much are these levels higher than the minimum required to perform these jobs. This is waste.	• Upon promotions and grade revisions change the job i.e. give the job to which higher status is attached and higher skills are needed to perform it. • Create avenues through diversifying or increasing capacity for real growth so that people keep moving up. • Educate and train employees for higher jobs and motivate them so that they take up responsibility and improve skills.
9	Absenteeism	• Workers do other jobs particularly seasonal jobs like agriculture due to: - Inadequate financial earnings in the company. - Considering company as second priority which would give them at least the salary, may be reduced, because of absence. Granting leave without pay frequently. - Higher absence in the days of sowing, irrigating or reaping.	Compile figures of absenteeism for every month and year.	• Give adequate salaries which can atleast fulfil the basic needs. • Take action against chronic absentees. Do not allow leave without pay as far as possible. • Make jobs and environment interesting, healthy and congenial for work. • Run a good incentive scheme so that people who have the capability of working elsewhere in addition to the company job, can earn good amounts in the company itself by working more. [S7.17]

S.No.	Area of Waste	Causes	Identification Techniques	Waste Mitigation
		• Bad habits like drinking and gambling etc. due to lack of education and social background. • Alienation from the place of work due to: - Monotonous job. - Flaws in the working atmosphere or environment.		• While selecting people try to find out their background to be assured that at a latter date company job will not become their second priority or interest. • Adopt job rotation and enrichment to make it interesting. • Provide opportunities for growth. • Educate and enlighten the employees about bad effects of drinking, gambling etc. and help them leave these bad habits.
10	Labour turnover.	• Dissatisfied employees due to less financial earnings, benefits, type of management or working conditions and environment. • Other better avenues with more salaries, perks and benefits and growth opportunities. • No or less opportunities for growth. • Getting government jobs. • Place where the factory is situated is not attractive because of: - Remote or under-developed place where facilities and luxuries of big cities are not available. - Does not suit the employee personally i.e. he has his own house elsewhere, his family is staying at some other place and he would go there if the opportunity comes his way.	Compile figures of labour turnover for a specified period e.g. a year or more and calculate how much waste has been there due to their selection & training etc.. Further the loss due to turnover of the officers can be assessed by taking a stock of incomplete or delayed development works in the company which were started by someone who has left.	• While selecting people give preference to those who look to be stable and have some interest in the city itself. • Make systems of doing work so that when an employee, particularly an officer leaves, work is not effected. • Regarding calibre of people, go in for only that much which fulfils your requirements. There is no need for going in for more as people with higher calibre are generally not stable. • Make the town itself more attractive by joining hands with other local industries and district administration. • Provide more opportunities for growth, give adequate salaries, clear cut responsibilities, authority and good working conditions.

SECTION 5 DETAILS OF IDENTIFICATION TECHNIQUES

S5.1 INPUT - OUTPUT ANALYSIS - MATERIALS

With the help of this analysis the differences between materials entering and leaving an industrial unit can be found out. Equation 5.1 can be used for this analysis.

Important points

- i) Opening and closing stocks of all materials, i.e. raw materials, in-process goods, finished goods etc. at all places have to be considered.
- ii) Inputs and outputs as are actually entering or leaving the defined system are to be considered.
- iii) The analysis should be integrated within the normal working of the organisation, specially with physical inventory exercise. Doing a physical inventory exercise specially is a very tedious job.
- iv) Data regarding weights of products at every stage of manufacture should be available.
- v) It is nearly impossible to do this analysis on a daily basis. A study period of one month is ideal. However, it can go up to three months.
- vi) For the purpose of ease of analysis the total industrial system can be divided into identifiable subsystems and input - output analysis done for each.

S5.2. INPUT - OUTPUT ANALYSIS - ENERGY

This analysis reveals the utilisation and waste of energy entering a system. Waste is found out.

$$\text{Energy Waste} = \text{Actual Energy Input} - \text{Energy Utilised on Productive Operations} \quad (9.1)$$

a) Actual energy input

Actual energy input can be found out by:

- i) Installing energy meters at all required points and noting down energy consumption in a specified period.
- ii) By actually measuring/recording the quantities of oils and other fuels used in a specified period.

b) Energy utilised on productive operations

Energy actually utilised on productive operations has to be calculated in one of the following ways:

- i) From values of voltage, current drawn and power factor during operation of machinery and equipment and time for which these values exist. Electricity consumed can then be found out by following expression.

$$\text{Energy Consumed} = VI \cos \phi \times \text{time} \quad (9.2)$$

- ii) From the wattage of the equipment and its running time.

$$\text{Energy consumed} = \text{Wattage} \times \text{time}. \quad (9.3)$$

There are some short comings with both the methods. While the first method gives accurate results, it cannot be practically used for a number of machines on shop floor. The current drawn keeps on changing during the cycle of operation. To note down the times for each value of current is very cumbersome and impractical as it would hinder with the normal working of the machines. The second method, though fast, is quite inaccurate because it assumes that the equipment is working at its full load.

In the wake of these shortcomings an approach as given below is recommended:

c) **Recommended Approach**

- i) Calculate the energy consumption on production operations with both the above methods for a random sample of machines and work out factor, f (say)

$$\text{where } f = \frac{\text{Energy consumption with method 1}}{\text{Energy Consumption with method 2}} \quad (9.4)$$

- ii) Use method 2 for the rest of machines and calculate actual energy consumption as under:

$$\text{Actual Energy consumption} = \text{Energy Consumption with method 2} \times f \quad (9.5)$$

$$\text{Total Energy Consumption} = \text{No. of operations} \times \text{Actual Energy consumption} \quad (9.6)$$

d) **Important Points**

- i) For finding out total number of operations performed in a specified period daily production records can be compiled. Alternately, figures of material input and output along with opening and closing stock can be had to find out the number of operations performed.
- ii) It is not possible to do this type of analysis on daily basis. A study period of one month is ideal.
- iii) While calculating time of operation, the actual time of operation of the energy consuming device is to be taken and not the total time of operation, e.g. in case of an automatic chamber furnace the actual times of operation of

heaters is to be noted. For this purpose, special studies have to be conducted to find out the working time as a fraction of the total operation time.

S5.3 SCRAP ANALYSIS

a) **Aims and objectives:**

To find out:

- i) The product resulting into maximum scrap.
- ii) The main defects causing scrap.
- iii) A detailed study of operations involved, material flow and other variables to find out reasons of scrap.
- iv) To give feed back to avoid reoccurrences.

b) **Procedure**

- i) Compile figures of scrap generated of products due to various defects on daily basis. Keep the scrap products separately at final inspection as well as in-process stages for atleast a day and show it to operators and production and quality control supervisors. A quality circle can be started for the purpose.
- ii) From the type and the pattern of defects locate the reasons and give a feed back to concerned personnel.
- iii) Compile cumulative figures of scrap of various categories of products in case of each defect and display them in the form of histograms.
- iv) From the monthly figures, locate the products and defects contributing maximum to scrap and try to find out reason by relating them to some variable like atmospheric conditions, overhaul or major maintenance undertaken, operator, input materials and so on.
- v) Compile yearly figures to find out any seasonal factors contributing to higher scrap.

S5.4 PHYSICAL INVENTORY EXERCISE

a) **Aims and objectives:**

This exercise is essential for:

- i) Conducting Input - Output Analysis.
- ii) Finding out amount of material wasted on account of spillage, deterioration, damage, theft and obsolescence.

- iii) To update records of stock of materials so that material planning is realistically done.

b) **Procedure**

- i) Physical Inventory exercise should be taken up preferably after a month but not later than three months.
- ii) Sufficient persons, well conversant with the product as well as the exercise should be deputed.
- iii) Either no material transfers should take place during the the exercise or every product should be marked after counting so that it does not get accounted for twice.
- iv) Weights of the products at all the processing stages should be available.
- v) Material lying at each processing stage i.e. in-process goods, raw material, rework, scrap or chips should be taken into account.
- vi) Production work should be resumed only after the completion of the exercise.
- vii) Results of physical inventory should be compiled and compared with those shown by records to find out the difference.

S5.5 REWORK ANALYSIS

a) **Aims and objectives:**

Experience has shown that for want of facilities and people, 80% of the products which are once declared rework are generally scrapped.

b) **Procedure**

- i) Compile figures of rework declared every day at final inspection. Handover the material along with feedback to concerned production department after highlighting defects and products contributing to rework.
- ii) Critically analyse each product and defect to find its cause. Cause should be removed or permanent arrangements for rework should be made.
- iii) Discussions should be taken up with the user departments of the product to look into the possibility of using 'rework' material without any further processing but by making small modifications like undercuts in fixtures etc. of subsequent operations.

- iv) Monthly and yearly figures of rework should be compiled to highlight defects, for giving feed back to concerned people and to look for any seasonal variations.
- v) Reworked material should be sent through final inspection separately so that a record is made as to how much material declared 'rework,' gets salvaged.

S5.6 HEAT LOSS DETERMINATION

a) Because of poor/week insulation

- i) When the equipment is new, note down the steady state temperature of the outside walls of the furnace against the ambient temperature and other environmental conditions in every season of a year. Take sufficient readings at different times in a day, once a week and make a complete record. Draw graphs or nomograms from records. During the subsequent years note down temperature and compare with record to find heat loss due to insulation.

OR

- ii) When the equipment is new put a standard charge in furnace and note time taken for attainment of a particular temperature. Repeat this exercise in different seasons and make a complete record of temperature attainment time against ambient temperature and other conditions. Draw graphs or make nomograms. Refer to this record subsequently to find out loss.

b) Heat loss from uncovered furnances

To get an idea of heat loss, work on the basis of Newton's law which states that heat loss is directly proportional to temperature difference and surface area exposed to atmosphere. Thus, for calculating heat loss:

- i) Calculate surface area of open end of furnace.
- ii) Note ambient temperature and temperature of the material in the furnace.
- iii) Calculate loss.

c) Heat loss with flue gases

- i) Find out the flow, i.e. volume displaced per unit time.
- ii) Note down temperature of flue gases at different times.
- iii) From the volume, temperature and times calculate heat loss.

S5.7 ESTABLISHING PROCESS TIMES TO PRODUCE UNIT PRODUCTS ON VARIOUS EQUIPMENTS

a) Aims and objectives:

These times can be established by actually observing the operations. Different situations in an industry need these timings, e.g. for calculating energy expenditure on operations.

b) Procedure

- i) Ensure normal working conditions and inputs. If they are not normal note down the prevailing conditions.
- ii) Record ambient conditions of temperature, humidity and so on.
- iii) Observe the processing time for a number of cycles and establish time.
- iv) Repeat the above steps for different states of equipment e.g. normal running or starting from cold.

S5.8. ESTABLISHING RUNNING TIMES OF THE ENERGY CONSUMING DEVICES OF THE EQUIPMENT

a) Aims and objectives

The energy consuming devices, generally, do not operate for whole of the equipment running time e.g. automatically operating heaters, motors of pumps, blowers etc. In such cases actual fraction running times can be observed as under.

b) Procedure

- i) Ensure normal working conditions of the equipment.
- ii) Observe the operations for a sufficiently long time and on a number of occasions. Note down starting or switching off of the device from the sound or from the value of current drawn and find out actual running time of energy consuming devices.
- iii) Repeat above steps for a number of cycles and under varying conditions and establish times.

S5.9 CALCULATIONS OF LOSS DUE TO UNDER UTILISATION OF MACHINERY AND EQUIPMENT W.R.T. ITS ABILITY TO PROCESS SIZE OR WEIGHT OF THE JOB

a) **Aims and objectives**

This analysis helps in choosing appropriate machines for varying size jobs.

b) **Procedure**

Calculation of such a loss precisely is a very tedious job. An approximate amount of this loss can be found out as discussed in Section 6.2.6 and section 7.2.2. A graphical approach as discussed below can also be employed to calculate energy loss.

b) **Graphical approach**

- i) Calculate energy consumption by each product at various stages and sum them up to find out total energy consumed on each product.
- ii) Calculate energy consumed per unit weight of each product.
- iii) Plot energy consumption per unit weight against weight of the product to assess the loss.
- iv) Calculate area under the graph representing loss either by counting squares or by employing differential equation.

SECTION 6 GUIDELINES ON MITIGATION OF WASTE

S6.1 DESIGN OF PREVENTIVE MAINTENANCE

Preventive maintenance can be put into two major heads.

- a) Regular preventive maintenance schedule.
- b) Planned maintenance.
- a) **Preventive maintenance**

In case of preventive maintenance schedules, actions are taken at regular intervals. Frequency is decided based on the probability of failures. This probability can be found out from one or a combination of the following ways (Sharma, 1991).

