CHAPTER 1

INTRODUCTION AND GENERAL BACKGROUND

1.1 INTRODUCTION

Computer Aided Process Planning (CAPP) serves as the bridge between CAD and CAM and has been one of the critical techniques for the implementation of CIM. Since the development of high level CAPP systems must be based on the thorough understanding of process planning, this chapter focuses on the theories, principles and methods of process planning which provide an important basis for CAPP [1].

It is necessary to understand the concepts of manufacturing process both in a broad and narrow sense. A manufacturing process is made up of a number of operations, each of which may include several operation elements, passes, settings and positions. Process plan must address each of these components.

The planning of machining processes is carried out under a series of preconditions. Even the same part may require different process plans under different manufacturing conditions [2]. Process planners must have the information before planning, so that a series of decisions can be reasonably made. These initial data include drawing and specifications of the part to be manufactured, drawing of the blank, planned volume of production, available equipment and tooling, and engineering and economic standards and handbooks.

The basic requirements to process planning are discussed in the following paragraphs from the standpoints of technology and
economics. These requirements should be fulfilled for the planning of each reasonable process. In most cases, low-cost production is the criterion for the evaluation plans. A method for the economical analysis of process plans is recommended, which is done by estimating and comparing the production costs of different plans.

In the product realization task, the first and the most important step involves making a process plan. Process planning is one of the significant functions of manufacturing planning. It can be defined as systematic determination of methods and means by which a product is to be manufactured economically and competitively. This planning takes up approximately 40\% of the preparation time for a new part. It thus, directly dictates the cost, quality and the production rate in the manufacturing set-up.

1.2 BASIC CONCEPTS OF PROCESS PLANNING

1.2.1 Introduction

Mass production, the tool that capitalists used to satisfy their consumer's needs, is no longer as effective as it used to be. Mass production and mass consumption, which had been considered to be a norm in the 1960's and 1970's, have been changed.

Over the years, the manufacturing business had become so profitable that more and more manufacturers have been participating in this market. As the number of manufacturers increased, the competition became tougher. More manufacturers mean more options
and more choices for the consumers. The consumer can always find a manufacturer to make something at a reasonable price. In essence, the manufacturer-consumer relationship has been reversed. In other words, the market is consumer-oriented, instead of manufacturer-oriented [3].

Also, as the consumer finds more and more choices of goods, the desire to have more choices becomes even stronger. The need for different kinds of merchandise grows faster than ever and at the same time the life cycle of each merchandise becomes shorter. As an example, the life cycle of an electric appliance is only 18 months.

The significant trend in present manufacturing industry is the product variety, frequent design change, and small in-process inventory restriction. As a result, the production volume for each product is very low. Today over 90% of all products are manufactured in batch sizes of less than 50 [Chang and Wysk, 1985][4].

Small batch production requires manufacturing systems with a reasonably high flexibility, not only in manufacturing equipment, but also in design, planning, scheduling, handling and management decision making.

Computer Integrated Manufacturing (CIM) is an integration of all aspects of manufacturing. In a CIM system, flexible automation of all manufacturing activities is realized and the coordination and optimization of the entire system is ensured. CIM represents the direction of the development of modern manufacturing.
1.2.2 Manufacturing Processes and Process Planning

The manufacturing (or production) process of a factory, in a broad sense is the sum total of separate processes involved in the conversion of raw materials or semi-finished products into final products. As far as a factory is concerned, its products can be blanks, finished parts, mechanisms, units or end products. The raw materials or semi-finished products used for manufacturing the products are often produced and supplied by other factories. Sometimes the products of the factory need to be further processed by other factories before they become the end products.

The manufacturing (production) process includes not only processes acting directly upon the manufactured objects, but also preparatory processes (such as production planning, process planning, production scheduling, tooling preparation etc.), and auxiliary processes (such as equipment maintenance, inter-shop material and workpiece handling, cutting tool sharpening, quality inspection, production statistics, cost accounting etc.).

The processes, acting directly upon the manufactured objects, change the shape, dimensions and properties of raw materials or semi-finished products, or assemble parts into final products. These processes are manufacturing (or production) processes in a narrow sense.

