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Effective use of Group Technology Based Coding and Classification System to a Case Company, Basic Metal Industry

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ABSTRACT

As the data collected shows, the major problems of the Metal Products Development Center are delay in delivery date, high product price, and low product quality (i.e., variation from the specification). To address these problems the researcher uses an approach of identifying the root causes of these problems and then finding out acceptable solutions and propose it in a form that can earn for the case company. To make this analysis the researcher collected all the relevant data from marketing, designing, and production departments. Then, the root causes are identified with the help of cause and effect method and looked for GT based solution to address these problems.

The result of the cause problems identification shows, the major causes are: unnecessary material handling because of the existing machines arrangements, the existed traditional design data storage method that does not let for design retrieval, treating each part separately rather than in family form, cost estimation that is doing based on unreliable data, and the absence and difficulty of production scheduling.

Thus, to be competent through solving the existed problems, the company needs to adopt and implement the modern manufacturing philosophy; and thus, the researcher proposed group technology as a solution. It includes the development of CCS that could encompass both rotational and non-rotational parts and formation of machine cells. It mainly aimed for the possibility of design retrieval and for further analysis of parts in order to use the similarity advantages among parts both in design and manufacturing attributes. And formation of machine cells in the production area, so that it can address in the reduction of non value added operations available in the company. It reduces material handling, setup time, and ease scheduling job.

The result of the proposed solutions shows a positive and considerable impact to the productivity of the company. It saves the cost of production by 19.1 percent with providing modern manufacturing methods in the designing and production area.

Key Words: Group Technology, Coding and Classification, Part family, Machine cell, Clustering, Retrieval system, Data management system, and cellular manufacturing.

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ACRONYMS

GT:	Group Technology
CCS:	Coding and classification system
PFA:	Production flow analysis
MPDC:	Metal products development center
GTCSPDC	Group Technology based coding structure for Metal products development center
GTCCSPDC	GT based coding and classification system for Metal products development center
ROC:	Rank order clustering
DCA:	Direct clustering algorithm
VB:	Visual Basic
DPDCS	Data base management system
DML	Data manipulation language
MICLASS	Metal Institute Classification System
TNO	The Netherlands Organization
SOM	Self organizing map
ART	Adaptive resonance theory
CAPP	Computer Aided Process Planning

CHAPTER ONE

PROBLEM AND ITS' APPROACH

1.1 Background of the Study

Manufacturing activity has become far more competitive than ever almost in all markets due to the fastidiousness of customers needs change and faster technological advancements. Thus, to take a major share in the markets, manufacturers are forced to rapidly change and develop their manufacturing capabilities. 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, 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 flush, 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 [3].

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 improved 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. To the fore mentioned and other reasons or advantages, it is important to use it for Ethiopian companies, which engaged on the production of a large range of variety of products with some similarity that can classify them in to groups. Based on this Metal products development centers is selected as a case for the study [8].

1.2 Problem statements

In the current experiences of Product Development manufacturing Industry, there are considerable problems in connection with its product quality, delivery time and price**.** And this is due to the high production cost, high design and production lead time, inefficiency in resource utilization, lack of efficient production planning and scheduling, material handling problem, etc. Moreover most of the machines in the company are arranged in a traditional job shop type layout (process type layout), where similar machines and labor with similar skills are located together.

In a little more detail, the problems observed in Metal products development center are:

- Like most of manufacturing industries of the country Metal products development center also face a problem of not having proper documentation system. Since there is no properly organized and manageable documentation system, information like past design and cost estimation is usually stored either manually or not in organized way for future use. This creates a high problem of identifying and retrieving data that are already available. In addition to this as employees leave the organization it is difficult to find out 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 cost.

- Even if the current manufacturing system in the company is completely job shop type of production, there is no means for using the similarity advantage of parts. Rather each product is treated individually and traditionally for design and production purpose. Thus, there are no any machine cells which are dedicated to produce group of parts. Treating each part separately in the company makes: material handling less efficient; material flow is less streamlined; production management tasks are more complex; longer lead time; no tooling and fixture standardization; less employee satisfaction and others.

- In the production area, machines are not arranged based on process flow requirements of parts. Rather most of them are arranged based on the similarity of machines. In some cases the arrangement is done according to the space availability and due to other factors, as shown in appendix part of the study. This layout, the conventional approach for small batch components, results in law machine utilization and high wastage of time. The high cost of material handling and set-ups for small batches result in high manufacturing cost.

Generally the major problems of the company are high products price, long delivery date, and low product quality. Further discussion on the available root causes of these major problems have presented in the data analysis part of the study. Thus, for the company to alleviate the fore mentioned problems and being competent in this era, it is important to look for a modern manufacturing philosophy.

However, in the existing current production system, small to medium batch production, which generates a great deal of industrial output has become the dominant manufacturing activity in the world. This domination has come in to being for cope up with the various processing changes; low price, short delivery time, high quality level, minimum raw material price, etc. One and the best method to cope up with the above changes in small to medium batch production is the application of Group Technology. From a manufacturing point of view, group technology is a manufacturing strategy that attempts to decrease the production cost by reducing material handling and other tangible or intangible costs. Thus to realize these advantages for the Metal products development center, Group Technology (GT) is chosen as a research topic [8].

1.3 Objective of the Study

The general objective is to address basic problems of the company and improve the efficiency of production through the development and implementation of GT based manufacturing philosophy.

The specific objectives of the study are to:

- Analyze the existing production process of Metal products development center Industry according to GT principles.
- Develop Program aided GT based parts coding and part design storage and retrieval model by using Microsoft Access and Visual Basic 6.0, based on the data obtained from the factory and from different literature resources,
- Develop appropriate part families and machine cells based on the data obtained from the factory.
- Develop GT coding based data management system for the case company.

1.4 Methodology

The methodologies adopted to achieve the objectives of this study include:

- **Literature survey:** different literatures and researches related with the subject matter studied and analyzed thoroughly from books, past research studies, and online internet sources.
- **Data collection:** after a serious study of literatures, data required for the study have been collected from the target company through: having direct physical contact with the production area, discussion type guided interview, and using available soft and hard copy data files. Most of the data have been collected from design, marketing, and production departments of the company; and it took more than three months to collect, organize, and analyze. This includes collecting:
  - ✓ The available drawings from already-made designs.
  - ✓ Existing facilities data in the workshops
  - ✓ Existing facilities layout of production area.

- ✓ Represent able amount of produced parts data from the past three years, in order to identify the types of parts and their attributes. This data collected from designing and marketing departments; and it was available in the form of both soft and hard copy.
- ✓ The major complaints of customers' and its consequence that had collected from marketing department head through guided interview type questions and available past sales history data from Performa file.
- ✓ Others.

- **Analysis of data:** after collecting all the relevant data, the analysis has been done with the help of knowledge found from the literature survey. The analysis is made with the focus on identifying the major causes of the core problems of the company and providing better approaches for proposing acceptable and long living GT based solutions. During the analysis there was repeated synthesis, so that it is possible to gain the required result of the study. For example, during the analysis of data for design the right coding scheme, different types of coding methods and components attributes had been considered. This was done in order to select which type of coding scheme and attributes can best engulf all parts produced in the company precisely and to meet the objective of the study. The same is true for machine cell formation analysis. Different clustering methods and machine labeling options are analyzed and synthesized, and complete steps for each alternative have been presented. And finally, the results of the analysis had been used for the formation of: computer based CCS and machine cells.
- **Model development**: during CCS model development, four component modules are designed first, so that they can communicate with each other and fulfill the overall requirement of the final model. Thus, based on the modules and program algorithm, a GT based parts coding, part design storage, and retrieval system had been developed by using an object oriented programming language (Visual Basic 6.0) with Microsoft Access database management system software.

1.5 Application of the Results

The result of this study is applicable for manufacturing companies that are fully or partially job shop or batch in production type. Specifically it works in the following areas of such manufacturing companies:

- **Design**: In the area of product design, the principal benefits are from the use of parts classification and coding system. When a new part design is required, the engineer or draftsman can devote a few minutes to figure the code of the required part. Then the existing part designs that match the code can be retrieved to see if one of them will serve as the base for the desired. This may save hours of the designer's time.
- **Production scheduling**: Production scheduling is simplified with group technology. In effect, grouping of machines into cells reduces the complexity and size of the parts scheduling problem. Thus the designed CCS will provide a standard time frame for operations and a means for classifications and groupings of parts.
- **Layout design:** it helps to use the advantage of both process layouts (flexibility) and product layout (efficiency).
- **Tools and setups:** it tends to promote standardization of tooling and fixtures. Work-holding devices are designed to use special adapters, which convert the general fixture into one that can accept each part family member. The machine tools in GT cell do not require drastic changeovers in setups because of the similarity in the work parts processed on them. Hence, setup time is saved and it becomes more feasible to try to process parts in an order, so as to achieve a bare minimum of setup changeovers.
- **Employee satisfaction*:*** the designed coding and classification system simplify the data management system and getting information, thus it has a positive impact on the working condition and workers morale. This tends to cultivate an improved worker attitude and a higher level of job satisfaction.

- **Estimation:** the designed CCS will simplify and makes more accurate estimation on products cost and processes operation time.

The beneficiaries of this research result are:

- The **customers**: - From the delivery of better quality products with lower price and short lead time.
- The **company: -** From lower product cost, shorter delivery time, providing better service for its customers, and higher profit and demand.
- The **country** as a whole: - since an improvement of a company means an improvement of the national economy, thus increasing the productivity of Metal products development center means an improvement of the host country too.
- The **Student.**
- Other **concerning companies and researchers: -** it provides a chance to them so that they can use this study as a base for developing their own GT based production system.

1.6 Organization of the Study

This study contains a total of eight chapters. The first chapter gives an introductory view of the study, a problem statement of the specific company, objectives, and methodology of the study. The next three chapters provide a related literature review, which deals on: basic concepts of GT, coding and classification system development concepts and principles, and basic principles and methods for machine cells formation, respectively. The fifth chapter presents the background of the company and other necessary data's with data analysis for the research. The next two chapters deal on the development of the proposed coding and classification system and machine cell formation, respectively. And finally, in the last chapter conclusion of the study and important recommendations had forwarded based on the results.

CHAPTER TWO

INTRODUCTION TO GROUP TECHNOLOGY

2.1. Introduction

The complexity of products is constantly increasing. To meet the world's growing demand on diversity, highly different products are required. This as well as historically grown product programs lead to changing product structures with a high number of variations in products and processes.

According to Burbidge, around 75 per cent of the parts produced by metallurgical industries are produced in batches smaller than 50 items, and there is the tendency to enhance the diversification of parts and products, thus increasing the necessity of new production planning techniques. In some cases, it is possible to verify that around 95 per cent of production time results in material displacement and queuing. Moreover, the part set is inordinate and the process planning (PP) becomes a very difficult task. Generally, long queues are formed during the production process due to bottlenecks [12].

However, the productivity increase can be accomplished by the reduction of the information flow necessary to the project and by the shop floor reorganization. It aims at the attainment of economy, which is normally associated with large-scale production, even though dealing with a small-lot manufacturing basis. This requires group technology employment.

Group Technology (GT) is a manufacturing philosophy in which the parts having similarities (Geometry and/or manufacturing process) are grouped together to achieve higher level of integration between the design and manufacturing functions of a firm.

2.2. Basic Concepts on GT

Finding universal definition for Group Technology (GT) is not an easy task since many have been introduced by a number of people who have written about it. However, the following definition that is given by Solaja helps to clarify its main concepts:- Group Technology is the realization that many problems are similar and that, by grouping similar problems, a single solution can be found to a set of problems, thus saving time and effort [7].

The basic idea of group technology (GT) is to decompose a manufacturing system in to sub systems. The concept aims at increased production efficiency by exploiting the design and process similarities of the parts. It involves the grouping of parts that have some sameness or similarities in design and manufacturing into part-families and machines in to machine-cells. This results in an organization of the production system in to self-contained and self-regulated groups of machines such that each group of machines undertakes a maximal production of parts. Such decomposition of the plant operations in to subsystems leads to reduced material handling activities, reduced production lead time, a smaller work in process inventory, reduced labor and tooling, improved human relations and reduced paper work [17].

The application of GT to a traditional manufacturing system can usually result in a simpler material flow system, so that a higher transfer rate and easier production planning and control functions can usually be achieved.

In a broader term, Group Technology is an attempt to achieve improved control by looking for commonalities i.e. looking for avenues for standardization and achieving better rationalization and harmonization through the same. Basically, cells are nuclei for control. These concepts of ˜rationalization of activities, harmonization of lows and nuclei of control can also be used in several situations other than manufacturing [40].

In general it could be said that many problems/tasks could be similar. By grouping such similar problems/tasks single solution to the problem or a single point of control for the tasks could be found. This saves time and effort. Group Technology could be viewed in this broader perspective. It appears the benefits that Group Technology could offer to the discipline of management have yet to be fully exploited.

In summary, group technology allows small batch production to gain economic advantages similar to those of mass production by retaining the flexibility of the job shop. It implies the notion of recognizing and exploiting similarities in three different ways: [38]

i. By performing like activities together
ii. By standardizing similar tasks
iii. By efficiently storing and retrieving information about recurring problems.

One of the first and most important problems faced in practice in the design of group technology based machine cells is to select and group parts with similar features into *part-families* and the corresponding machines into *machine-cells.* This problem is called *part-family and machine-cell formation.* To solve this part-machine grouping problem numerous algorithms have emerged in recent years.

2.3. Historical Notes on GT

GT has been employed for around a century by industries for factory organization, since Henry Ford to the present day. One of the pioneer works related to GT is credited to F.W. Taylor. Taylor observed the similarities between some jobs and he was able to categorize their similar attributes [1].

In the past, the ideas underlying production system organization were sparse techniques and, currently, they are a systematic set of concepts, applied in industries on a large and wide scale. Many concepts and strategies were developed after the advent of automatic machines and numerical control machines. Following the natural evolution in the quest for higher productivity, the computerized numerical control technology was reached. Adaptive control applications were developed; the concept of machining centers was created as well as flexible manufacturing systems; computer aided design and manufacturing (CAD/CAM); computer integrated manufacturing (CIM) and so forth.

Obviously, the above advances in technological resources have contributed to new philosophies for production system analysis [29].

A remarkable event in the GT history has taken place with the publication of Mitrofanov's book in 1959, in which the first formal description of GT was introduced. Mitrofanov proposed that it was possible to produce a theoretical composite component which incorporated all the major features of components belonging to a family, and that a machine could be tooled up to produce the composite component, thus providing the set-ups required for each component in the family. [1]

In the early 1960s, Opitz carried out an investigation into work piece statistics, which showed that although firms manufacture a variety of products, the spectrum of them all was remarkably similar. Based on the findings of this investigation, he established a classification system which enabled components to be codified by means of their geometrical similarity. [1]

A number of methods for classification and coding were being investigated at approximately the same time.

The advances in GT have been greatly influenced by the existence of a classification system devised by Brisch and Partners. The Brisch system was originally designed to facilitate variety reduction, component standardization and product rationalization. It was later developed to suit GT requirements. There have been many applications of GT using the Brisch system and the most successful example was probably that of Serck Audco Valves. [1]

Other methods were later developed as alternatives to the classification and coding approach. These were methods based on the analysis of production information. The most representative work was the Production Flow Analysis method proposed by Burbidge. Other similar methods were due to EL-Essawy, Purcheck and Nagarkar. These methods are different with respect to the underlying assumptions and the technique of analysis, but the general approach is to study a company's total system and to determine those families of components which are related by similarities in the production facilities required for their manufacture. [1]

After some initial experience with Group Technology in organizations, it became evident that a change in the workshop was not sufficient on its own. To obtain the full benefits, it was necessary to change other parts of the system, including, for example, production control, planning, payment systems, and accounting methods. For this reason, Group Technology was changed from being a technique in itself to being part of a new philosophy of production organization. [1]

Although Group Technology is out of favor in Ethiopia, because it is not yet implemented widely, it has flourished in other industrial nations. Since the 1960s, work has been done, though on smaller scales, in the Netherlands, Switzerland, Belgium, Sweden, U.S.A., Japan and West Germany. Today, many of these and other developed countries have more application of GT and they are continuing to press ahead with its development. In the United States, Group Technology has been accepted as a technique of raising manufacturing performance, and the merits of integrating it with the very popular production control technique of Material Requirements Planning are well publicized [1].

2.4. The Basic Forms of GT-Manufacturing Systems

From the literary references and practice, there are a number of well-known manufacturing processes to which different manufacturing systems can be allocated. Depending on the order batch size (small or large batches), *functional machine layout or process layout* and *flow line system or product layout* are already recognized in the industrial manufacturing process.

The Process Layout (Functional Machine Layout System)

This type of layout groups together all operations of the same type in a department. 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. The process layout is particularly useful where low volume is required for large variety of products. This type of layout is *more flexible* but it is highly *inefficient* (large volume of work-in-process inventory, longer production lead-time, large cost of materials handling, complicated production planning and control system etc.)

The Product Layout (Flow Line System)

In this layout the equipment used to fabricate a given product is lined up 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 work-in-process storage and material handling. However this type of layout is *highly inflexible**;*** i.e. a change in the product design (or change in product mix) necessitates a substantial change in the layout. This layout is recommended for mass production of few parts.

The concept of Group Technology or GT (also referred to as Cellular Manufacturing System) was developed to take the advantage of *process layout (flexibility)* and that of *product layout (efficiency).* The basic idea of GT originally consists of grouping parts with similar manufacturing characteristics together to form so-called ‘additive batches’, and routing them through the functional machine layout with the assistance of product ional control.

In a farther development of this idea, parts spectrums with similar machining requirements were setup and executed in corresponding machine groups. With due consideration of the literature, GT-manufacturing system can be related to the following basic forms:

- The ***GT-Flow Line***
- The ***GT-Cell***
- The ***GT-Center***

The three-layout forms lie between the functional machine layout- as the characteristics layout for one-off and small batch production-and the flow line system as the representative of large batch production.

GT-Flow-Line

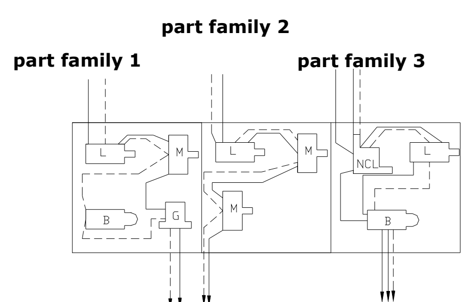
This type of layout can be made when each of the part families to be produced has almost the same process route resulting in the same production flow through machine tools. The GT-Flow-Line is the highest degree of rationalization for GT layout and can take considerable advantage of mass production as in the case of product layout.

GT-Cell

This is a GT layout in which the production flow for many of the parts in the family is not identical; therefore, a GT-Flow-Line is not established. It is one in which all the machining operations for one or more families can be accomplished in a collection of machine tools, namely, a GT-Cell. Thus, this cell layout allows feasible operation sequences depending on the type of the parts.

GT-Center

A GT-Center consists of a work place in which similar processing equipment are grouped together like that of functional process layout but locates the equipment so that a part family can be processed by the same equipment as far as possible. This type of layout is the lowest level of GT layout. Examples of the three types of GT layout are shown below in Figure (2.1. a, b, c)



(a) GT-Cell

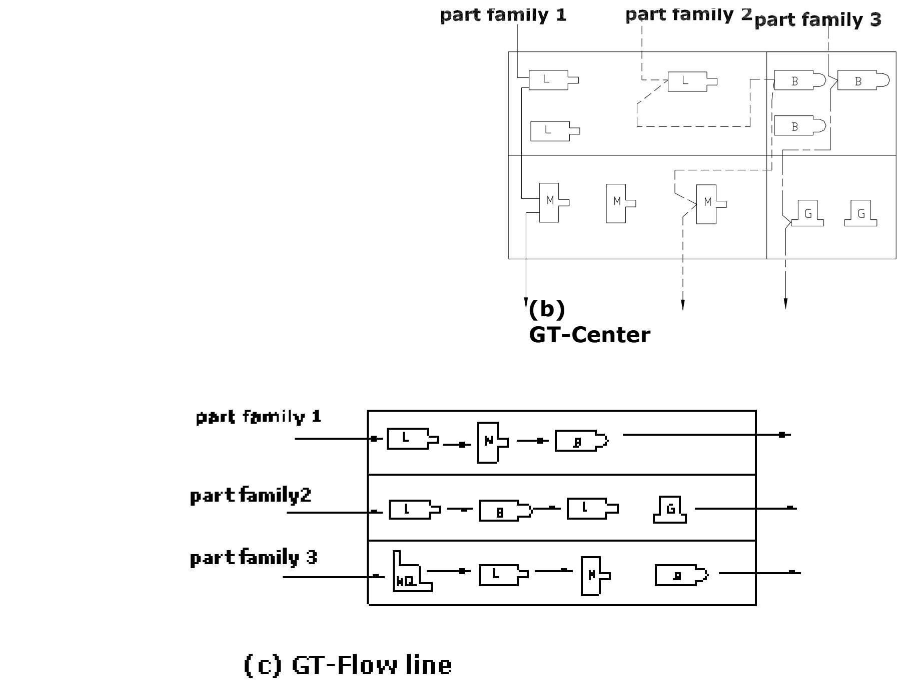


Figure.2.1. Types of GT layout

2.5. Part Family and Machine Cell

GT involves the grouping of parts in to part-families and machines into machine-groups (cells). This leads to an organization of the production system into self-contained and self-regulated groups of machines such that each group of machines undertakes a maximal production of a family of parts.

2.5.1. Part Family

A *Part family* is a group of parts that have some specific sameness and similarities in design features or production processes. A part family may be grouped with the parts having similar features such as geometric shape, size, material, etc, or a part family may be grouped with respect to production operations, that is, machines, processes, operations, sequence of operations, tooling, etc. These two types of part families are referred to as *design part family* and *product part family* respectively.

By grouping work parts into families, we may use group technology layout instead of process-type layout.

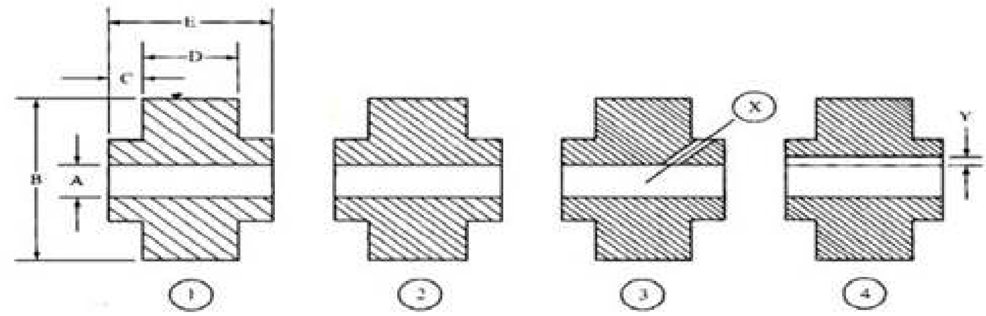


Figure.2.2. Parts grouped by geometric shape

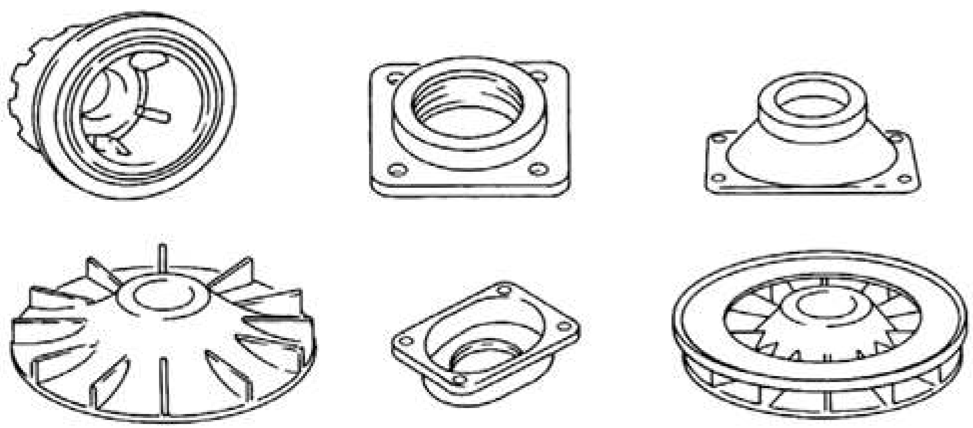


Figure.2.3. Parts grouped by manufacturing process

Methods for Developing Part Families

Different GT approaches have been developed to decompose a large manufacturing system into smaller, manageable systems based on similarities of design attributes and part features.

There are three main approaches for grouping parts into families and implementing group technology in a plant:

1. Visual Inspection Method
2. Classification and Coding by Examination of Design and Production Data
3. Production Flow Analysis

***1. Visual Inspection Method*:** Involves arranging a set of parts into part families by visually inspecting the physical characteristics of the parts or their photographs. It is the least sophisticated and least expensive method. Although this method is the least accurate one among the three, the first major success stories of GT in the US made the changeover using this method.

*2. **Parts Classification and Coding:***

The most time consuming and complicated of the three methods. A classification and coding system should be custom engineered for a given company or industry. The classification and coding *method* involves classifying the parts into families by examining the individual design and/or manufacturing attributes of the parts. The three basic part features that can be classified and coded are: [6]

a) Shape or geometry of part,
b) Function of part, and,
c) Manufacturing operation and tooling.

3. Production Flow Analysis

The *production flow analysis (PFA)* makes use of the information contained on the route sheet rather than the part drawing. Work parts with identical or similar routing are classified into part families.

It is a method for both identifying part families and associated groupings of machine tools. It will be discussed in cell formation approaches.

2.5.2. Machine Cell

A manufacturing cell is a cluster of machines or processes located in close proximity and dedicated to the manufacture of a family of parts. Primary objectives in implementing a cellular manufacturing system are to reduce: setup times, flow times, inventory, and market response time.

2.6. Advantages of GT

The advantages that could be gained from GT are: [28]

1. A good coding and classification system provides design engineering with a system that facilitates:
    - Efficient retrieval of similar parts.
    - Development of a data base containing effective product design data.
    - Standardization of designs.
    - Avoidance of design duplication.
    - Forming of part families.
    - Use of producibility tips.
    - Incorporation of engineering design changes into the engineering and manufacturing systems.
2. A good coding and classification system provides manufacturing with a system that facilitates:
    - Development of a computer-aided process planning system.
    - Retrieval of process plans for part families.
    - Development of standard routings for part families.
    - Development of machining cells.
3. Standard routings facilitate the development of tooling groups, NC program groups, and standard setups for part families.
4. Production planning and control can be simplified, so that it can be more comprehensive.
5. Production scheduling can be simplified.
6. Machining cells can reduce in-process inventory, resulting in shorter queues and shorter manufacturing through-put times.
7. Improved machine utilization yields shorter set up times and better scheduling.
8. Part family data facilitates improving plant layout, which in turn can reduce materials handling cost.
9. Purchasing can be more effective. It is easier to choose the proper vendor because the many different parts and materials have been grouped into families, which reduce the complexity of the problem.
10. Management can be more effective because the environment has been simplified.

2.7. Percentage Savings through GT

At 1989, Wemmerlov and Hyder were conducted a survey on 32 firms operating cells and they found the following benefits of GT as shown in Table below. [17]

Table: 2.1. Percentage savings through GT

		Improvement Percentage		
Category	**No. of respondents**	**Average**	**Minimum**	**Maximum**
Throughput time	25	46	5	90
WIP Inventory	23	41	8	80
Materials Handling	26	39	10	83
Job Satisfaction	16	34	15	50
Fixtures	9	33	10	85
Setup time	23	32	2	95
Space needed	9	31	1	85
Quality	26	30	5	90
Finished goods	14	29	10	75
Labor cost	15	26	5	75

- In summary, commonly there are a Potential savings of 5 to 75 % through properly designed and implemented GT.

2.8. Limitations of Group Technology

Group Technology is a great concept. But all good concepts do have their own limitations and need proper care in their application, for results to be realized in practice. Improper implementation and/or half hearted attempts may usually backfire. The concepts have to be applied with a great deal of thought prior to their application. The assumptions behind the theory have to be properly assessed. A good home work needs to be done before the application and a whole hearted implementation needs to follow. Thus, the limitations of cellular manufacturing may be as follows: [40]

1. Setup times or change over times may not always be significantly reduced just because the components in the family bear apparent similarity. Some of the literature on Group Technology reports that a major proportion of the features of a group of components must be virtually identical for the education in the setup times to take place.

2. Similarly the assumptions regarding raw material commercial work in process inventories need to be checked during the design of the cells. In a process layout, the machines share a common pool of inventories whereas in an ill-designed cellular system, machines may require own individual stocks of materials.
3. Improper cell formation, whether based on component shapes/features or on production flow analysis would turn out be in efficient in terms of time, investment and humanistic aspects. Load balancing situation of non-key machines and the placement of bottleneck machines are issues that need to be addressed during cell formation.
4. Inadequacies in employee education training and involvement could come in the way of proper implementation.

Cellular manufacturing the avatar of Group Technology in manufacturing has concerned only to the internal spatial arrangements. That is, it has been focusing on only dimension of the production/operations system. It has not been systematic in nature. To that extent the application has been limited in its scope. Therefore, the results may not be radical in their extent. Newer management technological such as Just-in-Time system have used the concept behind Group Technology that of bringing in the properties of a line layout in batch production in addition to several other concepts and measures which take care of other issues in the management of production and product delivery. The results have been quite positive remarkably so.

2.9. Achieving Competitive Advantage through Group Technology

The power of a competitive advantage based on superior product quality is beginning to wane as more and more firms improve the quality of their products. Flexibility is the new advantage: change fast, keep costs low, respond quickly. In manufacturing companies, flexibility can be achieved in a number of ways, such as with smaller production runs, shorter lead times, and more standardized subcomponents. Unfortunately, many of these can also increase production costs and diminish product differentiation. To be more flexible and maintain a competitive advantage, the manufacturing process itself may have to be changed. [11]

The ultimate strategy for becoming more flexible is to use a highly integrated, fully automated manufacturing system. However, such a system may not be a viable solution for all firms because many lack the capital or skills to implement it. Such firms need a less resource-intensive, more incremental approach to becoming more flexible in their manufacturing operations. [11]

A number of firms have become more flexible by adopting the concepts and techniques of Group Technology (GT). According to Min and Shin (1994), GT "seeks to improve productivity by grouping parts and products with similar characteristics into families and forming production cells with a group of dissimilar machines and processes." GT makes it possible for a firm to achieve higher levels of flexibility without increasing production costs or sacrificing product quality, thus leading to an improved competitive position for the firm [11].

Adopting GT can improve a firm's competitive position in a market by fortifying an existing competitive advantage or by developing a new position of advantage. Specifically, adoption of GT can improve product quality, profitability, and customer service levels [11].

2.10. Problems Preventing Widespread Application of GT

The problems that have prevented the widespread of the application of GT in the world are the following: [15]

- ❖ The problem of identifying part families among the component produced by the plants
- ❖ The expense of part classification and coding
- ❖ Rearranging the machines in the plant into the appropriate machine cells
- ❖ The general resistance that is commonly encountered when a new system is contemplated

CHAPTER THREE

GROUP TECHNOLOGY CODING AND CLASSIFICATION SYSTEM

3.1. Introduction

To classify in primitive sense is to divide extents 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].

In this paper context, the approach of classification is somewhat differ from the definition given in *Oxford Dictionary.* Here our interest is to look into the different approach and method of classification applications used in an industry. Thus the following definition was coined for coding and classification:

Coding: is the assignment of a symbol (or a set of symbols) to represent information. It is establishing symbols to meaningfully communicate features.

Classification: a protocol that is used to separate a large group of objects into separate sub-groups. Separate items into groups (and assign them a code) based on the existence or absence of characteristic attributes (features). Classification is the process of identifying and establishing the various classes or divisions that exist for a set of parts based on relevant attributes. However future manufacturing systems will be increasingly more dynamic. They have to be able to rapidly respond to changing conditions by concurrently balancing and optimizing multiple manufacturing constraints.

By doing so the variety will be reduced both for design and production advantages. The different methods of converging parts variety (or forming a part family) have been discussed in the previous section. In this section detail of coding and classification system had presented.

3.2. The Cost of Variety

Limiting the rate at which the variety of parts increases is a well-recognized objective for many engineering companies. Concern with the consequential costs of variety is the normal motivation for the decision to employ disciplines in the design function that seek to prevent the unnecessary proliferation of parts. There is little agreement in the literature as to the precise figure to be attached to costs that flow from the creation of a new part number but they do all agree that they are very significant (Sharma, 1978). A study at Scandia in the 1980s (Johnson and Broms, 2000) suggested that design and development costs were directly proportional to the size of the parts range. The same study suggested that distribution and production costs also fall by 30% and 10% respectively with a 50% reduction in the parts range. The opportunity or scope for design reuse is also an interesting question. A study of the application of group technology (GT) coding and classification (C&C) systems in engineering companies (Hyer and Wemmerlov, 1989) found that 20% of parts could be reused unmodified, 18% needed some modification and a further 12% required substantial change before they could be used. It seems clear that significant potential exists to achieve substantial savings providing an effective means can be found to encourage a designer to find a suitable existing part rather than create a new one [36].

3.3. Part Coding and Classification

Parts coding and classification analysis is mostly concerned with the use of individual part design features for group formation. Such features include tolerances, materials requirement, and parts shapes and sizes. This concept of using design features for the purpose of describing and grouping similar parts was introduced by Mitrofanov. Opitz later extended the idea to production cells and developed a comprehensive coding and classification system for work pieces. Since these pioneering efforts several other parts coding and classification systems have been developed to facilitate part grouping. [20], [24], [25]

They are an established way of retrieving or grouping manufactured parts on the basis of their geometrical or other properties. Most of these systems use a type of numeric code structure that originally was developed to meet the needs of manual storage systems. Even with computerized storage and manipulation of the part code, the process of encoding the geometric and other properties of the part still requires a human analyst to 'read' an engineering drawing. Once the code has been generated it may be used to provide a simple design retrieval facility. The retrieval performance of these systems seems to be generally accepted as satisfactory; for example, in one case (Tatikonda and Wemmerlov 1992) a company was reported to have saved $1400 00 in the first year of operation of a coding and classification system during which 2900 part numbers were eliminated. [36]

3.4. GT Coding

A GT code is a string of characters capturing information about an item. It is an alphanumeric string which represents critical information about the product in a concise manner. Comparing the GT codes of two products is a quick and efficient method for estimating product similarity in selected attributes.

There are a large number of coding schemes which differ:

- In terms of the symbols they employ such as numeric, alphabetic, or alpha-numeric.
- In the assignment of these symbols to generate codes.

Parts classification systems fall into one of three categories:

1. Systems based on part design attributes
2. Systems based on part manufacturing attributes
3. Systems based on both design and manufacturing attributes

There is a certain amount of overlap between the design and manufacturing attributes of a part.

1. *Design attributes* pertain to similarities in geometric features and consist of the following:
    a. External and internal shapes and dimensions,
    b. Aspect ratios (length-to-width or length-to-diameter),
    c. Dimensional tolerances,
    d. Surface finishes,
    e. Part functions.
2. *Manufacturing attributes:* pertain to similarities in the methods and the sequence of the manufacturing operations performed on the part. As we have seen, selection of a manufacturing process (or processes) depends on many factors, among which are the shapes, the dimensions, and other geometric features of the part. Consequently, manufacturing and design attributes are interrelated. The manufacturing attributes of a part consist of the following:
    a. The primary processes used,
    b. The secondary and finishing processes used,
    c. The dimensional tolerances and surface finish,
    d. The sequence of operations performed,
    e. The tools, dies, fixtures, and machinery used,
    f. The production quantity and production rate.

From these lists, it can be appreciated that the coding can be time-consuming and that it requires considerable experience in the design and manufacture of products. In its simplest form, the coding can be done by viewing the shapes of the parts in a generic way and then classifying the parts accordingly (such as parts having rotational symmetry, parts having rectilinear shape, and parts having large surface-to-thickness ratios). The parts being reviewed and classified should be representative of the company's product lines. A more thorough method is to review all of the data and drawings concerning the design and manufacture of all parts.

3.5. Types of Codes

Several schemes of coding and classification have been developed and the most common ones are: [44], [45] *(a) Hierarchical Structures (Mono-codes):*

Here, each digit (or position) in the code represents a feature/sub-group. The first digit represents an entire group. The next digit represents sub-groups of the feature, and so on. In this sense, each subsequent digit is qualified by the preceding digits (or, in an object-oriented sense, each subsequent digit inherits the properties of the previous digits).

Advantages of mono-codes:

1) With just a few digits, a very large amount of information can be stored.
2) The hierarchical structure allows parts of the code to be used for information at different levels of abstraction.

Disadvantages:

1) Impossible to get a good hierarchical structure for most features/groups.
2) Different sub-groups may have different levels of sub-sub-groups, thereby leading to blank codes in some positions.

(b) Chain codes (Polycodes):

In this method, the code digit represents one feature. Thus, the value of any given digit (or position) within the code has no relation to the other digits.

(c) Hybrid Structure:

In this case, the code for a part is a mixture of polycodes and monocodes. Such coding methods use monocodes where they can, and use polycodes for the other digits; in such a way as to obtain a code structure that captures the essential information about a part shape. This is the most commonly used method of coding and classification.

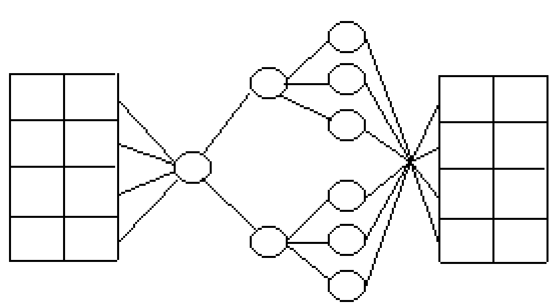


Figure: 3.1. Hybrid Structure

In summary, there are three different types of coding structures which were discussed, each having their own advantages and disadvantages.

3.6. Reasons for Using a Coding System

- Design retrieval: a designer faced with a task of developing a new part can use a design retrieval system to determine if a similar part already exists. A simple change in an existing part would take much less time than designing a whole new part from scratch.
- Automated process planning - the part code for a new part can be used to search for process plans for existing parts with identical or similar codes.
- Assess manufacturability of a product design.
- Machine cell design - the part codes can be used to design machine cells capable of producing all members of a particular part family. [43]

3.7. Selection of a Coding System

Several factors that should be considered in selecting a suitable classification and coding system: [28]

- **Objective**. What is the major objective of the classification system? Why is a system needed? Is it primarily for design retrieval or part-family manufacturing or both?
- **Scope and application**. What departments are involved in using the system? What are the specific needs and information to be coded? How wide is the range of products and how complex are the parts, shapes, process operations, tooling, etc.?
- **Cost and time**. How much expense will be involved in installation, training, and system maintenance? What are the cost estimates for consultant fees, in housing design, training, etc.? How long will it take to install and train the staff needed? How long will it take to realize the effects of the system in all areas of application, from design to production?

