
GROUP TECHNOLOGY BASED CLASSIFICATION AND CODING SYSTEM

***A CASE STUDY ON AKAKI SPARE PARTS AND HAND TOOLS
SHARE COMPANY***

***A thesis submitted to the School of Graduate Studies of Addis Ababa
University in partial fulfillment of the requirements for the Degree of Masters of
Science in Mechanical Engineering (Industrial Engineering stream)***

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CHAPTER ONE

INTRODUCTION

1.1 Background

Manufacturing activity has become far more competitive than ever almost in all markets. Due to the fastidiousness of customers and technological advancement, manufacturers are forced to rapidly change and develop their manufacturing capabilities so as to take a major share in the markets competition, This had been made possible through transforming production system from mass production to the production of a large product mix. Moreover this rapid advancement in technology tends to render products obsolete far more quickly than before. As a result of this, companies came to realize that developing advanced methodologies for modeling, design, analysis, and performance evaluation, scheduling and control of these systems is vital for increasing the capacity of producing many small volume batches consisting of complex parts in a short production period. Resort to this new approach is not as simple as it appears at the first blush, for it brings a host of challenges which not only renders the management's task more cumbersome, but also invites unwanted consequences such as an increase in production cost, and a decrease in efficiency of the mass production systems. One approach which has been proved and to be most effective in solving these problems is the adoption of manufacturing philosophy which is known as Group Technology (GT).

GT is generally considered as a manufacturing philosophy or concept on the basis of which certain manufacturing efficiency can easily be improve when part types are identified and collected into groups (known as part families) based on their similarities in design or manufacturing attributes and machines that are required to process the part family into machine-cell. This results in an organization of the production system into self-contained and self-regulated groups of machines such that each group of machines undertakes a maximum production of a family of parts. Such decomposition of the plant operation into subsystems leads to reduced material handling activities, reduction of production lead time and work-in-process inventory, reduction of setup time, reduction of order time delivery, reduction of unnecessary paper work and better supervisory control [11].

One of the fundamental requirements for implementing a GT based manufacturing system is having a developed classification and coding system (CCS). This coding scheme is used to classify the part or product and assign to it in accordance with the predetermined set of codes that relate to define physical or manufacturing characteristics. The CCS can also be used to organize part description so as to assist in the retrieval of parts and/or group parts according to the manufacturing process.

Although it is a precondition for applying GT, a well-developed CCS on its own right can make a significant contribution to the improvement of manufacturing

efficiency (such as effective design data retrieval, effective part family grouping, reduction of duplicated design, etc.). This is the reason, why a GT-based CCS it is chosen as research topic for the introduction of GT based production system in the Country. With the view to make the research more practical and realistic, the author conducted an actual case study. For this purpose, Akaki Spare Parts & Hand Tools Share Company (ASPHT S.Co.) has been chosen as for the following reasons:

- Most of the industries are currently experiencing considerable problems in connection with production equipment. Therefore, facilitating and increasing the manufacturing capabilities of ASPHT S.Co. will be very much helpful to reduce / eliminate these problems.
- It's big productive capacity and potentials, which provides essential service for both agricultural and industrials sectors automatically qualify the plant to assume a prominent position among the nations industries.
- Other manufacturing enterprises that wish to improve their manufacturing efficiencies could possibly adopt the system with certain modifications.

1.2 Objective

The general objective of this thesis is to introduce and develop a GT based classification and coding system taking ASPHT S.Co. as a case.

The specific objectives of this thesis are:

-
- A general survey of the current manufacturing trends of Ethiopian industries as regarding to a GT based production systems.
 - Analyzing and studying the different manufacturing units of ASPHT S.Co by giving more weight to the design section.
 - Based on the data obtained from the classification and existing factory manufacturing conditions, develop a GT based classification and coding system.
 - Based on the research findings prepare implementation proposal for the factory management.

1.3 Methodology

The methodology adopted to achieve the objectives of this study includes:

- **Literature survey:** studying and analyzing the different relevant literature dealing with the subject mater; make a general survey of the current manufacturing trends of Ethiopian industries.
- **Data collection:** this includes analyzing and studying the different manufacturing units of plant by giving more weight to the design section; selecting sufficient sample designs from an already ready-made designs.
- **Analysis of data (desktop research):** in this step the sample drawings are classified into groups in accordance with their design and manufacturing attributes;

-
- **Model development:** based on the data obtained from the classification, existing factory manufacturing conditions, from the different approaches and findings obtained from literature, develop a GT based classification and coding system using VB (Visual Basics 6.0) as front end and Microsoft Access as a back end; and finally preparation of implementation proposal from the research findings for the factory management.

1.4 Applications of the results

Since the developed CCS will improve efficiency, ASPHT S.Co. will be benefited from the study. Following are the advantages, which the CCS could bring to the plant.

- Permitting effective design and drawing data retrieval: if a designer faced with the task of developing a new part, it is possible to use this design retrieval system to determine whether a similar part is already available or not. Since a simple change in an existing part would be much less time-consuming than starting from scratch, it would save the designer's precious time which might otherwise be unnecessary waste.
- Providing reliable work piece statistics.
- Providing better machine tool utilization and better use of tools, fixture and manpower, etc.

Other manufacturing enterprises that wish to adopt the system and improve their efficiencies could benefit from the study as well. Moreover this study can also be of much help for other researchers conducting further studies dealing with issues pertaining to the adoption of GT by local industries.

1.5 Scopes and Limitation

Due to the time constraint while conducting the study, the classification and coding system will be made in such a way that to classify and retrieve drawings only for rotational parts made in the machine shop. Although, more than four hundred sample drawings are taken and analyzed, only small numbers are entered into the data base for the demonstration purpose. Therefore, with similar procedures, it is possible to continue for the non-rotational parts and different cast to make the CCS system complete.

1.6 Organization of the thesis

The report is organized as follows: chapter one is an introduction part and chapter two offers the basic of manufacturing systems. The impact of globalization in the current manufacturing trend is also discuss in chapter three. The present manufacturing trends of Ethiopian industries is presented in chapter four. A literature review with special emphasis and detailed introduction of Group Technology manufacturing system is also presented in chapter five. In chapter six, principles, methods, procedures of classification and coding and the different approaches on this respect are presented. The next chapter describes the proposed classification and coding system based on the existing problems of

ASPHT S. Co. and present practices of the existing classification and coding system. Finally the thesis concludes in chapter eight, by pointing out implementation proposals of the study and directions of future works.

CHAPTER TWO

BASICS OF MANUFACTURING

2.1 INTRODUCTION

The word manufacturing, which is derived from two Latin words *manu and factum*, means to make something by hand [16]. With the changing times and the changing style of manufacturing, the term may be a misnomer as fewer and fewer processes are labor-intensive. In the course of protracted technological development the concept has evolved from designating the mere art of manual operation in to representing complex science of mechanized process. In its present meaning the word applied to a complex set of ideas. Therefore manufacturing is a transformation process in which the inputs (raw materials, equipment, tooling, fixture, electrical energy, and labors) are converted into completed work-piece which carries some definite value in the marketplace. This transformation process usually involves a number of steps, in which the materials are brought closer to the desired final state in each step. These individual steps are generally called production operations, and includes such processes as planning, design, procurement, production, inventory, marketing, distribution, sales and management [17,28]. The key to successful manufacturing is therefore to produce constituent parts in accordance with the desired specification at the lowest cost in the shortest possible time so that provides financial the end result value to the customers.

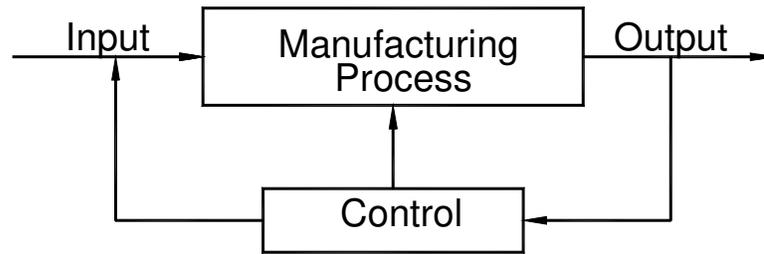


Figure 2-1. Manufacturing process model

2.2 TYPES OF MANUFACTURING COMPANIES

Depending on the nature of their production operations companies can be divided into two major categories, manufacturing industries which are typically identified with discrete-item production: cars, spare parts, machine tools, etc. and the process industries, which are represented by petro-chemical, food processing, cement and steel.

2.2.1. Classification According to Movement of Material

There are a number of ways to classify companies. One alternative would be to place a company in to one of the three categories listed below.

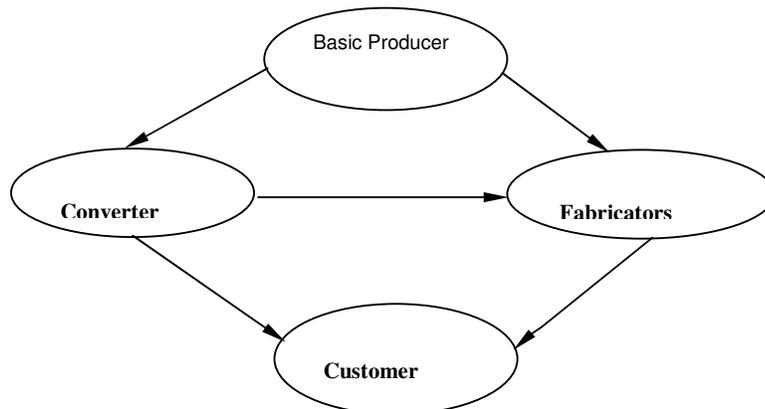


Figure 2-2. Types of manufacturing companies and their relationship.

1. Basic producer this type of manufacturers use natural resources as raw materials and refines or separates them into products which will be used as material inputs by converters and fabricators (by other industrials manufacturing firms), e.g. steel producers transform iron ore into steel ingot.

2. Converter plants belonging to this category put the materials supplied by basic producers through divergent processes to produce consumer goods or end items that can be used by a larger variety of manufacturers known as fabricators. A distinguishing characteristic of the converter is that its products are uncomplicated in physical form. The products are not assembled items. The production process used to make the products may be complex but the products themselves are not. For example the steel ingot is converted into bar stock or sheet metal.

3. Fabricator industries categorized in to this group produce either consumer goods or products for the class of manufacturers known as assemblers. The assemblers in turn combine these various components to produce finished goods for consumers. The bar stock and the sheet metal for instance are transformed into machined engine components and automobile body panel.

These three types form essential nerve centers in chain process of in the transforming natural resources and basic raw materials into goods for the consuming public. Of course the entire process is not as simple as this there are several complicated factors involved in this classification. And some industries themselves might carry activities that fall into more than one category. In certain cases some firms possess a high degree of vertical integration, which includes all the three categories. A typical example of these combined activities is an oil firm, which converts natural resources into finished petroleum products and then market these products directly to the consumers.

2.2.2. Classification According to Volume of Production

Another way of classifying manufacturing process can be made according to the volume and rate of production. These includes, project, jobbing, batch, line, and continuous process production [17,22]

1. Project Production this deals with the provision of a unique product requiring large-scale inputs to be coordinated, so as to achieve a consumer's requirement. The resource inputs will normally be taken to the point where the product is to be built, since it is not feasible to move it once completed. Typical example of this kind may include civil engineering projects, the construction of large-scale manufacturing or military facilities and aerospace programs. The most important tools supporting these activities are various network planning techniques including critical path analysis and PERT.

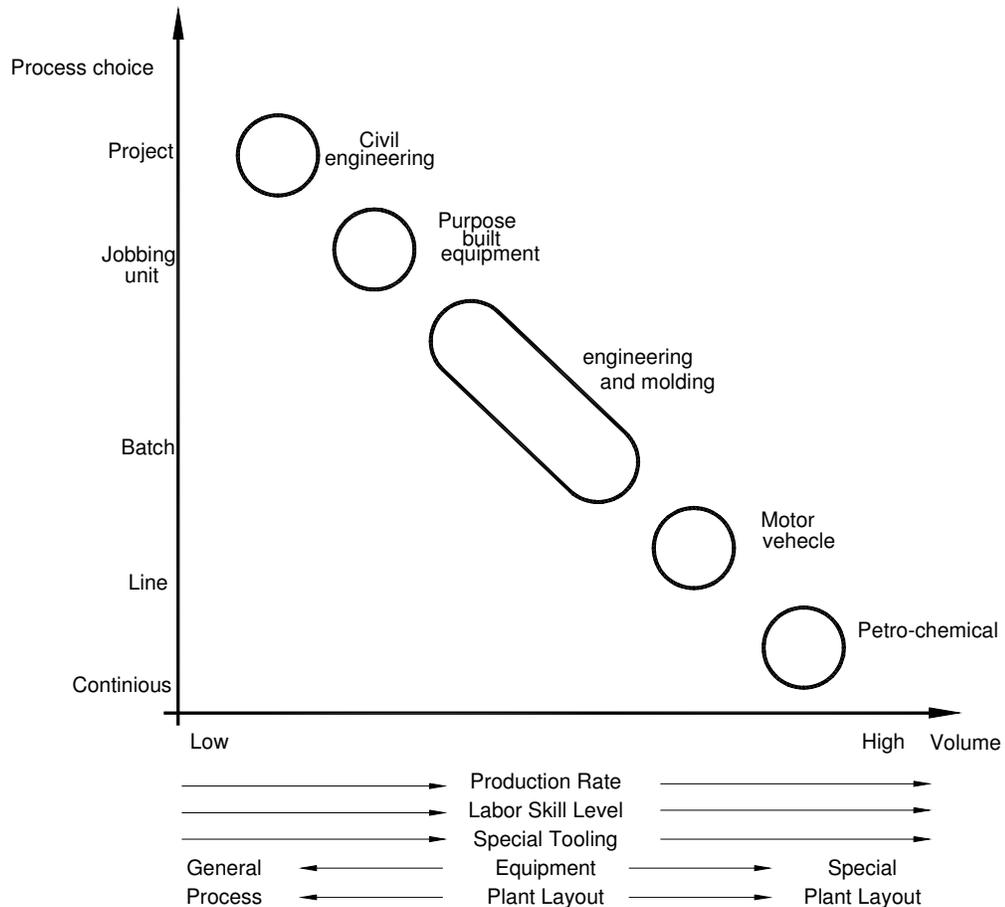


Figure 2-3. Types of production and choice of process related to product quantity and volume (Adopted from [17]&[22])

2. One-off Jobbing Production this type of manufacturing is used to meet the one-off (i.e. unique) order requirements of customers. This one-off provisions means that the product will not again be required in its exact form or, if it is, the demand will tend to be irregular, with long time periods between one order and the next. Therefore, the production equipment must be general-purpose and flexible

to allow for this variety of work. The product involved in this type of production process will have an individual nature and requires that the supplier interpret the customer's design and specification, while applying relatively high level skills in the conversation process. Thus a large degree of this interpretation will normally be carried out by the hands of skilled and experience workers. Regarding costs, they are likely to be high, reflecting high staff costs and investment in complex machines that may only be partially utilized. Some examples of this type of production may include prototypes, special spare parts and test equipment.

3. Batch Production in this process, production equipment is often used for many different products in which each product was being scheduled on the equipment in some cyclic fashion. In batch production, the production rate exceeds the demand rate. The cost of equipment changeover and setup is balanced against inventory holding charges. Typical batch production plants include machine shops, casting foundries and press working shops. In general 75% of all parts are manufactured in lot size of 50 pieces or less, and are produced through batch production. The general purpose manufacturing equipment such as turret lathes is used. Specially designed jigs and fixtures are also being used to increase productivity. The control system for batch production is very complex. We need to determine how many items should economically constitute a batch for a particular product, and how many batches of several products should be sequenced cyclically through the equipment. The purpose of batch production is often to satisfy continuous customer demand for an item.

4. Line or Flow Production when product volumes are high, the markets and designs stable, flow production becomes a viable option. Under this arrangement, parts or assemblies are passed to each successive operation as soon as the preceding operation has been completed. It follows that the throughput time can be drastically reduced and opportunities for mechanization arise with the standardization of products and process. A typical example of flow-line manufacturing of components is the dedicated automotive transfer line producing engine components. Such systems require a heavy capital investment and may become obsolete when product designs change. Usually such systems are being built with software-based control systems to allow the maximum possible flexibility while retaining the benefits of the flow line configuration. These systems are vulnerable to disturbances caused by lack of raw material, machine breakdown or quality defects. The task of designing a balance flow line, which requires the production times for each stage to be equal, is particularly complex in case of assembly systems that are required to accommodate a varying mix of products.

5. Continuous production with continuous process method, a basic material is passed through successive stages or operations and converted into one or more products. A typical example for this type is a petro-chemical industry. Basically the choices of this process is based upon two features

1. Very high volume demand
2. The materials involved lend themselves to be moved easily from one part of the process to another.

The high-volume nature of the demand justifies the very high investment involved. The process is designed to run all day and every day with minimum shut downs, due to the high costs of starting up and closing down (due to the high costs of starting up and shut down operations). In this type of operation, individual operations do not exist, the input gradually is converted to out put. Because of these special characteristics a strong emphasis is placed on design and planning. Once the process begins, re-planning is seldom possible, so the process is carefully monitored and controlled to ad hair the original plan.

