DEVELOPMENT OF PRODUCTION PLANNING AND CONTROL (PPC) SYSTEM OF JOB ORDER COMPANIES IN ETHIOPIA

A case Study on Akaki Spare Parts and Hand Tools Share Company (ASPSC)

By

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Aknowledgment

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List of Abbreviations

APP: Aggregate Production Planning

ASPSC: Akaki Spare Parts and Hand Tools Share Company

ATO: Assemble to Order

BOM: Bill of Materials

CIM: Computer Integrated Manufacturing

CODP: Customer Order Decoupling Point

CR: Critical Ratio

CRP: Capacity Requirement Planning

DPPC: Design, Production Planning and Control

EDD: Earliest Due Date

EEPCO: Ethiopian Electric and Power Corporation

EOQ: Economic Order Quantity

ETC: Ethiopian Telecommunication Corporation

ETO: Engineer to Order

FCFS: First Come First Served

FMS: Flexible Manufacturing System

JIT: Just In Time

LS: Least Slack

MPS: Master Production Schedule

MRP: Material Requirement Planning

MRP-II: Manufacturing Resource Planning

MTO: Make to Order

MTS: Make to Stock

PPC: Production Planning and Control

ROP: Reorder point

SFC: Shop Floor Control

SPT: Shortest Processing Time

WIP: Work in Progress

Abstract

Planning system of any profit oriented company determines its survival. Whether a company is service giving or production type, the first thing expected from it is setting its objective properly. The process of setting objectives and their courses of action is planning.

Manufacturing companies plan their production and formulate mechanisms of production controlling to be profitable and survive in the market. Production planning and control (PPC) is the process of deciding what to produce in advance, setting exact route of each item, fixing the starting and finishing date for each item, and following up the progress of products according to the order. PPC of job order companies is more complicated than that of non-job order companies.

In this thesis work, PPC systems of some selected Ethiopian job order companies are analyzed. The PPC system of Akaki Spare Parts and Hand Tools Share Company, it problems and possible solution to the problems have been discussed in detail.
Finally flowchart type of model which helps minimize the PPC related problems of ASPSC is developed. The model is developed after performing the following activities.

1. Visiting ASPSC and collecting all necessary data from it.
2. Visiting job order companies found in and outside Addis Ababa.
3. Visiting major customers of ASPSC.

Data which are obtained from job order companies are used to compare the PPC system of ASPSC with other job order companies. Data which are collected from major customers are used as feedbacks to identify shortcomings of the PPC system of the company.

Key words: PPC, Job Order Company, Forecasting, Aggregate Production Planning, Material Requirement Planning.

CHAPTER ONE

INTRODUCTION

These days, profit-making companies are facing great challenges of market competition. They are not guaranteed to stay in a market that was previously under their control for the days to come. Newly emerged or efficient existing companies may take considerable market share of an inefficient company. The competition gets tougher and tougher as time goes on. This is because of:

1. unlimited increase in customers' needs and tastes,
2. unlimited increase in number and types of profit making companies and
3. high technological development in both service giving and production companies.

The fast growth of information technology is also playing great role to make market competition global in its scope. Boundaries and barriers of market are dramatically vanishing all over the world.

To stay in market, any profit oriented company is expected to have sound planning system. Planning is the process of setting objectives and their courses of action. When we try to define planning from the production point of view, it refers to an attempt to allocate all the necessary resources (raw materials, manpower, machinery and capital). Whether a company is service giving or production type, the first thing it should do is set proper objectives. Once companies have clearly defined their objectives, they should be able to put the procedures of attaining the stated objectives.

Profit oriented companies can be grouped into production and service rendering companies. Comprehensive planning activity which incorporates both production and service giving is operation planning. Therefore, operation planning and control can be defined as the process of planning what to operation to undertake, determine all the necessary resources and follow up their progress.

Success of production companies is highly dependant on their production planning and control systems. Setting proper plans leads a company to an organized set of activities. Raw materials can be availed at the right time in the right quantity and at the right place. Other resources like manpower, machines, capital and spare parts are made ready timely only if the company has sound production plan. For a plan to be attained there should be relevant and consistent controlling mechanism of the production progress. Therefore, production planning and control systems determine the fate of manufacturing companies.

Production planning and control (**PPC**) is defined as the process of planning what to produce in advance, setting exact route of each item, fixing the starting and finishing date for each item to give production orders to shops, and lastly to follow up the progress of products according to the orders. In PPC, there are two main tasks: planning and control. The planning task includes allocation of resources, routing of each product, due date setting and dispatching of orders to shops. The controlling task includes follow-up of production progress, solving problems that may be faced at the shop floor and giving feedback to future planning works. From the definition, it can be understood that PPC is highly important to:

1) clearly foresee raw material, manpower, capital and other requirements to attain the goal of a company,
2) monitor the progress of production process,
3) take timely action based on the progress status and

4) ultimately make a company competent at market

Production planning and control is in fact productivity improvement service to companies whether they are in mass scale, batch or job shop production business. It brings only benefit whatever the type of the company is. Samuel D. Beiard in his article entitled “Job shop planning and control”, automation, (May 1968), has tried to list main benefits gained from production planning and control as follows **[3]**.

1. Reduction of manufacturing cycle times for all the products produced. A reduction in shop cycle times of 50% or more is not uncommon.
2. Improved reliability in meeting order promise dates. To be able to consistently do what you told the customer you would do provides your firm with a definite marketing strength. Delivery reliabilities of above 90% are objectives of most firms.
3. Reduction of raw material and in-process inventory relative to the shop output rate. Here also reductions in the 30 to 60% ranges of raw materials and in-process inventories are realistic through automated information decision systems.
4. Substantial reduction in expediting and dispatching efforts.
5. Increased labor and machine utilization through balanced shop loading.
6. Comprehensive forecast information for raw material ordering and scheduling, workstation labor loading, and planning job routings across bottleneck workstations.
7. Timely and accurate shop measurement and control information from which shop management can make sound plans and decisions.

8. Increased labor efficiency and utilization through more orderly material flow, improved job sequencing and the full control over each man's full daily activity.

However, it has to be realized that PPC introduces a lot of repetitive, clerical work. This has the disadvantage of making mistakes, and making the job monotonous for the clerical staff. This discouraging situation can be eliminated through computerization.

Different production companies have different product natures. Some companies produce single or very few types of products in mass production basis. Typical examples of such companies are sugar factories, cement factories and textile factories. Other companies produce very large varieties of products with small batch sizes of each variety. Most factories of metal sector are good examples of such companies. Spare part factories, sheet metal fabricating plants and machinery producing factories are some of the companies in the metal sector which have large variety of products. Such companies receive orders from their customers and they are known as job order companies. Their production size is entirely dependant on customers' order size. Most job order companies produce large varieties of products having small batch sizes. Product types and sizes of job order companies vary from time to time indeterminately.

Mass production companies can easily forecast their products' demand. Based on the forecast result, they can plan their production, allocate resources and set controlling mechanisms. Once their PPC system is implemented, it can be used for a very long time without any revision. However, the indeterminately varying nature of product types and sizes of a job order company makes PPC system implementation very complicated. It is not as simple as doing in mass production ones.

Some of the reasons that make PPC implementation in job order companies difficult are:

1) Since most production plans are customer order dependant, demand forecasting is complicated. Before reaching final production plan, the demand forecast result needs to be evaluated seriously and the evaluation may be full of subjectivity.
2) Frequent updating of action plans and control mechanisms is needed.
3) Customers can be attracted when production and customer services have good quality. Such qualities are attained by the participation of all the employees. In most cases, making all the workers participate for quality improvement is difficult task.

When it is said that PPC system implementation for job order companies is difficult, it does not mean that it is totally impossible to try it. It can be achieved. To overcome such difficulties and implement reliable PPC systems in job order companies needs great effort and commitment. We have to bear in mind that the implemented PPC system of such companies needs to be followed up for its effectiveness and efficiency regularly. Based on the follow up result, it has to be improved continuously. In the case of mass production companies like sugar factories, cement factories and cigarette factories, PPC system follow up and improvement frequencies are very limited since their product's demand fluctuation is less than that of job order companies. When we compare the market dynamism of job order companies to that of mass production companies, job order companies are always in a very dynamic market environment. The production planning and control system of job order companies should as much as possible be flexible enough to handle their dynamically changing market environment. That is why the system is supposed to be revised and improved frequently. The degree and frequency of improvement are contingent to the market situation. If it is predicted that drastic market change will be faced in the near future, the whole system may be revised and adjusted to handle the anticipated demand. Minor market fluctuations may easily be handled with little improvement of the system. Responsiveness to market dynamism is the best yardstick to good PPC system of job order companies.

With the arrival of flexible manufacturing systems (FMS) in the 1970s and computer integrated manufacturing (CIM) systems in the 1980s, a new type of manufacturing environment is beginning to emerge. This new environment is one in which total customer satisfaction is the most important target for manufacturing companies. Many companies now design and manage their planning and control systems with a customer oriented focus. These customer oriented production systems are required by production companies that are derived by the requirements of their customers and the competitive pressure at market. The trend in manufacturing system is shown in figure 1.1 below.

Table 1: 1 Trends in Manufacturing Systems

Year	Manufacturing System	
1920	Mass Production	**Standardization** ↓
1970	FMS	
1980	CIM System	
2000	One of a kind production	**Customization**

From the trend it can be seen that standardization, which was the main production system of the 20th century, is being replaced by customization, which is expected to be the production system of the 21st century. Manufacturing system is gradually becoming customer driven and tending towards the extreme case of one-of a kind production. One-of a kind production system is another name for job order production system. Competent companies always try to satisfy their customers' desires. They do that by customizing their products to their customers' interest. This indicates that the 21st century is the time for job order companies and it is the right time to think of PPC system implementation methods of such companies.

CHAPTER TWO

PROBLEM FORMULATION AND METHODOLOGY

2.1 Statements of the problem

Survival of any company is strictly dependant on its competitiveness at market. The higher it is competent; the better will be its existence. The competition may be in a national or international level. As technology grows fast, production of different items becomes simple and simple. This in turn results in dramatic change in customers' demand. For example, customers who could easily be satisfied with black and white television are no more interested to buy it these days. They need colored television if possible with additional facilities like game attachments. To cope with such dynamically changing demand, production companies try to identify their main problems they face in their day-to-day activities.

Akaki Spare Parts and Hand Tools Share Company faces market problem mainly because of its shortcomings associated with production planning and control systems. The company is in serious problem to handle and its partnership with its previous major customers like sugar factories and cement factories. It is also facing problems to attract useful potential customers which can generate considerable amount of annual production orders. The main problems that the company's production sector faces are stated as follows.

i. Production delivery dates, which are specified by the production planning and control section of the company, are not usually attained. This upsets customers and they don't want to come back again.

ii. Raw material ordering, purchasing and supply system doesn't seem to follow any scientific inventory control system.

    AS a result, the company suffers unnecessary inventory buildup and dramatic depletion of important raw materials. Currently, raw material depletion is an acute problem of the company.

iii. Manufacturing lead-time estimations are tentative. Standardized empirical formulas are not set to calculate estimates of lead-time.

iv. Because manufacturing lead times are tentatively estimated and workloads of shops are not well monitored, cost and delivery time estimations are under or over stated.

    This is highly affecting the company's market competitiveness.

v. Unstable organizational structure and high man power turnover: -

    - Since the company is not profitable, most employees are not interested to stay long in the company. This situation resulted in frequent revision of organizational structure.

vi. Inconsistent flow of production enquiry sheet preparation and evaluation

vii. Delayed response to customers about product status:-

- Mostly, customers complain that they can't get quick response about their ordered products' status. This may be due to absence of effective process monitoring mechanism.

viii. High Product variability

ix. Uneven job distribution among employees.

Because of the stated problems, the company is rapidly going out of market. Being full-fledged in various capacities, it is paradoxically vanishing from market at a very fast rate.

2.2 Objective of the thesis

Stating the objective of any research work gives good guidance to procedurally and consistently organize and analyze it. The effectiveness of the work will be measured against the attainment of the stated objectives. The objectives need to be feasible. They should also be able to address problems intended to be solved. Therefore, by considering main problems of the company which were stated in the previous section, this thesis is an attempt to attain the following objectives.

A. General objectives

i. Creating awareness about the importance of production planning and control systems for any manufacturing company

ii. Introducing systematic approach in analyzing problems related to PPC.

B. Specific objectives

i. Analysis of all PPC related problems of ASPSC in detail:-

- All the problems of the company, which have direct or indirect influence on the productivity of the production sectors, will be deeply analyzed.

ii. Comparison of PPC system at ASPSC and that of other relevant companies. This helps to know the weakness and strength of the company's PPC system.

iii. Identifying causes of the problems

- Causes of the major problems will be systematically identified and grouped using statistical quality control tools.

iv. Suggesting and evaluating possible solution to improve PPC efficiency

- Based on the outcome of number iii above, alternative solutions will be suggested and the best one will be select.

v. Model developing

2.3 Methodology of the Study

To conduct the study and reach at useful result, the following methodologies are proposed to be used.

i. Literature review:- The survey includes:

- Production Planning and Control system of any manufacturing company
- PPC of job order companies i.e. how they forecast their products' market demand, how they use forecast results for their production plan, how they handle demand fluctuation after strategic or action plan is approved and implemented, and how they update their production control mechanism.

ii. Survey of previous relevant works: Review of previously performed thesis works, articles and other documents on PPC whether for job shop or mass producing companies at national and international level

iii. Distributing two types of questionnaires:

1. Questionnaires for relevant job shop companies like Mesfin Industrial Engineering, Kality Metal Products Factory (KMPF), Ziquala Steel Rolling mill, Maru metals.
2. Questionnaires for ASPSC employees: This will be helpful to get feedback about the strength and weakness of the existing PPC system in the company

iv. Consultation and personal observation at the case factory and other relevant factories

v. Relevant data collection both from ASPSC and other companies

vi. Model development and discussion

vii. Result analysis, discussion and recommendation

CHAPTER THREE

LITERATURE REVIEW

MAIN ACTIVITIES OF PRODUCTION PLANNING AND CONTROL

3.1 Overview

The main concerns of production planning and control are problems of logistics, which are encountered in manufacturing. Organizing the detailed activities of what and how many products to produce, when they are to be produced, and how the necessary resources are to be obtained is the responsibility of PPC. Such logistic problems can be solved by properly managing information. Information includes all lists of products intended to be produced, list of available machines with their respective production capacity, raw material available in the warehouse, financial status of the company and others.

In order to understand clearly the need for proper approach to production planning and control, it is necessary to have an understanding of different types of production environments with regard to production order initiation. The four classic types of such production environments are:

1. Make to Stock (**MTS**)
2. Assemble to Order (**ATO**)
3. Make to Order (**MTO**)
4. Engineer to Order (**ETO**)

Make to stock environment is where manufacturing process takes place for well known and relatively predictable demand mix. Companies which are under the MTS environment try to anticipate product demand and produce to stock so that products are available to meet the demand. Products are typically stored in a central finished goods warehouse. They may also be distributed halfway along the distribution network or distributed to the final outlet of the distribution network in anticipation of actual demand. Make to stock companies are characterized by a limited number of products, produced and possibly distributed based upon forecasts. In this environment interaction with customers is rather distant. In most cases end users do not have direct contact with the producers. Best examples of MTS companies are cement factories, sugar factories, cigarette factories, textile factories, water pumps manufacturing companies and so on. Production volume of each sales unit is high and customer delivery time, which is determined by the availability of finished goods inventory, is relatively short (ideally zero lead time between product order and delivery). The inventory of finished goods protects against uncertainties of sales demand and stock outs. MTS system has the advantage of normally having quick delivery time, but inventory costs are high and customers are unable to express preferences as to the product design. Products of long and predictable life cycle are suitable to this environment.

Assemble to order environment involves having almost limitless number of possible end item configurations, all of which are made from combinations of basic components and sub-assemblies. For most end products the core assemblies are the same and all other components are made to be varying in accordance with the customers' desires. ATO companies have a hybrid planning and control approach and are often forced, by intense competition, to provide a wide range of products with short customer delivery time.

Final assembly work of the finished products is started after the confirmation of the customers order. In effect, ATO companies attempt to manufacture a series of semi finished modules that can quickly be assembled together to form a final product requirement of a customer. Demands for modules can therefore more easily be forecasted, enabling an MTS approach. The delivery time is of medium length and is based on the availability of major subassemblies. Demand uncertainty is handled by overlapping components and subassemblies. ATO companies attempt to provide competitiveness in terms of both lead time and product range. Some examples of ATO companies are automobile manufacturing companies, forklift trucks and construction machines manufacturing companies.

Make to order environment involves having all the components available along with the engineering designs, but the product is not actually specified and not started to be produced. The finished product from this system is partially one-of-a-kind, but not entirely so because the final product is not usually designed from a basic specification. Manufacturing of the product begins with the receipt of an order, and the configuration of the product is likely to change from the initial specification during the course of processing. Products are mostly customized to the specific needs of each individual customer, and the bill of material is usually unique for each product. As a result, the product range is very broad with very limited sales of each individual product. The degree of interaction with the client is very high. Compared to MTS and ATO environments, the delivery time of MTO is long. Sales volumes are difficult to forecast. To minimize the delivery time, stocking of raw materials based on forecasting may be useful. Promised dates for completion of orders are mainly based on the available capacity in manufacturing and engineering.

Engineer to order is an environment where the customer order requires that a new engineering design be developed. All the design work is entirely based on the customer's specification. This results in a unique set of part numbers, bill of materials and process routines of each product. The same characteristics apply to the case of MTO, but customer interaction is even greater. ASPSC is more or less in an ETO environment.

Moving from MTS to ETO environment increases the degree of customer interaction on production. The customer order decoupling point (CODP) for each manufacturing environment, which defines the point after which any material is dedicated to a particular customer order, is shown in figure 3.1. The point separates the parts that are driven by customer orders from the points that are driven by forecasts

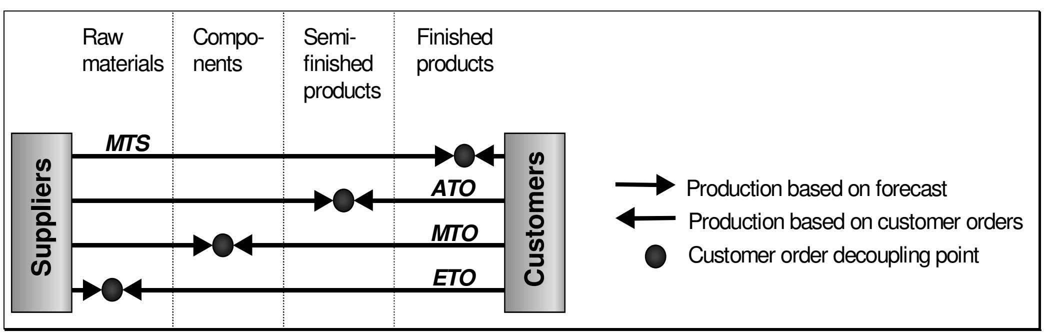


Figure 3: 1 CODP for different manufacturing Environments

Another common way of categorizing production systems is based on the size of products. The two main categories of production plants are continuous process industries and discrete parts manufacturing companies. Continuous process industries involve the continuous production of products, often using chemicals rather than using physical or mechanical means. Cement factories, beer processing factories and sugar factories are examples of continuous process industries. The discrete parts production system is further divided into mass-, batch- and job shop production types. Main characteristics of these production types are shown in table 3.1.

Table 3: 1 **Characteristics of Discrete Production types**

Characteristics	**Production Types**		
	Job Shop Production	**Batch Production**	**Mass Production**
Production Volume	Low	Medium	High
Product Variety	High	Medium	Low
Labor Skill	High	Medium	Low
Specialized Equipment	Low	Medium	High
Estimated Quantity of Annual production	1 to 100 units	100 to 10,000 units	10,000 to 1,000,000 units
Variation between plan and actual work	High	Medium	Low
Nature of Production Planning and Control System	Dynamically Changing	Averagely Stable	Easy to Handle

For each production types, there are appropriate plant layouts. The commonly known plant layouts are the following.

A. Static product (Fixed position) Layout

Static product plant layouts are used when the product to be made is large and bulky. In such cases, the product is manufactured or assembled at a fixed location and machinery is moved around the product as needed. Examples of such layouts are found in aircraft manufacture, ship building yards etc. The manufacture of such products is controlled on a project basis and the location of machinery changes as the project evolves.

B. Product (Production line) Layout

Product layouts are used when a single or a closely related set of products are to be manufactured in high volumes. Machines/workstations are arranged in a manufacturing/assembly line. The sequence of machines follows the order in which product processing is performed. Prior to the design of such a layout an assembly line balancing problem is often solved to determine the best set of tasks/activities that should be performed at each station. Workshops of Ziquala steel rolling mill, partial of Kality metal products factory are examples of product layout.

C. Group (Cellular) Layout

Group layouts are used when a family of components is to be manufactured by a small manufacturing cell. In this arrangement, a cluster of machines forms a cell. Each cell has its own material handling system, typically a robot or a conveyor system. If at all possible, a component part is completely processed in a single machine cell. Components are then routed to assembly areas. At ASPSC, there is a possibility of exercising this layout system.

D. Process Layout

Process Layouts group machines which perform similar activities into processing departments. Thus, in a plant with a process layout, there may be a turning department (all lathes), a milling department, a grinding department etc. Such layouts are common in job older plants and in job-shops. They require a large amount of material handling as parts move between departments for various operations. They have the advantage that workers and supervisors can specialize in their process. ASPSC is best example of this layout type. Figure 3.2 shows the summary of production types, their recommended plant layouts and estimates of each annual production size.

In the actual situation, discrete manufacturing systems are not purely job shop, batch or mass production types. They may be combination of them. ASPSC is good example of such situation. Some of its production orders come as mass production, others as batch production and most of its orders are job shop type orders.

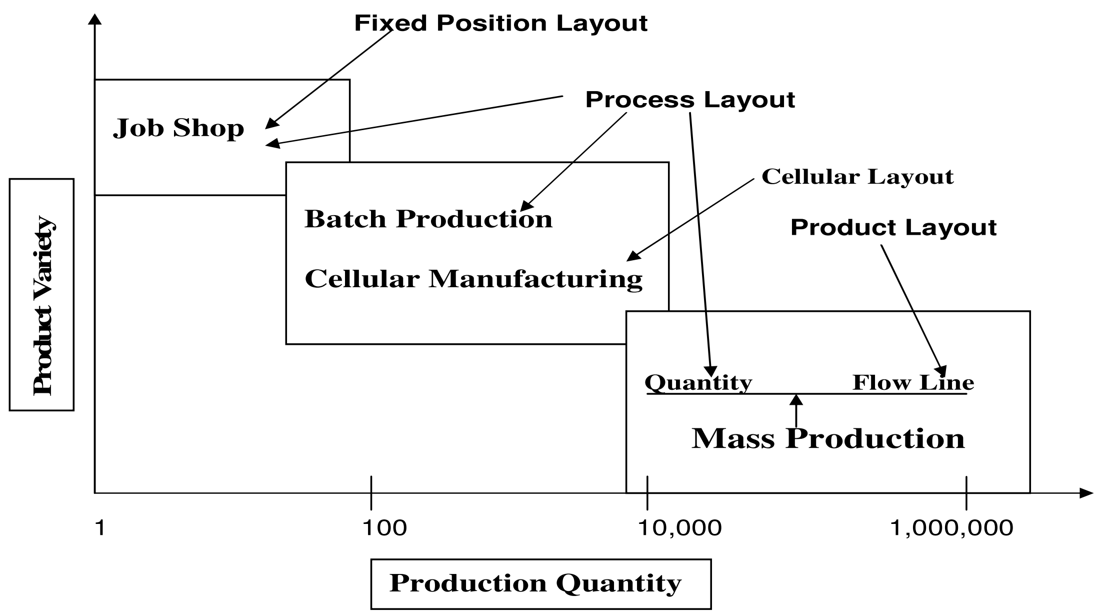


Figure 3: 2 Production types and their proposed plant layouts

PPC systems of mass, batch and job shop production types are different from each other. Mass producing companies can easily set their PPC system very easily. Since their product variety is low, raw material variety is low; machine load chart preparation is easy and production progress follow up can be conducted easily. On the other hand, job shop companies have high product variety and job order uncertainty. Therefore their production planning and control system is very dynamically changing and complicated.

Planning and control in PPC must themselves be integrated functions. It is insufficient to plan production if there is no control of the factory resources to achieve plan. And it is ineffective to control production if there is no plan against which to compare factory progress. Both planning and control must be accomplished, and they must be coordinated to each other and with other functions in the manufacturing firms, such as process planning, concurrent engineering, inventory control and updating systems, and marketing systems. What do the two dependant functions involve in each of them?

Production planning is concerned with

1. Deciding which products to make, how many of each, and when they should be completed,
2. Scheduling the production and delivery of products and
3. Planning the manpower, equipment and other resources needed to accomplish the production plan.

Activities within the scope of Production planning include:

- Demand forecasting
- Aggregate production Planning
- Master production planning
- Materials requirement planning
- Capacity planning

Production control is concerned with determining whether the necessary resources to implement the plan are provided, and if not, it attempts to take corrective actions to address the deficiencies.

Activities within the scope of production control are:

- Shop floor control

- Inventory control
- Manufacturing resource planning (MRPII)
- JIT manufacturing system

A model for hierarchical activities in production planning and control and their inter-relationship is shown in figure 3.3.

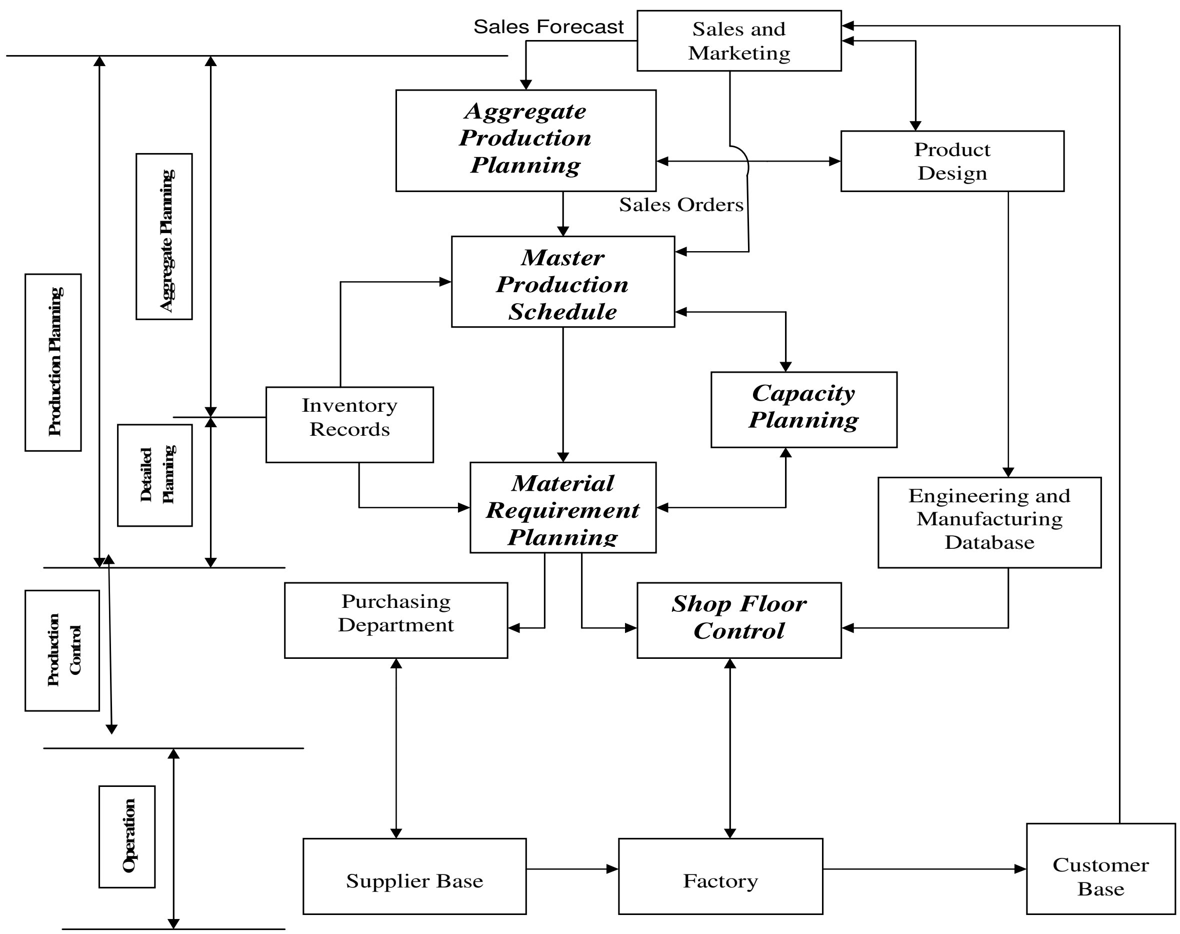


Figure 3: 3 Activities in PPC system (*bold italics* in the diagram)

As figure 3.3 indicates, production planning activities can be sub grouped into aggregate planning and detailed planning stages. In the aggregate planning stage the aggregate of the company's production is planned and the master production schedule is prepared. Based on the aggregate plan, the detailed planning follows. In this stage material requirement of each product and capacity requirements are planned in detail. Main activities of PPC both in the planning and control scopes are briefly discussed in the next sections.

3.2 Forecasting

Forecasting is the main input for production planning. Both job order companies and make to stock (MTS) companies can use forecast results for their production plan.

Forecasting is the process of using past data to determine future events. It is an estimate of occurrence, timing, or magnitude of future events. In short it is a statement about the future. The purpose of forecasting is to use the best available information to guide to future activities toward organizational goals. Using the demand estimates, input resources like raw materials, manpower, capital and machines can be planned.

A good forecast has the following elements in it **[23]**.

1. **The forecast has to be timely**. The forecast result needs to have enough time to be used in the planning process. For example, forecast of sugar mill roller demand may show that it will be double of the past year's demand. This indicates that the production capacity has to be increased. Capacity can not be increased overnight. Therefore, the forecast result has to be presented as early as possible so that the necessary preparations can be conducted with minimum possible time constraint.
2. **The forecast should be as accurate as possible**: It may be difficult to expect 100% accurate forecasts, but it should not be totally far from the fact.