- **Adaptability to other systems**. Is the system easily adaptable to the computer system and database being used in the company? Can the system be easily integrated with other systems, such as process planning, NC programming, management information systems, etc.?
- **Management problems.** Are all involved management personnel informed and supportive about installation of the system? Is there any union problem? Can good cooperation among the involved departments be obtained?

3.8. Qualities of a Good GT Classification and Coding System

For group technology applications a classification and coding system should meet the following requirements: [13],[36]

1. All embracing: it embraces all existing items being produced and/or purchased, and be able to accept new items.
2. Mutually Exclusive: must be mutually exclusive, that is, including like things while excluding unlike things.
3. Based on permanent characteristics: it must be based upon visible attributes or easily confined permanent and unchanging characteristics.
4. Specific to user needs: it should be developed to meet the needs of the user.
5. Adaptable future changes: it should be adaptable to future expansion and technological change.
6. Adaptable to computer processing: it should be operable without a computer. However, it is desirable to operate the system using a computer.
7. Company-wide applications: it should have application throughout the whole company.

Classification and Coding is the cornerstone of any Group Technology implementation. However, it is only the starting point. The classification and coding system must be continually reviewed to ensure that the system is adequately and effectively being used for satisfactory implementation of group technology.

3.9. Database Management Systems

As Cardinas (1985) points out, "A database is a collection of occurrences of a number of record types, where the record types and their occurrences are interrelated by means of specific relationships". Databases are used to bring together large amounts of data and make it available to many users. A database management system is a programming system that manages a database or large amounts of data efficiently (Ullman, 1976). Due to the need of integrated information system, industry frequently finds that database technology is essential for the continuing growth of the company.

There are three main types of database models. These are: [2]

1. Hierarchical model
2. Network model
3. Relational model

Among the three different types of databases, it is felt that the relational model is the most commonly used one. The relational data model is "the model of choice for the implementation of new databases." [35]

There are four steps common to the construction of most DPDCS's, which are as follows:[2]

1. Define the logical structure of the entities and relationships making up the database (logical schema).
2. Define and control access to any subset of the database.
3. Access the database, as the subschemas defined by a special data manipulation language (DML) or by a non procedural query language.
4. Define the physical structure, organization, and storage layout of the actual database (Physical schema).

These four concepts of design of a DPDCS are important because if any one is missing, the DPDCS will not be properly designed. If the purpose of this system is primarily to access shared information, a DPDCS is needed. [31]

3.10. Coding Systems for Manufacturing Industries

Most Commonly Used Coding Systems for Manufacturing Industries are:

- Optiz System
- Miclass System
- KK-3 system, and
- The CODE System

Optiz Classification System

Optiz classification system: (1970) - hybrid - The Optiz coding system uses the following digit sequence: 12345 6789 ABCD. The basic code consists of nine digits, which can be extended by adding four more digits. The first nine digits are intended to convey both design and manufacturing data. The general interpretation of the nine digits is indicated in Fig. The first five digits, 12345, are called the "form code" and describe the primary design attributes of the part. The next four digits, 6789, constitute the "supplementary code". It indicates some of the attributes that would be of use to manufacturing (work material, raw work piece shape, and accuracy). The extra four digits, "ABCD", are referred to as the "secondary code" and are intended to identify the production operation type and sequence. The secondary code can be designed by the firm to serve its own particular needs [24],[25].

In the form code, the first digit identifies whether the part is a rotational or a non-rotational part. It also describes the general shape and proportions of the part. Figure below shows the specification scheme. For the rotational workpieces, the coding of the first five digits is given in Fig. 3.3.

Example: The overall length/diameter ratio, L/D = 1.6, so the first code = 1. The part is stepped on both ends with a screw thread on one end, so the second digit code would be 5 the third digit code is 1 because of the through hole. The fourth and fifth digits are both 0, since no surface machining is required and there are no auxiliary holes or gear teeth on the part. - The complete form code in the Opitz system is "15100". To add the supplementary code, we would have to properly code the sixth through ninth digits with data on dimensions, material, starting work piece shape, and accuracy [24].

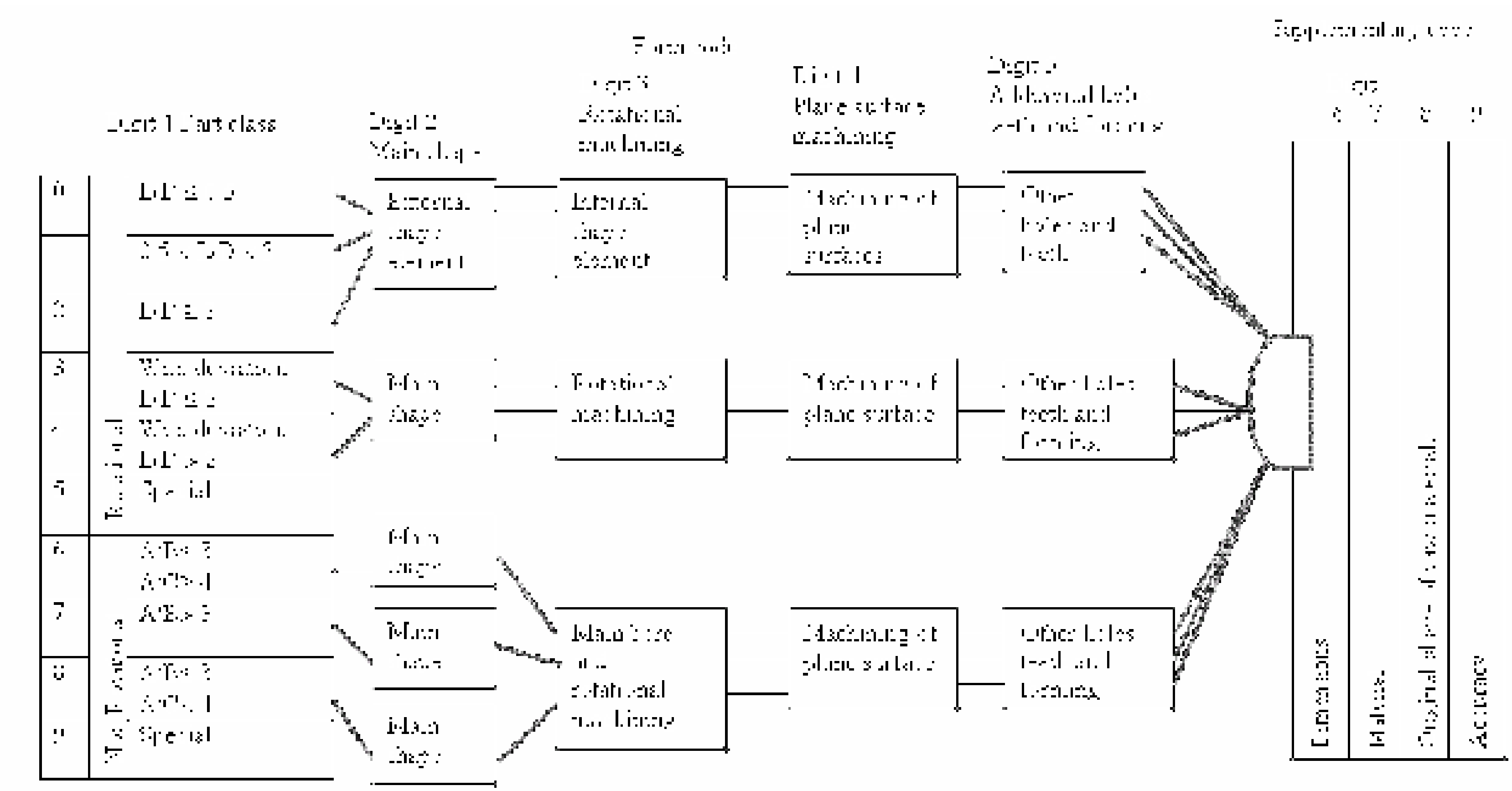


Figure: 3.2. Structure of the Optiz Coding System

The MICLASS System

The MICLASS System: (Metal Institute Classification System) of TNO (The Netherlands Organization) (1969) - chain - The MICLASS classification number can range from 12 to 30 digits. The first 12 digits are universal code that can be applied to any part. Up to 18 additional digits can be used to code data that are specific to the particular company or industry. For example, lot size, piece time, cost data, and operation sequence 'might be' included in the 18 supplementary digits.

The component attributes coded in the first 12 digits of the MICLASS number are as follows:

1st digit Main shape

2nd and 3rd digits Shape elements

4th digit Position of shape elements

5th and 6th digits Main dimensions

7th digit Dimension ratio

8th digit Auxiliary dimension

9th and 10th digits Tolerance codes

11th and 12th digits Material codes

One of the unique features of MICLASS system is that parts can be coded using a computer interactively. To classify a given part design, the user responds to a series of questions asked by the computer. The number of questions depends on the complexity of the part. For a simple part, as few as seven questions are needed to classify the part. For an average part, the number of questions ranges between 10 and 20. On the basis of responses to its questions, the computer assigns a code number to the part.

The KK-3 code

The KK-3 code: (1980) - chain - It was originally developed by the Japan Society for Promotion of Machining Industry. The domain is machining and grinding parts; primarily metal-cutting and grinding. The code is 21-digits, each of which is an integer [44].

Table: 3.1. Structure of the KK-3 coding system

Digit	Item (Rotational component)		
1	Parts name	General classification	
2		Detail classification	
3	Materials	General classification	
4		Detail classification	
5	Chief dimensions	Length	
6		Diameter	
7	Primary shapes and ratio of major dimensions		
8	Shape details and kinds of process	External surface	External primary shape
9			Concentric screw threaded parts
10			Functional cut-off parts
11			Extra ordinary shaped parts
12			Forming
13			Cylindrical surface
14		Internal surface	Internal primary shape
15			Internal curved surface
16			Internal flat/cylindrical surface
17		End surface	
18		Non-concentric	Regularly located holes
19			Special holes
20		Non cutting process	
21	Accuracy		

The CODE System

The code system is a parts classification and coding system developed and marketed by Manufacturing Data System, Inc (MDSI), of Ann Arbor, Michigan. It's most universal application is in design engineering for retrieval of part design data, but it also has applications in manufacturing process planning, purchasing, tool design, and inventory control.

The code number has eight digits. For each digit there are 16 possible values (zero through 9 and A through F) that are used to describe the parts design and manufacturing characteristics. The initial digit position indicates the basic geometry of the part and is called the major division of the code system. This digit would be used to specify whether the shape was cylinder, flat, block, or other. The interpretation of the remaining digits forms a chain-type structure. Hence the CODE system possesses a hybrid structure. It can be expanded to 12 digits to include heat-treat, hardness, finish, material, production cost, and time standards.

Implementing Coding and Classification

Coding and Classification presents some major challenges that are not usually evident to an inexperienced practitioner. This is especially true of large databases. But, then, large projects have correspondingly large returns. A successful project requires experience and judgment in coding system design, initial coding and in family development. It is not a task for the novice [8].

To implement the GT code the following stages are required:

1. Develop a GT code
2. The results of the coding should be reviewed. If too many parts have the same GT code, or there are not enough similarities between codes, then the code should be revised.
3. The remainder of the parts should be coded.
4. An examination of all the parts for the factory will allow the identification of patterns in production, or design. As a result, standard production routings, or standard product designs may be selected.

CHAPTER FOUR

MANUFACTURING CELL FORMATION

4.1. Introduction

A cell is a small scale, clearly-defined production unit within a larger factory. This unit has complete responsibility for producing a family of like parts or a product [34].

A primary application is in batch manufacturing where product variety is high and traditional layout design is by equipment function. The implementation of GT in this environment involves a number of comprehensive changes including the reconfiguration of plant equipment from a functional layout to a series of product oriented layouts that are referred to as manufacturing cells. The cells are dedicated to process families of parts that have similar machine operations [23].

Since it was asserted for the first time, the cell formation problem has grown into an area in which much research has been conducted. Various taxonomies of cell formation have also been proposed. And this chapter presents a review of related literatures in area of machine cell formation in Group Technology system.

4.2. Cellular Manufacturing

Cellular manufacturing (CM) is a very well known approach for implementing the principles of GT in a production environment wherein families of parts with similar manufacturing process are grouped together. The machines required for processing the parts may be arranged into cell so that all parts in a given family are processed within a cell following unidirectional flow. The advantages of cellular manufacturing over traditional functional manufacturing are many folds as it has been indicated in the previous chapter. Reduction in set-up time and work-in-process inventories, simplify flow of parts and tools, centralization of responsibility, and improvement of human relationships are just a few.

4.3. Machine Cell/ Work cell Design

It is a Rationalized Approach to Cellular Manufacturing. Their benefits are many and varied. They increase productivity and quality. Cells simplify material flow, management and even accounting systems. Work cells appear simple, but beneath this deceptive simplicity are sophisticated Socio-Technical Systems. Proper functioning depends on subtle interactions of people and equipment. Each element must fit with the others in a smoothly functioning, self-regulating and self-improving operation. [16], [37]

Proper design of manufacturing work cells is an engineering problem. Like any other engineering design, it proceeds through a logical sequence of steps. At each step, the designers make compromises between conflicting requirements or technical limitations.

Doing it well requires a deep and profound knowledge of the elements of a work cell, their functions, and their interactions. Unfortunately, many practitioners fail to recognize this. A desire for instant solutions exacerbates the situation. As a result, many manufacturers fail, create sub-optimum cells, or produce negative unintended consequences. [16], [37]

Four Tasks of Cell Design are:

Task 1: The goal of product selection is to find compatible families of products which a group of machines can process without undo changeovers or other difficulties that result from attempting too much variety. Important tools are Process Mapping and Group Technology.

Task 2: Engineering the process requires a deep understanding of every process event as well as the times required for setup, personnel activities and machine cycles.

Task 3: Infrastructural elements support the process but do not touch the product. They are many and varied. Examples are: Containers, Scheduling, Balance Methods, and Motivation. Infrastructure is intangible and cell designs often fail due to lack of awareness about it.

Task 4: The fourth task in work cell design is the physical layout. This is often straightforward if the previous tasks have been done thoughtfully. The Task Procedure diagrams can often be simplified. In many cases you may start with the process chart and move directly to a layout.

4.4. Types of machine cells

Machine cells can be classified as the following: [17]

1. *Single machine cell:* Consists of one machine, supporting fixtures and tooling. One or more part families with one basic type of process (such as milling) can be processed.
2. *Group machine cell with manual handling:* This type of cell is often organized into a U-shaped layout. Includes more than one machine to process one or more part families. Material handling is performed by the human operators who run the cell.
3. *Group machine cell with semi-integrated handling:* A mechanized handling system, such as a conveyor, is used to move parts between machines in the cell. If the parts made in the cell have identical routings, in-line layout is selected. If the routings vary, loop layout is more appropriate.
4. *Flexible manufacturing system (FMS):* Most highly automated machine cell. Combines automated processing stations with a fully integrated handling system.

4.5. Evaluation of Cell Design Decisions

Evaluation of structural issues: [38]

- Equipment and tooling investment (low)
- Equipment relocation cost (low)
- Inter- and intra-cell material-handling costs (low)
- Floor space requirements (low)
- Extent to which parts are completed in a cell (high)
- Flexibility (high)

Performance variables related to system operation: [38]

- Equipment utilization (high)
- Work-in-process inventory (low)
- Queue lengths at each workstation (low)
- Job throughput time (short)
- Job lateness (low)

4.6. Best Machines Arrangement

The important factors about determining the type of machine cell and the best arrangement of equipment in the cell include: [38]

- *Volume of work to be done in the cell:* Includes the number of parts per year and the amount of work required per part. Required to determine the number of machines in the cell, total cost of operating the cell, and the amount of investment needed to organize and equip the cell.
- *Variations in process routings of the parts:* Determines the work flow. One of straight-line, U-shape or loop flows is selected.
- *Part size, shape, weight, and other physical attributes:* Determines the size and type of material handling and processing equipment that can be used.

4.7. Production Flow Analysis

The implementation of CM involves the conversion of all or a portion of the firm's manufacturing system to cells. Each cell consists of a cluster of functionally dissimilar machines, which are placed in a close proximity to one another and are dedicated to manufacture a set of part families. Parts are grouped into part families depending on the similarity in parts' geometry, manufacturing process required, or both. Thus machine-cell and family formation is the first major step in the design of cellular manufacturing system.

As already stated in the previous chapter there are three methods of part family and machine cell formation. Out of these the third method, production flow analysis (PFA), makes use of the information contained on the route sheet rather than the part drawing. Work parts with identical or similar routing are classified into part families. Thus it is more suitable in machine cell design and it is the method used in this study.

The method involves the following stages:

1. In the first stage, machines are classified by numbers according to the type of operation that can be performed on them. Machines, which can perform similar

operation, are usually classified with the same number. The specific needs of parts for particular machines within a machine type are considered when the machines are finally allocated to the groups.

2. In the second stage, the part list and the information in the production route card are carefully checked to identify and ensure correctness of the essential information for analysis. The essential information for each part consists of the operation to be performed on it and the machines necessary to perform each operation.
3. The third stage, *factory flow analysis (FFP),* involves macro examination of the part flow through the machines. This allows the problem to be decomposed in to major machine-part groups. Although essential to the PFA process, these three stages are merely the necessary preliminaries to provide the required data for the ultimate purpose of the analysis-to determine appropriate machine-part sub grouping for cellular layouts.
4. The last stage, involving the problem of identification of machine cell part family, is the most difficult part of PFA. The difficulty comes from the amount of information that must be processed accurately to facilitate the information of manufacturing cells that is dedicated to specific part-family production.

A number of clustering methodologies have been used to tackle the machine-part analysis problem. A brief description of some methods is presented in the next section.

4.8. Clustering Methodologies

Clustering algorithms are broadly classified into the following five categories:

- Similarity-coefficient based methods,
- Graph theoretic methods,
- Mathematical programming methods,
- Artificial intelligence (AI) based methods, and,
- Matrix manipulation (Array based) methods.

These are considered in turn.

4.8.1. Similarity-Coefficient Based Methods

McAuley was probably the first author who applied similarity coefficients to solve cell formation problem. He used similarity coefficients to translate the incidence matrix to triangular machine-by-machine (M × M) similarity matrix. McAuley compared the similarity coefficients to a predetermined level to form machine cluster in his single-linkage cluster analysis. Seiffodini and Wolfe have used an average-linkage cluster analysis to construct the part families. Shafer and Rogers provided an overview of similarity and existence measures applicable to cellular manufacturing. They have also proposed a new similarity measure that is easy to calculate, intuitively appealing, and overcome the many existing similarity measures.

Single–Linkage Clustering Algorithm:

A similarity coefficient is calculated for each pair of machines to determine how "alike" two machines are in terms of:

1) The number of parts that visit both machines
2) The number of parts that visit each machine

Similarity coefficient

$$S_{ij} = \frac{a}{a+b+c}$$

Sij = similarity coefficient between machine i and j

Where: a = part visits both machines

b = part visits machine i

c = part visits machine j

d = part does not visit either machine

4.8.2. Graph Theoretic Methods

These methods treat the machines and parts as nodes, and the processing of the components as arcs connecting these nodes. The machine-part graph comes then. Rajagopalan and Barta have used graph theory to solve grouping problem. Tajinder have suggested a network approach to form manufacturing cells with minimal intercellular interactions is presented. *Commonly used* the *Graph-based clustring techniques are:* Hamiltonian path approach and Cut-node algorithm. They have used a modified Gomory-Hu algorithm to find a minimum intercellular interaction [47].

Gomory-Hu algorithm

The algorithm finds the minimal cuts between any pairs in graph. At the start the algorithm chooses two nodes and calculates the minimal cut between them and the min cut groups. These groups are being separating into two graphs and the algorithm remembers the minimal cut between them. Now in every iteration, the algorithm chooses two nodes from the same group and calculates the minimal cut between them, taking in account the other groups as a single dot (node), which the maximal flow to and from it (dot), is the maximal flow that was found in one of the previous iterations. At the end of the algorithm The Gomory - HU tree is built. That tree represents the maximal flow between all two pairs in the graph, which is the minimal edge capacity of the path between those to edges [47].

4.8.3. Mathematical Programming Methods

Recent advances in digital data collection and storage technology over the past decade have resulted in the growth of massive databases or data avalanches. Not only have these rapidly growing data avalanches occurred in everyday life, but they have also occurred in a variety of scientific and engineering research applications [46] as well as medical applications [51]. Research in finding meaningful patterns to make sense out of these massive data sets is often known as *Data Mining*. Data mining can be broadly defined as the analysis of large observational data sets to find hidden and unsuspected relationships and to summarize the data in novel ways that are both understandable and useful to the data owner [47]. The term data mining is also often known as knowledge discovery, which is referred to the process of extracting useful information from databases. Since data mining has to deal with data of massive size (curse dimensionality), most data mining tasks can naturally be optimized. Classification and clustering are the most critical tasks in data mining and are fundamentally optimization problems. Mathematical programming methodologies formalize the problem definition and make use of recent advances in optimization theory and applications for the efficient solution of the corresponding formulations. One of the major advantages of a formulation based on mathematical programming is the ease in incorporating explicit problem specific constraints. Mathematical programming approaches, particularly linear programming, have long been used in data mining tasks. The pioneering works in classification began in the 60's [49, 50] and the pioneering works in clustering began in the 70's [48].

The mathematical programming methods includes: Linear programming, Quadratic programming and Dynamic programming. Kusiac[48] has suggested the p-median model, an integer linear programming formulation, for the machine-cell or part-family formation problem. The modified model allows the control of the size of the machine cells or part families by introducing an upper bound on the maximum number of machines per cell or maximum number of parts per family. Choobineh [48] formulated an integer-programming (IP) problem which first determines part families and then assigns parts to cells with an objective of minimizing cost. Co and Aran[8] suggested a three-stage procedure to form cell and solved an assignment problem to group machines and components for cellular manufacturing system.

4.8.4. Artificial Intelligence (AI) Based Methods

A part family identification problem is based on the knowledge of manufacturing processing requirements. To perform this task, a knowledge-based expert system and the synthetic pattern recognition approach have been developed. The problem of AI based techniques is that they are not capable of generalization of a new input does not fall into the existing domain specific knowledge.

Artificial intelligence based models: Expert systems, neural networks, fuzzy logic, and pattern recognition. In the majority of these methods the machine-part incidence matrix is the main input.

Fuzzy clustering

Most of the clustering algorithms described above produce non-overlapping crisp clusters, meaning that a data point either belongs to a cluster or not. The issue of uncertainty support in clustering task leads to the introduction of algorithms that use fuzzy logic concepts in their procedure. Fuzzy clustering algorithms are partitioning methods that can be used to assign data points to their clusters. These algorithms can handle uncertainty in the data as they provide a degree of membership when associating a data point to a cluster. There are many fuzzy clustering methods being introduced [52]. The fuzzy *c*-means is the best known and most widely used algorithm [53].

Artificial neural networks

Artificial neural networks have emerged as viable methods for numerous applications in engineering [54]. They have been successfully used in both classification and clustering. Well-known examples of artificial neural networks used for clustering include self organizing map (SOM) [55] and adaptive resonance theory (ART) models [56].

One of the chief advantages of neural networks is their wide applicability; however, they also have two particular drawbacks. The first is the difficulty of obtaining suitable learning parameters. The second is the often time-consuming training required.

4.8.5. Matrix Manipulation (Array-Based) Methods

These methods rearrange the rows and columns of a matrix in order to bring the non-zero elements of the incidence matrix around the main diagonal. McCormick et al. have suggested the bond energy method. Askin and Subramanian have developed a clustering algorithm that considers the manufacturing cost such as machining cost, setup cost and material handling cost. The rank order clustering algorithm and its extension developed by King and Nakornchaim and the clustering identification algorithm developed by Kusiak and Chow is some examples in this category. Chan and Milner developed the direct clustering analysis algorithm, which was then corrected by Wemmerlöv [47].

Matrix manipulation methods have many advantages over the previous approaches as they avoid subjectivity involved in the similarity coefficient approaches and the complexity of set theoretic and integer programming approaches. Their popularity stems from these advantages as well as their computational simplicity. However, the array-based methods have the disadvantages of being dependent on the initial configuration of the zero-one matrix and not being able to provide disjoint part families and machine cells for ill structured matrix.

- **Rank-Order Clustering**

The steps required for developing the rank order clustering algorism are:

Step 1. Calculate total weight of each column, $Wj = \sum_{i} 2^{i} M_{ij}$

Step 2. Arrange columns by ascending weight, $Wi = \sum_{j} 2^{j} M_{ij}$

Step 3. Calculate total weight of each row,

Step 4. If rows are in ascending order by weight, STOP.

Else Arrange rows by ascending weight, GOTO Step 1.

- **The Direct Clustering Algorithm**

A problem with the rank-order clustering is that computation of weights can become problematic when the number of parts is large. For instance, if a shop has data for 2000 parts, then the weight factor for the rightmost column will be 2**2000, which is too large to compute directly! Even if we use indirect representations, we need 2000 bits to represent a weight of each row.

To avoid this problem, King and Nakornchai proposed the direct clustering algorithm, which is given as:

Step 1. Calculate weight of each row, $Wi = \sum_{j} M_{ij}$

Step 2. Sort rows in descending order $Wj = \sum_{i} M_{ij}$

Step 3. Calculate weight of each column,

Step 4. Sort columns in ascending order

Step 5. For i = 1 to n, move all columns j where Mij = 1,

to the right while maintaining the order of the previous rows.

Step 6. For j = m to 1, move all rows i, where Mij = 1, to the

top, maintaining the order of the previous columns.

Step 7. If current matrix = previous matrix, STOP;

Else go to Step 5.

4.9. Exceptional Parts and Bottleneck Machines

- The creation of independent machine cells is one of the important goals of cell design
- In practice, some parts need to be processed in more than one cell
- These parts are known as “exceptional” parts and the machines processing them are “bottleneck” machines
- The problem of exceptional elements can possibly be eliminated by:
  - Generating alternative plans
  - Duplication of machines
  - Subcontracting these operations

CHAPTER FIVE

DATA COLLECTION AND ITS ANALYSIS

5.1. Background of the Company

5.1.1. Introduction

Metal Product Development center is the government organization that design and Manufacture different moulds, cutting tools with conventional and modern machineries. It-re Organized in 2004 G.C Before that it was an Agency and it administers 16 governmental organizations in the country, which are Zuqualla steel Rolling Mill, Gafat Engineering Factory, Tatek Engineering Factory, Abay Technical service Enterprise, Akaki Spare Parts and Hand Tools Factory, Addis Mechanical Enterprise, Kolfe House hold utensils Factory, Ethiopian Plastic Factory, Addis Machine Tools Factory, Nazereth Tractor Assembly Factory, Nazereth Canvas sewing Factory, Kaliti Metal Products Factory, Addis car Battery Factory,Kotebe Metal Tools Factory, Ethiopian Iron and steel Foundary,Akaki Metal Products Factory.

5.1.2. Historical Back ground

The Metal Products Development Center is re-organized center accounted to the ministry Of Trade and Industry. To reach this level the organization Passes through three different stages. First it established in 1993 G.C. as engineering design and tool enterprise, and then it transfers in to Basic Metals and Engineering Industries Agency in the year 1997 G.C. after the combination of engineering industry commission and engineering design and tool. Finally it reaches the last stage of the organization, Metal Products development center, in the year 2004 G.C. Detail description of each stage with their Mission, establishment, objectives, and major activities are presented as bellow.

<u>Stage i:</u> Engineering Design and Tool Enterprise

− ***Establishment and Mission of EDTE***

The Ethiopian government and the united nation Development Program with UNIDO as Project executing agency established the EDTE Project in 1993. The Enterprise established by the Proclamation No 124/93 G.C in the Council of ministry,

− ***Objective of EDTE***

The general objective of the EDTE is this making sub-sector capable of designing and manufacturing machinery, equipment, tools and other material inputs for supply to the national economy and the international market, there by creating a favorable impact on growth and export earnings.

− ***Activity of EDTE***

The activity of EDTE includes

- Machinery, equipment design and Proto-type making.
- Equipment Pilot batch manufacturing.
- Tool (die, mould, jigs, and and fixture) design and making.
- Precision Parts and components manufacturing.
- On the job training.
- Tool testing.
- Engineering Product and manufacturing.
- Computer Services.

The major services of the EDTE can be classified under three main headings.

1. Engineering Design and Proto-types

Complete design files comprising market studies, design drawings and dated sheets, Operation and maintenance manual, tested and Proved Proto-types as well as well documented manufacturing methods for small lot mass Production with the required tooling. The Products will include agro-machines and equipment, Process equipment for Small-scale industries, construction equipment, etc….

2. Tool designs and tools

Complete design files for Product and tool designs, and the Production of Proved and tested tools for metal, plastic, rubber and tire, glass and leather industries. The type of tools will include moulds, Jigs and fixtures.

3. Training

The enterprise offers sound and task oriented technical training. The training Programs and designed a long term, short term and refresher Programs. Long term courses have been designed for trainees with diploma and/or degree in the area of mechanical engineering and who are already employed in metal working and engineering industries or services to Provide them with better technical Know-how and hands on experience so that they can Perform their engineering functions with a better quality, Productivity and efficiency.

The short-term courses are in the forms of seminars and lectures, supplemented by demonstration and audiovisuals on the carefully selected as per the need of trainees.

Refresher Programs are organized as and when local industries feel the need to upgrade the skill of their technicians to operate specific machines.

Stage ii: Basic Metal and Engineering Industries Agency (BMEIA)

- ***Formation***

Engineering design and Tool Enterprise dissolved by the Proclamation No 15/1997 and its right and obligation transfer to Basic metals and Engineering Industries Agency (BMEIA). The formation of BMEIA was the result of the combination of Engineering industry commission and Engineering design and tool. The BMEIA is established under Proclamation No 47/1996 to promote the basic metals and engineering industry and to make the sub-sector contribute to overall economic development. The BMEIA Was established as an autonomous Public organization having its own legal personality. The agency was accountable to the prime minister.

- ***Vision***

The agency aspired to be a center of excellence in research and development of the basic metals and engineering sub-sector.

– ***Mission***

BMEIA coordinates and provides new Products development; training consultancy, and information services that enable the sub sector produce globally competitive products.

– ***Objective***

The objective of the agency shall be to promote the basic metals and engineering industry and to make the sub sector contribute to overall economic development.

<u>Stage iii:</u> Metal products Development center

Metal Products Development Center is the last stage of the organization. It passes through different obstacles from its establishment to the present position. The change was based on the different activities that are performed by the agency. These activities are distributed in to different organizations that perform similar activity. So, the center is forced to perform only activities, which are Product development, training Programs in different engineering areas and advisory services in the field.

– ***Establishment***

The Previous Basic metal Engineering Industry agency rights and obligations transferred to ministry of Trade and Industry by the Proclamation no 411/2004 G.C and the organization becomes under the ministry of Trade and Industry and named Metal Products Development center.

– ***Mission***

The mission of the center is 'Giving Priority to the Production of capable and competitive manufacturing products for industry and rural development program, training Programs and giving advisory services.

- ***Objectives***

- New Product development depending on market study.
- Develop the Knowledge to design and manufacture technologies for small industries and also for rural development.

– ***Major activities of the center***

The following are major activities of the center:

1. Product development

Product development is the discovery of a new product or producing an existing product in new area or to a new customer and if the product is accepted by the customers, producing it in large quantity. It's supported by market study and marketing research.

2. Process of Product development

The new product development process is called integrated product development. The Process includes the following steps.

I. Idea generation

II. Market study

III. Putting alternatives

IV. Designing the product

V. Evaluating the designs

VI. Producing sample product based on the design

VII. Evaluating samples technically and putting them in the market

VIII. If the market, producing them in large quantity, accepts the products.

3. Training Product development

- This training includes all the steps of product development and it's given to different branches of manufacturing industries.
- Training on designing and marketing consists of the activities of the activities to translate the designed product in to a real product.
- Generally, the organizational structure of the center is presented as.

5.1.3. Location

MPDC located in the capital city of the country, Addis Ababa, around Gerji area with specific address: bole sub city, kebele 11.

5.1.4. Production Overview

Currently, as already stated in the company objective section, the company produces machinery and equipment, tools and dies, and different engineering designs. It has two design rooms for designing purpose and two workshops (one for equipment and

machineries; one for tools and dies). But actually equipment section also uses to produce tools and dies, and the reverse is also true. Both, equipment and tool workshops, have the same size, it covers 924 square meter floor area each.
It has a total staff of 136 persons on 1999 E.C. (90 persons on 2002), out of this it has 9 designers, 42 production staffs in the year 1999 E.C (9 designers and 28 production staffs on 2002).

5.1.5. Major Customers of the Company

The major customers of the company are:

- Textile and Apparel industries;
- Leather and Leather products industries;
- Horticultural industries; and
- Small and medium scale enterprises.

Customers with second priority from the above are:

- Other private and governmental enterprises, which produces for local consumption.

5.2. Data Collected for Analysis

After defining the scope of the study, the data collection was carried out in collaboration with the concerned personnel of the design, marketing, and production section. As a matter of fact, to make this study complete and meaningful of its contribution for the success of the study, and other researchers' further analysis, the data collected here should be true and relevant with the objective of the study. Thus the researcher uses different methodologies to collect the relevant and important data for the study. The methodologies used during collection process includes: direct visiting of the target company, using oral discussions with the employees at designs, marketing, and production departments, and gathering information from the soft and hard copy files available in the company - these includes magazines, broachers, drawings both in soft copy and hard copy, and others. Since most of the data's collected are found in hard copy form, thus it was necessary to change it to soft copy so that it will be easy for manipulating and presenting in a suitable way that could support the study. The data collection process had taken more than two and half months.

The relevant data and information collected includes: the available facilities in both equipment, and tools and die production workshops, three years drawings with amount of delays in due dates, selected sample representative parts (from 1998 – 2000 E.C.), the detail process flow of the selected sample representatives, major customer complaints, the existing facility layout, cost estimation method for parts production, etc.

The collected data is presented as follows:

- **Available Facilities (equipments) of the Company:** it has two separate workshops; by name equipment and tools and dies workshops. As the name indicates equipment workshop designed to produce different parts of industrial equipments; and tools and dies workshop designed to produce different tools and dies. But it does not mean they are independent each other, rather they share different machines during production of parts. The available facilities in each workshop are presented in appendix F.

- **Parts/Drawings Data**

Here a total of three hundred forty one components data from the past three years had been considered for the analysis of company's product types and for the determination of approximate percentage delay of designing job. It presented in the table below. Some of the drawings which are collected in soft copy form are presented at the appendix E.

Table 5.1.Drawings data considered

No.	Year	Drawings under equipments section	Drawings under tools and dies section	Total Drawings	App. total No. of Drawings completed below estimated time (%)	App. Total No. of Drawings completed over the estimated Time (%)	App. Total No. of Drawings completed exactly at Estimated Time (%)
1	1998 E.C.	45	41	86	26.67	59.21	14.22
2	1999 E.C.	79	41	120	35.39	42.18	22.43
3	2000 E.C.	78	57	135	29.15	50.73	20.12
			Total	341	30.07	52.01	17.92

- **Sample parts/drawings**

Sample representative parts that are considered for the analysis in the formation of machine cells had been selected and the result data were presented in appendix F in a tabular form.

- **The Existing Facility Layout of Equipment and Tools Workshops**

The existing production area layout of the company workshops has collected from a hard copy of the workshops floor plan that has done for machines electrical designing job with the necessary changes and modifications that has done based on the existing physical production area layout and additional machines added. Then the data had been changed to soft copy with the help of AutoCAD software and presented in Appendix D.

- **Major Complaints of Customers**

Although the factory have no experience on registering the customer feed back and complaint, as the result of the guided interview for the marketing manager the major customer complaints are;

- Delay in delivery date,
- Low product quality and
- High product price;

As the result found from the marketing manger, long delivery date and high product price covers the large portion of the reason for complaints. The information from the same source shows that there is a variation on the cost estimation result of the same product; the major reason for this is the problem on the accuracy of the input data for product cost estimation. The result of the estimation is exaggerated in some cases and it increases customers complain for high price and reduce demand.

- **Cost Estimation and Production Scheduling Method Used**

Currently the company doesn't have a data base system that can use for the next desired and any written form of production scheduling system. One of the reasons for scheduling problem is the range of variation of products produced in the company. Due to this, in the manufacturing area, it is common for parts to wait for long time while there are idle machines; thus it reduces efficiency of production.

The marketing department makes products price estimation job when new orders arrive based on the data provided by designing and production departments. They provide data on types of material required, estimated time required for designing a component, and operation time required on each machines. Out of this designing department provides the types of material and estimated designing time required for each part. And production department provide information on the types of operations and operations time required for the production of each component.

- **Design Time Range**

The information gained from the designing department shows that the minimum time required for the design of a single product is three hours and the maximum time required is two months. This data collected from the company designers past experience.

- **Major Operation Types with the corresponding machine requirements:** common operations done in the organization during production processes and corresponding required machines data had attached in appendix F.

5.3. Data Analysis

The major problems of the Metal products development center from the data on customer complaints are high product price, long delivery date, and low product quality. But for every problem there are different possible causes; and it is important to identify each of them. Thus this section discuss on identification of these causes and proposing the possible solution to address them.

The major identified causes are:

Problems	Major causes
Long delivery date	Type of method used in the design process
	Lack/difficulty of Scheduling
	High non-value added movements

	High setup time due to repeated change over of Tools and fixtures during production
High price	Long delivery date
	Inaccuracy of cost estimation method
	Manufacturing method itself
Quality (failure from meeting the required specification)	Size of product variety
	Machines are too old

Further discussion on each causes and proposing possible solutions for the causes had presented as follows.

Long delivery date:

- The type of method uses in the design process: - currently in the company designing of components makes from scratch for each part, since there is no any means of retrieval system. Most of past drawings data are stored in a hard copy form and even for those data, which are stored in a soft copy, there is no means that helps to facilitate the designing process. But in this globalization era, to be competent, it is important for companies to look for all the possible area of improvements. For companies like Metal products development center, which produces a range of products, this area (design section) is one of the right places to minimize the time of production.
- The scheduling problem: - as the data collected indicates there is long waiting time in the workshops of the company, while there are unreasonable idle machines. But through proper scheduling, it is possible to reduce the waiting time by increasing machines utilization through the right assignment of task on each machine at the right time. Thus, it is important to simplify the scheduling process of Metal products development center so that the production planning and control section can schedule each jobs on each machine properly without much complexity.
- The presence of non-value added movements, like unnecessary material handling distance due the arrangement problem of machines. Since in the Metal products development center the machines are not arranged based on the production flow as

shown in Appendix D, it increases the material handling of parts in the workshop. Then the time spent for unnecessary material handling increases manufacturing lead time. Thus improving the layout of machines can use to reduce the material handling.

- High set up time due to repeated changeover of tools and fixtures during production: - since in the company parts are treated individually and use part tooling, this increases the setup time. But it is possible to reduce setup times by using group tooling (cutting tools, jigs, and fixtures) that have been designed to process the part family, rather than part tooling, which is designed for an individual part. This reduces the number of individual tools required as well as the time to change tooling between parts. Thus it is one of the potential areas for reducing the delivery date of Metal products development center.