- i) Recommendations of machine catalogues.
- ii) Reliability analysis.
- iii) Condition monitoring.
- iv) Past data of breakdowns.

Reliability analysis and condition monitoring are quite cumbersome and demand large initial expenditure. A tried and tested approach is presented here to design a preventive maintenance schedule (Sharma, 1991).

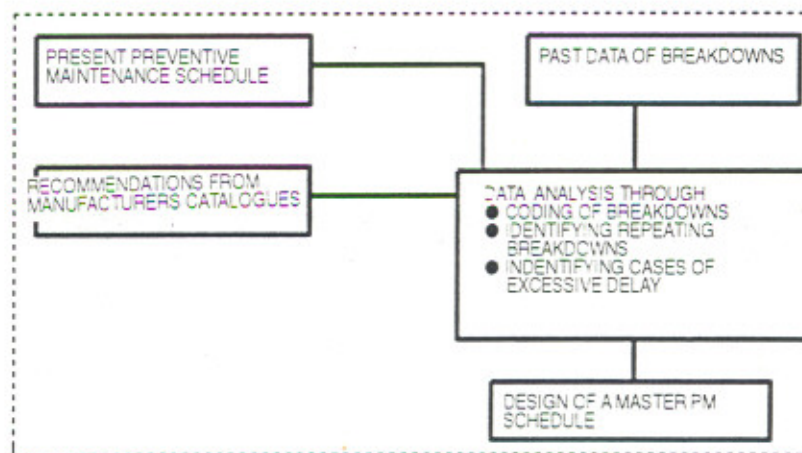


Fig. 9.1 : Design of preventive maintenance schedule

- b) **Planned maintenance**

This strategy deals with the planning and execution of thorough corrective actions at an appropriate time taking inferences from the present pattern of breakdowns. Frequent failures which are not attended to properly and require thorough action are planned in this

strategy.

To do planned maintenance effectively it is recommended that:

- i) Record of breakdowns is properly maintained.
- ii) This record is scanned every day to look for repeating breakdowns and machines requiring thorough action.
- iii) To undertake major work on next off days, whatever work can be taken up during the week days in the form of keeping replacement sub assemblies ready, should be done.
- iv) Plan the machines for repairs at the earliest opportunity.
- v) Identify some persons in the department who would only work for keeping the material e.g. repaired sub-assemblies and other spares ready for the next planned maintenance.

S6.2 DETERMINATION OF SYSTEM PARAMETERS

Certain operations require some system parameters to be maintained at predetermined values to achieve required quality levels e.g. temperature requirements of heat treatment furnaces, cooling rate for castings and pouring temperature and pouring rate of molten metals. Generally, these parameters are arbitrarily worked. Following systematic approach is recommended.

- i) Work out the required values of system parameters theoretically on certain assumptions.
- ii) Modify these parameters by making trial runs.
- iii) Establish the parameters after a number of trials.
- iv) Conduct trials in various seasons and under varying conditions of atmosphere, inputs and other variables and find the relationship of system parameters with these variables. Maintain graphs and make nomograms of the relationships.
- v) In future, use these relationships and graphs to find out the parameters for a given set of variables.
- vi) If for a certain set of variables which may occur in some seasons, the required quality cannot be achieved with any values of the parameters, the possibility of not making production in that season rather making excess production

before the setting in of that season and keeping inventory should be looked into. Cost benefit analysis of such a proposal should be undertaken. In the days of very high atmospheric humidity the casting and sintering operations face such problems.

S6.3 INSTALATION AND CALIBRATION OF FOOL PROOF CONTROLS

Following steps should be taken:

- a) Take up a special study in your organisation to critically see and list all areas where manual controls are in use.
- b) Wherever possible change manual controls to automatic or semi-automatic. Leave nothing to skill and care of the human beings.
- c) Depending upon the financial expenditure the company is in a position to make, a control can be selected. For example the cheapest control for temperature can be a siren on the attainment of required value. More expansive control can be a temperature pyrometer. More sophisticated electronic controls with digital displays, while more expensive, are definitely more reliable too.
- d) Whatever are the type of controls, they need calibration. Following important points should be observed for calibration.
 - i) In the beginning when the equipment is installed do the calibration more frequently to see the amounts and frequency of adjustments which have to be made for calibration. Decide the future frequency from here.
 - ii) Draw conclusions from the amounts of adjustments made every time and take remedial actions.
 - iii) Make the controls temper free by enclosing them.
 - iv) Calibrate pressure gauges etc also. Generally these are overlooked.

S6.4 EFFECTIVE SHOP FLOOR CONTROL SYSTEM

An effective shop floor control system should provide information on the following aspects.

- i) Daily and cumulative scrap rates and the defects.
- ii) Utilisation of machinery and equipment and reasons of under-utilisation.
- iii) Status of jobs on shop floor viz.-a-viz. the scheduled or planned work.
- iv) Status of all factors of production i.e. availability of materials, toolings and

other things for production.

- v) Performance and absenteeism level of workers.

In addition, any special information should be available in a glaring form so that it has an impact and corrective action can be planned.

Use of computer package involving all the production operations is recommended. Complete computerisation rather than partial computerisation involving separate small packages for materials or tools or products will help automatic and timely generation of the reports involving no extra labour. It is essential for an industry with large variety of products.

S6.5 PLANNING GENERATION AND DISTRIBUTION OF COMPRESSED AIR

Special considerations in this regards are:

a) Selection of compressors:

- i) Calculate the volume requirements of machines and add up along with allowances to arrive at the total required capacity of the compressors.
- ii) Consider all loading conditions in a shop and accordingly select a combination of small and large size compressors. Loading conditions may be running all machines, less number of machines in a shop during power cuts or restrictions on loads or it may be running of just one or two machines on week ends. The compressor sizes should be such that generally bigger compressors for small compressed air requirements are not run.
- iii) Make an arrangement of a portable compressor in shops to avoid running central units for local requirements on a machine or two.

b) Distribution

- i) Precisely work out the pressure requirements for various machines and shops and accordingly plan high pressure and low pressure lines.
- ii) Give separate pipes to separate shops. Donot give too many tappings from one main pipe to various shops. This will avoid fluctuations and consequent higher pressure requirements.
- iii) Make provisions for effective water separators and remove water regularly.
- iv) Avoid to many change of diameters and bends in the main distribution pipe.
- v) Lay the main pipe and the pipes in the shops overhead to facilitate maintenance and detection of leakages.

- vi) For distribution from the main pipe to various work centres.

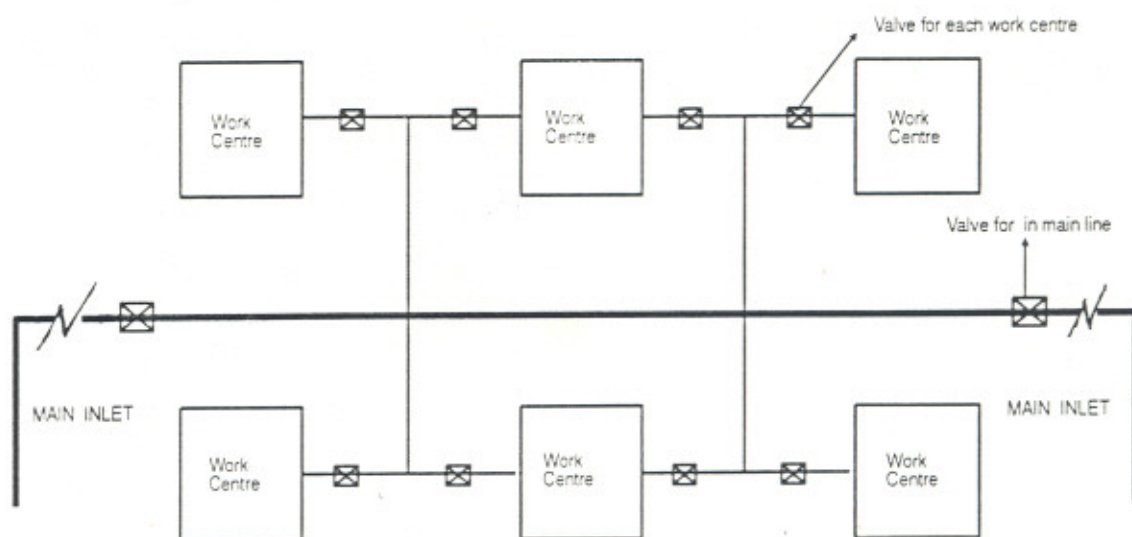


Fig. 9.2 : Distribution from main pipe to work centre.

- Provide a valve for connection to each machine.
- Provide valves after a set of 4, 6 or 8 machines as shown in the figure.
- Make a closed loop i.e. give supply to both ends of the distribution pipe of a shop.
- Use appropriate and good quality fittings with proper stuffings.
- Try to reduce the number of tapplings as far as possible by using quick change couplings and using one tapping for a number of purposes.

S6.6 SELECTION OF INDUSTRIAL MACHINERY AND EQUIPMENT FROM ENERGY POINT OF VIEW

Following points should be considered for the selection of industrial machinery and equipment:

- a) As far as possible machines suiting job sizes should be purchased.
- b) If the company has a large range of products involving variations of size and weight, the whole range of products should be divided into smaller sub-ranges and machines suiting requirements of each sub-range be procured. Cost-benefit analysis of such a proposal should be conducted.
- c) At the time of starting a new plant, the funds available are generally limited and there are so many other constraints and risk factors that the investor avoids blocking too

much capital in various sizes of equipment suiting individual product groups. The investor must make a value analysis and futuristic checks to select the equipment.

- d) For expansion plans or equipment replacements, viability of going in for various sized equipments suiting product groups (including future plans) should be seen. This is generally feasible at this stage as the orders for each group of products are sufficient.
- e) Proper procedure for procurement of equipment should be adopted involving capable people having adequate exposure to latest technology.
- f) As per a rough thumb rule, go in for SPM's instead of GPM's if the machine is to be occupied repeatedly on producing similar jobs for 60-70% of its engaged time. A cost-benefit analysis should be conducted.

S6.7 WASTE COLLECTION, RECYCLING AND DISPOSAL

In any industrial unit some waste is inevitable. Materials and energy wastes can be recycled or made use of in some other area. In this regards following points will be helpful.

- a) Material waste should be segregated at source. To achieve source segregation following tasks should be done.
 - i) Collect chips of various sizes differently by providing sieves, vibrators or other gravity feed devices on machines.
 - ii) Wet and dry chips should be piled up separately.
 - iii) Preferably employ an automatic system for collection of chips. Remove chips regularly. Keep separate workmen for waste collection and use suitable equipment.
 - iv) Provide separate storage space for scrap materials like different metals, alloys, wood, slag etc.
- b) As far as possible recycle the chips and scrap products. If it needs some pre-processing involving special equipment, cost-benefit analysis should be done.
- c) Conduct chemical analysis of slag and other such wastes to find out the content of useful materials in it. It should be recovered, if economically viable.
- d) Material which can not be profitably recycled should be either disposed of to a potential user or some alternate use should be made e.g. slag can be used for landfills etc.

- e) In case of energy, the heat going as waste with the flue gases can be used for any of the following purposes.
 - i) Pre-heating of air, water or oils etc..
 - ii) Using heat exchangers to recover heat to be used elsewhere.

S6.8 REDUCTION IN ENERGY WASTE DUE TO USE OF MOTORS OF HIGHER H.P.

This loss can occur due to the following two main reasons:

- i) Flaws in calculation of the required H.P. of motors.
- ii) Use of replacement motors of higher H.P.

The loss can be appreciably reduced by undertaking the following courses of action.

- a) Work out the required H.P. of the motors from machine size, job sizes and production rates.
- b) Provide overload tripping devices. Select and maintain cutting tools etc. to avoid overloads.
- c) For selection of replacement motors it is recommended that a special detailed study is conducted involving the following:
 - i) Make a complete list of all the motors fitted on the machines with following details:
 - The physical characteristics like shaft size, mounting type, other mounting details etc.
 - H.P. of each motor, single phase or three phase and other electrical details.
 - The frequency or total time of use of machines from past records of production times on various machines.
 - The probability of breakdown of each motor from record of breakdowns.
 - ii) Choose the replacement motors minimising sum of loss due to inventory of motors and running of bigger motors. Nearly exact size motors should be fixed on machines which run for longer time while sparingly used machines can afford to have bigger motors in emergencies.

