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NPTEL ONLINE CERTIFICATION COURSES

NPTEL

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Automated CAPP (Part-II)

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DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

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Automated CAPP (Part-II)

- **Lecture-1:** Process Optimization and CAPP
- **Lecture-2:** FMS and CAPP
- **Lecture-3:** Process Optimization and CAPP: Numerical Examples
- **Lecture-4:** Process Planning and Concurrent Engineering
- **Lecture-5:** Autonomation

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Automated CAPP (Part-II)

✓ **Process Optimization and CAPP**

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CIM and CAPP

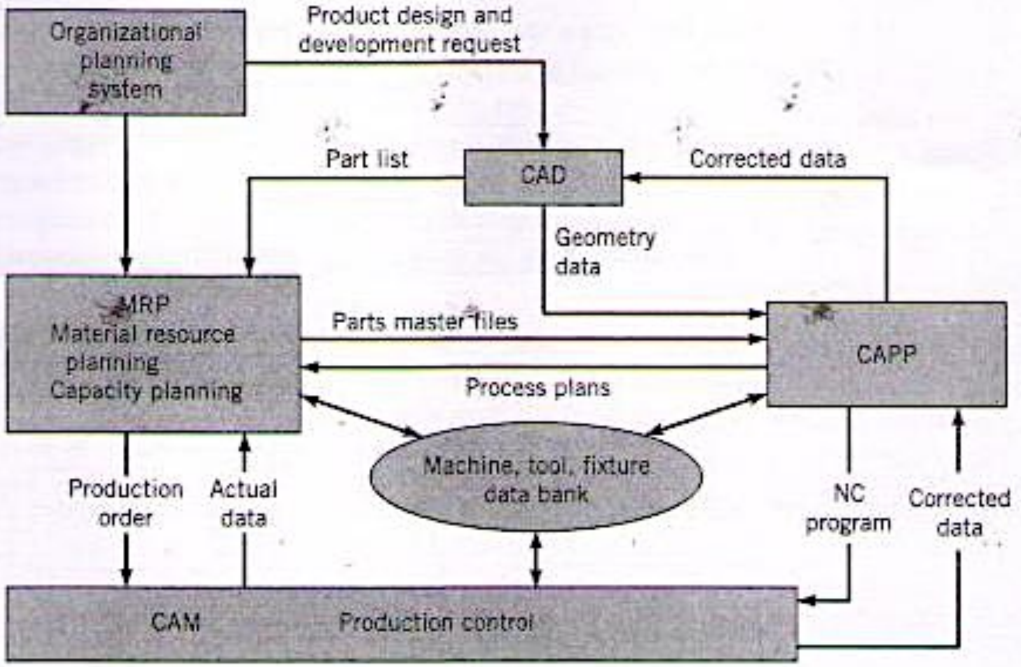

FIGURE 5.9 A computer-aided process planning framework.

Decision Tables

- Decision tables provide a convenient way to document manufacturing knowledge. They are the principal elements of all decision table-based process planning systems.
- The elements of a decision table are conditions, actions, and rules.

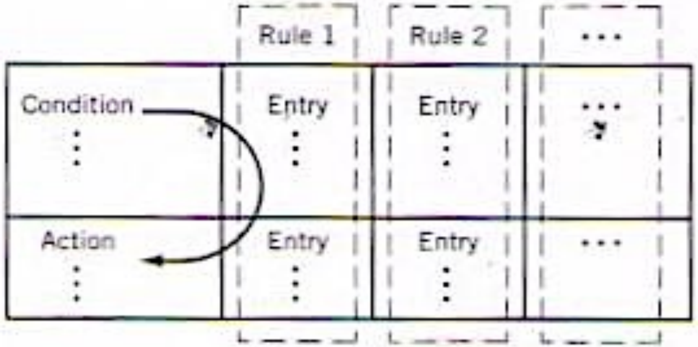

FIGURE 5.10 Format of a decision table.

