# PROCESS PLANNING & COST ESTIMATION – ME 8793

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- Objective

  To introduce the process planning concepts to make cost estimation for various products after process planning.

  - Introduction of process planning
  - Process planning activities
  - Introduction of cost estimation
  - Production cost estimation
  - Machining time calculation

**ME8793 PROCESS PLANNING AND COST ESTIMATION**

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**OBJECTIVE:**

- To introduce the process planning concepts to make cost estimation for various products after process planning

**UNIT I INTRODUCTION TO PROCESS PLANNING 9**

Introduction- methods of process planning-Drawing interpretation-Material evaluation – steps in process selection-.Production equipment and tooling selection

**UNIT II PROCESS PLANNING ACTIVITIES 9**

Process parameters calculation for various production processes-Selection jigs and fixtures election of quality assurance methods - Set of documents for process planning-Economics of process planning- case studies

**UNIT III INTRODUCTION TO COST ESTIMATION 9**

Importance of costing and estimation –methods of costing-elements of cost estimation –Types of estimates – Estimating procedure- Estimation labor cost, material cost- allocation of over head charges- Calculation of depreciation cost

**UNIT IV PRODUCTION COST ESTIMATION 9**

Estimation of Different Types of Jobs - Estimation of Forging Shop, Estimation of Welding Shop, Estimation of Foundry Shop

**UNIT V MACHINING TIME CALCULATION 9**

Estimation of Machining Time - Importance of Machine Time Calculation- Calculation of Machining Time for Different Lathe Operations ,Drilling and Boring - Machining Time Calculation for Milling, Shaping and Planning -Machining Time Calculation for Grinding.

**TOTAL: 45 PERIODS**

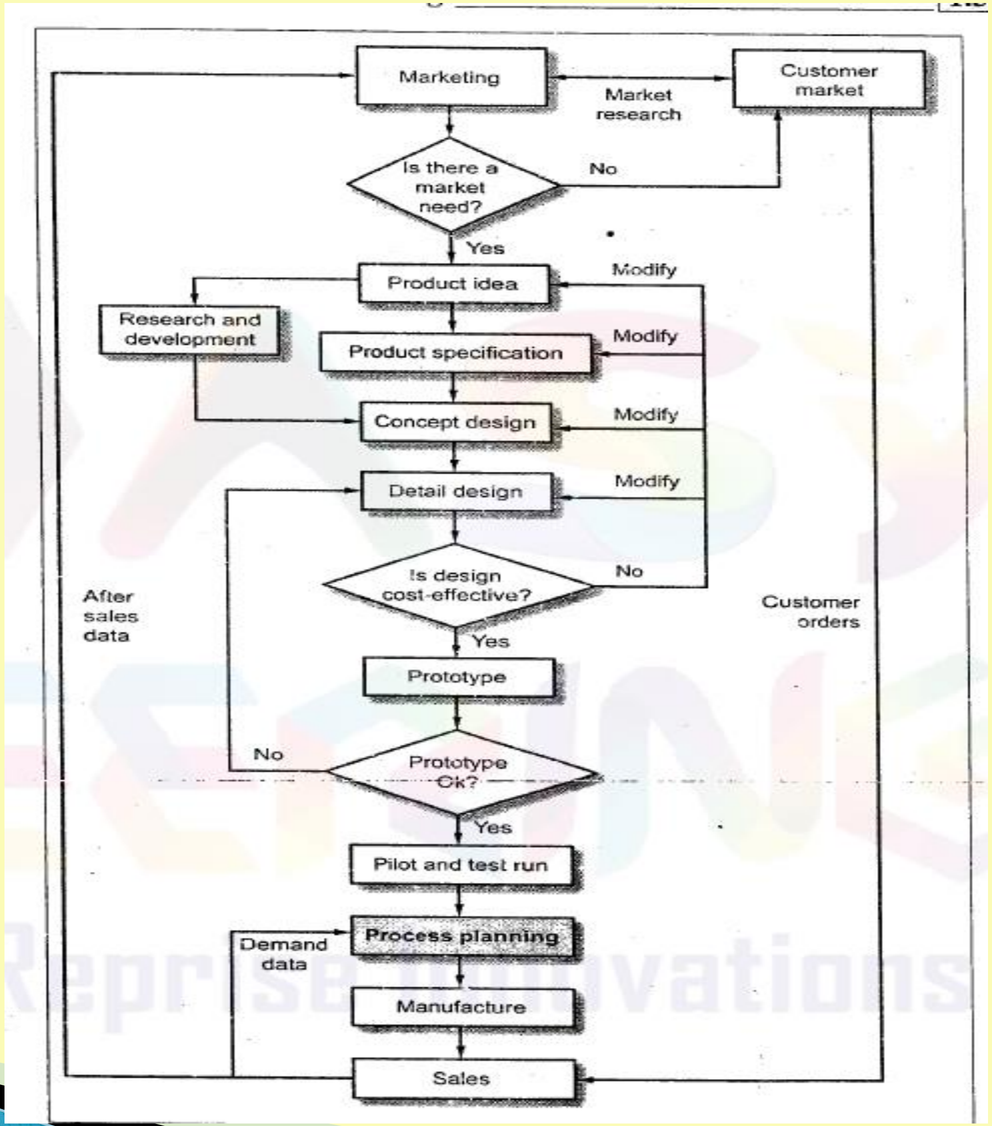
# UNIT I
# Introduction to Process Planning

- Methods of Process planning
- Drawing Interpretation
- Material Evaluation
- Steps in Process Selection
- Production Equipment and Tooling selection

# Process Planning

- An act of preparing the detailed work instructions for the manufacture and assembly of components into the finished product in discrete part manufacturing environments.
- Systematic determination of methods by which a product is to be manufactured.

# Design and Mfg., Cycle



# Process planning activities

1. Drawing interpretation
2. Material evaluation & process selection
3. Selection of Machines, tooling & Work holding devices.
4. Setting process parameters
5. Selection of quality assurance methods
6. Cost estimation
7. Preparing the process planning documentation
8. Communicating the manufacturing knowledge to the shop floor.

# Activities

*Table 1.1. Process planning activities*

| | |
|---|---|
| *Step 1:* | ***Drawing Interpretation***—Analysis of the finished part requirements as specified in the engineering design. |
| *Step 2:* | ***Material Evaluation and Process Selection***—Evaluating the materials specified and determining the appropriate manufacturing processes. |
| *Step 3:* | ***Selection of Machines, Tooling and Workholding Devices***—Selecting the proper equipment to accomplish the required operations. |
| *Step 4:* | ***Setting Process Parameters***—Establishing specific parameters for each operation for each machine. |
| *Step 5:* | ***Selection of Quality Assurance Methods***—Specifying the inspection criteria for all critical processing factors. |
| *Step 6:* | ***Cost Estimating***—Estimating the manufacturing costs of producing a component/product. |
| *Step 7:* | ***Preparing the Process Planning Documentation***—Preparing routing sheets and operations list. |
| *Step 8:* | ***Communicating the manufacturing knowledge to the shop floor*** |

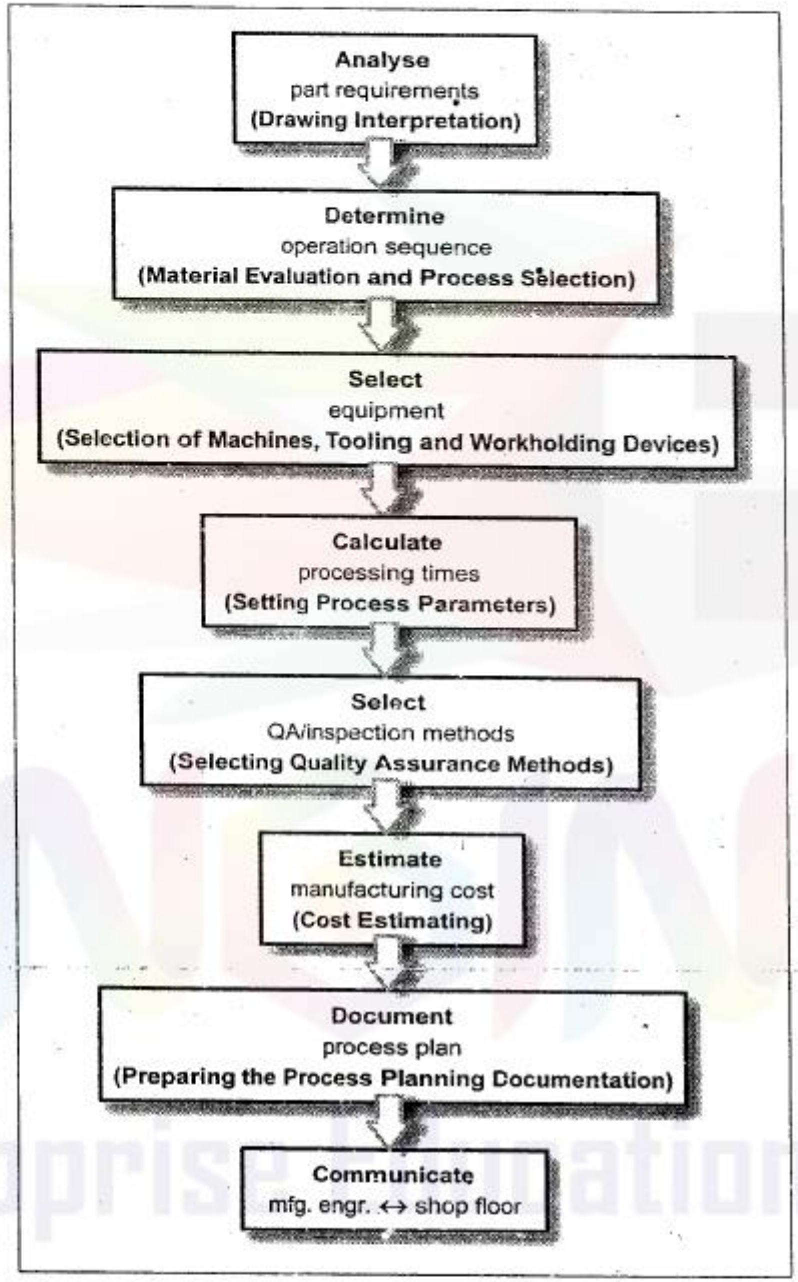


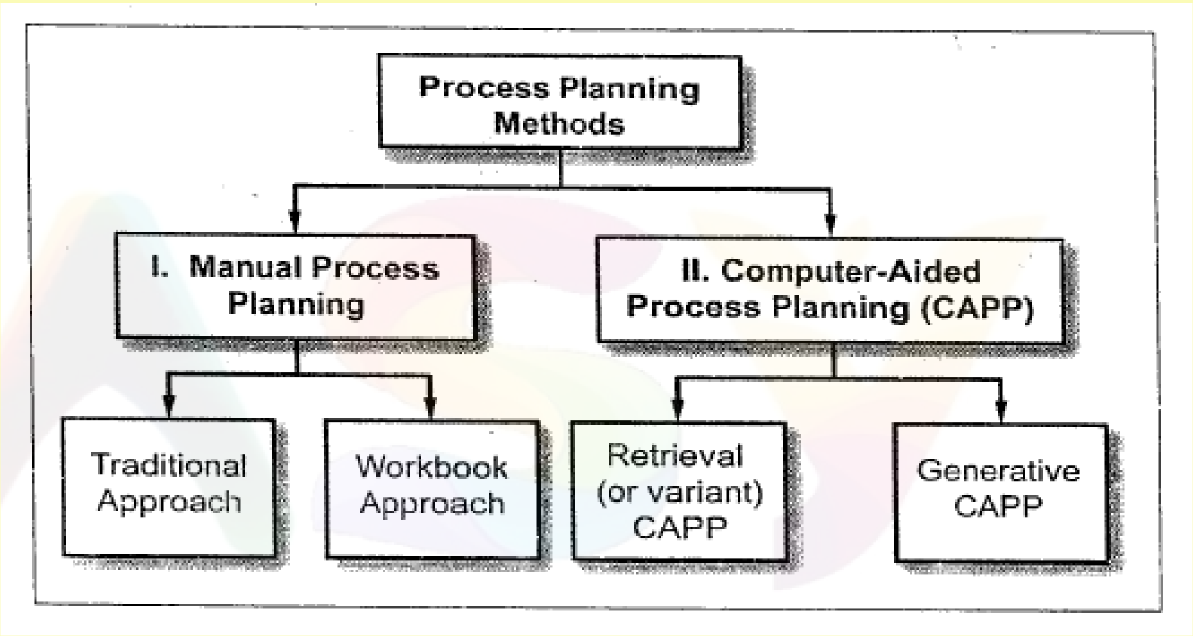

*Fig. 1.3. Process planning activities*

### 1.2.3. Responsibilities of Process Planning Engineer

The specialists managing the process planning task are called process engineers or process planners. The various responsibilities of a process engineer are given below:

1. Interpreting part print analysis, and symbols.
2. Gathering the fundamental details of product design, such as
   - (*i*) type of rough stock,
   - (*ii*) dimensional tolerances,
   - (*iii*) type of finish,
   - (*iv*) production rate,
   - (*v*) production volume,
   - (*vi*) scrap losses,
   - (*vii*) downtime,
   - (*viii*) design changes, *etc.*
3. Selecting the machining processes.
4. Selecting proper machining with allied tooling based on:
   - (*i*) required machine capability,
   - (*ii*) set-up time,
   - (*iii*) practical lot size,
   - (*iv*) quality of parts,
   - (*v*) cost of tooling, and
   - (*vi*) type of tooling.
5. Sequencing the operations.
6. Deciding on the inspection equipment in order to meet the desired quality.
7. Determining appropriate production tolerances.
8. Determining proper cutting tools and cutting conditions.
9. Calculating the overall times using work measurement techniques.

# Process planning Methods



# Manual PP

- Traditional Approach
  - The process plan is prepared manually.
  - It is very much depended on the skill, judgment and experience of the planner.
- Workbook Approach
  - Developed workbook used for preparing the route sheet.
  - The workbooks of predetermined sequence of operations for possible elements of operation of product are developed.
  - Once the drawing interpretation is carried out, suitable predetermined sequence of operations are selected

- Advantages
  - Very much suitable for small scale companies with a few process planes to generate.
  - Highly Flexible.
  - Low investment.
- Disadvantages

(i) Manual process planning is a very complex and time consuming job requiring a large amount of data.

(ii) This method requires the skilled process planner.

(iii) More possibilities for human error because this method depends on the planner's skill, judgement and experience.

(iv) It increases paper work.

(v) Inconsistent process plans result in reduced productivity.

(vi) It is not very responsive to changing manufacturing environment, new processes, new tooling, new materials, *etc.*

# Computer Aided CAPP

- In order to overcome the drawbacks of manual process planning, the computer aided process planning is used.
- With the use of computers in the process planning, one can reduce the routine clerical work of manufacturing engineers.
- We have two types of CAPP
  - Retrieval CAPP
  - Generative CAPP.