S6.9 REDUCTION IN ENERGY WASTE DUE TO RUNNING OF MACHINERY AND EQUIPMENT FOR LONGER TIME THAN REQUIRED

As this loss can occur due to varied reasons ranging from material shortages to workers' attitude, a series of measures can only help. A few prominent measures are given below:

- a) To reduce loss due to willful slow-working by workers:
 - i) Have separate production incentives for separate sections and for energy savings too.
 - ii) Conduct studies to find out time the operation should take and then try to achieve them in the normal routine through motivation or pressurising.
 - iii) Give the workers some very light manual jobs like reworking etc on their finishing the main work early.
 - iv) Ask the workers to finish the energy intensive operations as early as possible after which they can either sit idle or relax in the rest rooms. This can, of course, create other problems. Nevertheless this proposal should be looked into.
- b) Keep the machines in the proper working condition so that they do not take longer time in completing the operations.
- c) Do proper material planning for each work centre so that material is available when required but not too much in advance. This is particularly true for molten alloys etc. In such cases, the consumption rates, the quantity of one fill (batch) etc. should be taken into account to find out as to when does a machine need replenishment.

S6.10 HEAT LOSS FROM OPEN SIDE OF MELTING OR HOLDING FURNACES AND ITS REDUCTION

Generally the open ends of the above category of furnaces are not covered and a lot of heat is wasted. Main reason of not covering are the obstruction put by these covers in drawing or filling the furnaces and carelessness on the part of operating personnel. To mitigate the loss, specially designed covers can be provided as under:

- i) Double walled covers with lower surface of heat resistant steel stuffed with refractory or other insulating material can be fabricated and made use of.
- ii) These covers can be made to operate electrically or pneumatically at the

time the alloy has to be taken out.

S6.11 QUALITATIVE MODELLING USING OFM, OPM, AHP AND FST FOR SELECTION OF MOST EFFECTIVE MEASURES TO REDUCE MAN-POWER WASTE.

With this technique, a large number of courses of actions to reduce manpower waste can be generated and the most effective option selected considering the prevailing conditions and desired objectives (Chapter 8).

S6.12 REDUCTION IN TIME SPENT ON MACHINE SETTINGS

Setting time can be reduced by undertaking following steps.

- i) Use special jigs and fixtures.
- ii) While making production schedules care should be taken to arrive at the production sequence which results in minimum setting times. This is because it sometimes depends upon the previous setting as to how much of the tooling has to be changed.
- iii) Make arrangements to do most part of the settings away from machines before hand. To achieve this use tool packets instead of tools, and surface plates and base plates to set dies etc. away from machines. Cost-benefit analysis of such a proposal should be conducted.
- iv) Apply Goal programming technique to find out the product mix resulting into minimum setting times (Chapter 7).

S6.13 REDUCTION IN LOSS DUE TO LESS DECLARED CAPACITY AND LACK OF LINE BALANCING

It is generally seen that production personnel keep too much of safety margins while working out the installed capacity. This results into reoccurring loss as targetted production is always kept much below the actual capacity of the plant.

- a) **How to find out the actual capacity**
 - i) Calculate standard times of operations on various products giving all allowances.
 - ii) Calculate the maximum number of parts a machine can make in a month.
 - iii) Add up the capacities of similiar machines to calculate the capacity for operations.

- iv) Calculate stream factor considering the expected loss of time due to shortages, interruptions in power supply and so on.
 - v) Multiply the maximum capacities of operations with the stream factor to find out the available capacities for operations.
- b) **How to find out the loss**
- i) Find out the difference in capacities of operations to calculate the lack of line balancing.
 - ii) Find out difference between declared capacity and the capacity calculated above to have an idea of extent of loss.

S6.14 INVENTORY LEVELS BETWEEN DEPARTMENTS AND WORK CENTRES

a) **Aims and objective**

The objective of working out these optimum inventory levels are two fold; To have requisite materials to avoid shortages and to have minimum amount of inventory.

b) **Procedure**

Inventory to be kept as buffer in a department or work centre depends upon the rate of consumption of work centre or department and the reliability and rate of supply of the previous work centre or department. Keeping these things in mind it is recommended that a special study as described below is conducted:

- i) Collect the details regarding consumption (production) rates of all work centers or departments.
- ii) From data of breakdowns calculate the probability of breakdowns and percentage availability of machines.
- iii) Considering percentage availability of machines, their production rates and type of production line, calculate figures of hours of inventory needed on each machine or in a department.
- iv) Striking a balance between inventory carrying cost and cost of loss of production due to non-availability of material from the previous machine and using frequencies of breakdowns and down times calculate the buffer stock, (Monks, 1987).

S6.15 AUTOMATION AND UPGRADATION OF TECHNOLOGY

Every concern should continuously go in for upgradation of technology and automation. Following points will be quite helpful in this regards:

- a) Upgrade knowledge of top managers by giving them exposure to latest technology and innovations through visits abroad and journals etc.
- b) Analyse each operation critically or hire some specialised independent agency for the purpose and find out areas needing automation. Choose areas where automation can be brought in.
- c) Aim at bringing in low cost automation by changing design of fixtures, providing jigs, bringing in some hydraulic or pneumatic circuitary and control of operations by limit switches etc.
- d) Bring in high cost automation e.g. NC/CNC machines, machining centres, robotics etc. where-ever justifiable. Cost- benefit analysis of any proposal is essential. The important point is that in every such analysis the proposed expansions and future level of competition etc should all be considered.
- e) For calculating the loss due to not having modernised i.e. the potential for modernisation, compare the production rates, number of people to be used, safety aspects, human aspects, investments and so on.

CHAPTER X

CONCLUSIONS AND RECOMMENDATIONS

The study has been conducted with an objective to analyse various aspects of the working of engineering industry with regard to various functional elements of waste management and to design a set of generalised guidelines in the form of waste management system. Analysis of the industrial systems has been the major portion of the study. By conducting a survey of waste management practices through a specially designed questionnaire, status of various industrial units with regard to waste management and the state of various resources of materials, energy, capital and manpower have been found out by analysing various areas and aspects of use and waste of these resources. Secondly, case studies, one each in the resources of materials, energy, capital and manpower have been conducted to find out areas and quantum of waste at various stages, their reasons and root causes and to generate alternate solutions. Case situations in each resource have been represented by suitable mathematical models for more detailed analysis and to facilitate effective planning and control of resources.

Analysis phase, thus, has generated a large data base on all aspects of waste and its management in engineering industry. This data base has served as a useful input for the the design of waste management system for engineering industry. In addition, the data base can also be used for more studies on the related subjects of productivity and micro level studies on some sub- areas of waste management. Literature survey, industrial experience of the candidate and suggestions/ advice of experts from industry and academics have been other inputs for the design of waste management system.

10.1 RESULTS OF THE SURVEY

a) General areas

- i) The response has been about 30 percent.
- ii) Special departments aiming at reducing waste e.g. WM department, industrial engineering department or R&D department exist in very few companies.
- iii) Special programmes like materials conservation, formal exercise of work study and energy conservation programmes are generally absent.
- iv) More than half of the companies fall in poor category with respect to waste

management.

- v) In case of energy three fourths fall in poor class. Manpower is the next critical resource followed by materials and capital.
- vi) At planning stage, efforts directed at selection of materials, fuels, machinery, equipment and manpower are missing.
- vii) Approaches like value analysis for selection of factors of production are not in much use.
- viii) Detailed cost-benefit analysis is generally not undertaken for make-buy decisions, machinery replacement decisions, expansions, modernisation and other vital areas.
- ix) Long range planning considering all related variables is not adequately done.

b) **Materials**

- i) Use of computers in management of materials is very low.
- ii) Economic order quantities, lead times and reorder points are generally not worked out considering all relevant factors.
- iii) Physical storage and handling of materials is not done systematically and scientifically.
- iv) Large gaps generally exist between physical inventory and materials present as per the records.
- v) Large inventory of materials is generally kept. Required inventory levels at various stages are not comprehensively worked out. Basic techniques of physical control and management of materials like ABC analysis are not in much use.
- vi) Materials get deteriorated, damaged or become obsolete in storage.
- vii) Techniques for reducing scrap such as inspection of incoming materials, statistical quality control and ensuring machine capability are all in use but not to full advantage.
- viii) To accommodate for flaws in the processes raw material sizes are kept on higher sides.
- ix) Waste collection, recycling and disposal is totally neglected. Source segregation of waste materials is nearly absent. It is the root cause for not

adopting of any subsequent steps of recycling or profitable disposal.

c) **Energy**

- i) Industries are not aware of the amount of energy spent per unit of the product at each stage and the required consumption levels.
- ii) Efficiency of machinery and equipment is of hardly any concern so long as it is doing its intended job.
- iii) Selection of machinery and equipment, installation, repairs and renovation generally omit the important consideration of energy consumption. As a result bigger machines or bigger motors on machines than required are used.
- iv) Day-to-day decisions of managers and supervisors and carelessness in the use of appliances and other equipment are contributing heavily to energy waste.

d) **Capital**

- i) Utilisation level of machinery and equipment is generally very poor.
- ii) Main reasons for under-utilisation have been materials shortages, labour attitude, breakdowns and settings.
- iii) Level of use of industrial engineering techniques like methods study, effective preventive maintenance strategy and aggregate planning, have been found to be quite low.
- iv) For establishing plant capacity, line balancing, selection of machinery and even justification of new machinery or upgradation of technology, exercises are generally not undertaken exhaustively and completely.

e) **Manpower**

- i) Most of the industries are undertaking reasonable amount of steps for the welfare of employees. There is, however, limited response.
- ii) Most of the benefits like housing, canteen facilities and subsidised transport are given to the workers.
- iii) Selection, placement and training are found wanting.
- iv) Calculations of manpower requirements using appropriate techniques have also been neglected.
- v) Overtimes are not justified.

- vi) There seems to be no mutual trust.
- vii) Initiatives on automation and modernisation are strongly opposed.
- viii) Industrial disputes, strikes, lockouts etc. do occur. Acts of indiscipline are generally overlooked.
- ix) Cooperation of workers in time studies and other matters of improvement is generally very poor.
- x) Absenteeism levels are generally high and effective working hours are very less.
- xi) Workers generally do not agree to do jobs other than their routine even in genuine cases.

10.2 RESULTS OF CASE STUDIES

a) **Materials**

- i) Maximum waste has been observed in press and machine shop followed by powder plant and sintering.
- ii) Waste found are, in order of their magnitude, process scrap, rework, oversize and unsuitable raw material, spillage and pilferage, non-recycling, poor disposal, damage, deterioration and obsolescence. Gross yearly wastage in monetary terms on account of materials is Rupees 5,41,74,815.
- iv) PST model has been found suitable to represent and analyse the case in more detail, transforming data into a form where analysis like material planning, capacity planning etc. can be conveniently applied and sensitivity analysis conducted.

b) **Energy**

- i) Maximum energy waste has been found in press and machine shop followed by powder plant, sintering and plating.
- ii) Main areas of wastage are, in order of magnitude, scrap, rejects or rework of materials, running machinery and equipment for longer times than required, breakdowns and other reasons of stoppages of machinery, large variety of products and poor selection of machinery and equipment and carelessness in the use of services and appliances. Total yearly monetary loss due to energy waste has been found to be above Rupees 13,77,688.

- iv) PST model, applied in two stages, has been found useful to represent and analyse the case accurately, for calculating requirements of energy and its cost at various stages for a unit output from the system and for applying sensitivity analysis.

c) **Capital**

- i) Machine utilisation has been revealed to be less than half the available production time.
- ii) Various reasons of under-utilisation have been idle time mainly due to material shortages, avoidable delays, absenteeism, breakdowns and unavoidable delays.
- iii) Under-utilisation of machinery and equipment with respect to its ability to process size and weight of the job has been of the order of 71 percent.
- iv) The company has a capacity to manufacture ten lac products against its targetted capacity of 7 lac products.
- v) Large capacities even upto 40 lac products per month are available for few operations indicating absence of line balancing.
- vi) Inventory levels are not determined; there is loose control on inventories and they are generally on higher side.
- vii) The company has lagged behind in automation and upgradation of technology.
- viii) Goal programming model shows 50 percent capacity utilisation and gross unbalancing of lines.

d) **Manpower**

- i) Critical analysis to locate root causes of waste of all resources has revealed that faults generally lie with the decisions taken, work done and other aspects of manpower working.
- ii) Overstaffing accounts for the main manpower waste followed by overtimes, expenditure on manpower and waste due to strikes etc.
- iii) Practically no waste is found in the area of using persons of higher skill.
- iv) A qualitative model using OFM, OPM, AHP and FST has been found to be very useful in the selection of the most appropriate and effective measures

for reducing manpower waste.