3. **The forecast should be expressed in meaningful units**. The forecast units can be monetary values, number of finished products, scheduling times, number of machines or others. These units should be used consistently.
4. **The forecasting techniques should be simple to understand and use**. If the forecasting technique is sophisticated, users may loose confidence to use. To avoid this problem, appropriate forecasting techniques should be used for different conditions. Any forecasting process involves six basic steps.

Step 1. Determine the purpose of forecast

Step 2. Establish time horizon

Step 3. Select a forecasting technique

Step 4. Gather and analyze the appropriate data

Step 5. Prepare the forecast

Step 6. Monitor the forecast for its performance according to the expectation

There are two types of forecasting techniques. They are qualitative and quantitative techniques.

3.2.1 Qualitative Forecasting Techniques

These techniques involve opinions and judgments of people to predict future events. The techniques are widely used when there is no time to gather and analyze quantitative data. It is also used when the market situation is dramatically changing. In a dynamic market situation, collected data may be obsolete very quickly. Newly introduced products do not have historical data to develop a quantitative model. In such conditions, it would be preferable to use qualitative forecasting techniques. Some of the qualitative forecasting techniques are:

- Marketing survey,

- Sales force composites,
- Executive Opinions and
- Delphi Technique

i. **Marketing survey:** To estimate future demand of a product, market will be assessed. Questionnaires are distributed to customers; and some selected customers are interviewed to learn about their attitude towards the product concerning its quality, the delivery time and after sales service. The qualitative data obtained from the survey will be analyzed and future demand will be forecast.

ii. **Sales force Composites:** Different sales persons are assigned to follow up customer tastes to the product. Since they have direct contact with the customers, it is simple for them to collect many useful feedbacks. By aggregating all the information obtained from the customers by different sales persons, total demand of the product for the coming production period can be estimated.

iii. **Executive Opinions:** A group of upper-level managers from marketing, finance and production departments may meet and collectively develop a forecast. It has an advantage of bringing useful knowledge of different experts together. However, there is also a risk that the view of one person may be dominant. The production manager, for example, may deliberately insist that the maximum production capacity is this much by hiding some capacity to avoid accountability. Therefore, care should be taken to avoid such useless dominances.

iv. **Delphi Technique:** This technique involves circulating a serious of questionnaires among selected experts who do not know each other. Responses of all the experts are summarized and distributed back to them with an improved questionnaire to give chance for the experts revise their original responses. The experts compare their previous response with that of others and revise their response if they are convinced that it should be revised. The facilitator continues to receive responses and send back an improver questionnaire to the experts until he/she gets satisfactory answers for the forecasting purpose.

3.2.2 Quantitative Forecasting Techniques

Quantitative forecasting techniques involve the development of mathematical models to estimate future events by using past quantitative data. There are two types of quantitative forecasting techniques. They are:

i. **time series methods and**

ii. **causal relations**

i. **Time Series Methods:** ***Time series*** is a time-ordered sequence of observations taken at regular intervals of time. The sequence of observation is usually tabulated or graphed to show the time dependence. Once the necessary numerical data are collected, future events are calculated from them. Main time series forecasting methods are:

A. **Naïve**

B. **Moving average technique**

C. **Exponential smoothing**

D. **Trend projection.**

A. **Naïve forecast:** Naïve forecast is the simplest of all techniques. It says that the forecast for any period equals the previous actual value. Even though it seems too simplistic, it is used by many companies and they got it satisfactory. It is advantageous in that it has virtually no cost, it is quick and easy to prepare, and it is easy to understand. It is disadvantageous in that it can not be used for dynamic market condition; it totally neglects the influence of two years and back actual events.

B. Moving average: It is a technique that averages a number of recent actual values and updates the average as new actual values are introduced.

MA = $\frac{\sum X_i}{n}$ Where MA = moving average

$\sum X_i$ = Summation of recent values

n= number of recent periods

Moving Average technique can also weight the values as required.

$MA_{wt} = \frac{\sum wt_i X_i}{\sum wt_i}$ Where MA_{wt} = weighted moving average

wt_i = weighting factor

X_i = recent values

C. Exponential Smoothing: It is a forecasting technique which weights past data exponentially. It gives higher weight to the recent values and lower weight to the old values. The forecast value, F_t, is given as **[26]**,

$F_t = F_{t-1} + \alpha (A_{t-1} - F_{t-1})$ Where: F_{t-1} = last period forecast

α = Smoothing constant, $0 \leq \alpha \leq 1$

A_{t-1} = Actual value of last period

- $F_t = \alpha A_{t-1} + (1- \alpha)F_{t-1}$

  $= \alpha A_{t-1} + \alpha (1- \alpha)A_{t-2} + (1-\alpha)^2 F_{t-2}$

- $F_t = \alpha A_{t-1} + \alpha (1-\alpha)A_{t-2} + \alpha (1-\alpha)^2 F_{t-3} + ..+ \alpha (1-\alpha)^{n-1} A_{t-n} + (1-\alpha)^n F_{t-n}$

From the above forecast formula, we can see that the value of $(1-\alpha)^{n-1}$ decrease as n increases because the value of α is between 0 and 1. Hence, recent actual values have higher weight than the earlier values have.

α can be estimated as: $\alpha = \dfrac{2}{N+1}$

Where N= number of observation in a moving average

D. **Trend projection**: In this technique forecast is estimated as the linear, exponential, or other projection of past trend. For example a linear trend equation is given as **[8]**,

$Y_t = a + b.t$ Where: t = Specified number of time periods

Y_t = forecast for period t

a= value of Y_t at t = 0

b= slope of the line

The two coefficient of the line, a & b can be computed from historical data using these two equation.

$$b = \frac{n(\sum ty) - \sum t \sum y}{n\sum t^2 - (\Sigma t)^2} \quad \text{and} \quad a = \frac{\sum y - b\sum t}{n} = \bar{y} - b\bar{t}$$

ii. Causal relations (associative) forecasting techniques: Associative techniques involve the development of a mathematical model that relates a dependant variable (forecast) with independent (predictor) variables. Amount of production for the coming year is dependant on raw material cost, customer demand, machine capacity and number of skilled manpower. The objective of associative forecasting technique is developing an equation that shows the relation between forecast values and predictor variables.

Y = f(R, D, M, S); for Y = amount of production, R = raw material cost, D = demand, M = machine capacity, and S = skilled manpower

Commonly used associative techniques are **regression and correlation**, and **econometrics**

a) **Regression and Correlation**: Regression is the process of fitting a line to a set of points to formulate an estimated linear relationship between dependant and independent variables. Simple linear regression is the simplest and most widely used method. In this method, one dependant variable is estimated as a function of one predictor variable. The line is referred to as **least square** line because the sum of squared deviations around the line is minimal.

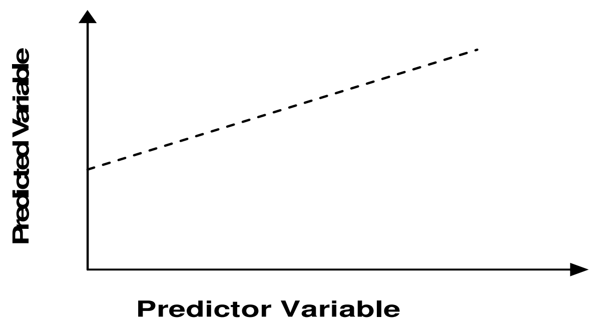


Figure 3: 4 Least square line fitted to set of points

The equation for simple linear regression is:

Y = a + b.X   Where: X = Predictor (independent) variable

Y = Predicted (forecast) variable

a= value of Y at t = 0

b= slope of the line

The constants a and b are given as:

$$b = \frac{n(\sum xy) - \sum x \sum y}{n\sum x^2 - (\sum x)^2} \quad \text{and} \quad a = \frac{\sum y - b\sum x}{n} = \bar{y} - b\bar{x}$$

Correlation is the test of how close the dependant and independent variables are **linearly** related. It measures both strength and direction of linear relation. The value of correlation coefficient is calculated by the following equation.

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{[n\sum X^2 - (\sum X)^2].[n\sum Y^2 - (\sum Y)^2]}}$$

Note: $-1 \leq r \leq 1$

r = 1 implies strong positive correlation i.e:- predicted variable increases as predictor increases

r = - 1 implies strong negative correlation

i.e:- predicted variable decreases as predictor increases

r = 0 implies that the two variables are not correlated and therefore, it is not advisable to use the developed linear regression function. Correlation decreases as coefficient of determination (r^2) decreases to zero.

b) **Econometric Technique:** In this technique, simultaneous solution of two or more multiple regression equations are estimated. The technique involves the development of multiple regression functions, which have two or more predictors. For example, the amount of beer to be sold in the coming sales period is a function of various predictor variables like, amount of sales advertisement, economic condition, quality of beer and number of competitors. The mathematical model developed for such conditions is a form of multiple regressions.

3.2.3 Forecast controls

Any forecasting technique, qualitative or quantitative, does not result in absolutely correct result; errors are encountered in it. Some of the possible sources of error are:

1. The model may be inadequate due to lack of important variable, change of variable type, or appearance of a new variable.
2. There may be irregular variation due to demand fluctuation, raw material shortage, machine breakdown or catastrophes.
3. Forecast techniques may be used incorrectly.
4. There is always a random variation in the data

To minimize forecast errors that may be caused by one or more of the above reasons, various forecast error measures are used. The commonly used are shown below.

1. MAD = Mean Absolute Deviation

$$= \frac{\sum |Error|}{n}$$

2. MSE = Mean Square Error

$$= \frac{\sum (Error)^2}{n}$$

3. Tracking Signal = $\frac{\sum Error}{MAD}$

4. MAPE = Mean Absolute Percent Error

$$= \frac{100}{n} \sum \frac{|Error|}{Actual}$$

Where Error = Actual – Forecast

n = number of periods

3.3 Aggregate production planning

Aggregate production planning (APP) is the process of determining output levels of product groups over the coming six to eighteen months on a weekly or monthly basis; the plan identifies the overall level of outputs in support of the business plan **[1]**. APP is a medium term capacity planning that determines minimum cost of workforce and production plans to meet customer demands. Its aim is to determine the production quantity and inventory level in an aggregate term. It is obvious that any business organization – public or private, manufacturing, service or agriculture must start with a plan. The company starts its plan by stating its business plan. Business plan is a statement of an organization’s overall level of business activity for the coming six to eighteen months, usually expressed in terms of monetary values of sales for its various product groups **[1]**. The business plan guides planning process of each functional area. In the operation function, a production plan (service organizations may refer to this as an operations plan) is developed to guide the more detailed planning that eventually leads to a master schedule. Figure 3.5 illustrates the planning sequence.

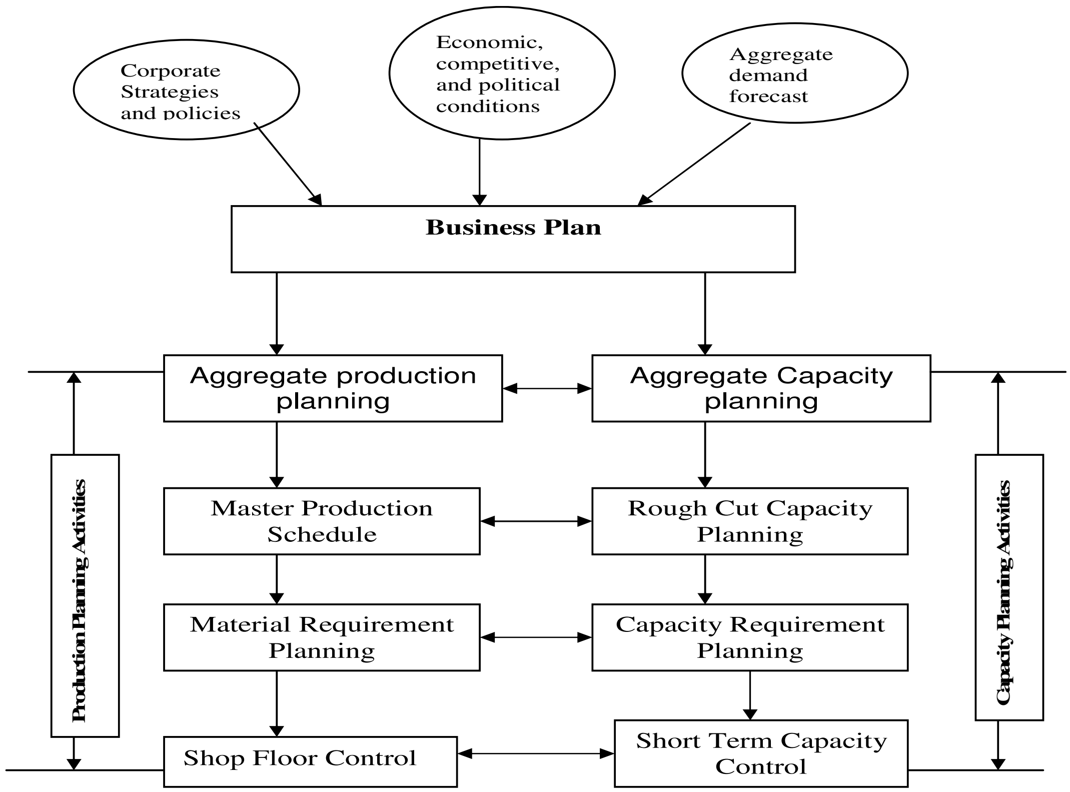


Figure 3: 5 Planning Sequence

Aggregate production planning translates the business plan into broad categories of products. In production or service giving companies, aggregate plans do not specify details but rather they show grouping. Planning at this level ignores such details as how many of each individual product, style, color option, or model to produce.

In aggregate production planning, factors to be considered are the existing fixed capacities, company's overall policies for maintaining inventories, employment stability and sub-contracting possibilities. Fixed capacities include daily or weekly production capacity of some machines of the company, maximum number of workers that can be assigned to a job, maximum budget that can be allocated to a given work. For example, fixed capacities to be considered in ASPSC are melting capacity of foundry furnaces, number of lathe, milling, grinding and gear hobbing machines available in the company, and number of workers that can be assigned to each work. Inventory policy of a company, which is overlooked in most Ethiopian companies, is used to optimize the stock level of raw materials and finished goods. It minimizes capital tie-up; it protects the company from stock deficit. The aggregate production plan should take inventory policy in to consideration. Employment stability is another factor which highly challenges the feasibility of APP. Any plan is set by considering the availability of workforce and level of skill. If the considered workers can not stay long, it is difficult to bring the plan into practice. Manpower turn over has to be minimized as much as possible. Availing possibilities of skilled manpower should also be known properly if the existing manpower is not assumed to stay long. Subcontracting of part of a work plays great role to make APP practical. By analyzing the benefits that can be gained and the associated costs, it is logical to subcontract part of a work.

Factors that affect APP ca be grouped in to those which are external to firm and those which are internal to firm. External factors are outside the company's direct control. Internal factors are at direct control of the production planners of the company. Figure 3.6 shows internal and external factors of APP. Planners can easily manipulate internal factors to derive feasible APP. Even though it is impossible to directly control external factors, their current and future states have to be understood and predicted properly.

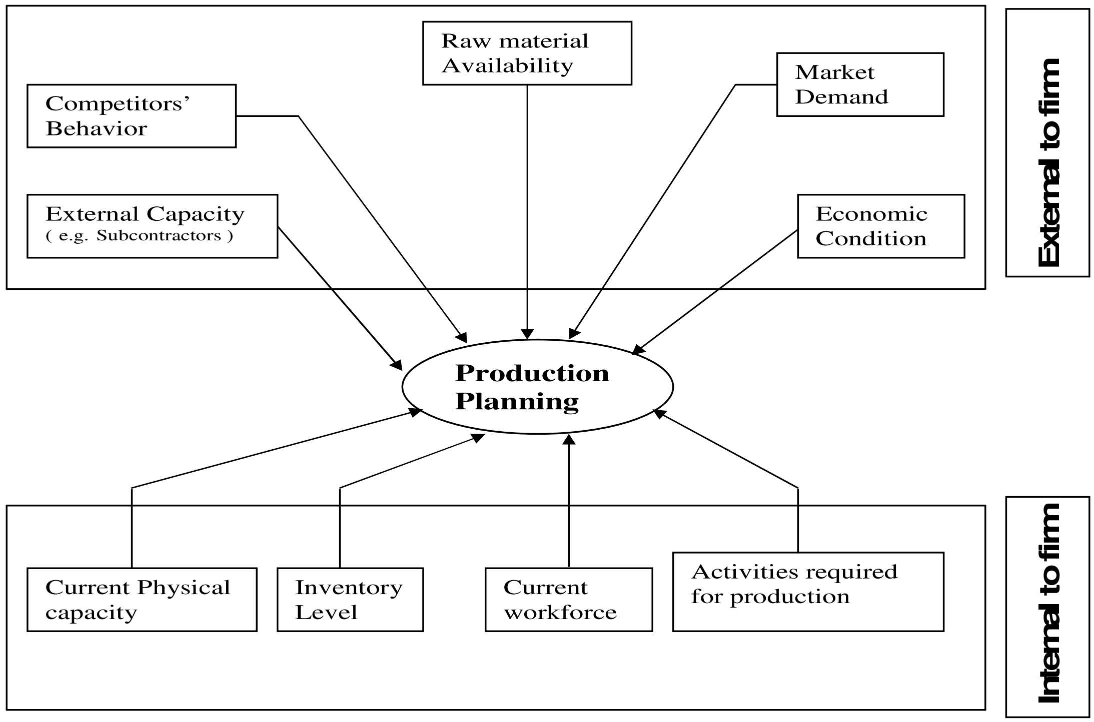


Figure 3: 6 Factors of Production Planning Environment

Main inputs of aggregate production planning are resources, demand forecast and employment policies. First, the available resources over the planning period must be known. Then, a forecast of expected demand must be availed. Finally, planners must take into account any policies regarding changes in employment levels **[23]**.

Once available resources (workforce, facilities and equipment) are known, aggregate production planning begins with a forecast of aggregate demand for the intermediate range. This is followed by a general plan to meet demand requirements by setting output, employment and finished goods inventory levels. Managers may consider a number of plans, each of which must be examined in light of feasibility and cost. If a plan is reasonably good but has minor difficulties, it can easily be corrected and implemented. A poor plan has to be discouraged and a reasonably good plan has to be searched for.

To develop an APP, concerned managers must first identify a meaningful measure of outputs. Organizations which produce single type of products do not have problem of setting measurement units. A brewery manager, for example, can plan the aggregate production in terms of gallons of beer. A steel producer can plan in terms of tons of steel, and a paint producer, in terms of gallons of paint. Most organizations, however, have several products, and a common denominator for measuring total output may not be so easy to find. A meaningful measure can usually be found by identifying groups of families of individual products that, although different from one another, share common production processes or consume similar resources. For example, different sizes of gears, shafts or sleeves can be planed in terms of units (amounts) of the representative items. Organizations strive for an overall measure of output that makes sense in the context of their unique production process and product mix.

3.3.1 Aggregate Production Planning strategies

APP is a complex problem largely because of the need to coordinate increasing variables in order for the firm to respond to the uncertain demand in an effective way. Production capacities of most companies are stable and predictable. But, the market demand of products is unstable and difficult to predict. That is why APP, which tries to reconcile the contradicting production capacities with fluctuating market demand, is complex task. To minimize the complexity of APP problems, different planning strategies are used. Commonly used strategies are:

1. varying size of workforce,

2. using overtime or Accepting idle time,
3. varying inventory levels,
4. allowing backlogs and
5. subcontracting

1. **Varying the size of workforce**: Depending on the market demand of products, size of workforce can be increased or decreased. As demand is predicted to increase, workers will be hired. When demand declines, some of the workers will be laid off.
2. **Using overtime or accepting idle time**: In this strategy, workforce size is kept constant. To meet the fluctuating demand, workers may work overtime for some months and they may be forced to be idle for other months. As demand increases, daily working hours of concerned workers will be increased with additional overtime payment. When demand decreases, workers will not produce at full capacity even at normal working hours. They will be idle for some hours everyday.
3. **Varying inventory levels**: This strategy uses constant rate of production and uniform amount of workforce. Demand fluctuation is monitored by varying stocks of finished goods. To prevent occurrence of any shortage, the beginning stock level of products should be calculated based on demand forecasts of all production periods of the planning horizon.
4. **Accept Back Orders**: A back order is an arrangement to fill a current order during a later period. In other words, lead-time of a current order will be extended by some duration. For example a company is ordered to produce 900 units in January and 400 units in February. Let the monthly production capacity of the company is 600 units. The company will be short of 300 units in January. But, in February it will have 200 excess units. Therefore the lead-time of 200 units, which were ordered in January, can be increased by one month to deliver them in February. The 100 units

(300 - 200) will be lost products. This strategy has problem of losing customer good will.

5. **Subcontracting:** When a company believes that it cannot finish all the works of an order, it will subcontract part of the work to other companies. These days it common for big companies to start very huge works by assuming that they will subcontract part of the works to other small companies. Table 3.2 shows the aggregate production planning strategies and their associated costs.

Table 3: 2 APP strategies and associated costs

S. No.	Decision Variables	Associated cost
1	Varying size of workforce	Hiring, training and layoff costs
2	Using overtime or accepting idle time	Wage premium and non-productive costs
3	Varying inventory levels	Carrying and storage costs
4	Accepting backorders	Stock out costs of lost orders
5	Subcontracting	Higher labor and material cost

When one of the above variables is used to absorb demand fluctuation, it is termed as pure strategy; when two or more are used in combination that is a mixed strategy **[5]**. In most cases, mixed strategies are widely applied to production planning process.

The above APP strategies can also be grouped into the following three broad categories.

1. Chase demand strategy
2. Level production Strategy
3. Stable workforce Strategy

1. **Chase demand strategy:** In this strategy production size is varied according to the demand size. The strategy permits hiring and layoff workers, use of overtime, and subcontracting as required. Inventory buildup is not allowed. Theoretically, the demand of each period is equal to amount of production.

2. **Level Production Strategy:** This strategy retains a stable workforce producing at a constant output rate. It is a strategy of producing at constant rate and varying inventory buildup. Inventory can be accumulated to satisfy peak demands. If inventory is believed to be depleted, part of the work at hand may be subcontracted to shorten lead time. Back order can also be accepted. Product advertisement and promotion may also be used to shift demand patterns. Often, such plan is chosen when the costs of changing the rate of output on a weekly or monthly basis are deemed too high. Boiler fuel consumption and electric furnace power consumption are examples of cost exaggerations if production rate is reduced below the optimum value. The main disadvantage of level production strategy is that there may be high inventory buildup or depletion.
3. **Stable Workforce Strategy:** This strategy retains a stable workforce but permits overtime, part-time and idle time. It is a strategy of stable workforce with varying utilization rate of the workforce capacity. When predicted demand increases, overtime and subcontracting may be used. This strategy may use inventory variation or back orders. The strategy discourages workforce layoff.

To choose the strategy which fits to a company the two important factors that must be considered are company policy and cost. For example, company policy may discourage layoff of workers except under extreme conditions. Company policy discourages subcontracting of some type of works for the sake of secrecy (e.g. a secret formula or blending process). Labor union agreements often impose restrictions of some strategies, like maximum overtime length per month, layoff and hiring procedures. Cost and benefit analysis of different strategies makes us to select the best one. Therefore, any company has to clearly understand policies and cost benefit analysis systems to select useful planning strategies.

3.3.2 Aggregate Production Planning Techniques

There are different planning techniques used in aggregate production planning. The commonly known techniques are:

- informal trial and error (graphical) technique and
- mathematical techniques which include linear programming, linear decision rules and simulation methods.

Even though informal technique is more commonly used, a considerable amount of research has been devoted to mathematical techniques.

Whether informal or mathematical techniques are used, aggregate planning procedures consist of the following steps.

1. Determine (forecast) demand for each period.
2. Determine capacities (regular time, overtime, and subcontracting) for each period.
3. Identify company or departmental policies that are pertinent to the planning work
4. Determine unit costs for regular time, overtime, subcontracting, holding inventories, back orders layoffs and other relevant costs.
5. Develop alternative plans and compute the cost for each of them.
6. If satisfactory plans emerge, select the one that best satisfies objectives. Otherwise, return to step 5.

1. Informal Trial and Error Planning Technique

The informal trial and error planning approach involves developing simple tables or graphs that enable planners to visually compare projected demand requirements with existing production capacity. Planning alternatives of this technique are usually evaluated in terms of their over all costs. Compared to the mathematical techniques, informal techniques do not necessarily result in optimal aggregate plan. The technique is relatively simple to understand and requires only minimal computational effort. The following steps can be followed to use graphical techniques of APP.

1. Draw cumulative productive periods in the horizontal axis and cumulative units of output in the vertical axis.
2. Plot the cumulative demand data (obtained from forecasting) for the entire planning horizon.
3. Select a planning strategy, taking into account aggregate planning goals. Calculate and plot the proposed output for each period in the planning horizon on the same set of axes used to plot the demand.
4. Compare expected demand and proposed output. Identify period of excess inventory and inventory shortages
5. Calculate the costs for this plan
6. Modify the plan, attempting to meet aggregate planning goals by repeating steps 3 through 5 until a satisfactory plan is established.

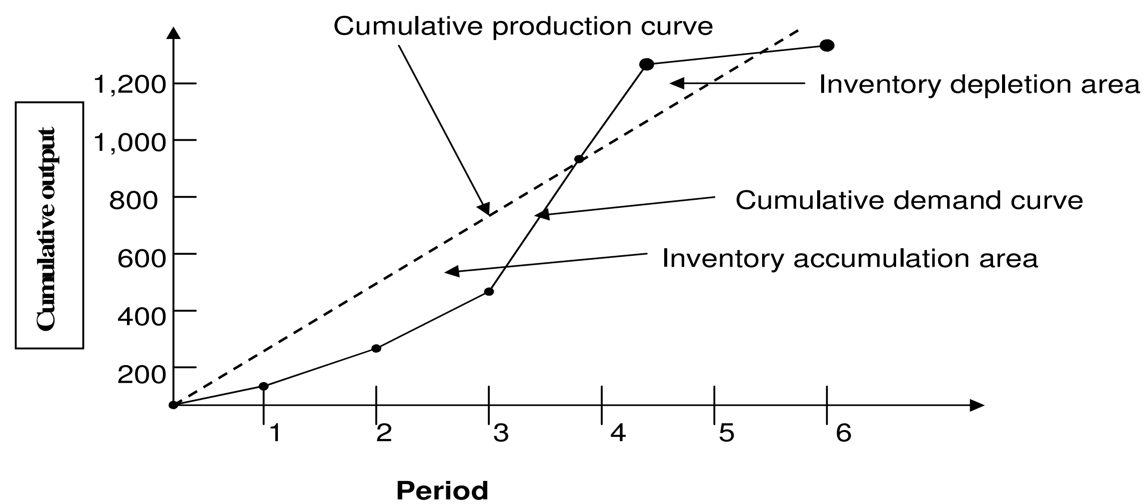


Figure 3: 7 **Graph of cumulative demand and planned output comparison**

As the above figure shows, graphical techniques are self explanatory to show the periods of inventory accumulation and depletion.

2. Mathematical Techniques

Even though graphical technique is simple, easy to understand, and requires no special equipment, it has drawbacks. Its primary drawback is that the planner has no assurance that a 'best' plan has been developed; it relays on the planner's experience and judgment. Mathematical techniques are used to determine optimum quantities of items in an aggregate production plan. The well-known mathematical techniques used in APP are linear programming, linear decision rule and simulation method.

Most mathematical models show several features. Some of the features are requiring planning horizon, securing aggregate demand, and identifying all decision variables.

A. Linear Programming (LP); Linear programming is a procedure which identifies the optimal plan for minimum cost, maximum profit or maximum output. As its name indicates, LP is appropriate to aggregate production planning if production cost and all decision variables have linear relationships. The demand needs to be treated as deterministic. The main components of LP are:

- **decision variable**: amount of individual products in APP case,
- **objective function**: cost function, profit function or production function which needs optimization,
- **constraint functions**; time constraints, capacity constraints, non-negativity constraints and
- **coefficients of functions**: production rates, unit costs.

LP is used to optimize the objective function, without violating all the constraint functions. Practically, most production costs do not have linear relation with the amounts of products. This is the main limitation of linear programming.

B. Linear Decision Rule (LDR): It is a mathematical model which provides set of equations to calculate the best workforce size, output rate, and inventory level for each time period in the planning horizon. This optimizing technique was developed by C. Holt, F. Modigliani, J. Muth and H. Simon. It seeks to minimize the combined costs of different planning strategies. Quadratic cost functions will be developed. Using calculus, two linear equations can be derived. One of these equations can be used to plan output for each period in the planning horizon, and the other can be used to plan the workforce for each period.

The advantages of LDR are that, like linear programming, it guarantees an optimal solution and avoids trial and error computation. It also accounts for non-linear cost relations. The technique suffers from the following limitations.

i. Each organization needs custom tailored cost function and considerable effort must usually be expended to obtain relevant cost data to develop the function.

ii. The technique may result in solutions that are unfeasible or impractical.

iii. Whenever the cost relationships change – for example, when salaries increase – the cost function must be derived as a new.

C. Simulation Models: Simulation models are computerized models that can be tested under different conditions to identify acceptable solutions to problems **[23]**. In this planning technique, a model company is developed and tested under different conditions to observe results. Based on the result, the aggregate plan will be implemented on actual company. Because of the mathematical sophistication, unrealistic assumptions and narrowness of models in scope, mathematical techniques are not widely used in APP. Summary of aggregate planning techniques with their assumptions, solution approaches and characteristics in solution in table 3.3.