Decision Tables

- Entries can be either Boolean-type values (true, false, and do not care) or continuous values.

TABLE 5.3 **Boolean Value–type Entries**

Length of bar ≥ 8 in.	T*	F	
Diameter of bar < 1 in.	T		
Diameter of bar ≥ 1 in.			T
Extra support	T		

* T, true; F, false; blank, do not care.

Decision Tables

TABLE 5.4 **Continuous Value-type Entries**

Length of bar (in.)		≤ 4	≥ 4	≤ 16	≥ 16
Diameter of bar (in.)	≤ 0.2	> 0.2	$1 >$ diameter > 0.2	≥ 1	
Extra support	T		T		T

* T, true; blank, do not care.

Decision Tables

❑ Example

Consider the problem of the selection of lathes or grinding machines for jobs involving turning or grinding operations. Data on conditions such as lot size, diameter, surface finish, and tolerance desired are available. They are compiled in the form of a decision table as shown in Table 5.5. Make a machine selection recommendation if

a) The lot size of the job is 70 units; diameter is relatively small; the surface roughness desired is 30µm; and the tolerance range required is ±0.003 in.

Decision Tables

b) The lot size of the job is less than 10 units; diameter is relatively small; the surface roughness desired is 45µm; and the tolerance range required is ±0.004 in.

c) The lot size is greater than 50 units; diameter is relatively small; surface roughness is 20µm; and the tolerance is less than 0.0008 in.

Decision Tables

- **Solution:**

a) From the set of conditions given in the problem, it is easy to see from Table 5.5 that rule 3 is suitable for this situation. The action, therefore is obviously turret lathe; that is, the operation is performed on a turret lathe.

b) Similarly, the solution is engine lathe.

c) From the conditions given in the problem, we find that rule 2 is most suitable. Therefore, the recommended actions are to finish parts on an engine lathe and subsequently on a centerless grinding machine to achieve the desired specifications.

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TABLE 5.5 **Decision Table for the Selection of a Machine(s) for Turning Operation**

*Conditions**	*Rule 1*	*Rule 2*	*Rule 3*	*Rule 4*
LS ≤ 10	X			
LS ≥ 50		X	X	
LS ≥ 4000				X
Relatively large diameters				
Relatively small diameters	X	X	X	X
SF in the range 40–60 min.	X			
SF in the range 16–32 min.		X	X	X
±0.003 ≤ Tol ≤ ±0.005	X			
±0.001 ≤ Tol ≤ ±0.003			X	
±0.0005 ≤ Tol ≤ ±0.001		X		X
Engine lathe	X	1		
Turret lathe			X	
Automatic screw machine				X
Centerless grinding machine		2		

* LS, lot size; SF, surface finish; Tol, tolerance.

Determining Machining Conditions and Manufacturing Times

- Mathematically, this can be expressed as

$$C_u = c_o t_1 + c_o t_c + c_o t_d \left(\frac{t_{ac}}{d}\right) + c_t \left(\frac{t_{ac}}{T}\right)$$

- The tool life equation as a function of cutting speed (v) is expressed as

$$VT^n = C$$

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Determining Machining Conditions and Manufacturing Times

Where

c_o = cost rate including labor and overhead cost rates ($/min)

c_t = tool cost per cutting edge, which depends on the type of tool used

C = constant in the tool life equation, $VT^n = C$

v = cutting speed in meters/minute

f = feed rate (mm/rev)

d = depth of cut (mm)

Determining Machining Conditions and Manufacturing Times

n = exponent in the tool life equation

t_1 = nonproductive time consisting of loading and unloading the part and other idle time (min)

t_c = machining time per piece (min/piece)

t_d = time to change a cutting edge (min)

t_{ac} = actual cutting time per piece, which is approximately equal to t_c (min/piece)

T = tool life (min)