High price of products:

- Long delivery date: - longer lead time of manufacturing increases the cost of production of a part than the one produced in shorter time without the need for a considerable additional investment on machines and automation. Thus reducing manufacturing lead time of Metal products development center only by changing the manufacturing philosophy, not change on basic resource types, can reduce the cost of production. Thus reducing the delivery date by solving the above mentioned causes for long delivery date will also reduces the cost of production. And again it reduces the price of final products.
- Problem on cost estimation method: - as the data indicates the current product price estimation method use in the company results variation from the actual one. In most cases it exaggerates the price due to the inaccuracy and variation of input data that use for the cost estimation. The result of the mistakenly exaggerated price of products puts on the customers, thus it causes for customer complaints on price.

  The data of table 5.3 shows that, out of 341 drawings, about 30.07% of the drawing has been completed before the expected design accomplishing time. Where as 17.92% of the drawings has been finished almost at the planned estimated time. And the rest 50.71% of the drawings takes extra time than expected. This shows that there is a deviation on the actual finishing time of designing job from the initially estimated time.

- Manufacturing method: - for companies like Metal products development center, which produces a range of variety products, using group technology based manufacturing method increases efficiency of production, as stated in section 2.2, than producing by using job shop type manufacturing philosophy. Thus by increasing the efficiency of manufacturing system of the company, it is possible to reduce the cost of production.

Finally, *product quality problem:*

- Products variety: - Since the Metal products development center produces a large variety of tools, spares, and equipments; it does not let specialization of machines, tools, and fixtures. Thus it increases the probability of variation from specification than the machine cell that specialize in producing a smaller number of varieties. So forming a cell that is dedicated to produce a smaller number of varieties in the Metal products development center workshop results better specialization with less variation (better quality).
- Machines are too old: - almost all machines which are available in the company has used for more than sixteen years. And it increases the variation on processes.

In summary, it is possible to point out different important conclusions from the data collected in the data collection phase. Some of these are:

- The company major problems are long delivery date and high price of product. And, low product quality is another problem next to them in magnitude.
- The company has no proper scheduling system due to the complexity of scheduling process in a manufacturing system in which machines are not arranged based on the process flow as shown in Appendix D, for a large number of varieties of products.
- There is high variation on product cost estimation result; and in most of the cases it is exaggerated.
- Machines arrangements are not based on the parts processes flow required.
- There is no retrieval system for designing job and other related purposes.

- Company engages in the production of products with both circular and prismatic shapes.

After analyzing the root cause problems of the company, it is important to find a solution that could address them. There may be different tools and philosophies that use to address the above cause factors of the final effects, i.e., long delivery date, high product price, and low product quality, but the researcher chose to use a group technology manufacturing philosophy for the following reasons:

- To address most of the above stated cause factors effectively at a time.
- Its effect in design process improvements requirements.
- To gain the benefits that could be gain from line type production system in a job shop production. It includes reduction of material handling distance, set up time, simplify scheduling, and specialization.
- It simplifies production scheduling: the similarity among parts in the family reduces the complexity of production scheduling. Instead of scheduling parts through a sequence of machines in a process type shop layout, the parts can simply scheduled through the cell.
- To reduce material handling: clustering all the machines required to produce a part in to close proximity (or forming cell) with an arrangement made based on the production flow requirements of parts reduces the material handling distance of parts during production.
- Its capacity to address designing and manufacturing areas of production, while providing information system for different section of the industry.
- To shorten manufacturing lead times, by reducing setup, work part handling, waiting times, and batch sizes.
- To form a machine cells that specializes in producing a smaller number of parts in order to reduce process variation (to improve quality).
- It is a modern technology in its kind; and the feasibility of it to apply for the case company.
- To develop a data management system that helps during product cost estimation and uses for files storage in a form that is easy to use for future purposes; and
- Others.

As the above section (i.e. reasons for proposing GT manufacturing philosophy as a solution) indicates, it is important: to form part families and associated machine groupings, and to develop retrieval and data management system in order to gain all the above stated benefits of GT through addressing the company problems. As section 2.5.1 indicates there are three stand alone methods for GT implementation, but the researcher proposes and uses coding and classification system in conjunction with PFA method for the solution. In this study, parts coding and classification system used for retrieval and data management system requirement of the company, while PFA method used for the formation of part family with the associated machine cells.

- ***Reasons for the choice of parts CCS method for retrieval and data management system development over PFA method*** :

Before comparing the two methods it is important to check company requirements according to the need for using CCS system. As section 3.6 indicates one of the reasons for using a coding scheme is the requirement of a retrieval system, thus it is feasible to use it for Metal products development center.

Now we shall compare the two methods: - In parts classification and coding system, similarities among parts are identified, and these similarities are related in a coding system. It uses both design and manufacturing attributes. But PFA is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather than on part drawings. Since PFA uses manufacturing data rather than design data to identify part families, it has drawbacks on meeting the objective of design retrieval system, which is to use the past drawing data so as to reduce the time required for designing of new pars. First, parts whose basic geometries are quite different may nevertheless require similar or even identical process routings. Second parts whose geometries are quite similar may nevertheless require process routings that are quite different. Thus developing a design retrieval system based on only process routing reduces the effectiveness of the system.

In addition, it is common and easy to find examples on coding scheme development that has done based on CCS, from different sources. Thus using CCS method for the development of retrieval system simplifies the task while meeting the objective of the study.

- Reasons for choosing PFA method for machine cell formation, in this study, over CCS method presented in the introduction part of chapter 7.

This implies using the two methods simultaneously for this study makes the study more effective both in time and target achievements.

In summary, the researcher uses this modern type of manufacturing philosophy through:

i. ***The development of GT based coding and classification system:*** to improve the designing process; to provide more accurate, fast, and relatively standardized input data for the required information for the cost estimation process; to provide data management system that also uses for the retrieval and for analysis of parts in order to use the similarity advantages of parts both in designing and manufacturing; to provide the input system for the development of computer based planning and control system; to generate data for calculating the standard time of operations that that uses as a base for planning and production control; for better communication system between departments; for parts standardization; and others.

ii. ***The formation of machine cells/manufacturing cell with PFA method:*** It is designed: to reduce the material handling and machines set up time; to gain the advantage of line type manufacturing system; to simplify production controlling and scheduling job through the formation of machine cells; to reduce the variation in the quality of the product through standardization of tools, through increasing the chance of workers specialization on the manufacturing process of parts, and through better employees satisfaction; and others.

Thus the next two chapters of the study present the development of the proposed coding and classification system and formulation of machine cells respectively for the target company.

CHAPTER SIX

DESIGN OF THE PROPOSED CODING AND CLASSIFICATION SYSTEM

6.1. Introduction

As a matter of fact, even if Metal products development center produces tools and dies, it also produces machines and equipments when there is a special demand for them. Thus the designed coding and classification system, in this section, should also take machines and equipments in to account. The common and simplest way for considering machine and equipment products of the company during the development of coding and classification system is to consider them in terms of their components. Since any machines and equipments are done with assembling all the required components for the particular product, thus through considering and encompassing its components it is possible to earn the benefits of coding and classification system for the machines and equipments produced in the company. Thus the designed CC system for the company had considered assembled parts too.

The designed GT based classification and coding scheme for parts produced in Metal products development center has presented throughout this chapter. And, the researcher had used the following steps to develop the coding and classification system:

1. Coding and classification objectives are stated; it is to address the problem of the company as presented in the data analysis part of the study.
2. Decide major group of part families: After analyzing the three years order data with the help of available drawings and physical products, and help from design and marketing departments of the company, the researcher set rotational and non-rotational parts as a basic group of parts for the company for this coding and classification.
3. Decide major attributes that are important to address the company's problems, and then set attributes and attribute values.
4. Decide type of coding whether numeric, alpha, or alphanumeric, and assign code.

5. Designing code analysis.
6. Modification or review has made.
7. Final code has developed, and
8. Appropriate data base has made based on objective of coding and classification requirements for the Metal products development center.
9. A model has developed based on the code scheme developed.
10. Finally, a computer program has developed for the model.

The detail formulation on the steps, i.e. from step three to eight, is provided in the following sections.

6.2. Code Structure

The hybrid code structure was selected to facilitate the design of a coding scheme so that the scheme would be efficient in length, efficiently store and retrieve the component's classification code and descriptions, and allow for the coding of a broad spectrum of components existing in Metal products development center. The proposed code is alpha - numeric in nature. Thus this code structure could offers 36 different descriptions per digit.

The hybrid code structure selected and designed here, is similar to Optiz coding with some modification based on the requirements for Metal products development center coding system. the reasons for Optiz coding structure to be selected as a base for the coding system of Metal products development center are: it helps to describes different attributes of components of a company in a short and all engulf way, again since the coding structure of Optiz is designed for manufacturing company with diverse variety thus it has direct relevance and positive and supportive impact to the case company; it is well organized in expressing different attributes of parts with more precise way; and the researcher from his knowledge point of view believes that there is no reason for not taking it as a base for coding of case company parts.

6.2. Code Attribute

The length of the code will depend upon the number of attributes which are vital to the component description. The following attributes were determined to be important in the description of Metal products development center products and product components, and to meet the objectives of the code development for the company. It determined through interviews, analysis of data obtained, and reviews of previously done researches for manufacturing industries, and relevant books. The major code attribute titles chosen are:

1. Part shape class
2. Basic external shape.
3. Basic internal/rotational shape: This digit applies to basic internal shape features (e.g. holes, threads) on rotational parts and general rotational shape features for non-rotational parts.
4. Plane surface: (eg. flats, slots).
5. Hole type.
6. Gear type and forming.
7. Shape of raw material.
8. Type of raw material.
9. Dimensional and geometric tolerances.
10. Surface finish.
11. Estimated time required for design.
12. Production flow and processes time.

But estimated design time, process flow and processing time are included in the coding structure more of for the purpose of managing data of the company for the cost estimation, production scheduling, process standardization, and other requirements.

6.3. The proposed classification and coding scheme

The actual coding table can be seen in tables 6.1 through 6.5. These tables are appearing in the order defined in relationship between components. Table 6.1 shows the parts overall shape class, whether rotational or non rotational part it is. The rotational parts are classified by length-to-diameter ratio; and non-rotational parts by length, width and thickness dimensional ratio.

Table.6.1. Overall shape of the component (Aspect ratio)

Digit 1

Assigned code digit	Description	
0	Rotational	$L/D \leq 0.5$
1		$0.5 < L/D < 3$
2		$L/D \geq 3$
3		Special
4	Non Rotational (Prismatic)	$A/B \leq 3$, $A/C \geq 4$
5		$A/B > 3$
6		$A/B \leq 3$, $A/C < 4$
7		Special

It gives a basic category for the code and represent the first digit of the Group Technology based coding structure for Metal products development center (GTCSPDC). This digit value determines the length of code structure and the interpretation of the next digits. The rotational parts digit 1 takes a value from 0-3 and the non-rotational parts first digit takes a code value of 4 to 7; thus based on this code value the next digit interpretation differs. That mean, Digit 1 is the beginning of the hierarchical code. Any digit beyond digit 1 linked hierarchically to digit 1 and must contain information about what digit 1 is in order to mean any thing at all till the point at which poly code structure (independent of the beginning digits point reaches; it is digit 8 for rotational and digit 6 for non-rotational parts).

Table 6.2 shows a form code of a rotational part which describes the digits 2 to 7 of GTCSPDC for rotational parts. It uses to identify the primary design attributes of the part.

Table 6.3 shows a form code description for Non-rotational parts. It provides different option to describe the prismatic products design attributes produced in the company. The corresponding code assigned for each attributes is presented in a column wise of the table.

Table.6.2 Form code - the primary design attributes of the part with assigned code digits, from 2nd to 7th, for rotational parts.

	Digit 2 and 3 Basic External Shape					Digit 4 Internal shape		Digit 5 Plane surface machining			Digit 6 Hole type		Digit 7 Gear type
Codes	0	1	2	3	Description:	Codes	Description:	Codes	Description:	Codes	Description:	Codes	Description:
	One Diameter, Include Tapered	Stepped to one end	Stepped both end (Multiple increase)	Others									
0					No machining	0	Solid	0	No plane surface machining	0	None	0	None
1					Smooth and no shape element	1	With hole; smooth	1	External plane surface and/or surface curved in one direction	1	Axial blind holes	1	External and/or intrnal spur gear
2					Thread	2	Thread	2	External groove and/or slot	2	Axial through holes	2	External and/or in-trnal helical gear
3					Functional groove and/or functional taper (and thread)	3	Functional taper and/or groove, keyways, (and screw thread)	3	External plane surface related one another with a pitch	3	Cross blind holes	3	External and or internal bevel gear
4					Knurl	4	Functional cone	4	External spline	4	Cross through holes	4	Worm gear
5					Functional cone	5	Spline (polygon)	5	Internal plane surface and/or groove	5	Axial and cross through and/or blind holes	5	Sprocket
6					Spline (polygon) and/or thread	6	Any combination of the above	6	Internal spline	6	One or both side stepped axial through and/or blind holes	6	Rack gear
7					Any combination of the above	7	Others	7	Any combination of the above	7	One or both side stepped cross through and/or blind holes	7	Two or similar gears on one shaft
8					Others			8	Others	8	Combination of two or more type	8	Other type gear teeth
										9	Special type hole		

Table.6.3 Form code of GTCSPDC; the primary design attributes of the part with assigned code digits, from digit 2nd to 5th, for Non-rotational parts.

Digit 2 Over all shape				**Digit 3 Rotational machining**		**Digit 4 Plane surface machining**		**Digit 5 Auxiliary hole, forming, gear teeth**			
	Description:				Description:		Description:		Description:		
0	Block or block like components		Rectangular prism	0	No rotational machining or bores	0	No surface machining	0	No auxiliary hole, gear teeth, and forming		
1			Rectangular with deviation (right and/or tri angle)	1	One principal bore, smooth	1	Functional chamfers	1	No gear teeth, no forming		Holes dilled in one direction only
2			Compound of rectangular prism	2	One principal bore stepped to one or both ends	2	One plane surface	2			Holes drilled in more than one direction
3			Components with a mounting or locating surface and principal bore	3	One principal bore with shape element	3	Stepped plane surface	3		Related by a drilling pattern	Holes dilled in one direction only
4			Components with a mounting or locating surface, principal bore with dividing surface	4	Two principal bores parallel	4	Stepped plane surface of right angles inclined ane/or opposite	4			Holes drilled in more than one direction
5			Component other than 0 to 4	5	Several principal bores parallel	5	Groove and/or slot	5	Forming, no gear teeth		Formed no auxiliary holes
6	Box and box like components	Not-split	Approximate or compounded of rectangular prisms	6	Several principal bores other than parallel	6	Groove and/or slot and 4	6			Formed with auxiliary holes
7			Components other than 6	7	Machined annular surfaces, annular grooves	7	Curved surface	7	Gear teeth, no auxiliary holes		
8		Split	Approximate or compounded of rectangular prisms	8	Complicated internal shapes	8	Guide surface	8	Gear teeth wit auxiliary holes		
9			Components other than 8	9	Combination of two or more types	9	Others	9	Others		
A	Complicated external shapes			A	Others						
B	Others										

The next table, i.e. table 6.4 provides supplementary information of parts like type and form of material, the required tolerance and finishing of parts.

Table 6.4 Supplementary codes of GTCSPDC

Type of raw material **Digit 8 (If digit 1= 0 to 3)** **Digit 6 (if digit 1= 4 to 8)**		**Shape of raw material** **Digit 9 (If digit 1= 0 to 3)** **Digit 7 (if digit 1= 4 to 8)**		**Dimensional tolerance** **Digit 9 (If digit 1= 0 to 3)** **Digit 7 (if digit 1= 4 to 8)**		**Surface finish (Accuracy)** **Digit 11 (If digit 1=0 to 3)** **Digit 8 (if digit 1= 4 to 8)**	
Code	Description:	Code	Description:	Code	Description:	Code	Description:
0	Milled Steel	0	Round bar	0	Free	0	Free
1	Alloy Steel	1	Rectangular bar	1	± 0.1	1	≤ 0.01μ
2	Carbon Steel	2	Plate	2	± 0.01	2	0.01 - 0.2μ
3	Cast iron	3	Sheet metal	3	± 0.001	3	0.2 - 0.6 μ
4	Copper	4	RHS/SHS	4	< 0.001	4	0.6 - 0.8 μ
5	Aluminum	5	Wire			5	0.8 - 0.12 μ
6	C-10, …,C-50	6	Flat			6	0.12 - 0.16 μ
7	Bronze	7	Other type			7	0.16 - 0.18 μ
8	Plastic, Rubber					8	0.18 - 0.28 μ
9	Other type					9	0.28 - 0.32 μ
						A	≥ 0.32 μ

Table 6.5 and 6.6 of the code shows secondary codes of GTCSPDC. It designed to address the company problems on time and cost estimation through providing a database for design and operation time of particular products. Again it provides a time data base for production scheduling. Generally it helps the company to have a well organized data management system especially for designing, marketing, and production sections. In table 6.5 the estimated time required for designing is presented and coded; this information on designing time will acquire from designing department of the company. The minimum value of the designing time is considered as 3 hour and the maximum time required for the designing assumed as two months, but still a space for longer design time requirement also left to increase the flexibility. This designing time range decided and formulated based on the data found from designing section of Metal products development center.

Table 6.5 Secondary codes - Estimated time required for designing a part

Estimated designing time Digit 12 (If digit 1= 0 to 3) Digit 10 (If digit 1 = 4 to 7)				
Description (in hours and days):				
3 hour	3 days	19 days	35 days	51 days
4 hour	4 days	20 days	36 days	52 days
5 hour	5 days	21 days	37 days	53 days
6 hour	6 days	22 days	38 days	54 days
7 hour	7 days	23 days	39 days	55 days
8 hour	8 days	24 days	40 days	56 days
9 hour	9 days	25 days	41 days	57 days
10 hour	10 days	26 days	42 days	58 days
11 hour	11 days	27 days	43 days	59 days
12 hour	12 days	28 days	44 days	60 days
13 hour	13 days	29 days	45 days	≥ 60 days
14 hour	14 days	30 days	46 days	
15 hour	15 days	31 days	47 days	
16 hour	16 days	32 days	48 days	
18 hours	17 days	33 days	49 days	
2 1/2 days	18 days	34 days	50 days	

Note: Hours represents working hours only, i.e. 8 hours per a day.

The needs for including design time data in coding scheme are:

- To simplify and increase accuracy of the drafting time estimation job of the drafts man by providing the past actual designing time data of parts as a base for the next use. Currently the drafts men's makes estimation on design time of parts just based on their experience based knowledge. But it is clear that to use the past real drafting time of parts in addition to knowledge base results more close time to actual design time requirement. As a matter of fact the newly ordered component may not be exactly identical with the past drawing; and again design time estimated by different drafts men may give different result, but still using the past actual time data in addition to the knowledge base gives better result. Especially for newly employed drafts man, including this attribute in a coding scheme has a more valuable advantage.
- To provide a better means of communication between design and marketing departments through providing a database system. It provides data on drafting time of parts, in addition to the type of material required, to the marketing department.
- It reduces paper work that was required during communication of the two departments, while making price estimation of products.

Table.6.6 Secondary codes - Operation types and time required for each

Operation Type and Required Time (The required time will be added by the user)		
	Description:	
	Operation type	Required time
Digit 13 and on wards (If digit 1 equals from 0 to 3), or Digit 11 and on wards (If digit 1 equals from 4 to 7)	Facing	
	Turning	
	Chamfering	
	Drilling	
	Treading	
	Grooving	
	Heat treatment	
	Grinding, surface	
	Boring	
	Milling keyway	
	Worm thread cutting	
	mill the flat surface	
	Lapping	
	Grinding, cylindrical	
	Forming	
	Slotting	
	Rolling	
	Sawing	
	Hobbing, teeth	
	Shaping, teeth	
	Shearing	
	Inspection	
	Other type	

The same is true for attribute in table 6.6., but the target departments for communication are production and marketing; and operation time data stored use for production planning and control section of production.

In the last table, table 6.6, the operation required for parts to be produced and time required for each operations for each part production being coded and stored in the data base of CCS.

Since the operation time for each component is varying based on the type of component being produced, thus this data should be filled or acquired by the production department while manufacturing of each components. Acquiring this data based on the real time taken for the operation has the advantage of providing more realistic information for the estimation that will be done based on it. Further it helps in determining the standard time for similar products. Then this standard time will use as a base for production scheduling and cost estimation; again improves the delivery time estimation for products. The same is true for designing time that will be filled by the designing department at the designing process.

One thing different here in table 6.5 and 6.6 is that codes are not assigned to each digits rather the corresponding values itself are assigned as a value of digits.

6.4. Computer System Development

6.4.1. Model Development

The system designed for the GT based classification and coding scheme developed for Metal products development center product components, consists of four modules. Each module is dependent upon three of the remaining modules so that it may be executed most efficiently. Though there is dependency among the modules, still independence is achieved, because each module can be changed individually. The four modules are shown and defined below and are discussed in the succeeding section.

1. **Main menu:** This module displays all the possible choices to the user and prompts for a selection.
2. **Add a component:** this module allows the user to add or edit a component of a building, and adds to or modifies the databases of relevance. It is shown in figure 6.1. The detail program algorithm structure, which is part of adding module has presented in annex part of the study.
3. **Retrieve a component:** this module permits the user to retrieve and edit or just glance at a component or part. It shown in figure 6.2.
4. **Utilities:** this module aids the user in maintaining the database and using system utilities. For example, deleting a record, printing records, exiting to window, etc.

After developing a model a detail program algorithm that helps in computer programming has formed and presented in appendix part of the study (Appendix A).

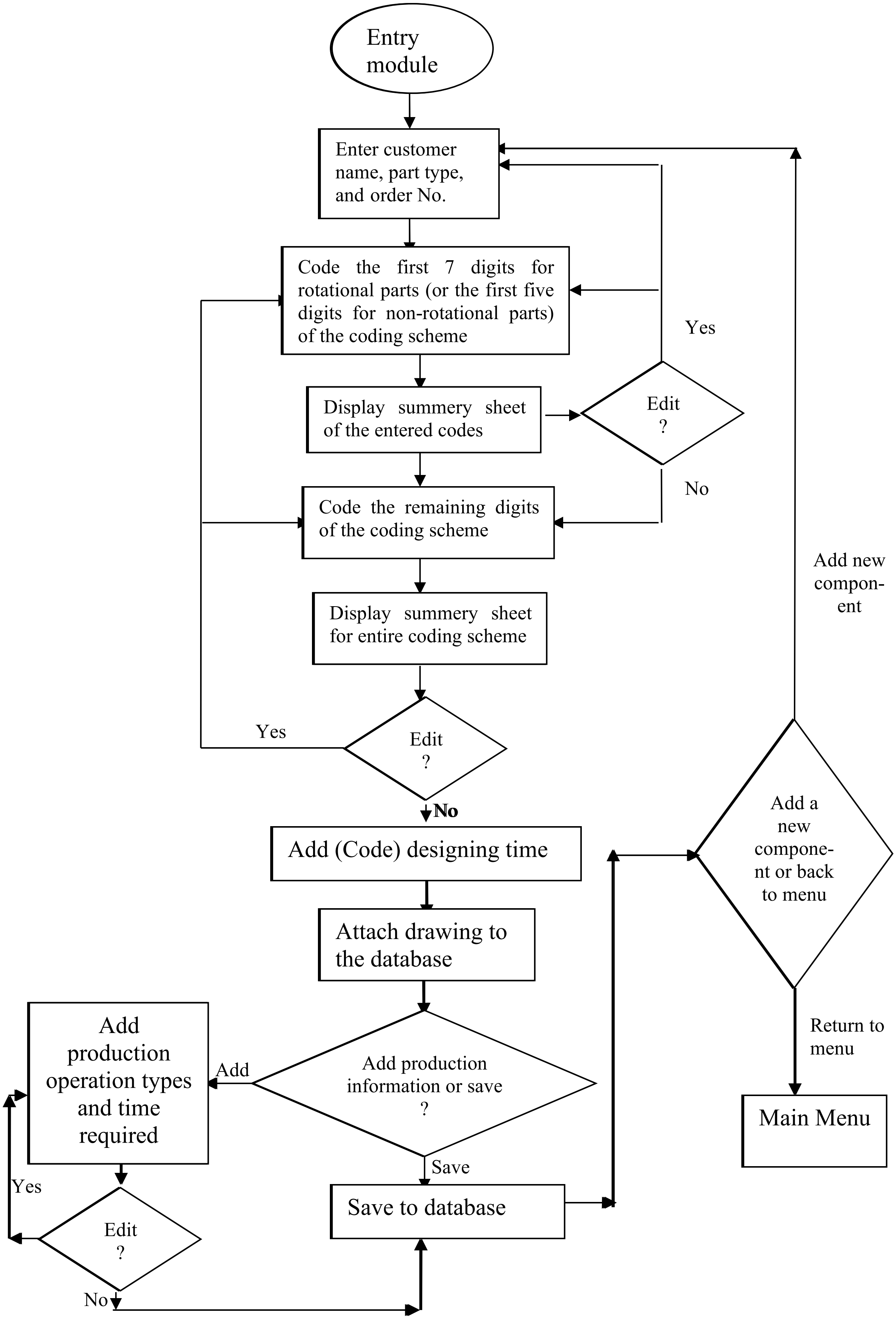


Figure: 6.1. Adding module for component to the GTCCSPDCI

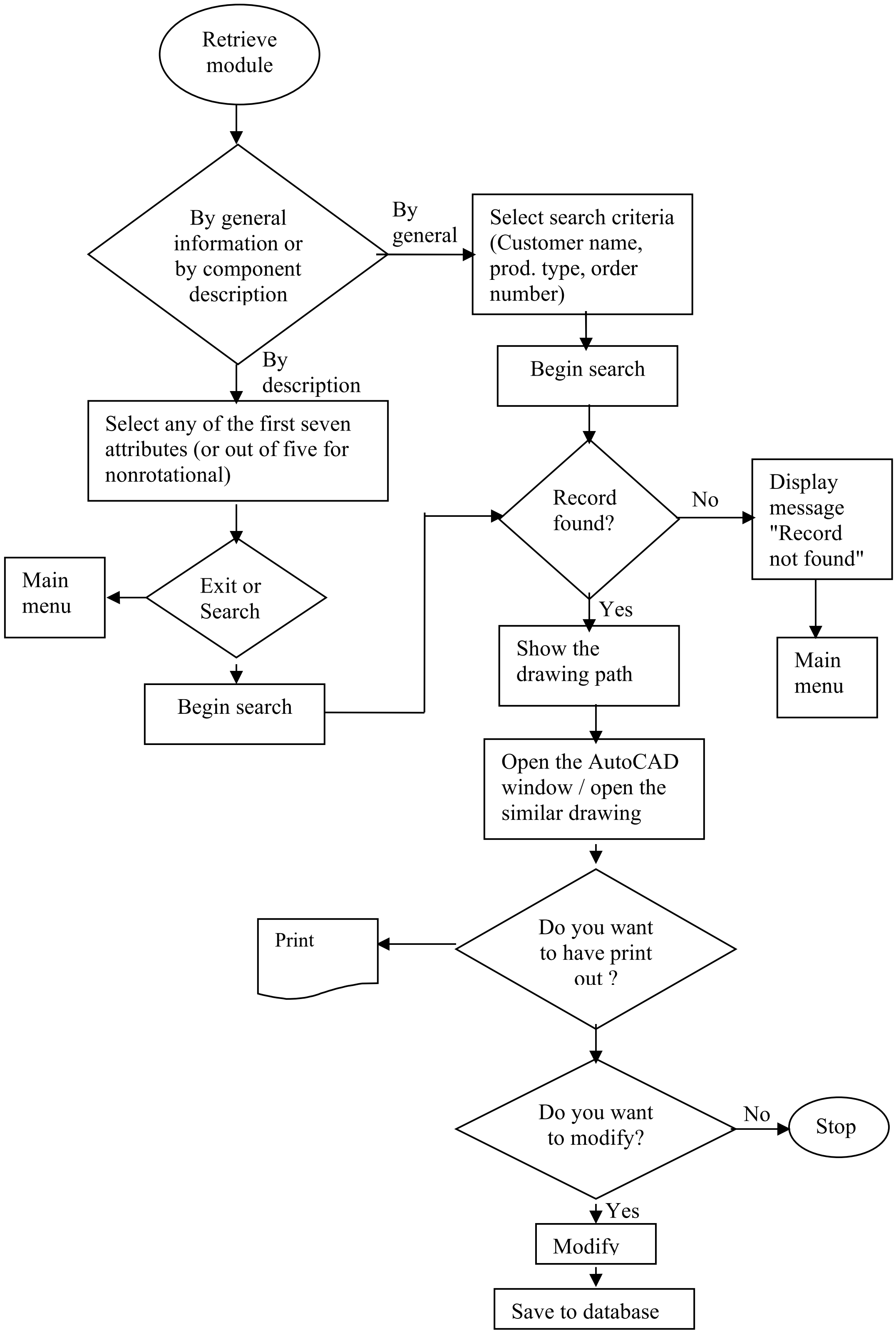


Figure: 6.2. Retrieval Module: from GTCCSPDCI Database

6.4.2. Programming

In this section, the computer program for the developed coding scheme had developed with the help of Visual Basic 6 and Access Software. It had done based on the model structures and algorithm of the program designed in the previous section. It had done with a user friendly form so that it can be used by wide range of users.

Selection of the correct programming language is pertinent to the outcome of any computer system. One of the main reasons to use VB-6 is, it is object oriented type with ease to use with required speed and flexibility for the designing. The programming code with the corresponding interface is presented in Appendix B.

6.5. A Feasibility of the Designed Classification and Coding Scheme

The designed GTCSPDC scheme meets the requirements described in literature part. The fulfillment of these requirements is shown below:

1. All Embracing: - the designed GTCSPDC encompasses all components that it was deigned to encompass, that is products produced in the Metal products development center - both rotational and prismatic (Non-rotational parts). The hybrid structure allows the scheme to accept new items.
2. Mutually Exclusive: - GTCSPDC is mutually exclusive based upon the particular component type. Each component has its own characteristics independent of another component type.
3. Based on permanent characteristics: - GTCSPDC scheme has done based upon the physical and geometrical characteristics of the components in the company. Since these components represent the end product, thus it can be said that these attributes are easily confined permanent and unchanging characteristics.
4. Specific to user needs: - GTCSPDC was designed to create a GT based data management system and produce feedback to the designers, estimators, and planners to facilitate the designing, cost estimation of products being produced, production scheduling and standardization, and better resource utilization for the company. Thus it designed based on specific need of the company.

5. Adaptable to future changes: - GTCSPDC uses alpha-numeric method of coding and allows each digit to have 36 possibilities, therefore leaving room for future expansion. Again the flexibility in the time estimations on designing and production operation leaves space for changes till it reaches to standardization.
6. Adaptable to computer processing: - the coding tables provided in tables 6.1 to 6.5 allows for manual coding of a component. But it is tedious to do it for many parts and retrieving it. Hence implementation of a computer based system is possible and presented in the next section.
7. Company - wide application: - the GTCSPDC supports the needs of the designer, planner, and estimator. It attempts at incorporating different applications of manufacturing company in to one coding scheme.

6.6. Benefits of the Proposed GT Based Coding and Classification System for the Company

In literature part and in the introduction part of this chapter, general advantages of a classification and coding system were discussed. In the data analysis section, some of the benefits of the developed CCS had already mentioned. But in this section, there is a further presentation of that how the classification and coding system designed for Metal products development center will benefit the company.

6.6.1. Design Support

This classification and coding system can support the design function by accomplishing the following:

1. ***Effective retrieval of similar design drawings and reduce time required:*** by having code represent a range, this classification and coding system can aid the designer in a preliminary design of a component. If the component was designed in the past why should it be redesigned again? For example, if a designer wants to design a gear with some specification, he would just search in the historical database of previously coded gears and see if similar component exists. The code will allow the designer to retrieve components similar but not necessarily exactly the same as requested. Then the designer will select closer drawing and can use as it is or with slight modifications.

2. Again if the designer want to update or edit already designed drawing; just by having a customer name or production order number or product type can retrieve for his/her secondary design purpose of the component. For example if a customer needs to change his product design that has already done, he can retrieve and modify it just simply by using customer name, product type, or order number then the designer need not to draw it again.
3. ***Establishment of a master database:*** the GTCSPDC will serve as an information system that will contain important details of a component. a lot of drawings, without the need of wasting time, the need of large printouts, large space for storage, and without the need of having archive, can be stored in the computer database with all required information with easy management system of past files.

   Currently the company stores previous drawings in hard copy form in one store room with huge drawer with a size capacity of enough to hold A1 paper. From this traditional database system to search and find a drawing before long time ago is difficult and time consuming. For example, if one drawing has lost that has been done before three years ago for a special design, how could he get to do similar job at current time?
4. ***Formation of part families in an attempt to standardize the component design:*** A designer will be able to group components of a certain type to analyze the number of variations in that group. For example, a designer may want to form part families on components in the same class or sub-class used. Some of the components may be different from others in the same part families, it may be beneficial to make these two different types of components the same size so that the design and production work can be standardized and the number of reuses increased. The part to be assembled with it may be designed according to this part family and finally quality of the product will increase with repetition.
5. ***Allow for more effective use of framing systems:*** such a classification and coding system will aid a new designer in familiarizing himself with a company's style of designed framing systems that were used in the past. If a designer needs to make a decision between two equally good designs, he/she can refer to the classification and coding system. The GTCCSPDC will display the components which are similar to that of concern and will aid the user in understanding the nature of the component

based on the coding scheme. Similar characteristics may exist between the component of concern and the searched one, therefore allowing the user to see how the same decision was made in the past.

6.6.2. Application to a Production Planner, Production Section, and Estimator

1. ***Support in Formation of part families and further analysis of data:*** An examination of all of the parts that produces in the factory with the designed CCS system will allow the identification of parts with similarity in design and/or manufacturing flow attributes. And support in the formation of part family or classification of parts that are not considered in the sample drawings, which are already classified based on PFA method as shown in the result of the next chapter. It is also possible to analyze parts in order to use further of the advantages from parts similarity.
2. ***Better scheduling for production:*** since it helps to identify the part family of a newly designed part, it helps for assigning the parts to the associated machine cell. Thus it provides more streamlined process flow of parts through machines and hence it simplifies scheduling process. In addition, by using previous, operation type and time required to each operation, data that had been stored for the operations on closely similar parts, production planner can develop a standard time of operations for the parts. And it uses as an input for production planning and control process. Thus planning for production will be more accurate and actual, since it relied on more real data of standard times of operation.
3. ***Accurate estimating of changes to design (better communication between departments):*** if a designer makes a change on particular aspect about a component, the production planner can quickly retrieve the component to be modified, and make the necessary changes so that the impact of the change will be available on the final product. Again it reduces rework job, as a result of a variation on design and production specification.
4. ***Accurate estimation of cost of production:*** As described in the data collection phase, the major data's required for product cost estimation are designing time, material type, and operation type and time required. The marketing department, who make estimation on cost of production, can get all this information from GTCSPDC. By simply retrieving and analyzing of data's of similar parts that has done at different

time and situation, he can make more accurate and standardize cost estimation. The designer who feed designing time will also reach a more standardized time of designing estimation and performance. The same is true for production planner time estimation. Therefore it will alleviate unnecessary excess cost load on the customer. Again it will alleviate under estimation of product cost.

5. ***As a base for Computer Aided Process Planning (*****CAPP)**: in a manufacturing environment of smaller lots and shorter product life cycles, CAPP got its start with Group Technology. The developed coding and classification system use to identify similar components and processes. Then once "families of parts" are identified, they can be manufactured with standardized process plans. Early CAPP systems were based on this general principle, and still are, though there are now basically two approaches to how systems work--variant and generative. In the variant approach, a set of standard process plans is established for all the parts families identified through GT. Then when a new plan is required, an applicable standard plan is retrieved and edited to suit the specific requirements of the new part.

CHAPTER SEVEN

MACHINE CELL FORMATION BY USING PRODUCTION FLOW ANALYSIS METHOD

7.1. Introduction

The implementation of GT in Metal products development center involves a number of comprehensive changes including the reconfiguration of plant equipment from a functional layout to a series of product oriented layouts that are referred to as manufacturing cells. As already discussed in the literature part, there are three methods of GT for the formation of machine cell formation. But through a thorough consideration of the methods pros and cons for the development of cellular manufacturing cell in the workshops (machine cell design), production flow analysis method had selected for the following reasons.

It has the flowing advantages over the other two, especially over CCS method:-

- It gives quick result that met the requirements expected from the formation of machine cell. It is obvious that the requirements are meeting the objective of the study that could be addressed through the formation of machine cell as already presented in the data analysis part,
- The cost of implementing is less (relative to coding and classification method). As the literatures indicates and any one can understand easily, it is clear that the formation of GT based part family/machine cell, from zero, is more costly with CCS method. But in case of this particular study, since the researcher already developed codes and classification system, comparison should be made from this point. As to the researcher still using CCS method is costier. Since if the researcher uses the designed coding and classification system, it needs additional job of feeding design data of parts of about a year period of time and expert analysis. To do this analysis needs additional cost of specialized worker and considerable time. But in case of PFA there are already designed procedures and formulas for machine cell formation, and it makes the process easy and less costly.

- It is easier in computation, since it uses only production flow data of parts and it doesn't need the design of coding scheme, feeding detail code attributes of parts in the in a computer based system (as it should be done in the CCS system).
- It reduces the required next job by the target company experts in the implementation of GT, and
- The technique focuses solely on current manufacturing methods and uses existing processing equipments and tooling.

For the mentioned and other reasons production flow analysis method had been selected for the development of machine cell in this study.
After analyzing all the required data from the collected data in the data collection phase, the writer had presented the procedure and result of the formation of machine cell, in Metal products development center production area, throughout this chapter.

Developed Operations Code and Assigned Machines

At this stage, in the development of operation codes, machines with the same operations are categorized under the same group without considering the special requirements of parts. But latter the special requirements of each part families had considered and included in the assignment and arrangement of machines in each machine cell design.

Lathe operation

1. **L-1 -** which represents heavy duty lathe, machines with swing over diameter of up to 280 mm and turning length of 810 mm. It includes TS Harrison M250 machine.
2. **L-2** - which represents Medium and small duty lathe machines in size, it includes lathes with swing over diameter of up to 350 mm and turning length of 400 mm. which includes precision lathe machine, CM2 Type T410, and precision tool lathe (CNC) machines.

Some of the operations can be done under this category are: Turning, Facing, Tapering, Boring, Drilling, and internal and external Threading.

Milling

1. **M-1** - This represents Vertical milling machines and small universal milling machines that do not let attachment for gear forming. Some of the types of

operations that can be performed here are: vertical slot and key way, vertical drilling, reaming, and vertical boring.

2. **M-2 -** which represents universal milling machines; it includes CNC universal milling and other precision milling machines. Some of the types of operations that can be performed here are: Surfacing (rough), Slot and groove formation, polygon shapes with the attachment of dividing head, keyway, vertical and horizontal drilling, boring with the attachment for diameters greater than 60 mm, gear teeth making with attachment (it includes; external spur gear, helical gear, spline gear, bevel gear, and others except internal spur gear), and reaming.

