International Journal of Advanced Engineering and Technology
ISSN: 2456-7655
Impact Factor: RJIF 5.54
www.newengineeringjournal.com
Volume 2; Issue 2; May 2018; Page No. 49-54

Computer aided process planning in manufacturing: A review

Charles Chikwendu Okpala, Austin Kelechi Okonkwo
Department of Industrial/Production Engineering, Nnamdi Azikiwe University, P.M.B. 5025 Awka, Anambra State, Nigeria

Abstract

Process planning is defined as the sequence of individual manufacturing operations required to manufacture a product, it entails a set of manufacturing features which usually starts with the selection of raw materials through completion of the finished product. In the 21st century competitive manufacturing where emphasis has shifted from achieving customer's satisfaction to exceeding his expectations, there is a need to develop an efficient process plan with numerous advantages over the manual approach that is characterized with many shortcomings. The Computer-Aided Process Planning (CAPP), which is the integration of computer to process planning is an efficient technology that incorporates design and manufacturing, by offering the solution to the bottleneck situations experienced by manual or traditional process planners. This paper gave a detailed definition of Process planning, Computer-Aided Process Planning, the two dominant methods of CAPP – Variant/Retrieval and Generative, as well as the significant role of CAPP in a typical manufacturing industry. Apart from general manufacturing efficiency, less calculation errors, enhanced use of raw materials and production scheduling, other listed benefits of successful application of CAPP include: 47% reduction in product throughput time, 35% improvement in process planning efficiency, 32% reduction in setup time, 7% reduction in total production cost, 10% savings in direct labor, etc. The paper concluded by explaining that CAPP is very important in automated manufacturing, and thrives in an environment that produces a wide variety of products, as all the problems of manual process planning are addressed with its proper implementation.

Keywords: computer aided production planning, process planning, route sheet, CAD, CAM, CIM, variant/retrieval and generative CAPP

1. Introduction

Every part of finished goods has some design specifications which ensure their functionality, and the essence of manufacturing is to produce quality products that conform to design specifications. Process planning is the procedure of preparing for manufacturing and the achievement of the desired finished goods in line with the product design specifications. It entails a set of manufacturing features which usually starts with the selection of raw materials through completion of the finished product. As shown in figure 1, process planning acts as a bridge between design and manufacturing, by translating design specifications to manufacturing process details. It is that function within a manufacturing facility that establishes which machining process parameters are to be used, and the sequence to follow to convert a work material from its initial stage to a final form, as defined by the engineering design drawings.

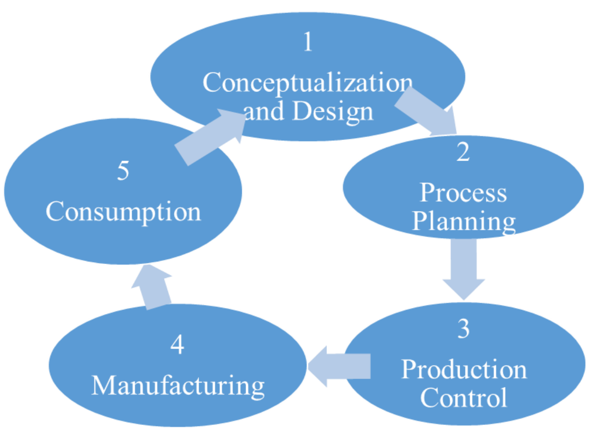


Fig 1: Product Life cycle

Although process planning may vary from one planner to another; the underlying principles remain the same, as it establishes an efficient and optimum sequence of operations, selects proper equipment and tooling and specifies their operations in such a manner that the product will meet the requirements stipulated in the design specifications. In some instances, the process planning and design stages are often inter-woven. As a matter of fact, basic process planning must begin during the product design stage, where the selection of materials and initial form manufacturing process - casting, forging, machining etc. are done.

Historically, process planning prior to 1970 was extensively done by manufacturing industries in the manual/traditional method. The traditional process planning despite its widespread use then, was posing a couple of problems to process planners due to its manual and paper-work nature. This largely depends on the process planner's knowledge and experience in a particular product manufacture or products which follow similar manufacturing pattern.