There are various manufacturing processes used for converting raw materials into finished parts. These processes include casting, forging, welding, punching, forming, machining, heat-treatment,
plating, coating, and so on. Amongst these, the machining processes have a significant role in the manufacture of parts.

The machining process of a part may include various machining operations, such as turning, milling, drilling, grinding etc., depending on the required shape, dimensions, accuracy and surface quality of the part. In order to ensure the quality of a completed part, well-planned process documents are necessary.

After a new product is designed, planning the processes for its component parts is the first step of the preparatory work for manufacturing. The planned process documents serve as the basis and initial data for all other preparatory work, and the rules and regulations for production operations. The quality of process plans influences directly the degree of complexity of the preparatory work for manufacturing, the time length of the preparatory stage, the quality of parts and products manufactured, the degree of complexity of production scheduling and operations sequencing, the make span of parts and products, and the production costs. Hence process planning is of key importance to manufacturing [Li.et.al. (1988)[5].

Often there exist alternatives of process plans for manufacturing a part. The quality of a process plan should be evaluated from a technological as well as an economical standpoint. A good process plan not only ensures the required quality of manufactured parts, but also reduces the production cost. In process planning, a comprehensive analysis of part structure, material and technical specifications, production volume and manufacturing conditions must
be made, so as to properly make all the decisions related to the planning of the process.

Considering the wide spectrum of manufacturing processes, it's very difficult to address them as far as process-planning activities are concerned. However, in the present work, the focus has been on the machining operations carried out in a small general machine shop.

A detailed process plan contains, the process route, process parameters, machines and tools required for production etc. However, when used in different industries and manufacturing shops, the process planning functions may involve few or all of the following activities:

- Selection of the blank and its manufacturing method.
- Selection of machining methods for part surfaces.
- Determination of operations sequences.
- Determination of workpiece setting method for each operation.
- Selection of machining equipment and tooling for operations.
- Determination of operating procedure for each operation.
- Determination of operational dimensions and tolerances for machining operations.
- Selection of machining conditions and determination of time standards of each operation.
- Tool path planning and generation of CNC part program.
1.2.3 Requirements for Process Planning

Process Planning is a significant task linking product design and product manufacturing, which greatly the quality of products, production efficiency and costs.

A reasonably good process plan should satisfy the following requirements:

- A process plan must ensure all the quality requirements of the part defined in the part drawing.
- A process plan should bring about reasonably high production efficiency in order to fulfill the production quota before its due date.
- A process plan should ensure low production costs.
- A process plan should help improve the working conditions and promote the uninterrupted development of manufacturing technology.

Product quality, production efficiency, and production cost are the main technological and economical considerations in process planning. Of these, product quality is of primary importance.

In process planning, the first important problem to be resolved is how to achieve the required accuracy to meet design specifications. When a process plan is implemented, it must ensure all the quality requirements as much as possible without relying upon the skills of the operator.

Other technological and economical problems should be resolved as well. For example, is it appropriate to adopt refined blanks
(precision castings or forging)? Is it suitable to use newly developed machining methods, machine tools or tooling (CNC machine tools, machining centre, Super-precision machining methods, advanced tools, jigs and fixtures, etc.), or unconventional machining methods? (ECM, EDM, Supersonic or Laser machining, etc.) All these questions have to be answered rationally in order to achieve reasonable manufacturing efficiency and low-cost production.

Several alternatives of process plans or some of its operations are evaluated and compared so that the best plan can be selected. The best alternative is to necessarily the one, which employs the most advanced machine tools, nor the one, which provides the highest manufacturing efficiency. The evaluation of the alternatives should be a systematic analysis from the technological and economical points of view. In most cases, the overall cost is the basis for decision. But it is important that the alternatives meet the requirements of quality and prompt production.

Depending on the production environment, the process plan can be very rough or can be detailed to a great extent [6].

**1.2.4 Basic Information for Process Planning**

The planning of machining process is based on the drawing and specification of the part to be manufactured, drawing of the blank piece from which the part is made, planned volume of production, available equipment and tooling for production and relevant engineering and economic standards and handbooks. They provide the initial data for process planning [3].
• **Drawing and Specification of a Workpiece**

Part drawing and its technical specification provide the essential basis for process planning. The information comes from a blueprint, a working drawing, or a CAD file.