Grinding

1. **G-H** - represents cylindrical grinder of heavy duty. It uses for Internal/external cylindrical grinding and tapering.
2. **G-MS** - represents for medium and small duty. It calls for operations like: external circular grinding, internal grinding with the help of attachments, and tapering.
3. **G-S** - represents Surface grinder and tool grinders.

Shaper

S-1 = shaper machine that uses for operations like: formation of internal spur gear, slot, keyway, groove, and other facing operations.

Engraving: **E-1** = Engraving machine that uses for operations like Lettering.

Drilling

D-1 - represents drilling operations and it includes Hydraulic Radial drilling, Column drilling, and Table drilling machines.

Bo -1 - represents boring machines.

Shearing: **S-A** = represents shearing machines.

Bn-2 - it represents bending machines.

R-1 - represents rolling machines, which includes both electrical and mechanical rolling machines.

7.3. Identifying Operations on Parts and Corresponding Machines Required

In the second stage, the representative sample parts list are taken from the data collected, and identification of the required production route, the operations performed on parts, and the machines necessary to perform each operation had done and presented the result as shown in the Appendix C.

7.4. Part - Machine Matrix

After a thorough examination of part flow through the machines, major part-machine group had been formed and presented in part-machine matrix form as shown in table 7.1. thus it provide the required data for the ultimate purpose of the analysis-to determine appropriate machine-part sub grouping for cellular layouts. The next section discusses the selection of appropriate clustering method for machine-part sub grouping.

Table. 7.1. Component versus machine matrix.

No.	Parts	Machines												
		L-1	**L-2**	**M-1**	**M-2**	**G-H**	**G-MS**	**G-S**	**S-1**	**D-1**	**B-1**	**S-A**	**R-M**	**B-2**
1	Threading die(T-D)		**1**				**1**			**1**				
2	Eye Bolt (E-B)		**1**	**1**						**1**				
3	Bolt (Bt)		**1**	**1**										
4	Guide (Gd)	**1**		**1**										
5	Bushing (Bu)		**1**											
6	Threaded Hub (T-H)	**1**												
7	Shaft (St)	**1**		**1**						**1**				
8	S-N		**1**	**1**						**1**				
9	Nut (Nt)		**1**	**1**						**1**				
10	Plate (Pl)			**1**						**1**				
11	Spur Gear (S-G)		**1**	**1**					**1**	**1**				
12	Worm Gear (W-G)	**1**		**1**										
13	Spline Shaft (Sp-St)	**1**		**1**										
14	Roller (Ro)	**1**												
15	Pinion Gear (Pi-G)		**1**	**1**						**1**				
16	Tension spring (T-S)		**1**		**1**									
17	Cutter (Ct)			**1**				**1**		**1**	**1**			
18	Bushing (Bu)		**1**						**1**					
19	Helical Gear (H-G)	**1**		**1**			**1**	**1**						
20	Guide Shaft (Gd-St)	**1**				**1**								
21	Finger Pin (F-P)		**1**	**1**			**1**							
22	Link (Lk)			**1**						**1**				**1**
23	Sleeve (Sl)		**1**				**1**		**1**					
24	Punch (Pn)			**1**			**1**	**1**						
25	Splined-Gear (Sp-G)	**1**		**1**										
26	Coupling (Cl)		**1**	**1**					**1**					
27	Shafted-Gear (Sh-G)		**1**	**1**					**1**					
28	Valve (V)		**1**		**1**									
29	Lead Screw (L-Sc)		**1**	**1**										
30	Arm (Ar)		**1**	**1**										
31	Blade (Bl)			**1**				**1**						
32	Support (Su)			**1**					**1**					
33	Saddle (Sd)			**1**						**1**				
34	chuck (Ck)		**1**	**1**			**1**							
35	Female die (F-D)		**1**	**1**			**1**		**1**					
36	Allen bolt (A-B)		**1**		**1**									
37	Cylindrical ring (Cy-R)											**1**	**1**	
38	Clamp screw (Cl-Sc)		**1**		**1**									

7.5. Selection of Clustering Algorithm

7.5.1. Introduction

Since the time of need for cellular manufacturing system (CM), different clustering algorithms have been created. As time goes different clustering methodologies have been adopted one after the other so as to reach at a better and more effective method out of the existing ones. This development of the already existing clustering methods has come up with sorting out the lacks of the previous ones. Hence, the importance for comparison between different tools for a better final solution of the same problem is undoubtedly visible.

7.5.2. Comparison of Clustering Approaches

As already stated or identified out in the literature part, Matrix manipulation methods have many advantages over the other approaches as they avoid subjectivity involved in the similarity coefficient approaches and the complexity of set theoretic and integer programming approaches. Their popularity stems from these advantages as well as their computational simplicity. However, the array-based or matrix manipulation methods have the disadvantages of being dependent on the initial configuration of the zero-one matrix and not being able to provide disjoint part families and machine cells for ill structured matrix.

In general, the ***Matrix Manipulation Method*** is the best clustering method among the other four approaches.

7.5.3. Comparison of Clustering Algorithms, and Machine-Part Sub Grouping

As the above section presented matrix manipulation method has already selected as the best method for this study, but it is important to evaluate and select the suitable array-based clustering algorithm for the study. In this study only the two commonly used array-based (Matrix manipulation method) clustering algorithms; namely, the ***Rank Order Clustering (ROC) algorithm*** and the ***Direct Clustering Algorithm (DCA)*** are treated for comparison.

In this section, a general procedure for evaluating these array-based clustering algorithms; is presented.

I. Evaluation Procedure

One major problem with clustering arises when a large number of components need to be processed in a machine (such a machine is called a bottleneck machine) or when exceptional elements exist in the machine/part matrix. Under these conditions, the parts or machines may not be divisible into mutually exclusive groups; in this case, additional processing or human interfaces are needed.

First of all, each algorithm clusters each problem set. If the results indicate that bottleneck machines or/and exceptional elements exist, additional procedures such as those described in the literature part are then applied. Such procedures, which introduce a human interface with the algorithm, offer much greater flexibility in dealing with exceptional elements and bottleneck machines.

II. Measures of Performance

The performance of clustering can be evaluated either according to computational efficiency or clustering effectiveness. Clustering efficiency is normally measured in terms of program executions time, the amount of memory needed, and the complexity of the algorithm. The following are the most widely used measures of effectiveness in the literature.

1) Total bond energy
2) Percentage of exceptional elements (parts)
3) Machine utilization
4) Grouping efficiency.

In this study, the BE and grouping efficiency is selected as measure of effectiveness (ME) for evaluating the two algorithms studied under matrix manipulation method. Hence, conclusions have been made regarding the effectiveness of the two algorithms in the next section.

III. Relative Performances of the Two Algorithms

In the comparison of performance, basically the input data taken were on the basis of their group ability manner. The first input data is one that can be completely grouped into separate part families and machine cells. In such data both methods considered are equally good. In all cases the final matrix has total bond energy (BE) of equal magnitude.

The second input data is one that can not be grouped into separate part families and machine cells. In such cases the ROC is found to be better of the two methods tested. In every test data used the ROC always resulted in a smaller percentage of exceptional elements & higher total bond energies. In some data sets where ROC could completely cluster without any exceptional element but DCA resulted in unacceptable number of exceptional cells and much less total bond energy. This indicates that the DCA have some deficiency; that is, it may not work well for some input matrices. Of course, the DCA performed well after taking additional procedures. This indicates that DCA is quite sensitive to data sets with exceptional elements.

In general, the ROC algorithm is better of the two methods. This result had also proven on the case company part - machine matrix data as shown below.

A. Direct Clustering Algorithm method

0.Data	L-1	L-2	M-1	M-2	G-H	G-MS	G-S	S-1	D-1	B-1	S-A	R-M	B-2	r
T-D		1				1			1					3
E-B		1	1						1					3
Bt		1	1											2
Gd	1		1											2
Bu		1												1
T-H	1													1
St	1		1						1					3
S-N		1	1						1					3
Nt		1	1						1					3
Pl			1						1					2
S-G		1	1					1	1					4
W-G	1		1											2
Sp-St	1		1											2
Ro	1													1
Pi-G		1	1						1					3
T-S		1		1										2
Ct			1				1		1	1				4
Bu		1						1						2
H-G	1		1			1	1							4
Gd-St	1				1									2
F-P		1	1			1								3
Lk			1						1		1			3
Sl		1				1		1						3
Pn			1			1	1							3
Sp-G	1		1											2
Cl		1	1					1						3
Sh-G		1	1					1						3
V		1		1										2
L-Sc		1	1											2
Ar		1	1											2
Bl			1				1							2
Su			1					1						2
Sd			1						1					2
Ck		1	1		1	1								4
F-D		1	1			1		1						4
A-B		1		1										2
Cy-R											1	1		2
Cl-Sc		1		1										2
SM-Bl			1				1							2
Sd		1	1			1								3
S-P											1	1	1	3
Lo			1				1		1					3
H-B		1												1
C-St		1				1								2
T-Ho			1						1					2
P-D			1				1							2
L-Sc		1		1										2

Table.7.2. Final DCA result Matrix

3.All Cols.	**M-2**	**B-2**	**R-M**	**S-A**	**G-H**	**L-1**	**G-MS**	**G-S**	**B-1**	**S-1**	**D-1**	**L-2**	**M-1**	**r**
S-G										**1**	**1**	**1**	**1**	4
Ct								**1**	**1**		**1**		**1**	4
H-G						**1**	**1**	**1**					**1**	4
Ck					**1**		**1**					**1**	**1**	4
F-D							**1**			**1**		**1**	**1**	4
E-B											**1**	**1**	**1**	3
St						**1**					**1**		**1**	3
S-N											**1**	**1**	**1**	3
Nt											**1**	**1**	**1**	3
Pi-G											**1**	**1**	**1**	3
F-P							**1**					**1**	**1**	3
Lk				**1**							**1**		**1**	3
Gd						**1**							**1**	2
Pl											**1**		**1**	2
W-G						**1**							**1**	2
Sp-St						**1**							**1**	2
Pn							**1**	**1**					**1**	3
Cl										**1**		**1**	**1**	3
Sh-G										**1**		**1**	**1**	3
Sd							**1**					**1**	**1**	3
Bt												**1**	**1**	2
Lo								**1**			**1**		**1**	3
Sp-G						**1**							**1**	2
L-Sc												**1**	**1**	2
Ar												**1**	**1**	2
Bl								**1**					**1**	2
Su										**1**			**1**	2
Sd											**1**		**1**	2
SM-Bl								**1**					**1**	2
Sd											**1**		**1**	2
T-Ho											**1**		**1**	2
P-D								**1**					**1**	2
T-D							**1**				**1**	**1**		3
Sl							**1**			**1**		**1**		3
Pt							**1**				**1**	**1**		3
T-S	**1**											**1**		2
V	**1**											**1**		2
A-B	**1**											**1**		2
Cl-Sc	**1**											**1**		2
C-St							**1**					**1**		2
L-Sc	**1**											**1**		2
Bu												**1**		1
H-B												**1**		1
Gd-St					**1**	**1**								2
T-H						**1**								1

B. Rank Order Clustering

No.	Parts	Machines												
		L-1	L-2	M-1	M-2	G-H	G-MS	G-S	S-1	D-1	B-1	S-A	R-M	B-
1	D		1				1			1				
2	E-B		1	1						1				
3	Bt		1	1										
4	Gd	1		1										
5			1											
6	T-H	1												
7	St	1		1						1				
8	S-N		1	1						1				
9	Nt		1	1						1				
10	Pl			1						1				
11	S-G		1	1					1	1				
12	W-G	1		1										
13	Sp-St	1		1										
14	Ro	1												
15	Pi-G		1	1						1				
16	T-S		1		1									
17	Ct			1				1		1	1			
18	Bu		1						1					
19	H-G	1		1			1	1						
20	Gd-St	1				1								
21	F-P		1	1			1							
22	Lk			1						1				1
23	Sl		1				1		1					
24	Pn			1			1	1						
25	Sp-G	1		1										
26	Cl		1	1					1					
27	Sh-G		1	1					1					
28	V		1		1									
29	L-Sc		1	1										
30	Ar		1	1										
31	Bl			1				1						
32	Su			1					1					
33	Sd			1						1				
34	Ck		1	1			1							
35	F-D		1	1			1		1					
36	A-B		1		1									
37	Cy-R											1	1	
38	Cl-Sc		1		1									
39	SM-Bl			1				1						
40	Sd		1	1			1							
41	S-P											1	1	1
42	Lo			1				1		1				
43	H-B		1								1			

Table.7.3. Final ROC algorithm result matrix

	M-1	G-H	L-1	G-MS	S-1	L-2	G-S	B-1	M-2	D-1	B-2	R-M	S-A	Wj
T-H		Cell 5	1											8
Ro			1											8
Gd-St		1	1											12
Bu						1								64
H-B						1								64
T-S	1					1								66
V	1		Cell 1			1								66
Bt	1					1								66
A-B	1					1								66
Cl-Sc	1					1								66
L-Sc	1					1								66
C-St				1		1								80
Sl				1	1	1								112
W-G			1						1					1032
Sp-St			1						1					1032
Spl-G			1						1					1032
Su					1				1					1056
Ar						1			1					1088
F-P				1		1			1					1104
Ck				1		1	Cell 2		1					1104
Sd				1		1			1					1104
Cl					1	1			1					1120
Sh-G					1	1			1					1120
F-D				1	1	1			1					1136
Bl							1		1					1152
SM-Bl							1		1					1152
P-D							1		1					1152
Pn				1			1		1					1168
H-G			1	1			1		1					1176
T-D				1		1				1				2128
Pt				1		1				1				2128
Pl									1	1				3072
Sd									1	1				3072
T-Ho									1	1				3072
Sd						Cell 3			1	1				3072
St			1						1	1				3080
E-B						1			1	1				3136
Sp-N						1			1	1				3136
Nt						1			1	1				3136
Pi-G						1			1	1				3136
Sp-G					1	1			1	1				3168
Lo							1		1	1				3200
Ct							1	1	1	1				3456
Lk									1	1	1			7168
Cy-R											Cell 4	1	1	24576
Co-R												1	1	24576
St-P											1	1	1	28672

The result matrix of the two methods shows that ROC method gives a better clustering of part families and machine cells. Thus for this study ROC clustering algorithm is selected as a tool for part family and machine cell formation and the result machine-part sub groups has presented in the next section.

7.6. Arrangement of Machine Cells in the Proposed Cellular Layout

Table.7.4. Part family versus machine cell table

Sr.No	Part Family	Machine Cell
1	Bu, T-S, V, Bt, A-B, Cl-Sc, L-Sc, C-St, Sl, H-B	**M-1, G-MS, S-1, L-2**
2	W-G, Sp-St, Sp-G, Su, Ar, F-P, Ck, Sd, Cl, Sh-G, F-D, Bl, SM-Bl, P-D, Pn, H-G	**G-MS, L-1, S-1, L-2, G-S**
3	T-D, Pt, Pl, Sd, T-H, St, E-B, Sp-N, Nt, Pi-G, Sp-G, Lo, Ct, Lk	**G-MS, L-1, S-1, L-2, B-1, G-S, M-2, D-1, B-2**
4	Cy-R, Co-R, St-P	**B-2, R-M, S-A**
5	T-H, Ro, Gd-St	**G-H, L-1**

The result from Rank Order Clustering algorithm shows that there are five part families with five group machine cell which each of them are dedicated to produce single part family components. But since there are only three cylindrical grinding machines in the company, to reduce the cost, by avoiding purchasing of one more cylindrical machine, it is important to share one cylindrical grinding machine for two machine cells. After considering the size of the components in the part families and feasibility based on flow lines and the type of machines of all part families, to share part family two and five becomes more logical and advantageous. But the machine selected and assigned here should be able to substitute the function of the two machines in the two machine cells, in a better way. Since heavy duty cylindrical grinding machine can do satisfy this requirement, thus it is enough to assign it here.

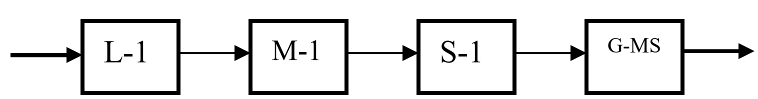
As the clustering result shows there is one exceptional component from cell 3, which needs a bending machine. To solve this exceptional component the researcher consider factors like, material handling distance in a new layout, the feasibility of manufacturing the part in other cell, and to assign one more bending machine to cell 3. But there is only one bending machine in the company and it already assigned to cell 4, thus assigning solution is not possible unless purchase one more bending machine. Since this component can be manufactured in cell 2, with the substitution of drilling operation by vertical drilling machine in place of drilling machine, thus the researcher proposes to assign it to cell 2 so as to reduce the material handling and additional investment for machine purchase cost.

After this the next vital step is forming a physical layout of each cell in the work shop. In determining the layout of each cell it is important to consider factors like: to recall the literature part of section 2.4 and section 4.6 with additional layout design principles knowledge; to consider the special requirements of each part family; production process flow of each components of the part family; the availability of machines; material handling distance; and space requirements. Since one of the main objectives of GT based cell formation is to gain the advantage of flow type layout in a job shop production, the machine arrangements developed in this section had taken all these factors in to account, with serious consideration.

The result arrangements of machines in the workshops are presented as follows:

I. Cell 1 - In this cell, a single machine from each of the required machine groups had selected and organized in a GT-cell layout or GT-flow type layout as an options as shown in figure 7.1 to produce parts, which incorporated in the first part family. To determine the appropriate layout the production flow of the part family (L $\rightarrow$ S; L$\rightarrow$M; L$\rightarrow$M; L$\rightarrow$M; L$\rightarrow$G; L$\rightarrow$S$\rightarrow$G) had considered and analyzed. And the GT-cell layout is selected for the advantages of: better space utilization, less material handling distance, and better capability in accepting larger variety of parts in the part family.

a) OPTION 1: GT-flow type arrangement of cell 1.



b) OPTION 2: GT-cell type arrangement of cell 1.

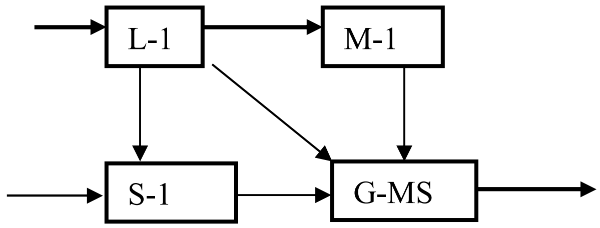


Figure. 7.1. Machines arrangement of cell 1

II. Cell 2 and Cell 5 - Here the two cells are considered together, since there is a machine requirement in common. The arrangement had designed with the consideration of space availability, reducing material handling distance, and increasing flexibility of the two cells in common, in addition to the above mentioned factors of considerations. The same methodology as the above had used and some of the part families production process flows: (L→M; L→M; L→S→M; M→S; L→M; L→M→G; L→M→G; L→M→S; L→S→M; L→M→S→G, M→S→G, M→SG, M→SG, M→CG→SG; L→M→CG→SG; L; L; L→G) are considered**.** And the required machine groups selected and organized in a multi-raw cellular layout (a hybrid of GT flow type and GT-cell type layout arrangement), as shown in figure 7.2 to produce parts, which incorporated in the second and fifth part families.

The factors that the reasercher considers in the decsion of sharing grinding machine for the two cells are: cost of additional machine, variation gap on size and operation type requirement of the two cells part families, and possible actions that should consider during arrival of components from two cells at a time.

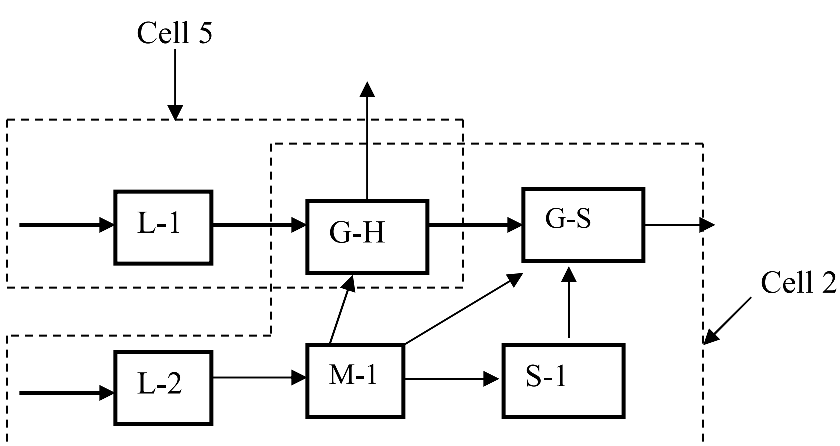


Figure 7.2. A multi-raw arrangement of cell 2 and cell 5.

The researcher proposes the following considerations to be taken at the common grinding machine of the two cells in a case when there is an arrival of parts at the same time from the two lines.

- It is advisable to use FIFO scheduling principle unless the second urgency of the second work-in-process forces to be first.
- The buffer size of the two lines should also be considered. To give priority for line with large buffer size, by giving due consideration for the urgency of order, is advisable.
- For the arrival of parts with large variation in operation time length with equal delivery date constraint, giving priority for the part with shorter operation time reduces work-in-process inventory.
- In case of large buffer size development due to the common machine, it may be necessary to use a shift work of the two cells lines.

III. Cell 3. In this cell, a single machine from each of the required machine groups had been selected and organized in a multi-row cellular layout (a hybrid of GT flow type and GT-cell type layout arrangement), as shown in figure 7.3 to produce parts, which incorporated in the third part family. Some of the process flow required for production of parts in this part family that had been considered for the determination of this cell machines arrangement are: L→G; M→D; L→D→G; M→D; M→D; L→D→M; L→M→D; L→M→D; L→M→D→S; L→D→M; M→D→SG; M→D→B→G; M→D.

Since there are only two functional shaper machines in the company, thus it is reasonable to substitute the shaper in this machine cell with milling machine.

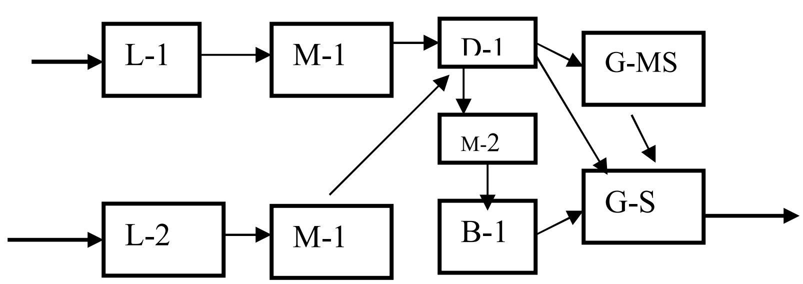


Figure 7.3. Machines arrangement of cell 3

IV. Cell 4. In this cell, a single machine from each of the required machine groups will select and organize in a GT-cell cellular layout as shown in figure 7.4 to produce parts, which incorporated in the fourth part family.

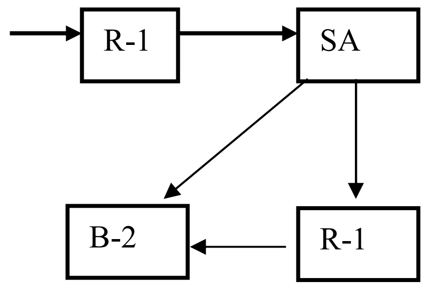


Figure 7.4: A GT-cell type arrangement of cell 4

Table.7.5. Machines assignments of each proposed cell.

Assigned machines	***Cells***
Center lathe CMZ T410 x 1500	C-1
Milling FU-3	
Cylindrical grinder DELTA	
Tool grinding BOXFORD G200	
Shaper CMZ L550	
Lathe HARRISON M300	C-2
Lathe HUICHON-5	
Milling FU-3	
Shaper CMZ L550	
Milling M/C FTV - 4	
Surface grinder DELTA	
Lathe HARRISON 250	C-3
Lathe HUICHON-5	
Universal CNC milling machine	
Milling FU-3	
Vertical milling	
Surface grinder DELTA	
Cylindrical grinder GER RHC 1500	
Hydraulic radial drill	
Boring Machine	
Tool BOXFORD G200	
Large diameter power roller	C-4
Angle Bender	
Shearing machine	
Rubber shearing machine	
Power saw	
Hack saw SAB 1	
Engraving machine	
Medium and small diameter rollers	
Lathe HARRISON M460	C-5
Milling FU-3	

7.7. Advantages of the Proposed Machine Cell Formation

The proposed machine cell based arrangements of the machines in the production area lets the company to gain the following advantages:

Less Material Handling Cost: as already stated earlier, currently, machines in Metal products development center are not arranged based on production flow of components, rather most of them are arranged functionally (process type), in some cases based on the available free space in the workshop for newly added machines, and others. It is known that the company is dedicated to produce a large variety of products. But because of not having machine cell that dedicated to produce group of parts with similar flow of production; material handling is less efficient due to forward and back ward movement of components during production and longer material handling distance between consecutive operations. But the developed GT based arrangement of machines makes to gain the advantage of flow type layout, like: reducing the back-truck movement of work-in-process and shorter distance movement (material handling) between consecutive operations. Generally, the newly proposed GT based machines layout reduces the material handling distance of parts in process by 44.9 percent in average. Thus the cost of material handling will also reduce by the same amount. The researcher uses 42 sample components material handling distance through machines as shown in table.

Table: 7.6. Material handling saving calculation of the proposed machines layout

No.	*Parts*	**Associated Machine cell number**	**Material Handling distance in the existing layout (in meter)**	**Material handling distance in the proposed layout (in meter)**
1	T-D	3	14.67	9.89
2	E-B	3	19.88	6.62
3	Bt	1	8.31	3.85
4	St	3	21	11.3
5	S-N	3	19.8	6.62
6	Nt	3	13.1	6.62
7	Pl	3	14.34	2.96
8	W-G	2	8.93	5.16
9	Sp-St	2	13.01	5.16
10	Pi-G	3	18.2	6.67
11	T-S	1	8.93	3.85
12	Ct	3	35.83	14
13	H-G	2	14.95	16.77
14	Gd-St	5	8.65	3.84
15	F-P	2	12.04	8.45
16	Lk	2	32.5	20.73
17	Sl	1	14.59	6.49
18	Pn	2	19.77	9.95
19	Sp-G	3	22.78	10.11
20	Cl	2	31.79	5.6
21	Sh-G	2	20.13	7.5
22	V	1	13.01	3.85
23	L-Sc	1	10.8	3.85
24	Ar	2	5.17	3.24
25	Bl	2	8.65	4.84
26	Su	2	9.63	2.31
27	Sd	2	32.01	10.26
28	Ck	2	32.01	10.26
29	F-D	2	38.7	14.2
30	A-B	1	8.93	3.85
31	Cy-R	4	4.45	3.11
32	Cl-Sc	1	8.31	3.85
33	SM-Bl	2	8.65	4.84
34	S-P	4	6.95	6.16
35	Lo	3	12.83	12.08
36	C-St	1	11.97	7.56
37	T-Ho	3	12.42	3.1
38	P-D	2	8.65	4.84
39	L-Sc	1	10.8	3.85
40	Sd	3	14.34	2.96
41	Co-R	4	6.59	2.51
42	Pt	3	18.4	11.13
	Total		656.47	294.79

Better production planning and control process, and increase efficiency of production: since the newly proposed cellular layout of machines has designed in a way that it can provide a smoother production flow of parts in the workshop and based on the concept of sub-grouping of parts produced in the company, thus the production management becomes easier. As a result production planning job will be possible with less effort and closer result to the actual data that will be get during production; and again, the production control job will be easier and manageable. These will help in the reduction of waiting time of parts in the production area. Thus, delivery time and cost of production will be lesser with a better efficiency of production.

Set up time: In the existing manufacturing system, set up time is arranged for a single item whether it is manufactured in piece or batch. Whereas in case of GT based manufacturing system set up time is arranged for a group of parts, which categorized in a part family. Therefore, the setup time is considerably reduced. And it is calculated by using the average setup time required on each machines, similar parts in a part family that can be manufactured on the same tool, work holding, and work piece setup of each cell and average saving in percentage is presented.

S/N	Types of machine	Average setup time of each machines (in Hour)	Percentage of setup time savings (in %)
1	Lathe Machines (various type)	3.5	48.0
2	Milling Machines (various type)	2.5	34.2
3	Slotting Machine	1.7	27.7
4	Grinding Machines (various type)	4.0	44.1
		Average	38.5

Thus for parts manufactured in the GT based manufacturing system, on average the setup time will reduce by 38.5 percent. Consequently, the throughput time will also reduce proportionally.

Increases Production Workers Specialization and Quality of Product: - due to the sub grouping of machine-parts the workers are going to dedicate on a production of a part family or a smaller group of parts with similar process requirements, thus it lets them to specialize on the task. The result of, specialization of workers, standardization of tools and fixtures, and better satisfaction of workers, reduces the variation on the final product from the design specification.

Better space utilization: - with the proposed facilities layout the space requirement machine shop reduced. It provides free floor area for assembly job that was done earlier on the aisle of the workshop. It saves a 10.4 percent of the production area.

Generally, it facilitates the over all production processes and increases the efficiency of the company manufacturing system.

7.8. Cost Benefit Analysis

This section discuss on calculations for estimation of cost of implementation for the developed CCS and machine cells, major savings (benefits) of the system, and the period of time required to return the implementation cost.

A. Implementation cost

The following are the components that constitute the capital cost of the system implementation.

1) Plant and Machinery
2) Electrical
3) Transportation and Erection charges
4) Know-how/ consultancy fees
5) Miscellaneous assets
6) Provision for contingencies

All calculations and estimations for the individual components that make up the system implementation cost presented as follows. The aims in deciding upon these components of project cost are to reduce the cost to the minimum, while keeping the functional requirements adequate, and to decide cost-benefits of the system.

1) Plant and Machinery

This cost includes the cost of machines that needs to be added during machine cell formation and cost of computers for CCS. But as we already discussed in section 7.6, the requirements for additional machines for machine cell formation are substituted with other available machines that can meet the desired purpose. Thus this cost component is only the costs of machines (computers) required for CCS system.

i. Server computer (quantity one) : 12,000 birr
ii. Mirror server (qty. 1) : 42,000 birr

(Mirror computer - uses to mirror the contents of critical server folders to a remote computer. it keeps an exact duplication of your server at a remote location, while providing automatic failover and recovery.)

2) Electrical:

For CCS installation:

i. Networking cables

Required length : 200 meter

Cost of purchase at the rate of 13 birr per meter before VAT.

Total : 3000 birr

ii. Hub : 1000 birr

For the formation of machine cells

iii. Electric starters, switches, cables, and other electrical items : 3500 birr

Total expense for electrical : 7,500 birr

3) Transportation and erection charges:

Total number of machines needs to be displaced and erected: 29 machines (18 relatively heavy and 11 light/medium weight machines)

i. Erection cost estimated for the heavy machines : 4000 birr

ii. Erection cost estimated for 11 relatively light weight machines : 1500 birr

Total : 72,000 + 16,500 = 88,500 birr

4) Know-how/Consultancy Fees

i. Training on basic concepts of GT and its application. It includes training on how to use the proposed CCS. Training time assumed for 1 ½ weeks for 12 employees with a total cost of 15,000 birr.

ii. Training on job scheduling for a week for six employees : 8,000 birr.

iii. Know-how fee to technical consultants: 25,000 birr. (It includes costs for data entry into the system, further analysis for part family formation, and related consultancy.)

Therefore, total training/know-how fees

(15,000 birr + 8,000 birr + 25,000 birr = 48,000 birr)

5) Other miscellaneous expenses during the project implementation stage:

Cost of idle time during relocation period = opportunity loss + direct labor cost of idle workers during relocation period

: 16.67% * (TP/year + 30% TLC/year)

: 54,160.83 birr

Where, TP : Total annual profit

TLC : Total labor cost per annum

Note: It is done with the assumption that relocation period is two month.

6) Provision for contingencies

Contingency assumed 3 percent of the total cost : 7,564 birr.

B. Savings of the proposed solution:

- Saving from retrieval system, i.e. from reducing designing time, is (with a result of a reduction of designing time by 32%) = 37,454.4 birr per annum. [where, designing cost covers nine percent of the total cost]
- Labor cost = 26,976 birr per annum from four operators salary save and with about 18 percent reduction of labor cost of production area and marketing department.
- Space utilization = 85.2 sq.m. * (tax rate per year + its advantage of providing space for assembly work and future expansion) = 14,000 birr per annum.
- Extra machines (1 Milling FU-5, 1 surface grinder DELTA, 1 lathe HARRISON M300, 1 column drill, 1 power saw) sells = summation of (price of each machines - depreciation cost of each machines) = 55,539.30 birr. [Note: All machines are used for 16.5 years; machines life considered for 20 years; and with salvage value depreciation calculation used]. Where initial costs considered are: 149000, 1263060; 156000, 36000, and 21600 birr respectively. The costs of machines are considered based on current money value. But it is important to take the principle of Ethiopia for used machines; thus the salvage value estimated for the above machines is 155,540 birr.
- Costs savings from material handling is 32,530.00 birr per annum.
- Saving from the save of set up time is 146,498.85 birr per annum.

C. ***Payback period calculation***:

Payback period of the investment project indicates the time period required to recover the original cash investment. Payback period (X) = (Total installation cost of the proposed solution if C_0 is the initial investment (cash outflow), and C_t is cash flow in the t^{th} year, then the payback period would be the value of k such that

$$\sum_{t=1}^{k} C_t - C_0 = 0$$

Cash inflows expected to be generated in different years are:

Year 1: cash flow = savings per year from the system + savings from machine sales

Year 2: cash flow = annual Savings from the system

From year 2 to year 5 assumptions had made that the cash flow be the same with year 2.

Thus, if the cash flows for a year are expected to generate uniformly through the period then the payback of 259,725 birr investment can be estimated as: 5 month period. But it estimated that one year is the time for fully implementing CCS system; thus the payback time for the investment is 1.4 year.

=> Thus, after one year and five months, starting from the date of installation of the system commences, the company will start to save 257462.25 birr per each year. This means, the proposed solution saves 19.1 percent of the total cost of production of the metal products development center.

Where, Company's costs data's per a year in birr are as follows:

Profit	180000
Overhead cost	520200
Raw material cost	346800
Labor cost	483000

CHAPTER EIGHT

CONCLUSION, RECOMMENDATION, AND FUTURE DIRECTIONS

8.1. Conclusion

Delay in delivery date, high product cost, and low product quality (i.e., variation from the specification) are the current problems of the company. And the result of the data survey shows that the major causes for the above problems are: unnecessary material handling distance because of the existing machines arrangements, the existing traditional design data storage method that does not let for design retrieval, treating each part separately rather than in family form, and the absence and difficulty of production scheduling.

To alleviate the mentioned problems of the company, implementing GT based manufacturing philosophy has been proposed as a solution. It includes the development of CCS that could encompass both rotational and non-rotational parts and formation of machine cells. It mainly aimed for the possibility of design retrieval and for earning the similarity advantages among parts both in design and manufacturing attributes.

In addition, the proposed CCS system provides: more accurate, fast, and relatively standardized input data for the required information of the cost estimation process; the input system for the development of computer aided planning and control system (CAPP); standard time of operations that uses for scheduling; and information system between departments.

Arranging machines in cells resulted in reduction of material handling, reduce set-up and throughput time, and to ease and improve production scheduling and control system. PFA method had been selected and used for the formation of machine cells. Five machine cells were formulated; and each machine cell designed to address a single part family.
The machines floor layout in production area had been changed and the newly GT based arrangement of machines is proposed. It increases floor space utilization by 10.4 percent; reduce material handling by 44.9 percent, and increases production efficiency.

After a period of one year and ten months from the point of initial installation, the proposed solution makes the company to benefits 257,462 birr per each production year (or to reduce 19.1 percent of the total production cost) continuously.

Generally from the over all contents of the literature survey and the results of this study, we can conclude that introducing and implementing a GT based manufacturing philosophy to local job shop manufacturing industries, will bring an extensive improvement to their manufacturing cost, product quality and delivery time.

8.2. Recommendation

Based on the hypothesis of the literature survey and the findings of this research, the researcher recommend on the following points.

- Since the proposed solution makes the company beneficiary, as the cost-benefit analysis result indicates, thus the researcher strongly advises metal products development center to implement the proposed solutions in order to gain its benefits.
- To earn the full benefits that stated, the company should implement both proposed solutions: coding and classification system and cellular manufacturing system.
- To use this material as a reference manual for the implementation of the solutions and for continuous increments on the earning advantages from the proposed manufacturing philosophy.
- Without strong support from top management, implementation of GT will be difficult. Therefore, all management personnel should be supportive and dedicated for installation of the proposed solutions.

8.3. Future Directions

- To create awareness to all the relevant personnel - Since GT concepts require changing how people work; therefore, employee resistance may be encountered. Hence to realize the effects of the system in all areas of application, the management should create awareness to the overall employees of the company and appropriate trainings should be prepared especially for employees of design engineering, marketing, and manufacturing departments. The training may includes on titles: Basic concepts and application of GT manufacturing philosophy, production scheduling, and CAPP. But training on CAPP is optional.

- Implement the CCS based on the steps provided in the literature part of the study and start feeding the drawing data to the system. It includes purchasing the necessary materials, like server computer, mirror backup server computer, and others. Then networking marketing, production and design departments is necessary. For earning the full benefits from the CCS system, it is important to feed enough number of parts that can represent all types of products which can be produced in the company for retrieval purpose and feed randomly selected parts about 200 so that the total of code numbers needed to represent all part families starts to level off during part family development.
- The implementation of machine cells formation involves the conversion of all or a portion of firms manufacturing system into cells. Its implementation is not a change of merely of interest and concern to the manufacturing floor. Rather it involves the physical change of machines layout, as stated in the appendix part of the study. thus it affects the work of the operators and supervisors as for personnel's and supporting departments like quality assurance, maintenance, manufacturing and industrial engineering, design, production and control, accounting, purchasing, and sale. In short, the implementation of machine cells has a multifaceted and complex impact on the organization as a whole; and hence it is vital to make rational plan for machines rearrangement job and implement it according to the plan.
- After starting of earning the benefits of the proposed solution, that means, after implementing CCS completely with analyzing to a minimum of 200 parts coding data and interpret it according to the requirements of GT manufacturing philosophy, it is advisable that METAL PRODUCTS DEVELOPMENT CENTER to invite other researchers for the development of CAPP system and other local company's with a job shop manufacturing system for sharing their experience and available materials, so that they can adopt this material with the relevant modifications based on their company's requirements.