Table 3: 3 Summary of aggregate planning techniques

S.No	Technique	Assumption	Solution Approach	Characteristics
1	Informal Graphical and Charting	None	Trial and Error	• Intuitively appealing • Simple to develop and easy to understand • Solution not necessarily optimal
2	Mathematical Techniques			
2.1	Linear Programming	Linearity	Optimizing	• Can handle a number of variables but often difficult to formulate • Assumption not always valid • Gives optimal solution
2.2	Linear Decision Rule	Quadratic Cost Function	Optimizing	• Uses mathematically derived coefficients to specify production rates and workforce levels in a series of equations • Complex to construct model. • Cost assumptions not always valid
2.3	Simulation	Existence of a computer based production system	Trial and Error	• Computerized models can be examined under a variety of conditions • Tests aggregate plans developed by other methods

3.4 Master Production Scheduling (MPS)

For the production plan to be translated into meaningful terms of production, it is necessary to disaggregate the aggregate plan. Disaggregating of the aggregate plan involves conversion of the product families to a very specific schedule of individual products. The result of disaggregating APP is master production schedule.

Master production scheduling (MPS) is a planning process which shows week by week how many of each product to be produced according to customer order or demand forecast. It is a list of products to be manufactured, when they should be completed and delivered, and in what quantities. The master schedule contains important information for marketing as well as for production. It reveals when orders are scheduled for production, and when completed orders are to be shipped. It identifies the quantity and timing of planned production, taking into account desired delivery quantity and timing as well as on-hand inventory.

An effective master production schedule provides the basis for:

- making customer delivery promises
- utilizing the capacity of the plant effectively
- attaining the strategic objectives of the firm as reflected in the production plan and
- resolving tradeoffs between manufacturing and marketing.

MPS follows aggregate planning and expresses the overall plan in terms of the amount of specific end items to produce and dates of production. It uses information from both forecasts and orders on hand, and it is the major control (driver) of all production activities. Tables 3.4 illustrate a specified aggregate production plan (a) and its subsequent master production plan (b) of drilling machines for twelve consecutive months.

Table 3: 4 **APP and MPS of drilling machines production**

Months	**Ja**	**Fe**	**Ma**	**Ap**	**May**	**June**	**July**	**Au**	**Sep**	**Oct**	**Nov**	**Dec**
No of drilling Machines	30	50	40	70	80	50	60	40	80	50	60	40

a. Aggregate plan

Months	**Ja**	**Fe**	**Ma**	**Ap**	**May**	**June**	**July**	**Au**	**Sep**	**Oct.**	**Nov**	**Dec**
1. Manual drilling Machines												
1.1. Wood drilling	10	5	-	50	30	-	20	-	40	10	-	5
1.2. Metal drilling	20	20	-	-	40	-	10	10	10	30	-	-
2. Electrical drilling Machines												
2.1. Portable drilling	-	25	25	-	10	40	10	20	15	10	30	30
2.2. Stand drilling	-	-	15	20	-	10	20	10	15	-	30	5

b. Master production Schedule

Inputs and outputs of MPS are shown on figure 3.8.

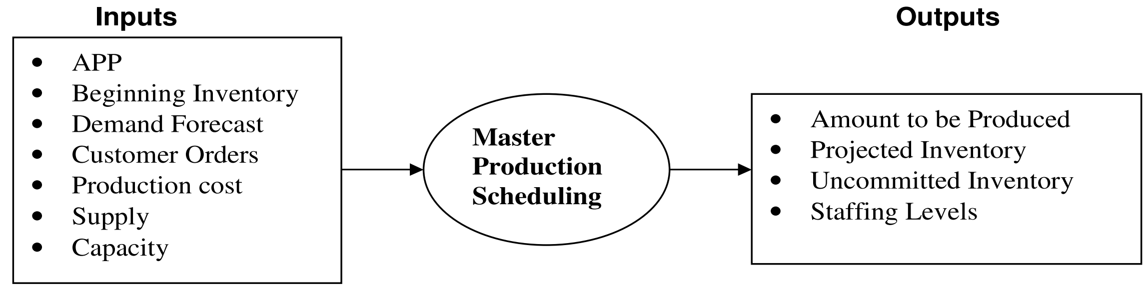


Figure 3: 8 Inputs and outputs of MPS

The master production schedule plays a key role in production planning and control systems. In this sub section, we have addressed what the MPS is, and how it is done. We see the following summarized principles from the discussion.

- The MPS unit should reflect the company's approach to the business environment in which it operates
- MPS is one part of PPC system – the other parts, which are derived from MPS, like MRP, capacity planning and shop floor control need to be in place as well.
- The order promising activities must be closely coupled to the MPS.
- The master production scheduler must keep the sum of the parts (MPS) equal to the whole (production plan).
- Production stability must be designed into the MPS and managed.
- The MPS should be evaluated with a formal performance measurement system.

3.5 Materials Requirement Planning

3.5.1 General

After preparing the master production schedule, we need to think of availing all the necessary materials to manufacture the planned items. As it is clearly discussed in section 3.4, the master production schedule shows the detailed time schedule to produce each model, type, and/or color of items. But it does not show when to make ready raw materials, components and sub-assembly parts of the planned items. The task of showing these details is left for materials requirement planning (MRP) phase of PPC. MRP, if properly implemented, plays great role in manufacturing systems. The production capacity of the company and material requirements can be balanced. It simplifies and makes the production systems very smooth but it is challenging task to practice it.

MRP can be defined as a system of planning and scheduling the time phased materials requirement for production operation **[23]**. It is a computer aided technique of determining the quantity and timing for the acquisition of dependant demand items needed to satisfy the MPS. A production plan for a specified number of finished products is translated into requirements for component parts and raw materials working backward from the due-date using lead-times and other information to determine how much to order. Hence, requirements for end items generate requirements for lower level components which are broken down by planning periods (e.g., weeks, months) so that ordering fabrication and assembly parts can be scheduled for timely completion of end items while inventory levels are kept reasonably low.

MRP replaces reactive inventory systems. MRP and reactive inventory systems differ in that former makes us to think what to do in the future but later limits our thought to what we should do now. MRP calculates and maintains an optimum manufacturing plan based on master production schedules, sales forecasts, inventory status, open orders and bills of material. If properly implemented, it will reduce cash flow and increase profitability. MRP will provide us with the ability to be pro-active rather than re-active in the management of our inventory levels and material flow. Reactive systems are simple to manage in many respects but have serous drawbacks like high inventory costs and unreliable delivery performance. On the other hand, MRP is complex to manage and yet it offers many advantages. The main complexity of MRP is associated with lead-time determination of raw materials and components.

Implementing or improving an existing MRP system can provide the following **benefits** for a company: **[15]**

- Reduced Inventory Levels
- Reduced Component Shortages
- Improved Productivity
- Improved Scheduling
- Optimized Purchasing and Production Cost
- Reduced Lead Times
- Improved Communication

There are two types of material demands: dependant and independent demands. When the demand of a particular item does not have any relation to the demand of another item, the stated demand is said to be **independent demand**. Independent demands are not derivable or calculable from the demand of something else. The only possibility to determine such demands is forecasting. If the demand of an item is directly related to the demand of another item, then it is **dependant demand**. For example, in a car manufacturing company, the number of cars demanded for a given budget year is not related to the demand of any other item. But the demands of engine blocks, crankshafts, bearings, axles, propeller shafts, tires and the like are dependant on the demand sizes of vehicles. Dependent demands are simple to calculate as far as the quantity of final product is exactly determined. In MRP, dependant demands of all components are calculated based on the demand of the final product (which is independent demand).

Main objectives of MRP are inventory reduction, lead-time reduction, realistic commitments and efficiency improvement.

There are two types of planning approaches. They are forward planning and backward planning. In forward planning, production planning starts with raw materials preparation scheduling. Then, schedules will be set for component manufacturing, sub-assembly production and final assembly production. In the backward planning case, the time scheduling starts from the final product. MRP follows backward planning system. It begins with a schedule for finished goods that is converted into a schedule of requirements for the sub-assemblies, component parts, and raw materials needed to produce the finished items in the specified time frame. Thus, MRP answers three questions: what is needed; how much is needed; and when is it needed?

For MRP to be effective, the necessary input materials and desired outs have to be clearly identified. Figure 3.9 shows inputs and outputs of MRP.

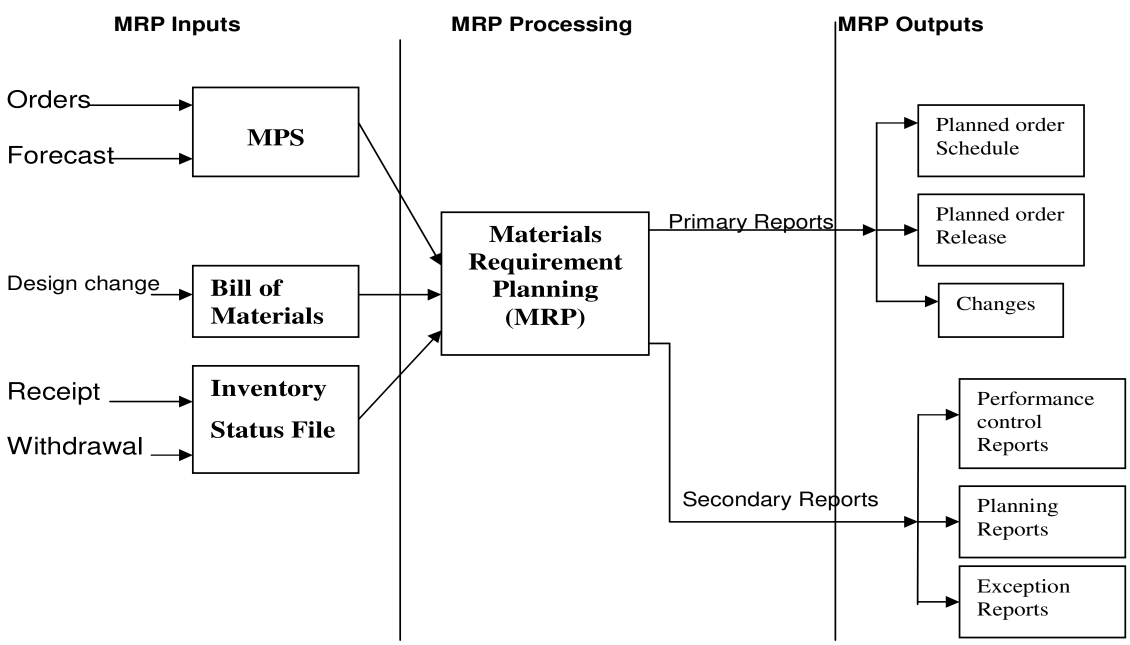


Figure 3: 9 Inputs and Outputs of MRP

3.5.2 MRP Inputs

AS figure 3.9 shows the main inputs of MRP are master production schedule (MPS), bill of materials (BOM) and inventory status file.

A. Master Production Schedule (MPS):

MPS states which end items are to be produced, when they are needed, and in what quantities. It is the backbone of MRP. It is a driving input which an MRP system depends for its real time effectiveness and usefulness because it is the determinant of future load, inventory investment, production, and delivery service.

The quantities of items in an MPS come from a number of different sources including customer orders, forecasts, and orders from warehouses to build-up seasonal inventories. Time schedule of each item in the MPS and MRP are set based on the lead-time of raw material preparation, components production, and sub-assemblies and assemblies production.

For effective implementation of MRP, proper lead-time estimation plays great role. **Lead-time** of an item is the time between placing an order for the item and receiving it in inventory. In manufacturing, lead-time is divided into ordering lead-time and manufacturing lead-time. An ordering lead time for an item is the time spent between order initiation and acquisition of the item. Raw materials have shorter order lead-time than manufactured items have because the later items need additional manufacturing lead-time. Manufacturing lead-time is the time needed to process the part through the sequence of machines specified in the rout sheet. It includes setup (machine preparation) time, process (operation) time, material handling time between operations and waiting time. From the stated manufacturing lead time components, the only productive time is the process (operation) time. Others are non-productive times. To estimate reasonably accurate manufacturing lead-time, the following factors need to be considered properly.

1. Raw material type
2. Process flow (route) of the work
3. Allowable feed rate of each machine for the considered raw material
4. Cutting speed
5. Material handling system
6. Bottleneck machines

Based on the above factors, empirical formulae for manufacturing lead time calculation may be developed.

B. Bill of Materials:

A bill of materials (BOM) contains a list of all the assemblies, sub-assemblies, parts and raw materials that are needed to produce one unit of a finished product **[1]**. To determine the bill of material of a finished product, its product structure must be clearly understood and shown. Product structure is the hierarchical level of components to produce an end product. It shows the parent - child relationship of assemblies and their components. For example, the end product can be coded as level 0; components needed for level 0 will be on level 1 and so on. Figure 3.10 shows product structure of a hypothetical product, p.

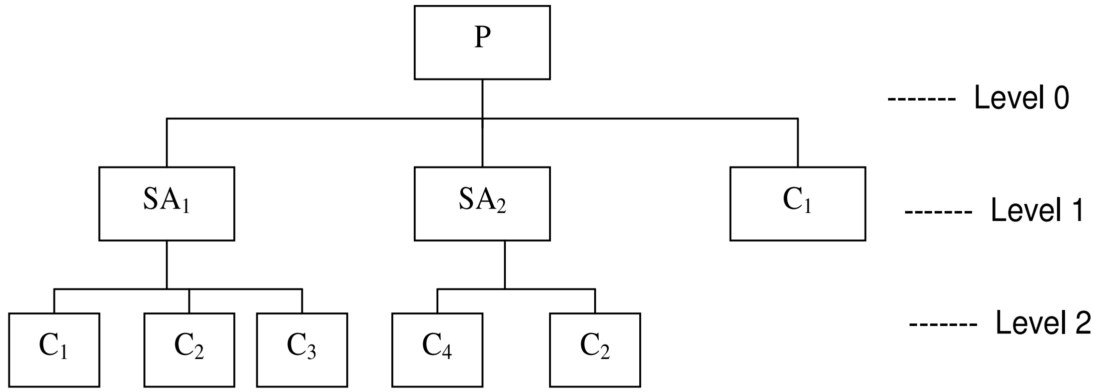


Figure 3: 10 Product Structure

Product structure is like a pyramid where top levels (parents) branch out to lower levels (children). Product, P is parent of sub-assemblies, SA_1 and SA_2, and component C_1. SA_1 in turn is the parent of components C_1, C_2 and C_3.

In product structure formulation, common use items, which are required at two or more places, are usually encountered. For example, in figure 3.10, components C_1 and C_2 are common use items. Each of them is required at two places. MRP collects these common use items from different products to effect economies in ordering the raw materials and manufacturing the components. The amount needed per unit of the end product of each raw material, component and sub-assembly should be shown on the product structure.

C. Inventory Status File

Inventory status file is the documentation of the inventory status of each item in the product structure, including item identification, on hand quantity, safety stock level, quantity allocated, and the lead time **[1]**. It comprises the individual item inventory records containing the status data required for the determination of net requirements. The inventory transaction (stock receipt, withdrawal, scrap, etc) changes the status of respective item inventories. Therefore, the position of each item inventory has to be updated according to the transaction.

In addition to the status data, the inventory records also contain planning factors like lead time, lot sizing algorisms, scrap allowance, and safety stock size. Lead times of each item shown in the inventory status file are ordering lead times, manufacturing lead times or the sum of the two. **Lot sizing** is the process of choosing a lot size for ordering or production of an item. A number of lot sizing algorisms are available to determine appropriate lot size of items. They range from relatively simple procedures to very complicated algorisms. Table 3.5 shows the most commonly used lot sizing algorisms (rules).

Table 3: 5 **Lot-sizing rules**

Method	**Short Description**
Lot to lot (Lot for lot)	Lot size = net requirements
Fixed order quantity	Fixed lot size, intuitive
Economic order quantity (EOQ)	Tradeoff between order/setup costs and inventory cost
Fixed order period	Fixed time between orders, lot size = demand of period
Periodic order quantity (POQ)	Fixed order period method with the idea of the EOQ
Part period balancing	Variation of EOQ

MRP depends on accurate inventory records to perform its planning function. This is accomplished by utilizing a computerized inventory system which maintains the inventory record file or item master file. The types of data contained in the record for a given item would typically include the categories shown in the figure below. The file contains three segments:

1. Item master data segment
2. Inventory status segment
3. Subsidiary data segment

<table>
<tr><td rowspan="3">Item master Data segment</td><td>Part no</td><td colspan="2">Description</td><td colspan="5">Lead time</td><td colspan="2">Std cost</td><td colspan="3">Safety stock</td></tr>
<tr><td colspan="2">Order Qty</td><td>Set up</td><td colspan="4">Cycle</td><td colspan="4">Last year's usage</td><td colspan="2">Class</td></tr>
<tr><td colspan="2">Scrap allowance</td><td colspan="3">Cutting data</td><td colspan="5">Pointers</td><td colspan="3">Etc</td></tr>
<tr><td rowspan="6">Inventory Status Segment</td><td rowspan="2">Allocated</td><td rowspan="2"></td><td rowspan="2">Control Balance</td><td colspan="9">Period</td><td rowspan="2">Total</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td colspan="2">Gross requirement</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Scheduled receipt</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">On hand</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Planned order release</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Subsidiary Data segment</td><td colspan="2">Order details</td><td colspan="11"></td></tr>
<tr><td colspan="2">Pending action</td><td colspan="11"></td></tr>
<tr><td colspan="2">Counters</td><td colspan="11"></td></tr>
<tr><td colspan="2">Keeping track</td><td colspan="11"></td></tr>
</table>

Figure 3: 11 Inventory Status File Sample

A. The item master data segment: It gives the item identification by part numbers, lead time, cost, and order quantity.

B. Inventory status segment: It provides a time- framed record of inventory status. In MRP it is important to know not only the current level of inventory, but also the future change that will occur against the inventory status. Therefore, the inventory status segment lists the gross requirements for the item, scheduled receipts, on-hand status, and planned – order release.

C. Subsidiary data segment: It contains miscellaneous information pertaining to purchase orders, scrap or rejects, engineering change actions, and so on.

3.5.3 MRP Calculation

An MRP system starts to calculate the requirements of each item by using MPS as an input and applying a set of procedures to generate a schedule for them. The commonly used terms of MRP calculation are briefly discussed below.

1. **Gross Requirement (GR):** GR is the total amount of sub-assemblies or components required to produce the demanded quantity of an item. For example, if 100 cars are required to be produced in a given production period and 8 roller bearings of same size are required for each car, then the gross requirement of the bearings is 8x100 = 800
2. **Scheduled Receipts (SR):** Scheduled Receipts are orders which are opened previously and are expected to arrive from vendors or elsewhere in the pipeline.
3. **On hand (OH)**: The expected amount of inventory that will be on hand at the beginning of each time period.

   On hand = scheduled receipt + available from last period
4. **Net requirement (NR)**: The actual amount needed in each time period.

   Net requirement = gross requirement - total scheduled receipt - on hand
5. **Planned order receipt (POr):** It is the quantity expected to be received by the beginning of the period in which it is shown under lot-for-lot ordering; this quantity will equal net requirement. Any excess is added to available inventory in next time period.
6. **Planned order release (POR):** It indicates a planned amount to order in each time period; equals planned-order receipts offset by lead time. This amount generates gross requirements at the next level in the assembly or production chain. When an order is executed it is removed from the "planned order-receipt" and planned-order-release row and entered in the "scheduled receipt" row.

3.5.4 MRP outputs

MRP provides management of a company with a fairly broad range of outputs. MRP outputs (see figure 3.4.1) are classified as ***primary reports***, which are the main reports, and ***secondary reports***, which are optional outputs.

A. ***Primary Reports***: These reports include planned orders schedule, planned order releases and possible change.

   a. ***Planned orders schedule***: It is a schedule indicating the amount and timing of future orders.

   b. ***Planned order release***: It is the process of authorizing the execution of planned orders.

   c. ***Change:*** It is report of notifying changes made to planned orders, including revision of due dates or order quantities and cancellation of orders.

B. ***Secondary Reports:*** These reports include performance control, planning, and exceptions.

   a. ***Performance Control Reports:*** They evaluate system operations. They aid managers by measuring deviations from plans, including missed deliveries and stock outs, and by providing information that can be used to assess cost performance.

   b. ***Planning Reports:*** They are useful in forecasting future inventory requirements. They include purchase commitments and other data that can be used to assess future material requirements.

   c. ***Expectation Reports:*** These reports call attention to major discrepancies such as late and overdue orders, excessive scrap rates, reporting errors, and requirement for non-existent parts.

3.6 Capacity Planning

Output level of an item is dependant on the production capacity of operating units (plants, departments, machines or workers) used to produce the item. **Production**

capacity is the maximum limit or ceiling on the load (product) that an operating unit can handle. It is the rate at which outputs are achieved from a process. It can be expressed as number of units that can be produced per unit of time, maximum size of a work piece that a machine can handle, or maximum weight of a work piece that can safely be loaded on a machine.

Capacity may be simple to measure for companies which produce single or limited amount of products. Automobile manufacturing companies measure their capacity in terms of number of vehicles produced per unit of time. Steel manufactures measure their capacity in terms of tons of steel produced per year. However, capacity measurement for companies which produce diverse product types (e.g. job shop companies) is very complicated task. It is impossible to state the annual production capacity for each product. What most job order companies use to measure their capacity is the available labor and/or machine hour per unit of time.

The capacity measures used in auto and steel companies are in terms of outputs. Inputs are used as capacity measures for job order companies. Therefore, an estimate of capacity may be measured in terms of either input or outputs. Table 3.6 shows some examples of capacity measures.

Table 3: 6 **Capacity Measurements**

	Measurement	
	In terms of	**Units**
Sugar Factory	Output	Ton of Sugar
Cement Factory	" "	' ' Cement
Automobile Manufacturers	" "	Number of Autos
Steel producers	" '	Tons of Steel
Job Shop	Input	Labor and/or machine hours
Air Line	" "	Number of seats
Hospitals	" "	Number of beds

For performance evaluation purpose capacities are grouped in to two. They are **design capacity** and **effective capacity. Design capacity** is the amount that a firm would like to produce under normal circumstances and for which the system was designed. **Effective capacity** is defined as the maximum possible output given a product mix, scheduling difficulties, machine maintenance, quality factors, and so on. Compared to effective capacity, design capacity is a capacity of ideal condition. Effective capacity is always less than or equal to design capacity. Actual output can not exceed effective capacity. Capacity efficiency can be evaluated as:

$$\text{Capacity Efficiency} = \frac{Actual\ \ Capacity}{Design\ \ Capacity}$$

The capacity of an operating unit is an important piece of information for production planning purpose. Together with the demand forecast results or customer orders, production capacity information can be used to generate feasible production plan. It enables production managers to quantify production capability in terms of inputs or outputs, and thereby make other decisions or plans related to these quantities.

The basic questions in capacity planning of any sort are the following.

1. What kind of capacity is needed?

2. How much of it is needed?

3. When is it needed?

The first question is raised depending on the nature of the product to be produced. For example if the items are small in size and large in quantity, the capacity in question is rate of output; how much units of items can be produced per day, week or month using the available facility? On the other hand, if the products are large in size and weight but small in quantity, the question will be determining the weight carrying capacity of machines and maximum dimensions of work piece that can be handled by the machines.

After determining the kind of the desired capacity, the second question to be raised is how much of it will be utilized. This question can be answered by comparing the product demand of each period with the available capacity. Utilizing the maximum capacity throughout the year may shorten the life of most machines. Therefore, it is advisable to adjust capacity utilization in proportion with product demand.

The third question is a question of timing. The design capacity may not be utilized uniformly throughout the year because of demand fluctuation, preventive maintenance planning or machine breakdown. Taking these factors into consideration, it is important to determine how much of the capacity to use at different times.

Capacity planning is the process of determining what labor time and equipment resources are required to meet the current MPS as well as long term future production needs of the firm. It is a critical activity that parallels the development of materials planning. Without the provision of adequate capacity or recognition of the existence of excess capacity, the benefit of an effective PPC system can not be realized. If the provided capacity is insufficient, the company may face deteriorating delivery performance, escalating work-in–progress inventories, and frustrated manufacturing personnel who will quickly turn back to an informal system to solve problems. On the other hand, excess capacity is a needless expense that should be reduced as much as possible. For example, some manufacturing companies like ASPSC have large number of machine duplicates like lathe machines, milling machines, gear hobbing machines and drilling machines which exaggerate the overhead costs. Even firms with advanced material planning capacity have found that their inability to provide the appropriate capacities of each work center prohibits them from gaining the maximum possible benefits. This emphasizes the importance of developing the capacity planning system in line with the production planning system. Therefore capacity planning is important to:

- meet future demand by adjusting the capacity to the fluctuating demand,
- minimize the initial cost, which is usually very high, to an optimum level, and
- increase competitiveness.

Availability of capacity which can quickly be increased may serve as a barrier against entry of competitors to the market.

Capacity planning involves the following general steps.

1. An assessment of the existing capacity
2. Forecasting estimates of future capacity needs (product, human and technological) over a selected planning horizon
3. Identification of alternative ways to modify capacity
4. Financial, economical, and technological evaluation of capacity alternatives, and
5. Selection of a capacity alternative most suited to achieving strategic mission

3.6.1 Hierarchy of Capacity Planning

Like production, capacity is planned hierarchically. Figure 3.12 shows the hierarchy of capacity planning and its relations to other modular activities.

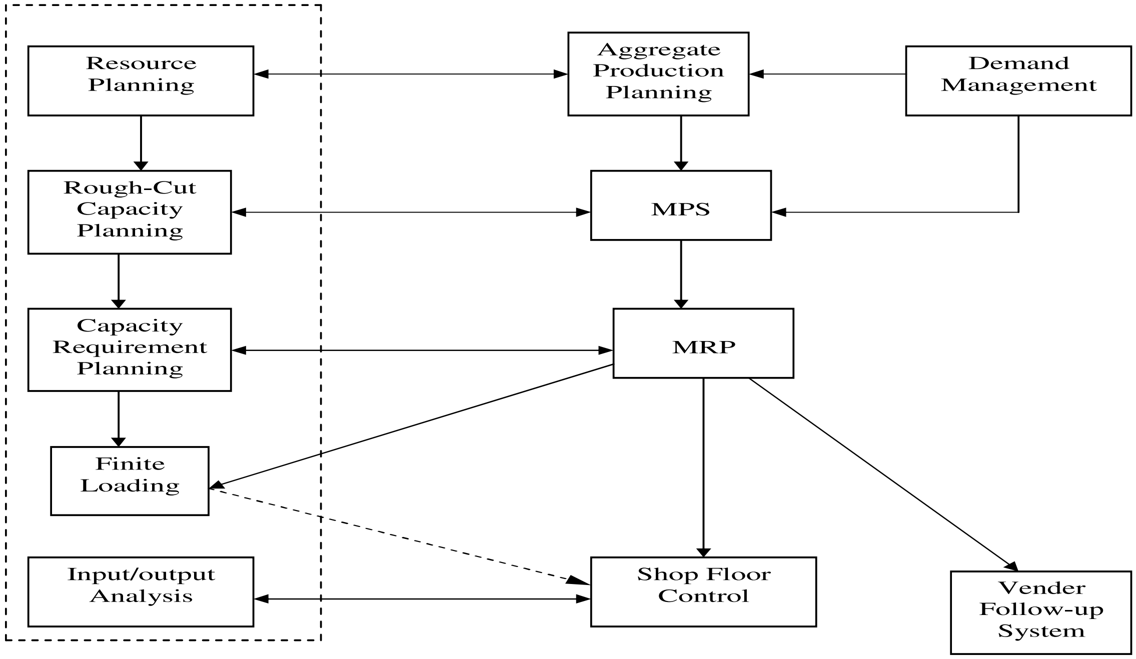


Figure 3: 12 Capacity Planning in PPC Systems

The issue of capacity planning starts at the moment aggregate production planning is started. It can be divided into five levels of activities, which range from large aggregation of capacity for long time period to very detailed machine scheduling for an hour or shorter time interval. The five levels of capacity planning are briefly discussed below.

1. **Resource planning**: It is also referred to as aggregate capacity planning. It is the process of testing the feasibility of aggregate production planning and evaluation of overall capacity utilization. Resource planning, which covers the longest range of capacity planning decisions, typically involves converting monthly, quarterly or even annual data from the production plan into aggregate resources such as gross labor hours, floor space, machine hours, and the like. This level of capacity may require new capital expansion, which requires a time horizon of months or years.

2. **Rough-cut capacity Planning**: In this capacity planning level, the feasibility of MPS is tested in terms of capacity. This planning level insures that the load distribution to all departments or machine centers is appropriate and the MPS is feasible. In rough-cut capacity planning, priority is given to the identification of bottleneck machines. These machines should be checked if they could handle all the planned production activities without serious backlog.

3. **Capacity Requirement Planning (CRP)**: CRP is the process of determining what personnel and equipment capacities (times) are needed to meet the production objectives embodied in the MRP. It is performed in conjunction with MRP. At this level, more accurate comparisons of available and needed capacity for scheduled workloads are made possible.