- v) It is revealed that an approach emphasising on welfare of the employees would be most effective.

e) **General outcomes**

- i) Basic causes of waste are poor quality of inputs, carelessness, incompetence, lack of interest and indifferent attitude of the human beings at various levels, flaws in the organisational set up, poor production planning and an inefficient shop floor control system and so on.
- ii) Managers and officers in the industry are too busy in their routine working and solving day to day problems. Most of their time is spent in crises management. The situation is further aggravated by not reposing confidence in the junior officers.
- iii) It is seen that managers generally do not find any fault with the present working and are not aware of the amount of waste being caused.
- iv) Having heard of the latest techniques like quality circles, TQM, TPM, JIT, I-O analysis, etc. managers and officers in the industry attempt to try them, within their time constraints and other limitations. It is seen that most of the times awareness regarding data requirements and other details of the techniques is poor resulting in inadequate gains.

10.3 FORMULATION OF WM SYSTEM

- i) Results of survey and case studies alongwith inputs from literature on the related topics, practical experience of the researcher and suggestions of experts have been used to formulate generalised guidelines on waste management in engineering industry.
- ii) Waste management system enlists various areas of waste in each resource in the order of their criticality, provides checklist of reasons of waste and recommends a number of alternate solutions for waste management.
- iii) In addition to the solutions suggested for waste in specific areas, a separate section of the guidelines provide general steps to be taken up by each industry for managing waste.
- iv) All probable areas of waste, reasons for waste, basic causes and ways out have been covered in the system.

- v) Emphasis has been laid on waste identification in each resource.
- vi) For each solution proposed a cost-benefit analysis has been recommended.

10.4 LIMITATIONS OF THE STUDY

- i) The study has been limited to engineering industry of the specified region, having an authorised capital of over Rs. one crore.
- ii) More emphasis has been given to waste identification and reduction.
- iii) Waste collection, recycling and disposal have been touched upon but not in depth.
- iv) The study involved all the resources viz. materials, energy, capital and manpower including machinery, equipment and inventories. Because of this the domain of the study became very large and involved varied areas, techniques used and types of analysis. Because of the multi-faceted areas included the study has been restricted to thorough analysis of the resources, finding out reasons and basic causes and suggesting solutions. Analysis to find outcome of the ways out suggested or their implementation has not been covered as this would have increased the work involved exponentially.
- v) In the study, at places, only basic analysis has been carried out. For example in case of calculations of manpower requirements detailed calculations have been undertaken only in case of major departments. Smaller areas involving the use of special techniques like simulation or queuing theory have not been separately analysed.
- vi) The study has been restricted mainly to production area. Other areas like overheads, finance and marketing have not been covered.
- vii) Waste management system has been made available in the form of an easily referable manual. It has not been computerised and separate sub-routines for actual analysis of the users' problems have not been provided.

10.5 SCOPE FOR FUTURE WORK

- a) In the present study only engineering industry has been analysed. The work should be extended to include other categories of industries like process industry.
- b) Similarly other sectors like municipal, domestic, agricultural, transport etc. should be taken up for detailed analysis and generalised guidelines designed for waste management.

- c) The present study has served the purpose of indicating various areas of waste. Some solutions have been proposed. Some of the solutions call for conducting complete studies at micro level. There are a number of areas needing such detailed studies as listed in the WM system. Some of the more important ones are:
- i) A detailed study of compressed air generation and distribution system to design specific guidelines on waste reduction. Detailed guidelines should be generated for working out requirements, selection of compressors, installation, distribution and use.
 - ii) Generation of guidelines for working the required inventory levels at various places including in-between work centres. The factors to be considered are breakdown rates of machines, production rates of machines, cost of items, cost of machines, importance of machines in the overall production system and so on.
 - iii) Generation of guidelines on selection of spare motors to be kept as stand-by to minimise production loss due to breakdown of motors and the inventory carrying cost of motors.
 - iv) Other areas where these guidelines could be generated after detailed studies are:
 - Selection of industrial machinery and equipment.
 - Design of a computer package for making production schedules alongwith generating requirements for toolings considering life of tooling and other factors.
 - Setting-up of system parameters considering atmospheric conditions and other factors.
- d) The interaction of quality with the techniques of waste management should be taken up in future work.
- e) In-house generation of electric power for use in the event of breakdown of supply from outside, its distribution to vital areas and other aspects should be analysed.
- f) With the rapid changeover from mass production to flexible manufacturing the impact of flexibility on management of waste in industry has become a potential area and should be taken up for study.
- g) Work should be done to study the integration of flexibility, wastivity and quality in industrial systems.

- h) In this study both quantitative and qualitative modeling of case situations in resources have been carried out. Work should be undertaken for development of flexible system methodology for modelling of industrial systems.
- i) The designed manual on waste management should be computerised and an expert system evolved.

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APPENDIX A1

PRE-TESTING OF THE QUESTIONNAIRE

Following tasks were undertaken for pre-testing the questionnaire.

- a) Suggestions received from the following were included:
- i) Deputy General Manager of M/S Escorts Limited, Bahadurgarh.
 - ii) Senior manager of M/S Escorts Limited, Bahadurgarh.
 - iii) Proprietor of a small scale industry in Patiala.
 - iv) Two managers from Gabriel India Ltd, Parwanoo.
 - v) Head, Mechanical and Industrial Engineering, Thapar Institute, Patiala.
 - vi) Two professors, one each from Thapar Institute and I.I.T., Delhi.
 - vii) Senior Manager, Purolators India Ltd., Parwanoo.
- (b) Questionnaire pre-tested on the industry to be surveyed.

A sample of 20 industrial units was selected on random basis covering each class of the industry. Sample contained the following:

	Class of Industry	Sample size
i)	Total	20
ii)	Private Sector	18
iii)	Public Sector	2
iv)	Large Scale	5
v)	Medium Scale	12
vi)	Small Scale	3
vii)	Punjab Region	7
viii)	Haryana Region	6
ix)	Himachal Pradesh Region	2
x)	Delhi Region	1
xi)	Chandigarh Region	4

Out of the above 20 industrial units only 9 units took keen interest and made suggestions. The feedback received from them was duly incorporated.

APPENDIX A2

BROAD ASPECTS AND CONTRIBUTING QUESTIONS

S. No.	Aspect	Contributing Questions			
		Materials	Energy	Manpower	Capital
1.	Awareness regarding the amount and type of waste being generated and ways to identify waste. Average Score*	M9,M11,M13, M14,M17,M18, M19,M22,M25, M28. [2.98]	E2,E4,E5,E6, E7,E15,E16, E17,E18,E20, E24,E25. [2.19]	H6,H7,H8,H9, H10,H13,H17, H19. [2.71]	C3A,B,C,D, C4A,B,C,D,E,F, C8,C13. [3.29]
2.	Efforts towards waste management at planning stage. Average Score*	M1,M2,M3,M4, M6,M15,M17, M24,M26,M27. [2.68]	E3,E8,E9,E10, E11,E12,E23. [2.61]	H1,H2,H3,H4,H5, H20B [2.74]	C5,C6,C7,C8 C9,C10,C11, C12,C13 [2.95]
3.	Efforts towards waste management at control stage. Average Score*	M3,M5,M8,M9, M10,M11,M12, M13,M20,M21, M22,M23. [2.76]	E3,E13,E14, E19,E21,E22. [2.08]	H2,H3,H4,H5, H20B [2.73]	C6,C8,C9,C10 C12 [2.96]
4.	Results of the efforts Average Score*	M14,M16,M18, M19,M25 [3.04]	E2,E4,E5,E6,E7, E9,E10,E15. [2.16]	H6,H7,H8,H9,H10, H11,H12,H13,H14, H15,H16,H17, H18,H19. [2.74]	C3A,B,C,D, C4A,B,C,D,E, F,C8 [3.31]
5.	Extent of use of IE techniques. Average Score*	M1,M2,M3,M4, M6,M7,M9,M11, M13,M15,M17, M23,M26,M27. [2.65]	E2,E3,E4,E5, E7,E9,E10,E11, E12,E13,E14, E20,E23. [2.22]	H1,H2,H3,H4,H5. [2.62]	C5,C6,C7,C9, C10,C11,C12. [2.89]
6.	Extent of use of computers. Average Score*	M3,M4,M10. [2.58]	- -	- -	- -

$$* \text{ Average score of a broad aspect} = \frac{\sum S_i}{N}$$

Where, S_i is the score of each contributing question

N is the number of contributing questions.

APPENDIX B1.1

Input-Ouput : Individual Product

Part Number		Reported Scrap		Actual Scrap
		Quantity	%age	%age
11NA30532	(B)	797	5.00	32.00
32402	(B)	948	4.00	29.00
52101	(B)	1755	2.00	25.00
71NH3109A	(B)	820	3.00	37.00
252305113101	(B)	2080	6.00	23.00
3520380610	(B)	8561	14.00	24.00
50101	(B)	1342	3.00	21.00
50103980	(W)	253	1.00	23.00
51010110	(W)	433	2.00	42.00
ME020328	(W)	3789	18.00	40.00
F4934730	(W)	519	1.00	19.00
95101	(F)	1939	9.00	37.00
C5NE6339	(F)	3614	20.00	50.00
0203410	(M)	1490	9.00	43.00
02320030	(M)	4474	16.00	38.00
2060131101	(M)	1748	7.00	27.00
51010106	(M)	430	4.00	52.00
51010107	(M)	459	3.00	29.00
51010304	(M)	1297	4.00	29.00
70308	(M)	178	7.00	4.00
8101020	(M)	3039	5.00	27.00

APPENDIX B1.3

Inprocess Scrap

Processing Stage	Description of Stage	Total Scrap	Percentage Scrap of total inprocess scrap
01	Damage	207	0.31
02-03	Strip Defect	27906	42.72
04	Blanking	12790	19.58
05	Flaring	19	0.02
06	Forming & Coining	5193	7.96
07	Bar Turning	-	-
08	Facing & Chamfering	3195	4.89
09	Hole Punching	1218	1.86
10	Milling	2710	4.14
11	Counter sinking	1422	2.17
12	Height Broach	5084	7.78
13	I. D. Broach	4760	7.28
14	Plating	-	-
15	Rusting	593	0.91
16	Shear Broaching	218	0.33
17	Power Failure	-	-
Total		65315	

APPENDIX B1.4

Stage wise Rework Generated in July

S.No.	Defect	Quantity	%age of the total rework
1	Burr on Steel side	1235	3.67
2	Step on groove	793	2.36
3	I.D.Chamfer	388	1.15
4	Wall Oversize	6440	19.17
5	OD Chamfer	3610	10.74
6	Lip Milling	12658	37.68
7	Chamfer	378	1.12
8	Height Oversize	2229	6.63
9	Step on groove	79	0.23
10	Facing	397	1.18
11	Line chamfer	125	0.37
12	Parting line Chip off	1833	5.45
13	Stamping	915	2.72
14	Notch Burr	294	0.87
15	Recoining	301	0.89
16	Height Variation	60	0.17
17	Rebroaching	1592	4.73
18	More Gap	161	0.47
19	Steel face rusting	100	0.29
Total		33588	

APPENDIX B1.5

Weight Removal at Facing and Chamfering

Part Number	Product	Weight (gms.)		%age Weight Remained
		Before	After	
1233127R1	(B)	123.2	117.59	95.10
		123.59	117.8	
50101N	(B)	92.11	85.25	92.69
		92.05	85.45	
3210331702k2	(Br)	78.22	70.19	89.73
		78.24	70.21	
X252303153223	(B)	93.55	87.22	93.18
		93.23	86.82	
1233520R1	(Br)	47.23	43.70	92.02
		47.65	43.61	
70101C	(Br)	91.63	85.38	93.46
		91.05	85.36	
53101	(Br)	116.73	109.43	93.52
		117.54	109.66	
3520381150	(B)	68.67	65.53	94.67
		68.40	64.24	
80101C	(Br)	65.90	61.30	92.44
		66.13	60.75	
70401	(Br)	36.80	33.95	92.05
		36.86	33.83	
90401	(F)	81.38	79.89	97.42
		82.13	79.41	
1121940R1	(Br)	29.24	26.77	91.92
		28.79	26.57	
3520510010	(B)	102.30	93.87	91.64
		101.50	92.90	
3023398	(B)	25.46	20.86	81.84
		25.63	20.80	
Average				92.26

APPENDIX B1.8

Weight of input and output for study period i.e. April ,May ,June, July '91

Input

Quantity blanked

Total Blanks	= 31,74,69	
Bushes	= 945657	= 73477.55 Kg
Bearings	= 1886598	= 165454.64 Kg
Washers	= 342444	= 9588.43 Kg
		= 248520.62 Kg

Output

1) Good Quantity

Total	= 26,26,185	
Bushes	= 7,75,724	= 44836.847 Kg
Bearings	= 15,67,971	= 106151.640 Kg
Washers	= 2,82,490	= 6808.009 Kg
		= 157796.500 Kg

2) Rejected Quantity

Total	= 2,22,355	
Bushes	= 43,967	= 2541.290 Kg
Bearings	= 1,66,313	= 2976.566 Kg
Washers	= 12,075	= 291.007 Kg

3) Shavings Produced (Only on bearings)

Total Quantity(Good+Rejected) = 17,34,284

Weight Removal at ID Broach Stage

Before operation Weight	= 0.0741Kg
After operation Weight	= 0.0682Kg
Difference	= 0.0059 Kg

Weight removal at ht. broach stage =

Before operation Weight	= 0.0682 Kg
After operation weight	= 0.0677 Kg
Difference	= 0.0005 Kg

Total Weight of shavings = 18903.6960 Kg

APPENDIX B2.1

Consumption Rate of Fuels on Equipment

S.No.	Equipment	Fuel	Consumption Rate
1.	Oil Fired Furnace	LDO	25-26 litres per hour for first heat 21-22 litres per hour for subsequent heats
2.	Boiler	LDO	7 litres per hour
3.	Sinter Furnace	LPG	18.8 kg./hour

APPENDIX B2.2

Details Regarding Time Spent

by Energy Consuming Devices for Unit Output in Various Sections.