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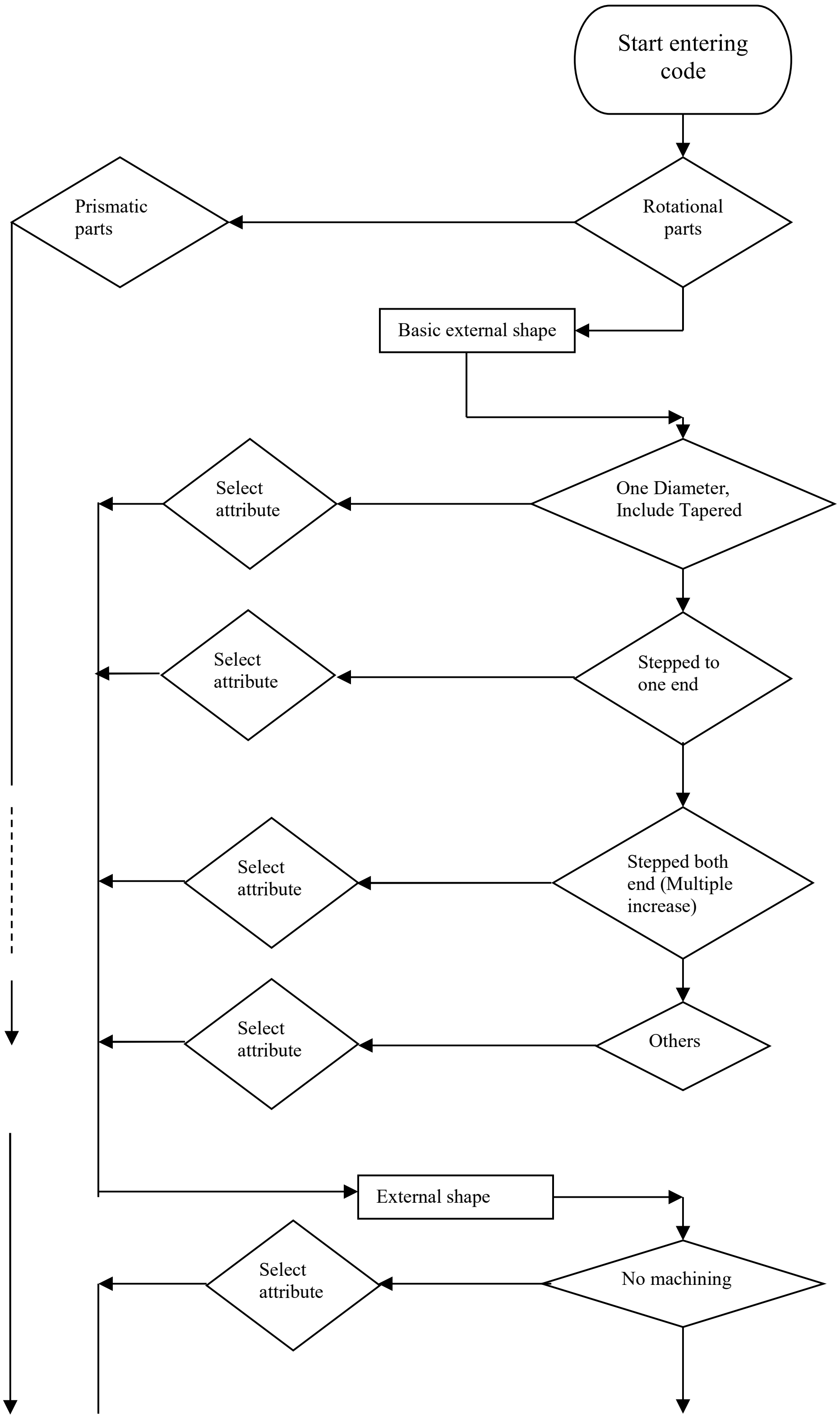
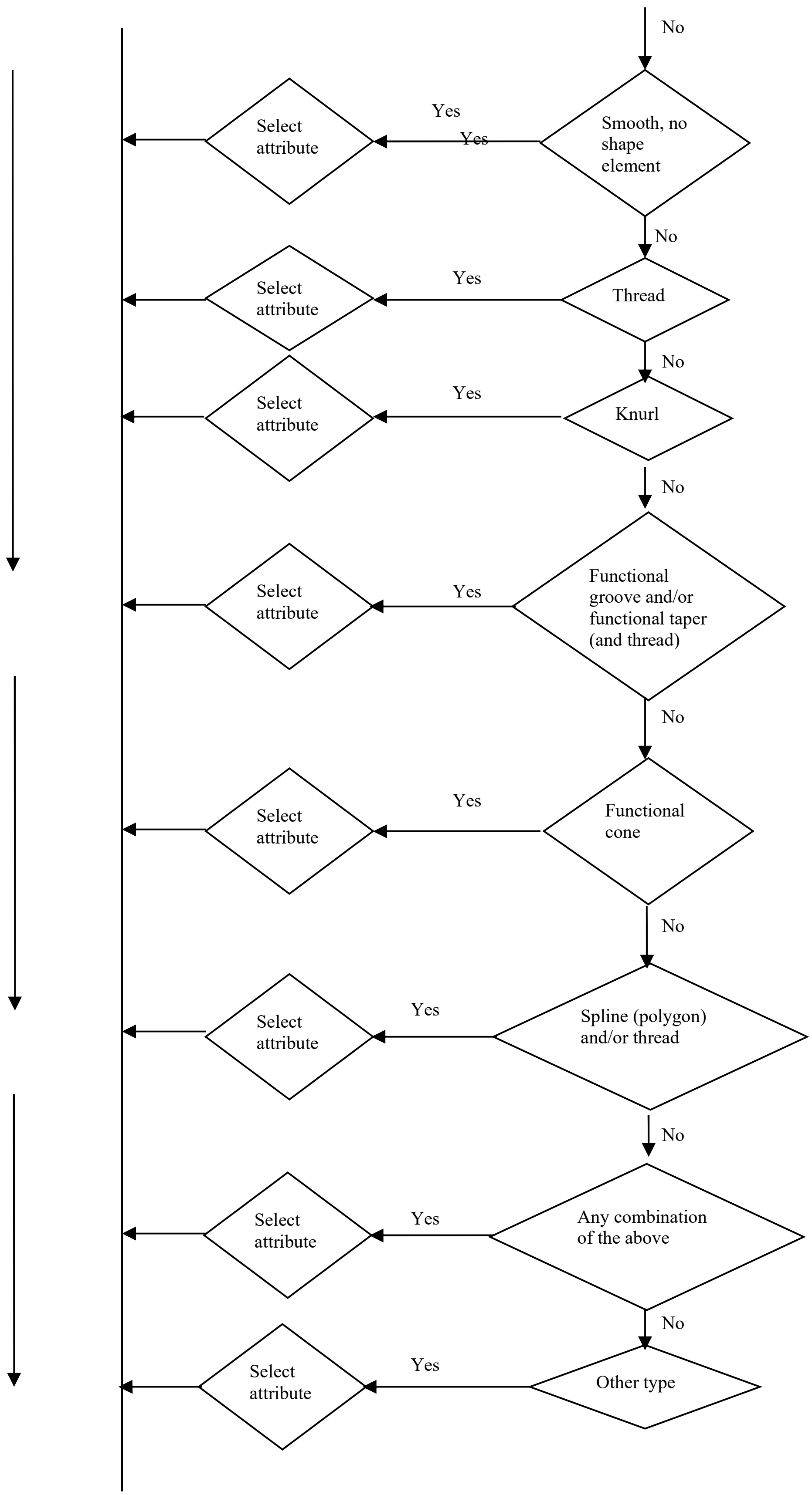
APPENDIX A: PROGRAM ALGORITHM STRUCTURE OF CODING SCHEME [12]

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Functional cone
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Other type
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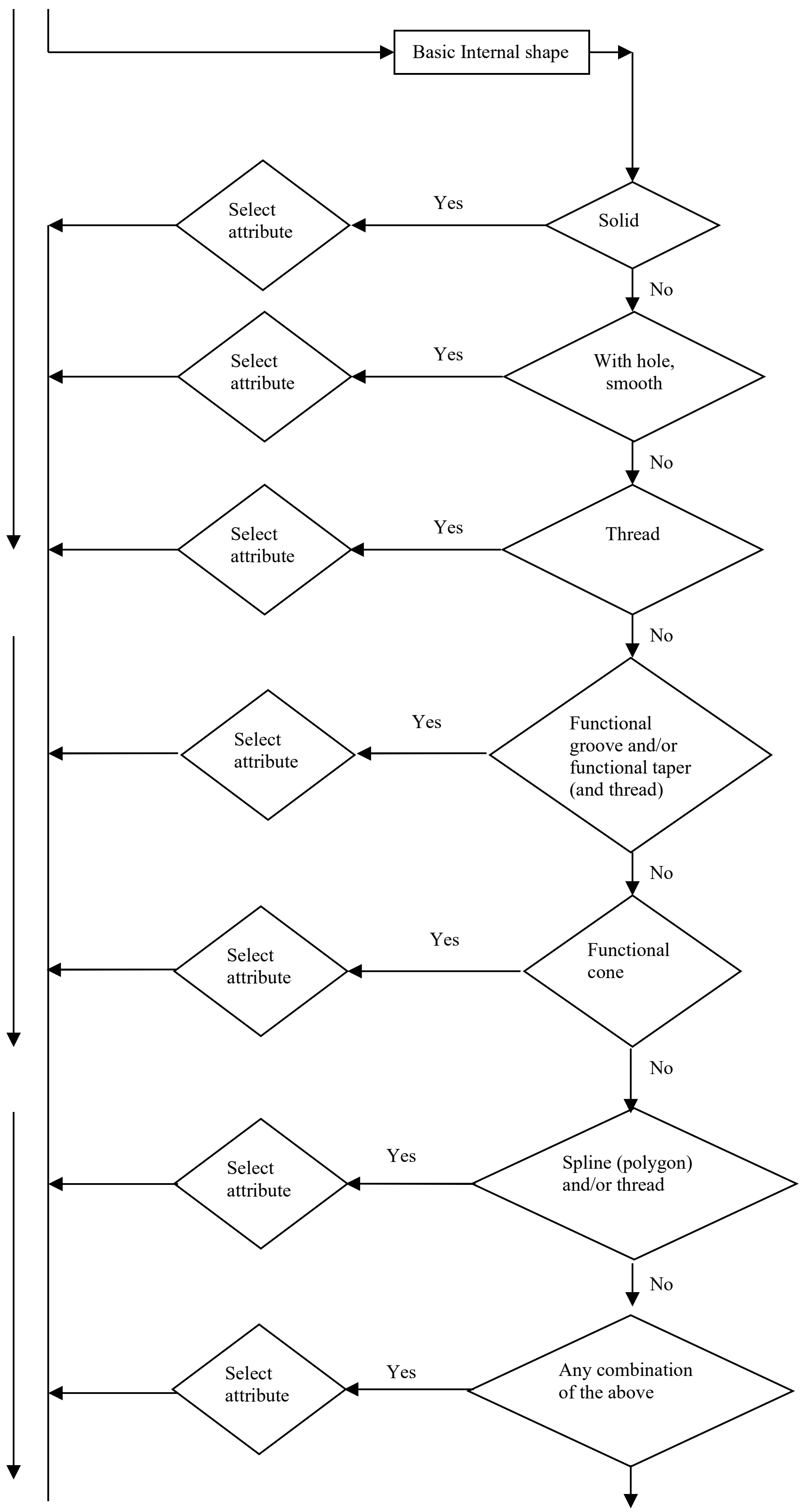
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No
Spline (polygon) and/or thread
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No
Any combination of the above
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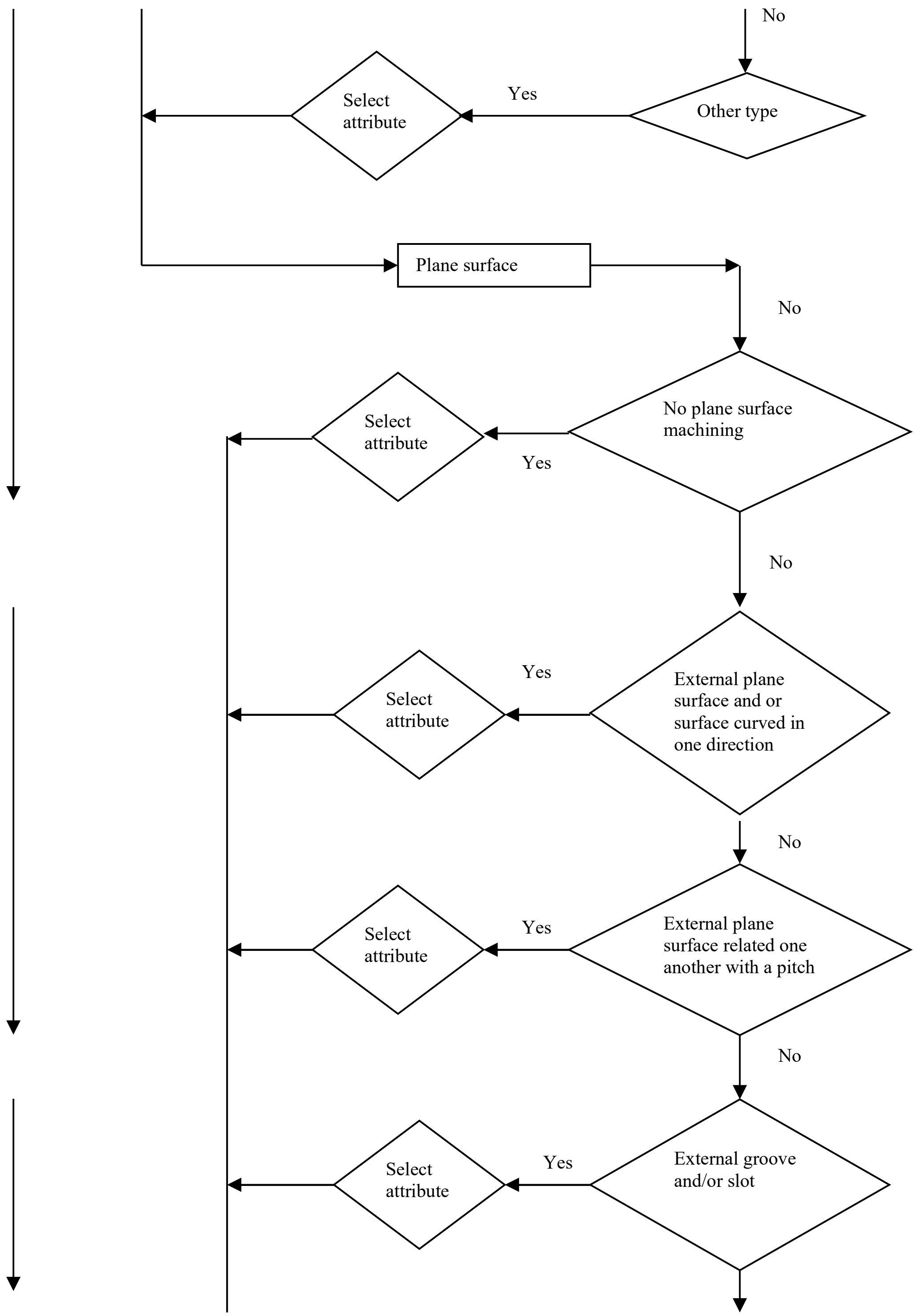
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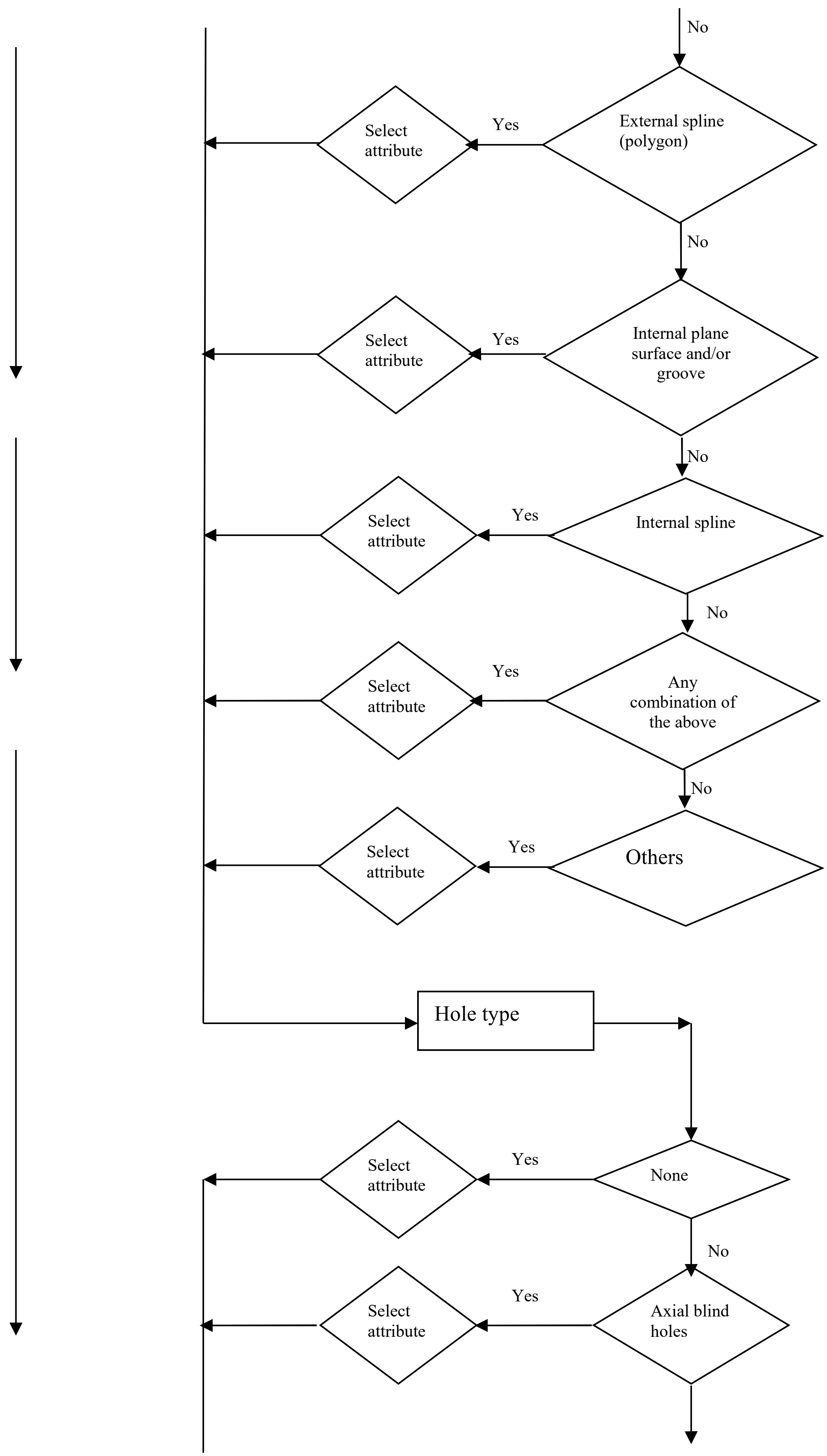
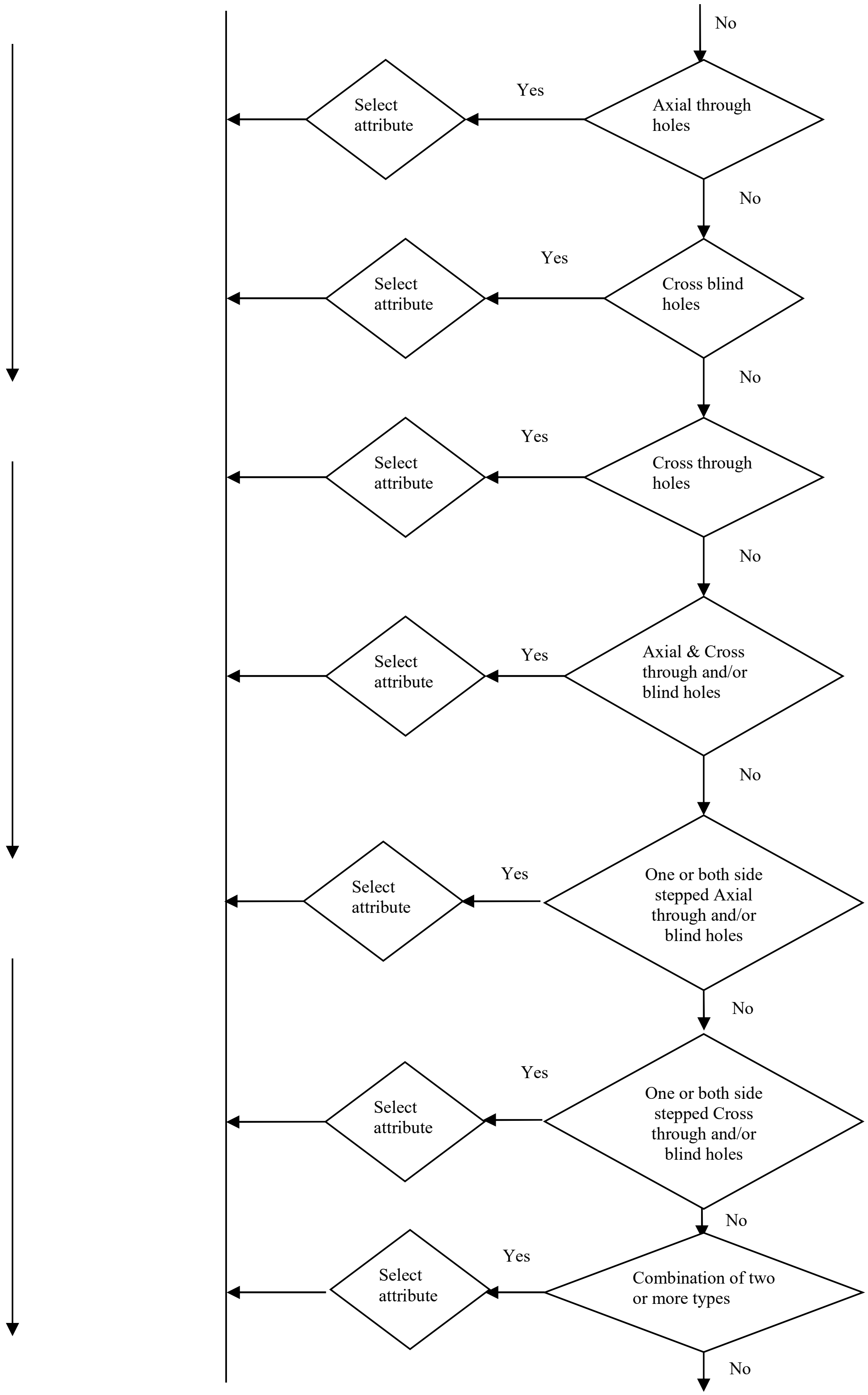
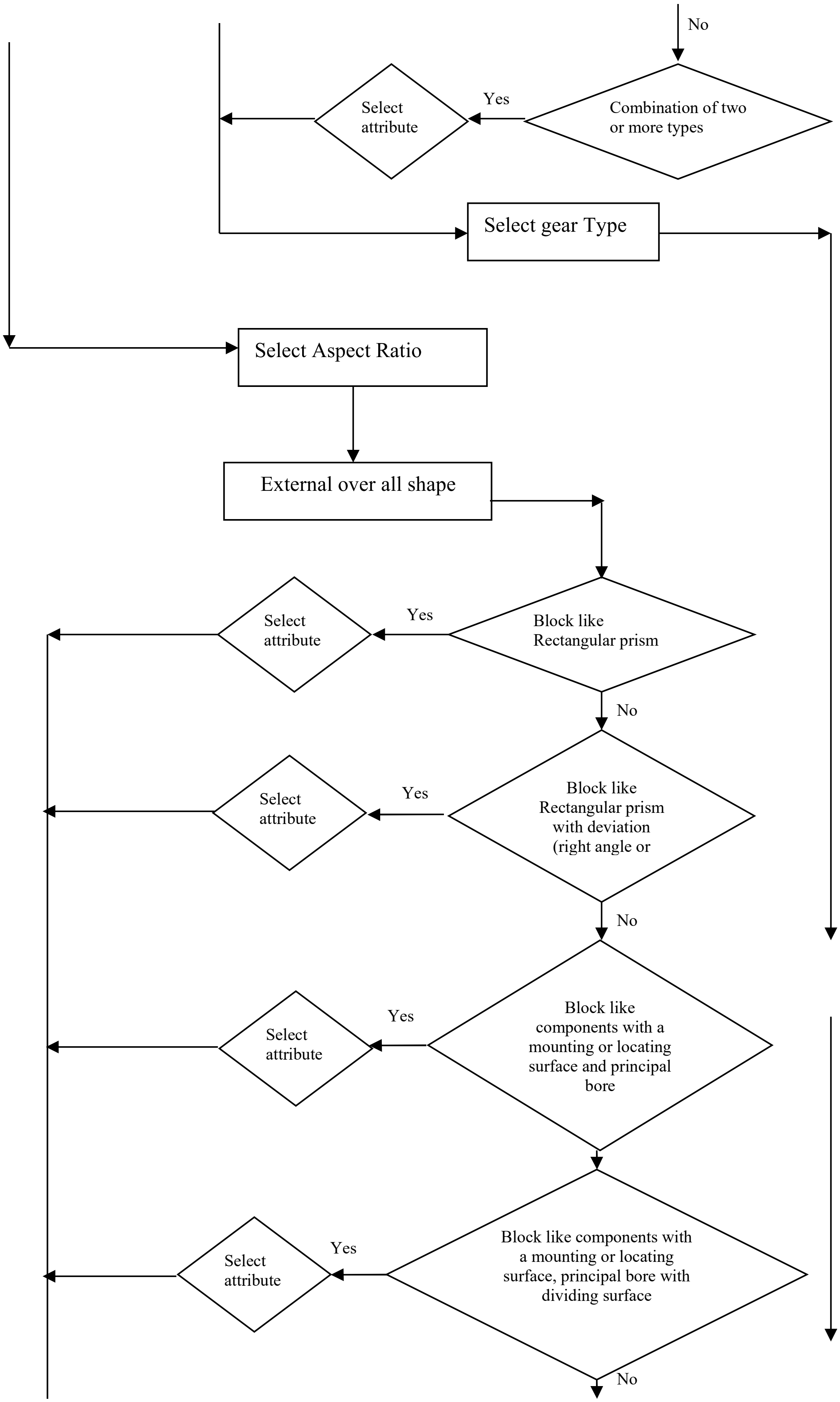
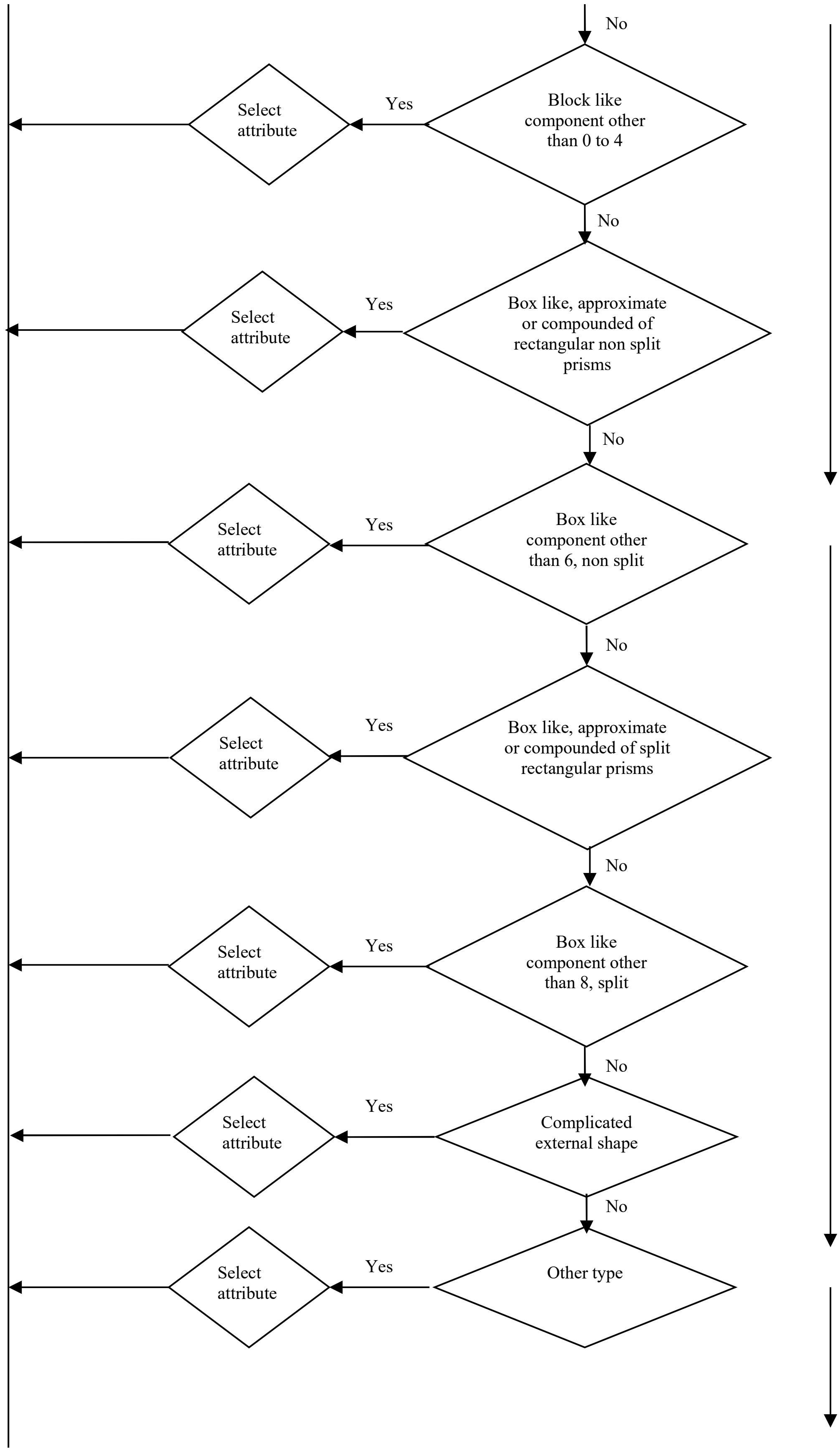
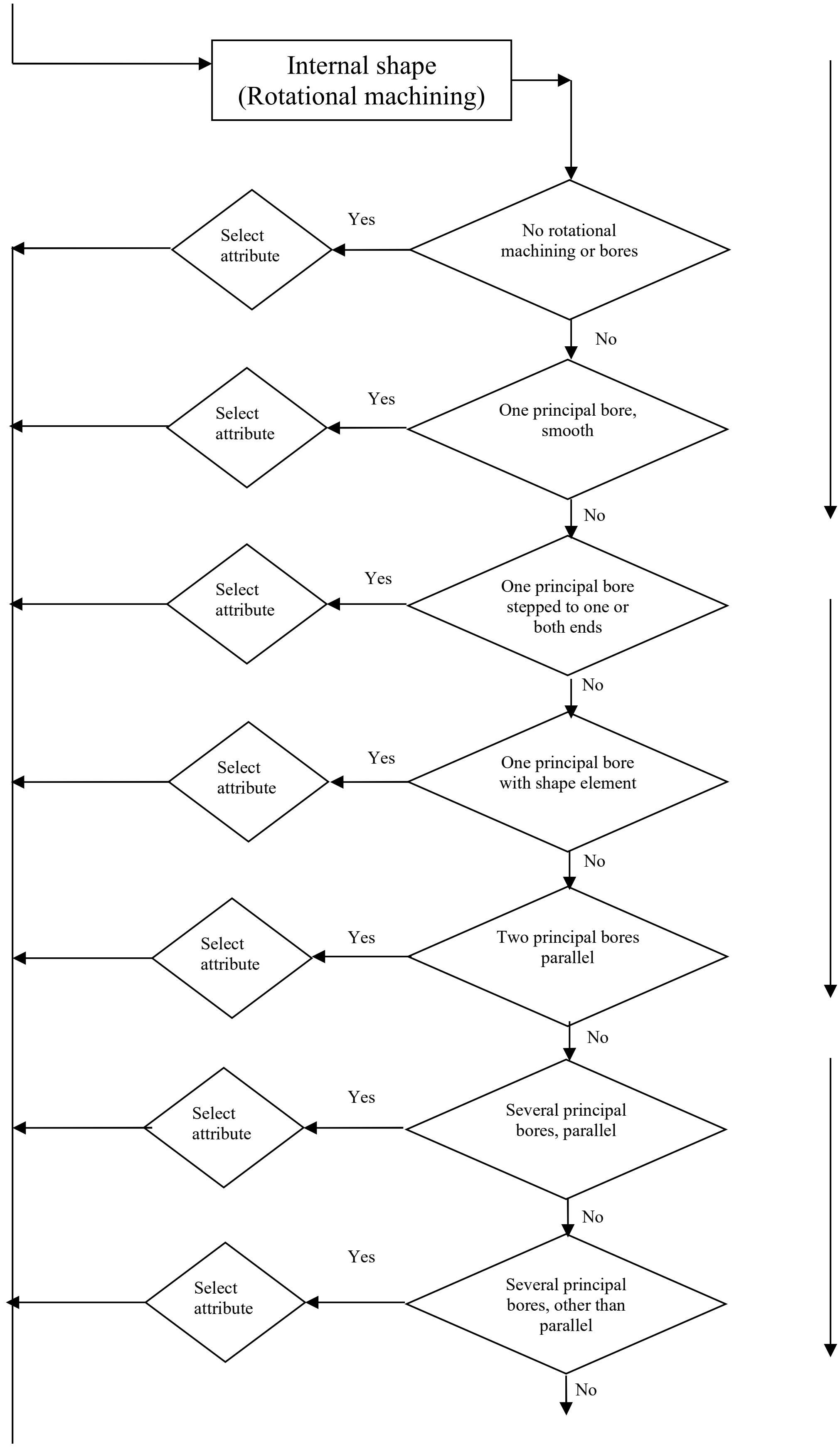
Yes
Other type
Plane surface
No
Select attribute
No plane surface machining
Yes
No
Yes
Select attribute
External plane surface and or surface curved in one direction
No
Select attribute
Yes
External plane surface related one another with a pitch
No
Yes
Select attribute
External groove and/or slot

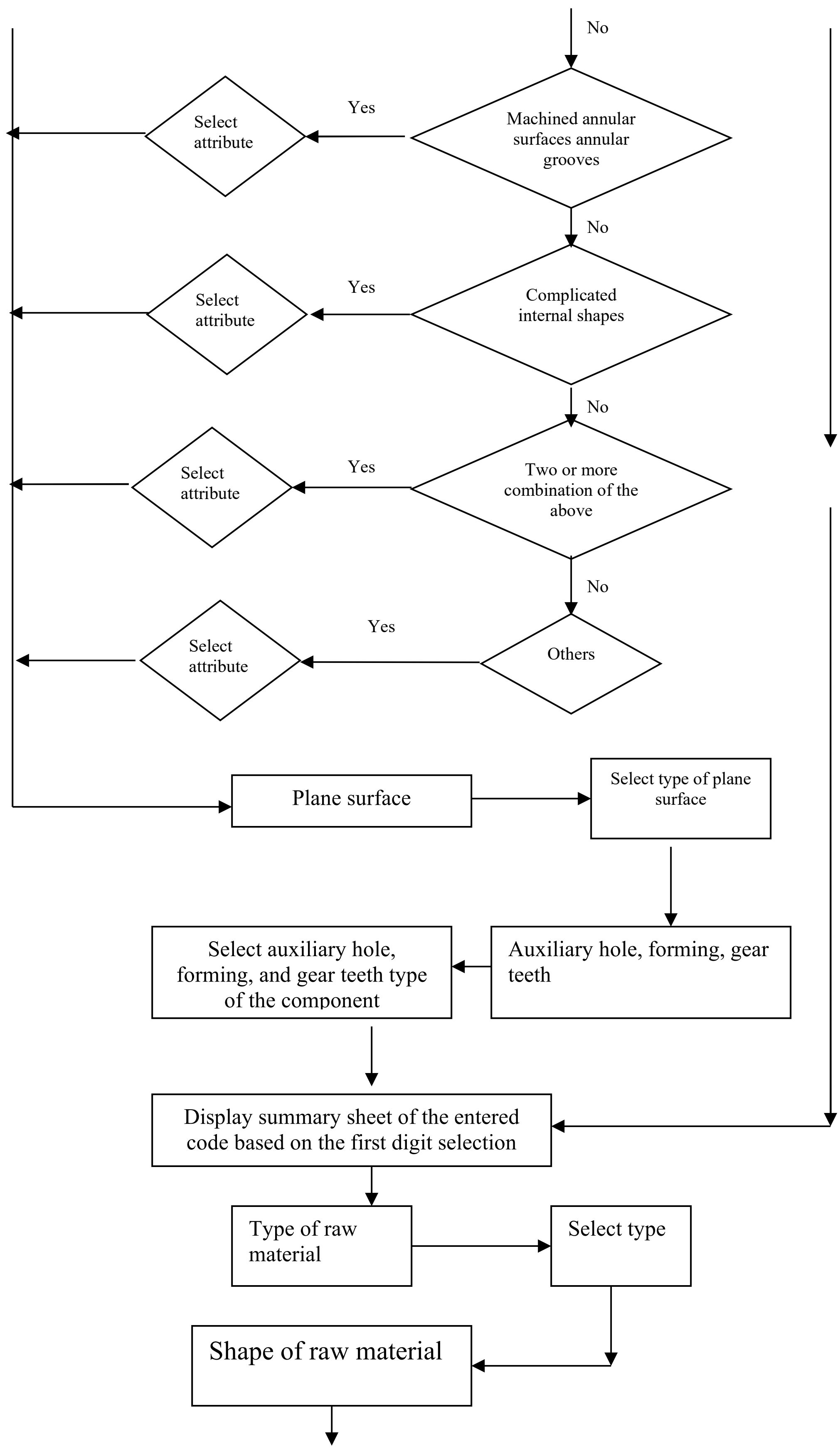

No
External spline (polygon)
Yes
Select attribute
No
Internal plane surface and/or groove
Yes
Select attribute
No
Internal spline
Yes
Select attribute
No
Any combination of the above
Yes
Select attribute
No
Others
Yes
Select attribute
Hole type
None
Yes
Select attribute
No
Axial blind holes
Yes
Select attribute