# Retrieval CAPP

- A retrieval CAPP system, also called a variant CAPP has been used in machining applications.
- The basic behind the retrieval CAPP is that similar parts will have similar process plan.
- In this system a process plan for a new part is created by recalling, identifying and retrieving an existing plan for a similar part and making the necessary modifications for the new part.

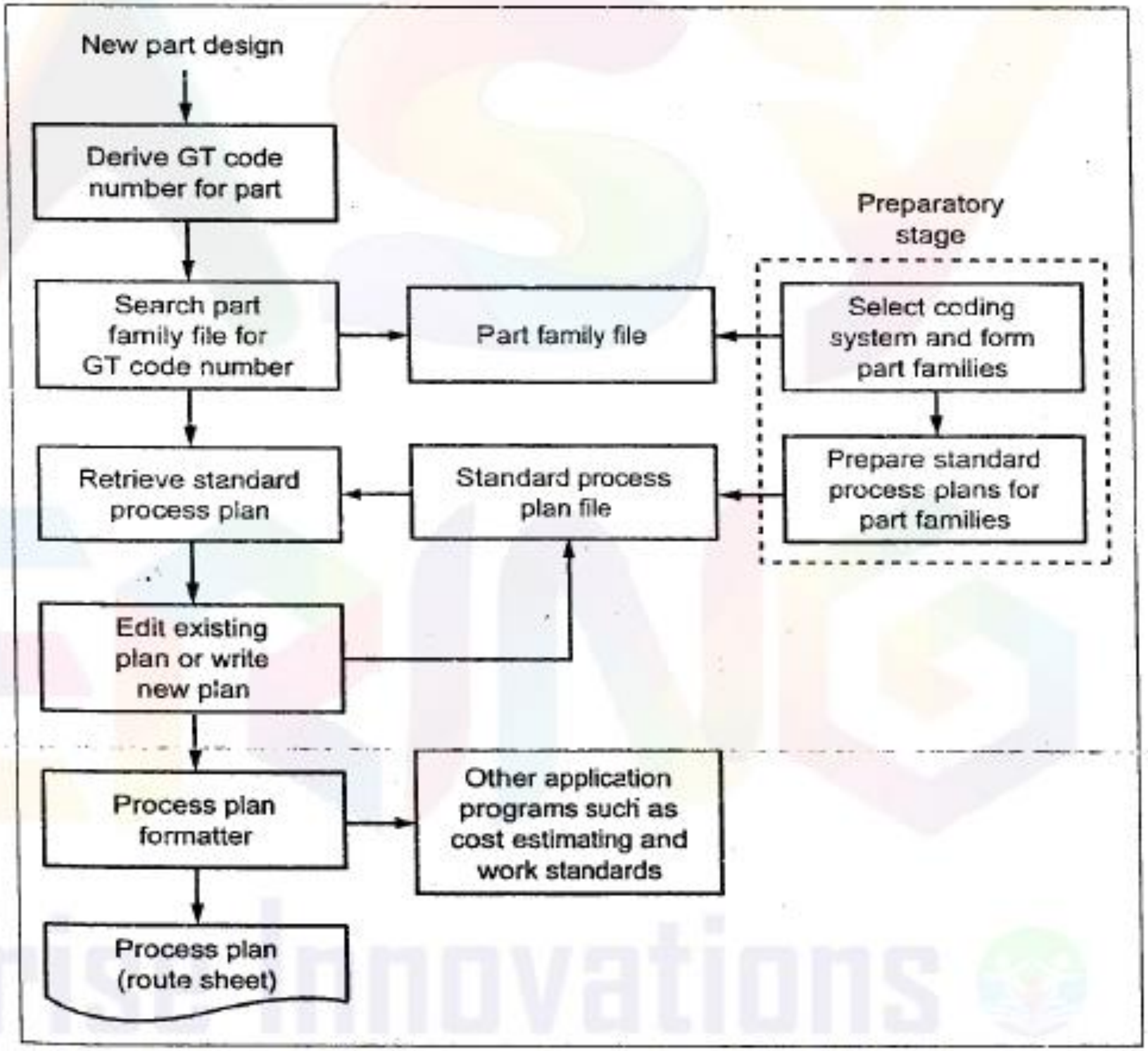



*Fig. 1.8. General procedure for using one of the retrieval CAPP systems*

- Advantages

(i) Once a standard plan has been written, a variety of parts can be planned.

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

(iii) The system is understandable, and the planner has control of the final plan.

(iv) It is easy to learn and easy to use.

- D

(i) The components to be planned are limited to similar components previously planned.

(ii) Experienced process planners are still required to modify the standard plan for the specific component.

# Generative CAPP

- In the generative approach the computer is used to synthesize or generate each individual process plan automatically and without reference to any prior plan.
- The computers stores the rules of manufacturing and the equipment capabilities.
- When using a system, a specific process plan for a specific part can be generated without any involvement of process planner.
- The human role in running system includes, inputting the GT code of the given part design and monitoring the function.

### 1.8.1. Components of a Generative CAPP System

The various components of a generative system are:

| | |
|---|---|
| *(a)* | ***A part description,*** which identifies a series of component characteristics, including geometric features, dimensions, tolerances and surface condition. |
| *(b)* | ***A subsystem to define the machining parameters,*** for example using look-up tables and analytical results for cutting parameters. |
| *(c)* | ***A subsystem to select and sequence individual operations.*** Decision logic is used to associate appropriate operations with features of a component, and heuristics and algorithms are used to calculate operation steps, times and sequences. |
| *(d)* | ***A database*** of available machines and tooling. |
| *(e)* | ***A report generator*** which prepares the process plan report. |

## 1.8.2. Advantages of



The generative CAPP has the following advantages:

(i) It can generate consistent process plans rapidly.

(ii) New components can be planned as easily as existing components.

(iii) It has potential for integrating with an automated manufacturing facility to provide detailed control information.

## 1.8.3. Drawbacks of Generative CAPP System

✓ The generative approach is complex and very difficult to develop.

# Drawing Interpretation

- The first step in the process planning is to analyze the finished part requirements as specified in the engineering design.
- The component drawings should be analyzed in detail to identify its features, dimensions, geometric tolerances, surface finish, the material specification and the number of part required.

**1.11.1. Types of Drawing**

The three types of drawings used in the industry are:

1. Detail drawings,
   (i) Single-part drawings, and
   (ii) Collective drawings.
2. Assembly drawings, and
   (i) Single-part assembly drawings, and
   (ii) Collective assembly drawings.
3. Combined drawings.

They are explained, one by one, in the following sections.

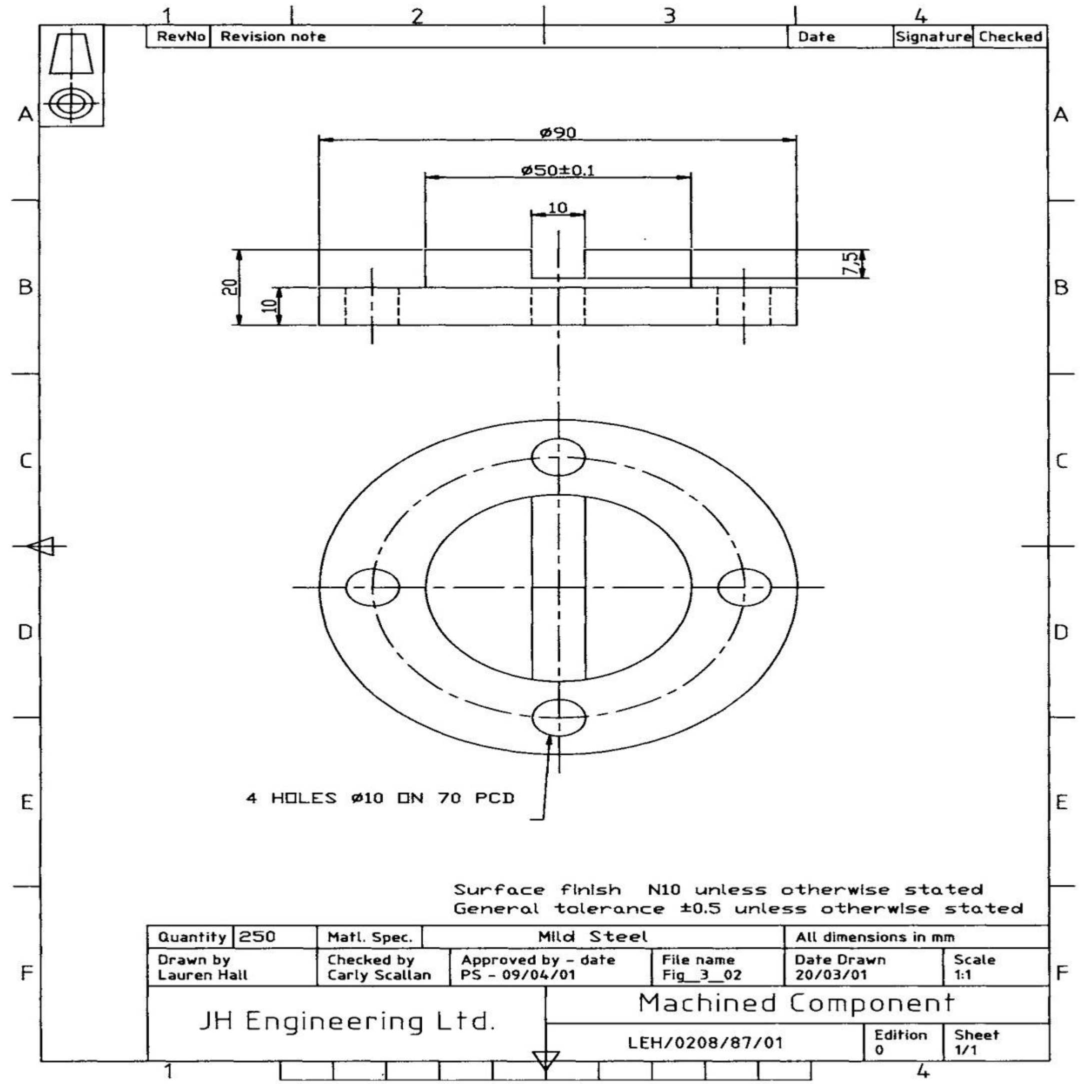
- 1. Detailed Drawings
  - The detail drawing provide all the information required for the manufacture of the required component.
  - This information include all dimensions, tolerances, surface finish specifications and material specifications.

  Two types of detailed drawings are,
  - Single part drawings
  - Collective single part drawings

- **Single part drawings**

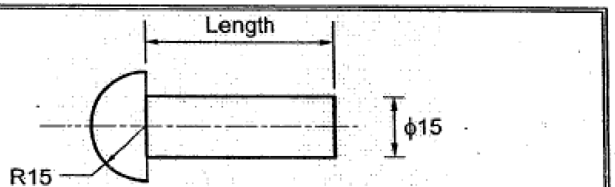
  – It contain the complete detailed information to enable a single component to be manufactured without reference to other sources.

  – The specification of the part includes information relating to the material used, the heat treatment required and surface finish details.



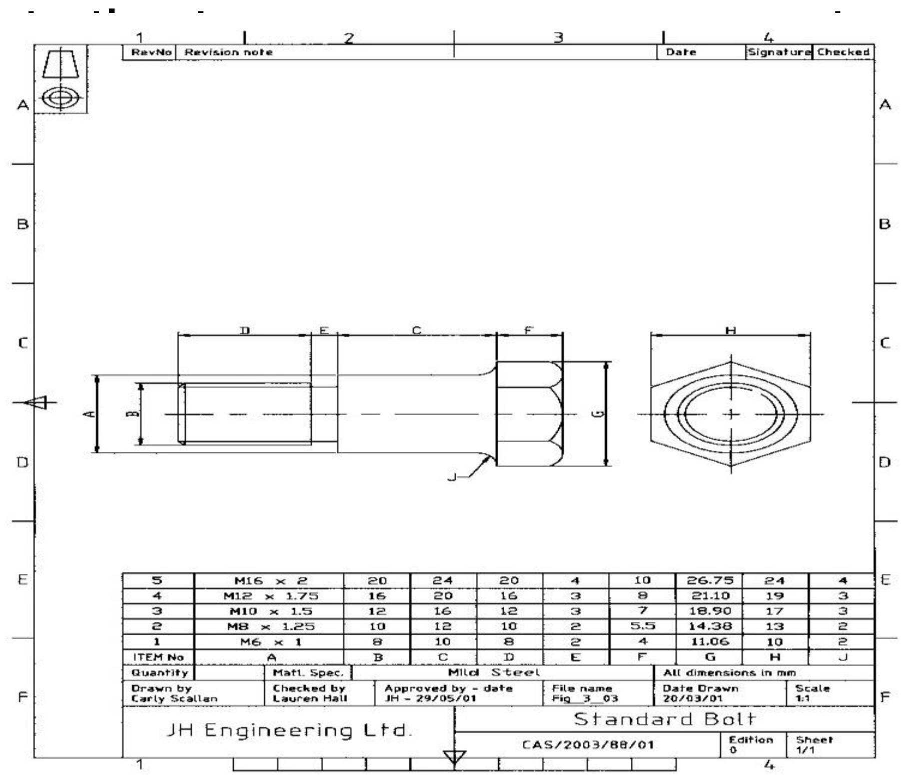

*Single-part drawing*

- Collective single part drawings
  - The collective single part drawings are used where one or two dimensions of a component are variable, all others being standard.
  - The drawing covers 20 rive




| Part No. | Length | Part No. | Length |
|---|---|---|---|
| S123/1 | 6 | /11 | 26 |
| /2 | 8 | /12 | 28 |
| /3 | 10 | /13 | 30 |
| /4 | 12 | /14 | 32 |
| /5 | 14 | /15 | 34 |
| /6 | 16 | /16 | 36 |
| /7 | 18 | /17 | 38 |
| /8 | 20 | /18 | 40 |
| /9 | 22 | /19 | 42 |
| /10 | 24 | /20 | 44 |
| Copyright note | Rivet | | Standard No. |
| | Material EIC-0 | | S 123 |

*Fig. 1.9. Collective single-part drawing of a rivet*




| ITEM No | A | B | C | D | E | F | G | H | J |
|---|---|---|---|---|---|---|---|---|---|
| 5 | M16 × 2 | 20 | 24 | 20 | 4 | 10 | 26.75 | 24 | 4 |
| 4 | M12 × 1.75 | 16 | 20 | 16 | 3 | 8 | 21.10 | 19 | 3 |
| 3 | M10 × 1.5 | 12 | 16 | 12 | 3 | 7 | 18.90 | 17 | 3 |
| 2 | M8 × 1.25 | 10 | 12 | 10 | 2 | 5.5 | 14.38 | 13 | 2 |
| 1 | M6 × 1 | 8 | 10 | 8 | 2 | 4 | 11.06 | 10 | 2 |

**Figure** *Collective single-part drawing (adapted from Collier and Wilson, 1978)*

- 2. Assembly drawings
  - Machines and mechanisms consist of numerous part and a drawing which shows the complete product with all its components in their correct physical relationship is known as assembly drawing.
  - A drawing which gives a small part of the whole assembly is known as sub assembly drawings.