Table 2-1 Investment and cost implications of process choice (Hill, 1983)

| Investment and cost | Typical Characteristics of Process Choices | | | | |
|--|--|--------------------|-------|-----------|----------------------------|
| | Project | Jobbing, Unit, One | Batch | Line | Continuous process |
| Amount of capital investment | Low | Low | | | High |
| Economies of Scale | Few | None | | | High |
| Level of inventory | Components and raw materials | As required | | | Planned with safety stocks |
| | Work - in - progress | High | High | Very high | Low |
| | Finished goods | Low | | | High |
| Operations | Material | Low | Low | | High |
| | Lab our | High | | | High |
| Opportunity to decrease operation's cost | Low | | | | High |

Table 2-2 Product/service implications of process choice (Hill, 1983)

| Investment and cost | Typical Characteristics of Process Choices | | | | |
|---|--|--------------------|-------|------|--------------------|
| | Project | Jobbing, Unit, One | Batch | Line | Continuous process |
| Product/service range | High diversity | —————→ | | | Standard |
| Customer order size | One-off | —————→ | | | Large |
| Volume of operations | One-off | —————→ | | | High |
| Degree of product change accommodated | High | —————→ | | | Nil |
| Make - to - order* | Yes | Yes | Some | No | No |
| Make - to - stock* | No | No | Some | Yes | Yes |
| Ability of operations to cope with new developments | High | —————→ | | | None |
| Orientaton of innovation -process or product | Product | —————→ | | | Process |
| Performance criterion: A make - to - order product/service is very readily a customer's requirement. It will not normally be reordered, if it is, the time delay between one order and the next will be long. Make - to - stock products are standard items. | Price is dominant | —————→ | | | Price |
| What dose the organization sell? | Capability | —————→ | | | Products |

2.3 NEW MANUFACTURING METHODOLOGIES

During the early stage of industrialization, things were made and for more or less stale customer demand who would be ready to buy them. The manufacturing world was characterized by success because there was very little competition. However, in today's era, where alternatives are abound, and one must truly understand customers needs and then articulate products and services to meet their changing needs if one wishes to stay on doing business [16]. Thus the business trend has become customer-oriented which takes the following distinct forms.

-
- **More product customization:** customers today demand greater choice in product features and faster response to changing tastes and preferences; this requires greater manufacturing flexibility and faster new product development.
 - **Better product quality:** each separate member of the production and distribution chain as well as the final customer demand better product quality.
 - **Faster order processing:** the same members also expect their suppliers to ship ordered materials, supplies, and merchandize much more quickly than in the past.
 - **Better customer service:** customers expect better follow-up after the sale and better warranties.

This new emphasis on customer satisfaction requires a complete change in attitude. This effort is characterized by time and quality based methodologies. This indirectly affects costs since many of the methodologies used to provide better customer satisfaction also tend to lower costs. The new methodologies and approaches exercised in today's manufacturing practices include: Flexible manufacturing systems Just-in-time (JIT) manufacturing. and Group technology (GT) manufacturing.

1. **Flexible Manufacturing systems:** Flexibility in manufacturing systems can take many forms, the most important being the ability to respond to quickly adapt to changing volume requirements and changing product

mixes. A truly flexible manufacturing installation is also able to accept new products, accommodate design specification, cope with machine

downtime, allow for expansion and reconfiguration so that a completely different line of products can be produced in a relatively short time.

The term *Flexible manufacturing system* (FMS) has come to mean a group of automated machines capable of processing a variety of products through different process routes with fully computer controlled. Clearly the analysis needed to identify part families is very similar to the routines for cellular manufacturing discussed below.

2. Just-in-time (JIT) Systems: JIT is an inventory control system with a single basic premise: arrange to have materials and parts available for use in the manufacturing process only in the exact quantities needed at a specific time. This is departure from the conventional approach of storing excess supplies of all materials and parts as insurance against running out and having to halt the production process. The benefit of JIT will result a decrease in inventory, work-in-process, defect reworks, rejects, scraps, setup times, handling, transporting, excess output, lead times and breakdowns (through better maintenance).

3. Group Technology (GT) Manufacturing: It is a method for improving the productivity of manufacturing operation by grouping the products to be manufactured into "families" based on their similarities in design and manufacturing attributes. One of the major applications of this type of manufacturing is Cellular Manufacturing (CM) where machines with the same functions are grouped together to form a single line or cell of machines to process

or assemble a family of production. The advantage of such a layout is that a wide range of different products with different process requirements can be supported simply by changing the routing through the plant. The following are some of the advantages obtained from this system

- Since parts visit only one cell rather than a variety of processes around the plant, the production control task becomes greatly simplified.
- Materials handling and throughput time were reduced with corresponding benefits from the reduction of work in progress.
- Machine set-up times can be reduced as the tooling and fixturing changes between parts of the same family are generally simpler than changeovers between unrelated parts.

CHAPTER THREE

THE IMPACT OF GLOBALIZATION ON THE CURRENT MANUFACTURING TREND

3.1 INTRODUCTION

The economic world and the market trend of the 1980s and beyond is and will be, very different from that of the preceding decades. Until the early 1970s, most companies were competing with a limited span, principally based on domestic rules. Their business strategies were often based on a drive only to improve their internal efficiency and effectiveness to be more competitive in their different markets.

During this period, most markets were growing strong enough for the products which would be sold largely on the initiative of the producer. But gradually, as the number and variety of manufacturing industries increased, markets increasingly began to exhibit the effect of saturation, and thus a period of low growth followed. This situation forced manufacturing companies to rapidly change and develop their manufacturing capabilities so as to compete more strongly for the limited number of customers.

Moreover the rapid advancement in technology together with the increasing fastidiousness of customers tend to render products obsolete far more quickly than before. As a result of this, the competition starts to follow a global norm

characterized by intense competition. Therefore, companies came to realize that developing new products ahead of their customer's need is a key for their survival in the competition. Thus came the new trend that made manufacturers to move from mass production to the production of a large product mix. This process of transformation brought about a radical shift in the prevailing trend of manufacturing strategies i.e. the transition from the economy of scale into the economy of scope.

Gradually, these changes in the manufacturing strategy started to facilitate an economic linkage that fosters economic well-being between countries by forming a free market competition at a global scale (i.e. market globalization). This creates ample opportunities for many multinational enterprises to conduct business and/or manufacturing activities by establishing business and/or manufacturing sites in various countries across the world. However for various reasons, most developing countries are to date marginalized in terms of actively participating in the competition. The successful ones typically reacted by offering more versions and so expanding possible demand.

In this context successful businesses can simply be identified as those who recognize this international competition (i.e. market globalization) as a reality and adjust themselves to become competitive under the terms of the new rule. For the most part, however, production decision-making in manufacturing industry has not changed to meet these new challenges. Therefore, this chapter

will attempt to provide a working definition of globalization and will try to explore some of its main effects on the current manufacturing practices.

3.2 CONCEPTS AND DEFINITIONS

It was not so infrequently observed the past two decades are characterized by a progressive consolidation of cross-border economic relationships and an ever growing integration of the international economy between nations. The greater mobility of goods and services and means of production has led to an ever expanding economic linkages and mutual dependency within the world economy. This in turn has brought about a new methodological approach that shifted the traditional boundaries of analysis and manufacturing trends to international trade and resource flows.

The recent growth in international integration is qualitatively different from the previous practices. In contradistinction to the earlier expansion of international trade, it has been characterized by the intensification of economic linkages that transcend national boundaries. Trade and resource flows have become more complex, often involving economic agents and structures acting at the micro level. This process of a growing international economic integration has been variously described as *Globalization*. Although globalization has become a fashionable concept in recent year, it has been used to describe a variety of tendencies. At the most general level it has been defined as [26]:

'The forging of multiplicity of linkages and interconnections between the states and societies which make up the modern world system. The process

by which events, decisions and activities in one part of the world can come to have significant consequences for individuals and communities in quite distant parts of the globe.'

From an orthodox market-oriented perspective, globalization is often considered as some of the advantage to be obtained through the operation of competitive markets and the freer international movement of goods, services, capital and technology. However, other observers, have criticized this simplistic view of the globalization process, for its neglecting some of its adverse consequences and the different impacts on various countries and for ignoring its distribution effects within countries.

But in many developing countries the growth in globalization has been viewed with apprehension, generating considerable uncertainty as to its impact on future growth and development prospects. In fact a number of reasons may be given to the issue what really has marginalized and prohibited them from actively participating in the market competition. Some of the problems of these countries encountered in the market competition include [12]:

- Inadequate infrastructures;
- Lack of coherently articulated economic policies;
- Inadequate skilled labor force;
- Untimely delivery of parts;

- The failure not attaining the required specifications;
- High production cost, etc.

In one way or another we also perceive the recurrence of the same problems, in most of Ethiopian industries. In order to alleviate these problems, and increase the manufacturing capabilities, so as to play a major roll in the competition,

following a new trend of manufacturing strategy will be a good alternative. But the introduction of this new economic trend might necessitates the capacity to produce many small volume batches consisting of complex parts in a short production period so as to fulfill the variety of customer needs. Evidences abound that all is not well with actual implementation, it may not only render the management's task more cumbersome, but also invites other unwanted consequences such as an increase in production cost, and a decrease in efficiency of manufacturing systems. Therefore, one possible solution can be the introduction of a **Group Technology (GT)** manufacturing system.

Studies conducted on-developing economies that have gone through the chronic problems of low industrial performance and inefficiency indicate, an astoundingly rapid economic improvement following a shift in industrial strategy. Considering the extremely low economic return characterizing most Ethiopian industries, a major constraint, which among other things, immensely contributed to the grime economic reality is failure to effectively utilize production capacities and potentials in accordance with the needs of the current market trends.

Therefore if a rapid recovery is central to the issue of economic development, the adoption of a GT based production system could be one solution.

CHAPTER FOUR

THE PRESENT MANUFACTURING PRACTICES OF ETHIOPIAN INDUSTRIES

4.1 Introduction

When we see the economy of our country, it is an agrarian rather than industrial. About 85 percent of the population lives in the rural areas by making agriculture the main source of income. The fixed size of the agricultural land and the day-to-day depletion of agricultural resources in general along with the rapidly increasing population has made it impossible for the sector to provide with sufficient and useful income to pull out the majority of the rural population from its miserable life.

If the expected rise in agricultural productivity attains its target of improving the income of the rural population, the non-agricultural sectors particularly the manufacturing sector need to expand and develop rather rapidly not only to be able to accommodate the customer needs but also to create demand for the unemployed urban labor force and to accommodate the expected migration from the rural areas as well. This is not the only reason why the manufacturing sector in Ethiopia or in any other developing country for that matter needs to expand. As the experience of the developed or the newly developed countries attest, there cannot exist an overall economic growth without some kind of industrialization. Therefore, if Ethiopia is to alleviate the crippling poverty that most of its citizens find themselves in, to increase the income of its working people, to generate the desperately needed employment for its youth, and to provide all this in a sustainable way, it has no choice but to find a way to significantly increase the size and the productivity of this crucial sector of the economy [36]. Therefore in this chapter, we will look the

historical development and the current practices of the manufacturing industries of the country.

4.2 Historical Background of Manufacturing Industries in Ethiopia

The establishment of modern manufacturing practice in Ethiopia developed with the emergence of centralized government and political stability during the end of 19th century. Among the many factors which contributed towards its development, the installation of Ethio-Djibouti railways and the strengthening of Ethiopian foreign relations, created a desire for modern manufacturing products among Ethiopian elites. The increasing settlement of foreign citizens from different countries like Armenia, Greece, Italy, and India were also brought the entrepreneurial capacity to develop and improve the local manufacturing industries. During this time the increasing problem associated with transporting imported commodities like wood, clay, and printing products etc. has contributed as an incentive for starting local manufacturing practices.

By 1927, about 25 factories were established in different cities of the country, like Addis Ababa, Dire Dawa, Asmara and Messawa which includes 5 wood and clay factories, 2 tanneries, 5 soap and edible oil plants, 2 ammunition factories, 1 brewery, 2 tobacco processing plants, 1 cement factory, 1 grain mill, and 2 salt factories. Thus except the two ammunition plants and the printing press, all were established by private entrepreneurs[36].

From 1928 – 1941, about ten manufacturing industries were established, of which two of them were founded before the Italian invasion, the rest were established during the Italian occupation. After the Italian war (1941-1950) that the manufacturing sector shows a rapid growth. Even during this period, this rapid increase in the number of manufacturing industries was not obtain by a conscious and deliberate industrial development policy and strategy. But later on a deliberate strategy to encourage the expansion of the industrial sector was formulated just to fulfill the high customer demand of the time. As the advancement of technology and the change in market competition increased different measure were taken to make the manufacturing industries more competent and reliable to satisfy the high customer demands. The development manufacturing industries of the country can be divided into the following three major political era.

4.2.1 The Imperial Period (before 1974)

The level of industrialization in Ethiopia during the Imperial period was considered as at an incipient stage. A conscious effort towards developing and establishing a modern industrial sector did not start till the 1950s. The main

agents for the expansion of the industrial sector during this period were foreign nationals residing in the country. It was believed that the settlement of foreigners along with the expansion of commercial farms would continue to give inertia to the growth and expansion of the industrial sector.

As a result of the conducive environment created during the later years of the imperial era, a number of manufacturing firms were established during this period. By the end of the imperial period, there were some 430 manufacturing establishments with a low level of employment creation comparing to the population size. These industries were designed to satisfy the limited domestic market and were seriously handicapped by poor infra-structural facilities and lack of clearly articulated government economic policy towards the development of the sector. The majority of the industries were in nature employing very few skilled personnel with a rudimentary concept of quality and market.

4.2.2 THE DERGE ERA (1974 – 1991)

As it was noted in the earlier section, the great majority of the manufacturing concerns in Ethiopia before the 1974 revolution, especially the medium and large scale ones, were owned by foreigners. The industrial sector of the country by 1974 was also small, and was characterized by production for the domestic market mainly to substitute imports. After the 1974 revolution, Derge changed the structure of ownership as part of its “socialist” policy, and nationalized

virtually almost all medium and large-scale industrial enterprises owned by Ethiopians and foreigners alike. This made, the industrial sector to be dominated by public manufacturing enterprise.

During this period, participation of the private sector was deliberately discouraged through the imposition of capital ceilings and preferences were given to

government owned enterprises in the allocation of foreign exchange, market access, subsidies and the like. Private ownership was mainly confined to small-scale industries and handicraft activities. Thus only the state took the responsibility in developing and managing the medium and large-scale industrial sector. However there were some measures that were taken by the government to change the traditional ways of manufacturing by way of giving training to the workers of the small scale and handicraft industries. In order to minimize and solve problems in connection with production equipment and spare parts for most parts of the industries, the government took measures to establish manufacturing industries like Akaki Spare Parts and Hand Tools Factory (ASPF). To improve the local indigenous capability different manufacturing industries were also established like AMCE, Nazareth Tractors Assembly Plant (NTAP), etc. The government sought to attract investment in this sector through the economic assistance it hoped to get from the then socialist countries. Although some investment in this area has been materialized, it certainly was not close to what the socialist industrializers hoped to achieve.

Following the collapse of state socialism in Eastern Europe and later in the former Soviet Union, and the increasing economic and political difficulties it faced, the regime tried to introduce some economic reforms by way of introducing a mixed economy policy. During this time a number of constraints for private sector development were reconsidered. For instance, the restriction of capital ceiling was relaxed. However, several of these encouraging measures were not materialized as the civil war reached its climax and diverted government resource towards

resolving security problems. In short, the industrial policy of the Derge regime has stifled the speedy development of the sector, which had resulted basically from too much government intervention and limited participation of the private sector.

4.2.3 THE POST - DERGE ERA (AFTER1991)

Following the collapse of socialism, the only choice that developing countries have in terms of planning their development strategy was following the line of an economic system that goes liberalized the existing economy of the country following its development so as to destine in to the more liberalized capitalist system. Accordingly, the transitional government of Ethiopia, which took power from the Derge, announced an economic policy whose basic elements can be characterized as “cautious capitalism”. The government accepted structural adjustment program although with some reservations to make conducive environment for investment.

The private sector was allowed to invest on different manufacturing industries both small and medium scale. But the state would be allowed to undertake areas of large–scale engineering, metallurgical, communication, power and pharmaceutical industries which may not be able to be undertaken by the private sector.

A new investment code was proclaimed in 1992 with a hope to attract private investment particularly foreign direct investment in areas of the economy destined for the privet sector. Laws were ratified to give enterprise

management autonomy, a more flexible labor code was proclaimed. Price was also largely decontrolled, and foreign trade and financial institutions including the foreign exchange market were partially liberalized.

The government of the EPRDF led Federal Democratic Republic of Ethiopia, which took over the transitional government indicated its intentions about the future of the Ethiopian economy by outlining its broad five year development program. The general idea of the economic part of the program is rural centered development with utmost emphasis on the agriculture sector as a springboard for expanding the development of the other sectors. According to this strategy, agriculture is to be the primary focus of the development in short and medium terms. This is, of course expected to increase the income of the rural people, which will in turn raise the purchasing power of the large proportion of the population. This will consequently increase the demand for industrial goods as

well. Agriculture would thus become a source of domestic market demand and a reliable raw material base.

Due to the change in economic policy, the number of manufacturing establishments increased and became 788[5]. Although the number shows an increment compared to the previous years, still it has to be enlarged and improved so as to accommodate the high customer demand. Therefore, manufacturers should gear their ways of manufacturing from mass production to the production of a large product mix.

4.3 The Size of the Manufacturing Industries

The Central Statistical Authority (CSA) has been annually conducted a survey for manufacturing establishments with 10 and above employees. Based on this survey a comparison was made just to show the number of manufacturing establishment and how the numbers vary during the three era's in table bellow. According to the survey made by CSA, the number of manufacturing establishment with 10 and above employees in 1975/76 were 430. This number declined to 402 in 1985/86, a decline of 0.82 percent per annum. It further declined to 273 in 1992/93, the lowest ever registered eventually growing to 642 by in 1995/96 and 788 in 1999/2000 [5,36].