However, in recent times the dependence was no longer sufficient as manufacturing began to get more complex. Ronald (1981) [7], observed that 45 to 80% of process planning task is clerical in nature and this implies that at least half of the engineer's time is spent on clerical tasks, which is inefficiency. He then noted that the clerical nature of process planning and its records is a problem compounded when there is a lack of maintenance and updating of records.

Consequently, when references are made to these records, the application of the information in them can result to poor or even inaccurate process plans. Sometimes, finding the existing process plan is difficult and this is true especially when previous manual process planners retire or leave the company. Furthermore, planning manufacturing processes the traditional way creates room aplenty for deviation from design specifications, defects, lot of quality and cost issues. This is a dire bottleneck situation for manufacturing in the present and future industry.

The size and complexity of manufacturing challenges have led to the development of a number of computerized packages. Computer Aided Process Planning (CAPP), is the most common and most applicable computer package for process planning. Stix (1984) [10], noted that Computer Aided Manufacturing International Inc. (CAM-I), developed a CAPP package known as CAM-I's CAPP, basically to demonstrate the feasibility of using computer technology to automate process planning in manufacturing. The author further explained that the CAM-I's CAPP developed in the 1970's is the first known CAPP software developed, and that since then many more CAPP packages have been made commercially available, with significant progress been made in addressing the basic problems posed by the traditional process planning method.

Computer Aided Process Planning (CAPP) entails all the activities that convert the specifications of a part design from engineering drawing into the required production procedures and strategies to translate a crude workpiece to a desired finished product. As a key factor of manufacturing cost and profitability, CAPP focuses on industrial processes, and involves the use of computer technology like Computer Aided Design (CAD), and Computer Aided Manufacturing (CAM) to design physical products.

Implementing CAPP in manufacturing is not an easy task to perform; this is because the positive yield of computer in process planning requires manual efforts and adjustments before they can be applied. However, the effective deployment of CAPP helps a manufacturing company to achieve routing (Route Sheet), process plans, as well as fabrication and assembly drawing to support manufacturing.

The route sheet is defined as the map or blueprint of the manufacturing process in production unit. It determines the sequence or order of arrangement of various departments in a facility. Thus, a route sheet is a document which has information and data inputs and a step wise listing of all the processes or transactions performed. It also contains details such as date and time, remarks, log in or out, point of contact etc. As shown in Tables 1 and 2, Arora (2004) [1], systematically illustrated a route sheet in its simplest form for a pencil manufacturing facility.

A typical route sheet contains the following information

- Identification and sequence of work product
- Symbol or sign of a component of the product
- Appraised or assessment of the process or method which is followed
- Computing the number of unit to be produced
- Machines and tools used in the operation, their run time, efficiency and capacity
- Evaluation of the entire production process.

Table 1: Illustration of a route sheet

Product Name	Pencil
Production begins (Tentative)	02-01-2010
Production ends (Tentative)	01-03-2010
Date of preparing the route sheet	10-11-2009
Number of sets	6 sets, 20 each
Raw materials required	Graphite, clay, wax cedar, ferrule, pumice, rubber, metal, prongs, dyes, pigments, gum
Symbols used in the manufacturing process	O = Operation I = Inspection T = Transportation S = Storage D = Delay

***Source*:** Arora (2004) [1]

Table 2: Process Flow Chart

Task Number	Symbols	Description of task	Time taken	Machinery Required
1.	OITSD		Record the exact run time of the machine	
2.	O	Making the graphite core		Die maker
3.	O	Processing the graphite by extrusion method and billet press method		Billet press, extrusion press, oven
4.	O	Making the wood casings		Cutter head, hydraulic press, shaping machine, conveyor machine
5.	O	Smoothening and varnishing		Felt disk, dryer
6.	O	Attaching ferrule and erasing		Metal prongs
7.	O	Stamping the company's logo		Steel dye

***Source*:** Arora (2004) [1].

At each stage, the inspection of the labor and machinery is done and delays are accounted for. A log book is maintained to record the time taken by machines to complete the work, and by employees to start and complete their tasks. After the completion of the manufacturing, the product is run through a quality control test.

Creating a route sheet is very important towards an effective, efficient and economical manufacturing of products. From all indications, the traditional or manual route sheets creation can be extremely stressful, tiresome and in most cases does not optimize the manufacturing operations sequence and resources. However, no matter how simple, moderate or complex a process is, a computer program can create their route sheet in few minutes or seconds, eliminating the stress on the human planner and saving time, energy and money.