Determining Machining Conditions and Manufacturing Times

- Consider a single-pass turning operation. If *L*, *D*, and *f* are the length of cut (mm), diameter of the work-piece (mm), and feed rate (mm/rev), respectively, then the cutting time per piece for a single-pass operation is

$$t_c = t_{ac} = \frac{\pi L D}{1000 v f}$$

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Determining Machining Conditions and Manufacturing Times

- Upon substituting these values as well as the tool life equation in the cost per piece equation, we obtain the following equation.

$$C_u = c_o t_1 + c_o\left(\frac{\pi L D}{1000 v f}\right) + c_o\left(\frac{\pi L D}{1000 v f}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}} t_d + c_t\left(\frac{\pi L D}{1000 v f}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}}$$

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Determining Machining Conditions and Manufacturing Times

- The feed rate and depth of cut are normally fixed to their allowable values. Therefore, the cutting speed *v* is the decision variable.

- Differentiating C_u with respect to *v*, equating to zero, and solving, We obtain the minimum unit cost cutting speed (V_{min}) as follows:

$$V_{min} = \frac{C}{T_{min}^{n}}$$

Determining Machining Conditions and Manufacturing Times

- Upon substituting the value of cutting speed in the tool life equation, we obtain the optimal tool life (T_{min}) for minimum unit cost as follows:

$$T_{min} = \left[\left(\frac{1}{n} - 1 \right) \left(\frac{c_o t_d + c_1}{c_o} \right) \right]$$

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Maximum Production Rate Model

- Another criterion used to determine the optimal machining conditions is maximum production rate.

- The production rate is inversely proportional to the production time per piece, which is given by,

- Time per piece, T_u = nonproductive time per piece + machining time per piece + tool changing time per piece

Maximum Production Rate Model

- Mathematically, this can be expressed as

$$T_u = t_1 + t_c + t_d\left(\frac{t_{ac}}{T}\right)$$

- Upon substituting the values of T, t_c, and t_{ac} in equation we obtain

$$T_u = t_1 + \left(\frac{\pi LD}{1000vf}\right) + \left(\frac{\pi LD}{1000vf}\right)\cdot\left(\frac{v}{C}\right)^{\frac{1}{n}} t_d$$

Maximum Production Rate Model

- Upon partially differentiating T_u with respect to v, equating to zero, and solving for v, we obtain

$$V_{max} = \frac{C}{T_{max}^{n}}$$

- And hence,

$$T_{max} = \left(\frac{1}{n} - 1\right) t_d$$

Manufacturing Lead Time

- Assuming that the lot size is Q units, then the average lead time to process these units will be

$$\text{Lead Time} = \text{Major Setup Time} + T_u . Q$$

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Automated CAPP (Part-II)

- ✓ **FMS and CAPP**

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FMS and CAPP

- Recent manufacturing trends indicate that a wide variety of components are produced in small to medium sized batches in facilities that are usually poor in productivity.
- This has necessitated the design and development of efficient techniques to effectively monitor and control manufacturing.
- In such cases, a FMS can provide the efficiency of a transfer line with the flexibility of a job shop.

FMS and CAPP

- The construction of a FMS, its materials handling system, computer control, quick setup, versatility, and robust nature give the machines the ability to perform different operations on a variety of parts in a random job sequence.
- The key concept is that jobs can be rerouted to avoid machines down for maintenance on those with long queues.
- A Computer-Aided Process Planning (CAPP) system that generates alternate techniques, sequences and job routes to manufacture a job would help route components efficiently to avoid bottlenecks, reduce in-process inventory level machine utilization, reduce flow time and streamline workflow.

FMS and CAPP

- Process planning is the task of transforming part design specifications rom detailed engineering drawing to a collection of operating instructions for part manufacture.

- Required inputs to the planning scheme includes geometric features, dimensional sizes, tolerances, materials and finishes.

- These inputs are analyzed and evaluated in order to select an appropriate sequence of processing operations based upon specific, available machinery and workstations.