Table 4-1 Number of Manufacturing Establishments (10+ group)

| Year | Number | Average Annual Change (%) |
|-----------------|--------|---------------------------|
| 1975/76 | 430 | - |
| 1985/86 | 405 | -0.82 |
| 1992/93 | 237 | -4.62 |
| 1995/1996 | 642 | 34.71 |
| 1999/2000 | 788 | 7.6 |
| 75/76 – 99/2000 | | 1.08 |

Source: CSA Survey: Results of Surveys of Manufacturing Industries (1975/76 – 1999/2000)

4.4 The Distribution of Manufacturing Industries by Major Industrial Group

The distribution of Large and Medium Scale Manufacturing Industries by major industrial group is shown in *Table 4-2* below. It is impossible to present an accurate picture of informal manufacturing activities since the very survey itself

includes only those establishments which engaged 10 persons and use power driven machines only.

Accordingly, the survey result indicates that the total number of Large and Medium Scale Manufacturing establishments for the country as a whole was 788 in 1992 E.F.Y. The data in this Table further demonstrates that for the country as a whole, manufacturing of food products and beverages industrial group ranks first in terms of the number of establishment accounting for 29.82 percent of the

total establishments in the sector. The next important industrial groups in this respect are manufacture of furniture; manufacture machinery and equipment and other non-metallic mineral products, which constituted 15.10 and 10.79 percent respectively. Thus the Ethiopian Large and Medium Scale Manufacturing Industries are mainly characterized by high concentration of food and beverage manufacturing industries.

Table 4-2 Number of Establishment (Large and medium Scale Manufacturing Industries) by industrial Groups, 1999/2000 (1992 E.F.Y.)

| INDUSTRIAL GROUP | TOTAL | PERCENTAGE (%) |
|--|-------|----------------|
| Manufacture of Food and Beverages | 235 | 29.82 |
| Manufacture of Tobacco Products | 1 | 0.13 |
| Manufacture of Textile | 36 | 4.57 |
| Manufacture of Wearing apparel | 25 | 3.17 |
| Tanning and Dressing of Leather | 53 | 6.73 |
| Manufacture of Wood and wood Products | 16 | 2.03 |
| Manufacture of Paper and Paper Products | 64 | 8.12 |
| Manufacture Chemicals and Chamental Products | 40 | 5.08 |
| Manufacture of Non-Metallic Products | 85 | 10.79 |
| Manufacture of Basic Iron and Steel | 8 | 1.02 |
| Manufacture of Rubber and Plastic Products | 29 | 3.68 |
| Manufacture Fabricated Metal Products Except Machinery and Equipment | 51 | 6.47 |

| | | |
|---|------------|------------|
| Manufacture of Machinery and Equipment N.E.C. | 15 | 1.90 |
| Manufacture of Motor Vehicles, Trailers and Semi-trailers | 11 | 1.40 |
| Manufacture of Furniture; Manufacturing N.E.C. | 119 | 15.10 |
| TOTAL | 788 | 100 |

Source: CSA survey [5]

4.5 Problems of Manufacturing Industries

There are a number of inter-related problems that have affected the growth and dynamism of the manufacturing industries. The problems may have different natures, some of them are internal to the organization while others are external to

it. Followings are the common problems which most industries would share.

These include:

a) Product Quality and Marketing: Due to the low level income of the majority of the population, the demand for manufacturing products are very small compared with the size of the population. The products of the industry are also of relatively low quality. Furthermore, since most products are import-substituting types, they have to compete with the imports. Due to the free market economic policy and the significant reduction in tariffs on most of the imported items, local manufacturing enterprises are facing difficulty in competing with cheap imports. Also the over-concentration of business in the same industries, have made the situation become worse. A consumer bias against local products is also real problem despite the availability of comparable or even better local products.

b) Technology Related Problems: Lack of sufficient information on appropriate technology is also a serious problem. In most cases, firms depend on informal

sources of information in evaluating the suitability of different technologies. The decision to acquire a given technology is not based on empirical analysis and test of its suitability to the quality of raw materials, the level of skill of the work force and other local conditions. The limited number of industries also make the provision of on-site support services uneconomical and unattractive to foreign suppliers of the technology. Local technical know-how is not developed enough

to provide technological support services to industries. With out this local skill, imported technologies will not be meaningfully absorbed.

c) Lack of Proper Documentation system: The biggest problem faced by most of the manufacturing industries of the country is not having proper documentation system. Since there is no properly organized and manageable documentation system, information are usually stored in the people's memory. This creates a high problem of identifying and retrieving data that are already available. In addition to this as people leave the organization it is difficult to remember and get the required information on time. There is a tendency of redesigning parts, ordering materials which might be already available in the store, etc. The sales department also faces the same problem in the estimation of cost of certain products, even for the products that have been produced by the plant some time ago. This lack of information sometimes forces the sales departments to overestimate the price. As a result of this most of the industries are forced to

import parts from foreign suppliers that could have been produced in the country for cheaper price.

Therefore with the recent market trends and global competition, countries should concentrate in how they can actively participate in the world market rather than local market. To achieve such goal manufacturing industries should aim to satisfy the need of largely diverse customers even if regional competition is sought for.

This means that industries have to produce high product variety with

less volume and better quality. In the traditional ways of manufacturing systems, most industries are found to incur large in-process inventory and high material handling cost. To avoid these problems and stay competitive, industries should acknowledge the new working principle known as Group Technology manufacturing principle. We will see what Group Technology and its benefits are in detail in the next chapter.

CHAPTER FIVE

THE BASICS OF GROUP TECHNOLOGY

5.1 INTRODUCTION

Group technology (GT) has been recognized as a method for rationalizing small and medium batch production for some time. With the increasing possibilities to analyze and evaluate the resultant data with the aid of electronic data processing equipment, this method has now become a practicable solution.

The term 'Group technology' signifies a method which endeavors to analyze and to arrange the parts spectrum and the relevant manufacturing process according to the design and machining similarities so that the basis of groups and families can be established for rationalizing the production processes in the area of small and medium batch sizes. [11]

The concept of Group technology (GT) as a manufacturing philosophy has been known for the past four decades. It was first proposed and developed in *Russia* by *Mitrofanov* in 1966 and originally translated as 'family planning' [22]; during his studies, *Mitrofanov* classified different parts based on their similarity of shapes in to several group cells (part families). For instance see the following figure.

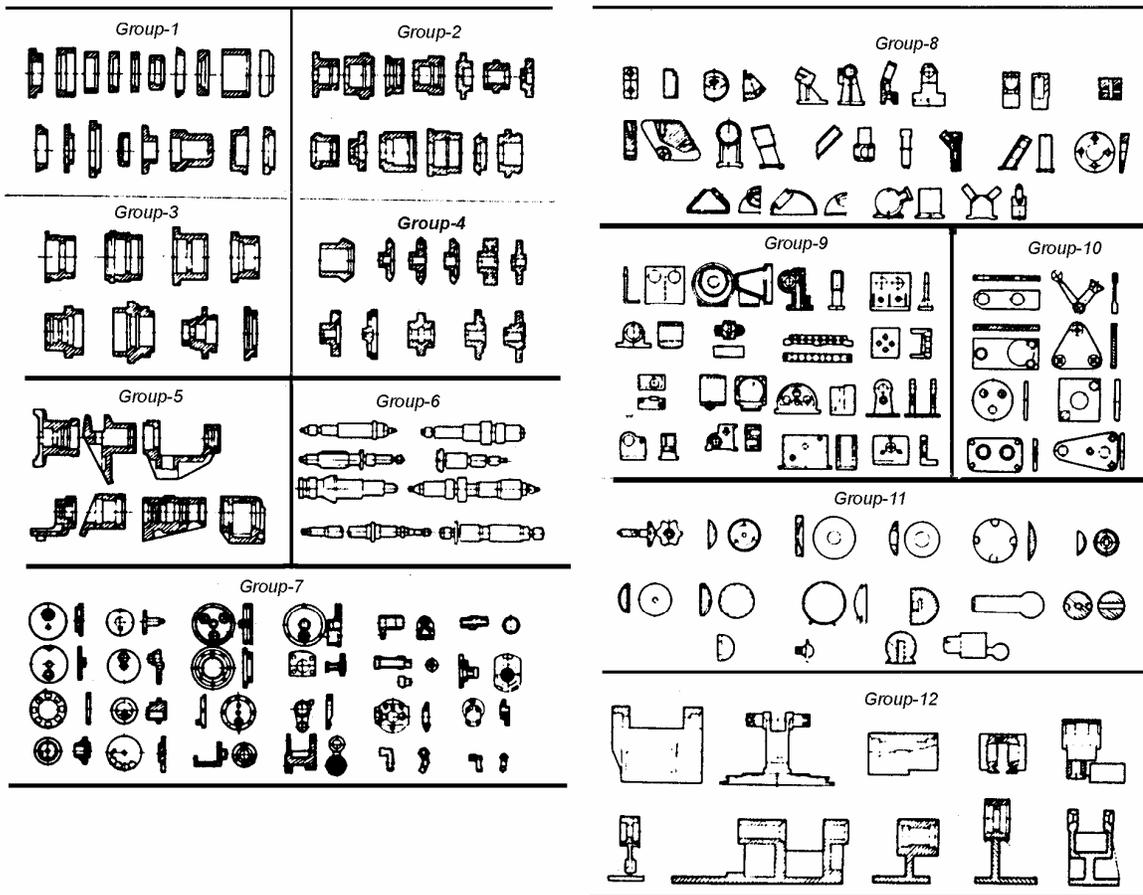


Figure 5-1. Grouping many different parts into several group cells based on their similarity of shape (after Mitrofanov, 1966) this is the case for a turning operation. (Adopted from [22])

However, much of the early development of Group Technology took place in the United Kingdom engineering industries during the 1960s and early 1970s [2]. But, it has been Japanese and American companies that have been recently teaching

us about the power and advantages of this technique, namely how to reduce costs, improve lead times, and get closer to customers requirements.

5.2 TYPES OF LAYOUT

As it was mentioned in chapter two; there are a number of well-known manufacturing processes to which different manufacturing systems can be allocated. Depending on the order batch of size (small or large batches), flow line systems or product layout (*Figure 5-2*) and functional machine layout or process layout (*Figure 5-3*) are already recognized in the industrial manufacturing process.

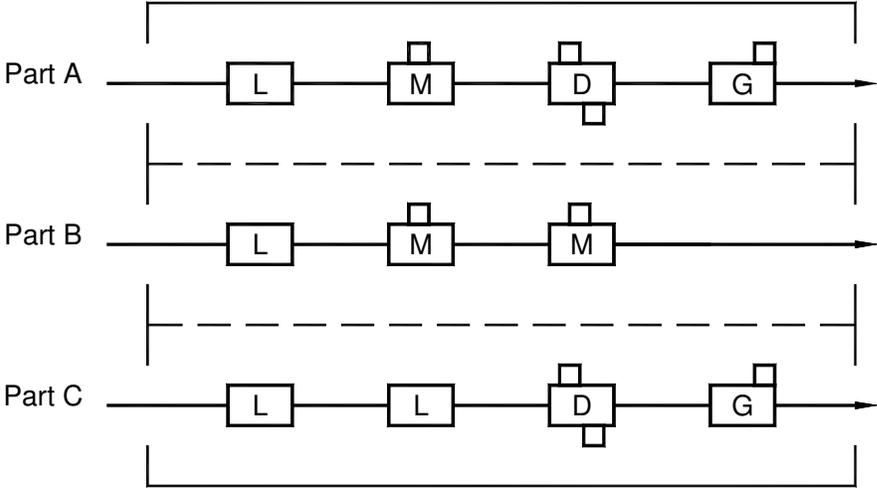


FIGURE 5-2. PRODUCT LAYOUT

Note: L: Lath; M: Milling Machine; G: Grinding Machine; and D: Drilling Machine.

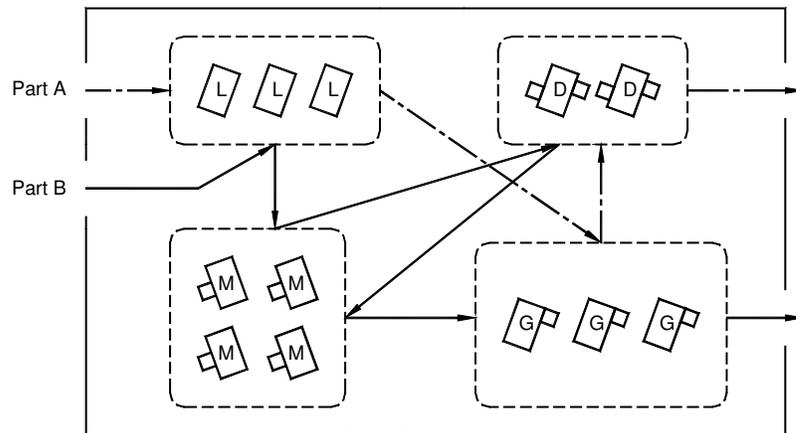


FIGURE 5-3. FUNCTIONAL LAYOUT

**Note: L: Lath; M: Milling Machine; G: Grinding Machine;
and D: Drilling Machine.**

5.2.1. Product Layout

In this type of layout only one product, or one type of product, is produced in a given area. The equipment used to fabricate a given product is arranged based on the sequence of operation. The raw material arrives at one end of the line and goes from one operation to the next quite rapidly, with a minimum of work-in-process storage and material handling.

Advantages of product layout:

- Lower total materials handling cost;
- Lower total production time;
- Less work-in-progress;
- Greater incentive for groups of workers to raise level of performance and greater possibility for group incentive pay plans with broader coverage;
- Less floor area required per unit of production;

-
- Greater simplicity of production controls and records needed, lower accounting cost, etc.

Limitations:

- It is highly inflexible; i.e. a change in the product design (or change in product mix) necessitates a substantial change in the layout;
- Only recommended for mass production of a small number of parts;
- Difficult in maintenance for a bottle necked machine.

5.2.2. Process Layout

The process layout- or functional layout, groups together all operations of the same types in a department. For example considering a simple production operations which requires four different machines during production process can be considered as a good example. i.e. all stamping is done in the press department for example; all milling is done in another area; all welding in another area; and all plating in the plating department. This type of layout is particularly useful where low volume is required. And also the product is not standardized, the process layout is more desirable, as it has greater flexibility than the product layout [24].

Advantages of process layout:

- Less duplication of equipment;
- Greater flexibility of production;
- Better and more efficient supervision is possible through specialization;

-
- Greater incentive for individual workers to raise level of performance (and greater possibility for individual incentive pay plans);
 - Better control of complicated or precision process, especially where much inspection is required;
 - Easier to handle breakdowns of equipment by transferring work to another machine or station, etc.

Limitations:

- Large volume of work-in-process inventory;
- Longer production lead time;
- Large cost of materials handling;
- Complicated production planning and control system, etc.

5.2.3. GT Layout

Thus the concept of GT was developed to exploit the advantages of both types of layout and involves the pursuit of production activities in cell. The basic idea of GT manufacturing originally consisted of grouping parts with similar machining characteristics together to form so-called 'additive batches', and routing them through the functional machine layout with the assistance of the production control [11].

In a further development this idea, parts spectrums with similar machining requirements were set up and executed in corresponding machine groups. With

due consideration of the literature [11, 15, 24], GT-manufacturing system can be related to the following basic forms:

- the GT-center (single machine system);
- the GT-cell (group layout system);
- the GT-flow line.

The three layout forms lie between the functional machine layout - as the characteristic layout for one-off and small batch production - and the flow line system as the representative of large batch production. The GT-manufacturing systems differentiate themselves principally through the degree of similarity of the parts in respect to manufacturing. The term '*GT-manufacturing system*' includes therefore not only the layout form, but also all the necessary measures, such as part design, process planning, work measurement, production control, wage structure and the psychological and sociological aspects of the work forms, like job enrichment.

1. GT-Center

The GT-center is developed from the functional layout and consists of a place of work which, from the technical and economical point of view, is laid out in such a way that a similar parts spectrum in respect to machining can be executed by the same type of operation, e.g. turning. The application area for the GT-center provides for a parts spectrum with a similarity in one type of operation and which can be carried out at one individual workplace or on one machine. It therefore

constitutes the first and lowest degree of rationalization within the framework of the GT-manufacturing systems.