It should be explicit to the most minor details. It includes:

- **Part configuration.** This should consist of necessary and sufficient projections, sections, cutaway views and dimensions in order to illustrate the shape and size of the part.

- **Technical specification.** All necessary dimensions and shape tolerance, the surface finish for all surfaces, and special specifications (for instance, the weight check, the balance check, the audio frequency check, etc.) should be clearly indicated.

- **Material.** The material of which the part is made should be specified; including required heat treatment, hardness of material, detection of defects, if any, and kind of blank (casting, forging, etc.).

All part information must be understood thoroughly by the planner. It should be regarded as the starting point of process planning. Incomplete, incorrect or indefinite part information will result in bad technological decisions and ineffective process plans.

• **Volume of Production**

The production volume of a part determines its production type and therefore, to a large extent, its process plans. In order to meet the needs of manufacturing efficiency and cost, alternate machining
methods, machine tools and tooling should be selected in process planning. It is of great importance in process planning to know the exact quantity of parts to be manufactured in a definite interval of time and the date of delivery.

Factories or workshops engaged in single-piece production adopt mainly general-purpose machine tools. All machine tools with similar functions (for instance, lathes, milling machines, grinding machines, planers, etc.) are organized in separate areas forming a functional layout. Standard cutting tools, universal work holders, and measuring facilities are used generally in this type of production. Operators in this type of factories or workshops should be very skilful, so as to cope with the diversified operations in production. In most cases, machine tools and their component parts are manufactured in piece production. They often are not of standard design and are subject to frequent changes. Therefore the principle of complete interchangeability can be fulfilled in this type of manufacturing.

In large-batch production, the volume of production is relatively large, while the variety of parts is limited. This type of production is comparable to mass production is which high efficiency and special-purpose machine tools and tooling are commonly employed. Machine tools and other equipment are arranged usually based on the sequence of manufacturing operations in order to form a product layout. This enables a high production efficiency and capacity with a great reduction in the labor input and the cost of production.
In traditional small and medium batch production, since the volume of production is low and the changes of operations on each machine tool is frequent, most of the equipment used are general-purpose machine tools, equipped with universal work holders and standard tools. Special machine tools are rarely adopted.

Product layouts are not always possible when the machine tools and other processing equipment are arranged in accordance with the sequence of manufacturing operations of the product. Functional layouts are widely used.

The current trend in plant layout is to build flexibility in a manufacturing system, in order to meet the variety and the frequent changes of the products to be manufactured. The manufacturing system designed with reasonable flexibility is called flexible manufacturing system (FMS), which represents the development trend of manufacturing, especially in small- and medium-batch and variety production. An FMS is composed of Computer Numerically-Controlled (CNC) machine tools or machining centers, industrial robots, inspection machines and so on, together with computer integrated materials handling and storage systems, which deal with high level distributed data processing and automated material handling. It combines the benefits of a highly productive, but inflexible transfer line, and a flexible, but inefficient job shop.

In mass production, specialized and single-purpose machine tools and tooling, with machining efficiency as high as possible, are employed extensively. Some of the plants or workshops engaged in
mass production bring about a full mechanization and automation. Principles of interchangeability are to be strictly observed. Since each workplace performs only a fixed and relatively simple operation, a lower skill level is required of the operator.

In a continuous production flow line, workpiece’s are transferred from workplace in a definite direction immediately after an operation is completed. The time required for completing a unit workpiece in each operation must be equal to, or a multiple of, the cycle time. This enables a sufficient loading for each workstation, in to avoid stockpiles in front of the machine.

Different types of production require different process plans. In single-piece production, only simple process plans, indicating the process routes, are required. However, in batch and mass production, the process plans should be in considerable details. In this way, not only the process routes, but also the details of each operation are included.

Also, for small time general machine shops may need the process plan/ details for specific task for a quick job. It’s also essential that, these systems must be developed carefully, on the same lines of any large Process planning system.