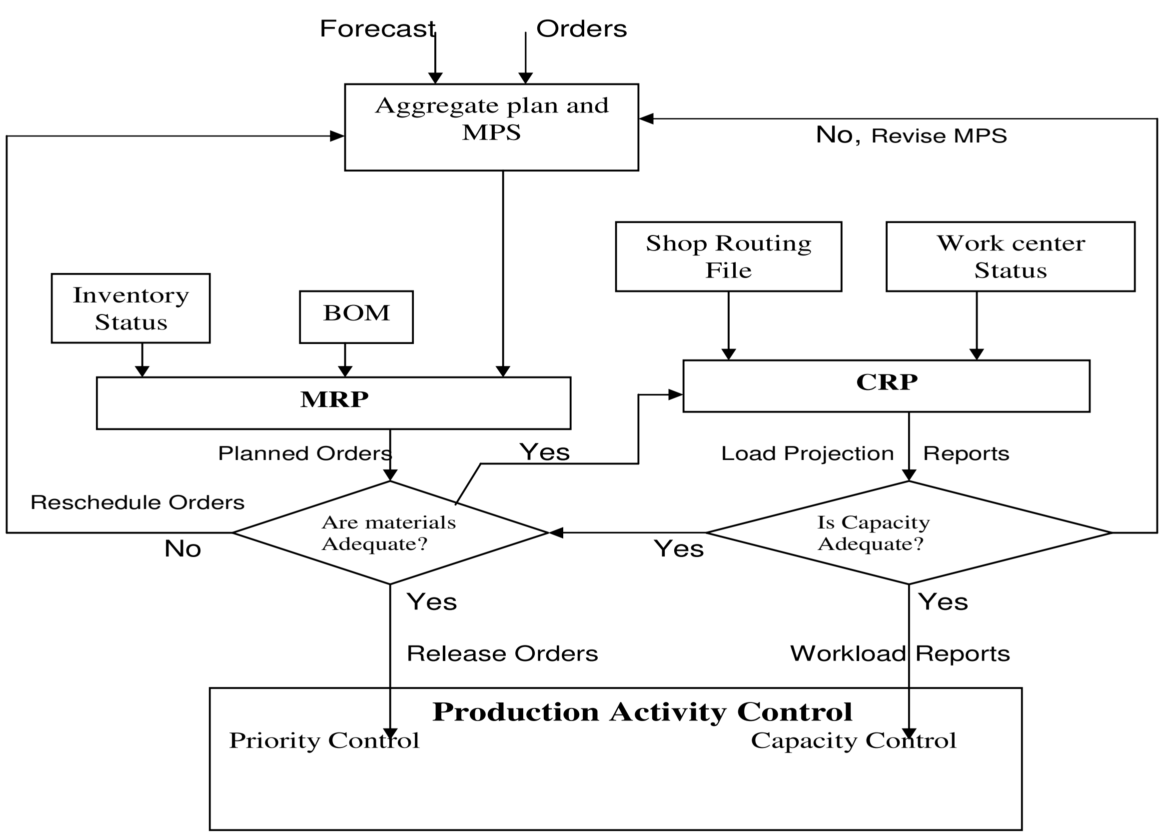


Figure 3: 13 Material and Capacity planning flow chart

4. **Finite Loading**: It is capacity planning level that shows the shop floor schedule. Based on information obtained from CRP and MRP, finite loading is prepared to clearly show the production scheduling and capacity availability at different times. Finite loading starts with a specific capacity level for each work center or resource grouping; this capacity is then allocated to work orders. Finite loading is used as an input for shop floor control.
5. **Input / Output** Analysis: Input / output analysis provides a method for monitoring and controlling the actual consumption of capacity during the execution of material plans. It is necessarily linked to the order execution systems and database for shop floor control. Input/output analysis can indicate the need to update capacity plans when actual shop performance deviates from current plans.

As a summary, the following principles of capacity planning can be stated.

- To realize production plans, capacity plans must be developed concurrently with them.
- Capacity planning techniques must be chosen to match the level of detail and actual company circumstances.
- Capacity planning processes can be simplified by developing good production planning.
- Capacity not only must be planned, but the achievement of that plan must also be controlled.
- The capacity measure should reflect realizable output from the key resource.

3.7 Shop Floor Control

Shop floor control (SFC) is an essential part of the overall production planning and control tasks of a company, responsible for operational control of the manufacturing related activities. SFC can be defined as a system for utilizing data from the shop floor as well as data processing files to maintain and communicate status information at shop orders and work centers **[5]**. It is concerned with the execution and control of production activities in different manufacturing shops of a company. It is the process of releasing production orders to the shops, monitoring and controlling of their progress at different work stations, and collecting current information on their status. An effective shop floor control system can lead to good due-date performance which satisfies customers' expectation. It reduces WIP inventory; and lead-times of most end items can reasonably be reduced.

The major functions of shop floor control are the following:

1. Assigning priority of each shop order,
2. Maintaining WIP quantity information,
3. Conveying shop order status information to office,
4. Providing actual output data for capacity control purpose,
5. Providing quantity of WIP at each location for accounting purpose, and
6. Providing measurement of productivity of manpower and machines.

SFC has three phases of activity. They are order release, order scheduling and order progress. SFC phases and their interaction with other PPC activities are shown in figure 3.14.

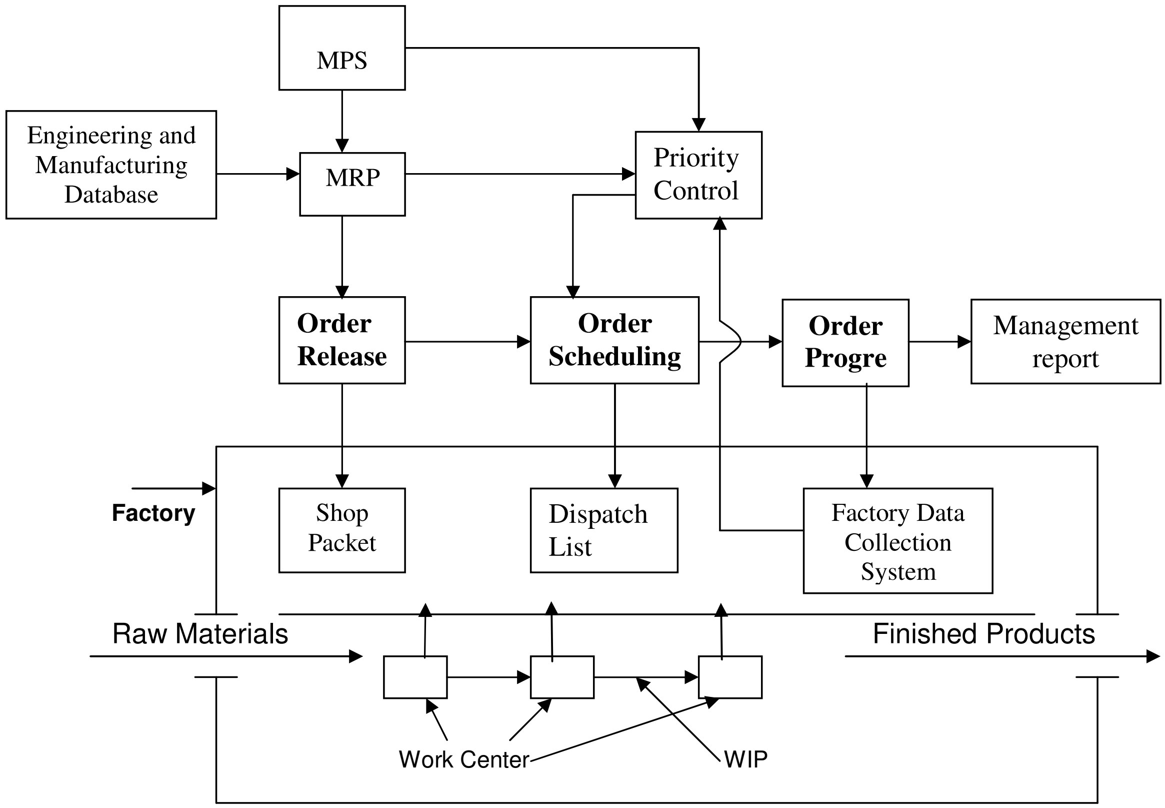


Figure 3: 14 **Shop Floor Control Phases (Bolded)**

1. **Order Release**: Order release converts a need from planned order status to a real order in the shop. In this first phase of SFC, production orders are documented to be dispatched to shop floor. Proper documentation of all orders enables the production controller to identify the routing of each product, materials required for the production, periodic status of each job. The collection of documents which facilitate production improvement is called **shop Packet.** It may consist of:

    i. **rout Sheet,** which shows the production sequence and machine selection to produce each component,

    ii. **material requisition,** which is used to draw necessary raw materials from inventory,

iii. **job card:** a slip which is used to record the direct labor time devoted to produce an item, and to indicate the progress of an item in a workshop,

iv. **move ticket,** which is used to authorize the material handling personnel to transport parts between work centers, and

v. **part list,** Which may be used for assembly production to show list of parts used in the assembly work.

2. **Order Scheduling**: Order scheduling phase, which directly follows from order releasing, is the process of assigning production orders to various work centers. In this module, a **dispatch list**, which indicates the allocation (loading) of production orders at various work centers, is prepared. The two problems that order scheduling phase solve are machine loading and job sequencing. **Machine loading** is allocating production orders to machine centers. Appropriate machine loading minimizes queue length of orders at each machine center. Not only machine loading but also logical job sequencing reduces queue length. **Job sequencing** is determining the sequence in which jobs will be processed in a given machine center. It is determined effectively by using appropriate priority control rules discussed below. Companies which produce multiple types of products have many jobs waiting to be produced. To decide which jobs to come next to which, one of the following priority rules is applied.

i. **First come first served (FCFS)**: In this rule, jobs are processed according to their arrival at the work center.

ii. **Earliest Due Date (EDD)**: Orders with earlier due dates are given higher priority.

iii. **Shortest Processing Time (SPT)**: Jobs with the shortest processing time are processed first.

iv. **Least Slack (LS)**: Slack, which is the difference between process time and due date, is first calculated. Then, orders with the least slack are decided to be processed first.

v. **Critical ratio (CR)**: CR is defined as the ratio of due date to processing time. Orders with the lowest critical ratio are given higher priorities.

vi. **Preferred Customer Orders:** According to this rule, some customers may be given priorities whether they reach first or last. Companies use this rule to give priority to major customers, when they are ordered by institutions like ministry of defense, or if the customer agrees for additional payment.

3. **Order Progress**: Order progress phase of SFC monitors the status of various orders in the plant. In this phase, production orders are expedited. **Expediting** is the process of tracking a job's progress and taking special actions to move it through the facility. Order progress provides information that is useful in managing the factory's production activities. The information is summarized in the form of reports as follows.

   a. **Work order status reports:** These reports show where each order is currently found, how much each workstation is loaded, and they can show raw material status.

   b. **Progress reports:** These reports are intended to show the performance of a company's workshop in a certain time period. It is used to compare the actual performance with the plan.

c. **Exception reports:** They indicate major deviations from the production schedule, or exceptionally achieved production performances.

Factory data collection is an activity performed in the order progress phase of SFC. Collecting necessary data and analyzing them is useful to monitor the trend of production. Feedback for future improvement can also be obtained. Data collection system may be manual, semi-automated or fully automated. Whether manual or automated, data collection is aimed at:

1. supplying status and performance data to the shop floor control system and
2. providing current information to production foremen, plant management, and production control personnel.

3.8 Inventory Control

Inventory is a store or stock of goods including raw materials, WIP, finished goods or supplies **[1]**. It is a set of activities that maintain stock keeping items (inventories) at desired level. Inventory control is concerned with two opposing objectives: (1) minimizing cost of holding inventory and (2) maximizing customer service. Inventory holding cost can be minimized by reducing the size of inventory to a minimum level, in the extreme case, to zero stock. Customer service maximization, on the other hand, is attained by keeping large stocks on hand from which the customer can choose and immediately take procession.

The most common problems with inventory are that they are uncontrolled, inefficient, costly and unreliable.

Implementation of appropriate inventory control systems is used to:

a. maintain a proper variety of required items,
b. increase inventory turnover,
c. reduce and optimize inventory and safety stock levels,
d. obtain lower raw material prices,
e. eliminate obsolete items,
f. increase cash flow and working capital,
g. reduce storage cost,
h. reduce insurance cost,
i. reduce taxes and
j. reduce insurance cost.

The types of inventory of great interest in PPC are raw materials, component parts, WIP and finished goods. Inventory costs which depend on the **order/manufacturing size (Q)** of inventory are inventory carrying cost, and set up or ordering costs. Inventory holding cost is the sum of investment costs, storage costs and cost of obsolescence or spoilage. Holding costs can be minimized by reducing inventory size. However, inventory size reduction results in shortage of finished goods to sale for customers according to their desire. Hence, dissatisfied customers will be forced to search for other suppliers. Cost incurred due to inventory shortage is **stock-out** cost. Therefore, PPC system of a manufacturing company is intended to balance the two contradictory costs: holding cost and stock-out cost.

Inventory control of PPC system addresses two basic questions.

1. How many units should be ordered?
2. When should the order be placed?

The first question is solved by identifying the economic order quantity (EOQ), which minimizes total inventory cost by optimizing different contradicting inventory cost components. The second question is an issue of determining reorder point (ROP) to replenish the inventory before total depletion.

3.8.1 Order/Manufacturing Quantity Determination

One of the main problems that manufacturing companies face in their production control stage is how to determine the quantity of raw materials to be purchased, the quantity of finished goods to be kept at stock. Some companies may have relatively constant rate of raw materials requirement. There are also companies whose raw material requirements fluctuate due to fluctuating demand of end products. Demand fluctuation of end products is common problem of job order companies like ASPSC.

Determination of order quantity in a constant demand rate situation is simple as compared to that of fluctuating demand situation. Different approaches are employed to determine order quantity. The most widely used approach is economic order quantity (EOQ) determination. EOQ can be formulated for the assumption of constant demand rate. Figure 3.15 shows the inventory level of item over time. Since the demand rate is constant, the inventory size decreases at constant rate. The order quantity brings up the inventory level to its maximum value at an instant of time.

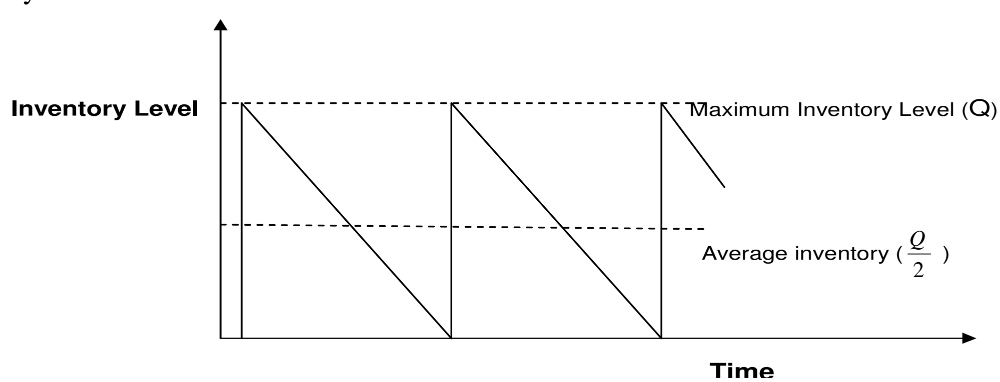


Figure 3: 15 Inventory Level

Basic EOQ is developed using the following assumptions.

1. ***Only one product is involved***
2. ***Annual demand is known***
3. ***Demand rate is reasonably constant***
4. ***Lead time dose not vary***
5. ***Each order is received in a single delivery***
6. ***There are no quantity discount***

Using the above assumptions, the total inventory cost which is a function of order quantity (Q) is given as follows.

TC (Q) = Setup cost + Carrying cost   Where TC = Total Cost

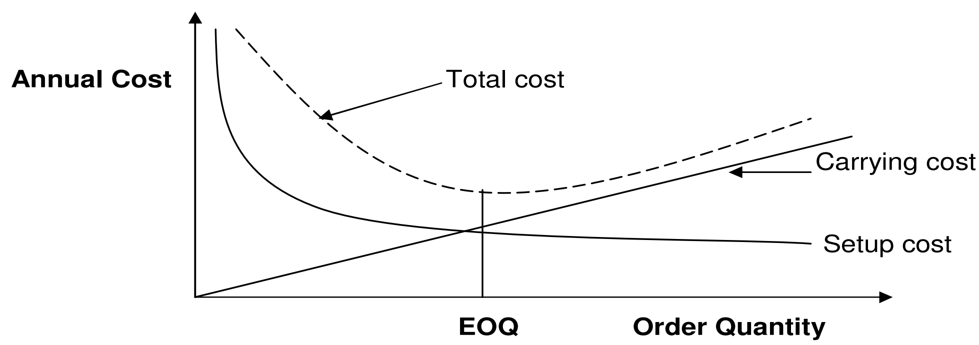


Figure 3: 16 Total Cost Curve

Setup Cost = $\frac{C.D}{Q}$ Where: C= Setup cost

D = Annual demand

Q = Order/manufacture Quantity

Carrying Cost = $\frac{H.Q}{2}$ Where: H= holding cost per piece per year

- TC = $\frac{C.D}{Q} + \frac{H.Q}{2}$

Total cost is minimum at $\frac{dTC}{dQ} = 0$

- $\frac{d}{dQ}(\frac{C.D}{Q} + \frac{H.Q}{2}) = 0$
- Q = EOQ = $\sqrt{\frac{2DC}{H}}$

3.8.2 Reorder point Determination

EOQ models answer the question of how much to order but not the question of when to order. After the economic order quantity is determined, the time when to order that quantity needs to be specified. Models that answer when to order are reorder point (ROP) models. ROP models are used to indicate when the quantity of an item drops to a given point, the item is reordered. There are four determinants of reorder point:

- Demand Rate (usually based on a forecast result)
- Lead time
- The extent of demand and/or lead time variability
- The degree of stock out risk acceptable to management

If the demand rate and lead time are constant, the reorder point is simply:

POR = Demand rate X Lead time

But in the actual case, demand rate and lead time can not be constant. To avoid depletion problems due to demand and lead time variability, it is necessary to consider additional inventory call **safety stock**. The ROP, therefore, will be:

ROP = Expected demand during lead time + Safety Stock

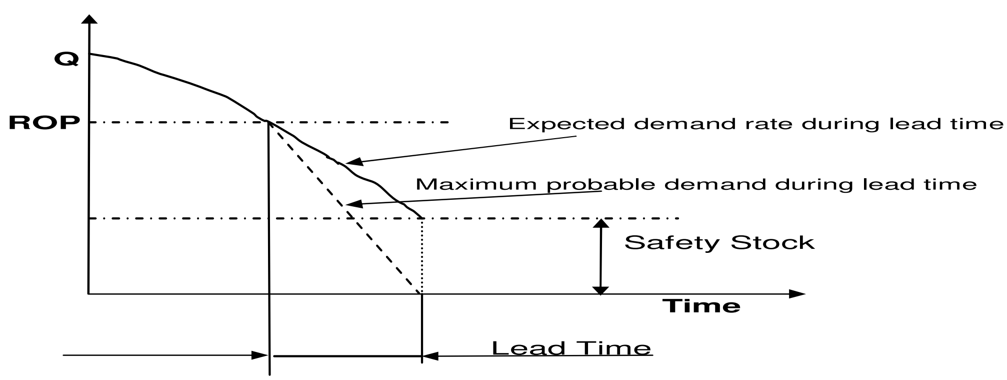


Figure 3: 17 Reorder point (ROP)

3.9 Manufacturing Resource Planning (MRP-II)

As it was discussed in section 3.4, material requirement planning is limited to planning of raw materials purchase order and factory work orders. It is strictly a material and parts planning tool whose calculations are strictly based on MPS. Since it has no feedback system to monitor how much its plans are accomplished, MRP is referred to as an **open-loop** system. To create an integrated PPC system, it was believed that MRP module should be tied to PPC packages. The PPC activity that evolved from MRP, which is used to tie MRP with other production control modules is manufacturing resource planning (MRP-II).

MRP-II can be defined as a computer based system for planning, scheduling, and control of materials, resources, and supporting activities needed to meet the MPS. It is expanded approach to production resource planning, involving other areas of a firm in the planning process such as marketing and finance. It is a closed loop system that integrates and coordinates all of the major functions of the business to produce the right product at the right times. It incorporates feedback data on various aspects of operating performance so that corrective action can be taken in a timely manner: i.e. MRP-II includes a shop floor control.

Mostly, production, marketing and finance operate without complete knowledge of what other areas of the company are doing. To lead a company into success, all areas of the firm need to focus on a common set of goals. MRP-II is, therefore, intended to integrate PPC functions such as forecasting, operations planning, inventory management, MRP calculation, dispatching and process control. It allows a manager to explore various ‘what if’ questions. Figure 3.18 shows MRP-II structure.

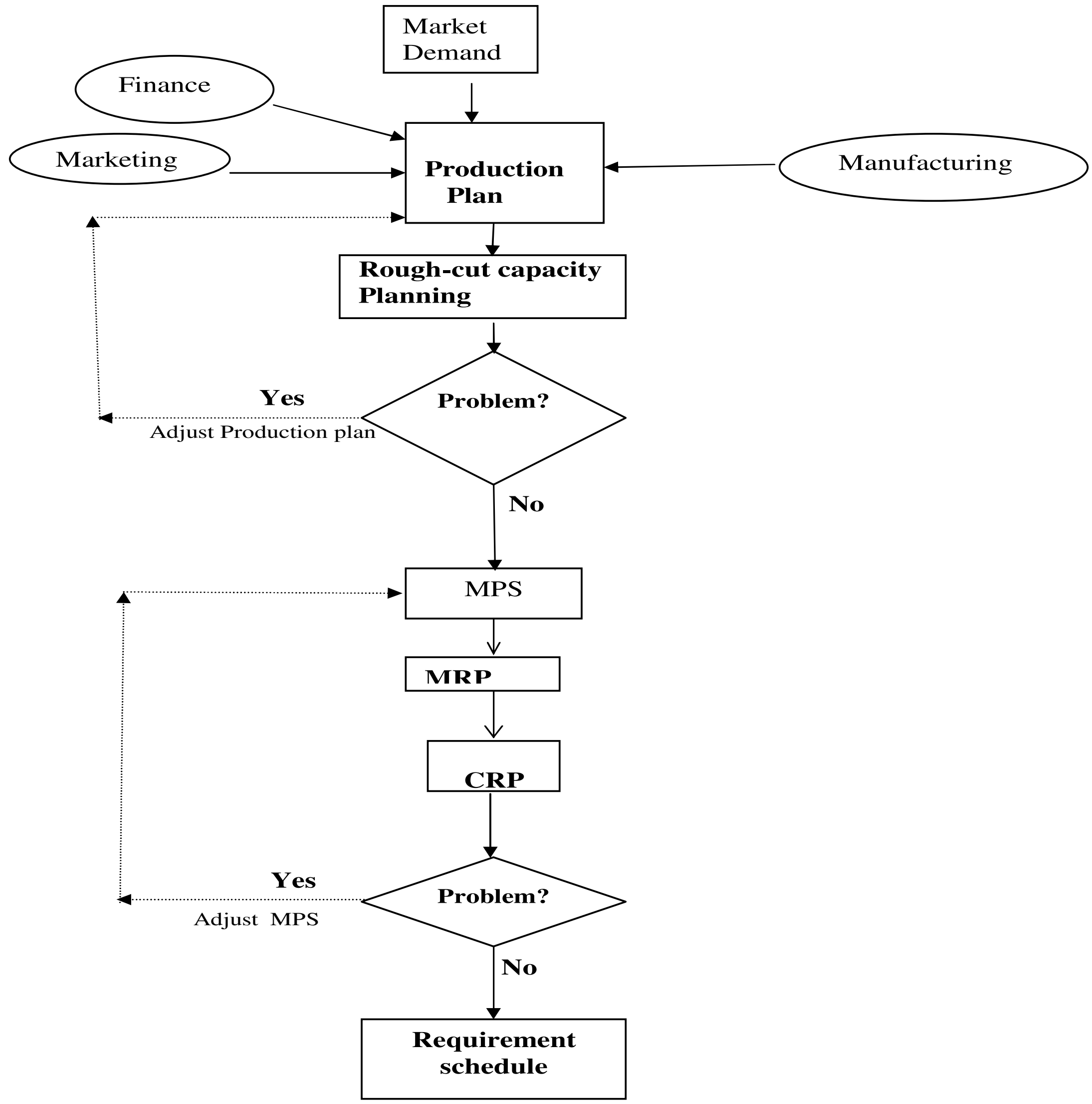


Figure 3: 18 MRP-II Structure

As the MRP-II structure shows, production planning, capacity planning and production control activities are integrated. The aggregate production plan is developed by the participation of finance, marketing and manufacturing departments. Materials requirement planning module is found at the heart of the MRP-II structure.

3.10 Just In Time (JIT) Manufacturing System

JIT is a production philosophy which is used to reduce production wastes by minimizing raw materials, WIP and finished goods inventory sizes. It fosters continuous production improvement by reducing in-plant inventories and developing the supplier and system capabilities to produce quality goods in relatively small lots when needed, i.e. just in time.

Main objectives of JIT production system are eliminating disruption, making the system flexible, reducing setup times and lead times, minimizing inventory of raw materials, WIP and finished products, and eliminating waste. It has the following distinctive features that make it different from traditional way of production.

1. Close tie with reliable few suppliers
2. Low inventories of raw materials, WIP and finished goods
3. Pull type movement of work through the system.
4. Small lot sizes with shorter lead times
5. Multi skilled flexible and responsible workforce

JIT is best to be applied if a company has warehouse shortage, capital shortage or if it produces easily perishable products. JIT was first developed in Japan at the Toyota motor company. As Japan is small country, JIT is used to alleviate space problem. In the Ethiopian companies' case, space may not be the problem to think of JIT. But, capital shortage forces them to think of it. Stocks of raw materials should not tie up considerable amount of capital. Therefore, it is logical to consider JIT production system in Ethiopia.

CHAPTER FOUR

JOB ORDER COMPANIES IN ETHIOPIA

4.1 What is meant by Job Order Company?

In chapter three, we have seen that production environments can be divided into four: make to stock, assemble to order, make to order and engineer to order. A company which is in the first production environment (make to stock) does not wait for its customers' order to produce its products. It produces and keeps stock of the finished goods.

On the other hand, companies which are in assemble to order, make to order or engineer to order production environments are not allowed to produce end products without getting customer orders. Their end products have to satisfy the interests of the end users. In fact, the three production environments have different levels of accomplishment. Assemble to order companies produce components and sub-assemblies and wait for their customers to order final assembly of end products. Make to order companies prepare designs of different products and they wait for their customers to select from the designed products. Engineer to order companies design their end products based on their customers' specifications. Even though their levels of changing raw materials to finished goods (before getting customer orders) are different from each other, the three production environments have something in common. The production size of their end products is strictly dependant on customer orders.

Job order companies can be defined as production companies which produce their end products after getting orders from their customers. All companies which are found in the ATO, MTO or ETO production environments are job order companies. Since their production rate dependant on the customer order size, job order companies have intermittent production system. At some time their workshops may be full of jobs; and some other times most of them may be idle.

The main challenge of job Order Company is that their production is not uniformly distributed. When they assume that they can get enough orders to make their workshops busy, they may fail even to acquire a single order. To the contrary, there are times when they are successful to win customer orders more than their expectation. Such customer order fluctuations are dependant on many conditions. Some of the conditions may be:

- seasonality of end products,
- emergence of unexpected opportunities,
- entrance of strong competitors,
- exit of weak competitors and
- changes in the economic development of a country

Since the product nature of most job order companies is difficult to predict in advance, it is a challenging task to prepare the annual production plan. An item which covered considerable percentage of the previous year's production size may not totally be ordered in the coming year. On the other hand, the company may be chanceful to get unexpected new order. The unpredictable fluctuating nature of product demand, which in turn makes the order size fluctuate, leaves the production plan to be unreliable. For example, in a given month, the company might have planned to manufacture 100 sets of steel chairs. However, when the month comes, the company may not have any order of chairs. It may, instead, have an order of 50 sets of water tankers. According to its plan, the company prepares raw materials for the steel chairs. But, at that specific month, what the company needs is raw materials for water tankers. For the case example, raw material difference is not the only problem. Process requirements, process time, and processing sequences of steel chairs and water tankers are also completely different. Such problems force most job order companies to revise their production plans when the actual orders differ from the plans.

To minimize discrepancies between planned raw material requirements and actual requirements, job order companies have to use appropriate forecasting techniques which are discussed in chapter three, section 3.2.

4.2 Job Order companies in Ethiopia

Ethiopia, which is one of the developing countries, has production companies which produce various types of products. Even though large percentage of its economy is based on agriculture, the production industry is also contributing a lot to the development of the country.

As any county's companies, Ethiopian production companies can be grouped in to make to stock (MTS) and job order companies. Some of the make to stock companies in the country are sugar factories (Wonji, Methara and Fincha), Breweries (Meta-Abo, St. George, Harar, Bedelie, Bati and Dashen), Cement factories (Mugher, Dire-Dawa and Mosobo), Textile factories (Akaki, Dire-Dawa, Awassa, Bahir-Dar, Arbaminch and Almeda), and others. All the above companies produce their end products and stock them at their main warehouses or distribute to branch warehouses for sale. Their production performance, which compares the actual production with the plan, is usually greater than 90%. This is because their end products are specific and raw materials are limited in type. Except the textile factories, most Ethiopian MTS companies are profitable.

Some of the job order companies in Ethiopia are:

- Akaki Spare Parts and Hand Tools Share Company, ASPSC
- Mesfin Industrial Engineering, MIE
- Maru Metal Works
- Radel Workshop

All the above companies produce 70-80% of their end products after getting orders from their customers.

ASPSC produces different spare parts, hand tools, cutlery and sheet metal products based on its customer orders. The company sometimes produces cast iron ingot bars, bronze ingot bars, brass ingot bars, cutlery, and hand tools as shelf items.

Mesfin Industrial Engineering produces liquid cargo trailer and semi trailer bodies, dry cargo trailer and semi trailer bodies, stone crashers, penstocks, and other sheet metal products. It gives machining services to vehicle parts like engine blocks and brake drums. Currently, almost all the company's products are produced after customers order them.

Maru Metal works produces trailer and semi trailer bodies, constructs steel structure of warehouses, oil stations and the like. Almost all its products are order dependant.

Radel workshop produces different cast and machined spare parts which are ordered by customers. There are also production companies which have partial job order nature. Examples are:

- Akaki Metal Products Factory,
- Kality Metal products Factory,
- Ziquala steel rolling mill and
- Ethiopian Iron and Steel Factory, EISFA.

These companies have considerable amount of products which are manufactured as shelf items. Akaki metal products factory produces galvanized roofing sheet and different size galvanized water pipes without getting orders from customers. Kaliti metal products factory produces different profiles of square pipes, corrugated sheets, circular pipes and angle iron in an MTS environment. Ziquala steel rolling mill and EISFA produce various size reinforcement bars which are used for beam and column re-enforcement. These companies, as any job order company, also receive customer orders and produce items according to their customers' desire. Ziquala steel rolling mill and EISFA, for example, produce smooth round bars of various diameters ranging from 15mm to 25mm when they are ordered. Kality metal products factory also produces water and fuel tankers, different sheet metal products, and steel structures for warehouse construction according to its customer orders.