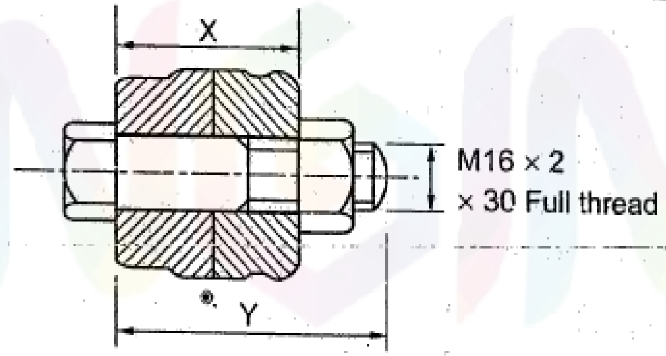
Two types of assembly drawings are

Single part assembly drawing,

Collective assembly drawing.

- Single part assembly drawing
  - It contains the information to build a single sub assembly or assembly.
  - It provide the following information's
    - Part list
    - Quantity required of each component
    - Overall dimensions
    - Weight
    - Material specifications
    - Operation details and instructions.

- Collective assembly drawings
  - It is used where a range of products which are similar in appearance but differing in size is manufactured and assembled.




| Part No. | X | Y | Part No. | X | Y |
|---|---|---|---|---|---|
| S456/1 | 40 | 60 | /6 | 90 | 110 |
| /2 | 50 | 70 | /7 | 100 | 120 |
| /3 | 60 | 80 | /8 | 110 | 130 |
| /4 | 70 | 90 | /9 | 120 | 140 |
| /5 | 80 | 100 | /10 | 130 | 150 |
| Copyright note | | Fastener assy.<br>Material: M.S | | Standard No.<br>S 456 | |

*Fig. 1.10. Typical collective assembly drawing of a nut with bolts of various lengths*

## Combined detail and assembly drawing of hub -puller

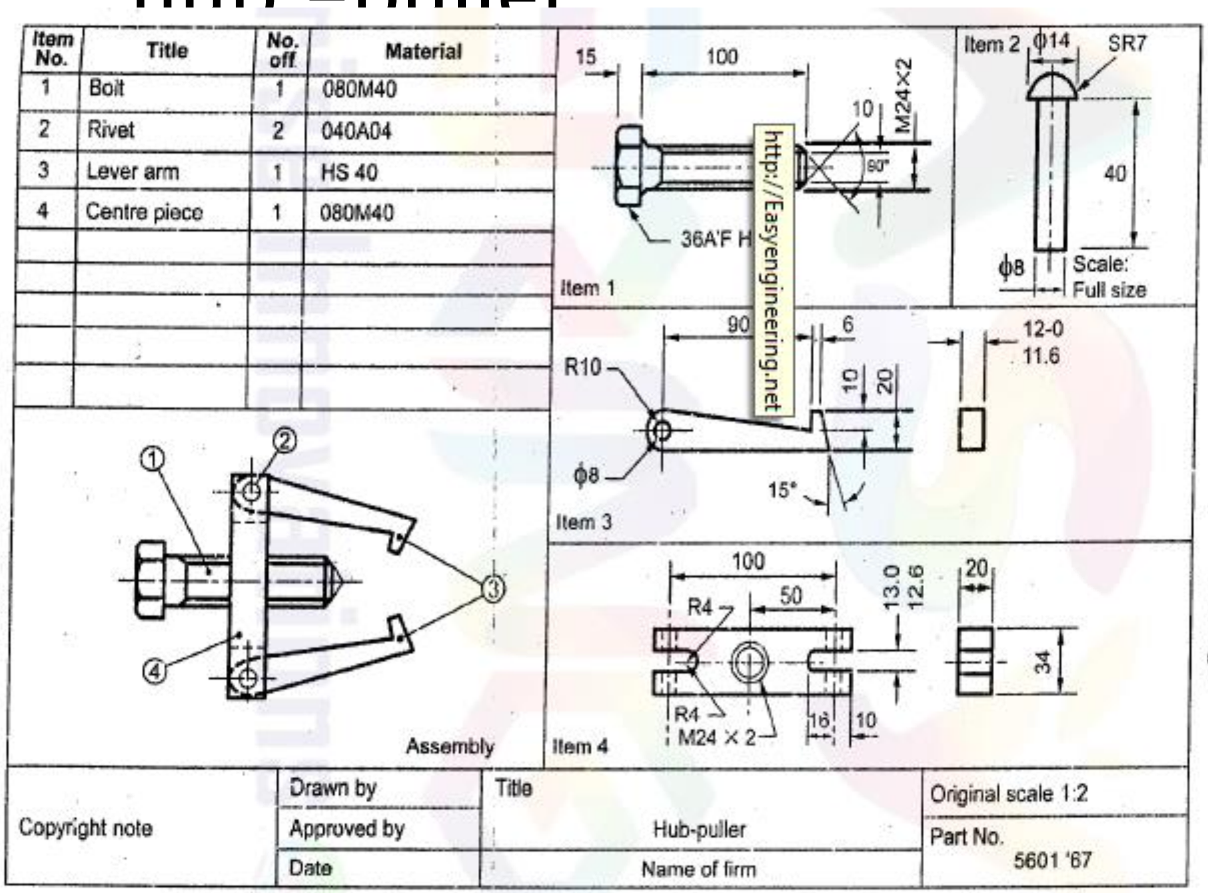



*Fig. 1.11. Combined detail and assembly drawing of hub-puller*

A Combined detail and assembly drawing shows an assembly with part list and the details of these parts on one drawing.
Such drawings are more suited to small 'one-off' or limited production assemblies.
It not only reduces the actual number of drawings, but also the drawing office time spent in scheduling and printing.

## Orthographic projection

Although there are several types of drawings commonly employed in engineering, they are all usually multi-view drawings , This means that they have two or three views of the part or assembly being represented. These views will usually be a view of the *front (a front elevation), the top (a plan) and the side (a side elevation).* This *method of detailing a three-dimensional object on paper, which is, of surface, is known as ort*

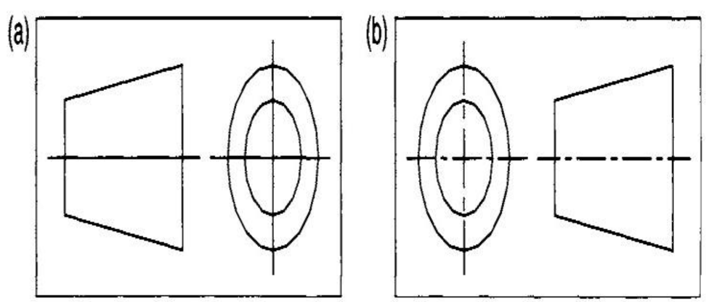



**Figure** *(a) First angle projection symbol. (b) Third angle projection symbol*

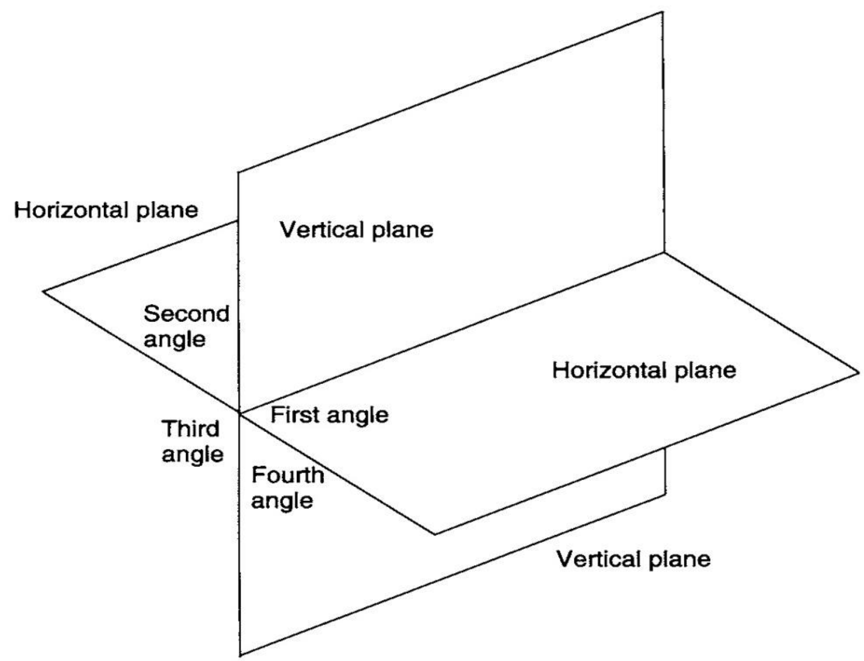



**Figure** *Planes of orthographic projection*

- Information on the drawing sheet required for process planning

The ***important information derived from the drawings that are required for process planning*** include:

| | |
|---|---|
| (i) | Geometric and dimensions |
| (ii) | Material specifications |
| (iii) | Notes on special material treatments |
| (iv) | Dimensional tolerances specifications |
| (v) | Geometrical tolerances specifications |
| (vi) | Surface finish specifications |
| (vii) | Tool references |
| (viii) | Gauge references |
| (ix) | Quantity to be produced |
| (x) | Part lists |
| (xi) | Notes on equivalent parts |
| (xii) | Notes on screw thread forms |

# MATERIAL EVALUATION

Manufacturing was defined in terms of transforming raw materials into a product. *The selection of a specific material for a particular part or product is an important part of the design and manufacture cycle.*

The four important factors influence the use of materials in manufacturing

- *The product design must meet the specified need;*
- *Materials with appropriate properties must be selected;*
- *Based on both of the above, suitable manufacturing processes must be selected;*
- *The response of the material during manufacture and in service.*

# MATERIAL EVALUATION

The Aim & Objectives to introduce the common materials and processes used in manufacture and the methods for their selection:

- identify and describe the **common materials used for manufacture;**
- identify and describe the *main properties of materials;*
- identify and describe *common material selection processes;*
- identify and describe the *common processes used for manufacture;*
- carry out an *overall evaluation of the selection of materials for manufacture in terms of processes;*
- select *suitable processes for a given part/product based on the critical processing factors* identified during the drawing interpretation.