S. No.	Main Area	Equipment	Running Time	Output
1.	Powder Plant	Ind.Furnace		150 kg.
		First Heat	1.50 Hours	
		Subsequent Heats	0.50 Hours	
2.		1. Reciprocating Pump	12 Min.	150 kg.
		2. Pneumatic Pump	11 hrs	1200 Kg.
		3. Cooling Pump	16 hrs	1200 Kg.
		4. Drier	10 hrs	1200kg.
		5. Pump	2 hrs	1200 Kg.
		6. Boiler	10 hrs	1200 Kg.
		7. Classifier	2 hrs	1200 Kg.
		8. Blender	2 hrs	1200 Kg.
		9. Oil Fired Furnace		
		First heat	1.5 hrs.	150Kg.
		Subsequent Heats	0.5hrs	
3.	Sintering	Sinter Furnace	1 Min.	1.524M of strip
		Sanding and Degreasing	1 Min.	12.192M of strip
		Annealing Furnace	1 Min.	2.2Metres
5.	Plating	<i>Tin Plating</i>		
		First Set	41 Min.	44 pcs.
		Subsequent Sets	1.05 Min.	44 Pcs.
		<i>LTC</i>		
		First Set	41 Min	35 Pcs.
		Subsequent Sets	1 Min.	35 Pcs.

APPENDIX B2.3

Times of Operations in Machine Shop

S.No.	Machine	Cycle Time (Minutes)	Allowances (Minutes)	Opn.Time (Minutes)
1.	BPO3 Blanker 200T	0.022	0.007	0.029
2.	BDO1 Drilling	0.050	0.015	0.065
3.	BDO2	0.050	0.015	0.065
4.	BLP04 63-T Forming	0.014	0.004	0.018
5.	BLP05 B225 Coining	0.090	0.027	0.117
6.	BF03,Bush Focing	-	-	-
7.	BCL01 Centreless Grinding	0.043	0.013	0.056
8.	B Exelo Bush Boring	0.018	0.005	0.023
9.	E-F01 Face & Chamfer	0.055	0.017	0.072
10.	EP01 Punch Press	0.034	0.010	0.044
11.	EP02 Punch Press	0.034	0.010	0.044
12.	ED01 Drill & Chamfer	0.050	0.015	0.065
13.	ED02 Drilling	0.050	0.015	0.065
14.	EM01 Notch	0.076	0.023	0.099
15.	EM02 Notch	0.076	0.023	0.099
16.	EM03 Lip mill	0.071	0.021	0.092
17.	EM04 Lip mill	0.040	0.012	0.052
18.	EM05 Lip mill	0.062	0.018	0.080
19.	E-101, E-IDI, ID Broaching	0.050	0.015	0.065
20.	E-B01 Bett Grinder	-	-	-
21.	E-0H1 Ht Broach	0.063	0.019	0.082
22.	L2-P01 Blanker	0.067	0.020	0.087
23.	L2 P02 Forming & Coing	0.024	0.007	0.031
24.	L2-FO2-Fac. & Chamf	0.042	0.013	0.055
25.	L2P01 Punch press	0.035	0.009	0.044
26.	L2P02 Hole punch	0.035	0.009	0.044
27.	L2-M01 Grooving TCC-II	0.071	0.021	0.092
28.	FN3	0.111	0.033	0.144
29.	L2-ID1-ID Broach	0.050	0.015	0.065
30.	L2-B01 Bett Grinder	-	-	-
31.	L2-H01Ht Broach	0.050	0.015	0.065
32.	L3P09 Coining 54OT	0.058	0.017	0.075
33.	L3 P10 Blanking 16OT	0.023	0.007	0.030
34.	L3-F04 Face & Chamfer	0.076	0.023	0.099
35.	L3 MOI	-	-	-
36.	L3 MOI	-	-	-
37.	L3 M02 Notch	-	-	-
38.	L3 ID1 ID-Broach	0.050	0.015	0.065
39.	L3B01 Bett Grinder	-	-	-
40.	L3 H02 Ht-Broach	0.050	0.015	0.065
41.	L3 S01 Shear Broach	0.050	0.015	0.065
42.	L3 M03 Pocket Mill	0.071	0.021	0.092
43.	B L05 Final Form	0.111	0.033	0.144
44.	Forming Line 1 4OT	0.033	0.010	0.043
45.	L3 Mo4 Grooving	0.250	0.075	0.325

APPENDIX B2.5

Processing Energy in Each Section and Waste Percentages.

S. No.	Section	Resource	Total Consumption	Utilised Energy	Portion of Supporting Operations (MJ) (c)*	Total Utilised	Material Processed (d) = (b) + (c)	Energy/unit Weight (f) = $\frac{(d)}{(e)}$	Energy waste (G) = (a) - (b)	Waste on Output (%) (h) = $\frac{(g)}{(b)}$
			(a)	(b)	(c)	(d)				
1.	Powder Plant	Elect.	37140 Kwh	15920 Kwh					21220 Kwh	133.2
		LDO	5654 Lts	2720 Lts					2934 Lts	107.8
		Energy	360881 MJ	166601 MJ	50264	216865	16695	12.76	194279 MJ	116.61
2.	Sanding	Elect.	20605 Kwh	14923 Kwh					5682 Kwh	38.07
		LPG	2160 Kg	1564 Kg					596 Kg	38.1
		Energy	199868 MJ	144731 MJ	43365	188396	86000	2.19	55136 MJ	38.1
3.	Sinter Line	Elect.	61815 kwh	44769 Kwh					17046 Kwh	38.1
			6485 lts	4696 Kg					1718 Kg	38.1
			599896 MJ	434404 MJ	131062	565466	86000	6.57	165490 MJ	38.1
4.	Blanking	Elect.	12000 Kwh	10160 Kwh					1840 Kwh	18.11
		Energy	43200 MJ	36576 MJ	11040	47610	69222	0.68	6624 MJ	18.11
5.	Machine Shop and Plating	Elect.	103210 Kwh	87952 Kwh					15218 Kwh	17.30
		Energy	371556 MJ	316627 MJ	95527	412154	50860	8.10	54929 MJ	17.30
6.	Supporting Operations	Elect.	132030 Kwh							
		Energy	475308 MJ	331558 MJ	331558					
Total			2050709 MJ							

$$*c = \frac{ESo \times b_i}{\sum b_i}, \text{ where } ESo \text{ is energy consumed on supporting operations.}$$

APPENDIX B3.1

Machine Utilisation and Factors of Under Utilisation(%)

S. No.	Machine Code	Utilisation Level	Idle Time	Absen-teeism	Unavoidable Delay	Avoidable Delay	Break-downs	Settings
1.	L2PO1 BLK	62.62	9.68	7.97	3.59	1.40	15.34	23.86
2.	L2PO2 FOC	60.71	5.57	14.32	0.31	16.04	3.06	30.60
3.	EF01 FAC	65.12	.67	18.48	1.41	3.37	4.96	19.58
4.	EMO3 GRV	35.12	35.37	13.45	0.31	15.19	0.56	7.60
5.	EHO1 BCH	61.89	6.37	21.51	1.65	5.82	2.76	13.24
6.	EIO1 BCH	63.42	14.98	13.57	1.96	6.07	0.00	9.94
7.	L2FO2 FAC	67.30	5.54	18.56	1.41	7.19	0.00	17.70
8.	L2PO1 PCH	44.82	23.74	6.27	2.85	16.34	6.01	15.70
9.	L2PO2 FOC	48.77	8.90	8.90	0.87	29.23	3.34	16.69
10.	L2MO1 GRV	49.51	26.18	11.43	0.85	9.31	2.72	5.99
11.	L2HO2 BCH	66.22	14.68	12.16	0.55	4.73	1.66	13.57
12.	L2ID2 BCH	47.66	24.91	16.05	0.86	9.40	1.11	12.18
13.	BLPO3 BLK	56.47	13.35	17.32	2.02	2.89	7.93	34.57
14.	BLPO4 FOC	38.41	30.79	0.92	3.81	24.29	1.77	9.19
15.	BLPO5 FAC	55.23	15.89	17.49	0.86	10.53	0.00	6.65
16.	BCLO1 CGR	44.31	37.68	10.18	1.40	3.90	2.50	4.39
17.	BLEXLOBBR	17.27	64.38	8.72	0.30	5.21	4.12	1.94
18.	L2DO1 DRL	10.81	71.37	5.84	0.31	11.67	0.00	0.00
19.	L2ID2 BCH	22.84	61.58	6.96	1.11	7.52	0.00	2.52
20.	EDO1 DRL	33.72	41.27	8.24	1.65	15.14	0.00	4.46
21.	L3ID1 BCH	53.26	24.76	13.05	1.11	7.82	0.00	20.26
22.	EMO2 GRV	33.26	31.83	14.38	0.55	19.97	0.00	1.97
23.	EMO1 GRV	48.75	31.78	9.44	1.91	8.13	0.00	2.45
24.	F FORMFOC	60.58	8.64	16.86	0.86	13.06	0.00	21.83
25.	EDO2 DRL	25.13	41.43	9.68	0.55	17.95	5.27	2.21
26.	L3FO4 FAC	44.32	8.35	16.33	0.55	22.40	8.04	12.71
27.	ETCC1 GRV	55.07	6.99	17.41	3.07	16.38	1.10	15.21
28.	EMO4 GRV	58.94	14.03	14.78	1.14	9.98	1.14	9.41
29.	L3MO1 GRV	75.64	7.75	12.18	1.11	3.31	0.00	9.96
30.	EHO3 BCH	51.22	21.07	11.61	1.11	7.50	7.49	18.00
31.	EPO2 PCH	57.04	23.79	9.17	1.62	6.23	2.16	18.33
32.	BLDO1 DRL	24.94	61.12	4.18	1.11	8.67	0.00	2.52
33.	BLDO2 DRL	12.43	73.92	1.97	0.55	11.14	0.00	3.57
Average		47.04	26.50	11.80	1.31	10.84	2.52	11.78

APPENDIX B3.2

Plant Utilisation and Factors of Under-utilisation (a)

S. No.	Day	Utilisation Level	Idle Time	Absenteeism	Unavoidable Delay	Avoidable Delay	Break-downs	Settings	Material Shortage
1.	1	49.72	13.26	11.92	22.32	0.87	1.10	10.91	13.12
2.	2	50.30	9.53	9.12	22.71	2.12	4.01	11.01	9.12
3.	3	36.42	9.57	10.35	31.14	2.07	8.28	1.35	8.66
4.	4	29.74	45.17	7.98	10.70	1.23	3.86	0.79	44.91
5.	5	22.96	49.42	8.53	10.39	0.16	5.97	0.23	48.49
6.	6	35.17	45.22	8.30	5.30	1.66	1.19	0.24	44.51
7.	7	28.35	42.64	10.39	0.71	0.96	0.0	0.00	42.03
8.	8	49.85	33.54	7.51	4.37	1.03	0.32	17.12	32.51
9.	9	52.63	23.38	1.23	2.96	0.92	3.19	16.15	23.11
10.	10	50.03	28.09	11.56	2.94	1.59	4.25	15.42	27.57
11.	11	50.81	22.31	14.91	2.61	0.00	6.75	15.56	21.11
12.	12	49.40	24.60	11.90	10.55	0.79	1.21	12.75	24.23
13.	13	56.25	19.86	16.97	1.38	0.93	1.95	16.84	19.28
14.	14	46.40	27.98	14.69	7.12	1.44	1.52	11.45	27.78
15.	15	39.00	22.36	22.21	9.82	1.18	4.39	13.67	21.72
16.	16	41.99	33.06	10.53	11.35	0.87	1.37	13.97	32.74
17.	17	47.65	19.89	17.74	8.47	1.80	2.55	12.64	19.25
18.	18	41.77	24.07	15.35	15.90	2.01	0.30	10.58	23.33
19.	19	57.52	21.17	10.59	4.19	1.60	4.13	17.78	20.04
20.	20	48.48	22.21	12.10	5.34	0.12	3.47	15.16	20.09
21.	21	52.54	22.66	15.40	2.80	1.75	1.33	13.69	19.26
22.	22	47.45	32.03	6.98	6.31	1.59	3.52	12.62	30.90
23.	23	53.06	20.89	9.96	7.76	1.51	2.29	13.18	19.47
24.	24	50.00	21.30	12.90	12.17	1.71	0.90	12.94	17.10
25.	25	50.50	20.62	12.25	11.50	2.82	1.37	13.62	18.43
26.	26	49.12	27.61	6.84	7.24	0.83	0.83	10.74	27.02
27.	27	59.40	22.19	7.07	7.52	0.57	2.76	14.91	21.74
Average		46.16	26.10	11.71	9.10	1.26	2.70	11.31	25.09