FMS and CAPP

- A process plan then need to generate operational details or outputs such as sequence of operations, speeds, feeds, depth of cut, material removal rate and job route.
- Initial material used in a facility may take a variety of forms such as bar stock, slabs, plates, castings and forgings.
- In order to produce good, consistent and accurate process plans, it is important that a logical, systematic process to develop, maintain and update plans exist.

FMS and CAPP

- This requires the establishment and maintenance of a standard database and implementation of an effective and efficient method to process the data.
- The computerization and the resultant automation of process planning has evolved due to the substandard need caused by the lack of qualified personnel inconsistency in planning, an the need for incorporation of knowledge on continually evolving new processes.
- CAPP implementation has been facilitated by the quality improvement in computer hardware and related facilities over the last decade, the need to reduce planning time, the skill level needed for a planner, planning time, costs, and the need to increase productivity.

FMS and CAPP

- **Process Planning Methods**

- There are essentially three possible different approaches to process planning- manual, computer-assisted variant, and computer generative.

- It may be more appropriate to use a parts approach under a given set of circumstances.

FMS and CAPP

- A generative process planning system synthesizes process information in order to create process plans for parts automatically.

- This technique uses an automatic, computerized system consisting of decision logic, formulae, technology algorithms, and geometry-based data to determine decisions required to furnish a process plan to transform a part from its rough to the finished state.

FMS and CAPP

- A generative system consists of two major components: a geometry-based coding scheme to convert physical features and drawings into computer interpretable data, and software consisting of decision logic, formulae, and algorithms to compare job requirements to machine availability and capability.
- Its advantage include:
  a) Consistent process plans can be generated very rapidly.
  b) New plans can be planned for as easily as for existing parts.
  c) Generative process planning does not require human intervention.

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FMS and CAPP

- Developing a generative process planning is a very complex process requiring the long-term investment of man, machine, and time.
- Generative process planning techniques can be further divided as those that use forward planning, and those that use backward planning.
- Forward planning involves modifying the workpiece until it obtains the features required by the finished product.
- Backward planning involves starting with the finished product, and filling in to the shape of the unmachined workpiece.
- Each machinery process is considered as a filling process.

Automated CAPP (Part-II)

✓ **Process Optimization and CAPP: Numerical Examples**

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Numerical Example-1

A lot of 500 units of steel rods 30 cm long and 6 cm in diameter is turned on a numerically controlled (NC) lathe at a feed rate of 0.2 mm per resolution and a depth of cut of 1 mm. The tool life is given by

$$vT^{0.20} = 200$$

The other data are:

- Machine labour rate = \$10/h
- Machine overhead rate = 50 % of labour

Numerical Example-1

- Grinding labour rate = $10/h
- Grinding overhead rate = 50 % of grinding labour
- Workpiece loading and unloading time = 0.50 min/piece

The data related to tools are:

Brazed inserts

- Original cost of the tool = $27.96
- Grinding time = 2 min
- Tool changing time = 0.50 min

Numerical Example-1

The tool can be ground only five time before it is discarded.

Determine the following:

a) Optimum tool life and optimum cutting speed to minimize the cost per piece.
b) Optimum tool life and optimum cutting speed to maximize the production rate.
c) Minimum cost per component, time per component, and corresponding lead time.
d) Maximum production time, corresponding cost per component, and lead time.

Solution

a) Optimum tool life and optimum cutting speed to minimize the cost per piece:

- $C_o = \text{Machine rate} + \text{Overhead rate} = \frac{10+0.50\times10}{60} = \$0.25 \text{ per minute}$
- $C_1 = \text{Original cost of the tool per cutting edge} + \text{grinding time} \times (\text{grinding labour rate} + \text{grinding overhead rate}) = \frac{27.96}{6} + \frac{2(10+0.50\times10)}{60} = \$5.16$

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Solution

- Therefore,

$$T_{min} = \left[\left(\frac{1}{n} - 1\right)\left(\frac{c_o t_d + c_1}{c_o}\right)\right]$$
$$= \left(\frac{1}{0.20} - 1\right)\frac{0.25 \times 0.50 + 5.16}{0.25} = 84.56 \text{ min}$$

$$V_{min} = \frac{C}{T_{min}^{n}} = \frac{200}{(84.56)^{0.20}} = 82.337 \text{ m/min}$$