- **Production Equipment**

  Process Planning may be engaged under two different conditions:

  - Process planning for a new plant or workshop to be built.
  - Process planning for an existing plant or workshop.
In the former case, it is possible to select solely the most reasonable machine tools, according to the manufacturing needs. In the later case, the machine tools should be selected from the existing equipment available in the plant or the workshop, unless the purchase of some new equipment is planned. Sometimes refitting is necessary to enhance the functions and to increase the productivity of certain existing machine tools to meet the requirements of the planned processes.

In either case, a process planner must possess necessary knowledge about available equipment when planning a process. Machine tool catalogues of existing machine tools are helpful. Thus, based on the requirements of manufacturing process planning and the data of machine tools, the optimal equipment can be selected properly.

- **Other Information about Manufacturing**

In addition to the above-mentioned information, a process planner must have data on tooling, which characterizes the tooling facilities that are available for production. These are in the form of tooling handbooks in which data on standard work holders and tools are given, or a tooling list.

When process planning for an existing workshop, the skill levels of the operators and the transportation means adopted within the shop.
• **Economics of Process Planning**

In process planning, usually there exist several alternative processes, which meet the requirements of product quality and production efficiency. However, in real production, these alternatives will produce different economical effects. For the sake of choosing the process plan that is most economical under given production conditions, an economical analysis on various alternatives should be performed. The economical analysis is done by estimating and comparing the production costs of different process plans. The optimal plan will be the one, which costs the least to implement.

The unit production cost is the sum total of all expenses for the manufacture of a single product or part. It can be divided into two parts: costs related to manufacturing process and costs unrelated to manufacturing process. In the economical analysis of process plans, only the former, called process costs, are analyzed and compared.

If the basic investments required by the different alternatives of process plan are close, then the process costs of each plan can be used as the criterion for economical evaluation. When the basic investments needed for the compared plans vary, and some of the plans can achieve a lower process cost through the adoption of high efficiency but more expensive equipment or tooling, the payoff period of the investment has to be considered. In addition, it should be pointed out that in economical analysis, the increase of productivity
and the improvement of working conditions and labor safety must be taken into account.

1.3 COMPUTER AIDED PROCESS PLANNING (CAPP)

In the product realization process, the first and most important step is making a process plan. The quality of the product and the cost of producing it are strongly influenced by the process plan. The functions like Production planning, scheduling, part programming etc, take the process plan as their input.

Problems with manual process planning such as lack of expertise, inconsistency of the plans and the need to automate the process planning function, led to the use of computers in assisting the, process planning function. An integrated CAD/CAM team can only be developed if there exists a sub-system that can utilize the design and feature data from CAD and information from manufacturing database.

The Computer Aided Process Planning (CAPP) aims at providing this interface between CAD and CAM. With respect to this lot of research has taken place and this has led to three basic approaches to CAPP - Variant, Generative and Automatic [6]. The variant approach uses computer terminology to retrieve plans for similar components using tables or look-up procedures. The process planner then edits the plan to create a "variant" to suit the specific requirements of the component being planned. Creation and modification of standard
plans are the process planner's responsibility. Generative approach, however, is based on generating a plan for each component without referring to existing plans. Generative-type systems are systems that perform many of the functions in a generative manner. The remaining functions are performed with the help of humans in the planning loop. Automatic systems, on the other hand, completely eliminate humans from the planning process. In this approach, computers are used in all aspects, from interpreting the design data to generating the final cutting path.

1.3.1 Variant Process Planning

The variant approach to process planning was the first approach used to computerize planning techniques. Implementation of variant approach uses Group Technology (GT)-based part coding and classification is used as a foundation. Individual parts are coded based upon several characteristics and attributes. Part families are created of parts having sufficiently common attributes to group them in to a family. This family formation is determined by analyzing the codes of part spectrum.

A Standard plan consisting of a process plan to manufacture the entire family is created and stored for each part. The development of a variant process planning system has two stages: the preparatory stage and the production stage. (See Fig. 1.1)

During the preparatory stage, existing components are coded, classified, and later grouped in to families. The part family formation
can be performed in several ways. Families can be formed based on geometric shapes or on process similarities.