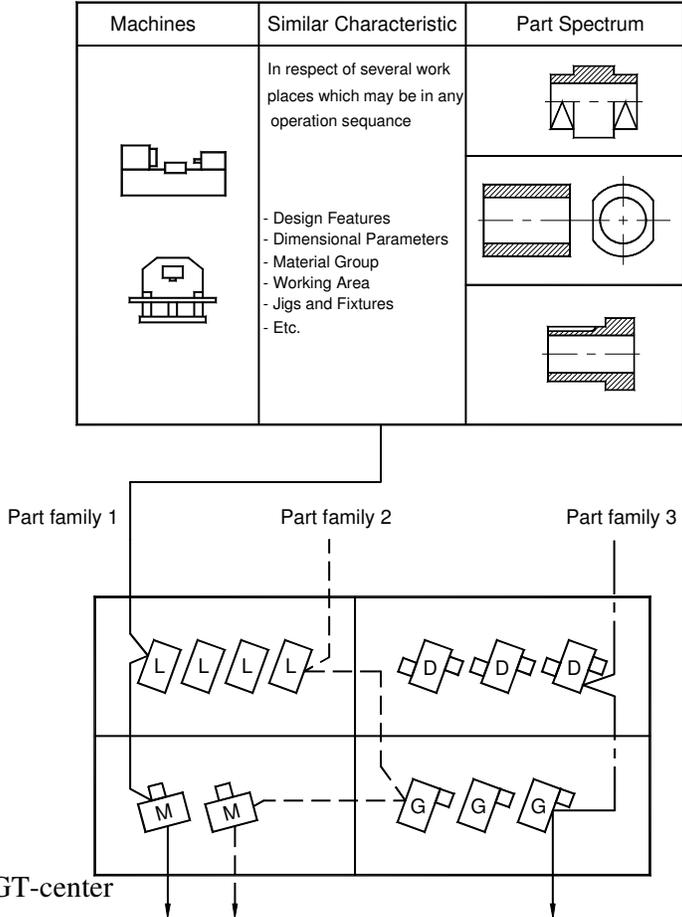


Figure 5-4. GT-center

2. GT-Cell

The basic idea of GT-cell is to split the manufacturing area into machine groups in which all the machining operations required for the manufacture of a certain parts spectrum can be accomplished. These basic types of GT-layout allows a flexible operation sequence and constitutes a second or medium degree of rationalization. In addition to this, the reduction of through put times and a more simplified form of production control also come to the forefront here. From the technical point of view, the layout is advantageous, because it constitutes a self-contained but

limited area of responsibility and thus allows quality assurance to be effected in a more simplified manner. Considering the sociological aspects, this method has also positive effect since it provides a good basis for the formation of work groups with common objectives.

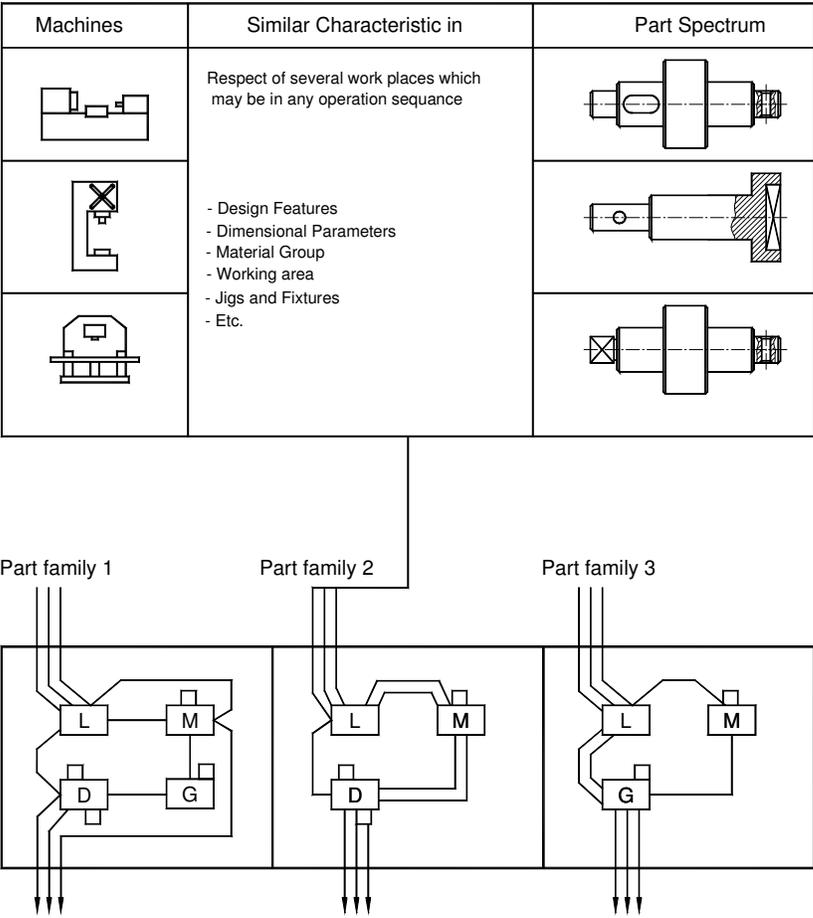


Figure 5-5. GT-cell

3. GT-flow – line

In the GT-flow line, the places of work for the associated parts spectrum are laid down in a layout according to a fixed operation sequence. It is the highest degree of rationalization for GT-manufacturing systems. It enables the transport between individual places of work with the respective handling equipment, depending on the parts characteristics and peculiarities of the workshop to be organized in a rational manner. If various machining times occur at the single places of work during the throughput, corresponding buffer areas and alternative machines must be an optimum utilization of an expensive key machine.

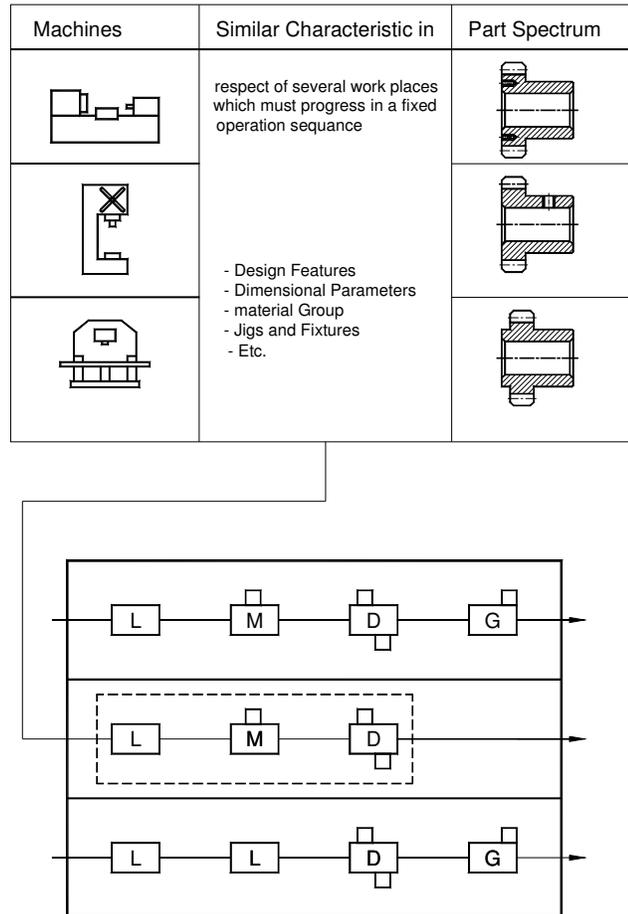


Figure 5-6. GT- flow - line

Advantages and Disadvantages of GT layout:

The brief comparison of the manufacturing cell with the job shop and flow line is important to highlight the advantages and disadvantages of GT-layouts over the other when a cellular manufacturing system is exercised [18]. These include:

- 1. Flexibility:** GT - layouts are less flexible in terms of the variability of routing than functional layout, yet are more flexible than flow lines. Routing flexibility is achieved via compromises in the mean machine utilization, since a GT-manufacturing environments typically requires the acquisition/maintenance of production capacity in excess of that associated with flow lines.
- 2. Material flow system:** Material handling is more efficient, and the material flow system is more streamlined in the case of a GT-manufacturing environment compared with a functional layout, and only marginally more complex (and less efficient) compared with product layout.
- 3. Work-in-progress (WIP):** Although the level WIP inventory need not vary between the layouts, the practices of industry have demonstrated that GT- manufacturing and product layouts typically result in a lower level of WIP compared with functional layout. This is primarily facilitated by the fact that production management tasks are less complex in these environments, permitting increased control of excess inventory.
- 4. Lead times:** Lead times are typically short in the case if GT layouts compared with functional layout (where considerable waiting and transportation time is incurred), and marginally longer compared with

product layout. Shorter lead times reduce the need for unnecessary handling to intermediate stores/buffers.

5. Production volume: GT - manufacturing environments are suitable for low - to - medium volume production. Functional layouts are ideally suited to prototyping and low volume production operations, while product layouts are suited to medium-to - high volume production (depending upon the level of quotation involved). The majority of production in most GT - manufacturing environments is in lot sizes of 50 or less.

5.3 Different approaches of cell formation

Cellular Manufacturing (CM) has been seen as the major application of Group technology. Many different techniques for grouping in CM have been suggested in the literature. These grouping algorithms or methods can be classified into two basic categories: coding and clustering analysis [31]. For the purpose of simultaneously forming part families and machine cells for CM, cluster analysis methods are superior to coding methods and have become the choice of most applications. The cluster analysis methods can be further divided into three categories according to different problem formulations: mathematical programming-based algorithms, matrix-based algorithms, graph-based algorithms.

5.3.1 Mathematical Programming

These approaches for the clustering problem are nonlinear or linear integer programming problems [4]. These approaches provide distinct sequences of

operations, alternative processes plans, setup and processing times, the use of multiple and identical machines, etc. These formulations also suffer from two critical limitations, first, because of the resulting nonlinear form of the objective function, most approaches do not concurrently group machines into cells and parts into families. Second, since the variables are constrained to integer value, most of these models are computationally intractable for realistically sized problems.

5.3.2. Matrix - Based Algorithms

Among others the matrix-based algorithms are the most popular method of clustering analysis. All matrix - based algorithms have a common feature: manipulation of a machine-component matrix such that the clusters of machines and components can be identified. There are different approaches of using this method. These include:

- **Bond Energy Algorithm (BEA)** This is a general matrix clustering procedure, developed by McCormick [38]. The purpose of the BEA is to identify and display natural variable groups and clusters that occur in complex data arrays. The bond energy of a matrix element is defined as the sum of the product of the adjacent elements, as expressed in the equation below.

$$BE_{ij} = a_{ij} [a_{ij+1} + a_{ij-1} + a_{i+1j} + a_{i-1j}] \quad (1)$$

where,

BE_{ij} : bond energy of a_{ij}

a_{ij} : the element in the row i and j column in the matrix;

$$(a_{ij} = a_{m+1j} = 0; j = 1..n)$$

m : number of rows of the matrix;

n : number of columns of the matrix.

The objective of the BEA is to maximize the total bond energy of elements over all row and column permutation of the input matrix, i.e., to maximize *equation .2*.

$$Max \sum_{i=1}^m \sum_{j=1}^n a_{ij} [a_{i,j-1} + a_{i,j+1} + a_{i-1,j} + a_{i+1,j}] \quad (2)$$

This problem is basically a form of quadratic assignment problem.

- **Rank Order Clustering** The rank order clustering (ROC) algorithm was originally developed by King [23]. The ROC algorithm is basically designed to solve the clustering problem for matrices with binary entries. The basis of ROC algorithm is to cluster the positive entries (1's) into group, and place them along the diagonal of the matrix.

5.3.3 Graph - Based Algorithms

In this type of algorithms, the cell formation problem will be treated in the form of networks, bipartite graphs, etc. Rajagopla and Bata were among the first to apply a purely graph theoretical approach to cell formation problem in which the

nodes represent the machines and the arcs indicate the similarity among the machines [31]. They employed a graph partitioning approach to form the machine cells by assembling clique determined from the graph.

5.4 Part Family

One of the basic step for the implementation of GT, is to create a method for the recognition of part attributes which allow for the correct classification of parts requiring identical operations, or that are processed in a similar sequence. This can be achieved by using a multitude of approaches. It could be the geometric shape, material, size, form, etc., or with respect to production operations, the sequence of operations, tooling, machines, process, etc.

There are different ways by which part families can be formed [24]. These are:

- Visual inspection (or "ocular group technology")
- Production flow analysis
- Classification and coding

1. Visual inspection

This is a simple and crude method of examining and grouping parts and machines through the bare eye according to the judgment of an inspector. Classification of parts into families is simply made by looking at their shapes and these shapes are usually design features. Inaccuracies become magnified when the complexity of the parts increases or the number of machines and parts used are numerous.

Classification based on visual inspection is hence the least accurate though the least costly as compared to the other types. Therefore, it should be the last choice. But it can be used as a starting point by which one can begin to judge whether or not Group Technology seems to make sense in his environment. *Figure 5-7.* shows the type of objects we would have in a family if visual inspection is used for part family formation.

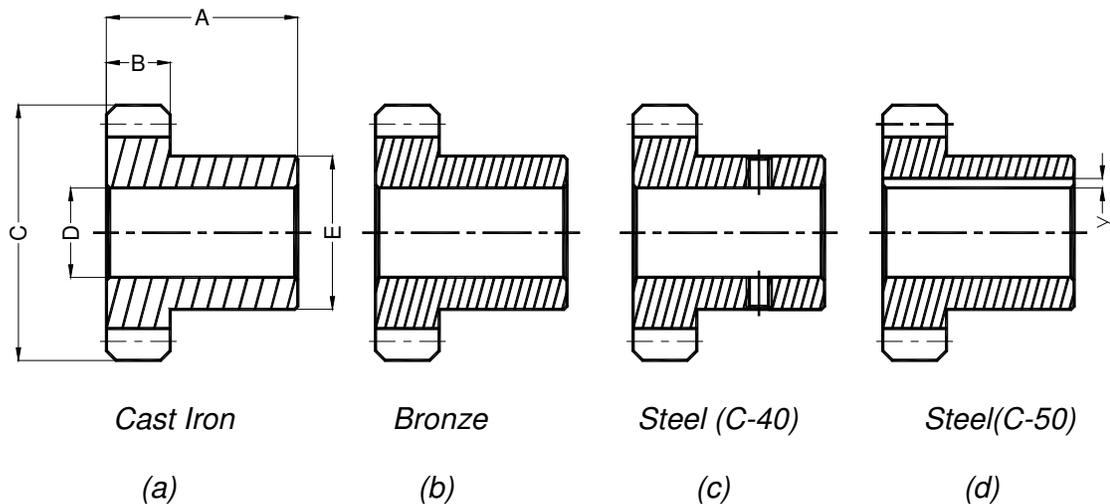
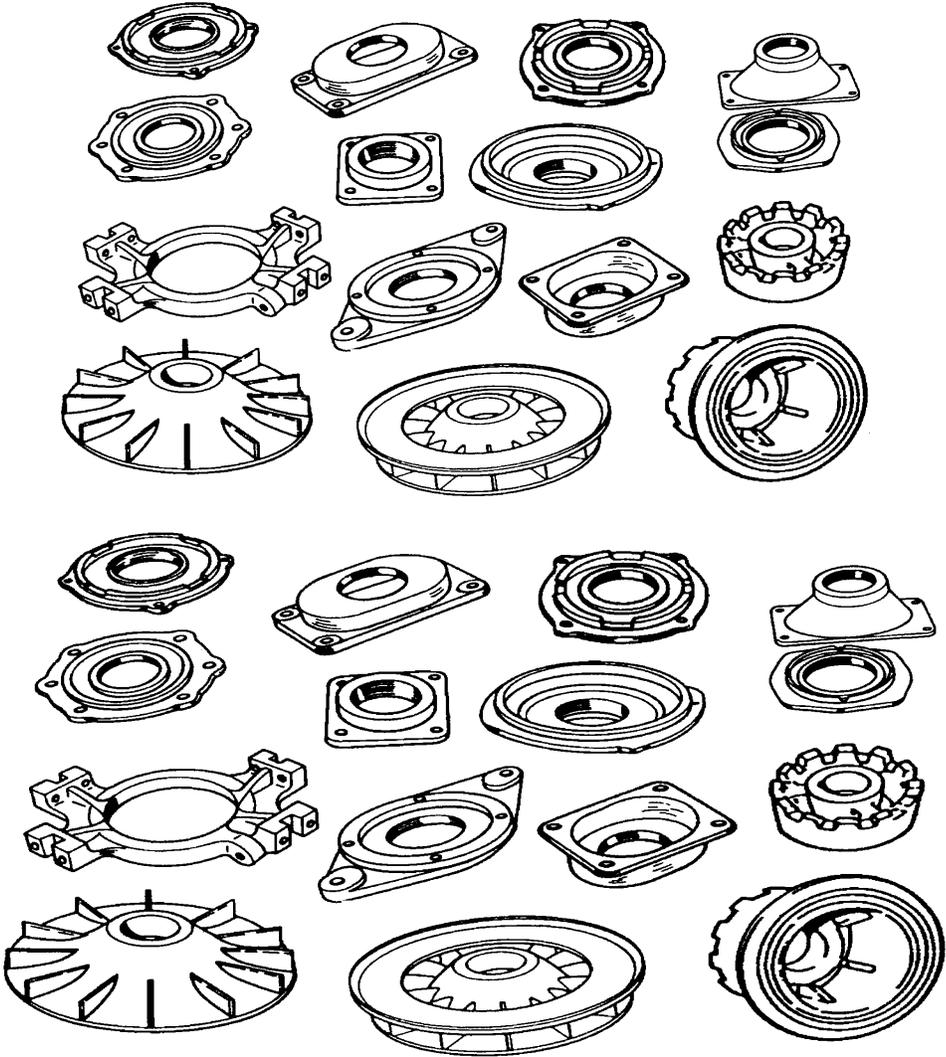


Figure 5-7. Parts with identical shape but different manufacturing requirement

2. Production Flow Analysis (PFA)

Production flow analysis (PFA) is a method for identifying part families based on the sequence of operation and machine routing needed to produce the part [8,24]. Since PFA uses manufacturing attributes rather than design attributes to identify and form part families, it can overcome two possible anomalies. First, parts whose basic geometries are quite different may have similar or identical process routings *Figure 5-8.* Second, parts whose geometries are similar may require

different process routings *Figure 5-7*. However, the disadvantages with this method of part family formation is that it accepts previously set routes sheets without consideration of its being logical or consistent, there is no mechanism for rationalizing the manufacturing routings



**FIGURE 5-8. PARTS WITH SIMILAR MANUFACTURING PROCESS
but different design attribute**

The procedure in Production flow analysis can be organized into the following steps.