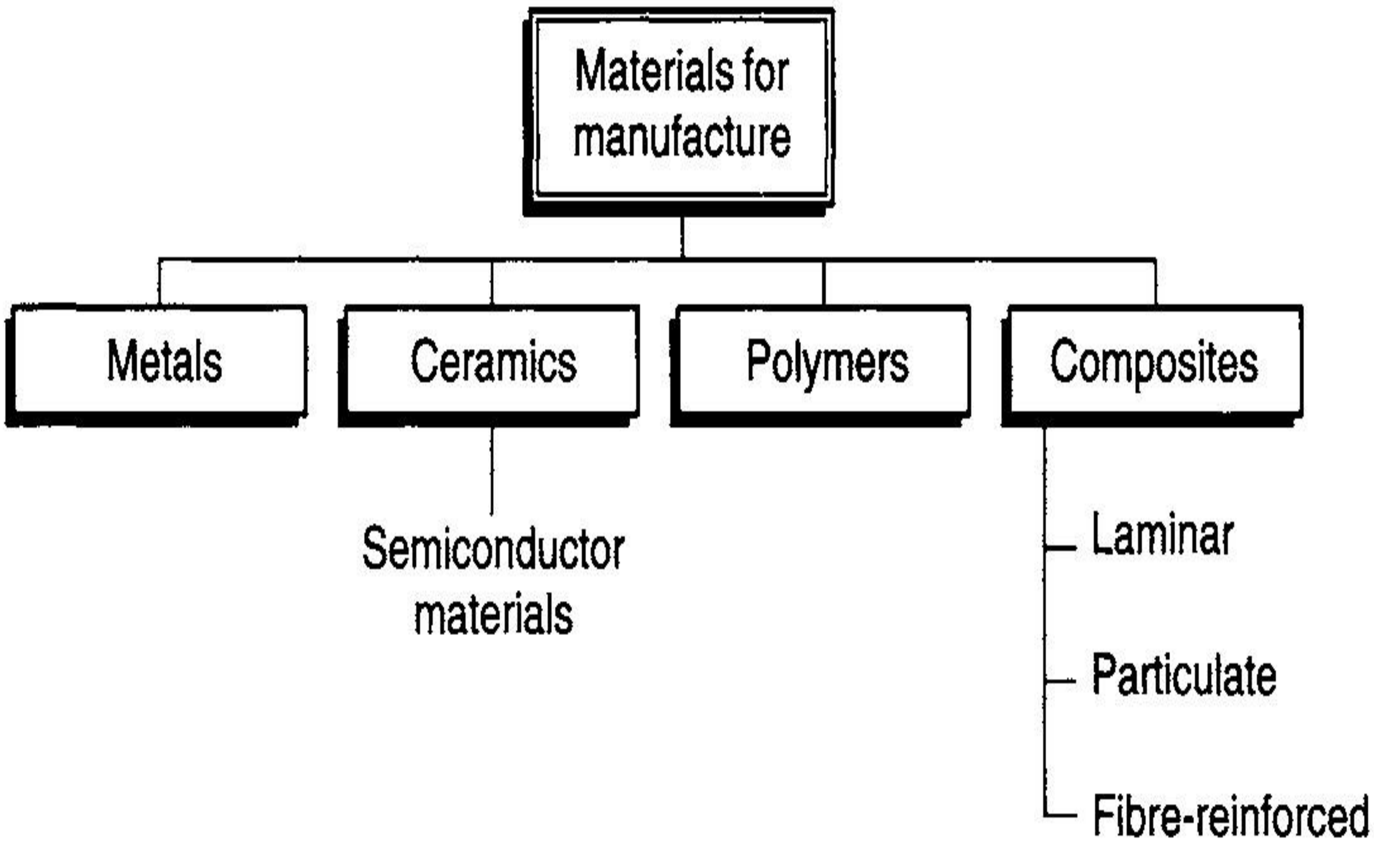



**Figure** *General classification of materials for manufacture*

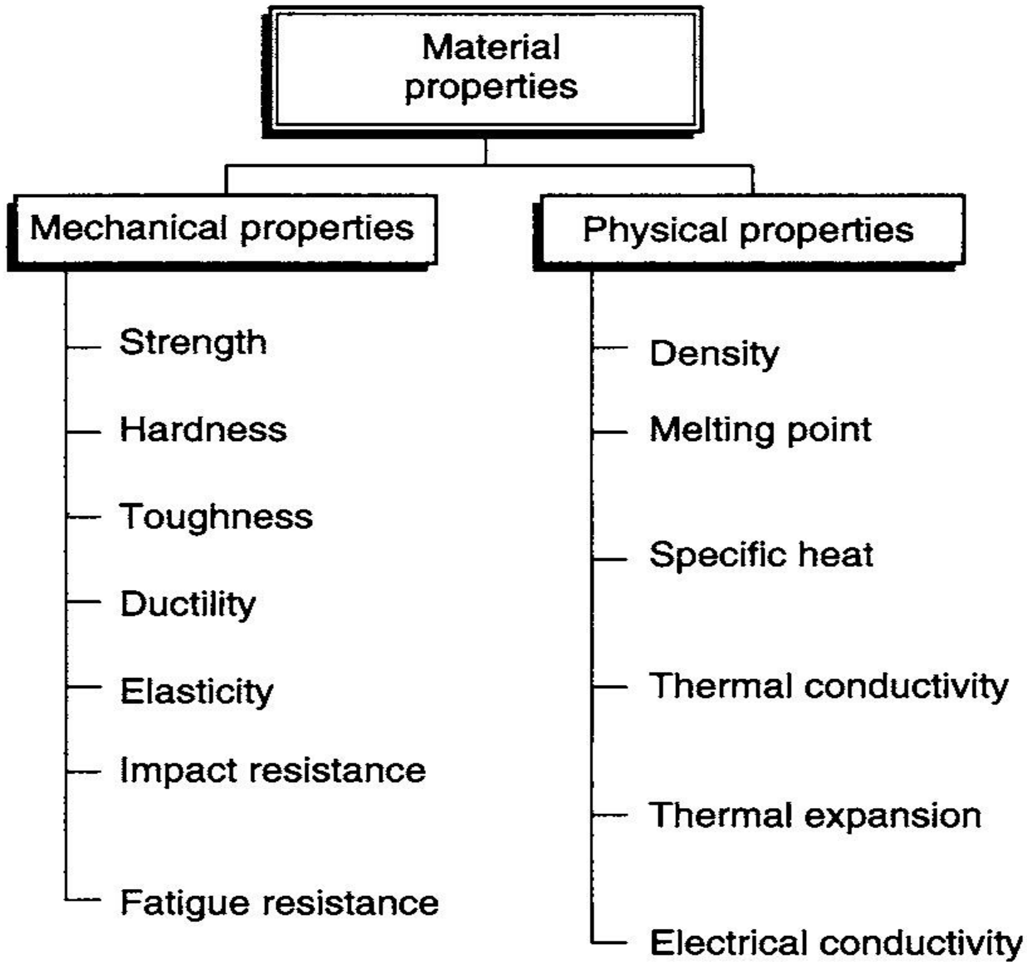



**Figure** *General mechanical and physical material properties*

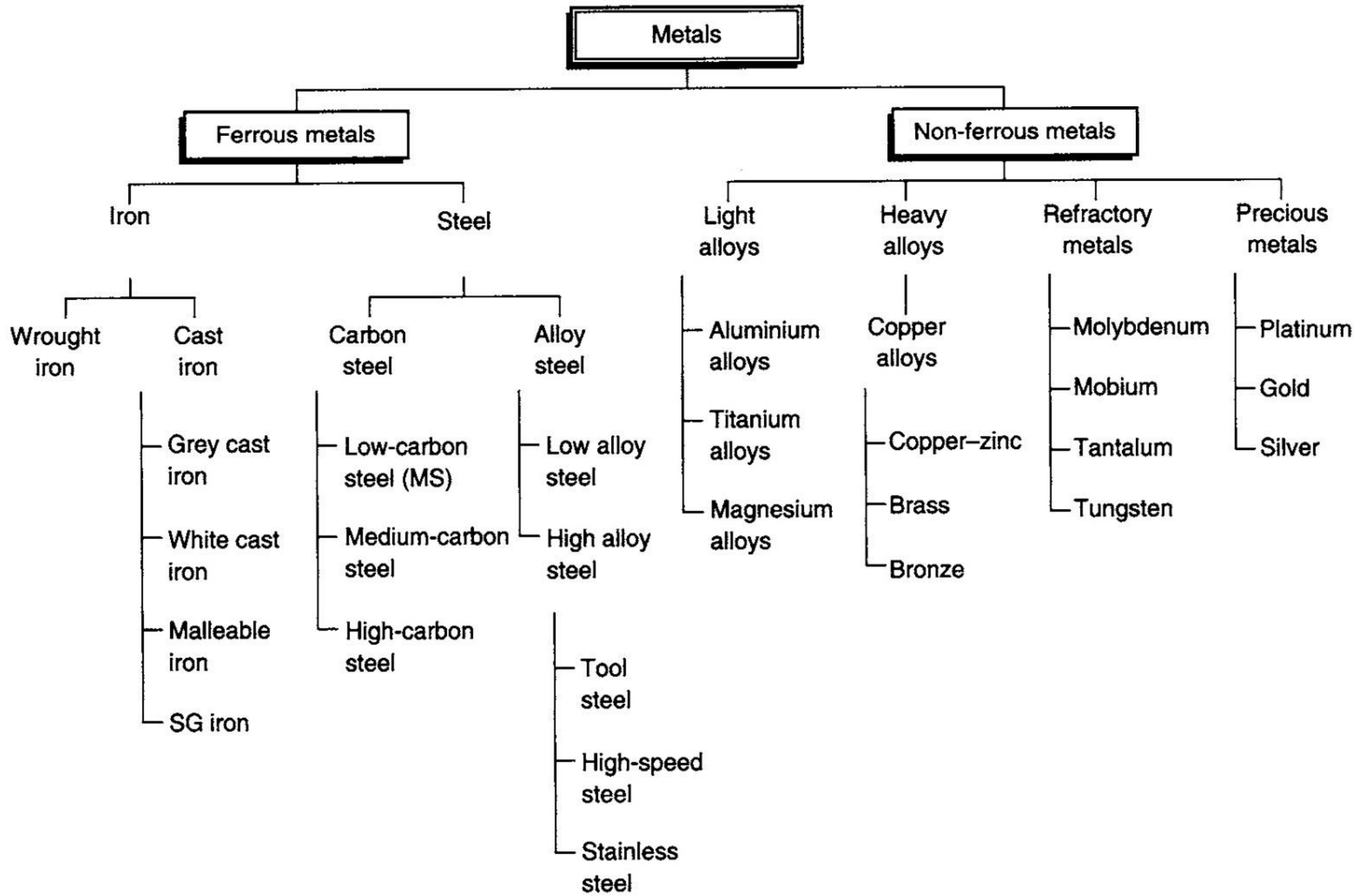



**Figure** *General classification of metals*

# MATERIAL EVALUATION

## Material selection process

*The selection of an appropriate material or materials for a product design is a difficult and complex task.* There are two distinct approaches arise for the materials selection process:

- ***the design and development of a new product;***
- ***the modification of an existing product.***

The most thorough approach to any materials selection problem is to view it as the design and development of a new product. There are five basic steps that can be followed for this approach (Dieter, 2000):

- *Specify the performance parameters of the design and translate these into the required material properties, for example, strength, hardness, etc. taking into account the cost and availability of materials.*

# MATERIAL EVALUATION

**Material selection process – I**

- Specify the ***manufacturing considerations*** such as the *quantity/batch size, weight and complexity of the part; dimensional and geometrical accuracy required*, the *surface finish required*, any *quality requirements and the overall manufacturability* of the material.
- Draw up a *shortlist of candidate materials* from the largest possible database of materials deemed suitable for the application.
- Evaluate the candidate materials in more detail. Compare each, based on *product performance, cost, availability and manufacturability*. The result of this evaluation should be the selection of a single material.
- Develop *design data and/or a design specification* for the chosen material.

# MATERIAL EVALUATION

## Material selection process – II

The second approach of *modifying an existing product* is usually carried out *to reduce costs and/or improve quality*. In terms of the material selection process, this is *often referred to as materials substitution*.

Again, there are five basic steps to the material selection process:

1) Evaluate the current product in terms of the *materials performance, manufacturing process requirements and cost.*
2) Identify which characteristics have to be *improved for enhanced product performance.*
3) Search for *alternative materials and/or manufacturing routes*.
4) Compile a shortlist of materials and manufacturing routes. Evaluate each in terms of the cost of

# MATERIAL EVALUATION

There is a ***third approach***, which is similar to the above approach, known as ***the case-history method***. The assumption is that *something similar has been previously manufactured successfully* and that the combination of materials and processes can be used again.

- The *slightest difference in product performance requirements* can render the previous material selection useless.
- The other disadvantage is that *developments in technology, materials and processes tend to be overlooked*.

# MATERIAL EVALUATION

## Material selection methods

Several methods have been developed for material selection problems, some not only applicable to material selection but also any design selection procedure. Although no one method is accepted as the standard approach, there are a number of commonly used methods (Dieter, 2000):

- *selection with computer-aided databases;*
- *performance indices;*
- *decision matrices;*
- *selection with expert systems;*
- *value analysis (particularly for materials substitution);*
- *failure analysis;*
- *cost-benefit analysis.*

# MATERIAL EVALUATION

Based on the material selection processes and methods, the process planner merely evaluates the result of the material selection process, that is, *the material selected in terms of how the part should be manufactured*. This evaluation should focus on three main areas,

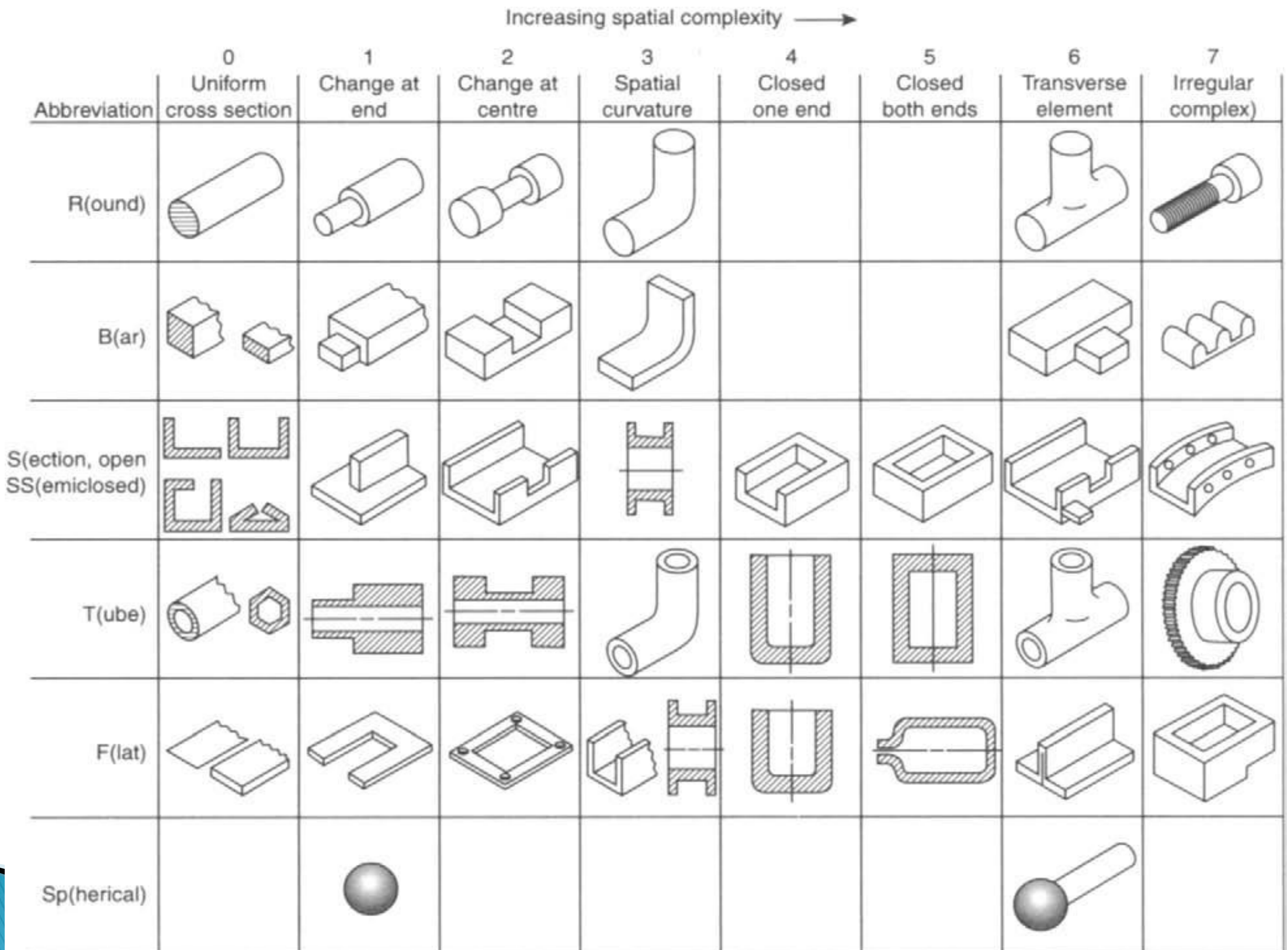
- *Shape or Geometry considerations;*
- *Material property requirements;*
- *Manufacturing considerations.*

This three-stage evaluation procedure was originally developed as a *materials selection procedure* (DeGarmo *et al.*, 1988) and has been *adapted to be used for the purpose of material evaluation*.

# MATERIAL EVALUATION

**Shape or Geometry Considerations** *affects the manufacturing process.* Typical considerations are:

1. What is the *relative size* of the component?
2. How *complex is the shape*? Is it *symmetrical* at all? Uniform cross-sections? Will it be more than one piece?
3. Are there *enough dimensions* to enable manufacture?
4. Are there any *dimensional tolerances outside the general tolerance requirements*?
5. How does this part *mate in a sub-assembly or assembly*?
6. What are the *surface finish requirements*?
7. Have *allowances* been made for wear during service?
8. Are there any *minor design modifications* that can significantly improve manufacturability, that is, *design for manufacture*?


Increasing spatial complexity
0
Uniform cross section
1
Change at end
2
Change at centre
3
Spatial curvature
4
Closed one end
5
Closed both ends
6
Transverse element
7
Irregular complex)
Abbreviation
R(ound)
B(ar)
S(ection, open
SS(emiclosed)
T(ube)
F(lat)
Sp(herical)

# MATERIAL EVALUATION

- All of the above should have been considered during the drawing interpretation *to help identify the critical processing factors*.
- *The material and shape/geometry should also be assessed in terms of the raw material or billet form.* In many cases, the forming of the billet may simply be a case of *cutting the material to the required size from stock material*.
- However, ***for complex geometry*** the billet may be *formed using manufacturing processes from the casting and forming/shaping categories*. Raw materials come in many shapes and forms for many different processes as given in Table 3.