CHAPTER FIVE
DATA COLLECTION

Data collection is the process of searching for important information and gathering it for further analysis. The data may be obtained from reports, journals, procedure manuals, physical observations, interviews and responses to questionnaires. After collecting the raw data, the researcher analyzes them the way he/she intends to analyze, and draws conclusion based on result of the analysis.

To analyze main problems related to the production planning and control system of ASPSC, relevant data were collected from different companies. In the data collection process, the following procedures were used.

1. Introducing the objective of the research to the concerned officials in the visited companies,
2. Visiting production flow in the factories,
3. Distributing questionnaires to **Concerned** workers, and
4. Interviewing them to strengthen the information obtained using the questionnaires.

The companies which were visited are categorized into three:

1. ASPSC, which is the main case company of the thesis work
2. Job order companies which are assumed to have similar Product nature to that of ASPSC
3. Samples of major customers of ASPSC

5.1 Data collection from ASPSC

Since the main objective of the thesis is analyzing the PPC problem of ASPSC and proposing methods of improving the system, various useful data are collected from different divisions of the company.

A. The production system of the company is physically observed.

B. Different department managers, division managers and concerned workers were interviewed and asked to respond to the questionnaire designed for ASPSC workers.

C. Raw data of monthly production performance, sales performance reports, monthly order on hand reports, monthly quality assurance service reports, and cost variance reports of cost and budget division are collected.

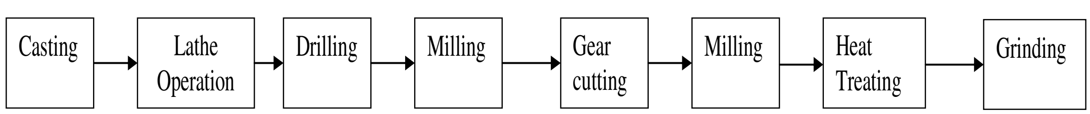
D. The existing PPC system of the company was studied in detail (refer Chapter six).

A. Physical (Personal) Observation

From the physical observation of the production system, it is understood that different products of the company follow different production processes. Main processes of the company are summarized as:

- **casting** (pattern preparation, molding, melting, Pouring, shot blasting)
- **machining** (turning, milling, Gear tooth cutting, grinding and drilling)
- **sheet metal fabrication** (plate shearing, rolling, bending and welding)
- **forging** (upsetting, forging)
- **forming** (punching, thread rolling, blanking, an piercing)
- **surface treatment** (galvanizing, chrome-plating, and phosphating) and
- **heat treatment** (annealing, hardening, tempering, and galvanizing).

Depending on its nature, a product may pass through most or some of the above processes. For example a heavy duty gear of diameter 600mm may pass through the following processes.



On the other hand, there are simple products which pass through few parts of the available process. For example, a light duty shaft needs only the following processes.

In short, the company has diversified production process which gives opportunity to manufacture different types of products. If there is skilled manpower and market demand, the company has capacity of producing more than 90% of the automobile parts.

B. Interview / questionnaire responses

Questionnaires were distributed to some selected workers of the company. The selection was partially biased and partially random. Department and division heads were deliberately selected. Planning engineers, sales engineers and shop planners were randomly selected. As some workers preferred the response to be in interview form, they were interviewed. Others filled the questionnaire. The interviewed workers of the company are concerned department, division and section heads, sale engineers, production planning engineers and workshop planers. Totally, 20 workers were interviewed.

The manufacturing department manager and DPPC division manager have been contacted many times starting from the time of proposing the thesis. The Marketing and supplies department manager and the Sales and Sales promotion division heads were formally contacted twice to discus about market assessment problems of the company, customer handling problems, after sales service, and other relevant issues. The questionnaire prepared for ASPSC workers is shown on Appendix A. Objective of the questionnaire is to survey response of the workers about the following important issues.

1. ***Major products of the company***
2. ***Customer identification***
3. ***Major tasks of PPC***
4. ***Comments on the existing PPC system***

5. ***Production planning procedures of ASPSC***
6. ***Forecasting technique utilization***
7. ***Reasons for failure to attain delivery date***
8. ***Test of customer satisfaction***
9. ***Cost estimation and evaluation procedures***
10. ***Capacity utilization measures***
11. ***Major performance reports***

Summarized responses of questionnaires and interviews are discussed in section 6.3 of chapter six.

C. Data obtained from performance reports

To observe the trend of production performance, capacity utilization, complaints on failure to attain delivery date, and failure due to defect of two budget years relevant raw data are collected. The collected data are shown in Appendix C.

5.2 Data Collection from Other Job order Companies

To compare the PPC system of ASPSC with other job order companies, some selected job order companies from the metal sector were visited.

They are:

- **I.** Hormat Engineering
- **II.** Mesfin Industrial Engineering
- **III.** Kality Metal Products Factory
- **IV.** Maru Metal Industry
- **V.** Radel Foundry
- **VI.** Ziquala Steel Rolling Mill

At each company, the production systems were visited and questionnaires were distributed to concerned workers. The questionnaire prepared for other job order companies is shown on Appendix B. The questionnaire is designed to collect information about the following points.

1. ***Main products of the company***
2. ***Production flow***
3. ***number of workers***
4. ***Plant layout of the factory***
5. ***Customer identification and handling methods***
6. ***PPC department presence and its tasks***
7. ***Procedural planning activities***
8. ***Forecasting techniques used in the planning process***
9. ***Job initiation and dispatching procedures***
10. ***Survey on customers' response***
11. ***Manufacturing cost estimation and evaluation techniques***
12. ***Capacity utilization evaluation and improvement system***
13. ***Major performance reports of the company***

Physical observations and summarized responses to interviews /questionnaires of each company are briefly discussed as follows.

I. Hormat Engineering:

The researcher has made two days visit in the factory. It is constructed to increase the military strength of the country. It produces five types of heavy duty riffles. Ministry of Defense is its owner and customer. The factory is not profit oriented. Currently, it is not engaged at full capacity production. The factory has five districts. Among them, the machine and foundry shops were visited. The machine shop consists of different capacity press machines, copy lathe machines, lead through robots, and other light duty machines. In the machine shops round bars of different sizes are cut, heated, forged extruded and turned to produce the desired size of bullets. Main raw materials used in the machine shops are steel and bronze round bars. Steel round bars are used to produce the bullet; and bronze round bars are used to produce the cartilage. The foundry workshop consists of induction furnaces, dry sand molding system and other machines.

In the shop, one of the five product types is cast and sent to machine shop for further machining.

The production and technique department head was given a questionnaire prepared for job order companies. After seeing it, he proposed that it would be better to make it in an interview form.

Summary of the interview's response contains the following main points.

- The factory has 700 workers.
- The plant layout is more or less process type
- The factory does not have formal PPC system
- It has not yet started to produce at full capacity.
- There is no production cost estimation
- If a product is planned to be produced, it will be produced whatever it may cost.
- The factory has not started to prepare its annual business plan.
- Currently, the main objective of the factory is on job training of its workers.
- For the future, it has the plan to develop an organizational structure which includes PPC as a division or section.

II. Mesfin Industrial Engineering (MIE).

MIE, which was founded at Mekele in 1992, was visited for four days. Most of its produced items are sheet metal products. Its main products are truck mounted water and fuel tankers, truck body, bus body, depot shell, overhead crane, stone crusher, and warehouse hangar structures.

The factory has three main units.

- **Material preparation unit**
- **Fabrication unit**
- **Machine shops**

The **material preparation** unit consists of shearing, rolling, bending and torch pantograph cutting machines. The pantograph and bending machines are computerized and hence, most manual works are replaced by automatic works. In this unit, raw materials, mainly plates and sheet metals, are cut, rolled and/or bent to prepare them for further fabrication.

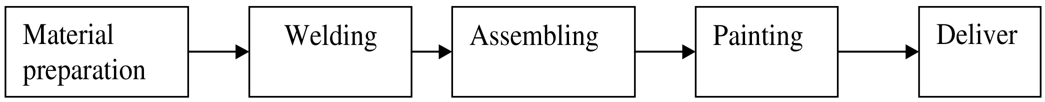
In the **fabrication units**, welding and assembly works are performed. The units are flexible to produce different products. For example, a unit which produces truck mounted tanker can be used to produce penstocks. The only thing to do is to prepare jigs and fixtures which fit to the desired product. The high capacity fabrication unit of the company is mega rolling unit. It is used to roll and weld fuel reservoir of up to 80,000,000 liters capacity.

The **machine shop** consists of old model lathe, milling, crankshaft grinding, honing, and other machines. The shop is used to produce accessories for the fabrication units' products, and to give service for customers like grinding, brake drum boring, cylinder honing and so on.

The company is profit oriented; and it has been profitable since its establishment. The interviewed workers are the acting PPC section head, production planning engineers, and production engineers. Respondents of the questionnaire and interview say that the company almost knows its customers. Some of them are companies from the transport sector, construction companies, different factories like cement and brewery.

Responses to questionnaires, interviews and physical observations can be summarized as follows.

1. The factory has 450 workers.
2. Production flow in the workshops depends on the type of products. However, most products follow the following general procedures.



3. The factory tries to follow main activities of PPC (APP, MPS, MRP) when it prepares annual, monthly or weekly production plan.
4. Manufacturing cost is estimated by a group of engineers from PPC, design and quality control divisions.
5. Actual manufacturing cost is not properly evaluated. Actual time spent for each operation is not recorded.
6. Compared to ASPSC, MIE has selected types of products, and this simplifies shop floor control
7. Delivery times of most products are attained. About 80% of our customers are satisfied with our delivery time and product quality.
8. The quality assurance division has five types of non destructive tests: visual inspection, x-ray test, ultrasonic test, electromagnetic test, and liquid penetrating test.

III. Kality Metal Products Factory

The factory was visited for one day. Its major products are different sizes of roofing sheets (EGA300, EGA400, EGA500, EGA600 and EGA700), Square pipes, circular pipes, LTZ profiles, Secco profiles, Cut to size plates, windows, doors, fuel tanks and so on.

Activities done in the data collection are visiting the workshop and interviewing the PPC division head.

The workshop has two units. They are **construction unit** and **manufacturing unit**. The construction unit produces tress, doors, form works, window, and warehouse hangars according to customers' desire. The unit is totally dependant on customer orders. The manufacturing unit produces stock items, whose production orders are initiated based on the annual production plan of the factory. These products are square pipes, rectangular pipes, circular pipes, LTZ profiled pipes, Secco profiled pipes, EGA roofing sheets, and cut to size plates.

Summarized response of the interview made to the PPC head contains the following main points.

1. The factory has 295 workers.
2. Almost all products use two types of raw materials: coils of black sheet metal or coil of galvanized sheet metal.
3. The factory is partially job order type and partially MTS type. Above 75% of its annual production is produced in an MTS environment.
4. The plant layout of the factory is more or less product layout type.
5. Main customers of the company are construction companies, private and government owned workshops, fuel stations, and warehouse building companies.
6. The factory has PPC division
7. Business planning is informally understood as annul production planning
8. Aggregate production planning is performed properly.

9. Design capacity of the factory is not clearly known. We are trying to set the effective capacity of the plant in terms of some selected products.
10. Cost estimation standards are already set in terms of birr per Kg for different levels of production complexities. Actual cost is evaluated and used for future cost revision.
11. Since the companies products are limited in type and large in quantity, production control is not that much difficult
12. Computer soft wares like MS word and MS excel are used for annual production plan preparation and report generation

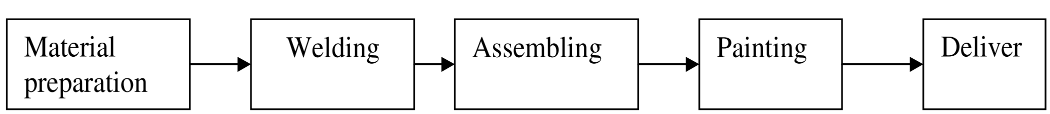
IV. Maru Metal Industry

The researcher has contacted the company for two days. Activities of the data collection include visiting the workshop and interviewing the deputy general manager.

The factory's major products are liquid cargo bodies, trailers, warehouse hangars, and various sheet metal products.

Summarized responses of interview made to the deputy general manager contain the following main points.

1. The factory has 108 workers
2. Production flow of the company can be stated in a condensed way as:



3. The plant layout of the factory is more or less product type. But, it is flexible to adjust it to suit different types of products.
4. The factory knows is present and potential customers. It makes market assessment to properly identify them.

5. Currently, the factory does not have PPC department or division. The engineering and production departments do the planning and controlling works respectively.
6. Aggregate production plan of every budget year is prepared. However, in most cases, the plan and the actual work do not match. And this is expected in job order companies.
7. Approximately 75 – 80% of our customers are satisfied with our products.
8. Manufacturing costs are estimated by calculating the sum of raw material cost, labor cost and machine overhead cost. Actual manufacturing cost is also evaluated to get feedback.
9. We measure our capacity utilization in terms of machine hours; and our capacity utilization is approximately 45%.
10. Main reason for low capacity utilization is shortage of production orders.
11. Production control mechanisms include
    i. daily status report,
    ii. close follow-up by foremen,
    iii. willingness of every worker for his/her task and
    iv. monthly status report.
12. Application software like MS word, MS Excel and Auto CAD are extensively used for different purposes related to production planning and control.

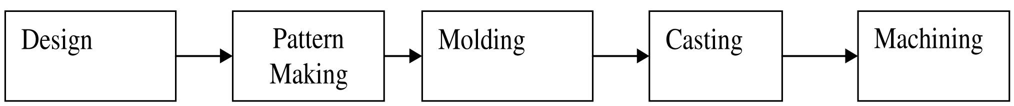
V. Radel Foundry Shop

A one day visit was conducted at the workshop. Activities done in the data collection are interviewing the deputy general manager and short visit to the workshop.

The workshop produces different cast, machined, and cast and machined spare parts for factory machines and automotives. About 90% of its products are manufactured after a customer initiates an order. To make its market sustainable, it is trying to produce some selected items as commercial goods. For example, the workshop is successful to make cylinder liner a commercial product. Different sizes of cylinder liners are manufactured as stock items and sold to auto dealing companies and garages.

Summarized responses of interview made to the deputy general manager contain the following main points.

1. The workshop has 58 workers.
2. The production flow of the workshop can be summarized as:



3. The Plant layout of the factory is process type layout.
4. The workshop groups its customers in to two:
   i. customers on hand: like transport sector, construction companies and sugar factories
   ii. potential customers: like cement factories and earth moving equipment users.
5. The workshop does not have PPC department or division. The planning work is jointly done by the sales and marketing department and production and technique department.
6. Annual plan for raw material consumption is prepared based on the melting capacity of the furnace. APP, MPS and MRP are not practiced in the workshop. Production planning is performed after orders are received.

7. More than 90% of our customers are satisfied with our delivery time and product quality.
8. We estimate manufacturing costs.
   - Standard items like ingot bars and liner plates have standard prices which are set per Kg or per piece.
   - For other products, costs are estimated before manufacturing. If the order quantity is large, test products will be manufactured and their actual cost will be evaluated. If the cost is exaggerated, we communicate the customer for cost revision.
9. We measure our capacity in terms of tones of iron melted in the furnace. The maximum capacity we have so far utilized is 40%.
10. Reason for low capacity utilization is production order shortage.
11. Production control mechanisms:
    - daily follow-up by sales persons
    - delivery time information to the production department
    - Foremen are fully authorized and responsible for the work they receive.
12. Application software like AutoCAD and MS Excel are used.

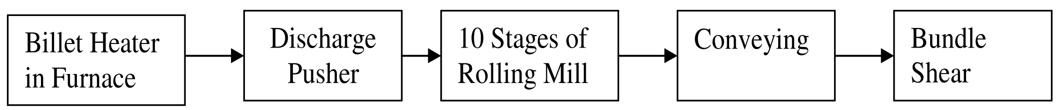
VI. Ziquala Steel Rolling Mill

A one day contact was made to the factory. Activities performed in the visit are interviewing the production division head and short visit to the production system.

The factory produces re-enforcement bar of $\phi 10mm$ - $\phi 32mm$, round bar of $\phi 10mm$ - $\phi 32mm$, square pipes and angle iron. Currently, its main product is re-enforcement bar, which is produced as stock item. Round bars are produced when a customer initiates an order. For the time being, production of square pipes, angle irons and strips is stopped due to some technical problems. The production division head says that the factory is prepared to produce these items in the 1997 budget year.

Summarized responses of the interview made with the production division head contain the following main points,

1. The production flow of the factory can be summarized as:



2. The plant layout is fully product type layout.
3. The factory has 300 workers.
4. The factory knows its customers. They are huge construction companies like Midroc, Varnero, sun shine, and so on.
5. The factory does not have PPC department or division. The production planning and control work is done by the production division. The sales division prepares the sales plan. Based on the sales and maintenance plans, the production division prepares its annual production plan.
6. The procedural production planning activities are more or less practiced in the factory.
7. The factory uses qualitative forecasting techniques like market survey.
8. Since the factory's products are limited in type, manufacturing costs and actual cost evaluations are easily performed.
9. We measure our production capacity in terms of tones of output. Design capacity is 48,000 tones per year. We have so far attained 14,380 tones in the 1995 budget year. Therefore, our maximum capacity utilization is about 28%.
10. Reasons for low capacity utilization are:

- raw material shortage
- machine breakdown
- Exaggerated design capacity
- Low market demand of easily producible products like $\phi 32mm$ re-enforcement bar

11. For production control, we use daily reports of:
    a. down time
    b. production in tone
    c. raw material utilization
    d. coble (scrap) rate
    e. fuel consumption

When the figures of the above parameters are above or below the expected value ranges, necessary actions will be taken.

12. We use application software like MS Access, MS Excel and MS word. Computer networking of departments and divisions is started.
13. Performance reports of the production division are monthly production reports which show:
    a. billet consumption,
    b. output size,
    c. yield,
    d. downtime analysis,
    e. rolling rate and
    f. fuel consumption

5.3 Data collection from Sample Major customers of ASPSC

To get feedback on the strength and weakness of the production planning and control system of ASPSC, some major customers have been visited. The visited companies are:

1. Mugher Cement Factory
2. Wonji Sugar Factory
3. Methara Sugar Factory
4. Mossobo Cement Factory

In the data collection process, two major activities were performed.

i. Factory visit to assess spare parts that can be manufactured at ASPSC.

ii. Interviewing concerned workers to get feedback about the PPC system of ASPSC

The three important things that any customer needs from its supplier are fair selling price, quality product and shortest possible delivery time. The data collection was conducted with respect to the above points. Feedbacks obtained from the visited companies are briefly discussed as follows.

I. Mugher Cement Enterprise

The researcher visited the factory's production system, interviewed concerned professionals and referred to useful materials for two days. Main feedbacks obtained from the visit and interviews of the factory are briefly shown below.

a. Main spare parts that can be produced at ASPSC are:

i. mill lining plates
ii. Diaphragm Plates
iii. crusher hammer
iv. bucket elevator
v. Impact Beam
vi. cement balls

b. Shortcomings of ASPSC:

- poor metallurgical quality of cast and heat treated spare parts,
- poor delivery date performance,
- poor workmanship in some spare parts and
- time taking price quotation procedure

c. Comments to improve delivery dates;

- Proper assessment of your customers' demand
- Create close relations with your major customers
- Get necessary information like drawings of spare parts, working condition of each spare part, annual consumption of spare parts from your customers

- Based on the drawings obtained from your major customers, prepare your engineering drawing for all spare parts that you can manufacture.
- Prepare your annual production plan after contacting your major customers.
- Try to shorten or cut unnecessary paper works to prepare price quotation.

d. Comments to improve product quality:

- Most of product defects are related with metallurgical problems. You have to train your concerned workers on casting and heat treatment.
- Conduct a research work on metallurgical problems. For example, manufacturing methods of liner plates and cement balls have to be deeply studied by your engineers.
- Every machinist should be aware that quality is everybody's responsibility.
- Defect can be minimized if you get all important information from your customers.

II. Wonji Sugar Factory

The factory was visited for two days. Main feedbacks obtained from the visit and interviews of the factory are briefly shown below.

a. Main spare parts that can be manufactured at ASPSC are:

i. sugar mill rollers
ii. trash plates
iii. scrapper plates
iv. draw bars
v. furnace grates
vi. elbows
vii. flanges
viii. cast iron pipes

b. Shortcoming of ASPSC:

In our opinion, most workers are willing to do what they can do. However, we observed the following limitations.

- The company does not try to be selective in order receiving.
- We sometimes face defective products.
- Poor delivery date

c. Comments to improve delivery date:

- Our overhaul maintenance plan is always in the summer season. We don't need ordered spare parts urgently. Therefore, we don't feel the delivery date problem of ASPSC. However, we recommend that the company has to give due attention to improve its delivery date estimation system.
- ASPSC has to be selective in its customer identification.
- To logically estimate delivery dates and attain the specified delivery date, the company has to strengthen its shop floor control system.

III. Methara Sugar Factory

The researcher stayed at the factory for two days. Main feedbacks obtained from the visit and interviews of the factory are briefly shown below.

a. Main spare parts that can be manufactured at ASPSC are:

i. sugar mill rollers
ii. trash plates
iii. Scrapper plate
iv. furnace grates

b. Shortcoming of ASPSC:

The factory is about 90% satisfied with you products. It is also observed that most workers are willing to do what they can do. However, we observed the following limitations.

- Some of your cast products have porosity problems.
- Poor delivery date

c. Comments to improve delivery date:

- The factory's overhaul maintenance plan is always in the summer season. To be safe, we initiate orders very early. Therefore, we don't feel the delivery date problem of ASPSC. However, we recommend that the company has to give due attention to improve its delivery date estimation system.
- ASPSC has to be selective in its customer identification and give special attention to selected customers.
- To logically estimate delivery dates and attain the specified delivery date, the company has to strengthen its shop floor control system.

IV. Mossobo Cement Factory

A one day stay was made at the factory. Main feedbacks obtained from the visit and interviews of the factory are briefly shown below.

a. Main spare parts that can be produced at ASPSC are:

- mill lining plates
- crusher hammer
- impact beam
- cement balls

b. Shortcomings of ASPSC

- Poor delivery date performance.
- Defective alloy steel casting.
- Long bureaucratic chain of price quotation

c. Comments to improve its delivery date performance:

- The company should not promise what it can't attain.
- Delivery time estimation should be as objective as possible.
- The company has to develop strong production progress follow-up system.

CHAPTER SIX

ANALYSIS OF PPC PROBLEMS OF ASPSC

6.1 Company Background

Akaki Spare Parts and Hand Tools Share Company (ASPSC) is one of the biggest job order manufacturing companies in Ethiopia. It is located in the south-east direction at 22 Km from Addis Ababa adjacent to the main asphalt road to Debrezeit. It started operation in 1989. The main objectives of the company's establishment are:

1. Supporting local factories by supplying various spare parts. Some of the assumed factories to get their spare parts from ASPSC were:
    a. Textile factories
    b. Sugar factories
    c. Cement factories
    d. Transportation sector
    e. Addis Tire
    f. And others
2. By supplying spare parts from local factory, it was intended to save foreign exchange of the country and to minimize waste of time in long lead-time.
3. Enhancing the development of Metal Sector in the country:
    - There are different metal processing public and privately owned factories in Ethiopia. Most of them were established prior to ASPSC. Almost all of these factories are limited to machining, sheet metal fabrication and assembly works with very limited capacity. Before the establishment of ASPSC, no metal processing plant of Ethiopia had foundry workshop of steel and cast iron. Automotive Manufacturing Company of Ethiopia (AMCE), the only automobile assembly plant of the country, at the time, has no in house capacity to produce parts for its assembly. Therefore, ASPSC was

established with almost all rounded capacity to give useful support to the development of these infant factories.

The company has fixed capital of $83,381,000. Presently, about 600 workers are employed but at full capacity, it can employ 900 workers. Its electric power requirement is about 12MVA. It is established on a total area of 155,000m^2 of which 30,500m^2 is covered. ASPSC produces various types of metal products. Its main products can be classified into four major groups. They are:

i. **machines and sheet metal products** such as wood lathe machines, double end grinding machines, sheet metal rolling machines, sheet metal shearing machines, cold press machines, water and fuel tankers, and high and medium tension electric cable carrying hooks and pins,

ii. **spare parts of different machines** such as shafts, rollers, sleeves, gears, sprockets, coil springs, sugar mill rollers, ingot moulds, scraper plates, trash plates, armor plates, cement balls, various types and sizes of cast and machined products

iii. **industrial hand tool**s such as wrenches, pliers, screw drivers, hammers, cutters and other hand tools and

iv. **cutlery** such as forks, spoons and knives.

Among the various types of the company's products, some are frequently ordered by customers and they are treated by the company as **Selected Products**. As they are economically useful both to the company and to the customers, they are given special attention. The estimated annual production capacity of the company for some selected products, among a number of them, is shown in table 6.1.

Table 6: 1 **Annual Production Capacity of ASPSC for selected Products**

S.No	Product Name	Customer	Annual Pdn Capacity (Pcs)	Estimated Production Cost	
				Unit	Total
1	Sugar Mill Roller	Sugar Factories	40	88,920.00	3,556,800.00
2	Trash Plates	Sugar Factories	50	9,800.00	490,000.00
3	Scrapper plates	Sugar Factories	55	4,550.00	250,250.00
4	Draw bars	Sugar Factories	3,000	1,372.00	4,116,000.00
5	Linner plates	Cement Factories	2,400	995.00	2,388,000.00
6	Brake drum	Transport Sector	1,200	1,925.00	2,310,000.00
7	15Kv Hooks	EEPCO	130,680	21.95	2,868,426.00
8	N-95 Hooks	EEPCO	232,320	6.90	1,603,008.00
9	N-80 Hooks	EEPCO	232,320	5.70	1,324,224.00
10	33 Kv Pins	EEPCO	72,600	23.70	1,720,620.00
11	Termination Sleeve	ETC	390,000	9.20	3,588,000.00
12	Distribution Support	ETC	400,000	31.30	12,520,000.00
13	Stay Rod	ETC	120,000	65.00	7,800,000.00
14	Central Support	Transport Sector	2,500	2,089.00	5,222,500.00
	Total				**49,757,828.00**

For better understanding of the company, the organizational structure of the company is shown in figure 6.1.

As the organizational structure shows, the direct production area of the company is divided in to four divisions. They are:-

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

All the four production divisions and two additional supporting divisions (Design, Production Planning and Control (DPPC), and Maintenance) are under the supervision of manufacturing department.

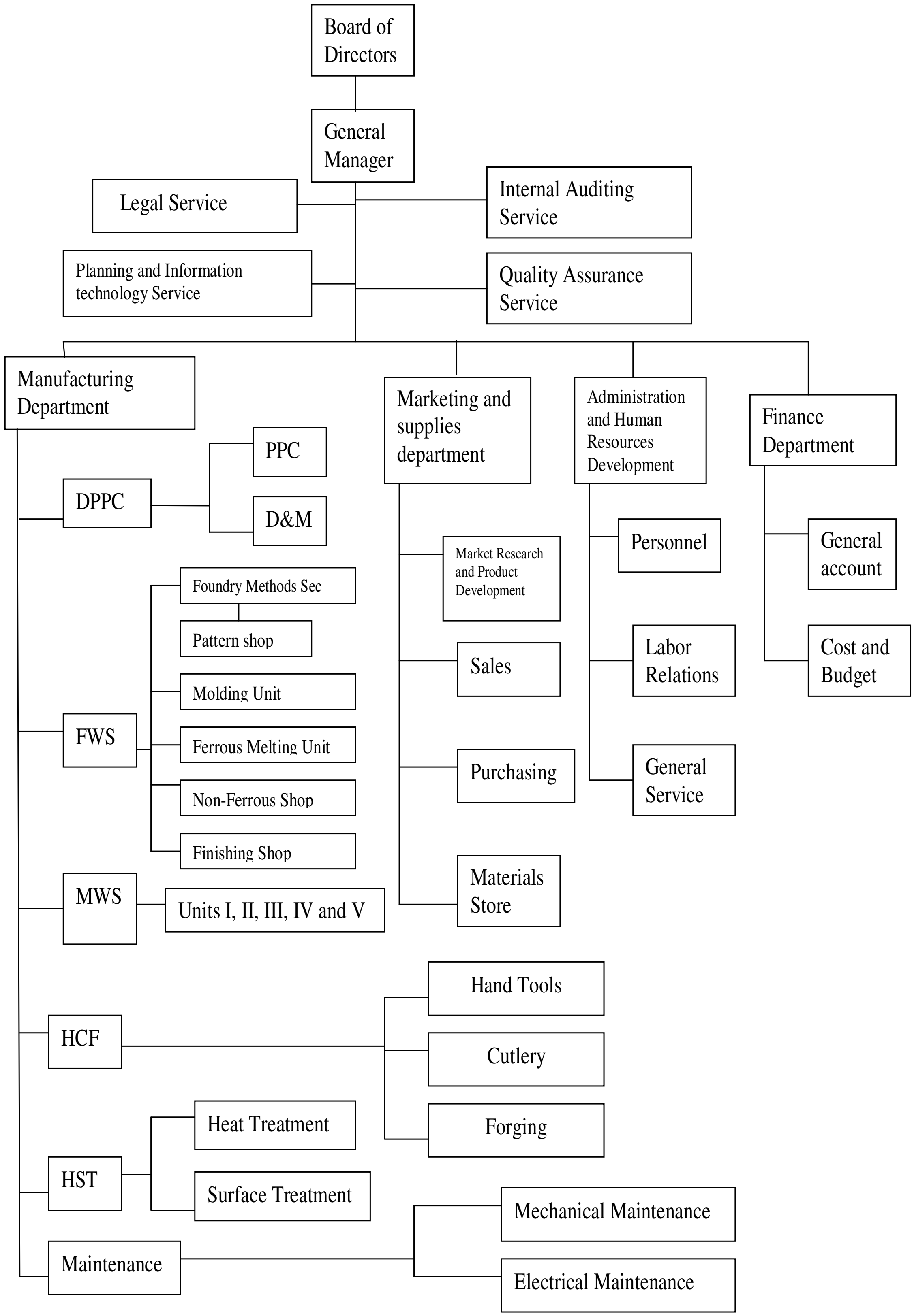


Figure 6: 1 Organizational Structure of ASPSC

1. Foundry workshop (FWS):-

This workshop is used to cast different metal products and supply to the next workshop for further machining or to the finished goods store for sale. The units and sub-shops, which are under foundry workshop, are shown in the organizational structure of ASPSC on figure 6.1. Ferrous metals melting unit of the workshop has four induction furnaces, which have total capacity of 10.25 tones of ferrous alloys at a time. The non-ferrous shop has also furnaces of total capacity of 1.5 tones at a time.