1. Data collection The first step in PFA procedure is to decide on the scope of the study and to collect the necessary data. The scope defines the population of parts to be analysed. Once the population is defined, the minimum data needed in the analysis, the part number and the machine routing (operation sequence) for every part, is collected. These data can be obtained from the route sheets. Additional data, such as lot size, time standards, and annual production rate, might be useful for designing machine cells of the desired production capacity.

2. Sorting of process routings This is the second steps were parts are arrange into groups according to their similarity of their process routings. For large number of parts in the study, the only practical way to accomplish this step is to code the data collected in step 1 onto computer cards. A sorting procedure would be used on the cards to arrange them into "Packs." A pack is a group of parts with identical process routings.

3. PFA chart The processes used for each pack are next displayed graphically on a PFA chart. It is merely a plot of the process code numbers for all the packs that have been determined.

4. Analysis This is the most subjective and difficult step in PFA, yet it is the curtail step in the procedure. The difficulty comes from the amount of information that

must be processed accurately to facilitate the formation of manufacturing cells that are dedicated to specific-part family production. The PFA model prompted research into qualitative methods to alleviate the computational burden of the manual resolution of the CEP.

3. Part Classification and Coding

This is the method by which grouping and classifying parts into family is made by examining and analyzing the design and/or manufacturing attributes of each parts. The basic principle is that numerical or alphabet values that reflects similarity

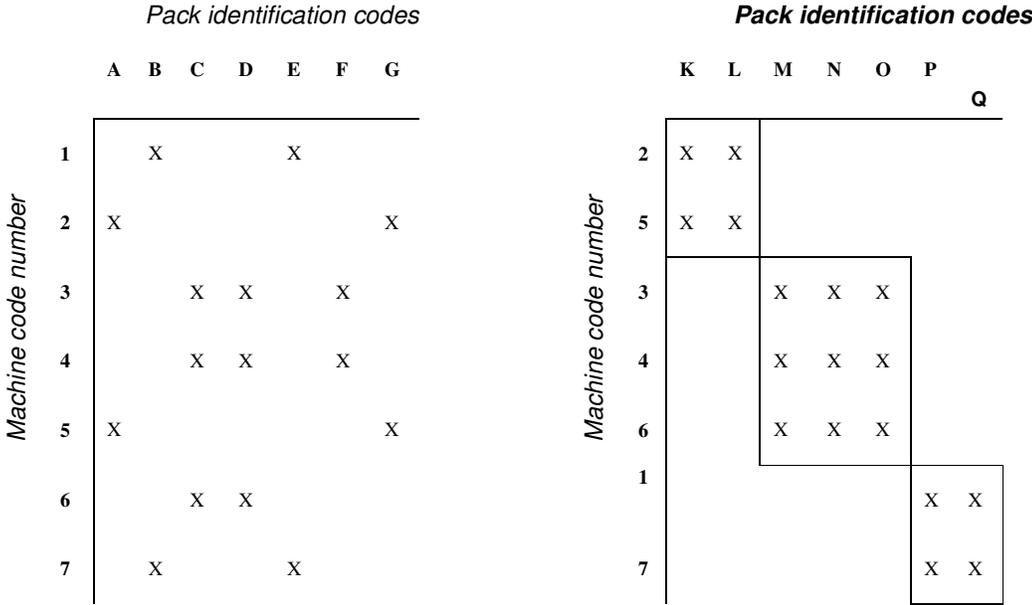


Figure 5-9 (a) PFA chart (highly simplified) (b) Rearranged PFA chart (indicating possible and optimal machine groups)

could be assigned to parts and some advantages can be obtained from these similarities. Since this is the major area of this study, we will discuss it more thoroughly in the next chapter.

5.5 Benefits of Group Technology

There are several advantages that can be obtained by adopting Group Technology, and some of them are typically realized in the following areas [11,24]:

- Design;
- Setting time, and Batch quantities;
- Materials handling;
- Production and inventory control;
- Process planning, and
- Effective Supervision and job satisfactions

The most quoted disadvantage of Group Technology is that machine utilization is likely to be lower than with the traditional functional layout. As we shall see shortly, this is more realistically regarded as offsetting of some of the benefit of lower investment in work-in-progress. Probably the biggest disadvantage is the effort required to changeover to a Group Technology method of working, perhaps combined with some risk, if one has not done it before, of not obtaining sufficient benefit to justify the effort.

a. Product design benefits

In the area of product design, the principal benefit will be obtained by using from the use of a developed part classification and coding system. When a new part design is required, the designer or draftsman can devote a few minutes to figure out the code of the required work part. Then the existing part designs that match the code

can be retrieved to see if one of them will serve the desired function. The few minutes spent searching the design file with the aid of the coding system may save several hours of the designer's time. If the exact part design cannot be

found, perhaps a small alteration of the existing design will satisfy the required function. Since a simple or minor change in an existing part would be much less time-consuming than starting from scratch, it would save the designer's precious time which might have otherwise been unnecessarily wasted. Another advantage of Group Technology is that it promotes design standardization. Design features such as inside, corner radii, chamfers, and tolerance are more likely to be standardized with GT.

b. Reduced lead time, Setting time, and Batch quantities

Selection of components to form a family invariably means bringing together components which have similarities, although these similarities may not be obvious at the outset. This usually reduces the time required to reset the machines between batches. This reduction may be taken entirely as reduced set up cost. However it may be more beneficial to sacrifice o this advantage for the sake of smaller batch quantity. If for instance, the average setting time per batch were halved, batch quantities could be reduced equally without increasing total setting cost per year. This could also reduce the working stock of the components in the family by half and also further reduce the throughput time of each batch hence, manufacturing lead time is reduced.

c. Materials handling

Another advantage in manufacturing is a reduction in the work part move and waiting time. The group technology machine layouts lend themselves to an efficient flow of materials through the shop. The contrast can be visible when the flow line cell design is compared to the conventional process-type layout. This will optimize the use of material handling and reduce the cost as well.

d. Production and Inventory control

Several benefits accrue to a company's production and inventory control function as a consequence of group technology. Production scheduling is simplified with group technology. In effect, grouping of machines into cells reduces the number of production centers that must be scheduled. Grouping of parts into families reduces the complexity and size of parts scheduling problem. And for those work parts that cannot be processed through any of the machine cells, more attention can be devoted to the control of these parts. Because of reducing setups and more efficient materials handling within machine cells, manufacturing lead times and work-in-process are reduced and makes the inventory control much simpler.

e. Process Planning

Proper parts classification and coding can lead to an automated process planning system. even without an automated process planning system, reductions in the time and cost of process planning can still be accomplished. This is done through standardization. New part designs are identified by their code as belonging to a certain parts family, for which the general process routing is already known.

f. More Effective Supervision and Job Satisfaction

In traditional batch production, with the machines laid out by type, the supervisor inspects a group of machines. Thus he supervises some of the operations on many components but perhaps may not supervise the complete production of any component. In Group Technology, a supervisor can supervise a group of machines and an operator which manufactures from raw material to a finished state of all the components in a family. This means that the supervisors must acquire knowledge of all type of machines with which they have not previously acquainted with. Another fundamental change which often has to be accepted is that some of the operators in a group have to be operate more than one machine. But once those changes have been over come, the following important benefits will occur. Supervision of quality will be more effective. Work part quality is more easily traced to a particular machine cell. Shop supervisor should in any case be responsible for seeing that the quality of the work done conform to the standard set forth. This is more simple if one supervisor is responsible for the whole production from start to finish. Tractability of part defects is sometimes very difficult in a conventional process-type layout, and quality control suffers as a result.

In traditional process layout the operators see only part of the operation as being performed in their specific department, so they don't get the chance to see through the whole operation. But i the case of Group Technology the complete process is handled in a single cell and so workers are able to realize their contributions to the firm more clearly. This tends to cultivate an improved worker attitude and a higher level of job satisfaction.

CHAPTER SIX

CLASSIFICATION AND CODING

6.1 CLASSIFICATION AND ITS PRINCIPLES

6.1.1. Introduction

To classify in primitive sense is to divide existents of universe of discourse - concrete or conceptual things or ideas into two groups. That is all like ones are put into one group and unlike ones into another. The 'like' and 'unlike' can have meaning only in relation to an attribute which can be used to classify things. For instance if possession of having two legs is chosen as an attribute, then men and birds will fall into one group. While beasts and chairs will fall in to another group, or if the ability to fly is the attribute to be chosen then birds, bats and butterfly will fall in to one group while men, beasts, and chairs will fall into the other. Soon this idea of classification was developed and changed. And it was defined as a technique to organize and related data in logical and systematic order that groups like things together [32].

This approach of classification were differ somewhat from the definition given in *Oxford Advanced Learners Dictionary* which states that:

1. *A classifying or being classified, arrangement according to some systematic division into classes or groups.*
2. *group or class into which something is put.*
3. *In biology placing of animals and plants into groups according to seminaries of structure origin etc.*
4. *in libraries etc according to their subject.*

Here our interest is to look into the different approach and method of classification application used in an industry. Thus the following definition was coined for

classification adapted to these specific applications by Joseph Gombinski [38]:

A technique to organize specific data relating to the relevant component element (s) of a business or institution in a logical and systematical hierarchy whereby like things are brought together by virtue of their similarities and then separated by their essential differences.

Of course this application of classification was derived from the work of Linnaeus in the eighteenth century. Linnaeus described the details of his classification theory in his book *Systema Nature* in 1758. In his classification technique he tried to present a classification method and a standard nomenclature for all flora and fauna known to exist at that time. The Linnaean hierarchical and systematical taxonomy, showing the classification structure is shown in the below.

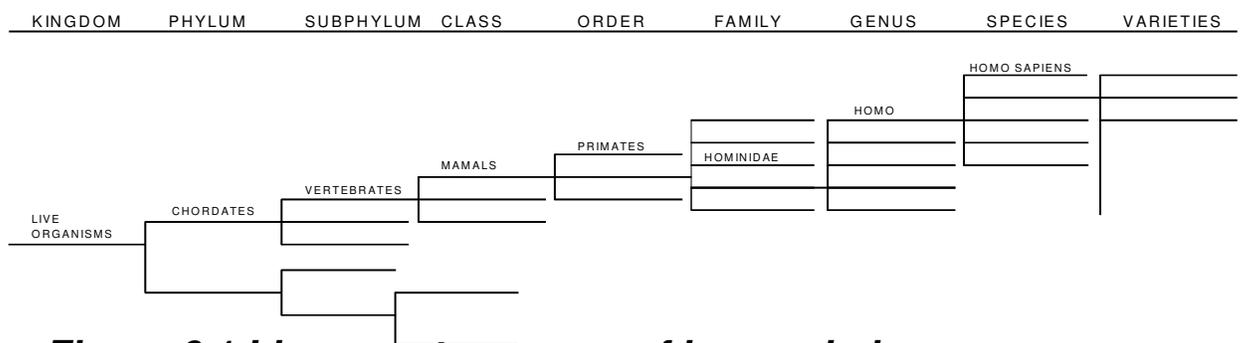


Figure 6.1 Linnaean taxonomy of human beings an example of the Tree of Porphyries (Adopted from [38]).

The above figure displays the structure of a classification for a specific application. The branching bush like structure is aptly named *Tree of Porphyries*, in Greek means *Christmas tree*. This will use as a useful means for branching and dividing population into defined categories. And also used to solve logical relationships and to display the parameters of commonality (or exclusivity), which hallmark a sound classification.

Later on Ediward Brisch a mechanical engineer adopted the hierarchical classification of the taxonomist to aid and facilitate data that were not retrievable

because of lack of procedures. Brisch developed a structure that may appear fixed and rigid as dose the taxonomic structure, but in fact, it is completely flexible, to provide for the population distribution at the several levels of the classification.

Due to the increasing and developing of manufacturing industries, the need for having an efficient and effective classification system were become very important. Because having a well-developed classification system are significantly improving documentation system by arranging the files into families of similar parts. This greatly reduces search time, particularly eliminated duplication of design work. Therefore, people and organization were start to developed different types of classification systems to improve the traditional ways of manufacturing system.

6.1.2 Principles of classification

In order to apply classification to any population of things, we must follow the following basic principles. Thus a classification should be [1,38]:

1. **All embracing:** A classification must embrace all existing items and be able to accept necessary new items into the defined population of items.
2. **Mutually Exclusive:** A classification must be mutually exclusive that is included like things to bring them together clearly defined parameters.
3. **Based on Permanent Characteristics:** A classification must be based up visible attributed or easily confirmed parameters and unchanging characteristics.

-
4. **Specific to User's Need:** A classification should be developed to meet the specific needs of the user not the classifier.
 5. **Adaptable to Future Changes:** A classification must leave a room to accommodate and include any future changes to the population.
 6. **Adaptable to Computer Processing:** For easiness of accessing and retrieving the required data, a classification must compatible and adaptable to computer programs.
 7. **Applicable Company wide:** a classification must be applicable and communicable by each department of the organization.

6.2 CODING: PRINCIPLES, METHODS, AND PROCEDURES

6.2.1 Introduction

It is true that classification helps to bring like things together, but with out having a proper coding system which reflecting the classification is introduced, handling, processing families of similar data or retrieving relevant information is more

cumbersome and inefficient. Most of the time, coding is thought of in its cryptological sense, meaning to restrict and suppress the dissemination of intelligence and/or information during communication. However, when we describe it in the business and industrial context, quite the reverse is true. In industries properly designed codes are used as a shorthand, as a means to compress information and improve its communication effectiveness through the business and the outside environment.

6.2.2 Types of Coding

Industrial codes can take several forms. Those, which use the alphabet and/or numerals, are called alpha or numeric codes or as combinations of the two as alphanumeric codes. But there are also *special symbol* codes which are not derived from either alphabetic or numeric sources. Here we can see the different types of codes as follows.

6.2.2.1 Attribute code structure:

In this type of structure, the interpretation of each symbol in the sequence is fixed and represents one feature. Thus, the value of any given digits (or position) within the code does not depend on the preceding digits. Another name of this type of symbol is *poly-code*. The problem associated with *poly-code* is that the code tends to be relatively long. On the other hand, the use of *poly-code* allows for convenient identification of specific part attribute. This can be helpful in recognizing parts with similar processing requirements. A typical attribute code is

illustrated in the table below. As we can see from the table, each digit and each value in the specific digit has a specific meaning. Thus, for example, the first digit may always describe external shape of the part, the second digit describe internal shape, the third digit describe there is internal hole, the fourth digit describe the type of hole and so on.

Advantages:

- Easy to formulate

limitations:

- Less information is stored per digit; therefore to get a meaningful comparison of, say, shape, very long codes will be required.
- Comparison of coded parts (to check for similarity) requires

Table 6-1. Attribute code structure (adopted from [16])

| Digit Position | 1 | 2 | 3 | 4 | ... |
|----------------------|---------------------|-----------------|-------|-----------------|-----|
| Feature Class Number | External shape | Internal shape | Holes | Type of Holes | ... |
| 1 | Shape1 (Rotational) | Shape1 (Hole) | 0 | Axial | ... |
| 2 | Shape2 (Prismatic) | Shape2 (Spline) | 1-2 | Cross | ... |
| 3 | Shape3 | ... | 3-5 | Axial and Cross | ... |
| 4 | Shape4 | ... | 6-8 | ... | ... |
| ... | ... | ... | ... | ... | ... |

6.2.2.2 Hierarchical Type:

In this type of code structure, each code number is qualified by the preceding digits (characters). Thus if the first digits define the type of material used, such as steel, the second digits will define a feature related to steel (like carbon constraint), and the next digit will define a feature related to the feature defined in the second digit and so on. A typical hierarchical code structure is shown in *Figure 6-2*. As it was shown in the diagram, each digit is directly related to the preceding digits. Thus the second digits “2” may define a power unit of the work part, the digit in the third position may then define the type of power system (i.e. whether it is mechanical, hydraulic, or electric). In the fourth position if a digit “1” is preceded by “1”, then it may define the sub unit of the driving system that is a rotational part, or if it is preceded by “3” it might have totally different meaning.

Advantage:

- It is also works well in a manual system.
- Hierarchical code is good for design retrieval,
- The code system can represent a large amount of information with very few code positions.

Limitations:

- Complex and relatively difficult to develop.
- Because the same digit in the same position may have different meanings at different times depending on the preceding digit, hierarchical codes do not lend themselves to computerization or to easy analysis. Their usefulness is thus limited when analysis and comparisons of data are desired.

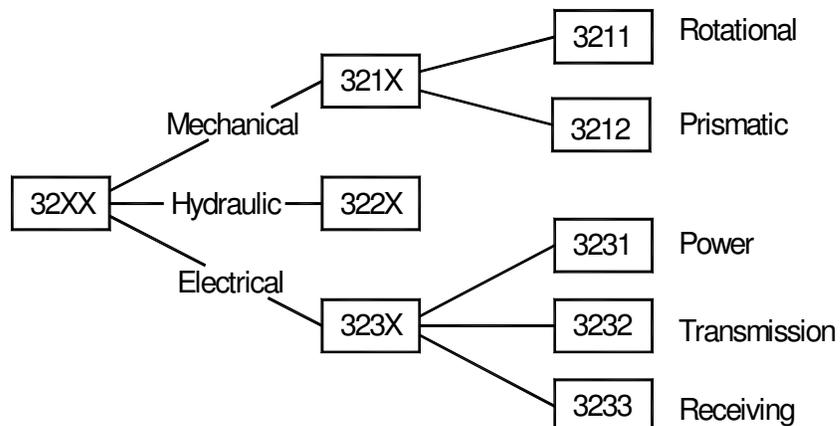


Figure 6-2 The structure of a classification and coding system based on hierarchical principles.