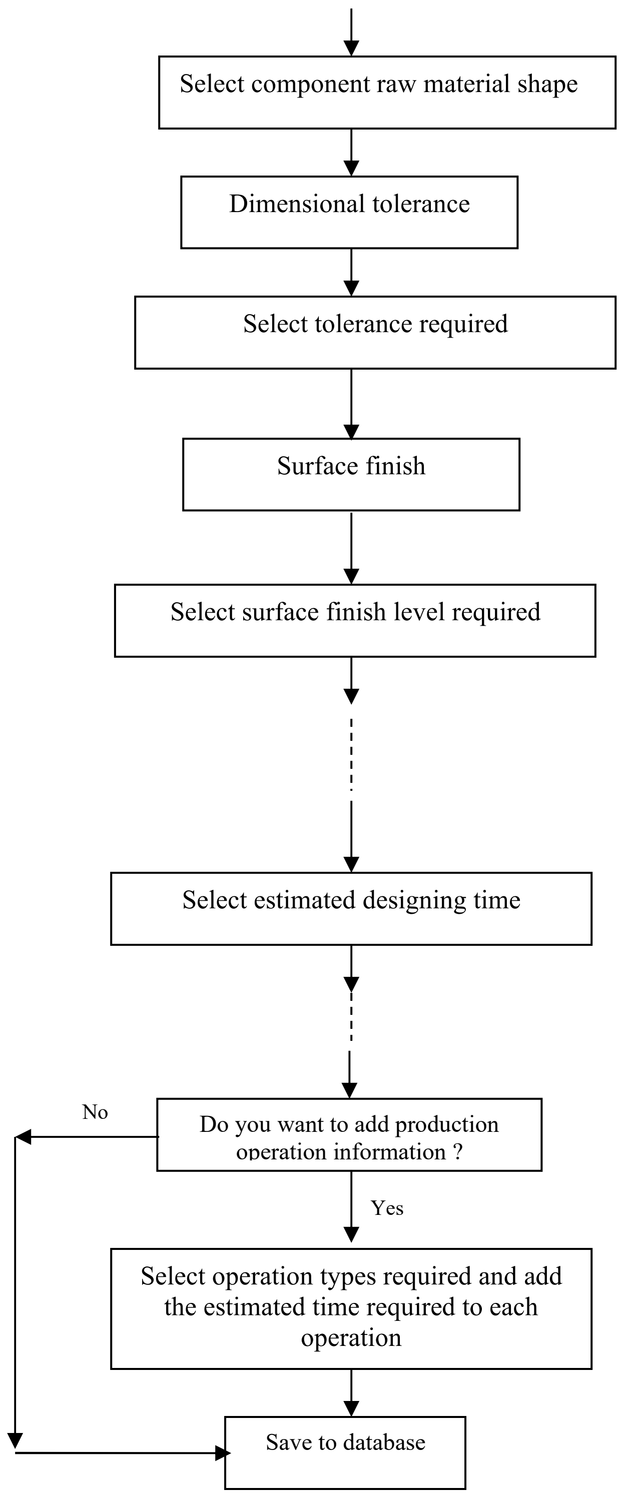

No
Axial through holes
Yes
Select attribute
No
Cross blind holes
Yes
Select attribute
No
Cross through holes
Yes
Select attribute
No
Axial & Cross through and/or blind holes
Yes
Select attribute
No
One or both side stepped Axial through and/or blind holes
Yes
Select attribute
No
One or both side stepped Cross through and/or blind holes
Yes
Select attribute
No
Combination of two or more types
Yes
Select attribute
No


No
Select attribute
Yes
Combination of two or more types
Select gear Type
Select Aspect Ratio
External over all shape
Select attribute
Yes
Block like Rectangular prism
No
Select attribute
Yes
Block like Rectangular prism with deviation (right angle or
No
Select attribute
Yes
Block like components with a mounting or locating surface and principal bore
Select attribute
Yes
Block like components with a mounting or locating surface, principal bore with dividing surface
No


No
Block like component other than 0 to 4
Yes
Select attribute
No
Box like, approximate or compounded of rectangular non split prisms
Yes
Select attribute
No
Box like component other than 6, non split
Yes
Select attribute
No
Box like, approximate or compounded of split rectangular prisms
Yes
Select attribute
No
Box like component other than 8, split
Yes
Select attribute
No
Complicated external shape
Yes
Select attribute
No
Other type
Yes
Select attribute

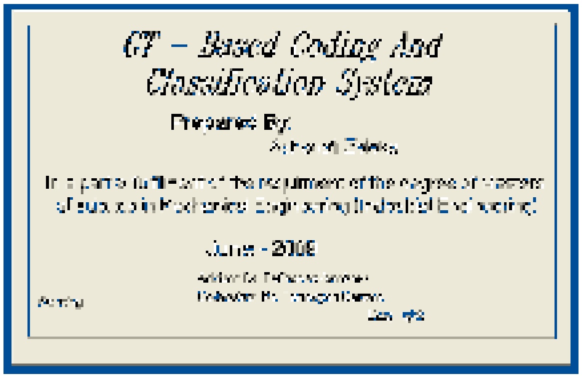

Internal shape
(Rotational machining)
No rotational machining or bores
Yes
Select attribute
No
One principal bore, smooth
Yes
Select attribute
No
One principal bore stepped to one or both ends
Yes
Select attribute
No
One principal bore with shape element
Yes
Select attribute
No
Two principal bores parallel
Yes
Select attribute
No
Several principal bores, parallel
Yes
Select attribute
No
Several principal bores, other than parallel
Yes
Select attribute
No


No
Machined annular surfaces annular grooves
Yes
Select attribute
No
Complicated internal shapes
Yes
Select attribute
No
Two or more combination of the above
Yes
Select attribute
No
Others
Yes
Select attribute
Plane surface
Select type of plane surface
Auxiliary hole, forming, gear teeth
Select auxiliary hole, forming, and gear teeth type of the component
Display summary sheet of the entered code based on the first digit selection
Type of raw material
Select type
Shape of raw material

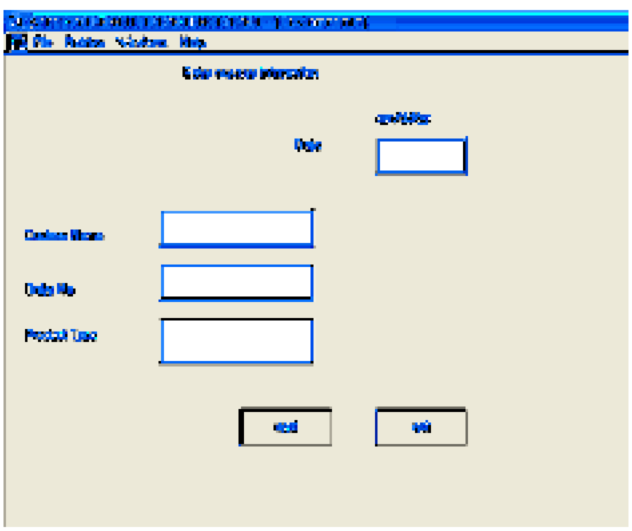

Select component raw material shape
Dimensional tolerance
Select tolerance required
Surface finish
Select surface finish level required
Select estimated designing time
No
Do you want to add production operation information ?
Yes
Select operation types required and add the estimated time required to each operation
Save to database

APPENDIX B: USER INTERFACE OF THE CCS SYSTEM WITH THE CORRESPONDING PROGRAM CODES

```
Option Explicit
Public LoginSucceeded As Boolean

Private Sub cmdCancel_Click()
   LoginSucceeded = False
   Unload MDIForm1
   Unload Me
End Sub
Private Sub cmdOK_Click()
   Static h As Integer
   If txtPassword = "ashu" Then
      LoginSucceeded = True
      frmSplash.Show vPDCodal
      Unload Me
   Else
      h = h + 1
      MsgBox "Invalid Password, try again!", vbCritical, "Ashudalsoft"
      txtPassword.SetFocus
      'SendKeys "{Home}+{End}"
      If h >= 3 Then
         MsgBox "Invalid Password, Over!", vbCritical, "Ashudalsoft"
         LoginSucceeded = False
         Unload MDIForm1
         Unload Me
      End If
   End If
End Sub

Private Sub Form_Load()
Load MDIForm1
frmLogin.Move 5000, 5000
End Sub
```

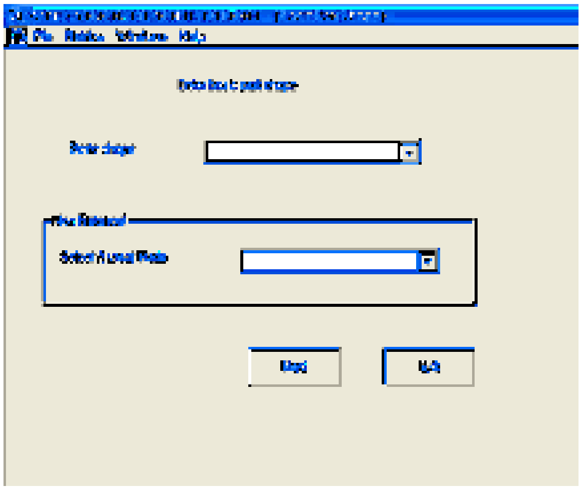



```
Option Explicit

Private Sub Form_Click()
    Unload Me
End Sub

Private Sub Form_KeyPress(KeyAscii As Integer)
    Unload Me
End Sub

Private Sub Frame1_Click()
    Unload Me
End Sub

Private Sub Timer1_Timer()
'Unload Me
End Sub
```



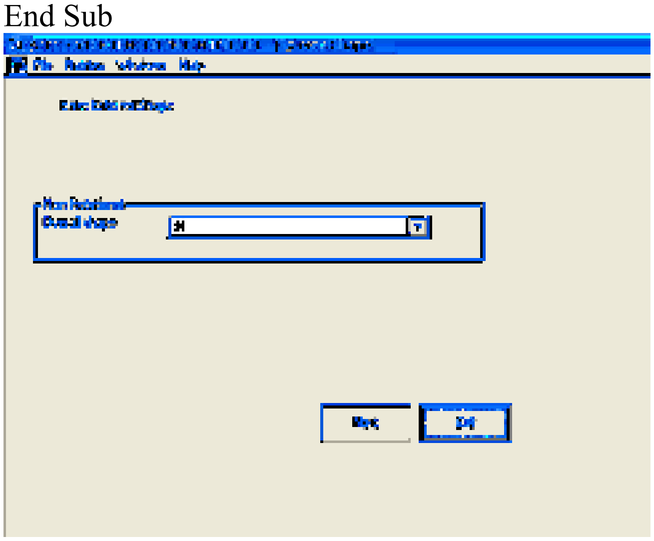
```
Private Sub exit_Click()
```

```
    Unload Me
End Sub

Private Sub next_Click()
    Static a As Boolean
    a = False

    If Text1.Text = "" Then
        MsgBox "Please Enter CUSTOMER NAME", vbInformation, "misgudalsoft"
    ElseIf Text2.Text = "" Then
        MsgBox "Please Enter ORDER NUMBER", vbInformation, "misgudalsoft"
    ElseIf Text3.Text = "" Then
        MsgBox "Please Enter DRAWING NUMBER", vbInformation, "misgudalsoft"
    ElseIf Text4.Text = "" Then
        MsgBox "Please Enter DATE", vbInformation, "misgudalsoft"
    Else
        On Error GoTo llk
        Dim dat As Date
        Dim cname, orderno, drawingno As String
        cname = Text1.Text
        orderno = Text2.Text
        drawingno = Text3.Text
        If Text4.Text <> "" Then
            dat = CDate(Text4.Text)
        End If
        a = True

        BasicPartShape.Show
        CustomerInfo.Hide
llk:
        If a = False Then
            MsgBox "Please Enter the Date with the above format only", vbInformation,
"misgudalsoft"
        End If
    End If
End Sub
```



```
Private Sub Combo1_Click()
   If Combo1.ListIndex = 0 Then
      Frame1.Visible = True
      Frame2.Visible = False
   Else
      Frame1.Visible = False
      Frame2.Visible = True
   End If

End Sub


Private Sub exit_Click()
   Unload Me
End Sub

Private Sub next_Click()
   If Combo1.ListIndex = 0 Then
      If Combo2.ListIndex = 0 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "0" +
vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
      ElseIf Combo2.ListIndex = 1 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "1" +
vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
      ElseIf Combo2.ListIndex = 2 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "2" +
vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
      ElseIf Combo2.ListIndex = 3 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "3" +
vbCrLf
```

```
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        Else
        End If
    Else
        If Combo3.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "4" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo3.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "5" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo3.ListIndex = 2 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "6" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo3.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Aspect ratio" + vbTab + "7" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        Else
        End If
    End If


    BasicPartShape.Hide
    ExternalShape.Show

End Sub
```

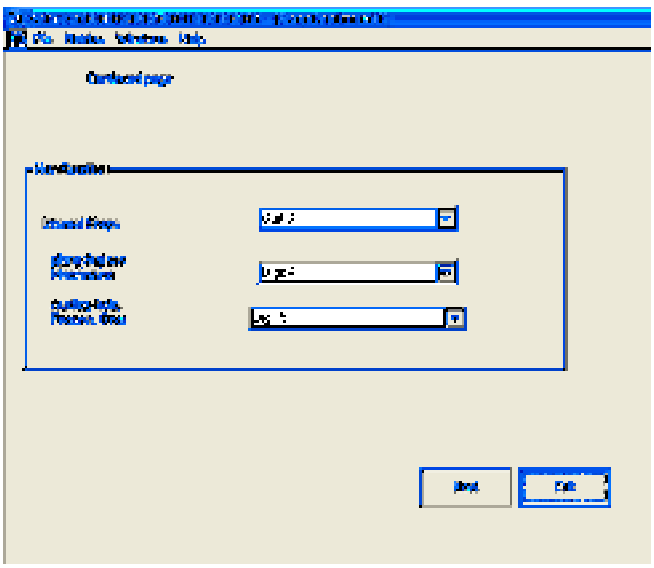


```
Private Sub exit_Click()
    Unload Me
End Sub
```

```
Private Sub Form_Load()
   If BasicPartShape.Combo1.ListIndex = 0 Then
      Frame1.Visible = True
      Frame2.Visible = False
   Else
      Frame1.Visible = False
      Frame2.Visible = True
   End If
End Sub

Private Sub next_Click()

   If BasicPartShape.Combo1.ListIndex = 0 Then
      If Combo1.ListIndex = 0 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Cylindrical Shape Explanation" +
vbTab + "0" + vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
      ElseIf Combo1.ListIndex = 1 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Cylindrical Shape Explanation" +
vbTab + "1" + vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
      ElseIf Combo1.ListIndex = 2 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Cylindrical Shape Explanation" +
vbTab + "2" + vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
      ElseIf Combo1.ListIndex = 3 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "Cylindrical Shape Explanation" +
vbTab + "3" + vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
      Else
      End If
      If Combo2.ListIndex = 0 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "0" +
vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
      ElseIf Combo2.ListIndex = 1 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "1" +
vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
      ElseIf Combo2.ListIndex = 2 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "2" +
vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
      ElseIf Combo2.ListIndex = 3 Then
         ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "3" +
vbCrLf
         FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
      ElseIf Combo2.ListIndex = 4 Then
```

```
            ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "4" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo2.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "5" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo2.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "6" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo2.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "7" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo2.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "External shape" + vbTab + "8" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        Else
        End If
    Else
        If Combo3.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "0" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo3.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "1" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo3.ListIndex = 2 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "2" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
        ElseIf Combo3.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "3" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo3.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "4" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo3.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "5" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo3.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "6" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo3.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "7" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo3.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "8" + vbCrLf
```

```
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        ElseIf Combo3.ListIndex = 9 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "9" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "9"
        ElseIf Combo3.ListIndex = 10 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "A" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "A"
        ElseIf Combo3.ListIndex = 11 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "d2" + vbTab + "B" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "B"
        Else
        End If
End If

    ExternalShape.Hide
    PageContinued1.Show

End Sub
```



```
Private Sub exit_Click()
    Unload Me
End Sub

Private Sub Form_Load()
    If BasicPartShape.Combo1.ListIndex = 0 Then
        Frame1.Visible = True
        Frame2.Visible = False
    Else
        Frame1.Visible = False
        Frame2.Visible = True
    End If
```

```
End Sub

Private Sub next_Click()
    If BasicPartShape.Combo1.ListIndex = 0 Then
        If Combo1.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "0" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo1.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "1" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo1.ListIndex = 2 Then
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "2" +
vbCrLf
        ElseIf Combo1.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "3" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo1.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "4" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo1.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "5" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo1.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "6" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo1.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "7" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        Else
        End If
        If Combo2.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "0" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo2.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "1" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo2.ListIndex = 2 Then
```

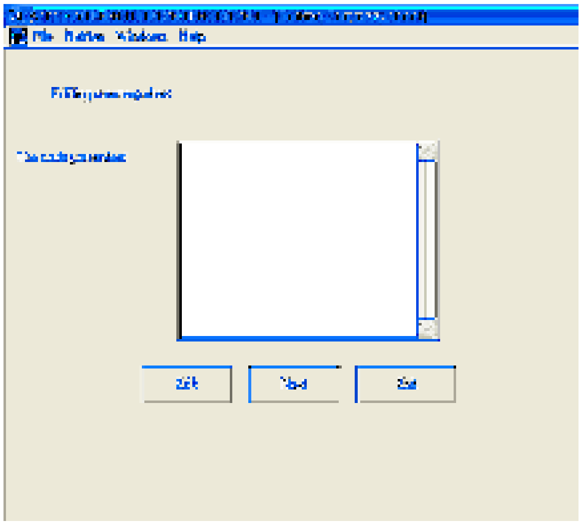
```
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "2" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
        ElseIf Combo2.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "3" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo2.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "4" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo2.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "5" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo2.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "6" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo2.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "7" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo2.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface" + vbTab + "8" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        Else
        End If
        If Combo3.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "0" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo3.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "1" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo3.ListIndex = 2 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "2" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
        ElseIf Combo3.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "3" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo3.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "4" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo3.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "5" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo3.ListIndex = 6 Then
```

```
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "6" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo3.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "7" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo3.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "8" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        ElseIf Combo3.ListIndex = 9 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "hole type" + vbTab + "9" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "9"
        Else
        End If
        If Combo4.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Gear type" + vbTab + "0" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo4.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Gear type" + vbTab + "1" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo4.ListIndex = 2 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Geer type" + vbTab + "2" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
        ElseIf Combo4.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Gear type" + vbTab + "3" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo4.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Geer type" + vbTab + "4" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo4.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Gear type" + vbTab + "5" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo4.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Gear type" + vbTab + "6" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo4.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Gear type" + vbTab + "7" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo4.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Gear type" + vbTab + "8" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        Else
        End If
    Else
        If Combo5.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "0" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo5.ListIndex = 1 Then
```

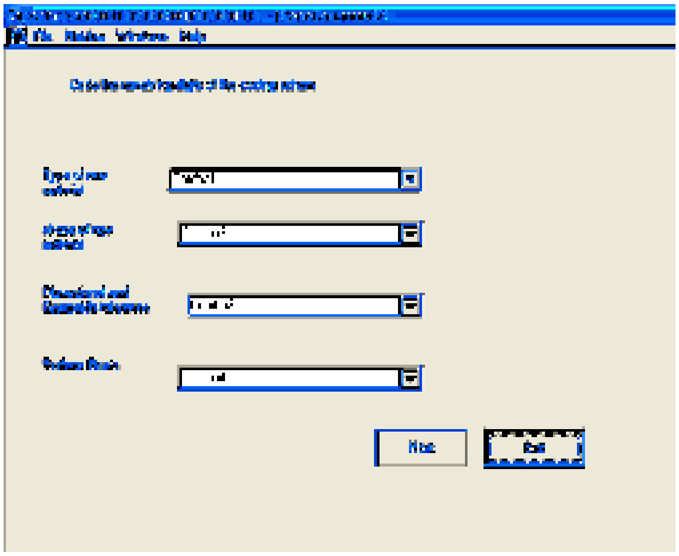
```
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "1" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo5.ListIndex = 2 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "2" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
        ElseIf Combo5.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "3" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo5.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "4" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo5.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "5" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo5.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "6" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo5.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "7" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo5.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "8" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        ElseIf Combo5.ListIndex = 9 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "9" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "9"
        ElseIf Combo5.ListIndex = 10 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "internal Shape" + vbTab + "A" +
vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "A"
        Else
        End If
        If Combo6.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "0" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo6.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "1" + vbCrLf
```

```
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo6.ListIndex = 2 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "2" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
        ElseIf Combo6.ListIndex = 3 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "3" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo6.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "4" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo6.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "5" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo6.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "6" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo6.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "7" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo6.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "8" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        ElseIf Combo6.ListIndex = 9 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "plane Surface Machining" + vbTab
+ "9" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "9"
        Else
        End If
        If Combo7.ListIndex = 0 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "0" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "0"
        ElseIf Combo7.ListIndex = 1 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "1" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "1"
        ElseIf Combo7.ListIndex = 2 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "2" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "2"
        ElseIf Combo7.ListIndex = 3 Then
```

```
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "3" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "3"
        ElseIf Combo7.ListIndex = 4 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "4" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "4"
        ElseIf Combo7.ListIndex = 5 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "5" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "5"
        ElseIf Combo7.ListIndex = 6 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "6" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "6"
        ElseIf Combo7.ListIndex = 7 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "7" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "7"
        ElseIf Combo7.ListIndex = 8 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "8" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "8"
        ElseIf Combo7.ListIndex = 9 Then
            ESsheet.Text1.Text = ESsheet.Text1.Text + "Auxiliary hole, Forming, Gear
teeth" + vbTab + "9" + vbCrLf
            FinalizingPage.Text3.Text = FinalizingPage.Text3.Text + "9"
        Else
        End If
End If

    PageContinued1.Hide
    ESsheet.Show
    FinalizingPage.Hide

End Sub
```



```
Private Sub Edit_Click()
Me.Hide
Text1.Text = ""
FinalizingPage.Text3 = ""
FinalizingPage.Text4 = ""
Unload BasicPartShape
Unload ExternalShape
Unload PageContinued1
CustumerInfo.Show
End Sub

Private Sub exit_Click()
    Unload Me
End Sub

Private Sub next_Click()
    FinalizingPage.Hide
    FinalizingPage.Text1.Text = Text1.Text

    ESsheet.Hide
    PageContinued2.Show

End Sub
```

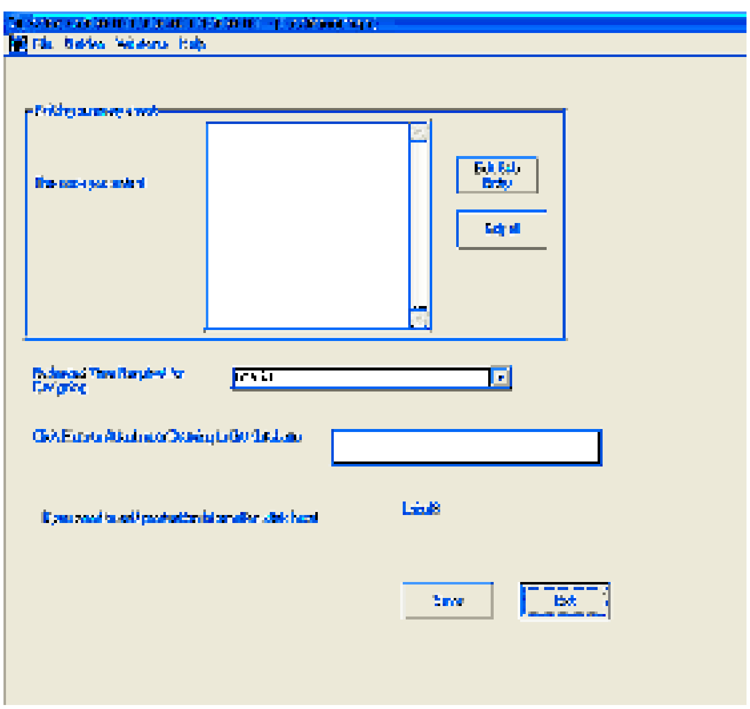


```
Private Sub exit_Click()
    Unload Me
End Sub

Private Sub next_Click()
        If Combo1.ListIndex = 0 Then
           FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "0" + vbCrLf
           FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "0"
        ElseIf Combo1.ListIndex = 1 Then
           FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "1" + vbCrLf
           FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "1"
        ElseIf Combo1.ListIndex = 2 Then
           FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "2" + vbCrLf
           FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "2"
        ElseIf Combo1.ListIndex = 3 Then
           FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "3" + vbCrLf
           FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "3"
        ElseIf Combo1.ListIndex = 4 Then
           FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "4" + vbCrLf
           FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "4"
        ElseIf Combo1.ListIndex = 5 Then
           FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "5" + vbCrLf
           FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "5"
        ElseIf Combo1.ListIndex = 6 Then
           FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "6" + vbCrLf
```

```
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "6"
        ElseIf Combo1.ListIndex = 7 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "7" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "7"
        ElseIf Combo1.ListIndex = 8 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "8" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "8"
        ElseIf Combo1.ListIndex = 9 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Type of raw material"
+ vbTab + "9" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "9"
        Else
        End If
        If Combo2.ListIndex = 0 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "0" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "0"
        ElseIf Combo2.ListIndex = 1 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "1" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "1"
        ElseIf Combo2.ListIndex = 2 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "2" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "2"
        ElseIf Combo2.ListIndex = 3 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "3" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "3"
        ElseIf Combo2.ListIndex = 4 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "4" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "4"
        ElseIf Combo2.ListIndex = 5 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "5" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "5"
        ElseIf Combo2.ListIndex = 6 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "6" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "6"
        ElseIf Combo2.ListIndex = 7 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Shape of raw
material" + vbTab + "7" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "7"
        Else
```

```
        End If
        If Combo3.ListIndex = 0 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Dimensional
tolerance" + vbTab + "0" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "0"
        ElseIf Combo3.ListIndex = 1 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Dimensional
tolerance" + vbTab + "1" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "1"
        ElseIf Combo3.ListIndex = 2 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Dimensional
tolerance" + vbTab + "2" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "2"
        ElseIf Combo3.ListIndex = 3 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Dimensional
tolerance" + vbTab + "3" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "3"
        ElseIf Combo3.ListIndex = 4 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Dimensional
tolerance" + vbTab + "4" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "4"
        Else
        End If
        If Combo4.ListIndex = 0 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "0" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "0"
        ElseIf Combo4.ListIndex = 1 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "1" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "1"
        ElseIf Combo4.ListIndex = 2 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "2" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "2"
        ElseIf Combo4.ListIndex = 3 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "3" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "3"
        ElseIf Combo4.ListIndex = 4 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "4" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "4"
        ElseIf Combo4.ListIndex = 5 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "5" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "5"
        ElseIf Combo4.ListIndex = 6 Then
```

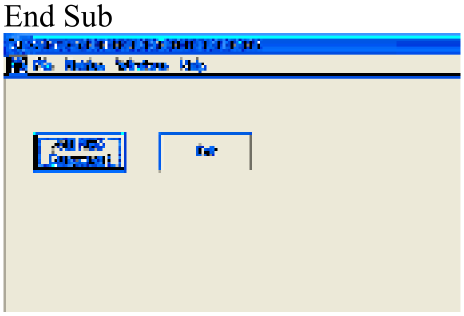
```
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "6" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "6"
        ElseIf Combo4.ListIndex = 7 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "7" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "7"
        ElseIf Combo4.ListIndex = 8 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "8" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "8"
        ElseIf Combo1.ListIndex = 9 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "9" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "9"
        ElseIf Combo1.ListIndex = 10 Then
            FinalizingPage.Text1.Text = FinalizingPage.Text1.Text + "Surface finish
(Accuracy)" + vbTab + "A" + vbCrLf
            FinalizingPage.Text4.Text = FinalizingPage.Text4.Text + "A"
        Else
        End If


    PageContinued2.Hide
    FinalizingPage.Show

End Sub
```



```
Private Sub Command1_Click()

Me.Hide
Text1.Text = ""
Text1.Text = ESsheet.Text1.Text
Text4.Text = ""
Unload PageContinued2
Load PageContinued2

End Sub

Private Sub Command2_Click()

Unload openPicture
Unload BasicPartShape
Unload ESsheet
Unload ExternalShape
Unload FinalizingPage
Unload PageContinued1
Unload PageContinued2
Unload ProductionInfo

Unload Me
CustomerInfo.Show

End Sub

Private Sub exit_Click()
   Unload Me
End Sub

Private Sub Label1_Click()
FinalizingPage.Hide
ProductionInfo.Show

End Sub

Private Sub Label5_Click()
CommonDialog1.Filter = "all file|*.*"
CommonDialog1.ShowOpen
Text2.Text = CommonDialog1.FileName


'FinalizingPage.Hide
'PicturePage.Show

End Sub
```

```
Private Sub Label5_MouseDown(Button As Integer, Shift As Integer, X As Single, Y As
Single)
Label5.BackColor = vbYellow
'Label5.MousePointer.

End Sub

Private Sub Label5_MouseMove(Button As Integer, Shift As Integer, X As Single, Y As
Single)
Label5.BackColor = vbBlue
End Sub

Private Sub Label5_MouseUp(Button As Integer, Shift As Integer, X As Single, Y As
Single)
Label5.BackColor = vbWhite
End Sub

Private Sub Save_Click()
'On Error Resume Next
        Dim date As Date
        Dim textdate, cname, orderno, drawingno As String
        cname = CustomerInfo.Text1.Text
        orderno = CustomerInfo.Text2.Text
        protype = CustomerInfo.Text3.Text
        date = CustomerInfo.Text4.Text
        textdate = CStr(dat)
    'Dim CHECK As New ADODB.Recordset
    'Dim a As New ADODB.Connection
    'Dim b As New ADODB.Recordset
    'a.open "provider=microsoft.jet.oledb.4.0;data source=" + App.Path +
"\GTCCSDataBase.mdb"
    'CHECK.open "select * from employee where(EID=" + CStr(ei) + ")", a
        'If CHECK.BOF Or CHECK.EOF Then
            Dim a1 As New ADODB.Connection
            Dim rec As New ADODB.Recordset
            a1.open "provider=microsoft.jet.oledb.4.0;data source=" + App.Path +
"\GTCCSDataBase.mdb"
            Y = MsgBox("You are inserting into GTCCSDataBase(Date,[Custmer
Name],[Order No],[Product Type]) Values(" + CStr(dat) + ",'" + cname + "','" + orderno
+ "','" + protype + ")", vbOKCancel, "misgudalsoft")
            If Y = 1 Then
                rec.open "Insert into GTCCSDataBase([Date],[Drawing Path],[Custmer
Name],[Order No],[Product Type],[Form Code],[Supplementary Code],[Estimated
Desinginig Time],Facing,Turning,Drilling,Threading,Grooving,Boring,[Milling
Keyway],[Worm thread cutting],[Cutting the gear teeth],[Mill the flat
suface],Lapping,Slotting,Shearing,Rolling,Forming,[Surface
griding],Engraving,Chamfering,Welding,[Shaping, teeth],Sawing,Inspection,Others)" _
```

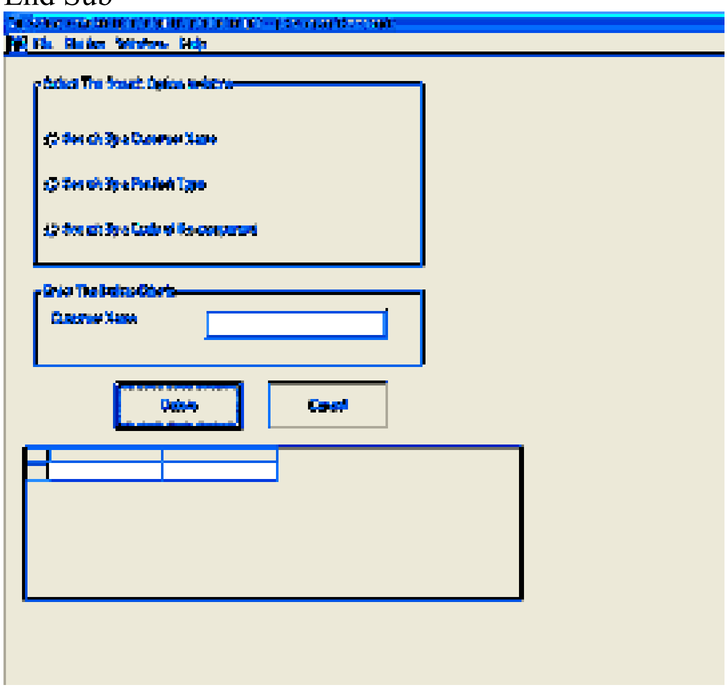
```
        & " Values('" + textdate + "','" + Text2.Text + "','" + cname + "','" + orderno +
"','" + protype + "','" + Text3.Text + "','" + Text4.Text + "','" + Combo1.Text + "'," +
ProductionInfo.Text1.Text + "," + ProductionInfo.Text2.Text + "," +
ProductionInfo.Text3.Text + "," + ProductionInfo.Text4.Text + "," +
ProductionInfo.Text5.Text + "," + ProductionInfo.Text6.Text + "," +
ProductionInfo.Text7.Text + "," + ProductionInfo.Text8.Text + "," +
ProductionInfo.Text9.Text + "," + ProductionInfo.Text10.Text + "," _
        & ProductionInfo.Text11.Text + "," + ProductionInfo.Text12.Text + "," +
ProductionInfo.Text13.Text + "," + ProductionInfo.Text14.Text + "," +
ProductionInfo.Text15.Text + "," + ProductionInfo.Text16.Text + "," +
ProductionInfo.Text17.Text + "," + ProductionInfo.Text18.Text + "," +
ProductionInfo.Text19.Text + "," + ProductionInfo.Text20.Text + "," +
ProductionInfo.Text21.Text + "," + ProductionInfo.Text22.Text + "," +
ProductionInfo.Text23.Text + ")", a1

      End If
    'Else
    '   MsgBox "ID cannot be repeated", vbInformation, "misgudalsoft"
    'End If
FinalizingPage.Hide
Recovery.Show

End Sub
```



```
Private Sub exit_Click()
  Unload Me
End Sub

Private Sub new_Click()

Unload openPicture
'openPicture.Text1.Text = ""
'
Unload CustomerInfo
'CustomerInfo.Text1 = ""
'CustomerInfo.Text2 = ""
'CustomerInfo.Text3 = ""
'CustomerInfo.Text4 = ""
'
Unload BasicPartShape
```

```
'BasicPartShape.Combo1.Text = ""
'BasicPartShape.Combo2.Text = ""
'BasicPartShape.Combo3.Text = ""
'
Unload ESsheet
'ESsheet.Text1.Text = ""
'
Unload ExternalShape
'ExternalShape.Combo1.Text = ""
'ExternalShape.Combo2.Text = ""
'ExternalShape.Combo3.Text = ""
'
Unload FinalizingPage
'FinalizingPage.Text1.Text = ""
'FinalizingPage.Text2.Text = ""
'FinalizingPage.Text3.Text = ""
'FinalizingPage.Text4.Text = ""
'FinalizingPage.Label3.Caption = ""
'FinalizingPage.Combo1.Text = ""
'
Unload PageContinued1
'PageContinued1.Combo1.Text = ""
'PageContinued1.Combo2.Text = ""
'PageContinued1.Combo3.Text = ""
'PageContinued1.Combo4.Text = ""
'PageContinued1.Combo5.Text = ""
'PageContinued1.Combo6.Text = ""
'PageContinued1.Combo7.Text = ""
'
Unload PageContinued2
'PageContinued2.Combo1.Text = ""
'PageContinued2.Combo2.Text = ""
'PageContinued2.Combo3.Text = ""
'PageContinued2.Combo4.Text = ""
'
Unload ProductionInfo
'ProductionInfo.Text1.Text = ""
'ProductionInfo.Text2.Text = ""
'ProductionInfo.Text3.Text = ""
'ProductionInfo.Text4.Text = ""
'ProductionInfo.Text5.Text = ""
'ProductionInfo.Text6.Text = ""
'ProductionInfo.Text7.Text = ""
'ProductionInfo.Text8.Text = ""
'ProductionInfo.Text9.Text = ""
'ProductionInfo.Text10.Text = ""
'ProductionInfo.Text11.Text = ""
'ProductionInfo.Text12.Text = ""
```

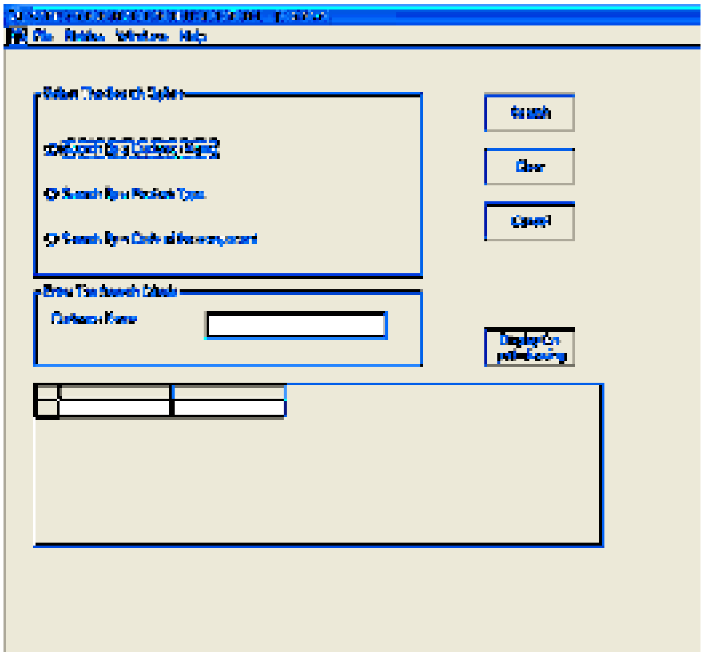
```
'ProductionInfo.Text13.Text = ""
'ProductionInfo.Text14.Text = ""
'ProductionInfo.Text15.Text = ""
'ProductionInfo.Text16.Text = ""
'ProductionInfo.Text17.Text = ""
'ProductionInfo.Text18.Text = ""
'ProductionInfo.Text19.Text = ""
'ProductionInfo.Text20.Text = ""
'ProductionInfo.Text21.Text = ""
'ProductionInfo.Text22.Text = ""
'ProductionInfo.Text23.Text = ""


Unload Me
Load CustomerInfo


End Sub
```



```
Private Sub Cancel_Click()
Unload Me
End Sub

Private Sub Delete_Click()
If Option1.Value = False and Option2.Value = False and Option3.Value = False Then
   MsgBox "Please Select one option To Search", vbInformation, "Misgudalsoft"
ElseIf Text1.Text = "" Then
   MsgBox "Please Enter delete Criteria", vbInformation, "misgudalsoft"
Else
```

```
Dim a As New ADODB.Connection
Dim b As New ADODB.Recordset
Dim b1 As New ADODB.Recordset
Dim b2 As New ADODB.Recordset
a.open "provider=microsoft.jet.oledb.4.0;data source=" + App.Path +
"\GTCCSDataBase.mdb"
b.CursorLocation = adUseClient
b1.CursorLocation = adUseClient
b2.CursorLocation = adUseClient
Dim search As New ADODB.Recordset
   If Option1.Value = True Then
      search.open "select * from GTCCSDataBase where ([Custmer Name]='" +
Text1.Text + "')", a
      If search.BOF Or search.EOF Then
         MsgBox "Recored with this" + Label1.Caption + "is not found", vbInformation,
"misgudalsoft"
      Else
         b1.open "select * from GTCCSDataBase where ([Custmer Name]='" + Text1.Text
+ "')", a
         Set DataGrid1.DataSource = b1
         Y = MsgBox("You are Deleting this below record(s)?", vbOKCancel,
"misgudalsoft")
         If Y = 1 Then
            b.open "delete from GTCCSDataBase where ([Customer Name]='" +
Text1.Text + "')", a
            b2.open "select * from GTCCSDataBase where ([Customer Name]='" +
Text1.Text + "')", a
            Set DataGrid1.DataSource = b2
         End If
      End If
   ElseIf Option2.Value = True Then
      search.open "select * from GTCCSDataBase where ([Product Type]='" + Text1.Text
+ "')", a
      If search.BOF Or search.EOF Then
         MsgBox "Recored with this " + Label1.Caption + " is not found", vbInformation,
"misgudalsoft"
      Else
         b1.open "select * from GTCCSDataBase where ([Product Type]='" + Text1.Text
+ "')", a
         Set DataGrid1.DataSource = b1
         Y = MsgBox("You are Deleteing this below record(s)?", vbOKCancel,
"misgudalsoft")
         If Y = 1 Then
            b.open "delete from GTCCSDataBase where ([Product Type]='" + Text1.Text
+ "')", a
            b2.open "select * from GTCCSDataBase where ([Product Type]='" +
Text1.Text + "')", a
            Set DataGrid1.DataSource = b2
```