Families can often be described by a set of family matrices. Since the processes of all family members are similar, a standard plan can be assigned to the family. The standard plan is structured and stored in a coded manner using operation codes (OP-codes).

![Diagram](Image)

Production stage
Fig 1.1 Block diagram of Variant Process Planning Approach

Before the system can be of any use, coding, classification, family formation and standard plan preparation must be completed. The effectiveness and performance of the variant process planning system depends to a very large extent on the effort put forth at this stage. The preparatory stage is a very time consuming process.
The production stage occurs when the system is ready for production. New components can be planned in this stage. An incoming component is first coded. The code is then sent to a part family search routine to find the family to which it belongs. Since family number indexes the standard plan, the standard plan can be easily retrieved from the database. The standard plan is designed for the entire family rather than for a specific component, thus editing the plan is unavoidable.

Variant process planning systems are relatively easy to build. However, several problems are also associated with them. Some of them being:

- The components to be planned are limited to similar components previously planned.
- Experienced process planners are still required to modify the standard plan for the specific component
- Details of the plan cannot be generated.
- Variant planning cannot be used in an entirely automated manufacturing system, without additional process planning.

Despite these problems, the variant approach is still an effective method; especially when the primary objective is to improve the current practice of process planning. In most of the batch manufacturing industries, where similar components are produced repetitively, a variant system can improve the planning efficiency dramatically. Some other advantages of variant process planning include the following:
Once a standard plan has been written, a variety of components can be planned.

Comparatively simple programming and installation (compared with generative systems) is required to implement a planning system.

The system is understandable and the planner has control over the final plan.

It is easy to learn and to use.

The variant approach is a popular approach in industry today. Most of the working systems are of this type, e.g., CAPP of CAM-I [Link, 1976][7], CUTPLAN [Zdeblick, 1985][8].

1.3.2 Generative Approach

Generative process planning is the second type of computer-aided process planning. It can be concisely defined as a system, which automatically synthesizes a process plan for a new component. The generative approach envisions the creation of a process plan from information available in a manufacturing database without human intervention. Upon receiving the design model, the system is able to generate the required operations and operation sequence for manufacturing the component [6].

Knowledge of manufacturing has to be captured and encoded into computer programs. By applying decision logic, a process planner's decision-making process can be imitated. Other planning functions such as machine selection, tool selection, process
optimization, etc. can also be automated using generative planning techniques.

A generative process planning system comprises three main components.

- part description
- manufacturing databases
- decision making logic and algorithms

The definition of generative process planning used in industry today is somewhat relaxed. Thus systems which contain some decision-making capability on process selection are called generative systems. Some of the so-called generative systems use a decision tree to retrieve a standard plan. Generative process planning is regarded as more advanced than variant process planning. Ideally, a generative process planning system is a turnkey system with all the decision logic built in. Since this is still far from being realized, generative systems developed currently provide a wide range of capabilities and can at best be only described as semi-generative.

The generative process planning approach has the following advantages:

- It generates consistent process plans rapidly.
- New components can be planned as easily as existing components.
- It has potential for integrating with an automated manufacturing facility to provide detailed control information.
Successful implementation of this approach requires the following key developments:

- The logic of process planning must be identified and captured.
- The part to be produced must be clearly and precisely defined in a computer compatible format.
- The captured logic of process planning and the part description data must be incorporated into a unified manufacturing database.

### 1.3.3 Automatic Process Planning Approach

The way in which the part description is input to the process planning system has a direct effect on the degree of automation that can be achieved. Traditionally, engineering drawings have been used to convey part descriptions. Automation of process planning requires that part features must be extracted automatically from CAD models. It has the potential to achieve complete automation and integration of the CAD/CAM process. Much of the ongoing research is being devoted to extract the features from 3-D CAD solid model.

This approach is of great significance when the process has to be developed from the product concept, which is usually conceived as a 3-D solid model. On the shop floors the machining or processing drawings used are of 2-D type. If the process plans are to be developed by referring to these drawings, system will have to extract the features from these 2-D CAD drawings.