At the foundry workshop the following are produced.

i. Steel casting
ii. Cast iron castings like
   - Nodular cast iron
   - Gray cast iron
   - White cast iron
iii. Bronze
iv. Brass
v. Aluminum

2. Mechanical Workshop (MWS) : -

At this workshop cast products of foundry workshop, round bars and plates are machined to their desired final shapes and sizes. Sheet metal products like fuel and water tankers and garbage tanks are fabricated at this workshop.

The shop comprises of:

i. Heavy and light Milling machines
ii. Heavy and light Lathe machines
iii. Heavy and light Grinding machines
iv. Gear Hobbing and Shaping machines
v. Heavy and light Drilling machinery
vi. Sheet metal rolling, folding and shearing machines

Some of the special featured machines of the shop, which are rarely available in the country, are:

1. **Vertical Lathe Machine**: It can face and turn a work piece of maximum diameter 1750mm.

2. **Center lathe machine**: It has a maximum center distance of 6000mm and center height without bed of 810mm.
3. **Horizontal Boring and milling machine**: It can bore up to 600mm diameter and 2100mm length. It can face up to 800 mm diameter.
4. **Universal Gear hobbing machine**: It can cut spur, helical and worm gears of diameter 1250mm, module of 16mm and hobbing length of 500mm.
5. **Straight Bevel Gear Generator Machine**: It can cut bevel gear of up to 610mm pitch diameter, cone distance of 305mm and module of 8mm.

The shop is divided in to five units. They are:-

- **Unit I** Where most light duty lathes and all cylindrical grinding machines are located
- **Unit II** Where most light duty lathes and all gear cutting machines are located
- **Unit III** Where most light duty milling machinery and all surface grinding machines are located
- **Unit IV** Where heavy duty lathe, milling and drilling machines are located
- **Unit V** where sheet metal work facilities are located

3. Hand Tools, Cutlery and Forging (HCF)

In this division there are three units. They are:-

i. **Hand tools manufacturing unit**: In the unit, different hand tools like:
   - open end spanners,
   - ring spanners and
   - screw-drivers are manufactured.

ii. **Cutlery manufacturing unit**: In the unit, different cutleries like
   - Spoons,
   - Forks and
   - knives are manufactured

iii. **Forging unit**: In the unit,

i. different diameters of round bars are forged to required shapes and sizes for further machining and

ii. upsetting works are performed

4. Heat and Surface Treatment Shop

The division consists of two units. They are:

i. **Heat treatment unit**: In the unit, hardening tempering and carburizing works are done.

ii. **Surface treatment unit**: The unit performs:

- Chrome plating
- Nickel Plating
- Galvanizing
- Phosphating

As the company is a job order type, it produces highly variable products both in type and batch size. About 75% of its products are customer-initiated orders. Since its production activity is highly dependant on the amount of orders initiated by customers, its production planning and control system faces different problems. Major problems faced by the company are briefly shown chapter two and they are further discussed in detail in this chapter.

6.2 The Existing PPC System of the Company

Since its establishment, ASPSC has production planning and control system. Before the implementation of the current organizational structure, the company had a production planning and control division which directly reports to manufacturing department. At that time, product design and development (PDD) division, and PPC division were independent divisions under the manufacturing department. Although the two divisions were assumed to have close relationships to facilitate smooth production flow, they could not have good coordination. The main reason for their poor coordination was their geographical location. The product design and development division was located very far away from the PPC division and most workshops. It was a tiresome task to communicate the design engineers every now and then to clear design ambiguities of dispatched orders. Since the two divisions were not well communicating, design errors were frequently faced. The design work was also time-taking which resulted in poor delivery date performance.

Therefore, it was proposed that the two divisions should merge into a single division which contains sections in it. The proposal was accepted and new organization structure developed. In the new organizational structure, the two divisions merged together and formed design, production planning and control (DPPC) division. Under this division, there are two sections:

- Production planning and control (PPC) section
- Design and method section

As the company is a job order company, most of its productions are performed after job orders are conformed. Flowchart that shows purchase requisition and purchase order procedures at ASPSC is shown in figure 6.2

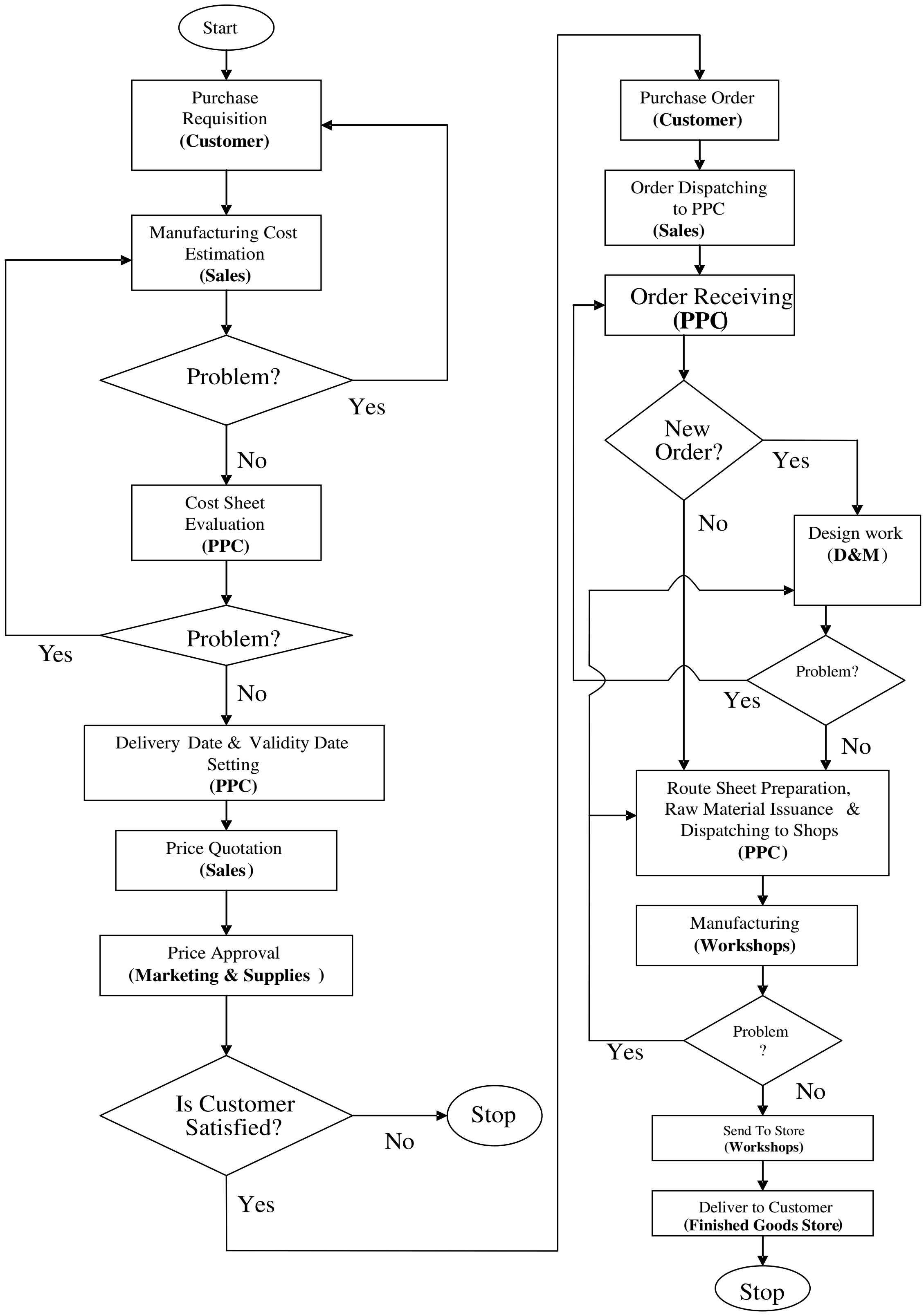


Figure 6: 2 Flowchart of Job Ordering Sequence

To effectively facilitate the production process of the company, PPC section is given the following main tasks.

1. Annual production plan preparation
2. Based on the annul production plan, monthly production plan preparation
3. Annual direct raw material consumption preparation
4. Inquiry sheet (cost sheet) evaluation and delivery date setting
5. Order receiving from sales division
6. Dispatching new orders to design and method section for design work
7. Route sheet preparation, raw material issuing and dispatching orders to concerned workshops
8. Follow-up of job progress
9. Report preparation, Main repots are
   - Weekly production performance of workshops
   - Monthly production Performance of workshops
   - Monthly status of orders on hand
   - Quarterly performance report
   - Annual performance report
10. Monthly updating of production plan based on actual orders on hand
11. Manufacturing data preparation for actual cost evaluation

Flowchart of production planning and control system of ASPSC is shown in figure 6.3

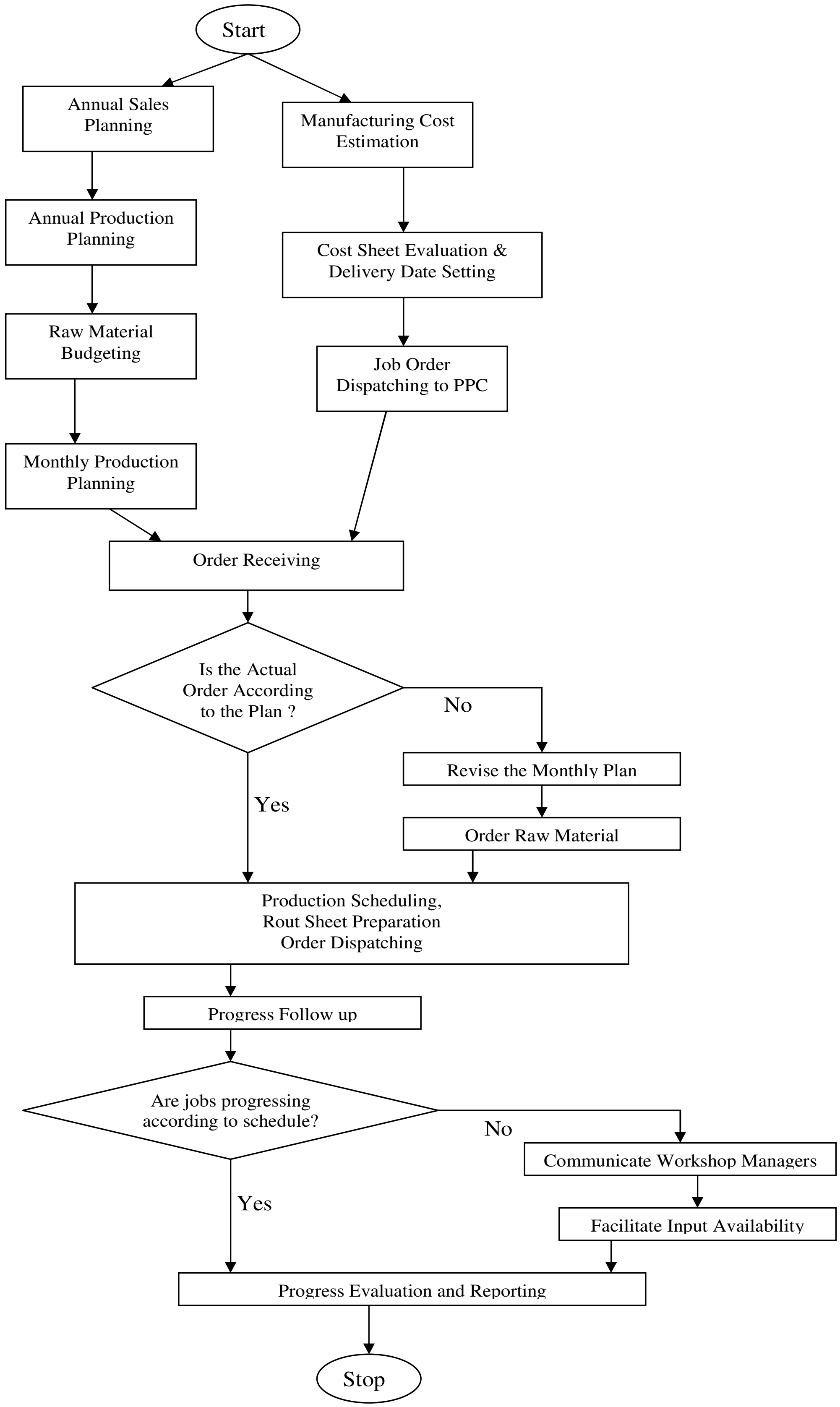


Figure 6: 3 Flowchart of PPC system of ASPSC

Divisions and sections with which the PPC section interacts are shown in figure 6.4.

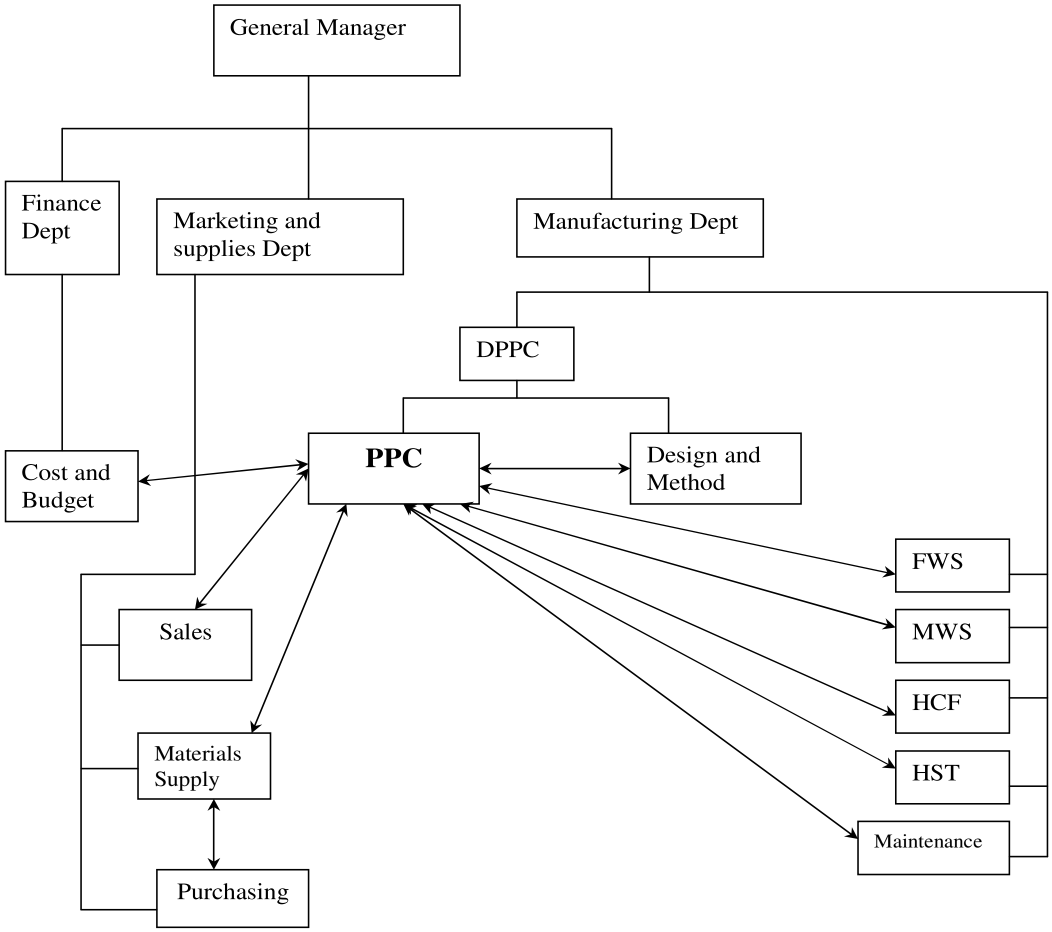


Figure 6: 4 Divisions and Sections with which PPC Section Interacts

PPC and sales interact for three activities: 1) annual production plan preparation, 2) cost sheet evaluation and 3) job order transfer.

For the annual production plan preparation, the section uses the sales plan, machine availability and maintenance planes. The sales division tries to forecast market demand of major products and prepares its sales plan. Based on the sales plan, PPC section prepares an aggregate production plan for the budget year. The DPPC manager checks the plan if it is feasible, and the manufacturing department manager approves it. However, as it has been repeatedly stated, what the company has planned to sale or manufacture does not usually happen to be practiced in its scheduled time. This phenomenon is showing a tendency of discouraging the planning. The main problem associated with unrealistic production planning is raw material planning. Most raw materials of ASPSC products are purchased from foreign market. To state few, round steels of different diameter and material composition, plates of up to 100mm thickness, stainless steel plates and round bars, tool steels and so on. All these materials are planned to be purchased according to the annual production plan. When the actual production does not go with the plan, most purchased raw materials will be stocked for a very long time tying the working capital of the company. Because of unbalanced raw material availability, it is also common practice to use large diameter round bars to manufacture small diameter spare parts. Alloy steels are also used to manufacture ordinary axles or shafts.

PPC section interacts daily with sales division to evaluate cost sheets and set delivery dates. **Cost sheet** (Inquiry sheet) is a cost estimation paper prepared by sales engineers which contains the estimate of material cost, labor cost and overhead cost. The production planning engineer checks the availability of raw material, the availability of machines, inclusion of all the necessary operations in the cost sheet and amount of orders on hand, and estimates the delivery date of the inquired work. After delivery date setting, the cost sheet is sent back to sales division. The sales division issues price quotation to the customer.

The other frequent interaction of PPC section and sales division is job order transfer. When customers are satisfied with price quotation and delivery date specification, they formally open job order. Sales division transfers the open job order to PPC. PPC checks whether the order is new or re-order. If it is new order, it will be sent to design and method section for design work. If it is re-order, it will have previously worked design. Therefore, route sheet (operation ticket) will be prepared for it and it will be dispatched to the concerned workshops. After completing the design of new orders, the design and method section sends them back to PPC; and PPC prepares route sheet and sends them to the workshops.

PPC interacts with manufacturing shops (FWS, WMS, HCF and HST) and maintenance division to follow up the status of job orders dispatched to the shops. To facilitate the daily follow-up, one workshop planner and controller is assigned for each shop. The shop planner and control dispatches jobs to shops and periodically follows up the status of each work. The production progress of each workshop is communicated to concerned departments through periodic reports like weekly, monthly, quarterly and annual performance reports.

The section prepares updated monthly production plan based on the actual orders on hand. To prepare this plan, the following points are considered.

- The monetary value of the updated plan is intended to be greater than or equal to monetary value of the monthly plan which was prepared based on the annual production plan.
- Job orders with shorter due date are given priority.
- The possibility of the jobs to be completed in the stated month is strictly checked.

Updating the monthly production plan is advantageous in that every workshop will be regularly informed which orders to give priority.

PPC section and materials supply division interact to update stock status of raw materials. The division prepares stock status report of raw materials and sends copy of it to PPC. All enquiry evaluations are performed based on the stock status report. However, it is practically observed that the stock status preparation period is very wide and it often misleads the planning engineers. Therefore, the planning engineers usually go to the raw materials store section and check the updated stock status from bin cards.

The finished goods store section of the materials supply division sends finished goods receipt note (FGRN) to PPC to inform what finished parts and how much of them are transferred to it. PPC uses FGRN as its input to prepare production performance and orders on hand reports.

After each job is completed and sent to finished goods store, its route sheet will be sent back to PPC section. The workshops send the route sheet to PPC section after filling the actual labor and machine hours spent to complete the job. Based on this information, the section prepares manufacturing data which shows raw material consumption, direct labor and machine hour utilization. The manufacturing data is sent to cost and budget division to calculate the actual manufacturing cost of the job. The actual cost will be compared with the estimated one and will be used as feedback to revise it for the future.

To summarize, the existing PPC system of ASPSC practices some parts of the production planning and control activities discussed in chapter three. Knowingly or unknowingly, the activities which are more or less practiced are:

- Business planning,
- Aggregate Production planning and

- Master production scheduling.

Materials requirement planning is not usually practiced in the company. If its advantages were understood, it could at least be practiced in some assembly products.

Principally, the company uses FCFS priority system. But, to identify the urgency level of some products, three urgency level codes are used.

- U_0 = Urgency level 0 = normal case
- U_1 = Urgency level 1 = urgent
- U_2 = Urgency level 2 = Top urgent

Manufacturing cost increases as urgency level increases. Raw material cost for the three levels is the same. For the labor and overhead costs the following empirical formulae are used.

Labor cost	Overhead cost
U_1 cost = 1.5 * U_0 cost	U_1 cost = 3.0 * U_0 cost
U_2 cost = 2.5 * U_0 cost	U_2 cost = 5.0 * U_0 cost

Delivery date length decreases as urgency level increases. U_2 orders will have the shortest possible delivery date considering the maximum possible overtime works.

Even though the company uses FCFS prioritization principles, some factors like product mix (especially at FWS), sudden machine failure, raw material shortage, and complexity of a job violate the principle. An order which comes very late may be completed vary fast; and an order which is opened early may delay for very long time.

The PPC system of ASPSC involves planning, expediting, status follow-up controlling and reporting activities to increase the production efficiency of the company. However, the company has not been profitable since its establishment. Main reasons for this are problems associated with PPC. Major problems and their possible causes are discussed in the next section.

6.3 Problems Faced by PPC Section

Even though ASPSC has well organized PPC system, most of its customers complain that it does not supply its products on time with the expected quality. To systematically identify main problems of the company, three important activities were done in the data collection process.

I. Data collection from performance reports of ASPSC
II. Questionnaire distribution and interviewing ASPSC workers
III. Feedback collection from major customers

I. Results obtained from Performance Reports Analysis

By using the data shown on Appendix C, sales and production performances, machine capacity utilization, percentage of delayed orders, and quality failure rates of the 1994 and 1995 budget years are calculated and shown on table 6.2 and table 6.3 respectively. Performances attained in the two budget years are also graphically shown on figures 6.5 and figure 6.6.

Table 6: 2 **Performances of 1994 Budget Year**

Month	Sales Perf. (%)	Pdn Perf. (%)	Capacity Utilization (%)	No. of orders delayed (%)	Quality Failure Rate (%)
July	89.97	169.05	36.49	60.48	0.37
August	104.18	145.42	31.14	28.74	0.62
September	60.70	53.45	32.09	74.31	0.20
October	63.84	62.73	35.67	47.40	0.54
November	91.36	159.43	46.94	72.09	0.28
December	54.14	77.94	35.18	68.57	0.21
January	46.56	46.13	30.63	63.48	0.28
February	96.93	77.78	33.60	75.66	1.01
March	120.38	100.92	33.34	63.81	0.27
April	64.24	56.95	33.35	64.92	0.35
May	96.86	116.35	29.64	65.78	0.18
June	376.15	341.25	34.93	45.79	0.11
Average	**91.36**	**101.79**	**34.39**	**58.56**	**0.33**

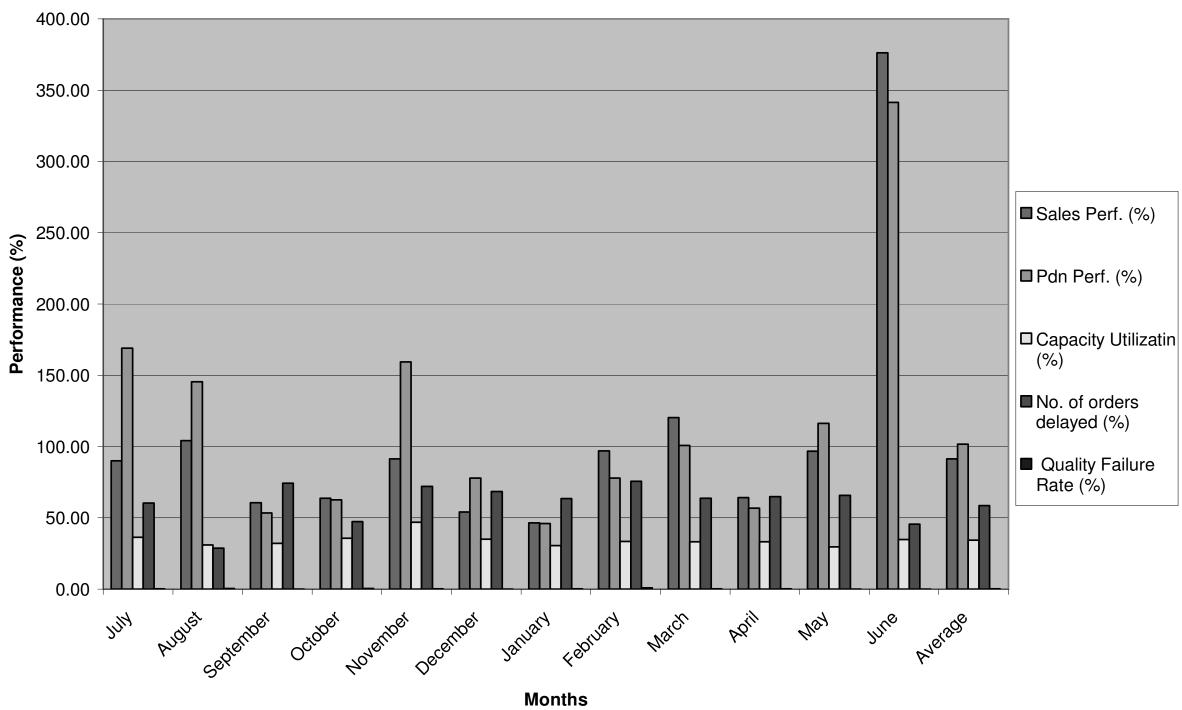


Figure 6: 5 **Performance Chart of 1994 Budget Year**

Table 6: 3 **Performances of 1995 Budget Year**

Month	Sales Perf. (%)	Pdn Perf. (%)	Capacity Utilization (%)	No. of orders delayed (%)	Quality Failure Rate (%)
July	26.68	51.75	36.49	57.94	1.06
August	21.79	71.70	31.14	58.80	0.78
September	47.44	51.53	32.09	52.40	0.53
October	42.54	51.59	35.67	71.96	0.51
November	57.83	78.46	46.94	81.28	0.19
December	43.02	44.65	35.18	68.12	0.50
January	106.59	79.13	30.63	49.42	0.35
February	119.40	69.39	33.60	67.57	0.45
March	87.82	62.66	33.34	69.68	1.56
April	59.16	138.23	33.35	58.61	0.07
May	82.58	127.08	29.64	62.81	1.02
June	205.53	182.55	34.93	51.35	0.56
Average	**70.88**	**77.94**	**34.39**	**62.26**	**0.59**

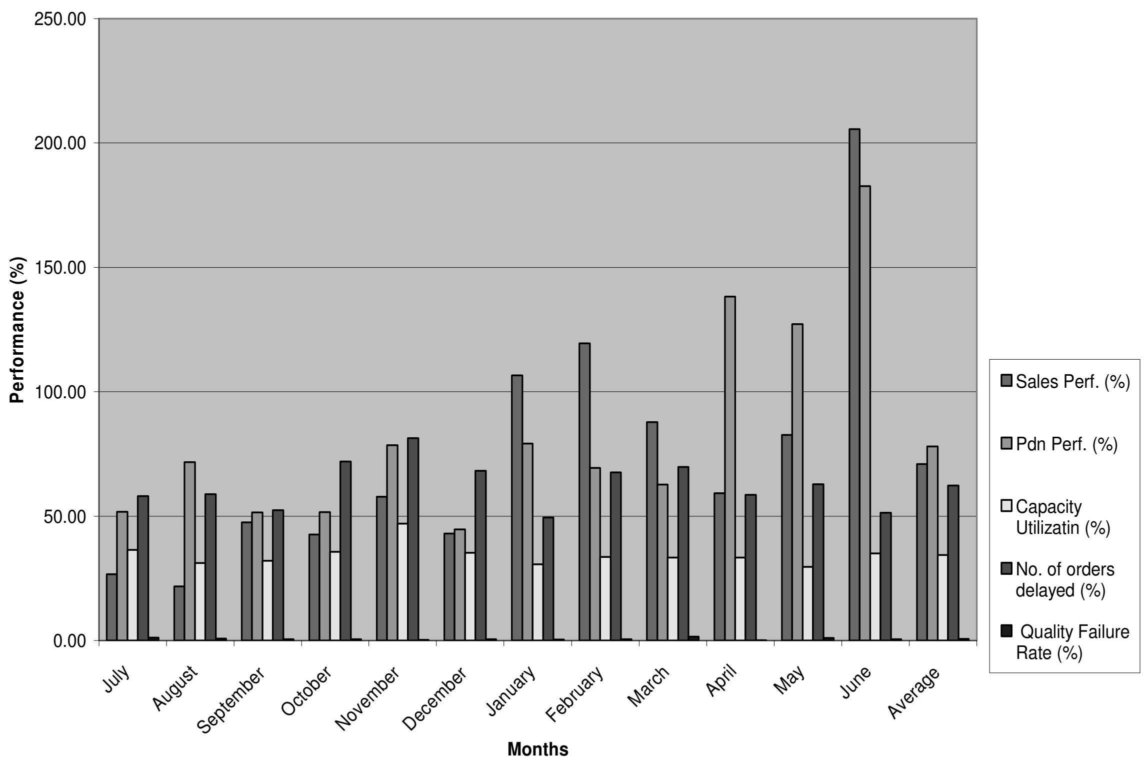


Figure 6: 6 **Performance Chart of 1995 Budget Year**

From the results show on the tables and charts, we can forward the following conclusions.

1. Production and sales performance of the two budget years were good even though there is performance decrease in the 1995 budget year. However, products which were produced and sold in each month of the two budget years were mostly different from the sales and production plans.
2. Percentages of delayed orders in the two budget years were much exaggerated. In the 1994 budget year, 58.56% of the orders were delayed. This implies that 58.56% of ASPSC's customers were dissatisfied in the budget years.
3. Even though there are exaggerated delays, the machine capacity utilization of the company is very low.
4. Defect rate, which is the percentage ratio of quality defects to production cost, is in an acceptable range because quality defect of up to 2% is practically accepted.