APPENDIX B3.3

Observed Times, Standard Times and Production Rates

S.No.	Machine Name	Observed Time(Min.) O.T.	Standard Time(Min.) O.T*1.2	No.of Products per Shift(Hrs.) (6.8)	No.of Products per Month
1.	BPO3 BLANKER	0.022	0.0264	15454	1159050
2.	BDO1 DRILLING	0.050	0.060	6800	510000
3.	BDO2 DRILLING	0.050	0.060	6800	510000
4.	BLPO4 FORMING	0.014	0.017	24000	1800000
5.	BLPO5 COINING	0.090	0.108	3778	280350
6.	BCLO1 CENTERLESS GRINDING	0.043	0.052	7846	588450
7.	B EXELO BUSH BORING	0.018	0.0216	18889	1416675
8.	EFO1 FACING & CHAMF	0.034	0.0408	10000	750000
9.	EPO1 PUNCH PRESS	0.034	0.0408	10000	750000
10.	EPO2 PUNCH PRESS	0.034	0.0408	10000	750000
11.	EDO1 DRILLING & Chamfering	0.050	0.060	6800	510000
12.	EDO2 DRILLING	0.050	0.060	6800	510000
13.	EMO1 NOTCH	0.076	0.0912	4474	335550
14.	EMO2 NOTCH	0.076	0.0912	4474	335550
15.	EMO3 LIP MILL	0.071	0.0852	4789	359175
16.	EMO4 LIP MILL	0.040	0.048	8500	637500
17.	EMO5 LIP MILL TCC-1 GROOVING	0.062	0.0744	5484	411300
18.	E-101 ID BROACH	0.050	0.060	6800	510000
19.	E-OHI HT BROAD	0.063	0.0756	5397	404775
20.	L2-PO1 BLANKER	0.087	0.0804	5075	380625
21.	L2-PO2 FORMING & COINING	0.024	0.0288	14166	1062450
22.	L2-FO2 FACING & CHAMFERING	0.042	0.0504	8095	607125
23.	L2-PO1 PUNCH PRESS HOLE PUNCH	0.035	0.042	9714	728550
24.	L2-PO2 PUNCH PRESS	0.035	0.042	9714	728550,
25.	L2-MO1 GROOVING	0.071	0.0852	4789	359175
26.	FN3	0.111	0.1332	3063	229725
27.	L2-IDI ID BROAD	0.050	0.060	6800	510000
28.	L2-HO1 HT BROACH	0.050	0.060	6800	510000
29.	L3 PO9 COINING 540T	0.058	0.0696	5842	438150
30.	L3 P10 BLANKER 160T	0.023	0.0276	14782	1108650
31.	L3 FO4 FACING & Chamfering	0.076	0.0912	4474	335550
32.	L3 ID1 ID BROACH	0.050	0.060	6800	510000
33.	L3 HO2 HT BROACH	0.050	0.060	6800	510000
34.	L3 O1 SHEAR BROACH	0.050	0.060	6800	510000
35.	L3 MO3 POCKET MILL	0.071	0.0852	4789	359175
36.	B LO5 FINAL FORMING	0.111	0.1332	3063	229725
37.	FORMING LINE 1 40T	0.033	0.0396	10303	772725
38.	L3 MO4 GROOVING(SB)	0.250	0.0303	1360	102000

APPENDIX B3.4

Physical Inventory and Average Inventory

S.No.	Material Type	Material	1st April 1991(Kg)	15th July 1991 (Kg)	1st Aug 1991(Kg)	15 Aug 1991 (Kg)	Average	No.of Day's Inventory.
1.	RAW MATERIAL							
	In Stores	Steel	152142	115121	101211	97125	116400	60 days
		Copper	12112	10217	10726	3527	9146	20 days
		Lead	2500	3102	2030	2911	2636	25 days
		Tin	400	927	726	850	726	24 days
	In Powder Plant	Copper	216	-	-	-	216	Half day
		Lead	408	-	-	-	408	4 days
		Tin	90	-	-	-	90	3 days
2.	WORK-IN-PROCESS							
	Powder Plant	Powder	9999	7878	3303	9272	7613	
		Powder	4512	-	695	-	2604	13 days
		Bi-metallc strip	13244m	12726m	13627m	10218m	12454m	13 days
	Machine Shop	Rework	28396	33526	29025	26749	29424	
		Blanks	66000	52795	43615	31726	48534	13 days
		Flaring	23178	20234	17618	19252	20071	13 days
		Coining	26042	17127	10424	9232	15706	7 days
		Bar Turning	15717	12124	20671	18765	16819	Half day
		Face & Chamfer	1291	507	15147	13288	7558	One hour
		Hole Punch	22994	16127	2889	4232	11561	One hour
		Grooving	11367	11172	26	12321	8722	2 hours
		C. Sinking	2722	3021	17667	12222	8908	2 hours
		Height Broach	8927	10256	10828	9275	9822	2 hours
		I.D. Broach	1442	579	2564	3235	1953	Negligible
		Shear Broach	2445	1562	1378	1421	1701	1 hour
		Deburring	700	872	754	1211	884	Negligible
		Plated	28764	26253	25805	20219	25260	10 days
3.	FINISHED PRODUCTS							
		Finish Goods Stores	Product	301718	299758	297525	303015	300504

APPENDIX B3.5

Achievement Level of Various Goals

Goal	Type		Goal Value	Trial 1		Trial 2		Trial 3		Trial 4		Trial 5	
				A*	D*	A	D	A	D	A	D	A	D
1	Effective Capacity Goals	M1	336960	188263	148697	191220	145740	144159	192801	184121	152839	144159	192801
		M2	449280	219728	229552	147019	302261	332715	116564	201355	247925	332715	116565
		M3	449280	137009	312271	130794	318486	116215	333065	112592	336688	116215	333065
		M4	224640	280793	-56152	281059	-56419	382596	-157956	262589	-37949	382596	-157956
		M5	112320	45499	66821	63466	48854	-	-	53666	58654	-	-
		M6	112320	17519	94801	24859	87461	-	-	21218	91102	-	-
		M7	336960	327650	9310	275444	61516	285576	51384	289325	47635	285576	51384
		M8	336960	167533	169427	136080	200880	339400	-2440	136076	200884	339400	-2440
		M9	336960	199246	137714	159930	177030	364079	-27119	159925	177035	364079	-27119
		M10	112320	183232	-70912	103662	8659	0	0	123314	-10994	-	-
2	In-process Inventory Goals	P1	5	1	4	1	4	1	4	1	4	1	4
		P2	5	1	4	1	4	1	4	1	4	1	4
		P3	5	1	4	1	4	1	4	1	4	1	4
		P4	5	1	4	1	4	1	4	1	4	1	4
		P5	5	1	4	1	4	1	4	1	4	1	4
		P6	5	1	4	1	4	1	4	1	4	1	4
3	Set-up Time Goals	M1	84240	129600	-45360	129600	-45360	129600	-45360	129600	-45360	129600	-45360
		M2	112320	36000	76320	36000	76320	36000	76320	36000	76320	36000	76320
		M3	112320	108000	4320	108000	4320	108000	4320	108000	4320	108000	4320
		M4	56160	54000	2160	54000	2160	54000	2160	54000	2160	54000	2160
		M5	28080	5400	22680	5400	22680	5400	22680	5400	22680	54000	22680
		M6	28080	10800	17280	10800	17280	10800	17280	10800	17280	10800	17280
		M7	84240	64800	19440	64800	19440	64800	19440	64800	19440	64800	19440
		M8	84240	21600	62640	21600	62640	21600	62640	21600	62640	21600	62640
		M9	84240	21600	62640	21600	62640	21600	62640	21600	62640	21600	62640
		M10	28080	3600	24480	3600	24480	3600	24480	3600	24480	3600	24480
4	Profit Goal(Rs)	200000	199995	5	168095	31905	227069	-27069	168779	31221	227069	-27069	
5	Weight Processed (Kg.)	13750	15750	-2000	14242	-492	12821	929	14307	-557	12821	929	

* A → Achievement D → Deviation

Appendix B4.1

Determination of Incentive Payment

Value of the index	Incentive to be paid(Rs)	Increment rate(Rs)	Value of index	Incentive to be paid(Rs)	Increment rate(Rs)
21.90-22.39	349	--	31.51-31.99	609	17
22.40-22.99	360	11	32.00-32.49	626	17
23.00-23.49	372	12	32.50-32.99	643	17
23.50-24.09	384	12	33.00-33.49	660	17
24.10-24.69	396	12	35.50-33.99	677	17
24.70-25.19	408	12	34.00-34.49	694	17
25.20-25.79	420	12	34.50-34.99	711	17
25.80-26.29	434	14	35.00-35.49	728	17
26.30-26.89	448	14	35.50-35.99	745	17
26.90-27.49	462	14	36.00-36.49	762	17
27.50-27.99	476	14	36.50-36.99	779	17
28.00-28.49	490	14	37.00-37.49	796	17
28.50-28.99	507	17	37.50-37.99	813	17
29.00-29.49	524	17	38.00-38.49	838	17
29.50-29.99	541	17	38.50-38.99	847	17
30.00-30.49	558	17	39.00-39.49	864	17
30.50-30.99	575	17	39.50-39.99	881	17
31.00-31.50	592	17			

Appendix B4.2

AHP Weights Matrix Repondent - Production Manager

Criteria	Reduction of manpower wastivity	Reduction in expenditure on manpower	Reduction in strikes, lockouts, disputes	Reduction in overtime	Reduction in wastage of resources due to manpower	To have healthy inter personal relations	GM	Weights
Reduction in manpower wastivity	-	7	3	9	7	5	81.33	0.75
Reduction in expenditure on manpower	1/7	-	1/7	5	1/7	1/5	0.0291	0.000026
Reduction in strikes, lockouts,disputes	1/3	7	-	7	5	7	23.90	0.2207
Reduction in overtime	1/9	1/5	1/7	-	1/7	1/5	0.0095	0.000087
Reduction in wastage of resources due to manpower	1/7	7	1/5	7	-	5	2.645	0.0244
To have healthy interpersonnel relations	1/5	5	1/7	5	1/5	-	0.377	0.00348

Appendix B4.3

AHP Weights Matrix Repondent - Personnel Manager

Criteria	Reduction of manpower wastivity	Reduction in expenditure on manpower	Reduction in strikes, lockouts, disputes	Reduction in overtime	Reduction in wastage of resources due to manpower	To have healthy inter personal relations	GM	Weights
Reduction in manpower wastivity	-	7	3	5	1/7	1/5	1.732	0.049
Reduction in expenditure on manpower	1/7	-	1/5	5	1/5	1/5	0.075	0.00213
Reduction in strikes, lockouts, disputes	1/3	5	-	9	7	7	27.11	0.773
Reduction in overtime	1/5	1/5	1/9	-	1/5	1/9	0.0099	0.00028
Reduction in wastage of resources due to manpower	7	5	1/7	5	-	1/3	2.886	0.082
To have healthy interpersonnel relations	5	5	1/7	9	3	-	3.273	0.0932
Sum							35.0859,	

Appendix B4.4

AHP Weights Matrix Repondent - Researcher

Criteria	Reduction of manpower wastivity	Reduction in expenditure on manpower	Reduction in strikes, lockouts, disputes	Reduction in overtime	Reduction in wastage of resources due to manpower	To have healthy inter personal relations	GM	Weights
Reduction in manpower wastivity	-	9	3	9	1/7	7	15.58	0.73
Reduction in expenditure on manpower	1/9	-	1/7	5	1/9	1/5	0.04199	0.00197
Reduction in strikes, lockouts, disputes	1/3	7	-	7	1/7	3	2.6457	0.124
Reduction in overtime	1/9	1/5	1/7	-	1/9	1/3	0.0108	0.00050
Reduction in wastage of resources due to manpower	1/7	1/9	7	9	-	7	2.645	0.124
To have healthy interpersonnel relations	1/7	5	1/3	3	1/7	-	0.3194	0.015
Sum							21.2522,	