Feature information of the product constitutes one of the most important and prime inputs for any CAPP system. All the decisions
and the configuration of the process plan/ part program generated are mainly based on the feature-related information. Any error in interpretation of the product features would cause a major effect in the execution of process planning functions. A system designed with a mechanism to extract the features from CAD models would provide a solution to this problem.

The theory and principles of automated process planning approach has been explained in detail in Chapter 2.

1.4 OBJECTIVES, OVERALL FEATURES AND SCOPE OF PRESENT THESIS

Since the beginning of the last decade, it has been recognized by both academic and industrial communities that planning in a manufacturing environment is vital to achieve the ultimate goal of unmanned and integrated factories in the future. Today, many research and development efforts have been devoted for analyzing, modeling and automating such planning activities.

Problems with manual process planning such as lack of expertise, inconsistency of the plans and the need to automate the process planning function, led to the use of computers in assisting the process planning functions. An integrated CAD/CAM system can only be developed if there exists a sub-system that can utilize the design and feature data from CAD and information from manufacturing
database. The automated process planning aims at providing this interface between CAD and CAM.

There have been 2 approaches that have been conventionally used to automate process planning: Variant and Generative. The Variant approach is based on group technology (GT). Generative process planning system synthesizes a new plan for each part. Each of them has both, positive and negative aspects.

The concept of Automatic process planning approach, proposed by Chang (1990) [6] has been the key technology in CAPP. This approach eliminates the human intervention in the CAPP procedure to a greater extent, such that the built in mechanism gets process plans/ CNC part programs, directly from CAD models.

One has to think of an integrated approach, consolidating the features and benefits of all these approaches. New computer based methodologies must be developed to help for going through the transition from current information sensitive industry to the prospective knowledge-intensive industry.

Given all the research and development efforts expended so far, it is discouraging to realize that only a few computer based planning system have actually been used by industry and that, even fewer have reached to a stage where they could make a significant impact on manufacturing practice. Part of this slow progress is due to the complex and dynamic nature of the planning domain, which will pose great challenges to the future research. An important reason is however, the lack of theoretical sound foundation and a scientifically
rigorous base for current planning approaches. As we near the third decade of manufacturing planning research, it is important to critically re-examine the methodologies and approaches currently being pursued by the researchers. It can be observed that planning activities are undergoing a long development form manual process planning in the past, through computer assisted planning and interfaced planning at present to Integrated and Intelligent planning in the future. In the process of developing computer assisted process planning systems and interfacing them, one has to look ahead the challenge of developing integrated planning systems and adding Intelligence to them. Intelligent planning requires more robust AI techniques which go beyond the rule based approaches. Also, in the whole crowd of CAPP systems, it appears that, no efforts have been made to have a simple CAPP system suitable for a small general machine shop, on an affordable PC level platform.

In the perspective of the above arguments present work addresses these questions and attempts to provide a broad-based general solution in the form of an **Intelligent System for Manufacturing Information - ISMI** suitable for a general machine shop, on a PC level platform which can be extended to become an online application.

The system has been developed with the following considerations:

- A uniform product description based on proper features defined either through user's interaction or CAD Models.
➢ Use of different module for each type of manufacturing operation.

➢ The possibility of facilitating user interaction wherever required.

➢ An effective common platform on which all these modules are made available to the user just at the click of a mouse button.

**ISMIP**, in order to provide integration, automation and flexibility needed in future process planning has been designed with the following concepts.

- **Integrated technique for process planning**

  The conventional process planning techniques viz. Variant and Generative have both positive as well as negative aspects. An Integrated, Feature based Generative approach has been considered most suitable for the present work. All the modules utilize this approach. Depending on the three dimensional part the operations/tasks are identified and the details of each operation in it has been generated based on theoretical rules, data bases or practical constraints.