6.2.2.3 Hybrid Type:

Most of the commercial parts coding system in industries are a combination of the two pure structure (i.e. poly codes and mono codes). The hybrid is an attempt to achieve the best feature of both poly-codes and mono-codes. Hybrid codes are typically constructed as a series of short poly codes. Within each of these shorter chains, the digits are independent, but one or more of symbols in the complete code number are used to classify the part population into groups, as in the hierarchical structure. This hybrid coding seems to best serve the need of both design and production.

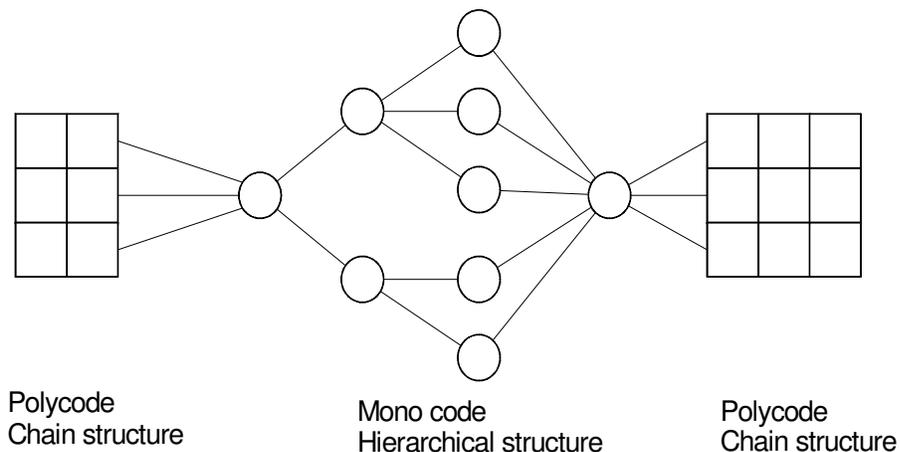


Figure 6-3. The hybrid structure of classification and coding system

6.2.2.4 Special Symbol codes:

This is a type of code that used picture or symbols of an object other than numbers or alphabets to represent an activity, event, words, etc. This special symbol codes can be hieroglyphical, which can best characterized by the symbolic therbligs, created by Frank and Lillian Gilbreths or of more recent vintage, the flow chart codes for tracking the handling of data within a system. During their study of work and time-and motion, they used an epitomized hieroglyphic code symbols to represent a fundamental motions such as reach, grasp, think, etc. The hieroglyphic code symbols described by the therbligs codes pictorially represent the action they describe. For example, the activity of planning can be represented by planning therbligs symbol by a person with his finger at his brow, denoting a thinking pose. Like wise, in the flow chart symbols, the operation performed on a lathe machine can be represented by a circle.

Sometimes a code used in a special symbol codes can have a little or no meaning in their shape or character or the code and the information it represents. The common flow chart symbols established and developed by The American Society

of Mechanical Engineers (ASME) show in the table below is a good example of such codes.

Table 6-2 Flow Process Chart, Non-hieroglyphic Symbol Codes

| (ASME) Symbol | Activity |
|---|-------------------|
|  | Inspection |
|  | Operation |
|  | Transportation |
|  | Delay |
|  | Storage |
|  | Combined Activity |

6.2.3 Principles of Coding

As in the case of classification, an industrial coding has also its own principles.

These includes[38]:

1. No code should exceed five characters without a break in the string. That means when the code number becomes shorter it becomes easy to handle and, fewer errors committed.
2. Identity codes should of fixed length and pattern. If we use varying-length codes within a given class of materials it will proliferate error rates and require justification in handling (right or left) to the longest code in use.

-
3. All-numeric codes produce fewest errors.
 4. Alphanumeric combination codes are acceptable if the alpha field is fixed and used to break a string of numbers.

6.2.4 METHODS OF CODING SYSTEMS

Due to its wide application to both design and manufacturing process, classification and coding become more familiar in many manufacturing industries. It had evolved from a means of manually indexing drawings for retrieval purposes to a compact vocabulary for the storage, recall, and use of large amount of design and manufacturing information. In classification and coding, code numbers are used to identify parts by their specific characteristics. By doing so, they make it possible to classify parts-group them according to their characteristics. In a sense, this is a shifting of all the company products and detailed parts by similarities. It is a major step in the translation of the seemingly random nature of batch manufacturing operations into a rational order. The length of a code number, which assigned to the work part was significant effect when it was made manually. Thus, the longer the code number makes the coding process tedious and the larger susceptible of committing errors in the transfer of a code number from one piece of paper to another. With the use of computer in the classification and coding system, the code length was no longer as critical. Thus the earliest truly comprehensive classification and coding system for design and manufacturing application was a matrix of 300 positions- a "sieve" with 300 holes (shown in *Figure 6-4*)[16]. When applying this system, the length of the code number could

be as long as 30 digits, and each digit has also possibilities of varying from zero to nine. This means that 30 different parameters could be coded, and each code has as many as ten different attributes.

Figure 6-4. Classification and coding scheme as a sieve (adopted from [13])

6.3 DIFFERENT PRACTICES OF CLASSIFICATION AND CODING SYSTEMS

It is apparent that when a company makes a particular series of a type of product, there inevitably arises a similarity among at least some of the parts in production. For example, a company producing electric motors may manufacture different

types of motors to meet the market demand. During the manufacturing practices, it is apparent to make many similar parts like stator, armchair, housing, bushing, etc. the same is true in the manufacture of automobiles, pumps, airplanes etc. Although, such similarities is obvious and has long been recognized, until recently it was difficult to take advantage of the similarities. Thus come the new manufacturing philosophy, which classify and group parts based on their similarities both in design and manufacturing attributes.

As we have said earlier, a developed *classification and coding system (CCS)* is one of the first pre conditions for implementing a GT based production system. It is also the most time consuming and complicated tasks compared to the other methods. The CCS can also be used to organize part description so as to assist in the retrieval of parts and/or group parts according to the manufacturing process. Although it is a precondition for applying GT, a well-developed CCS on its own right can make a significant contribution to the improvement of manufacturing efficiency.

The major benefits of a well –designed classification and coding system for group technology have been summarized as follows [16]:

- It facilitates the formation of part families and machine cells
- It permits quick retrieval of designs, drawings, and process plans.
- It reduces design duplication.
- It provides reliable work piece statistics.

-
- It facilitates accurate estimation of machine tool requirements and logical machine loadings
 - It permits rationalization of tooling setups, reduces setup time, and reduce production throughput time.
 - It allows rationalization and improvement in tool design.
 - It aids production planning and scheduling procedures.
 - It improves cost estimation and facilitates cost accounting procedures.
 - It provides for better machine tool utilization and better use of tools, fixtures, and manpower.

So far a number of classifications and coding systems were developed to increase and improve the manufacturing efficiencies of various organizations. To see the method and application of some of these models will be discussed as follows.

1. The Opitz Classification System:

This classification and coding system was developed by H. Opitz in 1970 at Aachen Technology University in West Germany. The coding system use the following digital sequence [11,24]:

1 2 3 4 5 6 7 8 9 A B C D

The basic code consists of nine digits that can be extended by additional four digits. The general interpretations of the nine digits are as indicated in fig *Figure6-*

5 and Table 6-3. The first five digits are called the *form code* and indicate the design or the general appearance of the part and hence assist in design retrieval. Later, 4 more digits were added to the coding scheme, in order to increase the manufacturing information of the specific work part. These last four digits are also called *supplementary code*. All four are integers, and respectively represent: *Dimensions, Material, Original shape of raw stock, and Accuracy* of the work part. The extra four digits, **A, B, C, and D**, called the *secondary code*, are used by the specific organization to include those characters that are specific to the organization.

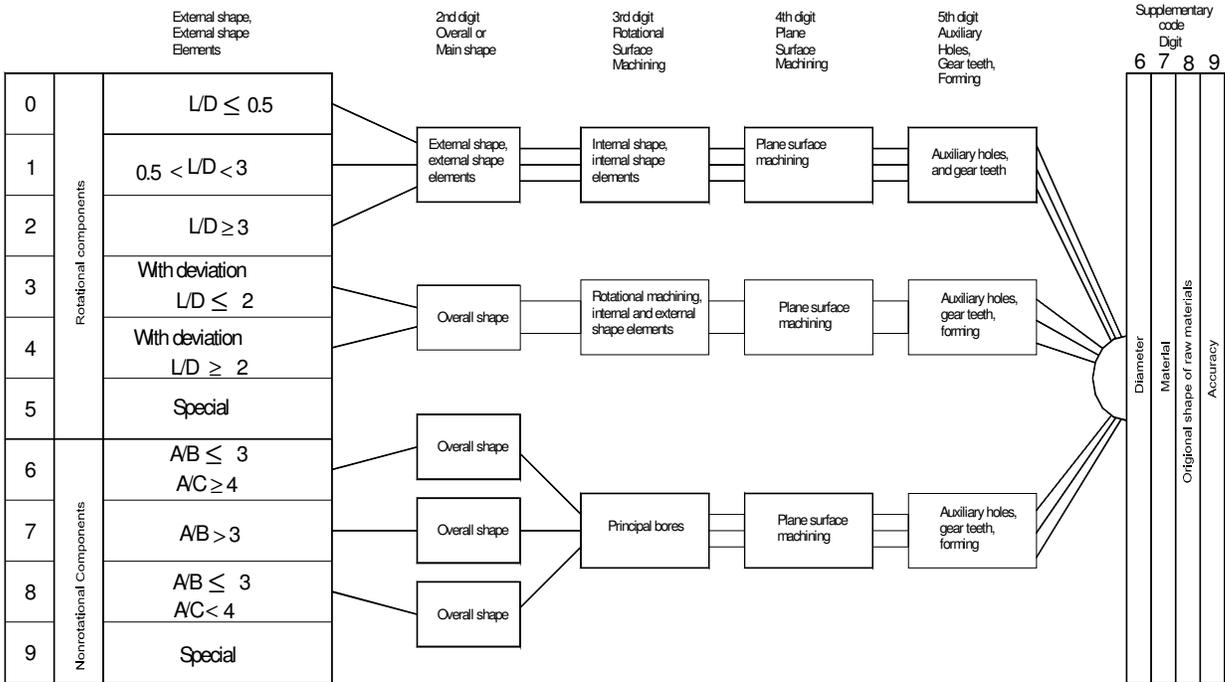


Figure 6-5 Basic structure of the Opitz system of parts classification and coding (Adopted from [24])

Table 6-3 Details of Optiz Part Classification and Coding system (Adopted from [38])

| 1 st Digit | | 2 nd Digit | | 3 rd Digit | | 4 th Digit | | | | | |
|-----------------------|------------------|-------------------------|---|---|---|--|---|--|---|-------------------|--|
| 5 th Digit | | External Shape, element | | Internal Shape, element | | Plane surface machining | | Auxiliary holes and gear teeth | | | |
| 0 | Rotational Parts | $\frac{L}{D} < 0.5$ | 0 | No machining | 0 | Without bore, without through hole | 0 | No plane surface machining | 0 | No auxiliary bore | |
| | | | 1 | Smooth no shape elements | | 1 | | With through hole | | 1 | External plane surface and or surface curved in one direction |
| 1 | | $0.5 < \frac{L}{D} < 3$ | 2 | No shape elements | 2 | No shape elements | 2 | External plane surface related to one another with a pitch | 2 | No gear teeth | Axial holes with indexing |
| | | | 3 | Screw thread | | 3 | | Screw thread | | 3 | External groove and or slot |
| 4 | | | 4 | Stepped to one end or smooth and or functional taper (and screw thread) | 4 | Stepped to one end or smooth Functional taper Radial groove and screw thread | 4 | External spline (polygon) | 4 | | Axial and or radial Holes with indexing And or in other directions |
| | | | | | | | | | | | |
| 6 | | | 6 | Stepped both ends (multiple increase) Screw thread | 6 | Stepped both ends (multiple increase) Screw thread | 6 | Internal plane surface and or groove | 6 | | Spur gear teeth With auxiliary holes |
| | | | | | | | | | | | |
| 8 | | | 8 | Operating thread | 8 | Operating thread | 8 | Internal spline External groove and/or slot | 8 | With gear teeth | Other gear teeth |
| 9 | | | 9 | Others | 9 | Others | 9 | Others | 9 | Others | Others |

2. MICLASS System

The name MICLASS stands for Metal Institute Classification System, and was developed by the Netherlands Organization for Applied Scientific Research (TNO) of Holland in 1969. After being implemented and applied in different manufacturing industries of Europe, it had been introduced to North America around 1974. Like Opitz classification system, MICLASS is also be made by using design and manufacturing attributes of the work part. The system was developed

in such a way that to standardize a number of different design, manufacturing and management function. This will includes, standardization of engineering drawings, easy of retrieval drawings based on their classification code, standardize process routing, automate process planning, selection of parts for processing on a particular machine groups and machine tool investment analysis. The total number of digits used in MICLASS classification system may vary from 12 to 30 digits. The digits can be divided into two. The first twelve digits are a universal nature and can be applied to any work part. The other 18 digits which is called supplemental codes can be used for data that are specific to the particular company. Those supplemental digits provide a flexibility to accommodate broad applications. Such as lot size, cost data, and operation sequence.

The design attributes used in the first twelve digits of MICLASS classification are as follows[24]:

| | |
|---|---------------------------|
| 1st digit | Maine Shape |
| 2nd and 3rd digit | Shape Element |
| 4th digit | Position of Shape element |

| | |
|---|---------------------|
| 5th and 6th digit | Main Dimension |
| 7th digit | Dimension Ratio |
| 8th digit | Auxiliary Dimension |
| 9th and 10th digit | Tolerance Code |
| 11th and 12th digit | Material Code |

One of the features of this coding system is that it can be coded interactively with computer. To classify a given work part the user is made to answer a number series of questions asked by the computer. The number of questions depends on

the complexity of the work part to be given the code. The answers to the question are simple ones requiring either numeric value or yes/no answer. After the end of the question the computer assigns code to the part. Then based on this number it is possible to retrieve a similar design or manufacturing procedure if there is any.

3. DCLASS:

This classification system was developed by Del Allen, Brigham University. It is used as both as a decision-making and classification system. It is a tree-structured system that generates codes for components, materials, processes, machines, and tools.

4. CODE System:

Developed by Manufacturing Data Systems, Inc. (MDSI). Use of an eight-digit code similar to Opitz system. However, it has a mixed code structure in which each digit is represented by a hexadecimal value that allows more information to be represented with the same number of digits.

5. VUOSO Classification System:

This type of classification uses a four digits code to represent part attributes. Three of which are arranged hierarchically to classify the part's shape, including size and proportions, and the fourth digit defines the material.

6. BRISCH System:

Use of four to six digits. A series of secondary poly codes can be added to cover additional classification requirements.

CHAPTER SEVEN

FORMULATION OF PROBLEM AND MODEL DEVELOPMENT

7.1 GENERAL DESCRIPTION OF ASPSC

7.1.1 Historical Background

Most of the industries, which were nationalized during the Derg regime, were obsolete and in a poor physical state owing to the lack of spare parts and effective maintenance routines. This situation had resulted a considerable loss of production because of unavoidable machinery downtime. This also necessitates a great demand for spare parts, which had to be imported with a considerable amount of foreign currency. In order to alleviate their shortage of spare parts, some factories were tried to manufacture some of the parts in there own workshop. Though, their move was appreciable, the result was not that much encouraging due to the fact that the manufactured parts were of inferior quality. This is due to lack of skilled personnel, use of unsuitable materials, inadequate production facility and capacity etc. Furthermore, various problems were faced in connection with the imported parts. These include[33]:

1. **Availability:** Since most of the existing production machinery and equipment were old and obsolete, the required spare parts are no longer in the original suppliers' or manufacturer's production program.
2. **Delivery Time:** Although the required spares are available, their long delivery time will necessitate a high stock level which resulting in high capital and administration costs.

-
- 3. Prices:** Due to the advancement of technology and a change in production line, most standard parts are no longer available. Therefore special orders had to be placed which resulting in high prices.
 - 4. Foreign currency:** Due to the poor economic situation and growth of the country, having shortage of foreign currency for imported parts had further aggravated the problems.

By analyzing and giving attentions for the above mentioned problems, the Ministry of Industry had come up with a strong desire to commission a study in order to objectively assess and evaluate the feasibility of constructing and operating a SPARE PARTS FACTORY in the country. As a result of this the preliminary studies have been conducted in 1977 by the former German Democratic Republic (GDR) and two years later in 1979 by UNIDO.

A detailed feasibility study of the plant was conducted between 1980 and 1982 respectively by a Swedish firm, with the help of a grant obtained from the Swedish government. Thus SWECO conducted an extensive study and examined the likely requirement for spare parts in four main industrial sectors: the Sugar, Cement, Textile, and Metal Works Corporations. The result of the assessment made by the firms indicates that the demand for spare parts in the four major corporations was in the range of 10,000 different items. After having analyzed carefully the potential demands of spare parts and considering the technology to be involved, SWECO proposed the following three alternative production programs.

Alternative – 1: Constructing a plant with a capacity of producing all the required 10,000 different items.