Appendix B4.5

Position Matrix, Respondent - Production Manager

Profile ⇒ Criteria ⇓	Technology based approach	Employee based approach	Management based approach	Environment based approach	Mixed approach	Weight
Reduction in manpower wastivity	0.7	0.5	0.5	0.3	0.7	0.75
Reduction in expenditure on manpower	0.5	0.1	0.5	0.3	0.5	0.0002
Reduction in strikes, lockouts, disputes	0.3	0.5	0.7	0.3	0.7	0.2207
Reduction in overtime	0.7	0.1	0.5	0.3	0.5	0.00008
Reduction in wastage of resources due to manpower	0.9	0.7	0.5	0.5	0.5	0.02440
To have healthy interpersonal relations	0.3	0.5	0.5	0.5	0.7	0.00348

Appendix B4.6

Position Matrix, Respondent - Personnel Manager

Profile ⇒ Criteria ↓	Technology based approach	Employee based approach	Management based approach	Environment based approach	Mixed approach	Weight
Reduction in manpower wastivity	0.5	0.7	0.5	0.5	0.5	0.04900
Reduction in expenditure on manpower	0.5	0.7	0.5	0.5	0.7	0.00213
Reduction in strikes, lockouts, disputes	0.3	0.7	0.3	0.7	0.7	0.77300
Reduction in overtime	0.3	0.5	0.5	0.3	0.3	0.00280
Reduction in wastage of resources due to manpower	0.5	0.7	0.5	0.5	0.7	0.08200
To have healthy interpersonal relations	0.3	0.7	0.3	0.5	0.5	0.09320

Appendix B4.7

Position Matrix, Respondent - Researcher

Profile ⇒ Criteria ⇓	Technology based approach	Employee based approach	Management based approach	Environment based approach	Mixed approach	Weight
Reduction in manpower wastivity	0.9	0.5	0.7	0.5	0.5	0.07300
Reduction in expenditure on manpower	0.5	0.3	0.7	0.3	0.5	0.00197
Reduction in strikes, lockouts, disputes	0.7	0.3	0.7	0.3	0.5	0.12400
Reduction in overtime	0.7	0.3	0.7	0.3	0.5	0.00050
Reduction in wastage of resources due to manpower	0.9	0.5	0.7	0.3	0.5	0.12400
To have healthy interpersonal relations	0.7	0.5	0.5	0.5	0.5	0.01500

Appendix B4.8

Weighted Position Matrix, Respondent - Production Manager

Profile ⇒ Criteria ↓	Technology based approach	Employee based approach	Management based approach	Environment based approach	Mixed approach
Reduction in manpower wastivity	0.525	0.375	0.375	0.225	0.365
Reduction in expenditure on manpower	0.0001	0.00002	0.0001	0.00006	0.0001
Reduction in strikes,lockouts,disputes	0.662	0.1103	0.15449	0.06621	0.015449
Reduction in overtime	0.00005	0.000008	0.00004	0.00002	0.00004
Reduction in wastage of resources due to manpower	0.02196	0.01708	0.01220	0.01220	0.01220
To have healthy interpersonal relations	0.00104	0.00174	0.00174	0.00174	0.00243

Appendix B4.9

Weighted Position Matrix, Respondent - Personnel Manager

Profile Criteria ⇓	Technology based approach	Employee based approach	Management based approach	Environment based approach	Mixed approach
Reduction in manpower wastivity	0.0245	0.0345	0.0245	0.245	0.245
Reduction in expenditure on manpower	0.00106	0.00149	0.00106	0.00106	0.00149
Reduction in strikes,lockouts,disputes	0.25509	0.5411	0.25509	0.5411	0.5411
Reduction in overtime	0.00084	0.00147	0.0014	0.00084	0.00084
Reduction in wastage of resources due to manpower	0.041	0.0574	0.041	0.041	0.0574
To have healthy interpersonal relations	0.02796	0.06524	0.02796	0.0466	0.0466

Appendix B4.10

Weighted Position Matrix, Respondent - Researcher

Profile ⇒ Criteria ↓	Technology based approach	Employee based approach	Management based approach	Environment based approach	Mixed approach
Reduction in manpower wastivity	0.657	0.365	0.511	0.365	0.365
Reduction in expenditure on manpower	0.00098	0.00059	0.00137	0.00059	0.00098
Reduction in strikes,lockouts,disputes	0.0868	0.0372	0.0868	0.0372	0.062
Reduction in overtime	0.00035	0.00015	0.00035	0.00015	0.00025
Reduction in wastage of resources due to manpower	0.11160	0.062	0.0868	0.03720	0.062
To have healthy interpersonal relations	0.01054	0.0075	0.0075	0.0075	0.0075

APPENDIX C1

SUGGESTIONS FROM INDUSTRY FOR THE DESIGN OF WM SYSTEM

To ensure the suitability of WM system for the engineering industry, persons (experts) at various levels and from different disciplines from the industry were actively involved in the following tasks:

- i) **Deciding the format of the WM system:** Initial format made on the basis of the outcomes of the analysis phase was revised as per the suggestions of the experts.
- ii) **Deciding the weightages of various types of wastes, reasons and ways-Out:** These areas were weighted independently by each expert in the draft of the WM system. The changes suggested were then incorporated.

The experts involved were:

- i) General Manager - Production, Escorts Ltd., Bahadurgarh, Patiala.
- ii) Senior Manager-Tool Room and Machine Building, Goetze India Ltd., Bahadurgarh, Patiala.
- iii) Proprietor of M/S Kad Enterprises, Patiala.
- iv) Divisional Manager - Foundry, Escorts Ltd. Bahadurgarh, Patiala.
- v) Assistant Manager - Quality Control, Gabriel India Ltd., Parwanoo.
- vi) Personnel Manager, Purolators India Ltd., Parwanoo.

APPENDIX C2

Brief Description of Standard Techniques.

SECTION 7 - WASTE MANAGEMENT SYSTEM

S7.1 VALUE ANALYSIS

Value analysis is a process of objectively studying every item, purchased or manufactured, standard or special to eliminate every cost factor which does not contribute to usefulness. In other words, value analysis is an organised approach to find out and eliminate unnecessary costs where ever they occur (Mudge, 1971).

S7.2. MACHINE CAPABILITY STUDIES

Machine Capability is the ability of a machine to produce products repeatedly within desired tolerance limits. To find out capability of a machine it is studied under controlled conditions to determine natural or inherent variations. Capability can be expressed as a number which can be compared to the specified tolerances. Since most industrial processes tend to follow normal probability distribution, this number is defined as the six standard deviation spread (6σ). Another number which extends this idea is the capability ratio expressed in per cent.

$$\text{Capability Ratio} = \frac{6\sigma}{\text{Total tolerance}} \times 100$$

In general, new equipment is considered capable if this ratio is 67% or less, and existing equipment is considered capable if the ratio is 75% or less (Grant and Leavenworth, 1988).

S7.3 WORK SAMPLING

Work Sampling is a fact finding tool. It is based upon the laws of probability. A sample taken at random from a large group tends to have the same pattern of distribution as the large group or universe. The determination of the percentage of working day that the operator or machine is working or idle is based on the theory that percentage number of observation recording the worker or machine as idle is a reliable measure of the percentage time that the operation is in the delay state (Barnes, 1987).

S7.4 COST BENEFIT ANALYSIS

This analysis can help the decision makers in selecting and implementing an alternative by striking a balance between the initial expenditure to be incurred on the proposal and the benefits expected by its implementation. The payback period of such a proposal is also worked out (Monks, 1987).

S7.5 BREAK-EVEN ANALYSIS

Break-even analysis is based on the fundamental model of economic theory which states that profits arise from the excess of total revenue over total costs. A break-even chart is a convenient means of graphically describing the relationship between the costs and revenues for different volumes of output (Monks, 1987).

S7.6 INSPECTION AND STATISTICAL QUALITY CONTROL TECHNIQUES

a) Principle:

Statistical quality control works on the principle that sample averages and ranges of almost all industrial processes form normal distribution curve if sample size is 4 or more. If they do not make a normal curve it shows that samples have not come from one population or in other words there is something which is disturbing the machine setting i.e. the assignable causes of variation are present. In statistical quality control, thus, samples of processes are taken, their averages and ranges calculated and plotted. These plots are called control charts. Control charts provide information on the 3 aspects (Grant and Leavenworth, 1988).

- i) Presence or otherwise of assignable causes of variation.
- ii) Natural variability of the process.

- iii) Average level of quality being achieved.
- c) **Areas of Use**
 - i) SQC helps to reduce scrap and rework by removing causes of deviations, setting quality level properly and by selection of capable machines.
 - ii) There is no need to use better materials, tools or men than recommended to cover up incapacities of the processes.
 - iii) Weights and Measures: Where some weighed quantity of a material is filled by some industrial process, SQC helps to reduce the quantity of overfill (Bindra, 1991).

S7.7 INCOMING INSPECTION

Following points would be helpful in this regards.

- a) In case of components purchased from vendors, proof of controlled production and statistical sampling are ideal techniques. Proofs of controlled production can be in the form of SQC charts of operations or even a proof of the observance of required system parameters. Sampling plans should be judiciously designed to give protection to both the supplier and the purchaser.
- b) In case of raw material following can be used:
 - i) Certification by the supplier.
 - ii) Checking a small, sample of the material by chemical analysis, visual inspection or trial production.
- c) In case of indirect material like tools, cutters, spare parts, bearings etc, the incoming inspection can be as under:
 - i) Check the material visually.
 - ii) For specialised checking, request user department and get this inspection done under actual working conditions. The dimensions of bearings etc. and other features of the indirect materials should be checked by user department.
 - iii) For materials like cutters, tools, blades and gaskets, trial production with a sample of the material should be carried out. Special conditions of over load can also be created to save time.

S7.8 MATERIAL PLANNING

The most important requirements of effective material planning are: material should be available when needed; and minimum inventories should be kept. Following steps would be helpful in this regards.

- i) Plan the materials and decide about their acquisition as early as possible but acquire them only when they are needed. Net requirements should be calculated as soon as the master production schedule is ready.
- ii) PST model should be used to calculate the gross requirements of the materials at various production stages.
- iii) Calculate net materials requirements using MRP (Material requirements planning) technique (Monks, 1987) and computer programme.
- iv) Vendors or other suppliers should be given time schedules for the supply of the material.
- v) Further, for regular items, economic order quantities, lead time and reorder points should be worked out and an automatic ordering system should be installed.
- vi) Material should be classified in A, B and C categories and accordingly due emphasis should be paid to each category.
- vii) The procedure of the receipt or issue of material should be such that ensures

updating the records. Computers should be used for updating, however use of Cardex is also recommended provided due care is taken.

S7.9 ADMINISTRATION AND ORGANISATION

- i) Management should be strict as far as possible and only genuine demands of the workers should be accepted. No acts of indiscipline should be tolerated or ignored fearing immediate trouble otherwise this will spoil and pamper the workers and their demands and acts of indiscipline will increase over time endangering factory working.
- ii) Have fair, human and open Management.
- iii) Set-up a clear organisational structure with responsibility and authority clearly defined.
- iv) Build up mutual faith.
- v) **Responsibilities of managers/supervisors:** It is common to see officers, managers and even top people doing routine jobs intended for lower rank people. Instead, clear instruction should be given and lower rank supervisors should be made responsible. Given free hand, they will surely respond. Higher calibre people should be given time to plan for future.
- vi) Set procedures for doing everything. Excessive formalities in these procedure should be removed.
- vii) Make fair selections. Resist outside pressures and avoid favouritism in this regards.
- viii) Give adequate on and off the job training.
- ix) Instead of making selections at so many times in a year make them enmass after long intervals. This will help trying out people on different jobs and choosing the best. As far as possible give job of his choice to a workman.
- x) Encourage and educate people on acquiring multi-skills in order to reduce too much division of work and need to make every small section self-sufficient.

S7.10 EFFECTIVE PRODUCTION PLANNING SCHEDULING & CONTROL

For effective production planning, scheduling and control undertake the following steps:

a) Process Planning

Do effective and realistic process planning. Do not unnecessarily go in for closer tolerances and higher levels of accuracy than required. List all the machines, operations, toolings, fixtures, jigs and other equipment required for the production of an item. A computer programme can be made which would interface the master production schedule, bill of materials and process planning data to generate requirements of tools, fixtures and other materials.