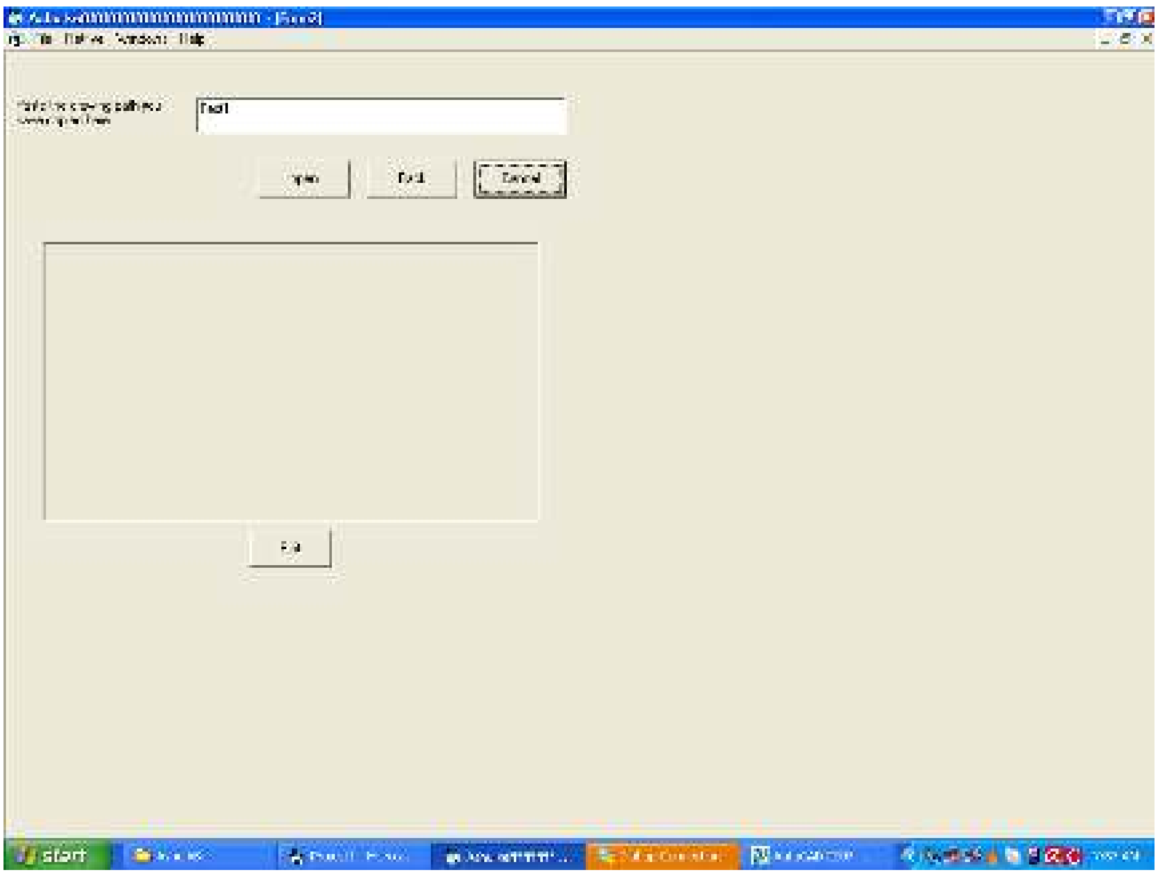
```
      End If
    End If
  ElseIf Option3.Value = True Then
    search.open "select * from GTCCSDataBase where ([Form Code]=" + Text1.Text +
")", a
    If search.BOF Or search.EOF Then
      MsgBox "Recored with this" + Label1.Caption + "is not found", vbInformation,
"misgudalsoft"
    Else
      b1.open "select * from GTCCSDataBase where([Form Code]=" + Text1.Text +
")", a
      Set DataGrid1.DataSource = b1
      Y = MsgBox("You are Deleteing this below recored(s)?", vbOKCancel,
"misgudalsoft")
      If Y = 1 Then
        b.open "delete from GTCCSDataBase where([Form Code]=" + Text1.Text +
")", a
        b2.open "select * from GTCCSDataBase where([Form Code]=" + Text1.Text +
")", a
        Set DataGrid1.DataSource = b2
      End If
    End If
  End If
End If


End Sub

Private Sub Option1_Click()
  Label1.Caption = "Customer Name"
End Sub
Private Sub Option2_Click()
  Label1.Caption = "Product Type"
End Sub
Private Sub Option3_Click()
  Label1.Caption = "Form Code"
End Sub
```



```
Dim R2 As New ADODB.Recordset
Dim bool As Boolean
Dim caw, m As Integer

Private Sub Command1_Click()
If Option1.Value = False And Option2.Value = False And Option3.Value = False Then
    MsgBox "Please Select one option To Search", vbInformation ', "Misgudalsoft"
Else
    If caw >= 1 And bool = False Then
        MsgBox "First You have to clear the previous Search Result, 'Click on Clear
button'", vbInformation, "misgudalsoft"
    Else
        If Text1.Text = "" Then
            MsgBox "Please Enter Search Criteria", vbInformation ', "misgudalsoft"
        Else
        Dim C2 As New ADODB.Connection
        C2.open "provider=microsoft.jet.oledb.4.0;data source=" + App.Path +
"\GTCCSDataBase.mdb"
        R2.CursorLocation = adUseClient
            If Option1.Value = True Then
                    R2.open "select * from GTCCSDataBase where([Custmer Name] = '" +
Text1.Text + "')", C2
                    Set DataGrid1.DataSource = R2
            ElseIf Option2.Value = True Then
                    R2.open "select * from GTCCSDataBase where([Product Type] = '" +
Text1.Text + "')", C2
                    Set DataGrid1.DataSource = R2
            ElseIf Option3.Value = True Then
                    R2.open "select * from GTCCSDataBase where([Form Code] = '" +
Text1.Text + "')", C2
```

```
                Set DataGrid1.DataSource = R2
          End If
         caw = caw + 1
   If R2.EOF Or R2.BOF Then
      MsgBox "No Mach for your search", vbInformation
      R2.close
      bool = True
   Else
      bool = False
   End If
      End If
   End If
End If
'If m <> 3 Then
'   If R2.EOF Or R2.BOF Then
'      MsgBox "No Mach for your search", vbInformation
'      R2.close
'      bool = True
'   Else
'      bool = False
'   End If
'End If
End Sub

Private Sub Command4_Click()
Dim t As Integer
If (bool = True And caw >= 1) Or (bool = False And caw = 0) Then
   MsgBox "No Search Result to Clear", vbInformation, "Misgudalsoft"
Else
   Y = MsgBox("Do you want to Clear this Search Result?", vbYesNo, "Misgudalsoft")
   If Y = 6 Then
         bool = True
         R2.close
   End If
End If
'Set m = 3
End Sub

Private Sub Command2_Click()
   Unload Me
End Sub

Private Sub Command3_Click()
Static c As Integer
If c = 0 Then
MsgBox "Please copy the drawing path which you need to open, from the 'drawing path'
column, any time before going to the next step!", vbInformation
Else
```

```
Retrive.Hide
openPicture.Show
End If
c = c + 1
End Sub

Private Sub Option1_Click()
   Label1.Caption = "Customer Name"
End Sub
Private Sub Option2_Click()
   Label1.Caption = "Product Type"
End Sub
Private Sub Option3_Click()
   Label1.Caption = "Form Code"
End Sub
```



```
Private Sub Back_Click()
Retrive.Show
openPicture.Hide

End Sub

Private Sub Cancel_Click()
   Unload Me
End Sub
```

```
Private Sub Command1_Click()
'On Error Resume Next
Dim Y As String
Y = InputBox("Please Enter the Version year of the AutoCAD in Your system. Example:
'2000' 0r '2007'")
Shell ("C:\Program Files\AutoCAD" + " " + Y + "\acad.exe"), vPDCaximizedFocus '
C:\Documents and Settings\kibreta\Desktop\Kibre_VBA\2000b.dwg" ' & Text1.Text &
".dwg"
'Unload Me

End Sub

Private Sub open_Click()
   Picture1.Picture = LoadPicture(Text1.Text, , 100, 100)
End Sub
```

```
Private Sub aboutme_Click()
Unload faboutme
Load faboutme
End Sub

Private Sub ancomponent_Click(Index As Integer)
'ActiveForm.Hide
Unload CustomerInfo
Load CustomerInfo
End Sub
```

```
Private Sub cascade_Click()
Arrange vbCascade
End Sub

Private Sub close_Click(Index As Integer)
End
End Sub

Private Sub closein_Click(Index As Integer)
If Not ActiveForm Is Nothing Then
        Unload ActiveForm
End If
End Sub

Private Sub editp_Click(Index As Integer)
Unload openPicture
Load openPicture
End Sub

Private Sub faq_Click()
Unload ffaq
Load ffaq
End Sub

Private Sub MDIForm_Load()
frmLogin.Show vPDCodal
End Sub

Private Sub rbginfo_Click()
Unload Retrive
Load Retrive
End Sub

Private Sub rcomponent_Click()
Unload RemoveRecored
Load RemoveRecored
End Sub

Private Sub thorizontaly_Click()
MDIForm1.Arrange vbTileHorizontal
End Sub

Private Sub tverticaly_Click()
Arrange vbTileVertical
End Sub
```

APPENDIX C. SAMPLE PARTS WITH PROCESS FLOW

Sample parts with the corresponding drawing number, the types of processes and equipments required for the production, and process flow.

	Drawing No.	Description	Process required	Machines required	Tools and Cutters required
1	T-1-15-1514	Threading die	-Facing -Turning -Chamfering -Drilling -Threading -Grooving -Heat treatment -Grinding	-Lathe -Drilling -Heat treatment -Grinding	-Facing tool -Turning tool - Drill bit -Threading tool -Boring tool -Grooving tool
2	T-1-15-1063	Eye Bolt	-Facing -Turning -Drilling -Threading -Mill the curved eye end	-Lathe -Milling -Drilling	-Facing tool -Turning tool -Threading tool -End mil / Forming tool
3	E-1211	Bolt	-Facing -Turning -Chamfering -Threading -Mill the hexagonal bolt head	-Lathe -Milling	-Facing tool -Turning tool -Threading tool -End mil
4	E- 1225	Guide	-Facing -Turning -Drilling -Boring -Threading -Mill the Slot/Groove	-Lathe -Milling	-Facing tool -Turning tool -Drill bit -Boring tool -Threading tool -End mil / Forming tool
5	T-1-15-1229	Bushing	-Facing -Turning -Drilling -Recess/Groove	-Lathe	-Facing tool -Turning tool -Recessing/boring tool -Drill bit
6	T-15-0042/99	threaded Hub	-Facing -Turning -Drilling -Threading	-Lathe	-Facing tool -Turning tool -Threading tool -Drill bit
7	T-15-0068/00	Shaft	-Facing -Turning -Chamfering -Drilling -Grooving -Milling the indexed teeth	-Lathe -Milling -Drilling	-Facing tool -Turning tool -Grooving tool -Drill bit -Form milling cutter
8	T-1-15-1190	Spray Nozzle	-Facing -Turning -Chamfering	-Lathe -Milling -Drilling	-Facing tool -Turning tool -Threading tool

			-Drilling -Threading -Milling the square flat surface		-Drill bit -End mill/Plane milling cutter
9	E-1174	Nut	-Facing -Turning -Chamfering -Drilling -Boring -Threading -Milling the hexagonal surface	-Lathe -Milling -Drilling	-Facing tool -Turning tool -Boring tool -Threading tool -Drill bit -End mill/Plane milling cutter
10	E-03-00/00	Plate	-Milling the flat surface -Milling the functional cut outs -Drilling	-Milling -Drilling	-End mill/Plane milling cutter -Milling forming tool
11	E-8-0093/01	Spur Gear	-Facing -Turning -Chamfering -Drilling cross & axial holes -Boring -Cutting the gear teeth	-Lathe -Drilling -Gear shaper	-Facing tool -Turning tool -Module cutter/Gear shaping cutter
12	T-15-0030/99	Worm Gear	-Facing -Turning -Chamfering -Grooving -Key way cutting -Worm thread cutting	-Lathe -Milling	-Facing tool -Turning tool -Grooving tool -Threading tool - End mill
13	T-1-15-1163	Spline Shaft	-Facing -Turning -Chamfering -Cutting the gear teeth	-Lathe -Milling	-Facing tool -Turning tool -Module cutter/Forming tool
14	T-1-15-1195	Roller	-Facing -Turning -Chamfering	-Lathe	-Facing tool -Turning tool
15	E-8-0029/99	Pinion Gear	-Facing -Turning -Chamfering -Drilling -Slotting -Cutting the gear teeth	-Lathe -Milling -Drilling -Slotter	-Facing tool -Turning tool -Drill bit -Slotting tool -Module cutter
16	T-1-15-1176	Tension spring	-Coiled with lathe -Heat treatment	-Lathe -Milling	-
17	T-15-0027/00	Cutter	-Mill the flat surface -Drilling -Boring -Threading -Heat treatment -Grinding	-Milling -Drilling -Jig boring -Heat treatment -Surface Grinder	-End mill/Plane milling cutter -Drill bit -Boring tool -Threading Tap
18	E-03-00/00	Bushing	-Facing	-Lathe	-Facing tool

			-Turning -Chamfering -Drilling -Boring -Heat treatment -Lapping	-Lapping m/c -Heat treatment	-Turning tool -Drill bit -Boring tool -Lapping bar with emery cloth
19	T-15-0090/2001	Helical Gear	-Facing -Turning -Chamfering -Drilling -Boring Grooving/Slotting -Gear making -Heat treatment -Grinding	-Lathe -Slotter -Gear shaper -Heat treatment -Internal Grinding -Surface Grinding	-Facing tool -Turning tool -Drill bit -Boring tool -Slotting tool -Module cutter
20	E-8-0074	Guide Shaft	-Facing -Turning -Chamfering -Grooving -4- different diameters -Heat treatment -Surface Grinding	-Lathe -Heat treatment -Grinding	-Facing tool -Turning tool -Recessing tool -Drill bit -Boring tool
21	E-03-00/00	Finger Pin	-Facing -Turning -Chamfering -Milling functional flat surface -Milling rectangu VR5A lar surface with radius cut outs -Heat treatment -Surface Grinding	-Lathe -Milling -Heat treatment -Grinding	-Facing tool -Turning tool -Recessing tool -End mill/Plane milling cutter
22	T-15-0039/99	Link	-Milling -Bending or Forming -Drilling -Radius end forming	-Milling -Drilling	-End mill/Plane milling cutter -Milling forming cutter -Drill bit
23	E-8-0092/01	Sleeve	-Facing -Turning -Chamfering -Drilling -Boring -Key way/groove -Under cut (internal groove) -Heat treatment -Grinding	-Lathe -Slotter -Heat treatment -Grinding m/c	-Facing tool -Turning tool -Drill bit -Boring tool -Slotting tool
24	T-1-15-1494	Punch	-Milling -Drilling -Threading (two blind holes with thread) -Heat treatment	-Milling -Drilling -Heat treatment -Grinding m/c	-End mill/Plane milling cutter -Milling forming cutter -Drill bit -Threading tap

			-Grinding (radius nose formation & finishing)		
25	E-8-0029/99	Splined-Gear	-Facing -Turning -Chamfering -Drilling -Grooving -Threading -Slotting (Internal spline) -Gear making -Heat treatment	-Lathe -Slotter -Gear shaper -Heat treatment	-Facing tool -Turning tool -Drill bit -Slotting tool -Module cutter
26	T-1-15-1468	Coupling	-Facing -Turning -Chamfering -Drilling -Boring -Milling the taper groves -Milling the key way	-Lathe -Milling -slotter	-Facing tool -Turning tool -Drill bit -Boring tool -Slotting tool -End mill/Plane milling cutter
27	E-1166	Shafted-Gear	-Facing -Turning -Chamfering -Drilling-blind hole -Grooving -Threading -Slotting (Internal spline) -Gear making -Heat treatment	-Lathe -Slotter -Gear shaper -Heat treatment	-Facing tool -Turning tool -Drill bit -Slotting tool -Module cutter
28	T-15-0069/00	Valve	-Facing -Turning -Chamfering -Taper turn -Threading -Grooving (The five equally spaced radius grooves) -Heat treatment	-Lathe -Milling -Heat treatment	-Facing tool -Turning tool -Threading tool -Drill bit -Slotting tool -Milling forming tool
29	E-1190	Lead Screw	-Facing -Turning -Chamfering -Threading (Sq. thread both side, blind hole with internal thread at one end) -Taper cross hole -Key way making	-Lathe -Milling	-Facing tool -Turning tool -Threading tool -Drill bit -Threading tap
30	T-1-15-1168	Arm	-Facing -Turning (Stepped turn) -Drilling (the two	-Lathe -Milling	-Facing tool -Turning tool -Drill bit -Threading tool

			different axis cross holes) -Thread cutting (Squ. axial) and on one of cross holes		
31	T-1-15-1386	Blade	-Milling the external flat surface -Drill and make the slots axialy -Heat treatment -Grind the surface and the blade edge	-Milling -Heat treatment -surface grinding	-End mill/Plane milling cutter -Drill bit
32	T-1-15-1190	Support	-Milling the external flat surface -Milling the different profiles and groves -Slotting (Rectangular holes)	-Milling -Slotter	-End mill/Plane milling cutter -Milling forming cutter -Slotting tool
33	T-1-15-1235	Saddle	-Milling the external flat surface -Milling the different cut outs and profiles -Drill taper holes -Drill axial holes with threads	-Milling -Drilling	-End mill/Plane milling cutter -Milling forming cutter -Drill bit -Threading tap
34	T-15-0079/00	chuck	-Facing -Turning (the stepped turn) -Chamfering -External thread -Stepped & straight blind one side make thread -Drill blind hole the other end and make it internal taper turn -Mill the grove -Heat treatment -Grinding	-Lathe -Milling -Heat treatment -Grinding	-Facing tool -Turning tool -Drill bit -Grooving tool -Threading tool -End mill/Plane milling cutter
35	T-15-0057/00	Female die	-Facing -Turning -Chamfering -Drilling -Alkali coloring -Heat treatment -Grinding -Internal Lapping	-Lathe -Milling -Heat treatment -Grinding -Lapping -Alkali coloring	-Facing tool -Turning tool - Drill bit -Lapping material
36	T-1-15-1180	Allen bolt	-Turnning -Facing -Threading	-Lathe -Miller	-Turnning tool -Facing tool -Threading tool

			-Milling		-Milling cutter
37	E-8-0072/00	Cylindrical ring	-Cut to size -Roll -Heat treatment	-Shearing metal -Rolling m/c -Heat treatment	-
38	E-03-00/00	Clamp screw	-Turning -Threading -Facing -Knurling -heat treatment	-Lathe -Milling	-Turning tool -Threading tool -Facing tool -Knurling tool
39	E-15-079/00	Shearing machine blade	-Milling -Surface grinding -Sharpening -Drilling	-Surface grinder -Milling -Heat treatment	-Surface milling tool -Drilling tool
40	T-1-15-1216	Stud	-Facing -Turning (Stepped straight & taper turn) -Chamfering -Grooving -Threading both end -Milling (taper wrench size) -Heat treatment -Grinding	-Lathe -Milling -Heat treatment -Grinding	-Facing tool -Turning tool -Drill bit -Grooving tool -Threading tool -End mill/Plane milling cutter
41	E-8-1236	Steel pipe	-Rolling -Shearing -Bending	-Electrical roller -Shearing m/c -Bending m/c	-

APPENDIX D: EXISTING AND PROPOSED LAYOUTS OF WORKSHOPS MACHINES

Existing and the new proposed GT based machine cells (or cellular layout) arrangement of machines in the workshop of Metal products development center has attached under here with a drawing number of 01 and 02 consecutively.

APPENDIX E: DRAWINGS OF COMPANY'S PARTIAL PRODUCTS

Since the company does not have data management system, most of the company products sketches has stored in hard copy form. Parts that have soft copy also do not organized well. Out of which some of the parts drawing are presented here.

APPENDIX F: COLLECTED DATA

Table F1. Facilities in equipment workshop:

No.	Equipment Description	Unit	Qty.
1	Milling FU-3	Set	1
2	Milling M/C FTV - 4	Set	1
3	Lathe al-pin 300	Set	1
4	Lathe HUICHON-5	Set	1
5	Lathe Harrison M300	Set	1
6	Lathe Harrison M460	Set	1
4	Pantograph Flame Cutting	Set	1
5	Tool grinding BOXFORD G200	Set	1
6	Cylindrical grinder RIBON	Set	1
7	Cylindrical grinder GER RHC 1500	Set	1
7	Surface grinder DELTA	Set	1
8	Hydraulic Radial drill	Set	1
9	Pedestal grinder	Set	2
10	Hacksaw SAB1	Set	1
11	Shaper CMZ L550	Set	1
12	Radial Shearing machine (for plastic, rubber, and small thickness and size metal sheet)	Set	1
13	Roll bender (Automatic for large diameters)	Set	1
14	Roll bender (Mechanical for medium diameter work)	Set	1
15	Roll bender (Mechanical for small diameter work)	Set	1
16	Angle bender	Set	1
17	Shearing machine	Set	1
18	Power saw	Set	1
19	Press machine	Set	1
20	Spot welding	Set	1
21	Welding table fan	Set	3
22	Quenching tank fan	Set	1
23	Electric furnace KS800/37	Set	1
24	Spray booth exhaust fan	Set	2
25	5 tones crane	Set	1
26	DC welder	Set	1

Table F2. Facilities in tool and die workshop:

No.	Equipment Description	Unit	Qty.
1	Lathe HARRISON M250	Set	1
2	Center lathe CMZ T410 * 1500	Set	1
3	Lathe HUICHON-5	Set	1
4	Milling FU-3	Set	2
5	Vertical miller	Set	1
6	Milling FV-3M	Set	1
7	Universal CNC miller	Set	1
8	CNC tool Miller (MAHO)	Set	1
9	ROBOFIL, EDM center 200 (Wire Cut)	Set	2
10	ROBOFORM, EDM center 200 (Spark Erosion)	Set	1
11	Cylindrical grinder GER RHC 1500	Set	1
12	Surface grinder DELTA	Set	2
13	Shaper CMZ L550	Set	1
14	Engraving machine	Set	1
15	Band saw	Set	1
16	Power saw	Set	1
17	Boring machine	Set	1
18	Tool and cutter grinder	Set	2
29	Bench grinder Pinnaste	Set	1
20	Table drill	Set	1
21	Column Drill	Set	1
22	Press 100N	Set	1
23	Electric furnace	Set	3
24	Quenching tank	Set	2
25	Welder, Maxicompact 270	Set	1
26	DC welder type 354	Set	1
27	Welding table	Set	2
28	Air compressor	Set	2
39	Traveling crane	Set	1

Table F3. Sample parts/drawings considered for machine cell formation

No.	Drawing No.	Description
1	T-1-15-1514	Threading die
2	T-1-15-1063	Eye Bolt
3	E-1211	Bolt
4	E- 1225	Guide
5	T-1-15-1229	Bushing
6	T-15-0042/99	threaded Hub
7	T-15-0068/00	Shaft
8	T-1-15-1190	Spray Nozzle
9	E-1174	Nut
10	E-03-00/00	Plate
11	E-08-0093/00	Spur Gear
12	T-15-0030/99	Worm Gear
13	T-1-15-1163	Spline Shaft
14	T-1-15-1195	Roller
15	E-8-0029/99	Pinion Gear
16	T-1-15-1176	Tension spring
17	T-15-0027/00	Cutter
18	E-03-00/00	Bushing
19	T-15-0090/2000	Helical Gear
20	E-8-0074	Guide Shaft
21	E-03-00/00	Finger Pin
22	T-15-0039/99	Link
23	E-8-0092/01	Sleeve
24	T-1-15-1494	Punch
25	E-8-0029/99	Splined-Gear
26	T-1-15-1468	Coupling
27	E-1166	Shafted-Gear
28	T-15-0069/00	Valve
29	E-1190	Lead Screw
30	T-1-15-1168	Arm
31	T-1-15-1386	Blade
32	T-1-15-1190	Support
33	T-1-15-1235	Saddle
34	T-15-0079/00	chuck
35	T-15-0057/00	Female die
36	T-1-15-1180	Allen bolt
37	E-8-0072/00	Cylindrical ring
38	E-03-00/98	Clamp screw
39	E-15-079/00	Shearing machine blade
40	T-1-15-1216	Stud
41	E-8-1236	Steel pipe
42	E-08-1123/98	Locker
43	T-15-1087	Hollow bolt
44	E-03-0094	Calibration Shaft
45	T-15-0154	Tool holder
46	T-1-15-1324	Press upper die
47	T-15-0077	Lead Screw
48	E-08-0076	Saddle
49	T-15-0068	Collette ring
50	E-03-0243	Pestle

Table F4. Common and repeatedly done operations with the corresponding required machines.

No.	Operation type	Corresponding machines used for operations
1	Facing	Lathe
2	Turning	Lathe
3	Chamfering	Milling m/c
4	Drilling	Drill m/c, Lathe, Milling m/c
5	Treading	Lathe
6	Grooving	Milling m/c
7	Heat treatment	Heat treatment furnaces and quenching tankers
8	Grinding, surface	Surface grinder
9	Boring	Boring m/c, Milling m/c, Lathe
10	Milling keyway	Milling m/c
11	Worm thread cutting	Lathe
12	Mill the flat surface	Milling m/c
13	Grinding, cylindrical	Cylindrical Grinding m/c
14	Slotting	Shaper, Milling m/c
15	Rolling	Manual and Electrical Roller
16	Sawing	Power saw, Band-saw, and Hacksaw
17	Hobbing, teeth	Milling m/c
18	Shaping, teeth	Milling m/c, Shaper
19	Shearing	Shearing m/c, Pantograph m/c
20	Inspection	–

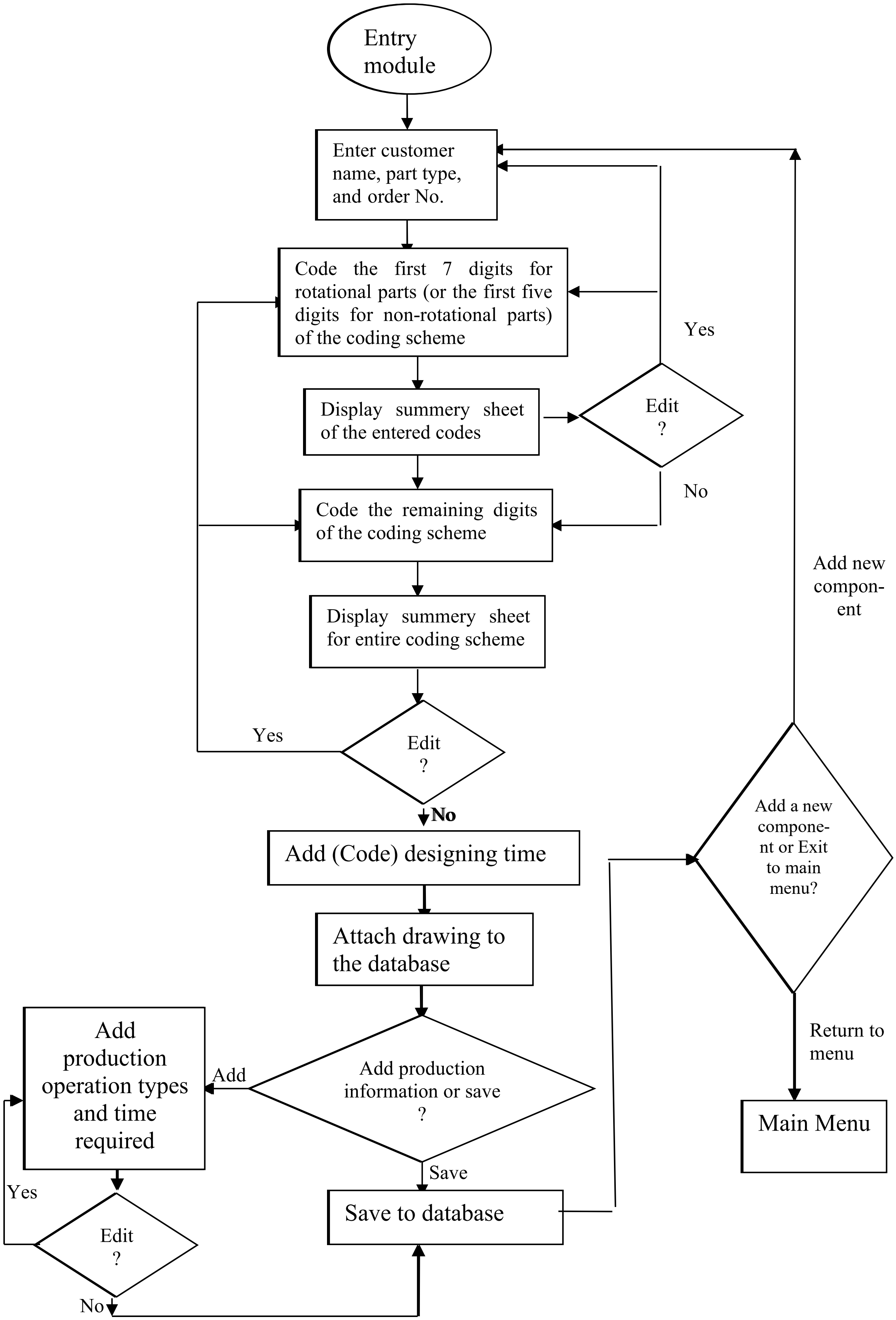


Figure . Adding module of component to the GTCCSBMI database

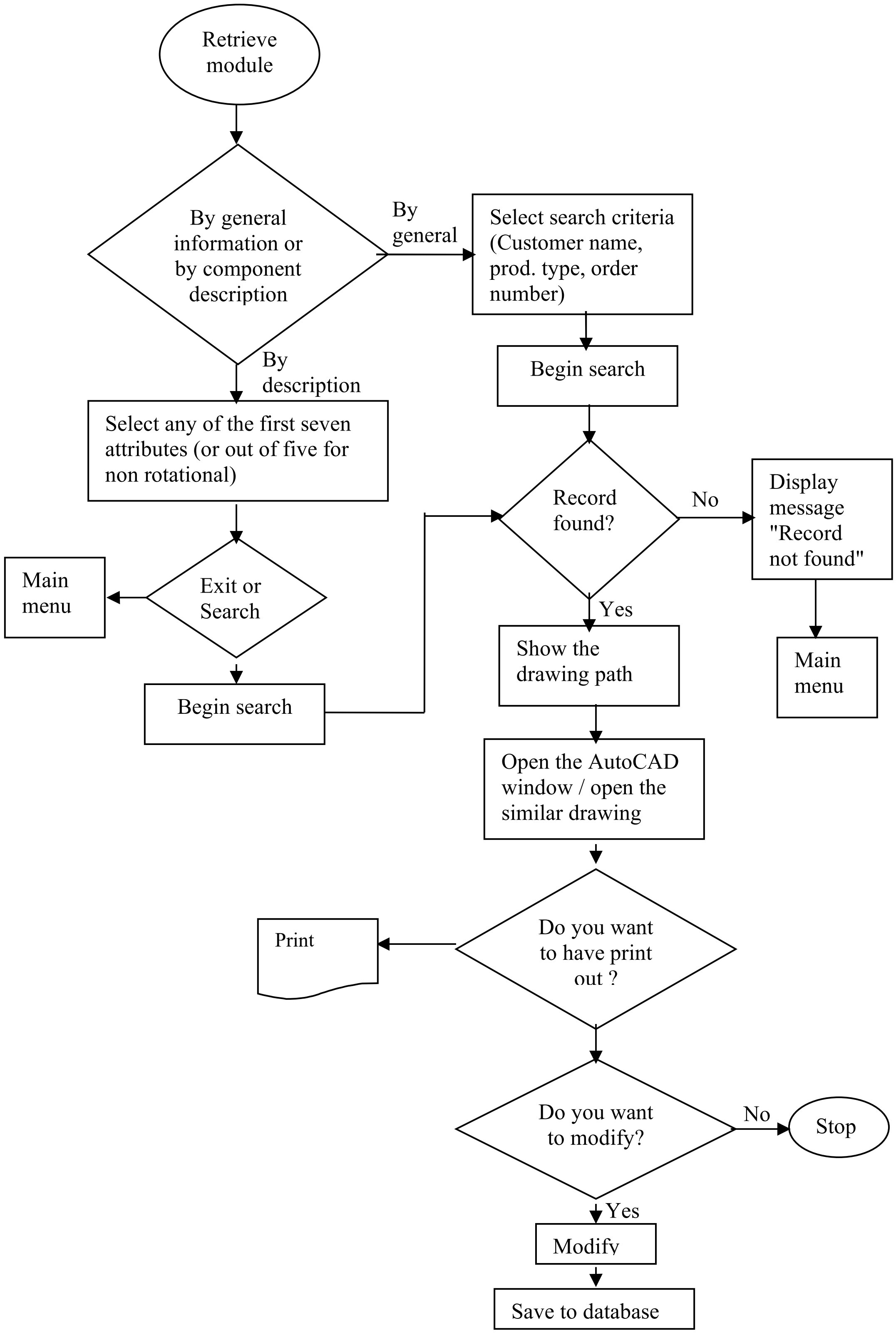
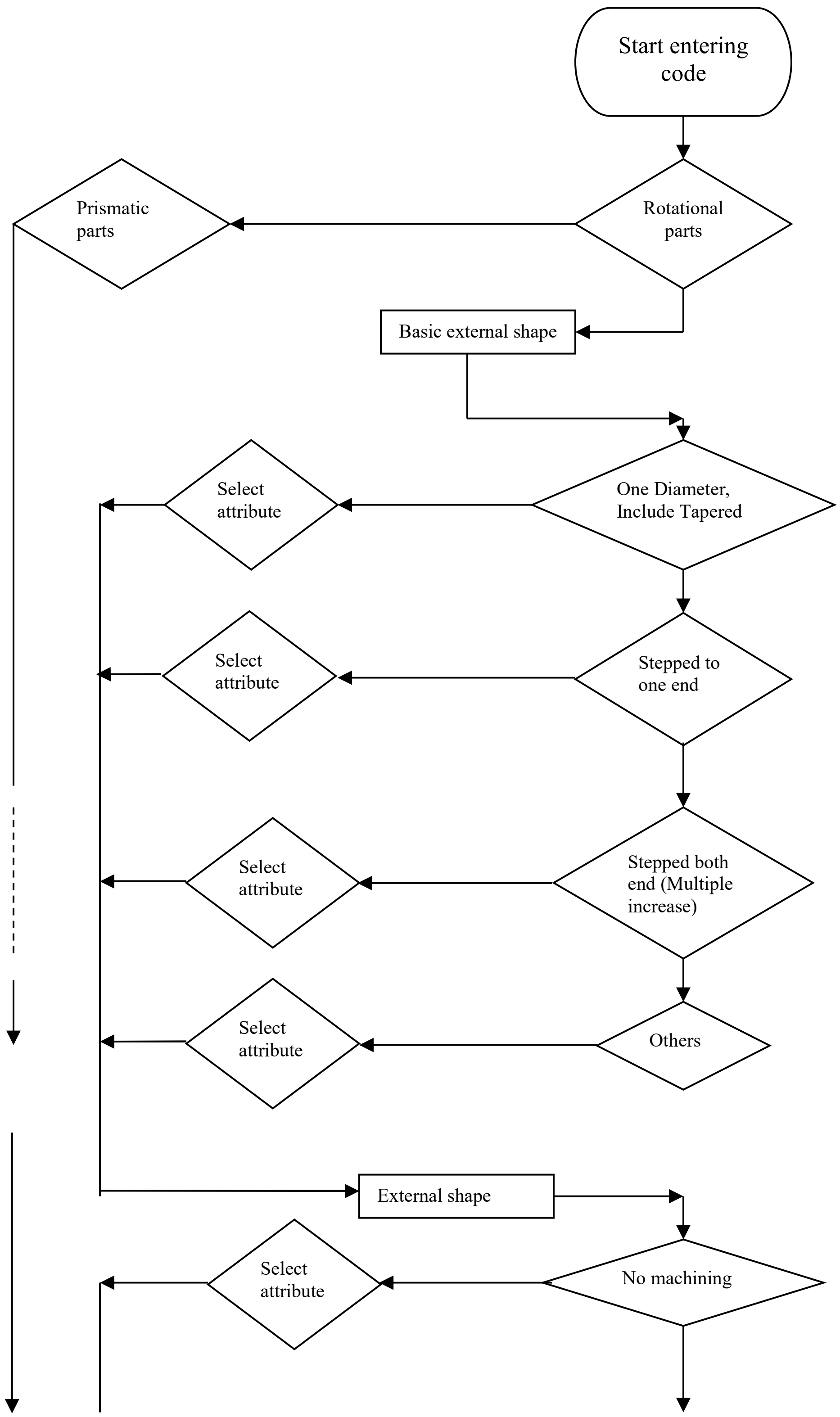
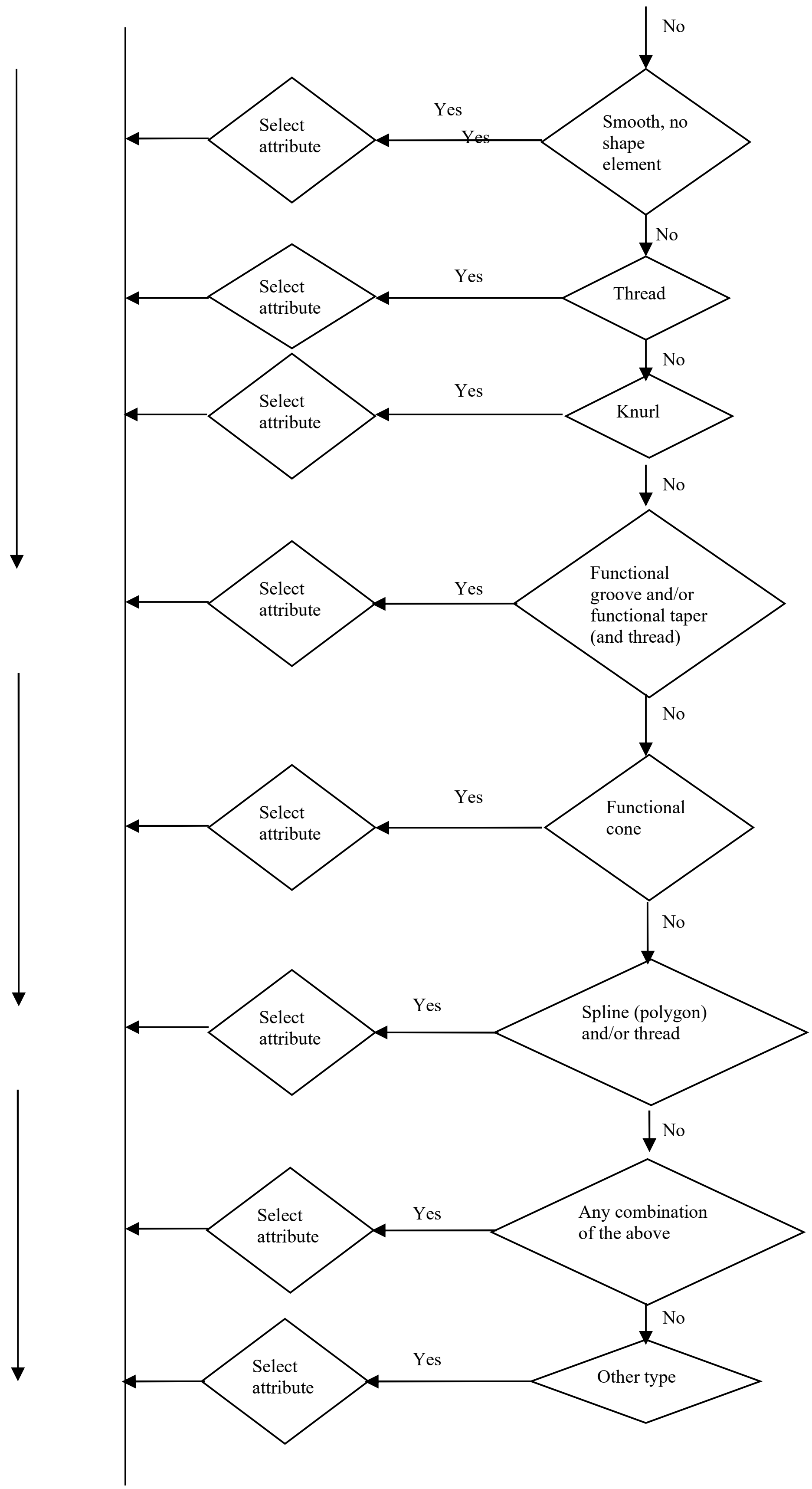
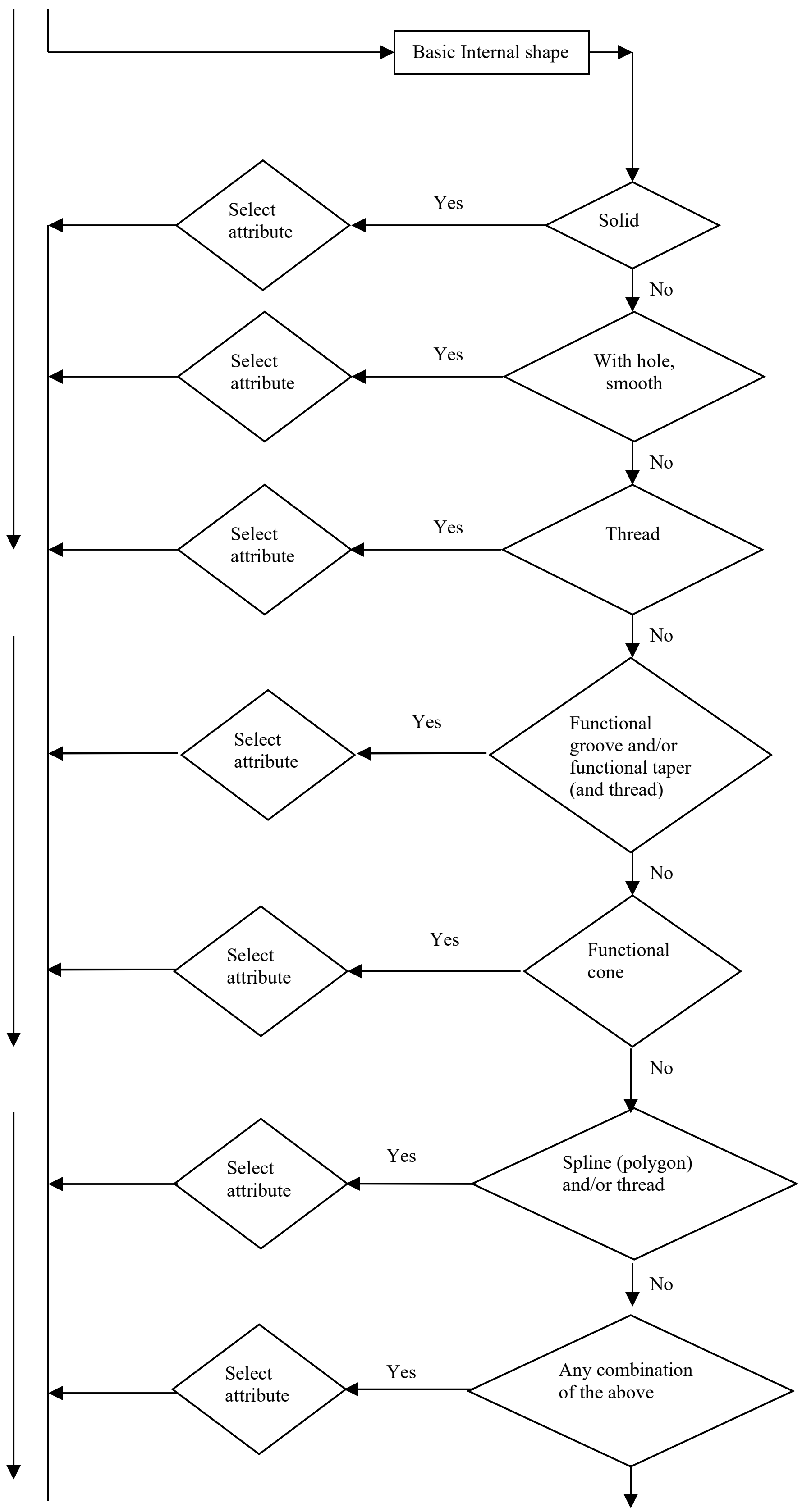