Alternative – 2: Constructing a plant which can produce the 10,000 different items by excluding those parts which have a consumption rate of less than 50 pcs/year unless the unit weight piece is more than 10kg. This makes the required 10,000 spare parts to be reduced in to 3,600 different items.

Alternative – 3: producing these 3,600 different items as indicated above together with a number of semi-finished and finished castings.

After a careful studies made among the above alternatives, *alternative-3* was been selected by eliminating those parts that had relatively low demand. In order to make the best use of the engineering capability and facilities of the plant, it was also decided to incorporate hand tool and cutlery manufacturing facilities.

Considering also the proper site selection, three alternative sites have been considered. The first alternative was Salo site, which is situated about 15km south of Addis Ababa, The second alternative was constructing the project a bout 8km south of Addis Ababa, and the third was the Akaki site, which is about 20km south of Addis Ababa and about 3km east of the village of Akaki. After analyzing the different factors which has to be considered to select the best site, the third alternative was been selected. Among the many advantages this location of the plant give an advantage of lower transportation costs and faster delivery to all

corners of the country. There are also excellent road with Ethiopia and to neighboring countries as well.

The construction work begins in 1986 under a turnkey contract between the former NMWC (National Metal Works Corporation) of Ethiopia and the Italian company, FATA and European Group SPA. All the construction and erection activities were covered by a soft loan obtained from the Italian government. The factory become operational in February 1989.

Figure 7-1. Present site of ASPHT S.Co

7.1.2 Production Capacity and Plant Facilities

7.1.2.1 Production Capacity of the Plant

The plant has the capacity to employ 900 people when operated at its full capacity.

Today, ASPSC provide work for around 600 people. The plant has the capacity to

produce up to 4,500 tons of spare parts, 1,600,000 hand tools and 600,000 pieces of cutlery per year.

The major products of the plant includes, all kinds of gears (i.e. spur, bevel, helical, worm gears), sprockets, shafts, wheels, rollers, sleeves, keys, levers, springs, steel balls, ingot moulds, brake shoes and drums, pistons for diesel engines, bearing housings, frames, liners, grates, pump bodies, drain covers, sheet and plate parts, various castings and forged parts, wrenches, cutters, pliers, screw drivers, hammers, forks, spoons, knives, etc. [25]

Table 7-1 Types of items produced by ASPHT S.Co.

| DESCRIPTION | Number of Line Items | Annual Capacity | Annual Export Surplus |
|---------------------------------|-----------------------------|------------------------|------------------------------|
| Industrial Hand Tools | 222 | 1,600,000 pcs | 640,000 pcs |
| Cutlery | 23 | 600,000 pcs | 240,000 pcs |
| Spare Parts and Various casting | 3,600 | 4,500 tons | 1,800 tons |

7.1.2.2 The Capability and Plant Facility

The plant is organized into a number of main production and auxiliary units to facilitate the manufacturing operations. Which includes

1. Mechanical Workshop The shop lays on total area of 11,666m², it is made up of eight different shops and appurtenant facilities. These shops, which are incorporated in the mechanical workshops, are as follows.

- **Cutting Section:** There are automatic types power hacksaws, which are capable of feeding the bar themselves and cutting up to a maximum diameter of 350mm. There is also a torch cutting with pantograph facility for plates up to a thickness of 250mm.
- **Turning Section:** This section is equipped with lathes, equipment for the manufacture of compression and tension spring, a balancing machine and a hydraulic press. The material, which is to be, turned mainly come from the cutting shop, the foundry or as bars from the raw material store. The maximum center height and center distance of the center lathe is 800/6000mm. There are also a vertical lathe to machine up to diameter of 1400mm and Turret lathes to accommodate bars up to diameter of 67mm. Shafts and gear blanks will be turned in the shop and the hydraulic press will be used together with universal balancing machine for straighten the shafts. The raw material for the spring winding equipment will be a special quality of steel delivered in the form of wire coils. It will be possible to manufacture springs with a wire diameter of 2-8mm.
- **Drilling Section:** The parts to be drilled will come from one of the other shops. It will be possible to make very small holes in the material with

the aid of high-speed bench drills, accurately positioning holes to a tolerance of 0.05mm and large holes up to 60mm in diameter in solid steel with the aid of the horizontal drill.

- **Milling Section:** This section was equipped with a universal milling up to traverse stroke of 1000 x 340 x 500 mm and a Plano miller machine which can handle up to a dimension of 1000 x 6000 x 900mm. There are also vertical milling machines up to a dimension of 800 x 280 x 420mm with a capacity of machining with in a tolerance limit of 0.02mm on surface flatness and 0.03mm on consistency of height.
- **Gear Making Section:** In this section a variety of gears like spur gears, helical gears, sprockets, worm wheels up to 1250mm diameter and module of 14. It can also possible to fabricate a straight bevel gear up to 610mm diameter and 8.5 module and helical bevel gears up to 210mm diameter and 6.25 module.
- **Heat Treatment Shop:** This shop equipped with complete thermal, thermo-chemical and chemical treatment facilities. The thermal treatment will include case hardening, tempering, annealing, normalizing, stress relieving induction hardenings. Where as the thermo-chemical treatment includes carbonizing, nitriding, carbonitriding. This treatment is carried out under fully controlled atmosphere using endothermic gas and ammonia, as required by the treatment.

Equipment will include muffle furnace up to 1000 x 650 x 500mm for use together with oil baths for hardening and convection oven for stress-relieving and tempering.

- **Forge:** The forge will primarily be used for the forging of steel balls for use in the cement industry and has a capacity of 200,000 balls per year. Precut pieces of special steel will leave the cutting shop, be heated to the correct temperature in the oven and then be formed into balls with a few blows of the forging hammer. It will also be possible to perform smith forging here. Burring will be performed manually with the aid of a trimming machine directly after the parts have left the forge. Die forging will not be carried out except in connection with the steel balls, since batch sizes of less than 1,000 are not economically viable owing to the fact that the tools are so expensive.

2. Foundry: The foundry will be able to produce a wide variety of casting made of steel, gray iron, aluminum alloys and copper alloys. It was designed in such a way that to have high degree of flexibility with regard to casting sizes and shapes as well as to batch sizes and different base materials. The equipment have all been well proven in use and have been chosen to maximize the use of local raw materials and other inputs, and to minimize machine stoppages and maintenance.

The available capacity both ferrous and non-ferrous casting is a maximum of 10 tons and 1.5 tons at a time respectively. In the ferrous department it is also possible to produce nodular cast iron, which allows the design engineer to chose a

cost effective engineering material. The non-ferrous foundry has a centrifugal casting machine which enables the manufacture of high quality bushing as well as piston for diesel engine and die casting machines.

3. Design and Method Division

The factory has own mechanical and foundry design and methods divisions which are expected to enhance design capability and to assist client industries in specifying correct measurements, type of material, finis, and accuracy of spare parts for appropriate and durable usage. These divisions have well trained engineers and draftsman who prepare the necessary detailed manufacturing drawings with all technical specifications, and lay out the manufacturing methods in detail for use in the various production shops.

4. Quality control Regarding the quality control, the plant has established laboratories in each shop, which are equipped with the most up-to-date testing and measuring equipment and instruments.

7.2 FORMULATION OF THE PROBLEM

As we have noted earlier ASPHT S.Co. shares the very same problems that frustrated the rapid growth and compete ability of most Ethiopian industries, not withstanding a number of problems peculiar to the plant, following are the most common problems that the plant currently face.

- The inability to attain the required specification during production process;
- Long delivery time;
- High production cost;

There fore the introductions of group technology based classification and coding system to the plant will contribute in solving these problems by providing:

- Quick retrieval of designs, drawings, and process plans.

-
- Less possibility duplication of design.
 - Since the system works with a design database, getting reliable work piece statistics will be very simple.
 - It aids production planning and scheduling procedures.
 - Since previously work parts are properly stored in the database, It facilitates cost estimation and improves cost accounting procedures.
 - It provides for better manpower utilization

7.3 METHOD OF DATA COLLECTION

After defining the scope of the study, the data collection was carried out in collaboration with the concerned personnel of the design section. To make the study complete it was tried to look into a five years drawing records, and this data collection activity took about 30 – 90 days. These data were obtained principally from the design section of the production and method division. Additional data,

such as plant history, number of order quantity, present manufacturing status was also obtained from the different section of the plant.

Table 7-2 Total number of drawing made with the respect to their accomplishing time (From 1996 – 2000)

| <i>Year</i> | <i>TOTAL NO. OF DRAWING</i> | <i>Total No. of Drawings completed below ES. Time(%)</i> | <i>Total No. of Drawings completed exactly at ES. Time (%)</i> | <i>Total No. of Drawings completed over the ES. Time(%)</i> |
|-------------|-----------------------------|--|--|---|
| 1996 | 108 | 24.07 | 3.7 | 72.22 |
| 1997 | 59 | 37.29 | 18.64 | 44.07 |
| 1998 | 128 | 34.38 | 20.31 | 45.31 |
| 1999 | 194 | 41.75 | 31.96 | 26.29 |
| 2000 | 262 | 23.28 | 22.90 | 53.82 |
| | 751 | 32.15 | 19.51 | 48.34 |

From the above table, the average number of drawings, which are made in the design section, will be 151. This indicates that out of these drawing, about 32.15% of the drawing has been completed before the expected design accomplishing time. Where as 19.51% of the drawings has been finished exactly at the planned estimated time. Also these drawings that will take extra time for their accomplishing are 48.34%. Graphically, it is shown in the figure bellow.

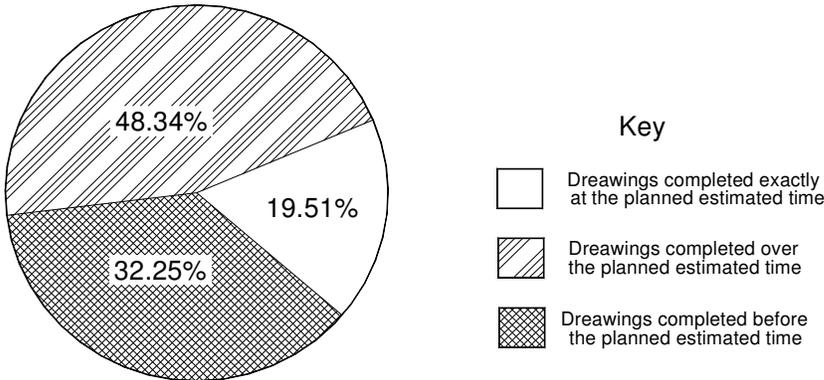


FIGURE 7-2 PERCENT OF DESIGN ACCOMPLISHING PER YEAR.

From the above findings we can see that most designs that are made in the design section will take extra time from the planned estimated design-accomplishing time. Of course, one may invoke a number of reasons for this, however it is obvious that something must be done to improve the design accomplishing time. And one possible solution for this is having a well develop GT-based classification and coding system.

7.4 THE CCS MODEL DEVELOPMENT AND SOLUTION

7.4.1 ANALYSIS OF DATA

A number of steps were taken to analyze the sample data to find out whether the product quality meet the requirement. The first step taken in this direction was to revise and classified the sample drawings as shown in the Figure 8-9 for further classification and checking.. This sample is made using visual inspection. After making the first steps of classifying the sample drawings, and considering the

existing design section problem. The final classification of the data was made for rotational parts made in the machine shop only. This is because of the time limitation that classifying both rotational and non-rotational parts including cast might take much time. A decision has to made in choosing one over the other, this was how the rotational parts are picked for classification purpose. And once the classification is made only for rotational parts it will be much more easier to work for the non-rotational parts.

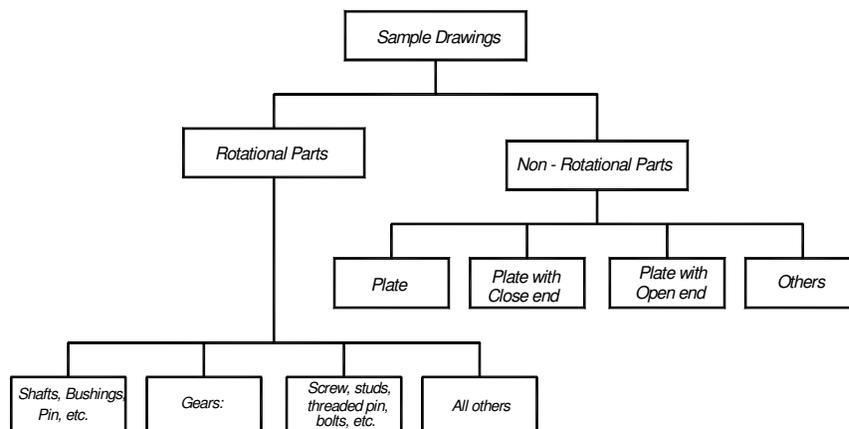


Figure 7- 3. Classifying the sample drawings using visual inspection

7.4.2 DEVELOPMENT OF THE CCS

After analyzing the different types of classification and coding system, and taking the existing design section problem into consideration, the program was developed using a hybrid code type. The coding system uses the following digital sequence:

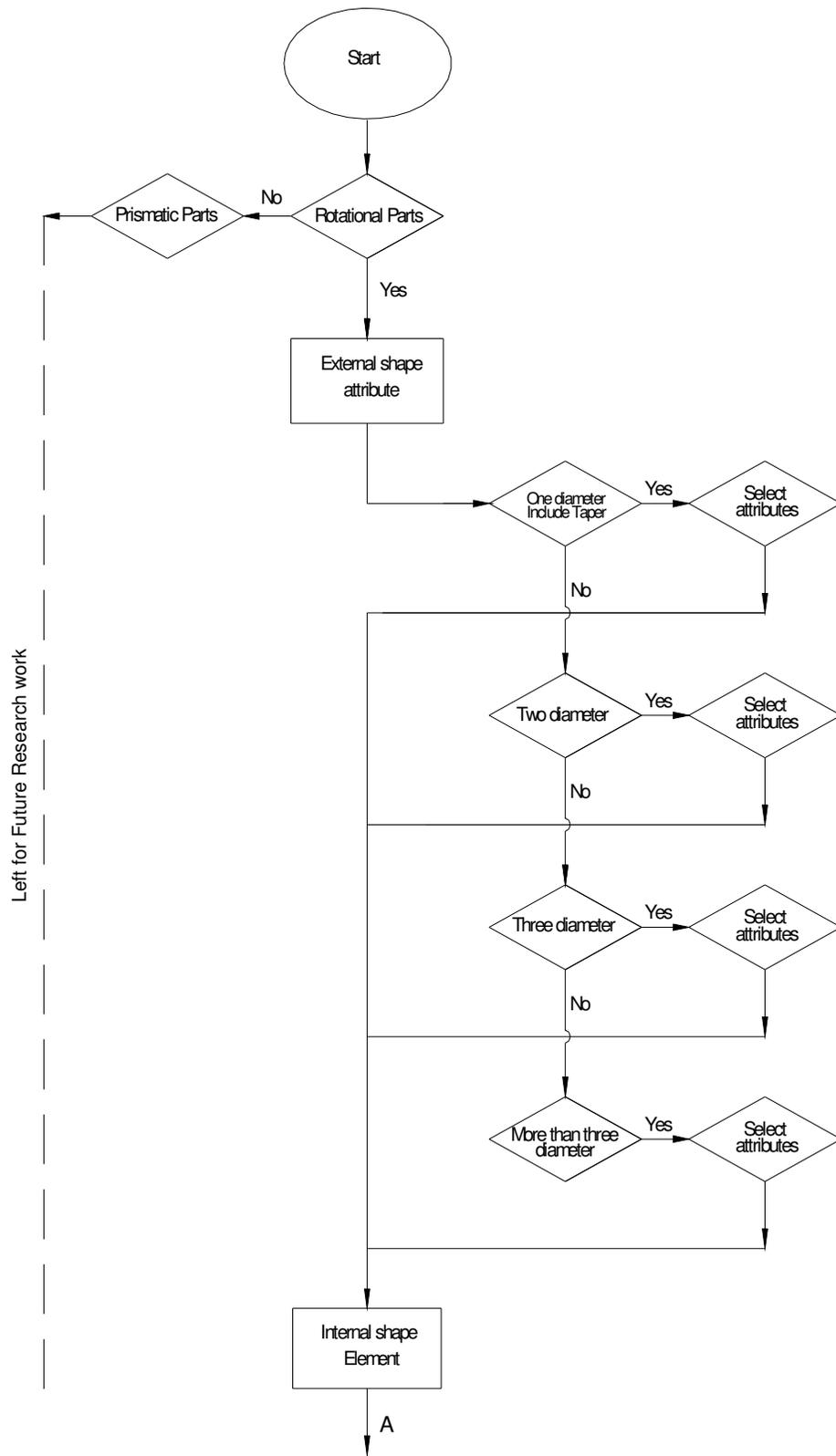
1 2 3 4 5 6 7 8 9

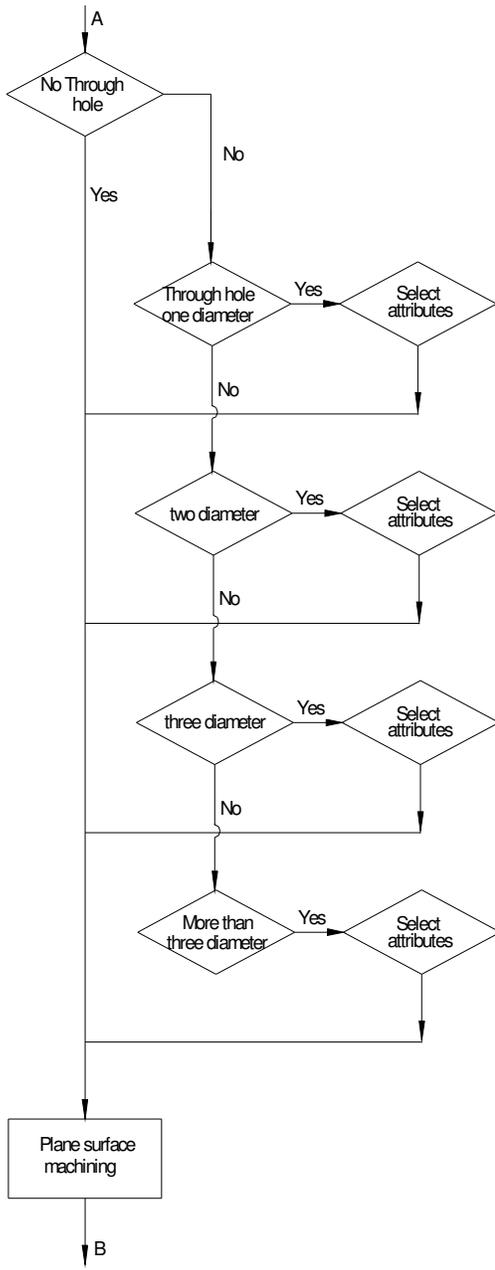
Like Optiz's classification and coding system, the basic code consists of nine digits. The general interpretations of the nine digits are as indicated in *Table 7-4* below. The first eight digits indicate the design or the general appearance of the part and the last digit represents the type of material. To make the classification more detailed, poly-code are being used for the external and internal shape attributes. Therefore, in order to take the advantages of both types of codes, the developed classification code is a hybrid code made by combining the two poly-codes and the mono-codes.