**TABLE 3** *Some raw material forms for common manufacturing processes*

| *Basic form* | *Variations* | *Manufacturing processes* |
|---|---|---|
| Bar | Round | Turning, grinding, milling, forging, cold forming |
| | Square | Grinding, milling, forging, cold forming, shaping/planing |
| | Hexagonal | Turning, threading |
| | Tube | Blow moulding |
| Sheet | Metal | Shearing, blanking, fine blanking, bending, deep drawing, stretch forming, spinning, continuous extrusion |
| | Polymer | Blow moulding, vacuum forming |
| Plate | Metal | Rolling, fabrication |
| Powder | Metal | Powder metallurgy |
| | Polymer | Continuous extrusion |
| Granules | Polymer | Injection moulding, continuous extrusion |

# MATERIAL EVALUATION

**Material property requirements** is a much more complex task and can be split into three distinct considerations namely: *(i) Mechanical properties, (ii) Physical properties and (iii) Service environment.*

## *Mechanical properties*

1. Are there any static loading needs with regards to particular processes?
2. Is failure likely during manufacture and, if so, how?
3. Is there the likelihood of impact loading? Type and magnitude?
4. Is there the likelihood of cyclic loading? Type, magnitude and frequency?
5. Is wear resistance needed? Where? How much?
6. Is there a temperature range within which the properties are stable?
7. How much can the material deform and still function

# MATERIAL EVALUATION

**Physical properties**

1. Will processing affect electrical property requirements?
2. Will processing affect magnetic property requirements?
3. Will processing affect thermal property requirements?
4. Is weight a significant factor?
5. Is appearance a significant factor?

*Service requirements*

1. What is the range of operating temperatures and rate of temperature change?
2. What is the most severe environment anticipated with respect to corrosion and deterioration of material properties?
3. What is the desired service lifetime of the product?
4. What is the anticipated maintenance for this component?
5. What is the potential liability if the product should fail?
6. Should the product be manufactured with recycling in mind?

# MATERIAL EVALUATION

**Manufacturing considerations**

A final concern is to determine the various factors that would influence the potential manufacturing processes. These include:

1. Have standard components and parts been specified wherever possible?

2. Has the ease of manufacture of the design been considered?

3. How many components have to be made and at what rate?

4. What is the minimum and maximum section thickness?

5. What is the desired level of quality compared to similar products on the market?

6. What are the anticipated quality control and inspection requirements?

7. Are there any special considerations to be made for assembly?

Finally, another useful tool in identifying candidate processes, in terms of the material selected, is the ***PRIMA selection matrix*** developed by Swift and Booker (1997) as illustrated in Fig.

# MATERIAL EVALUATION

## Manufacturing processes

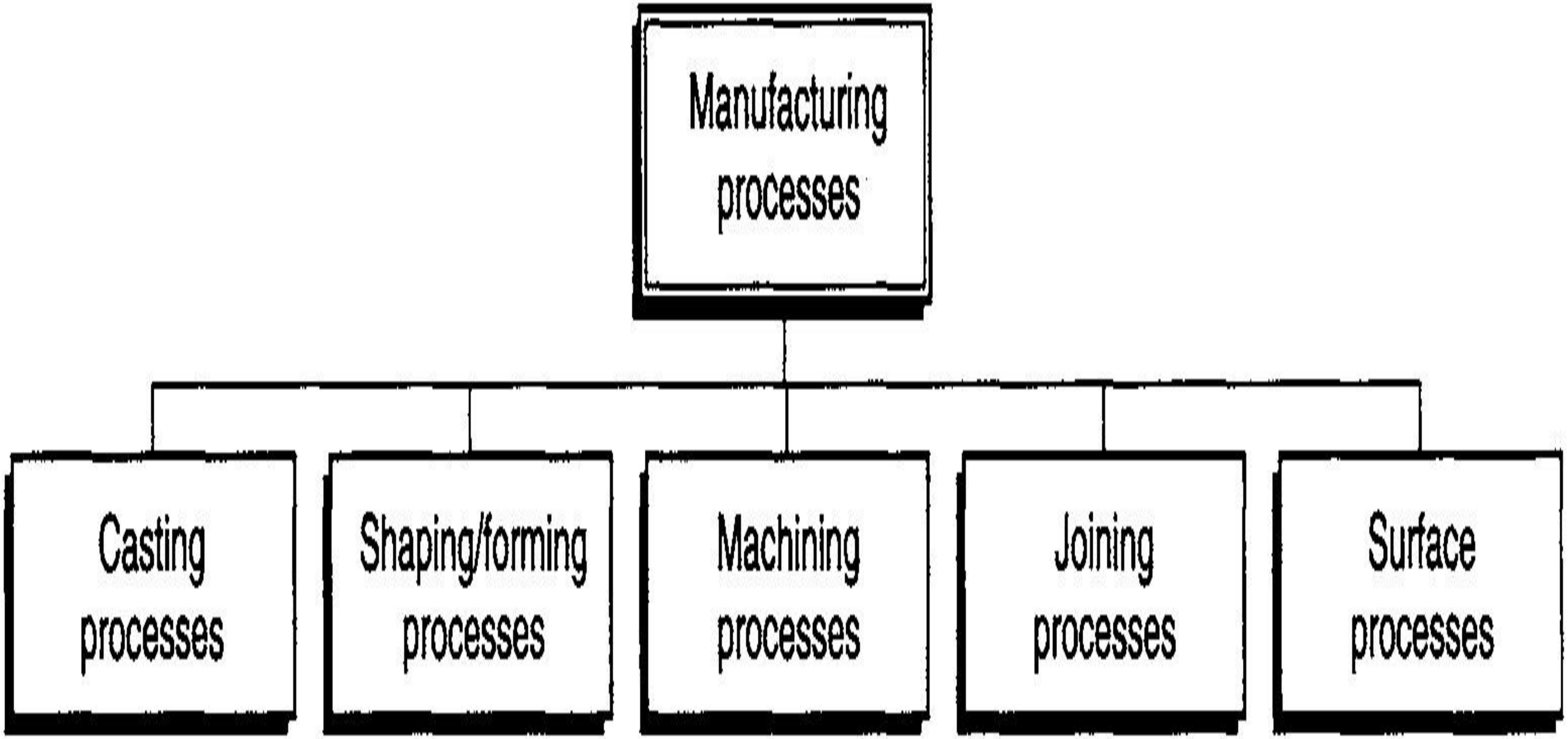



**Figure 8** *General classification of manufacturing processes*

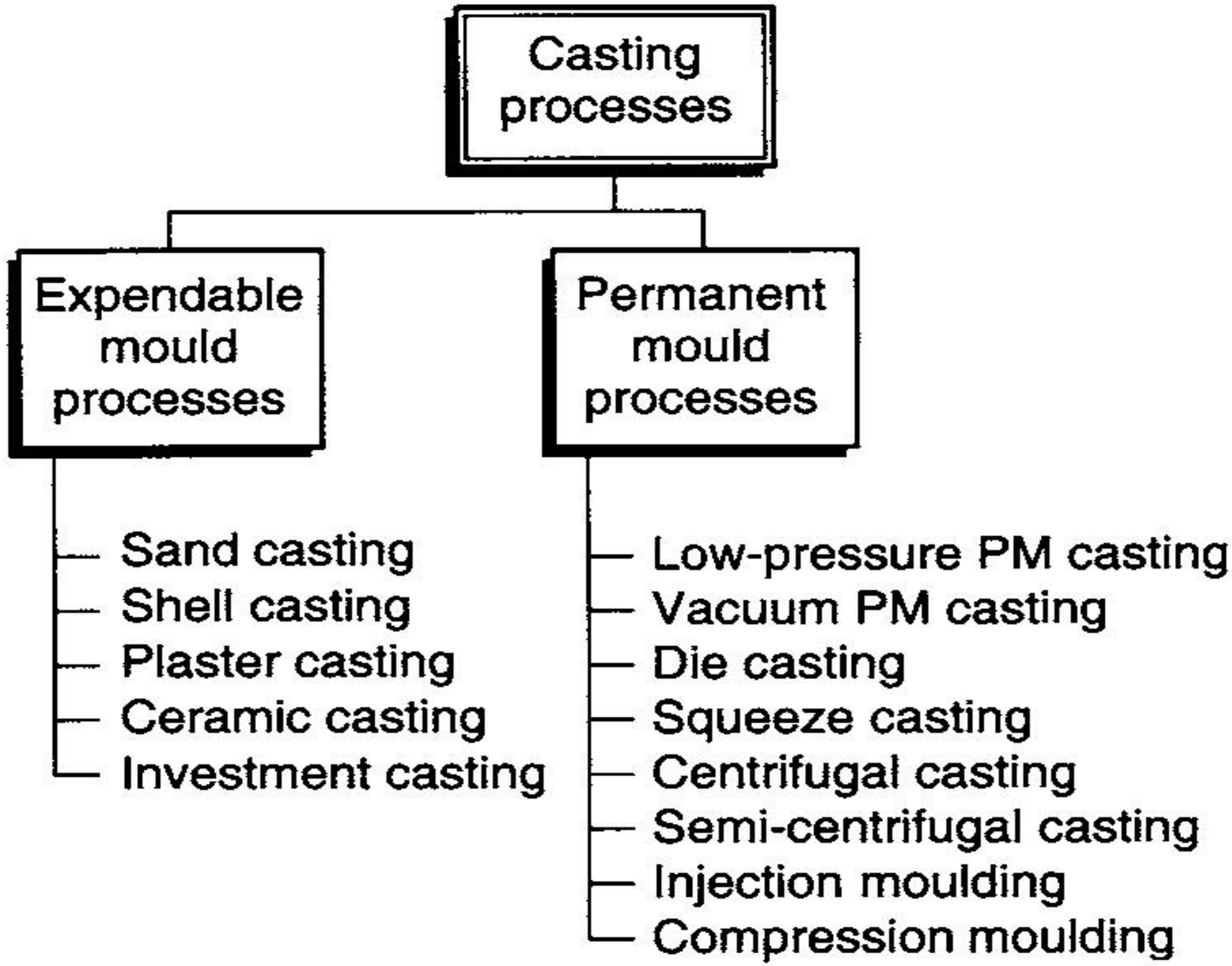
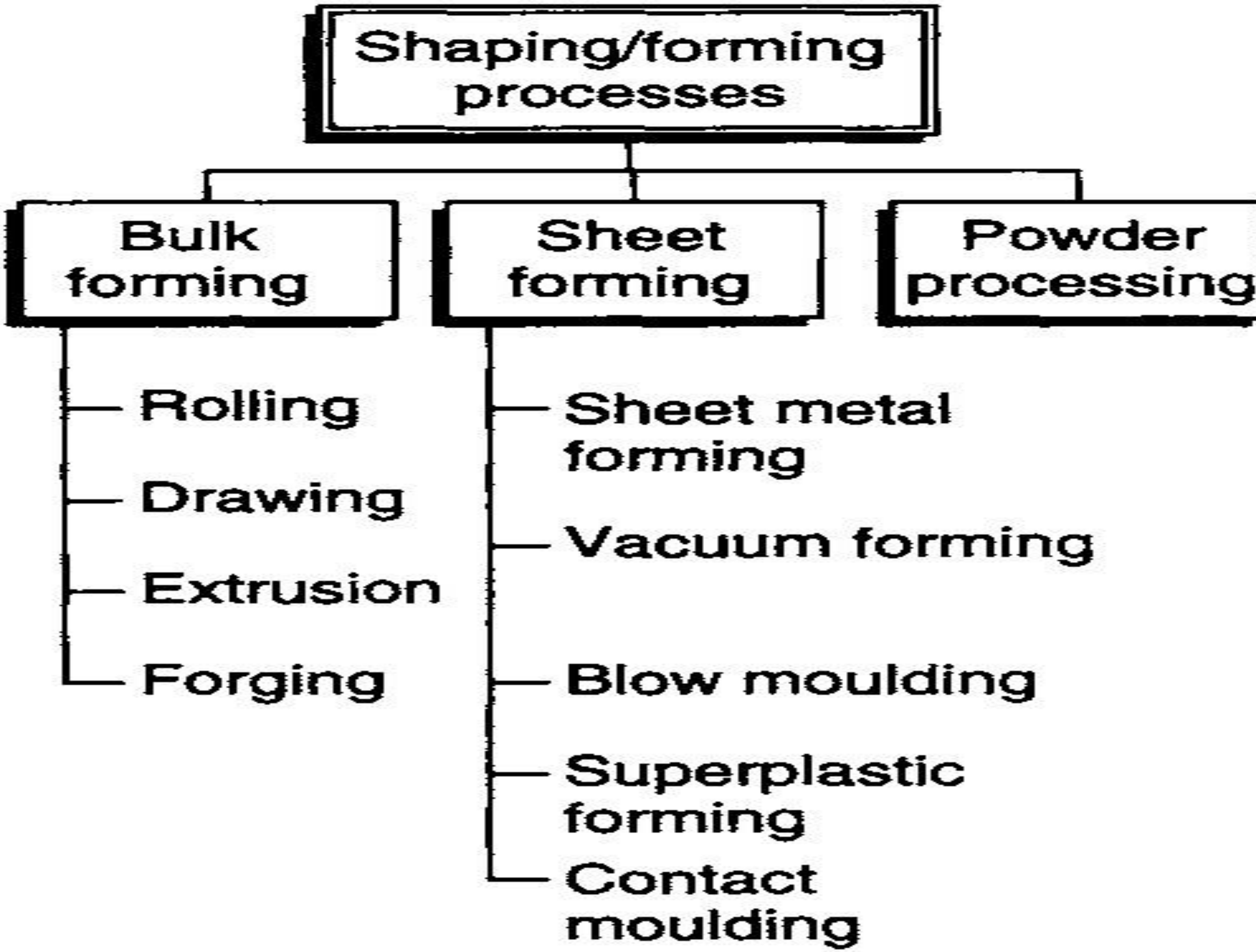
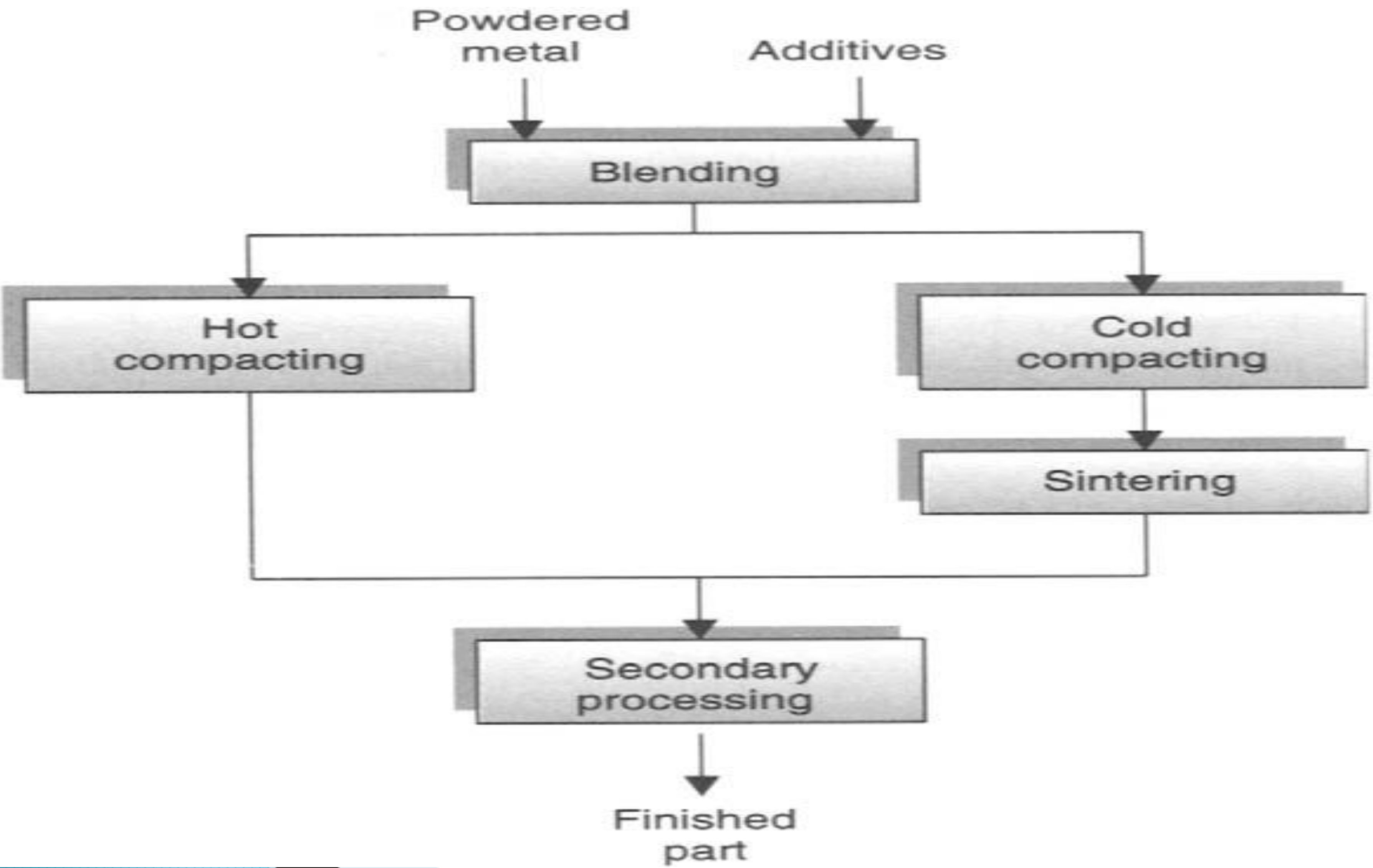