II. Summarized Responses of Questionnaires/Interviews of ASPSC Workers

As it was discussed in chapter five, 20 **relevant workers** of the company were asked to respond to a questionnaire. Points raised in the form of yes or no response and percentage of respondents are shown in table 6.4.

Table 6: 4 **<u>Percentage responses to Yes or No questions</u>**

S.No	Point	Yes	No
1	Possibility of Sketching production flow	6 (30%)	14 (70%)
2	Customer identification	18 (90%)	2 (10%)
3	Effectiveness of the existing PPC system	9 (45%)	11 (55%)
4	Business plan preparation	20 (100%)	0 (0%)
5	APP preparation	20 (100%)	0 (0%)
6	MPS and MRP preparation	8 (40%)	12 (60%)

Other questions were prepared to invite comments of respondents. Summary of the comments are listed as follows.

1. Main products of the company are spare parts of different machines, fuel and water tankers, and light duty machines.
2. Major tasks of PPC are:
    - Preparation of annual production plan
    - Delivery date setting
    - Machine load chart preparation
    - Operation ticket preparation
    - Raw material issuing
    - Job process follow-up
3. 55% of the respondents have said that the existing PPC system is not effective and it should be strengthened or restructured.
4. Reasons for delayed delivery date are:
    i. Wrong delivery date estimation system
    ii. Very weak follow up system
    iii. Negligence of some workers
    iv. Dissatisfactory salary
5. Theoretically the cost estimation procedure is good. But the time estimation of each operation is very subjective. Cutting speed and feed rates of machines are not considered.
6. Data for actual cost estimation is not properly filled in time.
7. Capacity utilization is measured in terms of the available machine hour. The maximum capacity utilization of the company is 35%, which is much less than the expected value.

8. Currently, the company does not use any PPC software. But if properly utilized, MS Excel and MS Access are enough to do much of PPC works.

III. Summary of feedbacks obtained from sample major customers

In chapter five, it was stated that major customers of ASPSC from the cement and sugar factories were visited to get feedback about the strength and weakness the company's PPC system. Response of each factory is discussed in chapter five. Summary of their response focuses on the following main points.

1. Most of the factory's products are not delivered within the pre-stated delivery date.
2. Price quotation procedure of the company is very long.
3. Frequent defects are observed on the cast products. Especially high manganese and chromium products are poorly heat treated.
4. Price quotation system is not updated dynamically.

6.4 Comparison of PPC System of ASPSC with that of Other Job Order Companies

As it is clearly stated in chapter five, the PPC systems of six job order companies were investigated to compare with that of ASPSC. With regard to their PPC system the visited companies can be grouped into three.

I. Companies which have PPC division
II. Companies which do not have PPC division but all planning and controlling activities are effectively performed

III. Companies which do not have PPC division and their planning and controlling activities are very weak.

Companies which have production planning and control division are Mesfin Industrial Engineering and Kality Metal Products Factory. Compared to ASPSC, the two companies produce selected type of products and they are profitable. Their PPC system becomes effective because their major products are very limited in type and they are dedicated to them. If production types are limited, production controlling activities will not be complicated. The two companies gain this advantage, which ASPSC lacks.

Companies which have no PPC division but perform all planning and controlling activities very effectively are Maru Metals Industry, Radel Foundry Workshop and Ziquala Steel Rolling Mill. The first two factories are privately owned and they effectively utilize their manpower. These factories use their production and engineering departments to plan and control their production. They give due attention for marketing. They frequently assess potential customers to get orders. Once they get the order, they are fully committed to deliver the product according to the due date. This is what ASPSC lacks. There is no commitment at ASPSC to attain delivery dates. According to interview responses obtained from the two private companies, their delivery date estimation procedure is not different from that of ASPSC. However, unlike ASPSC, they are committed to their promises. Ziquala Steel Rolling mill mainly produces stock items. Its daily production plan is not directly affected by customer demands. Production plan is prepared and controlled by the production division. Since re-enforcement bars are highly demanded at market and the factory has optimized its manufacturing cost, the company can produce what it plans. The only problems it is facing are raw material shortage and machine breakdown.

The only company which does not have PPC division, and whose planning and controlling activities are not strong, is Hormat Engineering. Currently, the factory does not have any production planning activity. The factory's production and technique department head says that it will start PPC activities very soon. Table 6.5 shows major comparison results of the surveyed job order companies.

Table 6: 5 Comparison of ASPSC with other job order companies

Company	Number of Workers	Capacity Utilization (%)	Level of Customer Satisfaction (%)	Current Status
ASPSC	600	34	40	Not profiting
Hormat Engineering	700	Unknown	Unknown	Not profit oriented
Mesfin Engineering	450	40	80	Profiting
Kality Metal Products	295	35	60	Profiting
Maru Metals	108	45	75	Profiting
Radel Foundry	58	40	90	Profiting
Ziquala Steel Rolling	300	30	70	Profiting

From the result shown in table 6:5, we can conclude that ASPSC is at very low level of satisfying its customers. It is also the only job order company of the metal sector which is working at loss.

In summary, important experiences shared from the visited job shop companies, which are useful to improve PPC system of ASPSC are the following.

1. Being specific in product types leads to good performance of delivery date.
2. Committed workers play great role in quality, delivery date and fair selling price attainment.
3. Production planning and controlling activities may not necessarily need the existence of PPC department.

4. Delivery date performance of ASPSC is the weakest of all the visited profit oriented companies because of high manpower turnover and lack of workers dedication.
5. Fast decision making in raw material purchasing, information updating, customer communication, and employees recruitment plays great role to improve delivery date performance.
6. Strong follow up of the dynamically changing market demand and quick adjustment of plan according to the current demand increases production and sales performance.

6.5 Cause and Effect Analysis

When we summarize the problems (findings) assessed by different approaches, main problems of the company are grouped into four. They are

- Poor delivery date performance: averagely 60% of orders are delayed
- Low capacity utilization: averagely only 34% of its capacity is utilized
- Poor quality products: averagely 0.46% of manufacturing cost is defective products' cost
- Expensive selling prices: most customers complain about it.

Among the four problems stated above, poor delivery date performance contributes the largest share for the company's weakness. Of course, the capacity utilization is also very low. However, if the delivery date problem is solved, more customers will be attracted and capacity utilization will be increased. Therefore, analysis of poor delivery date performance has to be given priority. To identify grass root level causes of poor delivery date performance problems of the company, cause and effect analysis is made to it using fishbone diagram shown in figure 6. 6. According the analysis, the root causes are listed below.

1. **Internal to the Company**
   i. Large number of product variety
   ii. Long stock status updating interval
   iii. Operation capital shortage
   iv. non-attractive salary scale
   v. Unwillingness
   vi. Subjective type cost and delivery time estimation
2. **External to the Company**
   i. spare parts shortage
   ii. Bottleneck machines
   iii. Most Raw materials Supplied from abroad

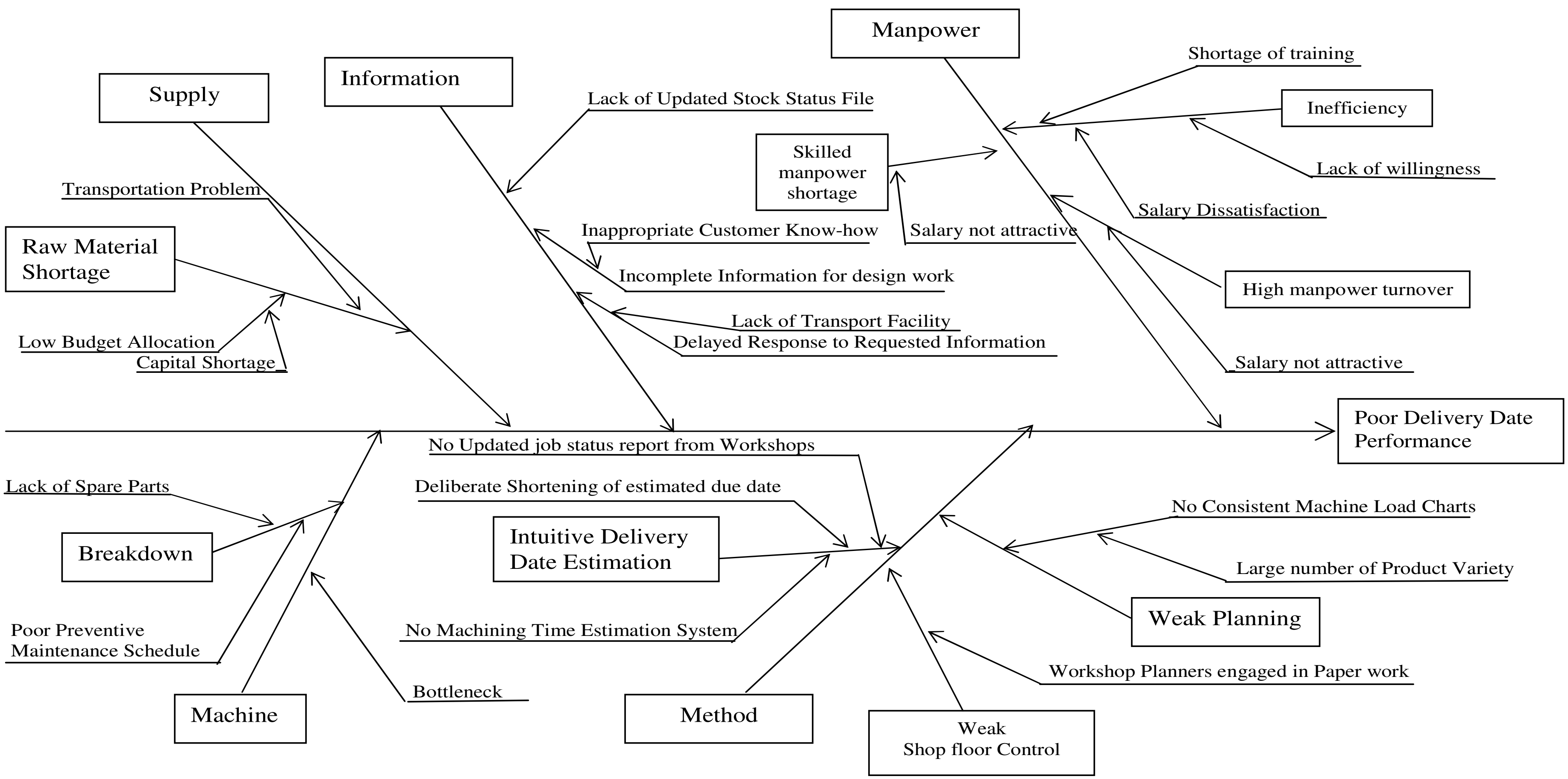


Figure 6: 7 Cause and Effect Analysis of Poor Delivery Date Performance

CHAPTER SEVEN

GENERATION AND EVALUATION OF ALTERNATIVE SOLUTIONS

The ultimate goal of any research is generating alternative solutions to an identified major problem, evaluating them and selecting the best ones for implementation. To generate logical and effective alternative solutions, the identified problem has to be the core problem of the system which is being investigated.

In chapter six, different problems of the existing PPC system of the company were identified. Among them, poor delivery date performance is major problem of the company. Searching for the best solution of the stated problem (poor delivery date performance) will make the company able to attract many of current and potential customers and this in turn leads it to profitability. The problem can be solved by solving its root causes which are stated in section 6.4.

To reach at the desired solution, the following steps are used.

1. Alternative generation
2. Evaluation of each alternative
3. Selection and implementation of the best solution

7.1 Alternative Generation

In the alternative generation phase, all possible solutions which are assumed to solve poor delivery date performance problem will be generated. This phase is also called brain storming phase. What ever idea is forwarded, it will be recorded. However, care should be taken that the alternatives have to address the core problem. In this thesis case, the identified core problem is poor delivery date performance. As a general guidance, the alternatives are expected to indicate ways of improving:

- delivery time estimation method,
- machining and setup time estimation method,
- raw material purchasing procedure,
- job receiving and dispatching procedures and
- production progress follow up and monitoring systems.

After getting the maximum possible alternatives, they will be checked if redundant solutions are suggested.

Possible alternatives generated to minimize delivery time problems are listed below.

1. Limiting product types of the company
2. Developing empirical formula to estimate manufacturing lead-times
3. Preparing machine load chart and updating it consistently.
4. Computer networking the sales, PPC, materials store and purchasing divisions and using MS Excel and MS Access software to interchange updated information.
5. Restructuring the manufacturing department to bring the workshops under the direct supervision of PPC.
6. Training the workers of foundry and heat treatment shops
7. Salary increment
8. Employing foreign experts in some selected working areas

9. Focusing on some selected spare parts production to local and neighboring countries' companies.
10. Trying to work cooperatively with other job order companies to subcontract some works as needed.
11. Focusing on machines production
12. Strengthening the market research work
13. Creating intimacy with limited raw material supplier
14. Creating competitive environment among the workers
15. Focusing on capacity planning and searching for market
16. Strengthening the maintenance planning process
17. Identifying bottleneck machines and increasing their number
18. Avoiding deliberate under estimation of due dates
19. Avoiding financially minor but complicated and time consuming works
20. Strengthening the shop floor control mechanism

7.2 Evaluation of alternative Solutions

In the evaluation phase, the generated solutions will be tested for their feasibility. Their merits and demerits will de evaluated and the best ones will be selected for implementation

Most of the generated alternative solutions to solve delivery date performance problems of ASPSC can simultaneously be used without contradicting to each other. Using one alternative does not prevent us from using another alternative; they are not mutually exclusive. Therefore, their evaluation will be based on:

1) their advantages and disadvantages,
2) priorities of their importance and
3) the possibility or impossibility of their implementation.

To evaluate the generated alternatives using the above criteria, the first thing to do is to bring them into groups of alternatives. When the generated alternatives are revised and rearranged, they may result in the following summarized alternatives.

1. Product specialization
2. Human resource utilization improvement
3. Improvement of data source for cost and delivery time estimation
4. Improvement of external resource utilization
5. Strengthening the market research work
6. Strengthening the production control mechanism

1. Product Specialization:

In this alternative solution, it is suggested that ASPSC has to limit the product types that it produces annually. It has to identify its major customers from which it can obtain sustainable amount of job orders. From its previous experience, its major customers are sugar factories, EEPCO, ETC, cement factories and the transport sector. In addition to its local major customers, the company has also to search for sustainable markets in the neighboring countries.

The company has to give due attention in the production of light duty machines like manual sheet metal rolling machine, manual shearing machine and wood lathe machine.

This alternative suggests also that financially minor but complicated spare parts have to be avoided as much as possible. Since they look simple to manufacture, their manufacturing cost and delivery times are under estimated. However, when they are started to be manufactured, they take time which is two or thee fold of the estimated value. If such spare parts have casting work, it is common practice to incur up to 30% reject cost. Therefore, this alternative suggests that such complicated works have to be avoided if they are proved that they do not have good return.

Advantages of product specialization:

- Raw materials will be limited in type
- Route sheet preparation will be simplified
- Standard workshop and assembly drawing can be developed
- Production progress follow-up is very simple
- Capacity utilization measurement can be simple
- There is high manpower skill development possibility.

Disadvantages of product specialization:

- There is high market problem. It needs great endeavor of market research to get satisfactory production order in a limited type of products.
- Production flexibility will be highly limited.
- Manpower skill development will be limited to specific product types

Possibility or impossibility of product specialization at ASPSC:

For a long time, the company has intended to limit its product types. It has tried to focus on the production of spare parts for sugar factories. It has also tried to focus on the production of spare parts for cement factories. Still, it is trying to be consistent spare parts supplier of the two industries. The company is more or less successful to capture considerable market share from the sugar industry. It is effectively producing main spare parts like sugar mill rollers, trash plates, scrapper plates and draw bars.

In the cement industry's case, the company has to work a lot. Most spare parts of cement factories, which have potential market for ASPSC, are alloy steel products. To produce such spare parts, the company needs to have skilled manpower in the metallurgy field. Therefore, it is strictly recommended that the company has to strengthen the skilled manpower in the metallurgy field at its foundry workshop.

Main drawback of product specialization alternative is that the company has wide workshop types. Focusing on one type of product makes some workshops busy and others idle. For example, spare parts which are produced for sugar and cement factories do not need machines from HCF. For this reason the alternative was discouraged by different managers in the company. They say that whatever order comes, it should be accepted.

Based on the above facts, let us see the possibility or impossibility of implementing product specialization as a solution for the company. It is stated that market problem, quality problem and wideness of company's workshops are obstacles of product specialization. Therefore, this alternative can only be used partially. The company has to intend to be selective step by step. It can go to product specialization by strong market survey for potential market sources. It should not wait for the customers to come. It has to take the initiative.

2. Human resource utilization improvement:

One of the causes of poor delivery date performance at ASPSC is inefficient human resource utilization. The company is known for its high employment and release rates. Fresh graduates of different field join the company, but more than 70% of them will not stay in it for two years. This situation has adverse effect on smooth flow of production. The efficiency of human resource utilization can be improved by:

- revising the organizational structure based on practically faced problems,
- giving appropriate training for concerned workers,
- increasing salary of workers to minimize dissatisfaction and
- creating competitive environment among the workers, for example incentive payment.

Advantages:

- Highly motivated workforce can be created.
- The highly motivated workforce in turn results in stable organizational structure.

Disadvantages:

- Initially it may cost the company a lot to increase salary and give appropriate training for concerned workers.

Implementation barriers of this alternative solution are:

- lack of capital to increase salaries of workers and
- shortage of appropriate trainings in the country.

If the two barriers can be handled, it will be simple to increase the efficiency of human resource utilization in the company.

3. Improvement of data source for cost and delivery time estimation:

In this alternative solution, it is suggested that machine preparation and operation times of product groups must have a developed empirical formula. Manufacturing lead times must be estimated by using the formula. Each shop has to prepare machine load chart and it should be updated daily. The actual time taken to accomplish each activity has to be recorded by the concerned operator or machinist and filed for future use. Maintenance schedule must be prepared consistently. Poor preventive maintenance schedule leads to unplanned corrective maintenance which highly affects production plan and promised delivery dates. It is also proposed that production related divisions and sections have to be computer networked.

Advantages:

- Planning work will be simplified
- Delivery time may not be over stated or understated.
- Manpower utilization will be very high
- Feedbacks for future cost revision will be easily availed.

Disadvantages:

- Because of high variety of products, empirical formula development for machine preparation and operation time may be difficult task.
- Computer networking of selected divisions and sections may need high initial cost.

Implementation Barriers:

The main barrier to implement this alternative is lack of willingness. Empirical formula may be developed to calculate manufacturing lead times. However, unless the workers are willing to work efficiently, the formula by itself will lead nowhere. Machine load chart updating needs a willing worker who updates it daily and consistently. The other barrier may be financial problem of the company. It is stated that computer networking plays great role to increase data source for delivery time estimation. But, currently the company may not be able to afford the networking expense.

Therefore, it is recommended that empirical formula development, machine load chart preparation, proper recording of actual manufacturing time and preventive maintenance schedule preparations have to be done properly. Computer networking can be done after achieving the above tasks.

4. **Improvement of external resource utilization:**

External resources like sub contracting companies, raw material suppliers and labor power sources improve the delivery date efficiency of a company. Private companies like Maru metals, Radel foundry and others are very fast in deciding to utilize these resources when they get them very important. ASPSC has great opportunity to utilize external recourses. It can have sub contracting agreements with Maru, Radel, Kality metal products and so on.

The other problem that the company faces every now and then is raw material shortage. As it was discussed in chapter six, causes of raw material shortage are low budget allocation, transport problem and long bureaucratic chain of purchasing procedure. The company can minimize this problem by creating partnership with selected local and foreign raw material suppliers.

Advantages:

- Systematic way of sub contracting some works results in effective achievement of promised delivery dates. This in turn makes customers to relay on the company.
- Creating partnership with selected suppliers cuts the tiresome bureaucratic chain of purchasing procedures and shortens lead time of raw material supply.

Disadvantages:

- While subcontracting parts of a work it reduces the income of the company.
- Relaying on limited number of suppliers may sometimes cause raw material shortage.

Implementation Barrier:

The main barrier to implement this alternative is the financial policy of the country. The procurement procedure of state owned companies limit them not to have partnership with limited suppliers. They are forced to invite all participants for bid and those who offer lowest price will be selected. Raw materials with lowest price are usually poor in quality.

To improve its external resource utilization, the company has to be strong enough to convince the government that creating partnership with selected raw material suppliers is very important for the company.

5. **Strengthening the market research work:**

Feasible production planning is dependant on the available capacity and actual demand of products on the market. Especially, the actual demand of products governs the amount of production which can be sold without unnecessary finished goods build-up. Therefore, this alternative suggests that the actual sales plan of the company has to be developed after sufficient market assessment and sales forecasting.

Advantage:

- It makes the planning feasible; variation between plan and actual order will be minimized.
- As forecasting results of different years are accumulated, it will be possible to use quantitative forecasting techniques.
- Raw material-build up or depletion problem will be minimized.
- It will pave way to product specialization.

Disadvantage:

- The market assessment work may need the company to expend considerable amount of money.

- Most Ethiopian companies are not willing or are not able to give appropriate information about the spare parts that they need to order in the coming budget year.

Implementation Barriers:

Top management of ASPSC is theoretically convinced that market research is the key solution for the company's market problem. To minimize market shortage in the company, Market Research and Product Development Division is formed under the marketing and supplies department. However, the division is not effectively undertaking any significant market research. Its main problem is that the company does not allocate satisfactory budget for research works. Even though the company's top management is theoretically convinced by the importance of market research, practically it focuses on routine job receipt and expediting activities. Therefore, the main barrier of implementing market research work as an alternative solution is lack of practical commitment from management.

However, it is strongly recommended that the annul sales and production plan of the company has to be bases on extensive market survey results.

6. **Strengthening the production control mechanism:**

To effectively attain the promised delivery dates of job orders, production control plays great role. The estimated manufacturing lead times may be reasonably correct, but because of loose production progress follow-up, it may not be possible to finish the products in the predetermined time. Therefore, this alternative suggests that production control has to be given the fist priority. As it was stated in chapter three, important activities in production control are shop floor control and inventory control. Partially, shop floor control activities are being performed at ASPSC.

1. Orders are released to shops with route sheets and material requisition.
2. Delivery time of any order is properly recorded on the rout sheet.
3. Urgency level is also indicated on the route sheet.

However, order progress expediting is very weak at the company. Job order status is reported monthly. The report has to be prepared at least once in a week. Each workshop has its workshop planners and controllers. Therefore, the workshop planners and controllers have to give priority for the production progress follow up.

Advantages:

- Customers can get the status of their job order very easily.
- Delivery date estimation of new orders can be reliable
- Over looking of some orders will be avoided. All orders will be treated according to the first come first served (FCFS) principles of the company.
- The company will have good picture on its current and potential customers.

Disadvantages:

- Daily load chart updating is tiresome task.
- Report preparation of job order status is tiresome task.

Implementation Barriers:

The main barriers to implement this alternative are computer shortage, lack of dedication and high product variety. The PPC section has one computer. This computer is mostly used for performance report preparation. The shop planners do not get time to update job status on a computer. In addition to computer shortage, workshop planners are not dedicated to update job status of their workshops. High product variety makes the updating work very complicated. However, the best solution for delivery date performance is strengthening the production control mechanism by regular updating of job status.

Therefore, it is strongly recommended that regular follow up and updating of job status using MS Excel software must be practiced in the company. The workshop planners and controllers have to focus on progress follow up.

7.3 Selection of Best Solutions, Model Development and Discussion

All the generated groups of alternative solutions are very important for the improvement of the efficiency PPC system of ASPSC. However, since it may be difficult to implement all of them at a time they have to be given priorities and those with higher priority must be selected.

To select the best solutions, all of them have been evaluated for their advantages, disadvantages and implementation barriers. Among the proposed solutions, the following are selected to be given priority.

1. Improvement of data source for cost and delivery date estimations:

This alternative is given the fist priority because delay in most job orders is due to inappropriate manufacturing cost estimation and delivery time setting. Manufacturing cost is estimated by calculating three cost elements: material cost, direct labor cost and overhead cost. Material cost estimation is relatively objective and its estimation error is minimal. Dimensions and weights of all the components of the requested product will be measured and/or calculated. Based on the calculation result, blank size of raw materials which includes machining allowance, shrinkage allowance (for cast Products) and scrap allowance will be calculated. The calculated raw material size will be changed to cost by multiplying it with the cost rate which is developed by the company.

Direct labor cost and machine overhead cost estimations of the company are not reliable. The reason is that machine preparation and operation times do not have empirical formula which may assist the estimation work. This results in over estimation or under estimation of manufacturing cost and delivery time. To minimize this problem, using cutting speed, feed rate and material type, an empirical formula of time estimation which can be updated every budget year has to be developed.

In this selected solution, it is also suggested that maintenance plans have to be seriously prepared and communicated to sales and DPPC divisions.

2. Strengthening the Market Research Work

This alternative is given the second priority because the company faces high deviation of production plan and actual order. As it has been repeatedly stated, ASPSC faces this problem frequently. What it plans is rarely ordered according to its scheduled time.

Even though it is difficult for job order companies to get orders according to their plan, strong market research helps them to point areas of focus. ASPSC has to start its sales plan by making intensive market survey. Based on the survey qualitative technique of forecasting can be used to estimate sales volume of selected products.

3. Strengthening the Production Control Mechanism:

Next to poor cost estimation, the company's production control mechanism is very weak. Workshop planners and controllers try to follow up job status. However, most customers are complaining about the delay of their orders. Even though some orders delay due to incorrect delivery time estimation, machine breakdown or raw material shortage, considerable amount of orders delay due to loose production follow-up. Workshop planners and controllers waste their time in routine works like job dispatching, weekly report preparation and responding to customer questions about the status their orders.

The other problem associated with production control in the company is that workshops do not follow the production schedule of orders. They give priorities to high value orders and non-complicated works. It looks that there is inconsistency in the chain of command. What the production planning Engineer decided to be followed is usually violated. This results in some orders to be completed very early and most orders to delay. There fore, the production control work of the company has to be very strong.

7.3.1 Model Development

Taking the selected solutions into consideration, flow chart type of model which helps to improve PPC system of ASPSC is developed (See figures 7.1, 7.2 and 7.3). The developed model has three phases. They are sales and production planning phase, order receiving and dispatching phase, and shop floor control phase

1. **Sales and Production Planning phase**

In this phase, annual sales and production of the company are planned. The sales plan is decided to be dependant on practical market assessment works. In the data collection stage of the thesis work, it was observed that Radel Foundry is more successful than ASPSC because the former gives strict attention to market survey. The deputy general manager of Radel Foundry says that 60% of production planning work is completed at the market assessment stage. Once the possible job orders are identified, necessary production activities will be listed out and scheduled.

Next to market assessment, either qualitative or quantitative forecasting techniques need to be used to estimate the production quantity of each item. New and indeterminate products have to be estimated using qualitative method. Items which are usually ordered (example Sugar roller, scraper plate, trash plate and so on) can be estimated using quantitative method.

Based on the forecast results and customer comments, the sales division can prepare draft of annual sales plan. After preparing the draft plan, the company has to get comments from selected major customers so that it can improve it to be more feasible. After assuring that the plan is feasible, the marketing and sales engineers have to contact customers to get orders. If most customers are not satisfied with cost estimations and delivery date settings, they have to be contacted and necessary corrections must be done.

The production planning and control division of the company prepares annual production plan based on the sales plan. Production plan will be used to prepare annual raw material requirement plan, capacity requirement plan, and monthly production plans.

2. Order receiving and dispatching phase

In this phase, the fist thing to do is to identify whether the order is according to the plan or not and then to check whether material is available or not. If most orders being orders being received are not according to the plan, monthly production plans have to be revised according to the actual orders.

Another important thing to be considered in this phase is re-setting new delivery dates if the orders are not opened within their validity dates. The production planning engineer has to set new delivery date and inform the customer if he/she believes that the product can not be completed with the previously stated delivery date.

The second phase will be completed by preparing route sheets and dispatching the order to workshops.

3. Shop floor control phase

Main activities of the third phase are:

1. Test piece production for new products to calculate actual cost of production and to improve production method
2. Machine load chart preparation which helps to identify bottleneck machines, to realistically estimate delivery times and to simplify production progress follow up
3. Progress follow up , communicating encountered problems to concerned individuals, progress evaluation and reporting

Responsibility matrix, which shows main activities of the developed model and responsible parties, is shown in table 7.1.