2. Overview of CAPP

The manual process planning is often a tedious and time demanding engineering process and it is one of the activities in the preparatory stage of manufacturing. There are many routine, heuristic, deciding and intuitive activities used by the manual process planner. There is therefore every need for these activities to be supported by Computer Aided Process Planning (CAPP) which is a software for automating process planning and route sheet design. The contrast between the manual process planning and CAPP charts is depicted in figures 2 and 3.

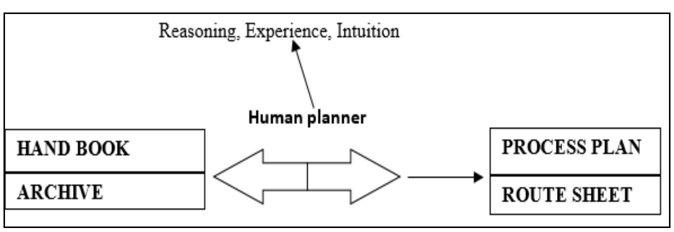


Fig 2: Manual Process Planning chart

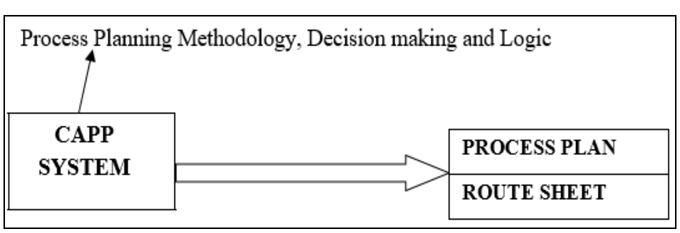


Fig 3: Computer Aided Process Planning chart

CAPP is not to be confused with Computer Aided Manufacturing (CAM) and Computer Aided Design (CAD). Cohen et.al., (1997) stated that while CAD refers to the first real stage of products manufacturing whereby a computer software is used to create the pictorial image and feel of a conceptualized product, dimension its features, specify the material to use and simulate its functionality, CAM, on its own refers to the stage of the manufacturing proper or raw materials conversion to products following a sequence of value adding operations which are consummated on computer controlled machines. Automated Computer Aided Design (AutoCAD) and SolidWorks amongst others, are some of the commonly available and used CAD software. CAD, CAPP and CAM are all aspects of Computer Aided Engineering (CAE).

In CAM, the product designed with CAD is manufactured according to the specifications and directive of the design. However, this is done using computerized or programmable automated machines with computer software that can translate design parameters into actual production, requiring little or no human interference. It includes Direct Numerical Control, Computer Numerical Control, DNC and CNC machines respectively. As shown in figure 4, CAPP is the link between CAD and CAM in a CAD/CAM system.

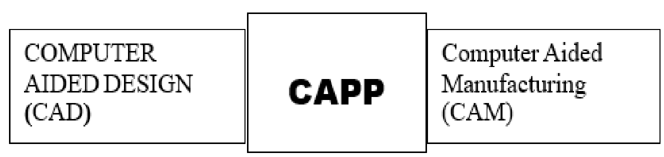


Fig 4: Relationship between CAD, CAPP and CAM

Computer Aided Process Planning acts as a bridge between design and manufacturing, by translating design specifications into manufacturing operations details. Synergy results when CAD is linked to CAM by CAPP. In such a system, CAPP becomes a direct connection between design and manufacturing. Mikell (2014), observed that a manufacturing environment involving CAD and CAM systems inter-connected by the CAPP system is known as a Computerized Integrated Manufacturing (CIM), which is the future of the world's manufacturing industries.

CAPP which exists as software must be written in computer programming language, by a software programmer with the description of manufacturing made to him by an experienced manufacturer or manual process planner.

3. Methods of CAPP

There are two basic approaches to CAPP:

- Variant or retrieval method; and
- Generative method.

Variant or Retrieval CAPP

Variant or retrieval CAPP implements a coding and classification scheme by which a process plan for a previously planned part is retrieved. Standard process plans are stored in the CAPP database files for each part or product code number, usually alpha-numeric characters and can be retrieved based on the similarity to the new part to be manufactured. These process plans or route sheets are based on current product routings or on an ideal process plan that has been prepared for each product family.