Solution

- Therefore,

$$T_{min} = \left[\left(\frac{1}{n} - 1\right)\left(\frac{c_o t_d + c_1}{c_o}\right)\right]$$
$$= \left(\frac{1}{0.20} - 1\right)\frac{0.25 \times 0.50 + 5.16}{0.25} = 84.56 \text{ min}$$

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Solution

b) Optimum tool life and optimum cutting speed to maximize the production rate:

$$
\begin{aligned}
T_{max} &= \left(\frac{1}{n} - 1\right) t_d \\
&= \left(\frac{1}{0.20} - 1\right) 0.50 \\
&= 2 \text{ min}
\end{aligned}
$$

$$
\begin{aligned}
V_{max} &= \frac{C}{T_{max}^{n}} \\
&= \frac{200}{(2)^{0.20}} \\
&= 174.11 \text{ m/mm}
\end{aligned}
$$

Solution

c) Minimum cost per component, time per component, and corresponding lead time:

$$\frac{\pi L D}{1000 V_{min} f} = \frac{3.14 \times 300 \times 60}{1000 \times 82.337 \times 0.20} = 3.4325$$

$$C_o = 0.25 \times 0.50 + 0.25 \times 3.4325 + 0.25 \times 3.4325 \times \left(\frac{1}{84.56}\right) \times 0.50 + 5.16 \times 3.4325 \times \left(\frac{1}{84.56}\right)$$

$$= \$1.197 \text{ per piece}$$

Solution

The production time per piece at V_{min} is

$$T_u = t_1 + \left(\frac{\pi L D}{1000 V_{min} f}\right) + \left(\frac{\pi L D}{1000 V_{min} f}\right)\left(\frac{V_{min}}{C}\right)^{\frac{1}{n}} t_d$$

$$= 0.50 + 3.4325 + 3.4325 \times \left(\frac{1}{84.56}\right) \times 0.50$$

$$= 3.9528 \text{ min}$$

Therefore, the lead time (ignoring major setup time) to 500 units is $500 \times 3.9528 = 1976.40$ min

Solution

d) Maximum production time, corresponding cost per component, and lead time:

$$\frac{\pi LD}{1000V_{max}f} = \frac{3.14 \times 300 \times 60}{1000 \times 174.11 \times 0.20} = 1.623$$

The production time per piece at V_{max} is

$$T_u = t_1 + \left(\frac{\pi LD}{1000V_{max}f}\right) + \left(\frac{\pi LD}{1000V_{max}f}\right)\left(\frac{V_{max}}{C}\right)^{\frac{1}{n}} t_d$$

$$= 0.50 + 1.623 + 1.623 \times \left(\frac{1}{2}\right) \times 0.50$$

$$= 2.52875 \text{ min}$$

Solution

Therefore, the lead time (ignoring major setup time) to 500 units is $500 \times 2.52875 = 1264.375$ min

$$C_o = 0.25 \times 0.50 + 0.25 \times 1.623 + 0.25 \times 1.623 \times \left(\frac{1}{2}\right) \times 0.50 + 5.16 \times 1.623 \times \left(\frac{1}{2}\right)$$

$$= \$4.8195 \text{ per piece}$$

Automated CAPP (Part-II)

✓ **Process Planning and Concurrent Engineering**

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Process Planning and Concurrent Engineering

- The product design is the plan for the product and its components and subassemblies.
- A manufacturing plan is needed to convert the product design into a physical entity.
- The activity of developing such a plan is called process planning.

Process Planning and Concurrent Engineering

- It is the bridge between product design and manufacturing.
- Process planning involves determining the sequence of processing and assembly steps that must be accomplished to make the product.
- Production planning is concerned with the logistics issues of making the product: ordering the materials and obtaining the resources required to make the product in sufficient quantities to satisfy demand.