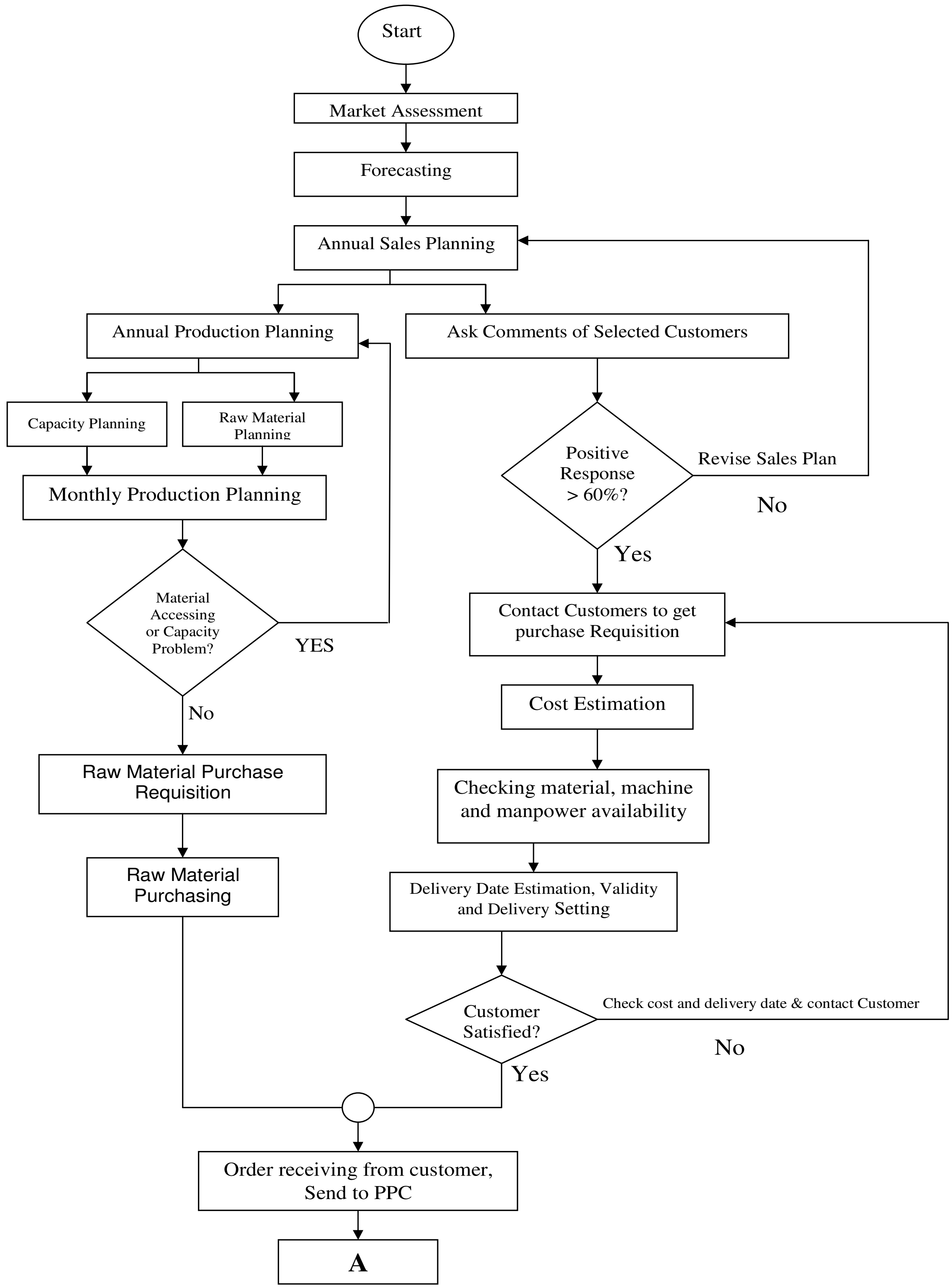


Figure 7: 1 Sales and Production Planning Phase

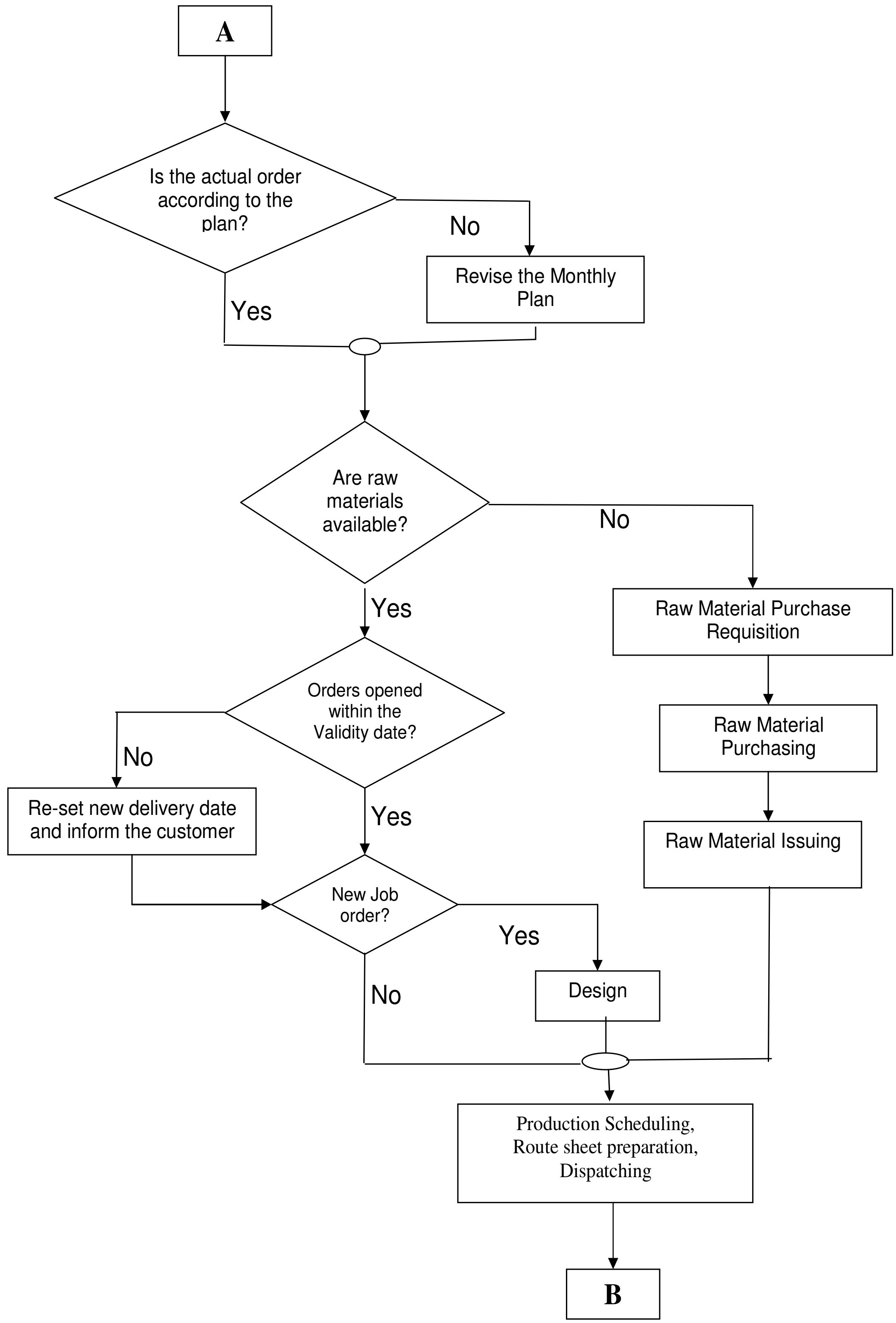


Figure 7: 2 Order Receiving and Dispatching Phase

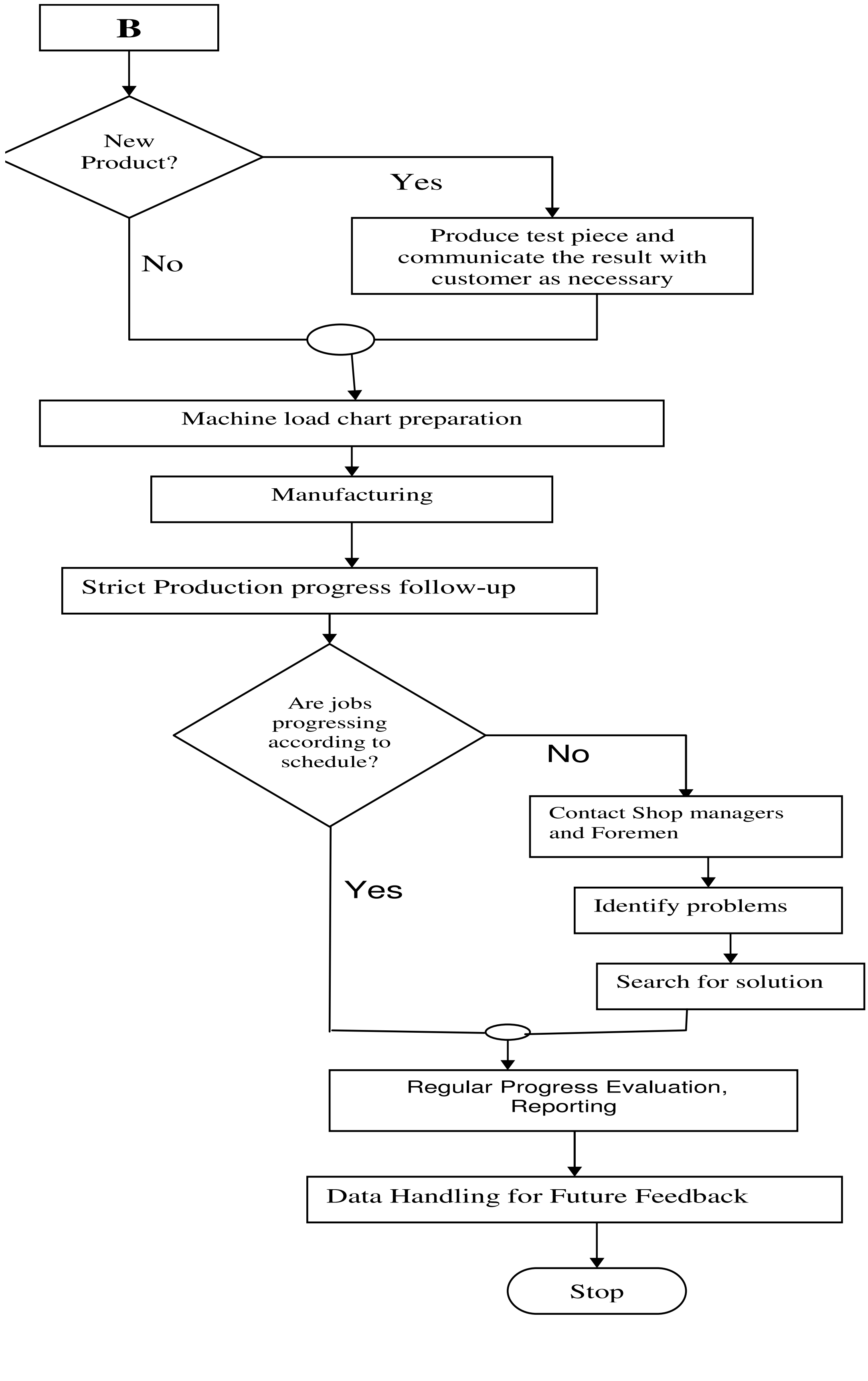


Figure 7: 3 Shop Floor control Phase

Table 7: 1 **Responsibility Matrix**

S. No	Activities	Responsible Parties									
		Marketing Engineer	Sales Engineer	Production Planning Engineer	Design Engineer	Workshop Planner and Controller	Purchasing Div.	Raw Material Store	PPC Clerk	Work shops	Maintenance Div.
1	Market Assessment	✓	✓								
2	Forecasting	✓									
3	Annual Sales Planning		✓								
4	Comment Collection		✓								
5	Annual Production Planning			✓							
6	Capacity Planning			✓		✓					✓
7	Raw material Planning			✓							
8	Monthly Production Planning			✓							
9	Raw material Requisition			✓				✓			
10	Raw material Availing						✓	✓			
11	Contact Customer		✓								
12	Cost Estimation		✓								
13	Evaluation and Delivery Date Setting			✓							
14	Order Receiving from Customer		✓								
15	Monthly Prod. Plan Revision			✓							
16	Delivery Date Re-Setting			✓							
17	Workshop Drawing Preparation				✓						
18	Production Scheduling			✓							
19	Route Sheet Preparation			✓							
20	Dispatching to Workshops					✓					
21	Test piece Production									✓	
22	Result Communication to Customer		✓								
23	Machine Load Chart Preparation			✓		✓				✓	
24	Strict Production Progress Follow-up			✓		✓				✓	
25	Problem identification and Solving		✓	✓	✓	✓				✓	✓
26	Progress evaluation and Reporting		✓	✓		✓				✓	
27	Data Handling for future Feedback	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

CHAPTER EIGHT

CONCLUSION AND RECOMMENDATION

8.1 Conclusion

Ethiopian job order companies are in fierce market competition for their survival. Because of the competition, most of them are working at lower than 50% of their capacity.

In addition to the market shortage, the country's job order companies are working at low capacity due to poor production planning and control practice. Almost all the visited companies do not use any forecasting technique. The privately owned job order companies like Mesfin Industrial Engineering, Maru Metals and Radel Foundry give strict attention for market assessment. After getting an order, they take all the necessary fast decisions to attain promised delivery dates and product qualities. Their limitation is that they do not give attention to formal production planning and control procedures. This makes them to be short sighted.

The state owned job order companies are less committed to market assessment than the privately owned ones are. Transferring responsibilities to others and blaming each other is common practice. High manpower turnover is also their headache. Actions like raw material procurement, risk taking while receiving strong commitment desiring job orders, sub-contracting part of a work, and employing workers within short time are not performed at the right time.

Delay in decision making is common problem at ASPSC. Most job orders are delayed because of delayed decisions to procure raw materials, maintain broken machines, clear ambiguities of customer needs and so on. Compared to all the visited job order companies, the production planning and control framework of ASPSC is good. However, because of high negligence and manpower turnover, the company is at lower efficiency and profitability than most Ethiopian job order companies.

The company's top management thinks that ASPSC has no PPC system. It is wrong to conclude that nothing has been previously done on PPC implementation in the company. At least, the following tangible facts can not be denied.

1. The cost estimation format (Inquiry Sheet) explicitly shows material, labor and overhead cost shares.
2. Route sheets (operation tickets) indicate all the necessary steps to follow while manufacturing a product.
3. The company has a format used to calculate the manufacturing data of manufactured items. The data are then used to calculate actual manufacturing costs and compare with the estimated values.

Nevertheless, the system has the following drawbacks.

1. Compared to other job order companies like Radel Foundry, Maru Metals and Mesfin Industrial Engineering, ASPSC is very poor at market assessment.

2. The annual sales plan is not prepared based on any forecast result. This results in high deviation between the plan and actual job orders.
3. The delivery time estimation is unreliable since machine load charts are not prepared, and operation and machine setup times are not properly calculated. To minimize the problem, the three phased model has been proposed. Responsible parties of main activities are also indicated.

8.2 Recommendation

It is obvious that chronic problems may not be solved overnight. As it was explicitly discussed in chapter six, ASPSC's chronic problems are low capacity utilization, poor delivery date performance and poor product quality. If the company gets committed and stable top management, it will not be difficult to minimize and then eradicate these problems from the company.

Therefore, it is recommended that the following important points should be considered to alleviate the problem.

1. Top management of the company should be convinced and committed to implement the proposed model.
2. Privately owned job order companies are surviving being profitable. So, why can't ASPSC do that being at higher capacity that they are?
3. Stabilization of human resource plays great role. Therefore, the company has to do a lot in this respect.

8.3 Future Works

To strengthen the PPC systems of job order companies in Ethiopia, interested researchers can make further research on:

1. Software development using the developed PPC model
2. Time study to develop empirical formula for machine preparation and delivery time estimation at ASPSC

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Appendix A

Questionnaire for ASPSC Workers

Addis Ababa University

Mechanical Engineering Department

Graduate studies in Industrial Engineering Field

Interview (questionnaire) guideline to assess <u>Production planning and control systems in job order companies</u>

<u>A case study on ASPSC</u>

<u>Note</u>: - *This questionnaire is intended to assess the necessary information to develop an effective and efficient* ***production planning and control system for job order companies in general and for ASPSC in particular.*** *The questions are assumed to be answered by Production Managers, Production Engineers, Supervisors, Foremen, Materials Managers, Sale Managers, Sales Engineers, Production Planners, and other concerned workers. If you encounter questions that you cannot answer, please leave them blank*

Thank you for your help.

Factory name ……………………………….…

Interviewee Name (optional) ……………………….

Job title…………………………........................

Work Experience ……………………………….

Date of interview …………………………………

Place of interview…………………………………

Interview conducted by: Mezgebu Bawoke

1. What are the main products of the company?
   ____
   ____
2. How many types (approximately) of main products does the company produce annually?
   ____
   ____
   ____
3. How many workers does the company accommodate?
   ____
4. Can you sketch the production flow of the factory? (You can use an attached paper)
   ____
   ____
5. What is the plant layout of the factory? __________________________

6. Does the company exactly know its customers? ____________________
7. If yes, list them ____

____

____

____

8. If no, don't you think that it is necessary to know? _______________

What is your comment? _______________________________________

____

9. The company has production planning and control section. What do think are its major tasks?

   a. ____
   b. ____
   c. ____
   d. ____

10. Do you believe that PPC section is discharging its responsibility?
    ____

11. If yes, why are most job orders delayed?
    ____

____

____

12. If no, what do you think the section should do to improve its performance?
    ____
    ____

13. What do you understand by business planning?
    ____

____

____

14. Do you believe that ASPSC prepares business plan? ______________
15. Does the company have business plan records of some two to five budget years? _________
16. ***The objective of aggregate production planning (APP) is translating the corporate strategic plan into broad categories of workforce size, inventory quantity, and production levels.***

Does the company prepare aggregate production plan? _______________

17. If so, what inputs are used to develop the aggregate production plan?

____

____

____

18. Do you use forecasting techniques for planning? _______________
19. If yes, which forecasting techniques are you using?
    ____
    ____

____

20. **Master Production Scheduling is disaggregating APP**.

Does ASPSC prepare Master Production Schedule (MPS) and Material Requirement Plan (MRP)? _________________________________

21. If yes, do the plan and the actual production match? ____________

22. If they do not match, how often is the plan revised?

____

____

23. How is production order initiated and dispatched to manufacturing shops?

____

____

24. Delivery dates of most products are not attained. Do you agree? _____

25. If yes, what do you suggest to improve delivery date estimation methods?

____

____

26. Does the company make any survey on customers' reaction to its products? _______

27. If yes, what are some examples of the survey?

____

28. How often are ASPSC customers satisfied with delivery times and quality of its products? ____

29. If you think that they are not satisfied, can you state some reasons of dissatisfaction? ____

____

30. Manufacturing (production) costs are estimated by sales engineers. Do you think that the inputs like overhead cost rate, labor cost rate and material cost rate for the cost estimation are enough and reliable?

____

____

31. What do you suggest for the improvement of cost estimation method? ____

____

32. Actual manufacturing costs are evaluated and compared with the estimated costs. Do you think that the evaluation is reliable? ___________________________________

____

____

33. If you think that it is not reliable what should be done ____

____

34. What corrective actions do you take when actual cost deviates from the estimated cost considerably? ____

____

35. What are the capacity utilization measures that ASPSC is using?

36. What percent of its capacity does it utilize (approximately)?

37. What do you think are the possible reasons for the factory to be limited to this much capacity utilization?

38. What mechanisms are used for production controlling?

39. Do you use any computer system in your production process?

40. If yes, which application software are you using? MS Excel, MS Access or else? State it,

41. For what purposes do you use the above software?

42. How are the sales, production planning, materials store, and purchasing divisions (departments) interrelated?

43. Currently, the above divisions are not networked. If they were networked, what advantages could be gained?

44. How does the production planning section get the information of raw material status?

45. Do you use any production planning and control software?

46. If yes, what is it, and how does it work?

47. What are the performance reports of your department?

Appendix B

Questionnaire for Other Job Order Companies

Addis Ababa University

Mechanical Engineering Department

Graduate studies in Industrial Engineering Field

Interview (questionnaire) guideline to assess <u>Production planning and control systems in job order companies</u>

<u>**Note**</u>: - *This questionnaire is intended to assess the necessary informations to develop an effective and efficient* ***production planning and control system for job order companies.*** *The questions are assumed to be answered by Production Managers, Production Engineers, Supervisors, Foremen, Materials Managers, Sale Managers, Sales Engineers, Production Planners, and other concerned workers. If you encounter questions that you cannot answer or questions which do not apply to your company, please leave them blank. I guarantee that the information collected here are to be used only for academic purpose.*

Thank you for your help.

Factory name ………………………………….…

Interviewee Name (optional) ……………………….

Job title………………………..........................

Work Experience ……………………………….

Date of interview …………………………………

Place of interview…………………………………

Interview conducted by: Mezgebu Bawoke

1. What are the main products of your factory? ________________________________

____

2. How many workers does the company accommodate? _______________________

3. How is production process (production flow) in the factory? (You can use attached paper)

____

____

4. What is the plant layout of your factory? ___________________________________

5. How many types (approximately) of main products do you produce annually?

____

6. Is your company profit oriented or non profit oriented? _______________________

7. Do you exactly know your customers? ____________________________________

8. If yes, list them ____

____

9. If no, don’t you think that it is necessary to know? __________________________

What is your comment? ____

____

10. Does your company have production planning and control section, division or department? ___________________________

11. If yes, what are its major tasks?

    a. ____

    b. ____

    c. ____

12. What do you understand by business planning? ____________________________

____

13. How much (in birr) is your annual business plan? ____________________________

14. Do you have business plan records of some two to five budget years? ____

15. The objective of aggregate production planning (APP) is translating the corporate strategic plan into broad categories of workforce size, inventory quantity, and production levels.

Does your company prepare aggregate production plan? _____________________

16. If so, what inputs do you use to develop you aggregate production plan?

____

____

17. Do you use forecasting techniques for planning? ____________________________

18. If yes, which forecasting techniques are you using? ______________________

____

19. **Master Production Scheduling is disaggregating APP**.

Does your company prepare Master Production Schedule (MPS) and Material Requirement Plan (MRP)? ____

20. If yes, do the plan and the actual production match? ________________________

21. If they do not match, how often do you revise your plan? ___________________

____

22. How is production order initiated and dispatched to manufacturing shops?

____

____

23. How often are your customers satisfied with delivery times and quality of your products? ____

24. If you think that they are not satisfied, can you state some reasons of dissatisfaction? ____

____

25. Do you estimate manufacturing (production) costs? _________________________

26. If yes, how is the estimation procedure? ____

27. Do you evaluate your actual manufacturing cost and compare it with the estimated cost? ____

28. If yes, how is the evaluation procedure? _____________________________

____

29. What corrective actions do you take if actual cost deviates from the estimated cost considerably? ____

____

30. What are the capacity utilization measures that you are using? _____________

____

____

31. What percent of its capacity does your company utilize (approximately)? ____

32. What do you think are the possible reasons for the factory to be limited to this much capacity utilization? ____

____

33. What mechanisms does your company use for production controlling? ____

____

34. Do you use any computer system in your production process? _____________

35. If yes, which application software are you using? MS Excel, MS Access or else? State it, ____

36. For what purposes do you use the above software? _________________________

____

37. How are the sales, production planning, materials store, and purchasing divisions (departments) interrelated? Are they networked? Where is there location in the organizational structure? ____

____

38. How does the production planning department get the information of raw material status? ____

____

39. Do you use any production planning and control software? ________________

40. If yes, what is it, and how does it work? ____

____

41. What are the performance reports of your department? ____________________

Appendix C

Raw Data of Performance Reports

Table C: 1 **Production and Sales Performance of 1994 budget Year**

Month	Sales (At Price)			Production (At cost)			Capacity Utilization (%)
	Plan (Birr)	Actual (Birr)	Perf. (%)	Plan	Actual	Perf. (%)	
July	1,499,367.00	1,348,914.00	89.97	1,178,839.00	1,992,856.00	169.05	36.49
August	1,565,707.00	1,631,224.00	104.18	1,229,041.00	1,787,328.22	145.42	31.14
September	2,561,508.00	1,554,722.00	60.70	2,021,111.00	1,080,328.00	53.45	32.09
October	2,468,572.00	1,575,885.00	63.84	1,853,863.80	1,163,020.00	62.73	35.67
November	2,065,719.00	1,887,148.00	91.36	1,343,383.10	2,141,743.50	159.43	46.94
December	2,539,373.00	1,374,937.00	54.14	2,023,996.00	1,577,420.05	77.94	35.18
January	2,728,513.00	1,270,455.00	46.56	2,127,437.80	981,296.00	46.13	30.63
February	1,643,958.00	1,593,479.00	96.93	1,346,556.62	1,047,306.95	77.78	33.60
March	1,636,974.00	1,970,550.00	120.38	1,305,316.00	1,317,279.00	100.92	33.34
April	2,055,975.00	1,320,763.00	64.24	1,800,649.00	1,025,406.63	56.95	33.35
May	1,760,721.00	1,705,466.00	96.86	1,481,375.10	1,723,556.20	116.35	29.64
June	1,175,029.00	4,419,896.00	376.15	915,156.00	3,122,947.00	341.25	34.93
Total	**23,701,416.00**	**21,653,439.00**	**91.36**	**18,626,724.42**	**18,960,487.55**	**101.79**	**34.39**

Table C: 2 **Production and Sales Performance of 1995 budget Year**

Month	Sales (At Price)			Production (At cost)			Capacity Utilization (%)
	Plan (Birr)	Actual (Birr)	Perf. (%)	Plan	Actual	Perf. (%)	
July	2,391,943.00	638,096.00	26.68	1,744,061.00	902,517.00	51.75	36.49
August	2,391,942.00	521,120.00	21.79	1,771,995.00	1,270,461.20	71.70	31.14
Sept.	2,412,250.00	1,144,394.00	47.44	1,821,764.00	938,714.00	51.53	32.09
October	2,795,412.00	1,189,127.00	42.54	2,396,126.00	1,236,076.00	51.59	35.67
Nov.	1,574,236.00	910,307.00	57.83	1,687,304.00	1,323,856.00	78.46	46.94
Dec.	1,648,424.00	709,132.00	43.02	1,795,915.00	801,880.90	44.65	35.18
January	1,892,573.00	2,017,223.00	106.59	2,276,788.77	1,801,563.20	79.13	30.63
Feb.	1,898,685.00	2,266,936.00	119.40	1,478,445.00	1,025,874.52	69.39	33.60
March	2,277,638.00	2,000,137.00	87.82	1,589,178.00	995,824.50	62.66	33.34
April	1,971,069.00	1,166,047.00	59.16	1,505,882.75	2,081,613.90	138.23	33.35
May	1,977,070.00	1,632,706.00	82.58	1,380,821.94	1,754,691.30	127.08	29.64
June	1,687,552.00	3,468,414.00	205.53	979,250.00	1,787,644.73	182.55	34.93
Total	**24,918,794.00**	**17,663,639.00**	**70.88**	**20,427,531.46**	**15,920,717.25**	**77.94**	**34.39**

Table C: 3 **Orders on hand and Quality Failure Cost Rates of 1994 Budget Year**

Month	Orders on hand								Failure Cost (Birr)	Failure Rate (Failure cost/pdn cost) (%)
	Delayed		Not Delayed		Total		Percentage of delay (%)			
	In number	In birr	In number	In birr	In number	In birr	In number	In birr		
July	150	1,340,903.00	98	1,465,320.00	248	2,806,223.00	60.48	47.78	7,381.30	0.37
August	48	1,787,463.00	119	966,224.00	167	2,753,687.00	28.74	64.91	11,053.86	0.62
September	243	1,968,233.00	84	2,016,419.00	327	3,984,652.00	74.31	49.40	2,194.53	0.20
October	738	404,775.00	819	1,318,562.00	1557	1,723,337.00	47.40	23.49	6,253.30	0.54
November	266	2,201,274.00	103	786,373.00	369	2,987,647.00	72.09	73.68	5,902.58	0.28
December	264	3,054,578.00	121	1,309,098.00	385	4,363,676.00	68.57	70.00	3,258.08	0.21
January	226	2,656,940.00	130	1,851,116.00	356	4,508,056.00	63.48	58.94	2,719.01	0.28
February	230	2,899,032.00	74	1,077,639.00	304	3,976,671.00	75.66	72.90	10,548.28	1.01
March	201	2,017,032.00	114	2,774,224.00	315	4,791,256.00	63.81	42.10	3,510.18	0.27
April	198	1,622,068.05	107	3,774,224.00	305	5,396,292.05	64.92	30.06	3,588.97	0.35
May	173	1,766,095.00	90	6,295,644.00	263	8,061,739.00	65.78	21.91	3,059.54	0.18
June	163	2,105,878.00	193	4,113,259.00	356	6,219,137.00	45.79	33.86	3,450.99	0.11
Total	**2900**	**23,824,271.05**	**2052**	**27,748,102.00**	**4952**	**51,572,373.05**	**58.56**	**46.20**	**62,920.62**	0.33

Table C: 4 **Orders on hand and Quality Failure Cost Rates of 1994 Budget Year**

Month	Orders on hand								Failure Cost (Birr)	Failure Rate (%)
	Delayed		Not Delayed		Total		Percentage of delay (%)			
	In No.	In birr	In No.	In birr	In No.	In birr	In No.	In birr		
July	135	2,734,790.00	98	5,158,924.00	233	7,893,714.00	57.94	34.65	9,594.58	1.06
August	127	2,126,608.00	89	3,643,356.00	216	5,769,964.00	58.80	36.86	9,947.75	0.78
September	153	1,665,249.00	139	4,672,268.00	292	6,337,517.00	52.40	26.28	5,021.08	0.53
October	213	2,284,319.10	83	2,856,683.00	296	5,141,002.10	71.96	44.43	6,356.74	0.51
November	152	1,592,744.80	35	3,147,582.00	187	4,740,326.80	81.28	33.60	2,465.60	0.19
December	156	2,782,982.00	73	2,162,473.00	229	4,945,455.00	68.12	56.27	4,036.97	0.50
January	128	2,552,991.00	131	2,560,971.00	259	5,113,962.00	49.42	49.92	6,348.98	0.35
February	150	2,956,094.00	72	1,259,727.16	222	4,215,821.16	67.57	70.12	4,579.42	0.45
March	131	2,520,046.00	57	2,415,746.90	188	4,935,792.90	69.68	51.06	15,567.70	1.56
April	143	1,873,218.50	101	3,532,370.00	244	5,405,588.50	58.61	34.65	1,402.83	0.07
May	125	1,176,331.00	74	2,865,961.00	199	4,042,292.00	62.81	29.10	17,885.33	1.02
June	76	1,702,002.00	72	6,494,811.00	148	8,196,813.00	51.35	20.76	10,007.18	0.56
Total	**1689**	**25,967,375.40**	**1024**	**40,770,873.06**	**2713**	**66,738,248.46**	**62.26**	**38.91**	**93,214.16**	**0.59**

Candidate's Declaration

I hereby declare that the work which is being presented in this thesis entitled "**Development of Production Planning and Control (PPC) System of Job Order Companies in Ethiopia: A case Study on ASPSC"** is original work of my own, has not been presented for a degree of any other university and that all sources of material used for the thesis have been duly acknowledged.

__________________________ _______________________

Mezgebu Bawoke Date

(Candidate)

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

________________________ ____________________

Dr. Ing. Daniel Kitaw Date

(Thesis Advisor)