The retrieved process plan is then manually modified as required for the new part design. Stix (1984) [10], posited that there is high probability that similar parts have similar process plans. This is a basic assumption of utilizing the variant or retrieval process planning method.

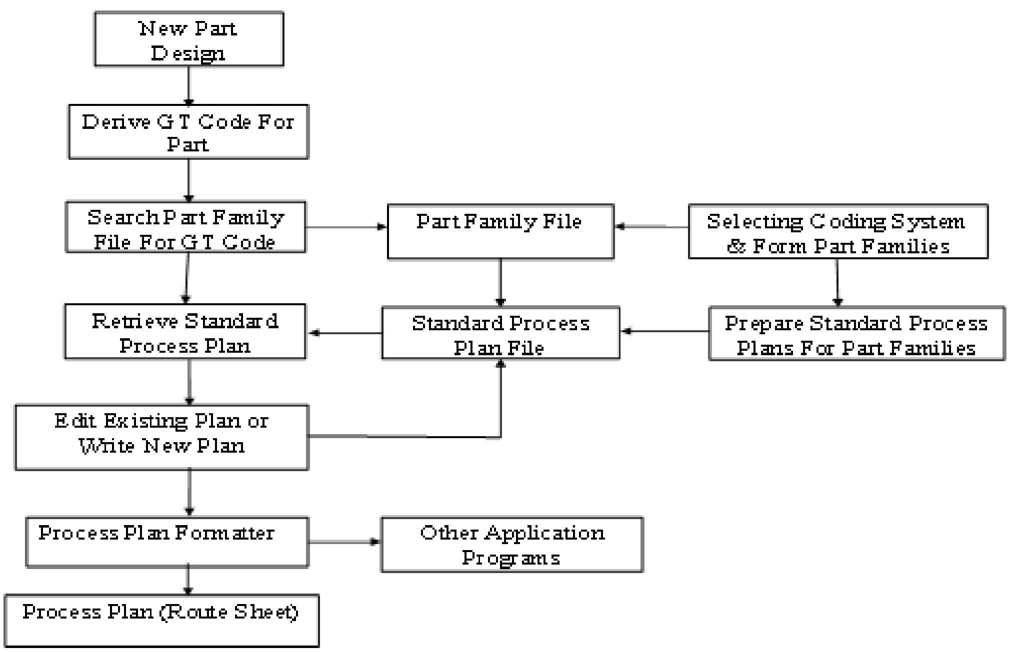
Other assumptions in the variant CAPP approach include:

1. The user is able to determine the appropriate classification codes needed to retrieve appropriate plans.
2. Process plans exist and include features which are closely similar to those of the new part.
3. The factory configuration is stable, with only minimal work station or process capability changes.

The variant approach to CAPP was the first method used in computerized process planning. It is based on the concept that similar parts have similar process plans. The computer is used as a tool to assist in identifying similar process plans, as well as in retrieval and accordingly editing the plan to suit the requirements for the specific part at hand. Variant or Retrieval CAPP is largely based on Classification Coding (CC) and Group Technology (GT). In these concepts, parts are classified and coded based on several attributes, and each code is a representation of an operation or process.

The GT coded data can be used for the retrieval of process plans for similar parts and this is intelligently done by the CAPP software. Substantial effort is applied in development of database of these standard process plans.

The retrieval or variant CAPP algorithm that started from new part design and ended with process plan or route sheet is shown in figure 5.



***Source*:** Sehgal (2013) [8]

Fig 5: Retrieval/Variant CAPP algorithm

In implementing this algorithm, Stevenson (2002) [9], explained that a significant amount of information must be compiled and entered into the CAPP database or data files, in what is known as the CAPP preparatory stage. Manafi, Nategh, and Parvaz (2017) [4] further buttressed this point by explaining that the preparatory stage of retrieval CAPP involves the selection of appropriate classification and coding scheme, forming part families or groups for all products of a company that is using the principle that parts with similar features follow similar manufacturing operations. This preparatory stage is done for new products that are introduced, thereby updating the company's database. Completing the preparatory stage makes a deployed CAPP system ready for use.