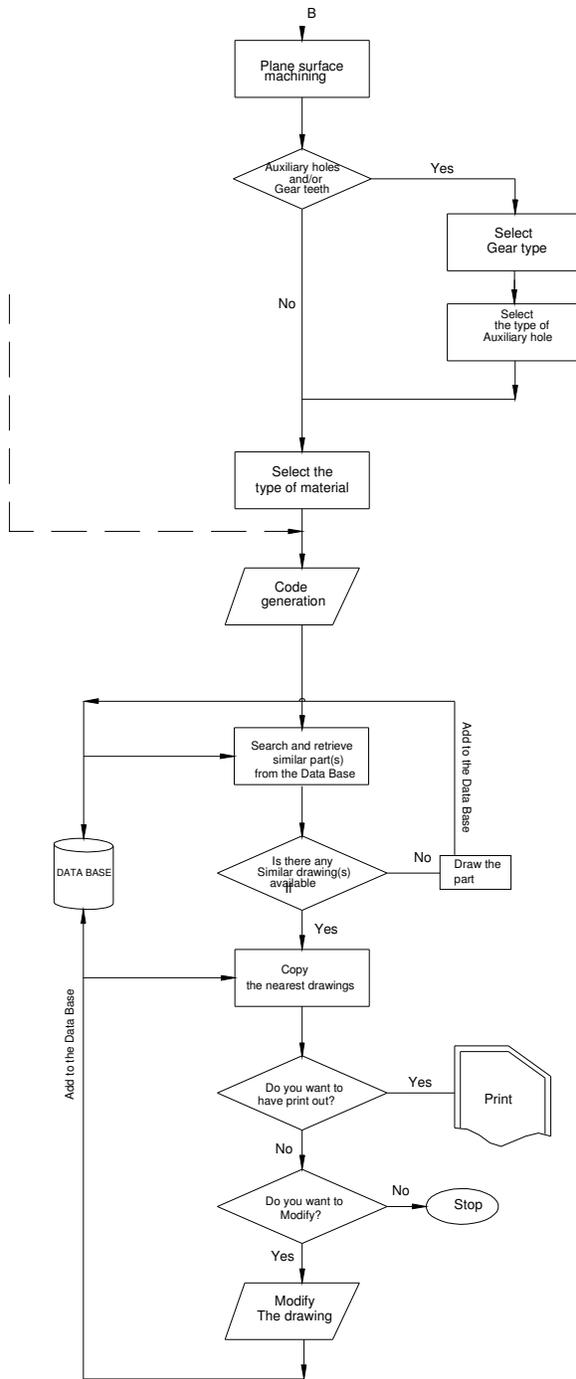
After analyzing and studying the Optiz classification and coding system, and the necessary steps required during the classification and coding process, the following algorithm is developed so as to develop the computer program. The computer program is developed using Visual Basic (Version 6.0) and Microsoft Access. Some forms are attached in the annex. The program was tested using

sample drawings, and the required class code was generated with drawings of similar design attributes were displayed.

Figure 7-4 Algorithm







CHAPTER EIGHT

Conclusion

The various advantages which a GT based manufacturing system provides are dealt in details in this study. One peculiar nature of this manufacturing system is that, it is possible to reap the advantages with out fully implementing the system. Thus, it is possible to obtain production benefits by introducing only the preliminary requirement of GT. (i.e. using a well developed classification and coding system). A closer examination of the tests conducted on the GT based classification and coding system applied to the needs of ASPHT S.Co., indicates that a number of advantages like easy design retrieval system, reduction of duplication of drawings, better work piece statistic, etc. can be obtain.

As it clear from the results indicated in the study regarding the developed CCS which was developed to solve the specific needs of ASPHT S. Co. there is no reason why other similar industries will not employee the same approach to overcame their problems.

In light of the above, further researches which will focus to alleviate the problems of various industries, through GT principles would help explore matters that falls beyond the scope of the present study, they might enrich the CCS both in theoretical and functional applications.

Finally by way of recommendation, the author wishes to propose that, there should be a continuation of future research works which will be made to include the prismatic parts and verity of casts so as to make the developed CCS complete. Hence most of the plants existing drawings are made manually, some means should be sought to convert the drawings into AutoCAD drawings so as to get easy retrieval and entry of drawings from and into the database.

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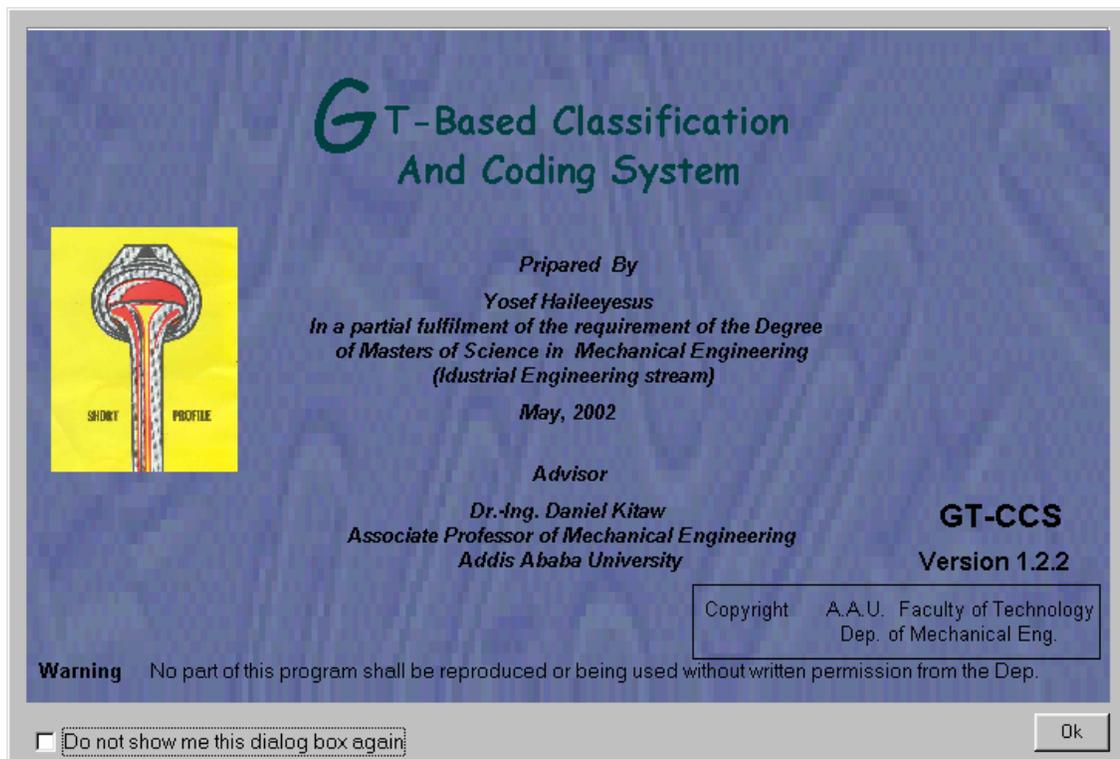
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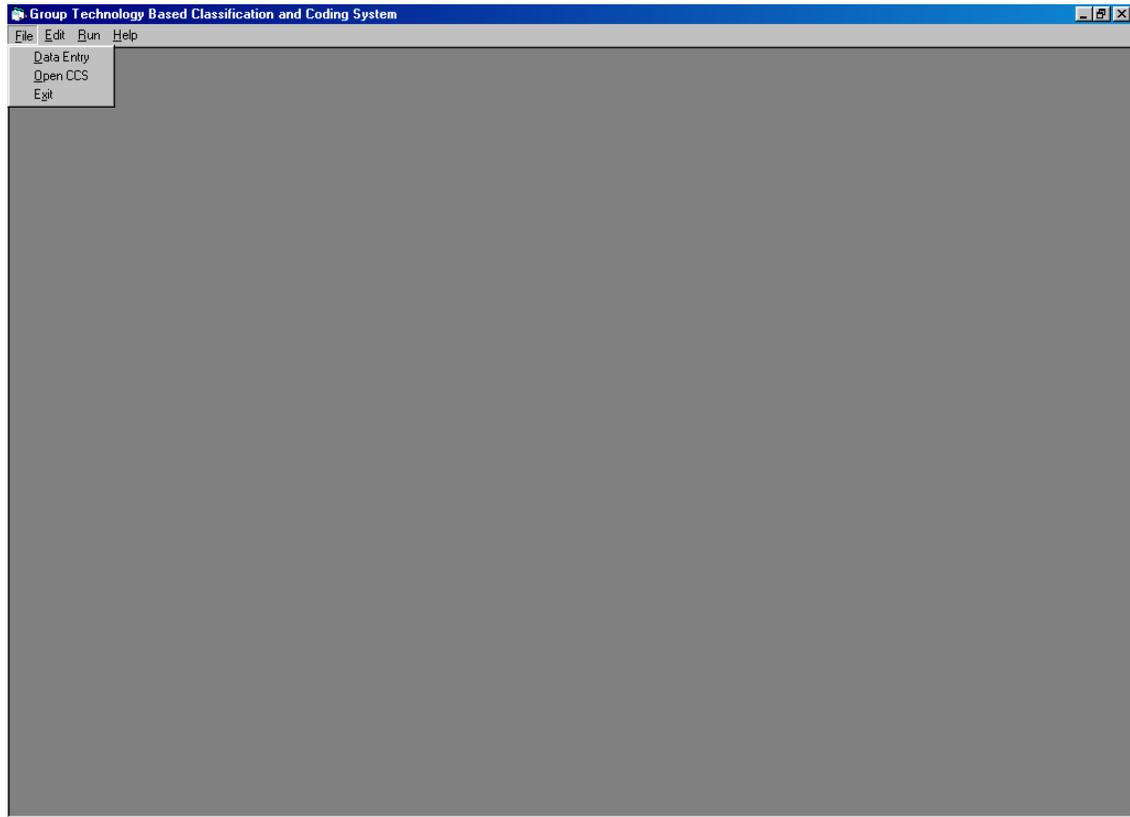
* ***Note that all the above list of materials, presented here, may not be directly referred in the text as a reference; I just used into some of the materials to understand the subject matter during my work.***

ANNEX

THE START-UP FORM



E GT BASED CCS APPLICATION



A DATA ENTRY FORM

Group Technology Based Classification and Coding System - [Data Entry Form]

File Edit Run Help

Description | Part Data | Employee | Drawing

Job Order No. 0000302 Job Class: J18 Enquiry Number: 0000302

Customer name: PRM

Sector: Manufacturing

Part name: STUD

Add
Delete
Update
Exit

Data1

MAJOR DIMENSIONS DATA INPUT FORM

Group Technology Based Classification and Coding System - [Main Form]

File Edit Run Help

Insert the major dimensions of the work part in mm.

Diameter (D) =

Length (L) =

Next >

< Back

Form used to select the external shape attributes for the rotational work part.

Group Technology Based Classification and Coding System - [Main Form]

File Edit Run Help

What external shape attribute does this rotational element have?

One Diameter, includes Tapered
Two Diameter
Three Diameter
More than Three Diameter

Next >

< Back

Form used to select the external shape attributes (this is the case for a rotational work-part with two outer diameter)

The screenshot shows a software window titled "Group Technology Based Classification and Coding System - [Main Form]". The window contains a form with the following elements:

- A question: "What external shape attribute does this rotational element have?"
- A dropdown menu with "Two Diameter" selected.
- Navigation buttons: "Next >" and "< Back".
- A central panel titled "Select one of the following feature" containing a grid of options, each with a technical drawing icon and a radio button:
 - Smooth, no shape element
 - Threaded
 - Functional groove, slot or key ways
 - Spline
 - Knurl
 - Flat(s)
 - Angular face end
 - Functional Cone
- Additional radio button options at the bottom of the central panel:
 - Combination of all the above
 - All Others
- A "Next >" button at the bottom left of the central panel.

Form used to select the internal shape attributes for the rotational work part.

Group Technology Based Classification and Coding System - [Main Form]

File Edit Run Help

What **internal shape** attribute does it have?

No Center Hole
Through Hole, One Diameter
Through Hole, Two Diameter
Through Hole, Three Diameter
All Others

Next >

< Back

Form used to select the internal shape attributes (this is the case for a rotational work-part with one internal diameter)

Group Technology Based Classification and Coding System - [Main Form]

File Edit Run Help

What internal shape attribute does it have?

Through Hole, One Diameter

Next >

< Back

Select one of the following feature

| | | | |
|---|---|---|--|
|  | <input type="radio"/> Blind Center Hole |  | <input type="radio"/> Through Hole With Splin |
|  | <input type="radio"/> Blind Center Hole With Threaded |  | <input type="radio"/> Through Hole With Radial Grooves, Keyway, Slot |
|  | <input type="radio"/> Through Hole |  | <input type="radio"/> Through Hole With Functional Cone |
|  | <input type="radio"/> Through Hole With Thread |  | <input type="radio"/> Through Hole With Flat(s) |

Combination of The Above

All Others

Next >

Form used to select the type of surface plain machining used.

Group Technology Based Classification and Coding System - [Main Form]

File Edit Run Help

Select the type of [surface plane machining](#) is appropriate for your work part

- No surface machining
- Surface plane and/or curved in one direction, external
- External plane surface related by graduation around a circle
- External groove and/or slot
- External polygon
- External plane surface related by graduation around a circle
- internal plane surface related by graduation around a circle
- Internal polygon

Next >

< Back

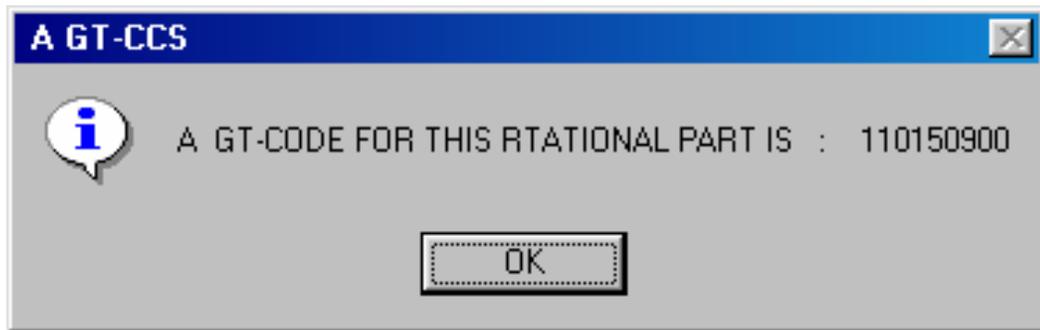
Form used to select the type of auxiliary hole or gear teeth.

The image shows a screenshot of a software application window. The title bar reads "Group Technology Based Classification and Coding System - [Main Form]". Below the title bar is a menu bar with the options "File", "Edit", "Run", and "Help". The main area of the window is a light gray background. In the center, there is a white dialog box with a thin gray border. Inside the dialog box, the text reads "Does the work part have any Auxiliary hole(s) and/or Gear teeth?". Below this text are three buttons: "Yes", "No", and "< Back". The "Yes" button is highlighted with a dotted border, indicating it is the selected option.

Form used to select material type.

The image shows a screenshot of a software application window. The title bar reads "Group Technology Based Classification and Coding System - [Main Form]". The menu bar includes "File", "Edit", "Run", and "Help". The main area of the window is a light gray color. In the center, there is a dialog box with a title "Select the type of material from the list". Inside this dialog, there is a list box containing the following items: "C-10...C-50", "Steel Alloy", "Bronze/Special Bronze", "Copper", and "Round Iron". The "C-10...C-50" item is currently selected. To the right of the list box are two buttons: "Ok" and "< Back".

THE GENERATED GT- CODE DISPLAY WINDOW



FINAL RESULT DISPLAY WINDOW