- b) Data of all tools, jigs, fixtures, and dies, must be maintained along with their inventory. Expected useful life of each of these items along with time of use already made must also be noted down. This can precisely calculate tooling requirements with use of a computer.
- c) As soon as master production schedule is available do the following things:
 - i) Plan the materials and send information to suppliers.
 - ii) Use PST model to find out the amount of material to be processed at each stage.
 - iii) Call a meeting of persons from production department, tooling department, SQC, maintenance etc and decide upon the factors of production required to meet production targets.
 - iv) Depending upon availability of above items, machine availability and by use of an optimisation criteria such as to minimise total processing time, make production schedules.
 - v) Instruct suppliers to supply material as per production schedule. Send copies of

schedules to all concerned departments i.e. production, next user deptt. quality control, maintenance, tool room, stores and so on.

- vi) Select toolings and other indirect materials judiciously by conducting trials of samples.
- d) **Production Control**
 - i) Ensure that all factors of production as planned while making the schedule are available and start the production.
 - ii) When present days' production is going on ensure that these factors would be available for the next day's production.
 - iii) If the factors are not available, schedule some alternative item and at the same time put in maximum efforts to acquire the items which were not available.
 - iv) Every day make a report as to what was planned and how is the production fairing. Gantt charts can be maintained for the purpose. One such representative daily report may contain the number of items left of each type of product and number of days left and the quantities left per day. Put maximum efforts towards the most critical items. A computer programme can also be made for the purpose.

S7.11 MOTIVATION

Salient features and special points related with this subject which every industry should know and which give guidelines as to which motivational measures would work in a given situation are briefly outlined here:

- a) Have a clear understanding of hygiene factors and motivators.
- b) Have a clear understanding of 'what are the goals to which a man works and the fulfilment of which he may regard as successful living?

It is strongly recommended here that work study exercise is used in the organisation. Work measurement must be carried out and based on that time standards, labour control, incentive schemes etc. be worked out. Further the jobs, the methods of doing work, the work place layout are all designed after doing method study. This will satisfy all the goals to which a man works, (Currie and Faraday, 1983.).

- c) A clear understanding of theory X and theory Y given by Douglas McGregor.
- d) Maslow's list of needs (Currie and Faraday, 1983)

Any motivational measure should be selected keeping all above in mind.

S7.12 MATERIAL STORAGE AND MOVEMENT

a) **Storage:**

- i) Store materials properly for easy identification. Materials can be categorised as raw materials, indirect materials etc.. Their bins and boxes can be numbered.
- ii) Make use of cubic space. This can be done by making special bins or racks which can be stacked one above the other. Matching material handling equipment has to be employed.
- iii) Store in a way to facilitate ordering process e.g., two bin system etc.
- iv) Fragile materials should be kept on specially designed racks.
- v) Material which can get rusted or damaged due to atmospheric effects should be kept wrapped or enclosed.
- vi) Decide the location of various types of materials depending upon their weights, size frequency of use and category.
- vii) To avoid obsolescence in storage use a defined retrieval system like 'first in first out.

b) **Movement/Handling:**

- i) Reduce transfer of materials from one rack to another as far as possible. For this

purpose design bins specially for each type of material so that same bins can be used for transportation of material from vendors end to the factory, for storage and for using on the line. The empty bins can be transported back to the vendor.

- ii) The design of the bin should be such that there is no damage to the stored material.
- iii) In case of certain heavy parts like connecting rods, gear box housings etc the design of the bin should be such that the material is kept in the bin in an orientation in which it is to be finally loaded on the machine.

The main advantage of these bins would be lesser damages and lesser amount of inspection needed. However, cost-benefit analysis has to be conducted to convince the vendor.

S7.13 MACHINE REPLACEMENT STUDIES

A machine or a piece of equipment needs replacement when:

- i) The quality requirements of products are not achieved.
- ii) There are frequent breakdowns and excessive down time.
- iii) Obsolete technology
- iv) Excessive working costs due to higher consumption of electricity or other resources or excessive cost of maintenance.

For taking a decision regarding machine replacement a cost comparison of the existent and proposed machines and the dependent items have to be conducted. All the costs associated with the old or new machine are to be converted into the same time frame i.e. present, future or per year. The costs to be included are:

- i) Initial cost/installation cost.
- ii) Yearly cost in the form of maintenance, energy cost and labour cost and other costs.
- iii) Cost of quality
- iv) Salvaging cost after useful life.
- v) Number of years of expected useful life.

S7.14 LAYOUT OF MACHINERY AND EQUIPMENT.

Layout of any shop should generally match the material flow as demanded by the operations and their sequence to ensure minimum material handling. Travel charting technique is used for layout designs. In practical situations it is found that certain movements of materials are more undesirable than others because of the weight, shape, size, temperature or fragility of the material. Thus an extension of travel charting technique is recommended which is as under:

- a)
 - i) Assign some weights to various types of materials which are to be handled, e.g. a very heavy material, an alloy at a high temperature which is losing heat or more fragile materials can be assigned higher weights.
 - ii) Make alternate layouts using templates or models and calculate sum of all weighted movements.
 - iii) Choose the layout with least weighted movements.
- b) While constructing the building and deciding upon the initial layout, future expansions must be kept in mind. This is particularly applicable to foundries where material to different dies, moulds or holding furnaces is to be fed from the melting furnaces.
- c) Have small decentralised units for lesser movement.

S7.15 SETTING OF REALISTIC TIME STANDARDS AND FIXING A DAYS' WORK FOR EVERY INDIVIDUAL

Time standards play a very important role towards resource utilisation in an engineering industry. It is only through time standards that a days work for every individual is determined and production schedules are designed. To set time standards the understanding of following is essential.

- a) **Unit of work** (Currie and Faraday, 1983)
- b) **Measurement of work**

Setting time standards

Considering the labour scenario prevailing in our industry, some important points for setting time standards are given below:

- i) Do not work out time standard based on past experience by patting or pressurising the workers, by approximations or by intuitions.
 - ii) Use an appropriate method of work study depending upon the prevailing environment. PMTS can be used if the environment is not conducive for time study.
 - iii) Entrust the responsibility to qualified and well versed work study men who have sound knowledge not only of the subject but also of the minutest details of the processes and who can get along with the people very well.
 - iv) Arrange exact equipment needed for the study.
 - v) Exercise due care in determining the process parameters.
 - vi) Update the knowledge of production managers and supervisors through 'on and off the job training' so that they can counter any attempt by the worker to give misleading figures.
 - vii) Conduct studies in two phases i.e. use both time study and PMTS for few operations and work out a factor relating their results. Now use PMTS for the rest of the machines and multiply by the factor to arrive at realistic results.
 - viii) In case of a new machine, set time standards before handing over the machine to the production shop. For time study use workers other than the ones who are finally going to operate them or independent persons from the supplier or some other agencies can also be used. Supervisors and junior engineers can also be asked to operate the machines for this exercise.
- c) **Fixing a days work** : In addition to work content and relaxation allowance other allowances are to be added to calculate standard time. These are contingency allowance, unoccupied time allowance interference allowance etc. Depending upon this the number of jobs to be made per day can be determined.

S7.16 EFFECTIVE LABOUR CONTROL

Following courses of action would be useful for effective labour control.

- a) **Fix every individual's day's work based on proper exercise** of work study involving clear concept of unit of work.
- b) Monitor performance of the worker, sections and departments regularly. Point out to the people performing below the set level and punish them while at the same time reward the employees or departments giving good performance.

$$\text{Performance Index} = \frac{\text{No. of units of work completed by the worker}}{\text{Standard no. of units of work}}$$

- c) Provide a sound administration and management.

S7.17 DESIGN OF INCENTIVE SCHEME

Incentive scheme should really motivate the worker to work more. For this it is essential that every worker understands regarding extra earnings possible by working more. Incentive schemes are failing because these are too complex to be understood and have just one target for the whole of the plant. Following important points should be kept in mind while designing incentive schemes.

- i) Determine time standards using work study involving the concept of 'Unit of Work.'
- ii) Scheme should ensure some incentive for reaching standard performance level.
- iii) For higher performance levels the incentive should increase more rapidly.

- iv) As far as possible there should be separate targets for separate individuals, sections or departments. If teams are made, these should be natural teams doing similar jobs. The physical boundaries should not be the criteria for determining the group for individual targets.
- v) Have incentive schemes for energy savings and scrap reduction too. These should also be separate for separate sections or departments.

S7.18 CALCULATIONS OF MANPOWER REQUIREMENTS

- a) While calculating manpower requirements:
 - i) Keep future requirements also in mind.
 - ii) Do not arrive at higher figure of manpower requirements yielding to union pressures.
 - iii) Choose some appropriate combination of the strategies of aggregate planning and work out the manpower requirements accordingly.
 - iv) Make small changes in work or method of doing work or responsibilities so that every individual is reasonably and equally loaded.
 - v) Do not have too much division of work while at the same time there should be separate people for doing specialised jobs. Try to acquire people with multiple skills.
- b) Use appropriate technique in a given situation. Various situations and the techniques to be used in each case are briefly presented here.

Short Cycle Repetitive Work

- i) Work out realistic time standards by work study.
 - ii) Project company's future sales including expected fluctuations.
 - iii) Calculate number of products to be made in a month considering scrap rates using PST model.
 - iv) Work out total available capacity of the machinery and equipment.
 - v) Work out percentage of available time these machines will have to be used to meet production requirements.
 - vi) Work out number of operators and other dependent workmen required from above information.
- b) **Long cycle Repetitive Work** This occurs when the cycle time of the machine is very long and the worker is unoccupied for a large proportion of the time.
- i) Draw multiple activity charts to represent on the same time scale the activities and busy or idle times of the operators, machinery and equipment and helpers.
 - ii) Find out the additional jobs to be given to workmen in their idle period. Modify the cycle, if possible, in this case. Train the workers on multiple jobs including inspecting the product and doing paper work. Alternately, operators can be given some additional light jobs in their unoccupied periods e.g. reworking.
 - iii) Calculate manpower requirement after filling idle periods as far as possible. Give due allowances.
- c) **Service Departments** : Queuing theory or simulation can be advantageously used to calculate manpower requirements.
- d) **Seasonal Variations** : Manpower requirements calculation exercise in this case should be integrated with aggregate planning exercise (Singh, 1992). Requirements of manpower in this case will vary considerably. Hire or fire the employees depending on the demand or keeping a constant work force with over time and idle time are the strategies available. The calculations involve:
- i) Project the sales for next few months say 24 or 36 months along with the seasonal variations on monthly basis. Plot the graph.

- ii) Calculate the manpower requirements for each month and plot them too.
- iii) Try various strategies of manpower planning i.e. constant work force size or higher and fire and find out from the graph the optimum figure of manpower in each case by calculating the areas on graphs either by counting the squares or by using an appropriate differential equation.
- iv) Give due allowances to arrive at final figures.

S7.19 ABC CLASSIFICATION

- a) **Aims and Objectives:** The objective of this classification is to select vital few areas, products or materials among a number of them. This is needed so that instead of focussing attention on all available areas, only potential areas are selected for improvement. (Monks, 1987)

S7.20 CAPACITY PLANNING

Capacity Planning is concerned with defining the long term and short term capacity needs of the organisation and determining how these needs will be satisfied (Monks, 1987). Capacity decisions must merge consumer demands (from the market) with the human, material and financial resources of the organisation.

An effective capacity planning needs important decisions to be taken both for phasing in capacity and phasing out capacity. In addition long range planning, particularly in today's competitive environment is a dire need.

S7.21 AGGREGATE PLANNING

Aggregate planning is the process of planning the quantity and timing of output over the intermediate time horizon (often 3 months to 1 year). Within that time frame, the maximum capacity of a production facility is relatively fixed. Given a forecast, planners are concerned with making the best possible use of the organisation's labour, material and capital resources to respond to expected demand - which might be either higher or lower than expected. Pure strategies of aggregate planning include, hiring and firing the people, keeping constant workforce, keeping constant rate of production and carrying inventories, delaying production, making minor changes in the plant capacity. Graphical and mathematical models are used to choose an appropriate mix of these strategies (Monks, 1987)

S7.22 METHOD STUDY

Method study is defined as 'The systematic recording and critical examination of the factors and resources involved in existing and proposed ways of doing work, as a means of applying easier and more effective methods and reducing costs.'

Through the application of Method Study an industrial unit can achieve improved factory and workplace layout, improved design of equipment, better working environment. Reduction of fatigue resulting in improved use of materials, plant and equipment and manpower and thus reducing wastivity (Currie and Faraday, 1983, Barnes, 1987).