Following the algorithm of fig. 5, if the process plan for a new product is to be determined, the first step is to derive the GT code for it. With this code, a search is made on the CAPP database to verify if a standard route sheet or process plan exists for the part or product GT code. If such exists, it is retrieved from the database and edited accordingly. But if it does not, the standard process plan which comes so close to what is desired is taken and used to write a new process plan for that part.

Sehgal (2013) [8], noted that even if there is no related standard process plan, a new plan is developed from the scratch by the user and it then becomes a standard process plan for that part or product code. The function of the formatter is to make the CAPP software interface with other application software; for example, machining conditions, bill of materials, standard operations times, cost estimation software programs, etc.
The advantages of implementing the retrieval or variant CAPP include considerable and affordable cost of investment, shorter development time and lower manpower consumption in developing process plan, and reliable in real production. However, Yusri and Karman (2014) [12] and Xun, Lihui, and Stephen (2010) [11], explained that the quality of the process plans created by retrieval CAPP systems depends on the expertise of the software programmer and the knowledge of the process planner. Examples of commercially available retrieval CAPP software include MultiCAPP, I-CAPP, MetCAPP, project manager V2.5, AutoCAPP etc.

Generative Capp

Unlike the variant CAPP, generative CAPP is a very complicated methodology. The description of part and knowledge bases are necessary for the process plan creation. In a generative process planning system, an adequate (usually feature-based) part model is utilized to build a process plan from the scratch. Arora (2004) [1], explained that this is done by utilizing the fully described geometry, derived parameters to determine applicable processes and resources that will correspondingly transform the raw material blind into the pre-determined part or product, following design specifications from CAD. Instead of retrieving and editing an existing plan contained in a database, a generative CAPP system creates the process plan by means of decision logics, formulae, algorithms and geometry based data which are fed as input to the system.
The generative CAPP system produces a route sheet or process plan without any human assistance, and without any set of pre-defined standard process plan. It aims at the automatic generation of process plans, starting from scratch for every new work piece description. This is accomplished by feeding data input to the system through interactive text input via the keyboard or by graphical input from CAD models.
Manafi, Nategh, and Parvaz (2017) [4], observed that when compared to retrieval or variant CAPP, generative CAPP is more accurate in result and more flexible for all sorts of parts to be manufactured. Also, it creates an optimal process plan easily than the retrieval type. However, it is a far more difficult approach to implement than the variant CAPP. Generative CAPP is also known as Expert System, which is a computer program that is capable of solving complex problems that normally would take humans years of education and experience to attempt.
Xun, Lihui, and Stephen (2010) [11], explained that there are several ingredients required in a fully generative process planning system. First is the technical knowledge of manufacturing and logic used by successful process planners which must be captured and coded into a computer program. The knowledge and logic of the human process planner are used in generating a knowledge base. The generative CAPP system then uses that knowledge base to solve process planning problems by creating route sheets.
A Second ingredient is a computer-compatible description of the part to be produced. This description contains all of the relevant data and information needed to plan the process sequence. This can be done by either of the geometric model of the part that is developed on a CAD system during product design or by GT code number of the part that defines the part features in significant detail. The third ingredient in a generative CAPP system is the capability to apply the process knowledge and planning logic contained in the knowledge base to a given part description.
In other words, the CAPP system uses its knowledge base to solve a specific problem, this problem-solving procedure is referred to as the Inference Engine. By using its knowledge base and inference engine, the generative CAPP system synthesizes a new process plan from the scratch for a new part.
The advantages of implementing the generative CAPP include all the advantages of the retrieval CAPP. In addition, it is fully automated and generates up-to-date process plan for each new part. Presently, there is no fully developed generative CAPP system in use. Mikell (2014), noted that purely generative CAPP is still a future prospect. ICEM-PART, PART-S, LOCAM, MicroCAPP etc. are some of the semi generative CAPP systems which are commercially available.

4. Benefits of implementing Capp

Good planning is the key to success for any task of significant size. This is most certainly the case when implementing a CAPP system. For manufacturing industries, investing in the CAPP system is very difficult to justify using standard accounting payback procedures.
Granville (1999) [9], noted that in order to make CAPP implementation easier, future planning is an essential step, because the automation of process planning implies that a company has a long term commitment to Computer Integrated Manufacturing (CIM). Thus, there must be a solid commitment of time and money by a company’s management.
To illustrate the level of importance and benefits of CAPP when applied to manufacturing industries, the first step is to clearly define the scope of the manufacturing process:

- Examination of the existing methods is a good place to start.
- What are the company’s needs, now and in the future?
- What is hoped to be gained?