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Process Planning

- Process planning consists of determining the most appropriate manufacturing and assembly processes and the sequence in which they should be accomplished to produce a given part or product according to specifications set forth in the product design documentation.

- The scope and variety of processes that can be planned are generally limited by the available processing equipment and technological capabilities of the company or plant.

- Parts that cannot be made internally must be purchased from outside vendors.

Process Planning

- Process planning is usually accomplished by manufacturing engineers (other titles include industrial engineers, production engineers, and process engineers).

- They must be familiar with the particular manufacturing processes available in the factory and be able to interpret engineering drawings.

- Based on the planner's knowledge, skill, and experience, the processing steps are developed in the most logical sequence to make each part.

Process Planning

- Following is a list of the many decisions and details usually included within the scope of process planning.

1. **Interpretation of design drawing:** First, the planner must analyse the part or product design (materials, dimensions, tolerances, surface finishes, etc.).
2. **Choice of processes and sequence:** The process planner must select which processes and their sequence are required, and prepare a brief description of all processing steps.
3. **Choice of equipment:** In general, process planners must develop plans that utilize existing equipment in the plant. Otherwise, the company must purchase the component or invest in new equipment.

Process Planning

4. **Choice of tools, dies, moulds, fixtures, and gages:** The process planner must decide what tooling is required for each processing step. The actual design and fabrication of these tools is usually delegated to a tool design department and tool room, or an outside vendor specializing in that type of tooling.

5. **Analysis of methods:** Workplace layout, small tools, hoists for lifting heavy parts, even in some cases hand and body motions must be specified for manual operations. The industrial engineering department is usually responsible for this area.

Process Planning

6. **Setting of work standards:** Work measurement techniques are used to set time standards for each operation.

7. **Choice of cutting tools and cutting conditions:** These must be specified for machining operations, often with reference to standard handbook recommendations. Similar decisions about process and equipment settings must be made for processes other than machining.

Make or Buy Decision

- An important question that arises in process planning is whether a given part should be produced in the company's own factory or purchased from an outside vendor.
- If the company does not possess the equipment or expertise in the particular manufacturing processes required to make the part, then the answer is obvious: The part must be purchased because there is no internal alternative.
- However, in many cases, the part could either be made internally using existing equipment or purchased externally from a vendor that possesses similar manufacturing capability.

Factors in the Make or Buy Decision

Factor	Explanation and Effect on Make/Buy Decision
How do part costs Compare?	This must be considered the most important factor in the make or buy decision.
Is the process available in-house?	If the equipment and technical expertise for a given process are not available internally, then purchasing is the obvious decision. Vendors usually become very proficient in certain processes, which often makes them cost competitive in external–internal comparisons. However, there may be long-term cost implications for the company if it does not develop technological expertise in certain processes that are important for the types of products it makes.

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Factors in the Make or Buy Decision

Factor	Explanation and Effect on Make/Buy Decision
What is the total production quantity and anticipated product life?	As the total number of units required over the life of the product increases, this tends to favour the make decision. Lower quantities favour the buy decision. Longer product life tends to favour the make decision.
Is the component a standard item?	Standard catalog items (e.g., hardware items such as bolts, screws, nuts, and other commodity items) are produced economically by suppliers specializing in those products. Cost comparisons almost always favor a purchase decision on these standard parts.

Factors in the Make or Buy Decision

Factor	Explanation and Effect on Make/Buy Decision
Is the supplier reliable?	A vendor that misses a delivery on a critical component can cause a shutdown at the company's final assembly plant. Suppliers with proven delivery and quality records are favoured over suppliers with lesser records.
Is the company's plant already operating at full capacity?	In peak demand periods, the company may be forced to augment its own plant capacity by purchasing a portion of the required production from outside vendors.