Figure . Retrival Module: from GTCCSBMI Database

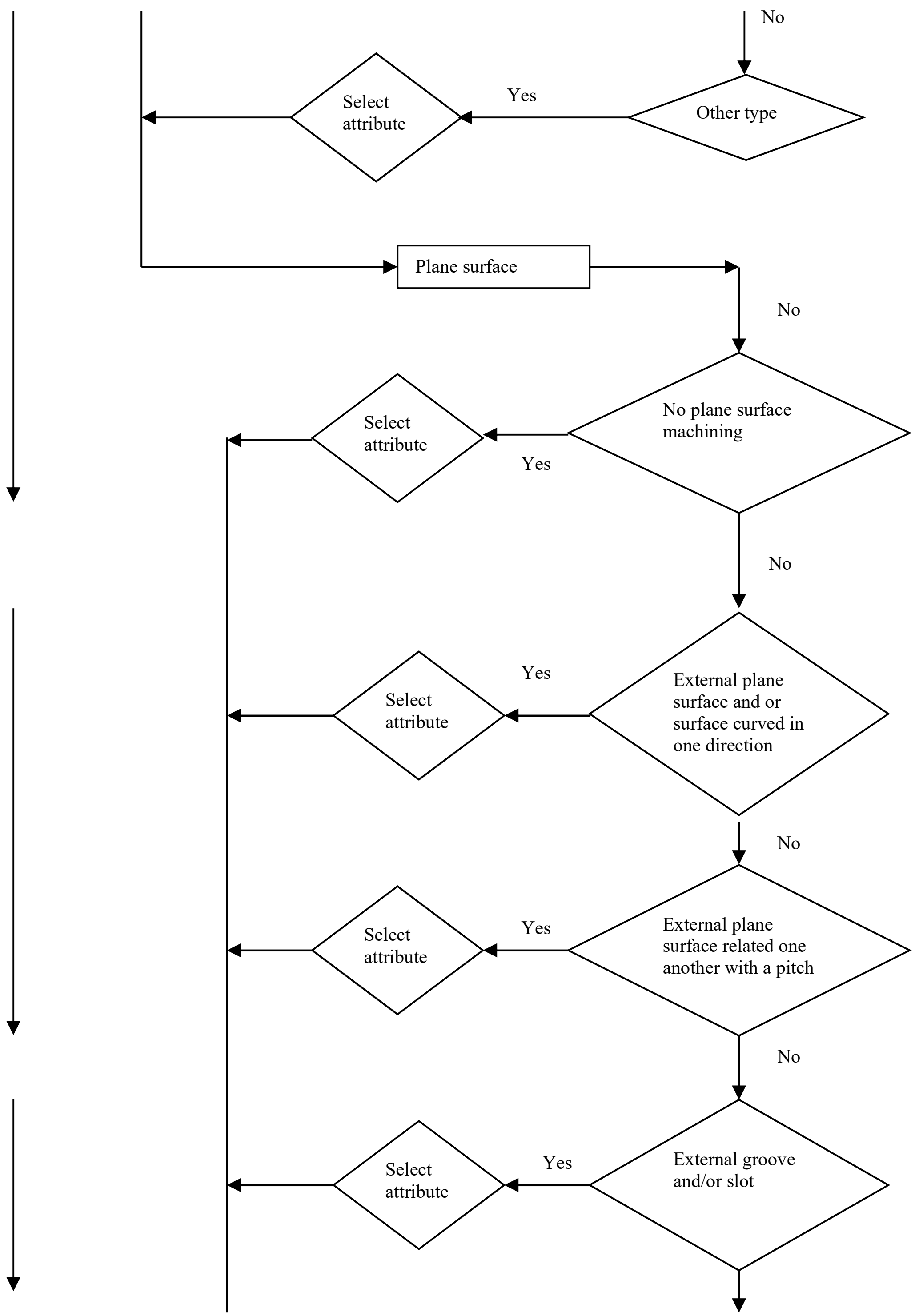

Start entering code
Rotational parts
Prismatic parts
Basic external shape
One Diameter, Include Tapered
Select attribute
Stepped to one end
Select attribute
Stepped both end (Multiple increase)
Select attribute
Others
Select attribute
External shape
No machining
Select attribute

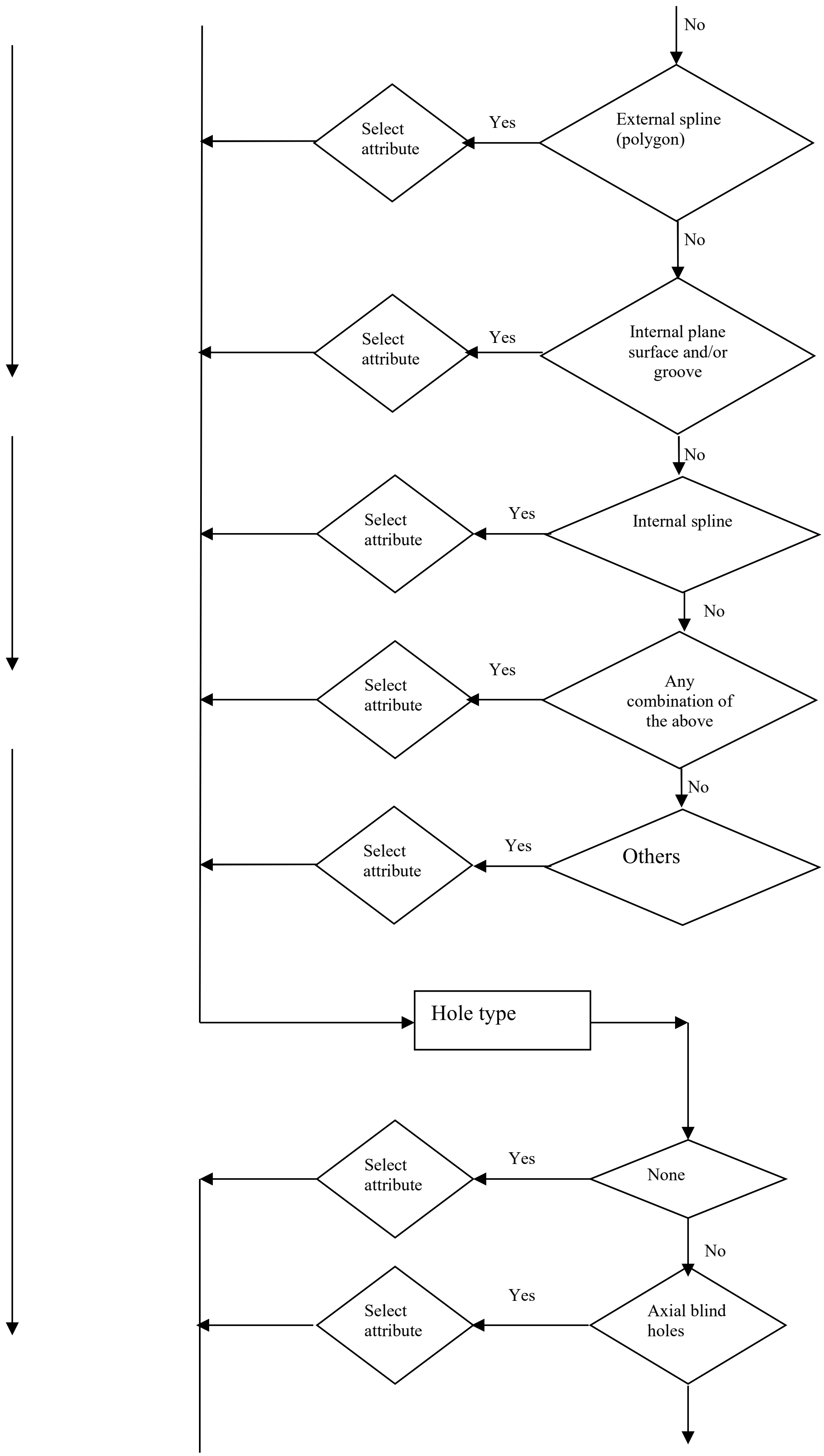


No
Smooth, no shape element
Yes
Yes
Select attribute
No
Thread
Yes
Select attribute
No
Knurl
Yes
Select attribute
No
Functional groove and/or functional taper (and thread)
Yes
Select attribute
No
Functional cone
Yes
Select attribute
No
Spline (polygon) and/or thread
Yes
Select attribute
No
Any combination of the above
Yes
Select attribute
No
Other type
Yes
Select attribute

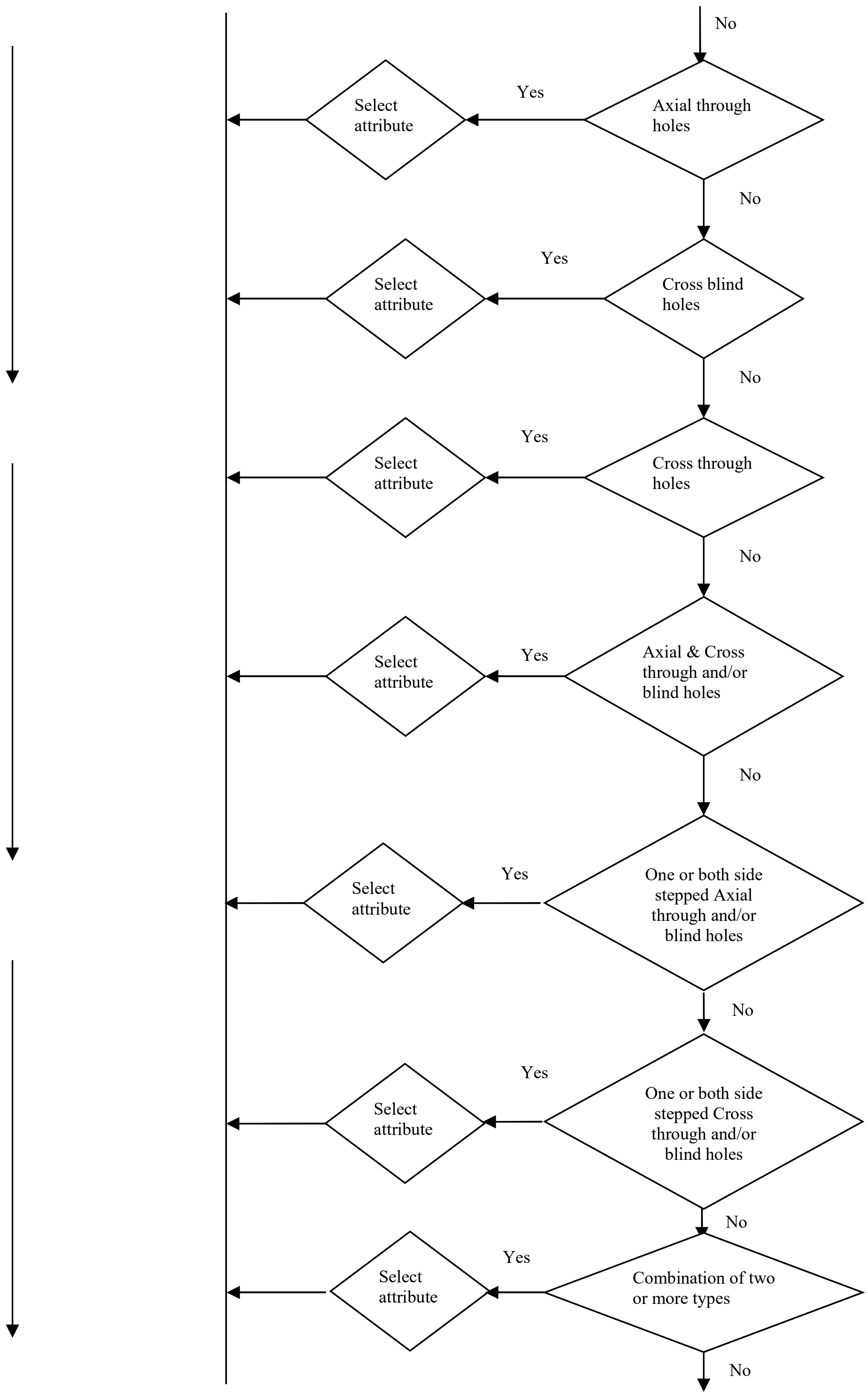


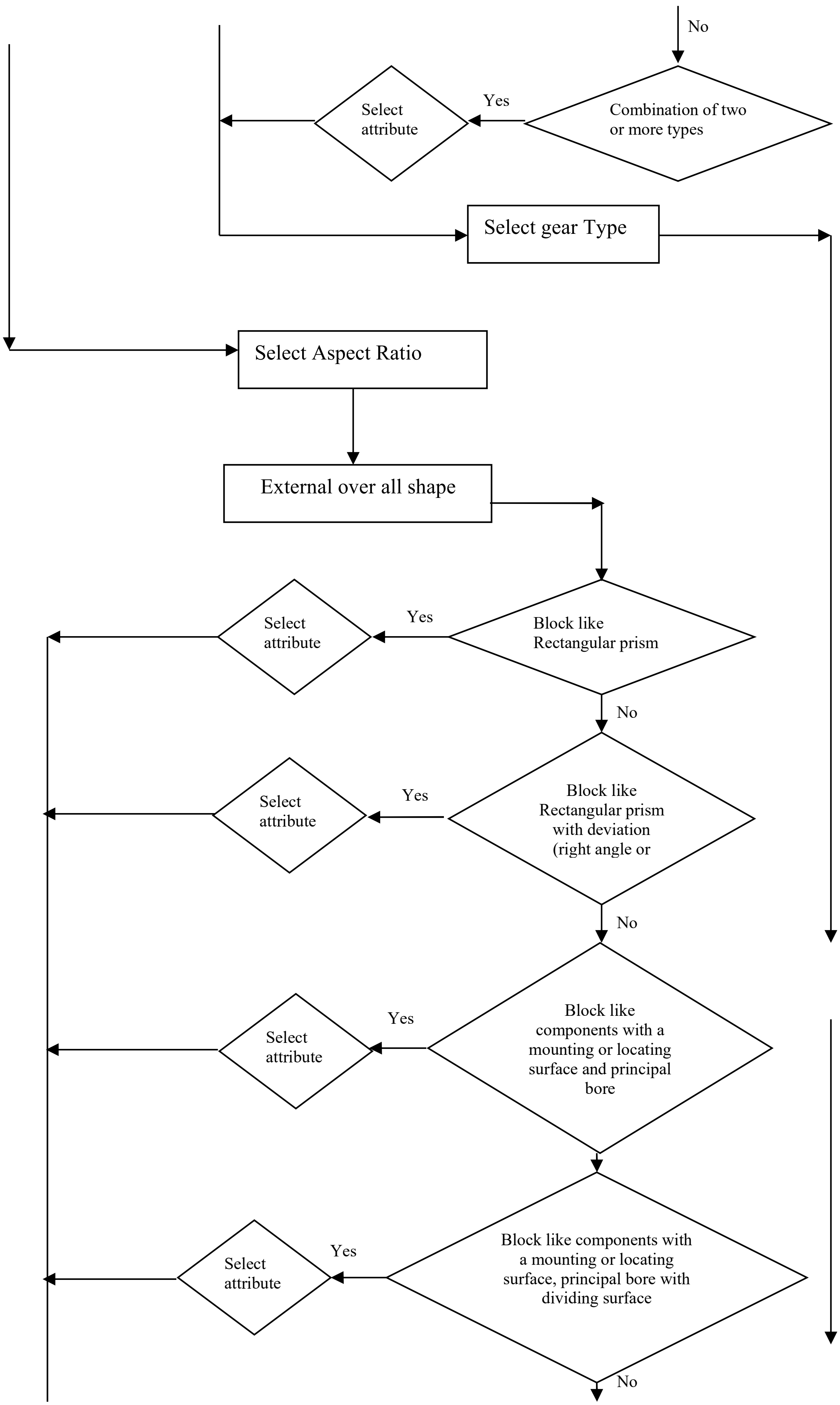
Basic Internal shape
Solid
Yes
No
Select attribute
With hole, smooth
Yes
No
Select attribute
Thread
Yes
No
Select attribute
Functional groove and/or functional taper (and thread)
Yes
No
Select attribute
Functional cone
Yes
No
Select attribute
Spline (polygon) and/or thread
Yes
No
Select attribute
Any combination of the above
Yes
Select attribute

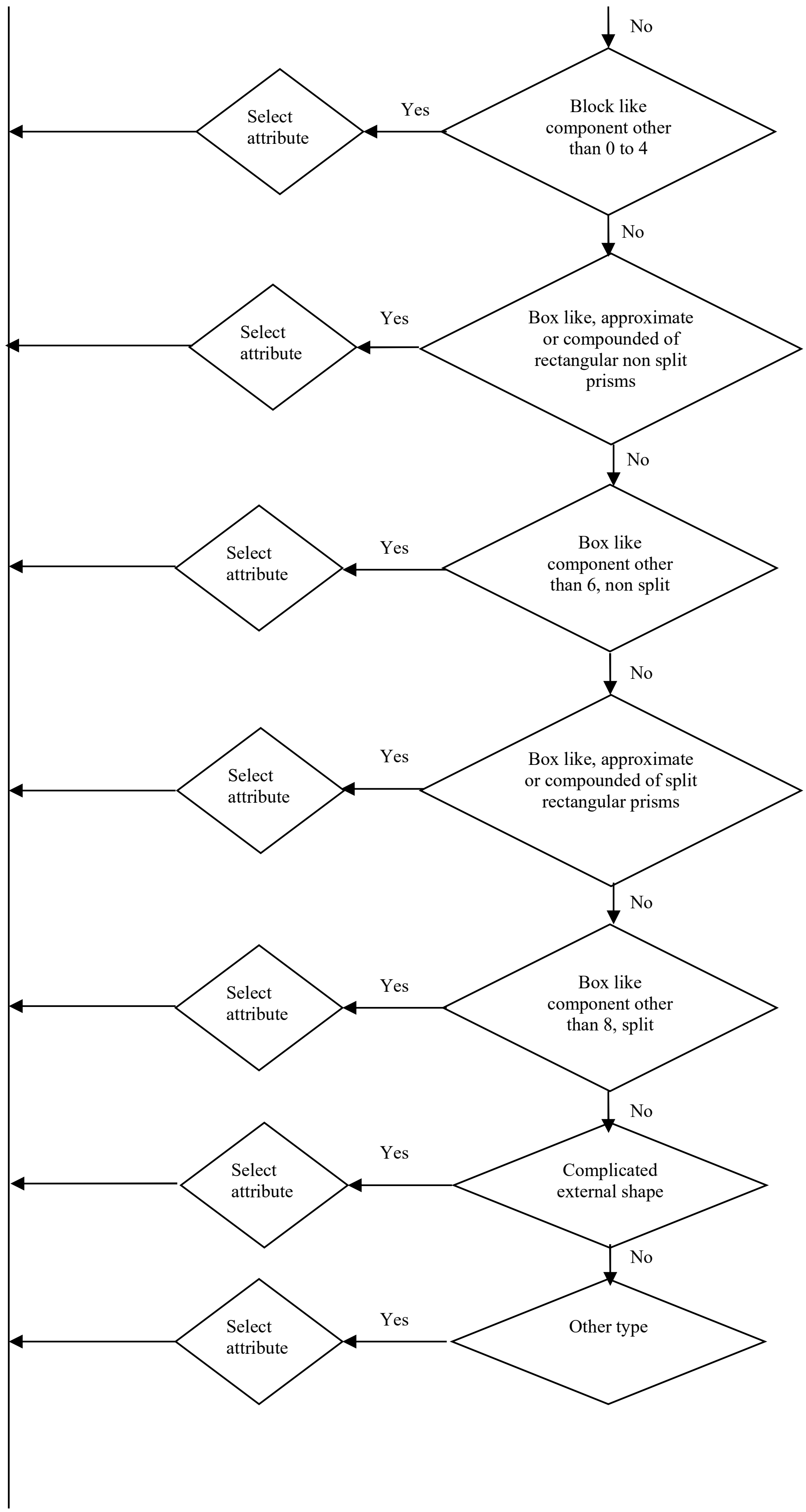

No
Other type
Yes
Select attribute
Plane surface
No
No plane surface machining
Yes
Select attribute
No
External plane surface and or surface curved in one direction
Yes
Select attribute
No
External plane surface related one another with a pitch
Yes
Select attribute
No
External groove and/or slot
Yes
Select attribute

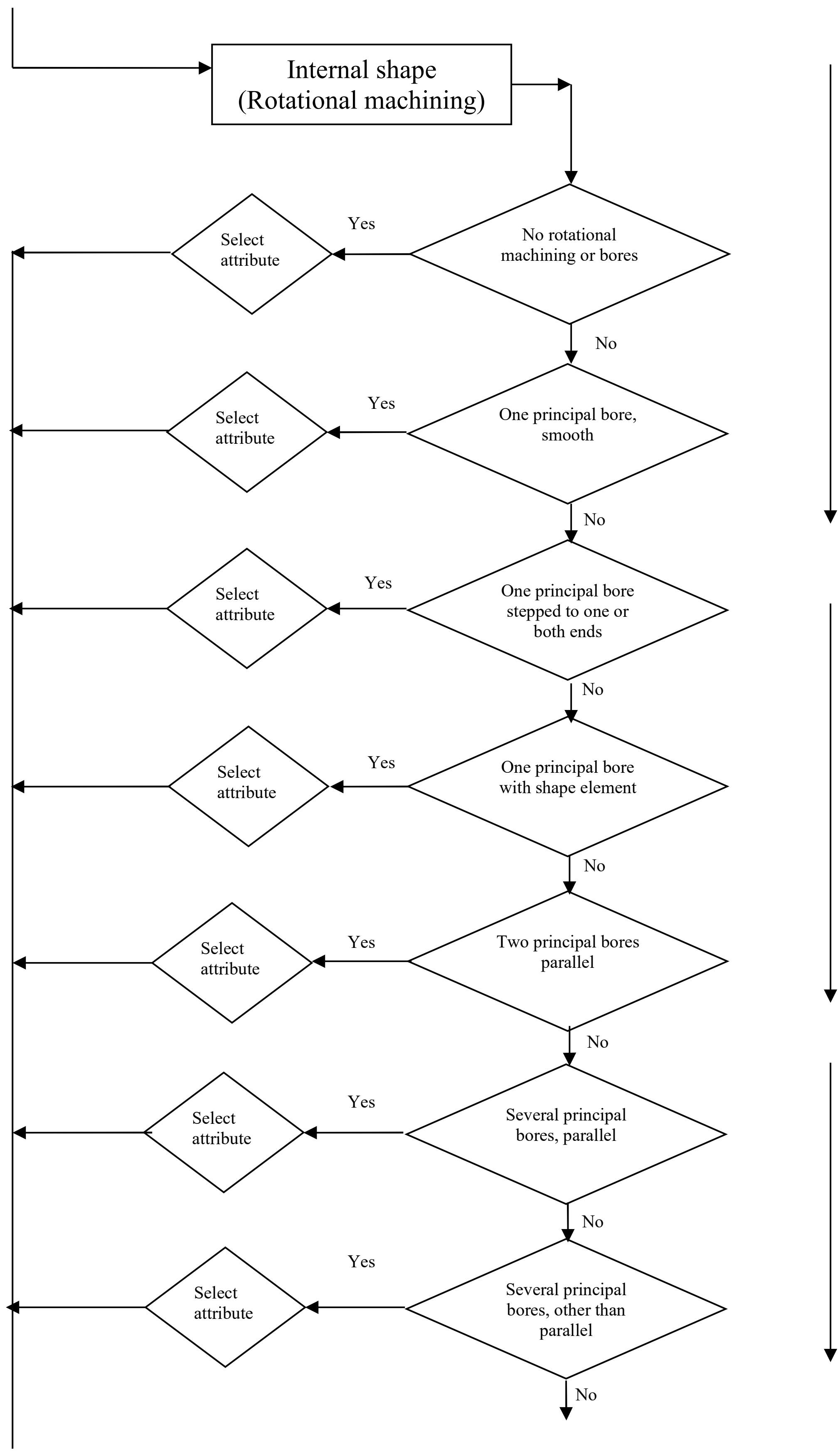


No
External spline (polygon)
Yes
Select attribute
No
Internal plane surface and/or groove
Yes
Select attribute
No
Internal spline
Yes
Select attribute
No
Any combination of the above
Yes
Select attribute
No
Others
Yes
Select attribute
Hole type
None
Yes
Select attribute
No
Axial blind holes
Yes
Select attribute

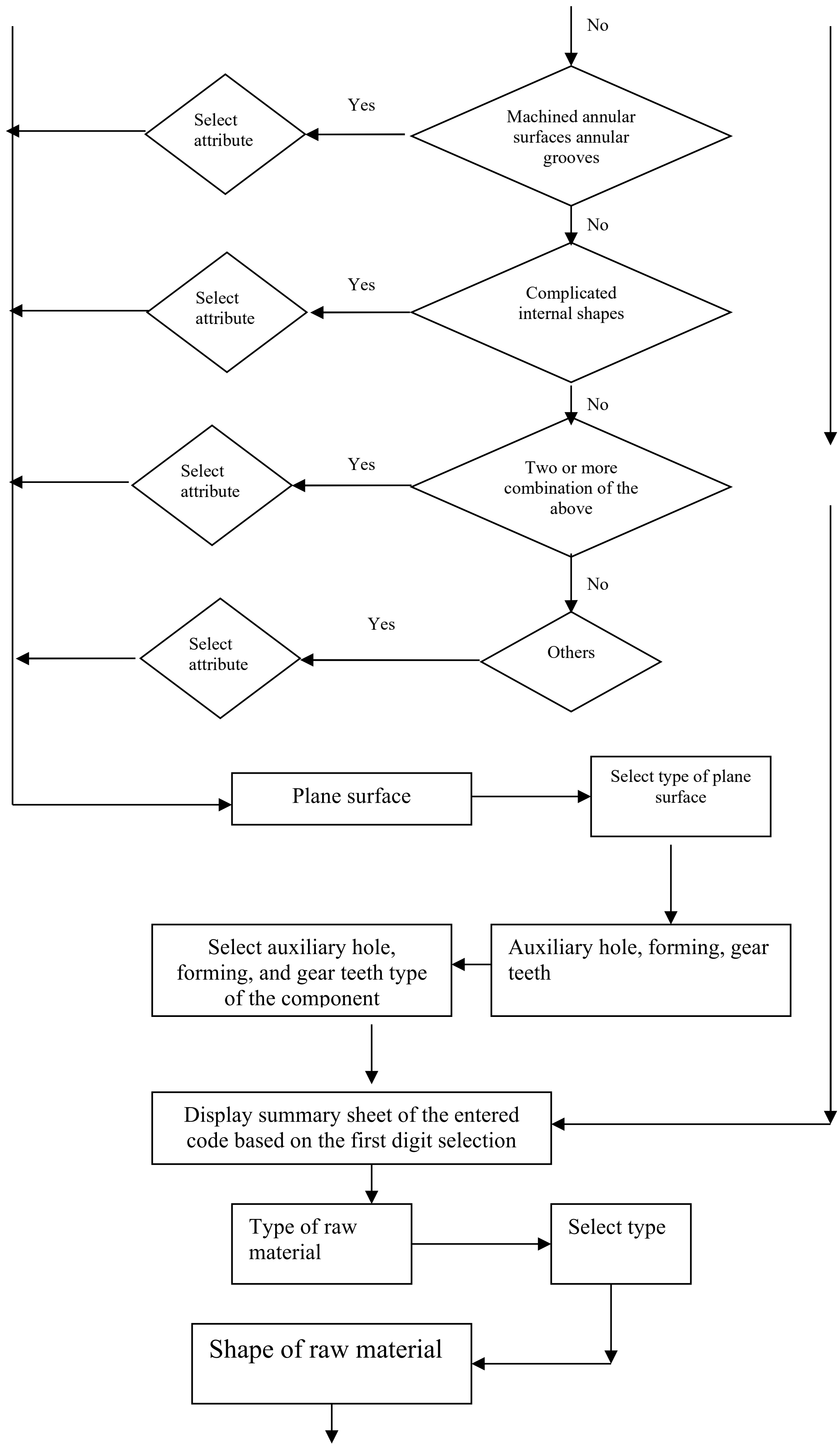

No
Axial through holes
Yes
Select attribute
No
Cross blind holes
Yes
Select attribute
No
Cross through holes
Yes
Select attribute
No
Axial & Cross through and/or blind holes
Yes
Select attribute
No
One or both side stepped Axial through and/or blind holes
Yes
Select attribute
No
One or both side stepped Cross through and/or blind holes
Yes
Select attribute
No
Combination of two or more types
Yes
Select attribute
No

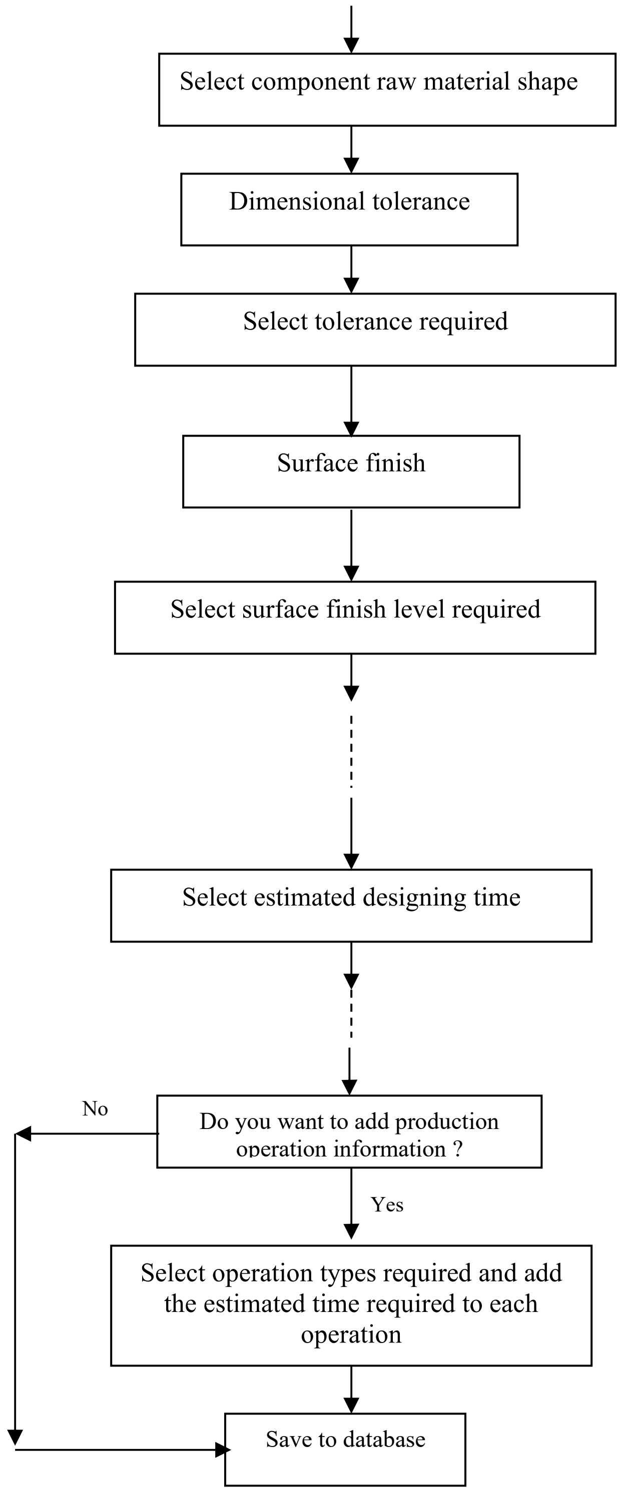

No
Yes
Combination of two or more types
Select attribute
Select gear Type
Select Aspect Ratio
External over all shape
Block like Rectangular prism
Yes
Select attribute
No
Block like Rectangular prism with deviation (right angle or
Yes
Select attribute
No
Block like components with a mounting or locating surface and principal bore
Yes
Select attribute
Block like components with a mounting or locating surface, principal bore with dividing surface
Yes
Select attribute
No


No
Block like component other than 0 to 4
Yes
Select attribute
No
Box like, approximate or compounded of rectangular non split prisms
Yes
Select attribute
No
Box like component other than 6, non split
Yes
Select attribute
No
Box like, approximate or compounded of split rectangular prisms
Yes
Select attribute
No
Box like component other than 8, split
Yes
Select attribute
No
Complicated external shape
Yes
Select attribute
No
Other type
Yes
Select attribute



Internal shape (Rotational machining)
No rotational machining or bores
Yes
Select attribute
No
One principal bore, smooth
Yes
Select attribute
No
One principal bore stepped to one or both ends
Yes
Select attribute
No
One principal bore with shape element
Yes
Select attribute
No
Two principal bores parallel
Yes
Select attribute
No
Several principal bores, parallel
Yes
Select attribute
No
Several principal bores, other than parallel
Yes
Select attribute
No


No
Machined annular surfaces annular grooves
Yes
Select attribute
No
Complicated internal shapes
Yes
Select attribute
No
Two or more combination of the above
Yes
Select attribute
No
Others
Yes
Select attribute
Plane surface
Select type of plane surface
Auxiliary hole, forming, gear teeth
Select auxiliary hole, forming, and gear teeth type of the component
Display summary sheet of the entered code based on the first digit selection
Type of raw material
Select type
Shape of raw material


Select component raw material shape
Dimensional tolerance
Select tolerance required
Surface finish
Select surface finish level required
Select estimated designing time
No
Do you want to add production operation information ?
Yes
Select operation types required and add the estimated time required to each operation
Save to database