**Figure** *General classification of casting processes*


Shaping/forming processes
Bulk forming
Sheet forming
Powder processing
Rolling
Drawing
Extrusion
Forging
Sheet metal forming
Vacuum forming
Blow moulding
Superplastic forming
Contact moulding




# STEPS IN POWDER PROCESSING

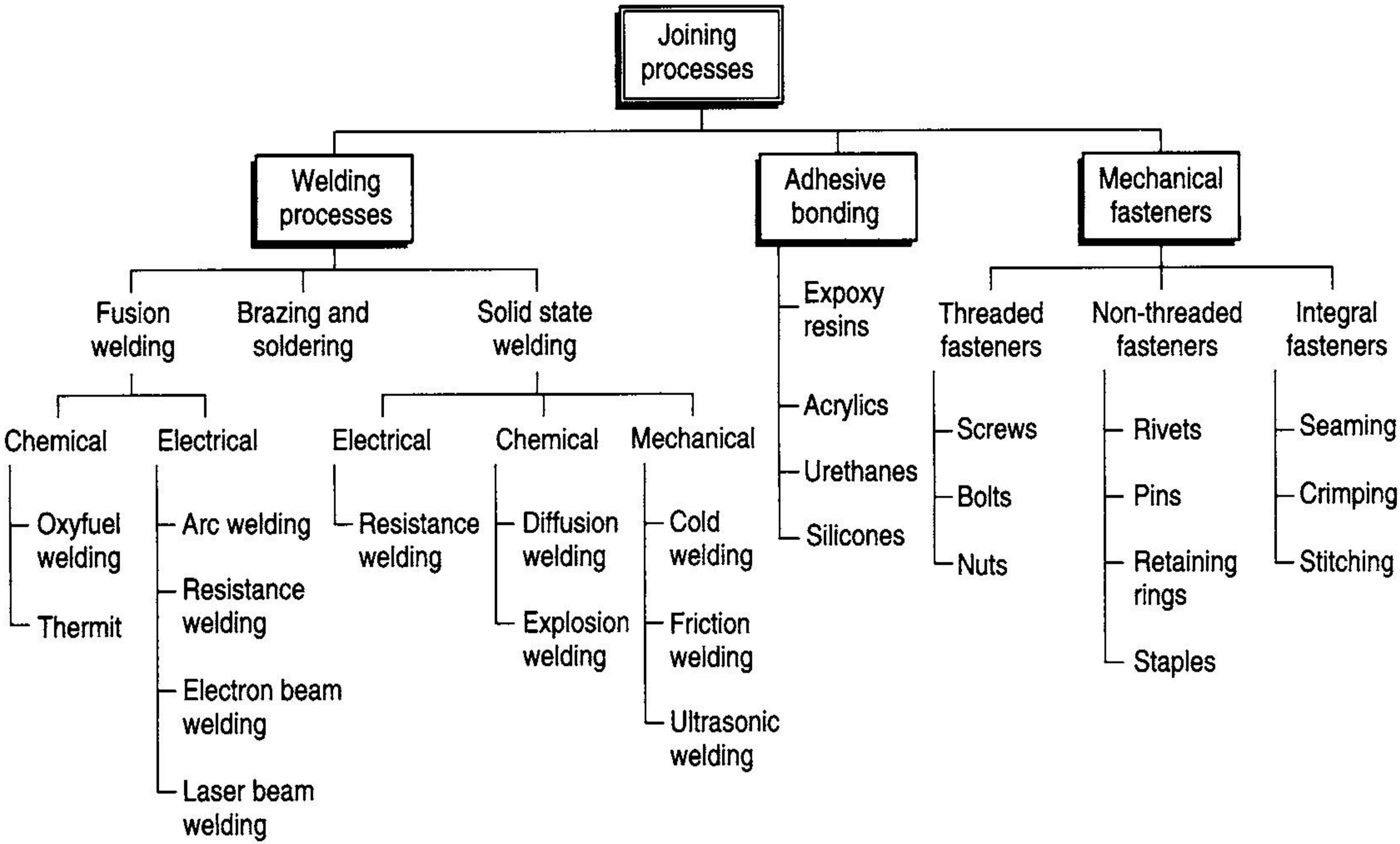



**Figure** *General classification of joining processes*

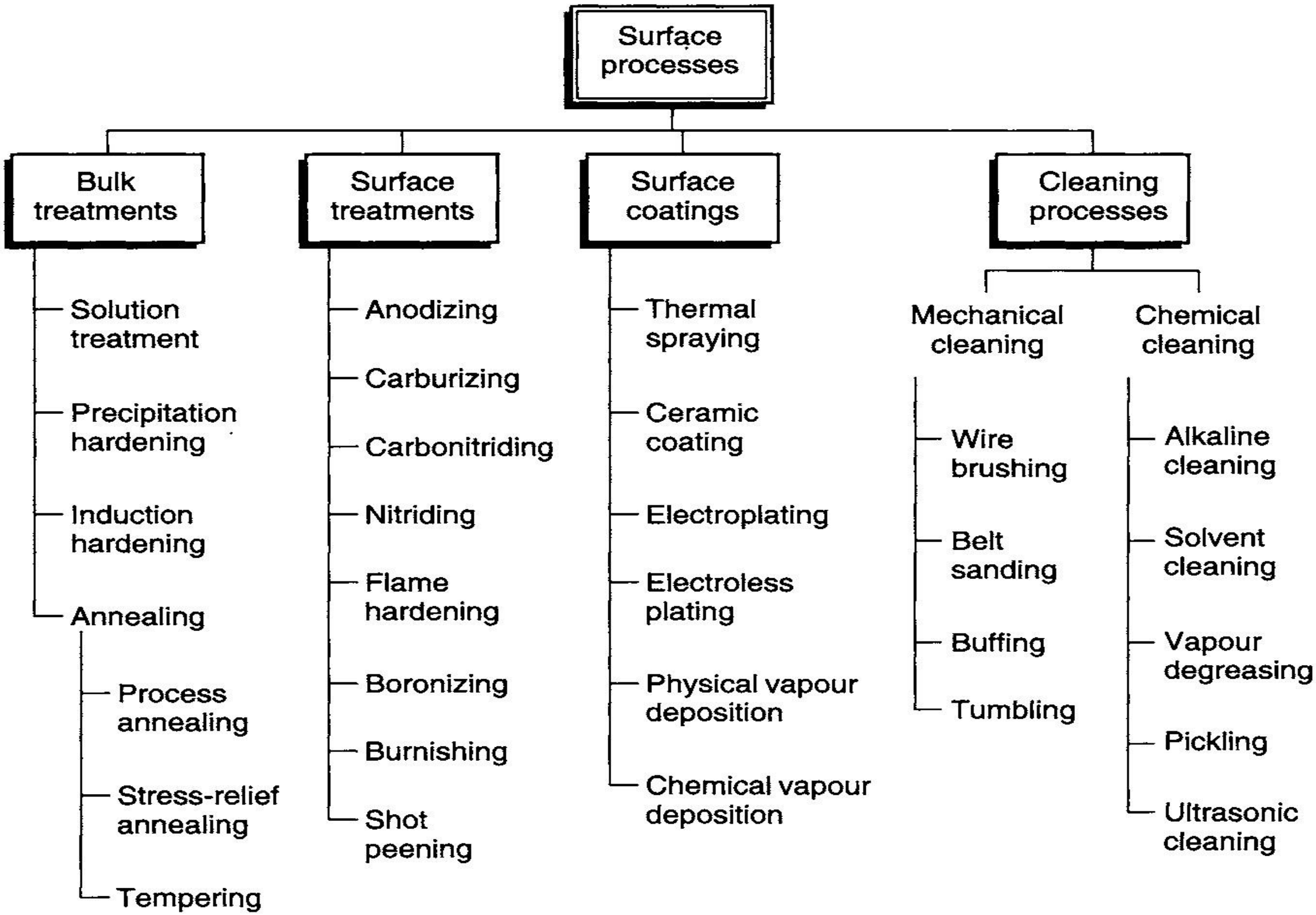



**Figure** *General classification of surface processes*

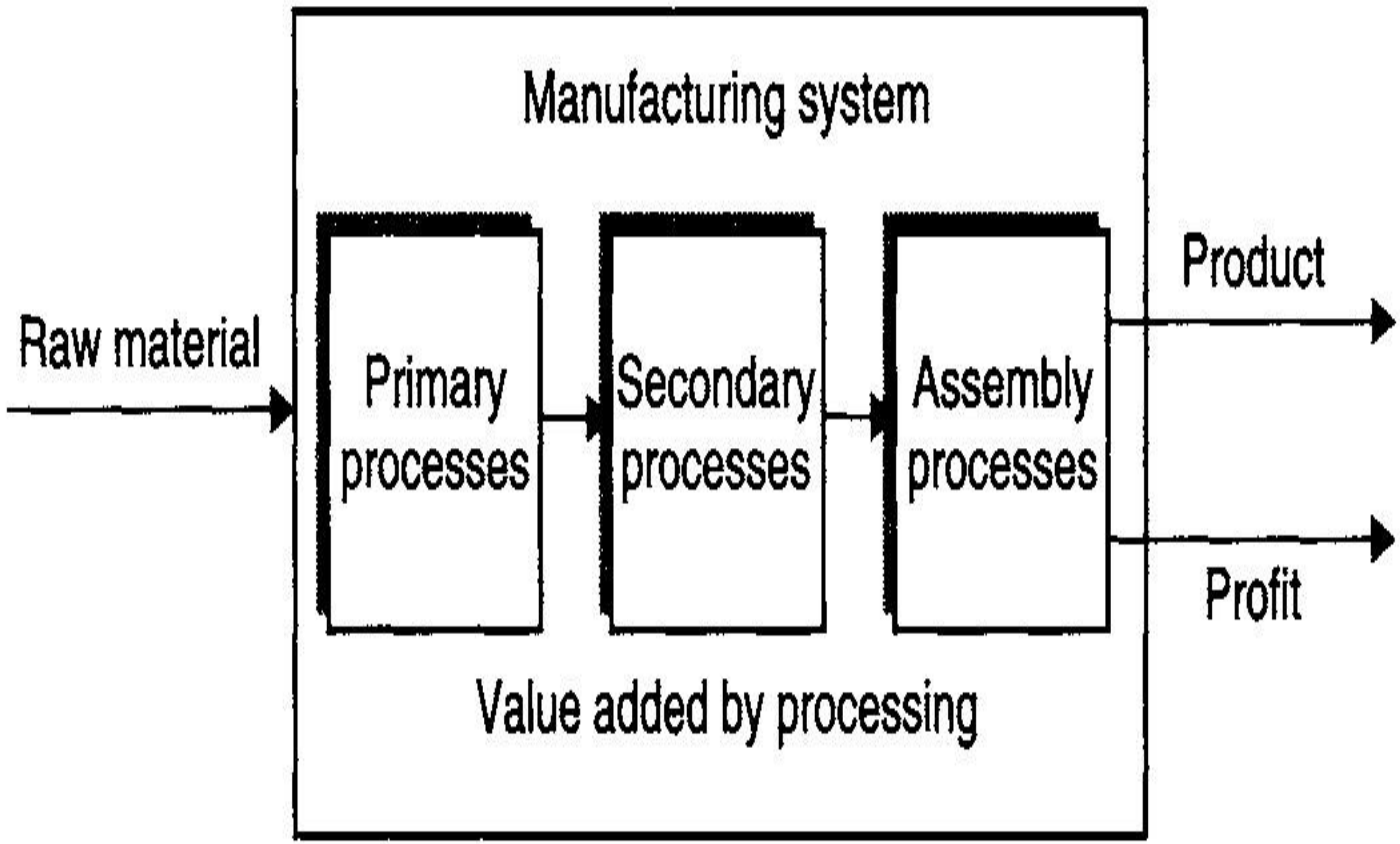



**Figure** *Processes used to add value in manufacturing*

# STEPS IN PROCESS SELECTION

**Factors in process selection**

Regardless of the material selection process employed, the result will be the selection of a suitable material or materials. The material itself will limit the manufacturing processes that can be used, as not all materials are suitable for all processes.