The next step is to make some considerations which include

- Defining the broad scope of the manufacturing process and gaps to fill.
- The various technical analysis: both the hardware and software aspects are extremely important for consideration.
- The software or CAPP program: the choice of the software is a case of make-or-buy decision making. The company may decide to buy commercial software from the market or develop in-house software for use.
- Cost analysis

According to Priti (2016), when a CAPP system is properly planned and implemented, the benefits it brings to manufacturing are enormous, they include

- Achieving consistent process plans
- More complete and detailed process plans
- Improved cost estimating procedures and fewer calculation errors
- Less errors, scraps, re-works and defects
- Reduced process planning and production lead time
- Faster response to engineering changes
- Improved production scheduling and capacity utilization
- Improved ability to introduce new manufacturing technology and rapidly update process plans to utilize the improved technology
- Optimization of process planning mainly on the basis of time and cost

However, to Granville (1999) [9], pointed out that recent studies on successful CAPP systems have shown that CAPP results in:

- 47% reduction in product throughput time
- 35% improvement in process planning efficiency
- 32% reduction in setup time
- 7% reduction in total production cost
- 10% savings in direct labor
- 10% savings in scrap
- 12% savings in tooling
- 6% savings in work-in-process inventory.

Stix (1984) [10], opined that once management support is given, it is imperative to continually keep them informed along each step so that the problems incurred with manual process planning can be overcome.

5. Conclusion

The scope of work explained in this paper concludes that manual process planning has numerous problems inherent in it, and that manufacturing of a part or product involves CAD, CAPP and CAM for an automated industry. Most CAPP systems in use are either purely of retrieval type or a hybrid of retrieval and generative type or semi generative. This means that a purely generative type CAPP is still a goal of the future. Strenuous research efforts are being made to develop a completely generative CAPP, which has the potential of creating a CIM architecture in combination with CAD and CAM. However in its present state, companies can enjoy the benefits of CAPP with minimal cost and risk.

CAPP is very important in automated manufacturing and it thrives in an environment that produces a wide variety of products, as all the problems of manual process planning are addressed with a proper implementation of CAPP. Be it variant or generative CAPP, its implementation has some methodology, computer hardware and software, and cost considerations. It is highly recommended for all metal based manufacturing industries who are interested in the intermediate and long run performance of their manufacturing businesses.

6. References

1. Arora K. Production and Operations Management University Science Press, New Delhi, 2004.
2. Cohen A, Morris B, Uday M, Apte C. Manufacturing Automation McGraw Hill, New York, 1997.
3. Granville C. Engineering Process Planning McGraw Hill, New York, 1999.
4. Manafi D, Nategh M, Parvaz H. Extracting the Manufacturing Information of Machining Features for Computer Aided Process Planning Systems Mechanical Engineering department, Tarbiat Modares university, Tehran, 2017.
5. Mikell P, Groover K. Automation, Production systems and Computer Integrated Manufacturing Fourth edition, Prentice Hall, New Jersey, 2014.
6. Priti S. Computer Aided Process Planning for Milling Operation International Journal of Mechanical Engineering and Technology, 2016, 7(5).
7. Ronald W. Computer Aided Process Planning: The Implementation and Evolution of CAPP systems Department of Industrial Engineering, Kansas State University, Kansas, 1981.
8. Sehgal A, Anuj A, Gopal S, Atul D. Computer Aided Process Planning Technique in Casting Industries: An Overview International journal of engineering research and technology, 2013, 2(2).
9. Stevenson W. Operations Management McGraw Hill, New York, 2002.
10. Stix G. Computer Decision [Online], Retrieved, 1984-2018, from www.researchgate.com
11. Xun X, Lihui W, Stephen N. Computer Aided Process Planning – A Critical Review of Recent Developments and Future Trends International journal of Computer Integrated Manufacturing, 2010, 24(1).
12. Yusri Y, Karman L. Computer Aided Process Planning: A Comprehensive Survey Springer-Verlag, London, 2014.