  This has been done knowing the fact that the generative process planning systems would best serve the long term need of the process planning domain and current research has focused on determining the best way to combine the artificial intelligence with various part description schemes to develop a truly generative process planning system. This methodology has been used extensively in the present work for Automatic Extraction of Features from CAD models.
Integration of CAD and CAPP

It has been recommended and accepted that, for a perfect integration features must be used as a technological and communicational interface between design and process planning and would form the basis to automatically extract all the product data. The way in which the part description is input to the process planning system has a direct effect on the degree of automation that can be achieved. Traditionally, engineering drawings have been used to convey part descriptions. It has the potential to achieve complete automation and integration of the CAD/CAM process.

The 3D CAD Solid models are increasingly becoming popular in the product development procedures. Considering this fact, in the present work all the modules have been developed considering 3D solid CAD models. The most innovative part of this work is that the most common and popular type of CAD data interface Standard for the Exchange of Product model data (STEP) has been used for the models, whereas in most of the reported works on 3D CAD models, Initial Graphics Exchange System (IGES) or Drawing Exchange Format (DXF) or other similar types of complex and unpopular interfaces were used.

Seen from the perspective of manufacturing, the product model should cover the geometrical and topological information of the workpiece. The manufacturing information such as tolerance and surface finish specifications etc. is of great significance in selection & sequencing of the processes, machine tools, selection of process
parameters etc. Also, precedence among the features is established on the basis of these manufacturing attributes. In the present work these manufacturing attributes are obtained from the knowledge base and also the product expert. The present system considers this aspect meticulously.

- **Integration with reference to the manufacturing environment**

  Process planning system must suggest the actions, considering the constraints, capacities and capabilities of the manufacturing processes, equipments in the manufacturing shops. Selection of the manufacturing process has to be based on matching the design and functional requirements, with process capabilities etc. Considering this, a product expert module backed up with the appropriate knowledge base contains these process capabilities.

  Most of the existing CAPP systems deal with only specific operations such as Turning, Milling etc. In the present work, the various islands of these operations have been put on a single platform. Specialized modules considering Turning, Milling, Drilling, Grinding and 3-axis complex cavity machining covering most of the types and features within have been incorporated. In general, the part has to move through various machining procedures before reaching the final state. Also, the user may need the short process plans for specific manufacturing tasks. It’s the need of the hour that most of the manufacturing procedures are incorporated on a single CAPP platform. The present system provides this feature with reference to a
general machine shop, clubbed with Automatic feature extraction from the CAD models.

One of the primary objectives of any process planning system is to generate an optimum and well designed process plan and to suit the present trend of flexible automation, CNC part program. CNC set-ups form the nucleus of any modern manufacturing set-up. In order to achieve flexible automation, the use of CNC systems is inevitable. The feature data and the process plan have been further extended for generation of CNC Part program. The part programs generated in the present work have been validated on FANUC controlled CNC machines.

1.5 ORGANISATION OF PRESENT THESIS

In organizing present thesis, an attempt has been made to provide complete validated information on various aspects of CAPP, in the course of covering each and every module of ISMI. The topic itself has been an intelligent integration of different modules, accessible from a single platform. The initial part of the thesis discusses about the basic concepts of process planning in general and CAPP in particular along with discussion on the various approaches used in CAPP.

General background of process planning and its related components has been mainly provided in Chapter 1. Chapter 2 presents an overview of various elements of CAPP based on AFR technique, related elements and an extensive literature survey,
identifying the research issues, problem definition and scope at the end. Chapter 3 addresses the methodology w.r.t present work, the logic used along with flowcharts in Feature recognition process for various components.

The three modules have been discussed in detail in Chapter 4. Overall methodology and features of each module of the present work have been overviewed.

Chapter 5 depicts the screenshots along with explanations w.r.t important selected components & highlights the flow of the system along with its output.

The Research contributions along with Validation of the output parameters like process plan and part program have been outlined in Chapter 6.

Chapter 7 gives the concluding remarks and suggests the scope for further work.

A list of the research papers and books referred for the work has been given along with 3 appendices. Appendix A shows a STEP file of Plate with a hole feature. Appendix B illustrates the concepts and equations used for machining time/ cost calculations. The data referred for Cutting speed, feed, DOC etc for various processes have also been shown in tables. Finally, Appendix C discusses in detail the comparisons between the Research application developed and other commercial software's w.r.t various parameters. Screenshots have been used to highlight the comparisons.