For example, when considering joining processes, cast iron cannot be used for resistance welding. However, there are a number of factors common to both the material and process selection decisions:

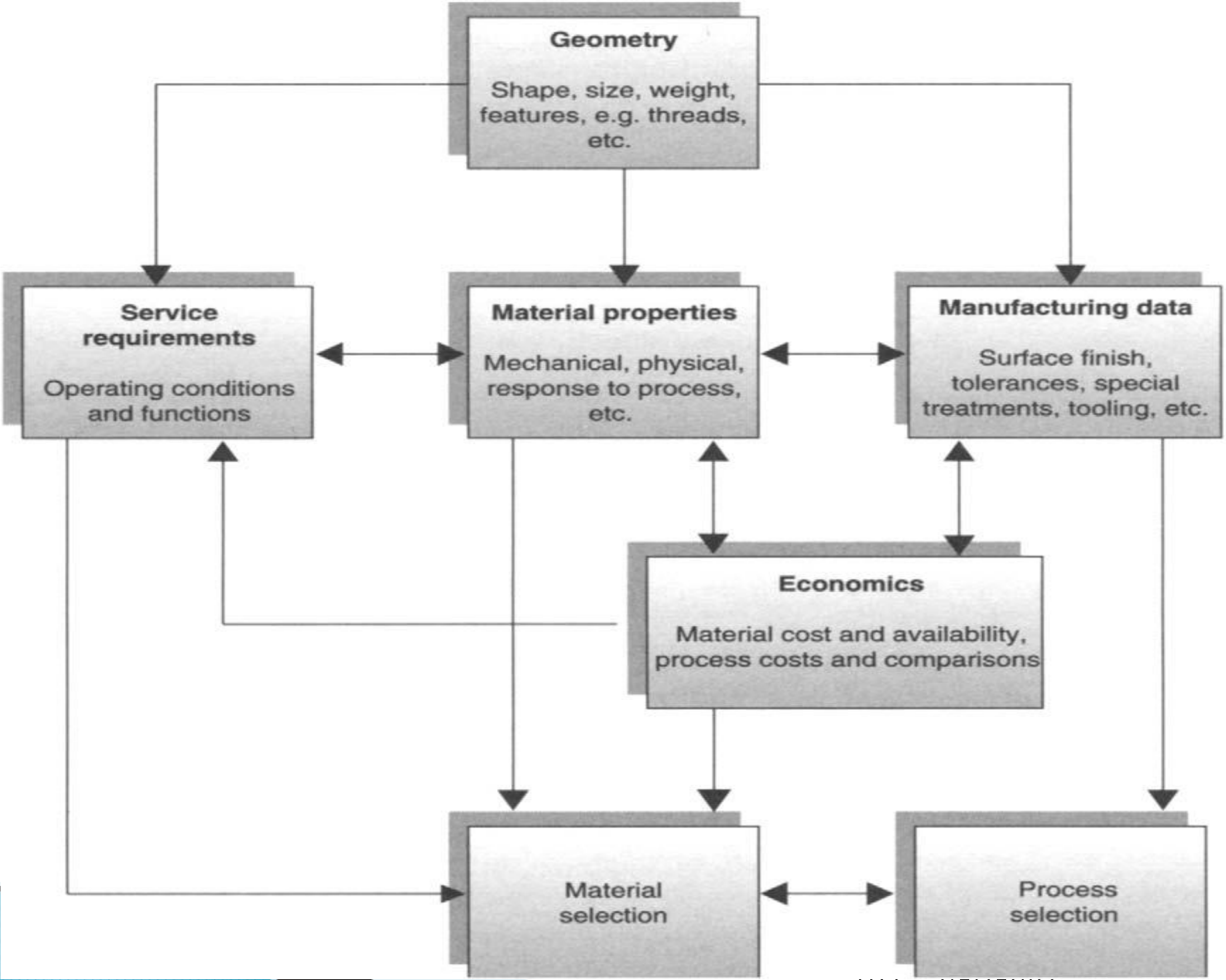
- *the number of components to be made;*
- *the component size;*
- *the component weight;*
- *the precision required;*
- *the surface finish and appearance required.*

# STEPS IN PROCESS SELECTION

In terms of the material evaluation for process planning, the focus will be firmly on *'Manufacturability' or 'Processability'*, as it is also known. This is defined as *the ability of a material to be worked or shaped into the finished component* and is *sometimes referred to as 'workability'*.

Thus terms such as *'weldability', 'castability', 'formability', 'machinability' are used to describe how easily the material can be used for specific processes*. The workability will also have a significant influence on the quality of the part, where quality is defined by three factors (Dieter, 1988):

- Freedom from defects;
- Surface finish;
- Dimensional accuracy and tolerances.


Geometry
Shape, size, weight, features, e.g. threads, etc.
Service requirements
Operating conditions and functions
Material properties
Mechanical, physical, response to process, etc.
Manufacturing data
Surface finish, tolerances, special treatments, tooling, etc.
Economics
Material cost and availability, process costs and comparisons
Material selection
Process selection

# STEPS IN PROCESS SELECTION

**General guidelines for process selection**

Numerous criteria such as *material form, component size and weight, economic considerations, dimensional and geometric accuracy, surface finish specification, batch size and production rate as already mentioned* can be used in the selection of manufacturing processes.

Here, some general guidelines can be applied for the selection of manufacturing processes.

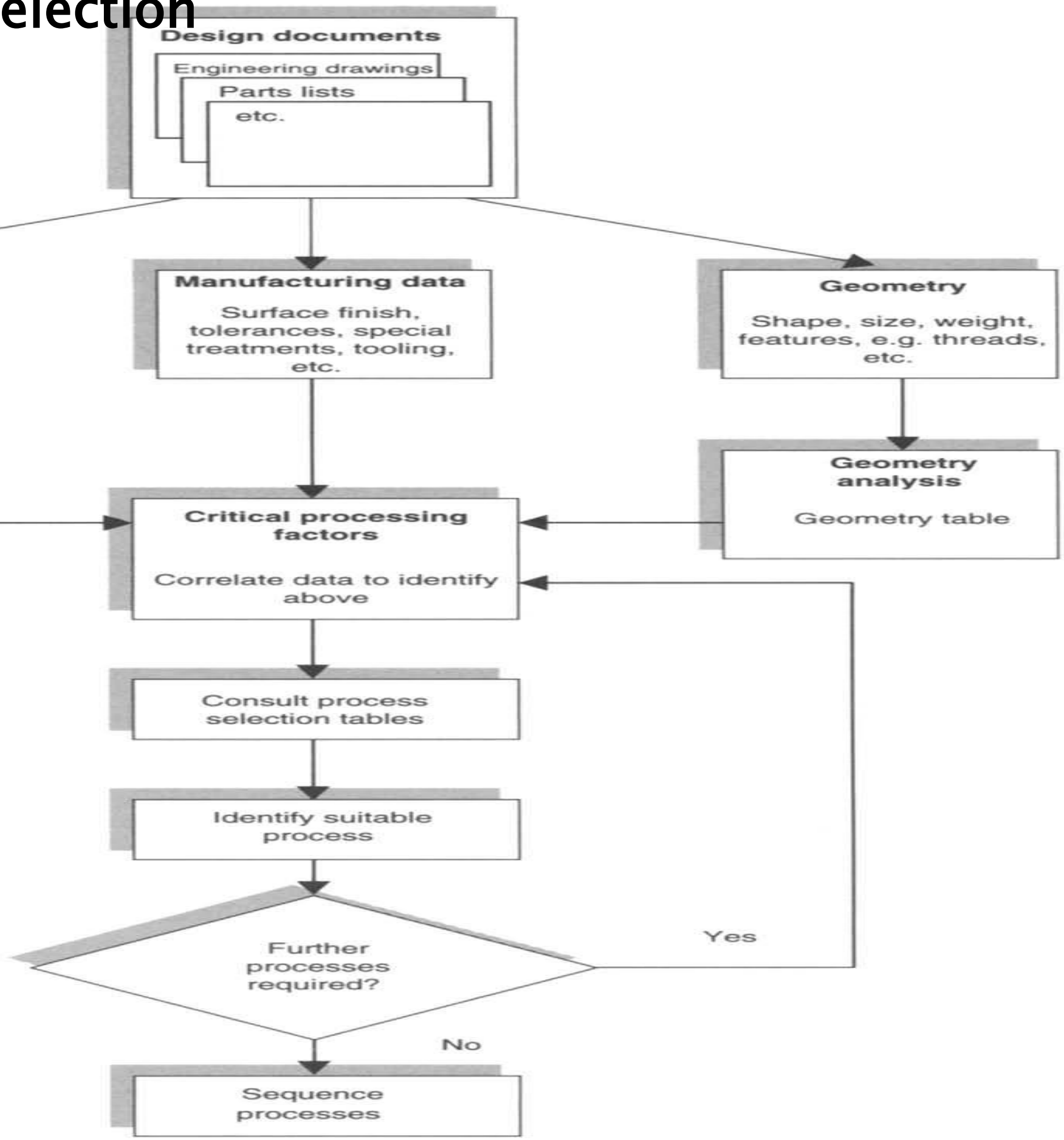
1. *Select a process capable of providing* the specified dimensional/geometric accuracy and surface finish.
2. *Specify the widest possible tolerances and surface finish variation* for products to allow the widest possible choice of manufacturing processes.

# STEPS IN PROCESS SELECTION

3. *Use prototypes as much as possible*, taking into consideration the variation in performance of methods used to manufacture a one-off compared with volume manufacturing.
4. *Carry out a detailed comparison of candidate processes* early in the design process, paying particular attention to the variation in assembly costs for different processes.

Two useful tools in identifying candidate processes are the geometry classification matrix and the PR/MA selection matrix illustrated previously in Figs, respectively. Once candidate processes have been identified, these can be narrowed down by using the process selection tables from previous section.

# Steps in process selection



# STEPS IN PROCESS SELECTION

There are four stages to this process selection method as follows:

**Step I: Drawing interpretation**

Drawing interpretation forms the basis for the process selection. This analysis can be broken down into three distinct analysis and outputs.

1. The first of these is the *geometry analysis*. Using the geometry classification matrix in Fig. The complexity of shape required and the size of the part will also be considered.
2. The second analysis and output is the *manufacturing information in the design documents*, which includes information such process parameters as the surface finish, dimensional and geometric tolerances, limits and fits, special treatments, gauge references and tooling references.
3. The third and final analysis and output is that of the *material evaluation stage*. This considers the material in

# STEPS IN PROCESS SELECTION

**Step II: Critical processing factors**

*The combined output from the first stage must be correlated to identify the critical processing factors*. In particular, the correlation of the candidate processes from the geometry analysis and the material evaluation may allow the list of candidate processes to be shortened using these factors.

**Step III: Consult process tables**

Using the correlated data from the previous stage, the candidate *processes are compared by using the appropriate process selection table*. In a case where *more than one process* can meet all the requirements, economic data may provide further clarification with a *detailed cost comparison made between processes to make a decision*. Finally, the decision being made maybe whether to *make or buy in a part/product based on availability of processes & resources*

# STEPS IN PROCESS SELECTION

**Step IV: Identifying a process**

*Using the data from the second step, and if required a detailed economic analysis, a suitable process should be selected*. If it is the case that one process is all that is required to make the part, then the process selection is complete.

However, except in the case of the use of some primary processes, secondary processing is usually required. Therefore, in cases *where further processing is required, the critical processing factors should be reconsidered* and third step repeated.

*Once all the required processes have been identified, the process selection is complete*. This four-stage method is illustrated further in Example 1.

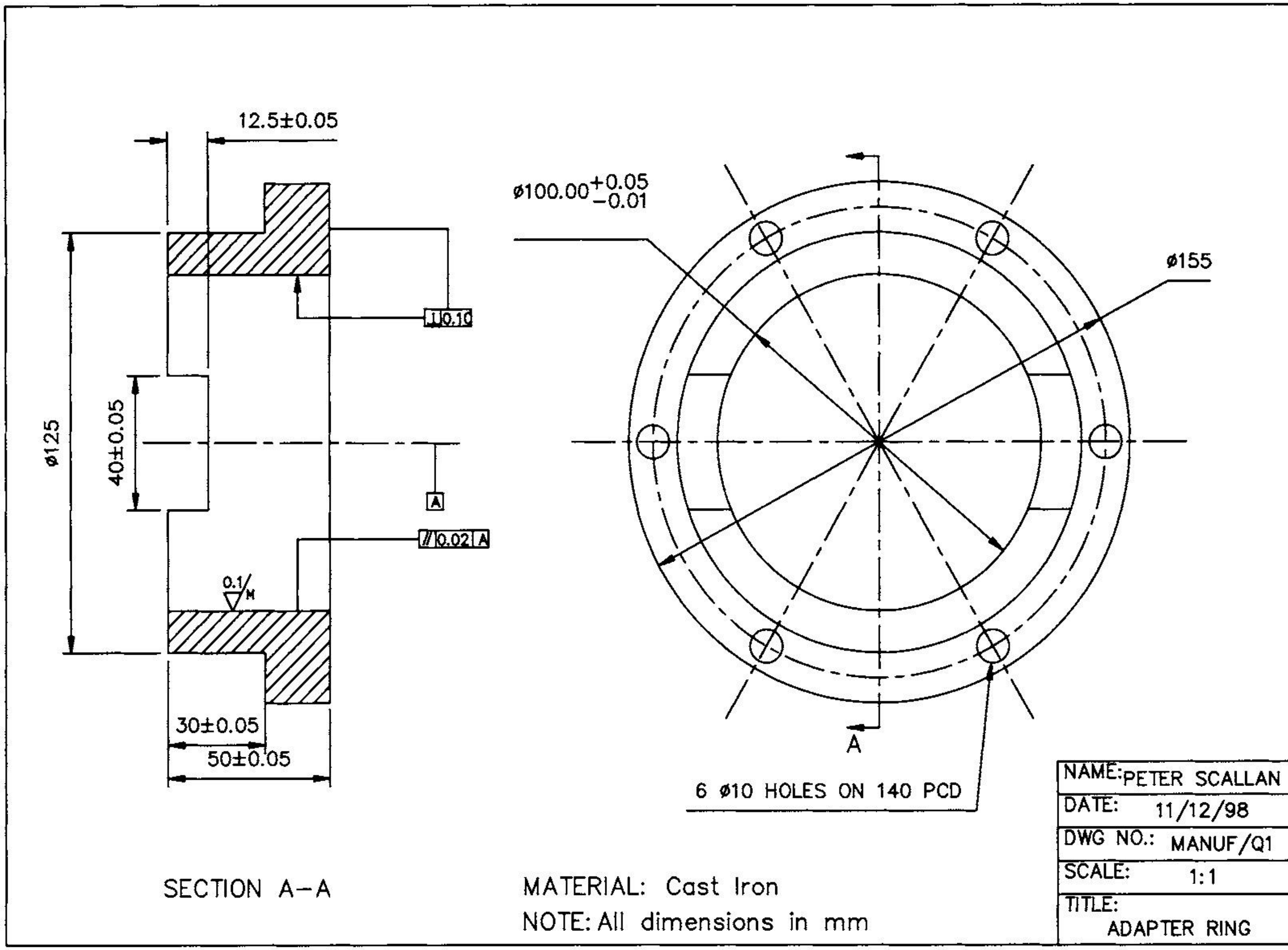



**Figure** *Adapter ring for case study*

Example 1: *Using the adapter ring component from Case study (see Fig), identify suitable manufacturing processes.*

*Solution:*

Step I :Drawing interpretation

*Stage 1: Geometric analysis*

- Considering the geometry of the part in Parts Geometry, the most appropriate classification is T1 (a tube with a change in cross-section at the end).
- *This gives an initial list of candidate processes of any of the casting processes listed, hot forging, turning, grinding, honing or lapping*.
- Of these, *grinding, honing and lapping are essentially finishing processes and can be discounted in terms of the formation of the initial geometry*.

## *Stage 2: Manufacturing considerations*

The manufacturing considerations are the process parameters stated within the drawing. In this instance the important process parameters are:

- The 100 mm diameter bore that holds the bearing cannot deviate from the nominal size by more than −0.01 or +0.05 mm;
- The 100 mm diameter bore must also be perpendicular to the bottom surface within 0.1 mm tolerance zone;
- The 100 mm diameter bore must be machined and have a surface finish of **0.1 μm;**
- the 100 mm diameter bore surface and centreline must be parallel to each other to within a tolerance zone of 0.02 mm;
- the shoulder depth and the overall depth of the part must not deviate from the nominal size by more than ± 0.05;
- the slot width and depth must not deviate from the nominal size by more than ± 0.05.

Although not stated on the drawing, the general dimensional tolerance is ± 0.5 mm and the general surface specification is 12.5 μm. Finally, the part is being made in batches of 400 and the raw material billet is Φ160 x 50 mm.

## *Stage 3: Material evaluation*

***The material specified by the designer is cast iron.*** Although it appears to be satisfactory in terms of property requirements, it obviously limits the process selection to a casting process.

However, it is still worthwhile evaluating the material selected in case there is an equally suitable material that can be used not previously considered. *Using the PRIMA matrix (Fig.) confirms the suitability of casting for irons*. Depending on the quantity required, *both automatic machining and powder metallurgy are*

**Step II : Critical processing factors**

Correlating the above information, the initial process required must:

- be suitable for use with cast iron;
- be able to meet the general dimensional tolerance of $\pm$ 0.5mm;
- be able to meet the general surface specification of 12.5µm;
- be able to economically produce in batches of 400;
- be able to meet the specific dimensional and geometric tolerances stated on the drawing.

From the above list, it is important that the initial process meets these requirements. However, *the last requirement is less important as it has already been specified on the drawing that machining must be carried out*. Therefore, *some of the specific dimensional and geometric tolerances can be met through secondary processing*. From this, it is quite clear that ***the initial processing will be casting***.

**Step III :** ***Consult process selection tables***

Consulting the casting process selection table, there are ***three possible processes*** that could be used. These are *shell casting, investment casting and centrifugal casting*.

*All three can meet the general tolerances and surface specifications set and are considered economical for batches of 400*.

In addition, *investment casting can also meet the specified dimensional tolerance of* $\pm$ ***0.5 mm***. This would reduce the machining required but would increase the complexity and cost of the casting.

Finally, ***in terms of labour, equipment and tooling costs*** *shell casting* ***is the cheapest***.

## Step IV : *Identify a suitable process*

Taking into consideration the information from Steps 1 to 3, ***the most suitable process in terms of meeting the process parameters and being economical for the batch size is Shell casting*.**

However, *secondary processing is required and this has already been designated as machining and therefore the process will have to be repeated.* Taking into consideration the features to be produced and the dimensional and geometric tolerances specified, the following would be appropriate:

- **Turning** *– to produce the Φ100 mm bore.*
- **Milling** *– to produce the 40 x 12.5 mm slot.*
- **Drilling** *– to produce the 6 x ·10 mm holes on the 140 mm PCD.*

# PRODUCTION EQUIPMENT AND TOOLING SELECTION

The factors to be considered while selecting production equipment are:

- *Machine's physical size, construction & power/capacity*
- *Speeds and feeds available, the maximum depth of cut*
- *Number and type of tools available*

All of the aforementioned factors will ultimately have some effect on the production rate, batch size and economic viability of the production equipment.

***Tooling in manufacturing refers not only to cutting tools, but also to work holders, jigs and fixtures (also known as durable tooling).*** The justification for this focus on cutting tools is that the majority of secondary processing will be material

# PRODUCTION EQUIPMENT AND TOOLING SELECTION

A successful machining process relies on the selection of the proper cutting tools for the operation. Among the factors to be considered in selecting appropriate tooling include:

- *Workpiece material,*
- *Type of cut,*
- *Part geometry/size,*
- *Lot size,*
- *Machining data,*
- *Machine tool characteristics,*
- *Cutting tool materials,*
- *Tool holding and quality/capability requirements.*

# PRODUCTION EQUIPMENT AND TOOLING SELECTION

## Factors in equipment selection

Some of the factors used to select a suitable process will be used again to select a suitable machine, for example, surface finish and machine accuracy. These factors can be categorized as either *technical or operational fact*

**TABLE 1** *Specific cutting force values for some commonly used materials*

| *Material* | *Specific cutting force K ($Nmm^{-2}$)* |
|---|---|
| Low-carbon steels | 2200 |
| Medium-carbon steels | 2600 |
| High-carbon steels | 3000 |
| Low alloy steels | 2500–3300 |
| High alloy steels | 3000–4500 |
| Malleable cast iron | 1200–1300 |
| Grey cast iron | 1300–1500 |
| White cast iron (nodular) | 1200 |
| SG iron | 2100 |
| Cast steel (unalloyed) | 2200 |
| Cast steel (low alloy) | 2500 |
| Cast steel (high alloy) | 3000 |
| Stainless steels | 2450–2800 |
| Titanium alloys | 1680 |
| Aluminium alloys (wrought) | 800 |
| Aluminium alloys (cast) | 900 |

## Technical factors

The main factors considered a

- Physical size
- Machine Accuracy
- Surface Finish
- Cutting forces
- Power

# PRODUCTION EQUIPMENT AND TOOLING SELECTION

## Operational Factors

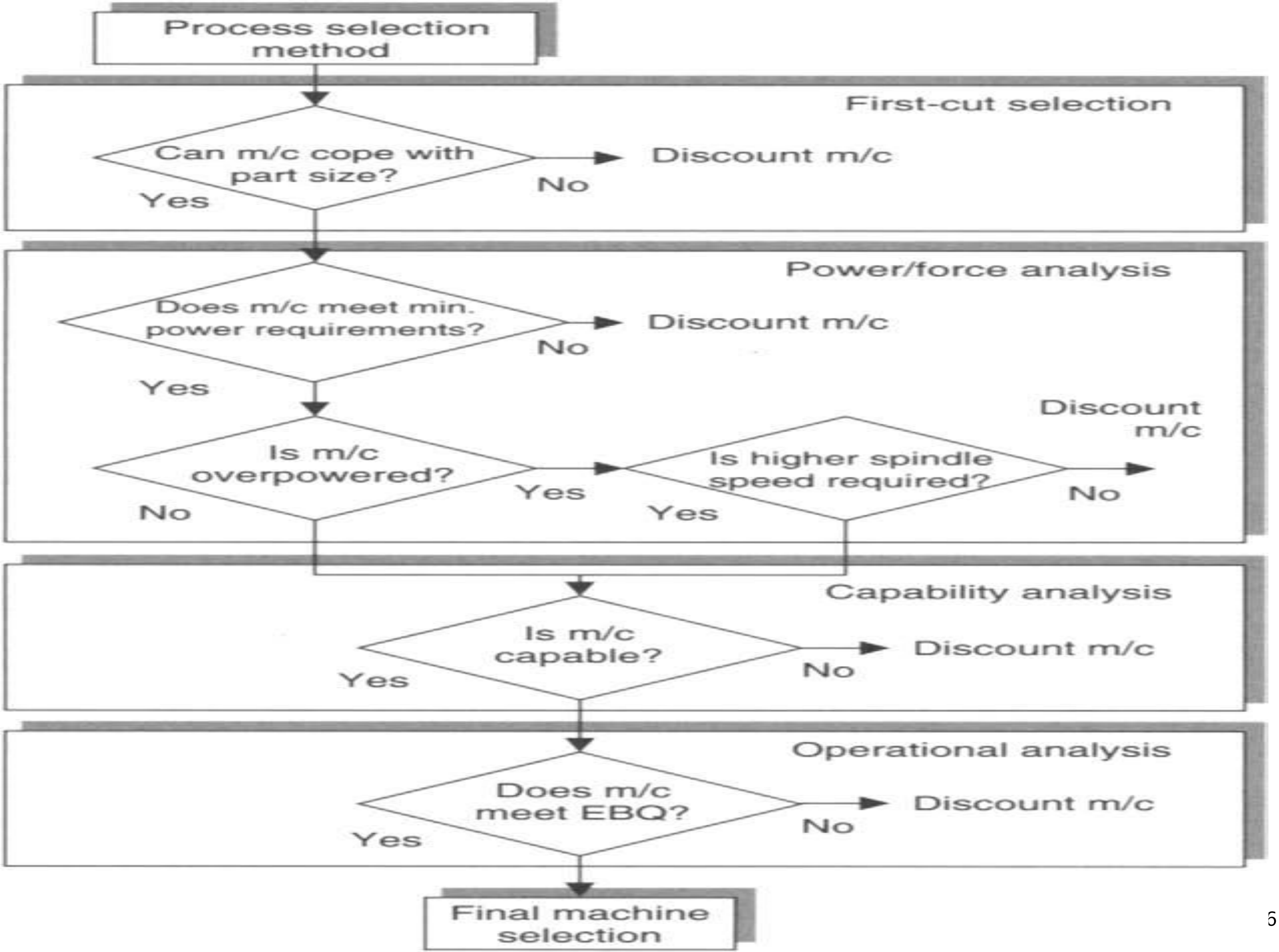
Master Production Schedule (MPS) is a schedule of what is to be made and when (Evans, 1996). The factors considered are more operations management issues than processing planning issues. The factors include:

- Batch Size
- Capacity
- Availability

## Machine Selection Method

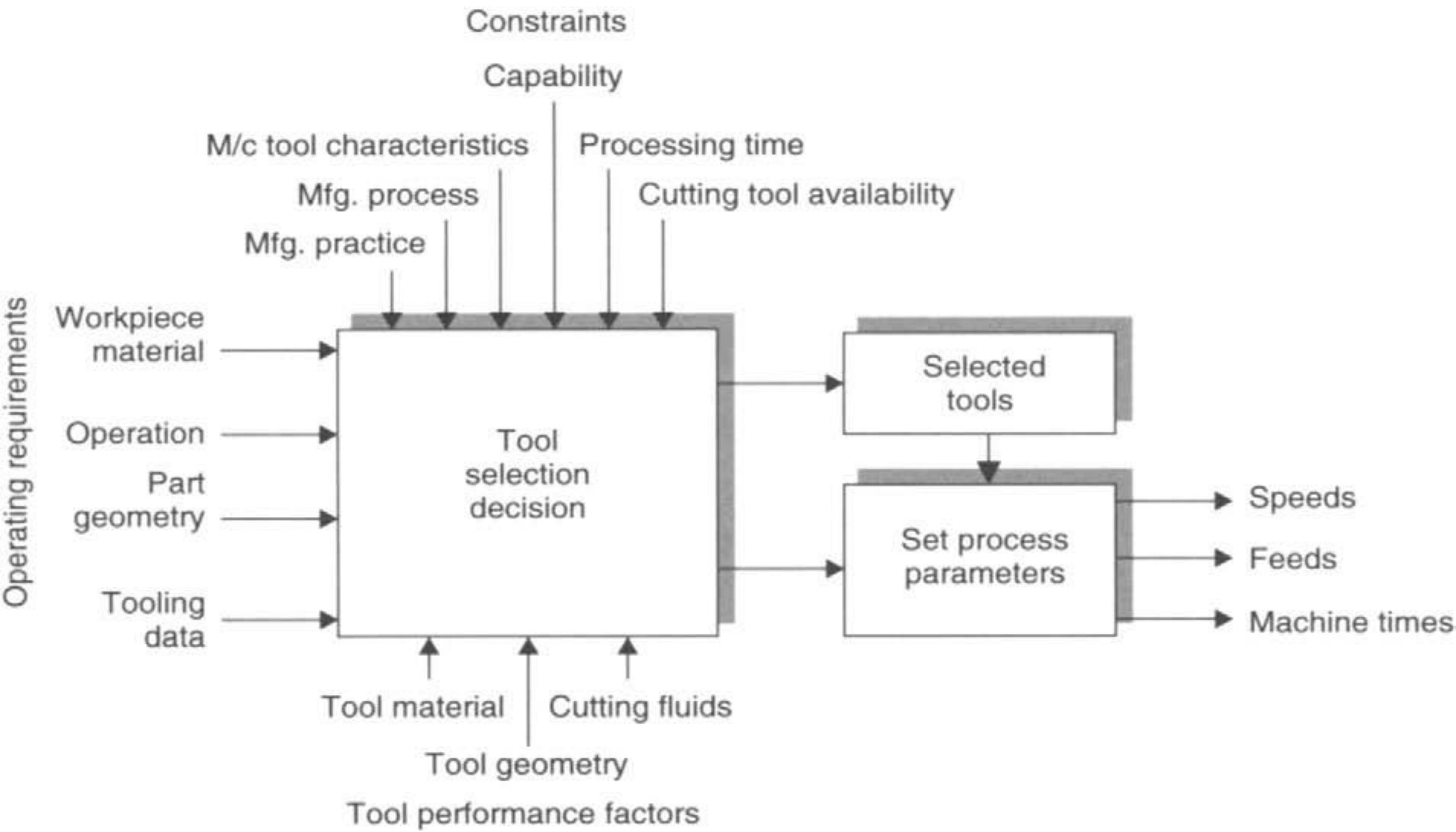
A systematic approach to machine selection, incorporating the factors described & outlined below. This is based on a preliminary machine selection method developed by Halevi and Weill (1995).

# Machine Selection Method



# PRODUCTION EQUIPMENT AND TOOLING SELECTION

## Factors in tooling selection



# PRODUCTION EQUIPMENT AND TOOLING SELECTION

**Tooling selection method**

A method for tool selection will be outlined which incorporates the selection factors. This is a five-stage process as follows:

1. *Evaluation of process and machine selections*
2. *Analysis of machining operations*
3. *Analysis of Workpiece characteristics*
4. *Tooling analysis*
5. *Selection of tooling* – There are two routes that the tool selection can take at this point. If single-piece tooling is being used, then a suitable tool holder should be selected before fully defining the tool geometry and material.

# PRODUCTION EQUIPMENT AND TOOLING SELECTION

**Tooling selection method**

If insert-type tooling is being used then the following steps should be followed (Black *et al., 1996):*

(i) select clamping system;

(ii) select tool holder type and size;

(iii) select insert shape;

(iv) select insert size;

(v) determine tool edge radius;

(vi) select insert type;

(vii) select tool material.

# Thank you