Factors in the Make or Buy Decision

Factor	Explanation and Effect on Make/Buy Decision
Does the company need an alternative supply source?	Companies sometimes purchase parts from outside vendors to maintain an alternative source to their own production plants. This is an attempt to ensure an uninterrupted supply of parts, for example, as a safeguard against a wildcat strike at the company's parts production plant.

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General Principles and Guidelines in DFM/A

Guideline	Interpretation and Advantages
Minimize number of components	• Reduced assembly costs. • Greater reliability in final product. • Easier disassembly in maintenance and field service. • Automation is often easier with reduced part count. • Reduced work-in-process and inventory control problems. • Fewer parts to purchase; reduced ordering costs.
Use standard commercially available components	• Reduced design effort. Fewer part numbers. • Better inventory control possible. • Avoids design of custom-engineered components. • Quantity discounts are possible.

General Principles and Guidelines in DFM/A

Guideline	Interpretation and Advantages
Use common parts across product lines	• Group technology can be applied. • Quantity discounts are possible. • Permits development of manufacturing cells.
Design for ease of part fabrication	• Use net shape and near-net shape processes where possible. • Simplify part geometry; avoid unnecessary features. • Avoid making surface smoother than necessary since additional processing may be needed.

General Principles and Guidelines in DFM/A

Guideline	Interpretation and Advantages
Design parts with tolerances that are within process capability	• Avoid tolerances less than process capability. • Specify bilateral tolerances. • Otherwise, additional processing or sortation and scrap are required.
Design the product to be foolproof during assembly	• Assembly should be unambiguous. Components should be designed so they can be assembled only one way. • Special geometric features must sometimes be added to components.

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General Principles and Guidelines in DFM/A

Guideline	Interpretation and Advantages
Minimize flexible components	• These include components made of rubber, belts, gaskets, electrical cables, etc. • Flexible components are generally more difficult to handle.
Design for ease of assembly	• Include part features such as chamfers and tapers on mating parts. • Use base part to which other components are added. • Use modular design.

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General Principles and Guidelines in DFM/A

Guideline	**Interpretation and Advantages**
Design for ease of assembly	• Design assembly for addition of components from one direction, usually vertically; in mass production this rule can be violated because fixed automation can be designed for multiple direction assembly. • Avoid threaded fasteners (screws, bolts, nuts) where possible, especially when automated assembly is used; use fast assembly techniques such as snap fits and adhesive bonding. • Minimize number of distinct fasteners.

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General Principles and Guidelines in DFM/A

Guideline	Interpretation and Advantages
Use modular design	• Each subassembly should consists of 5–15 parts. • Easier maintenance and field service. • Facilitates automated (and manual) assembly. • Reduces inventory requirements. • Reduces final assembly time.
Shape parts and products for ease of packaging	• Compatible with automated packaging equipment. • Facilitates shipment to customer. • Can use standard packaging cartons.

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General Principles and Guidelines in DFM/A

Guideline	Interpretation and Advantages
Eliminate or reduce adjustments	• Many assembled products require adjustments and calibrations. • During product design, the need for adjustments and calibrations should be minimized because they are often time consuming in assembly.

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Advanced Manufacturing Planning

- Advanced manufacturing planning emphasizes planning for the future.
- It is a corporate level activity that is distinct from process planning because it is concerned with products being contemplated in the company's long-term plans (2- to 10-year future), rather than products currently being designed and released.
- Advanced manufacturing planning involves working with sales, marketing, and design engineering to forecast the future products that will be introduced and determine what production resources will be needed to make those products.
- The future products may require manufacturing technologies and facilities not currently available in the firm.

Advanced Manufacturing Planning

- In advanced manufacturing planning, the current equipment and facilities are compared with the processing needs of future planned products to determine what new technologies and facilities should be installed.
- The general planning cycle is portrayed in Figure 24.5.
- The feedback loop at the top of the diagram is intended to indicate that the firm’s future manufacturing capabilities may motivate new product ideas not previously considered.
- Activities in advanced manufacturing planning include (1) new technology evaluation, (2) investment project management, (3) facilities planning, and (4) manufacturing research.

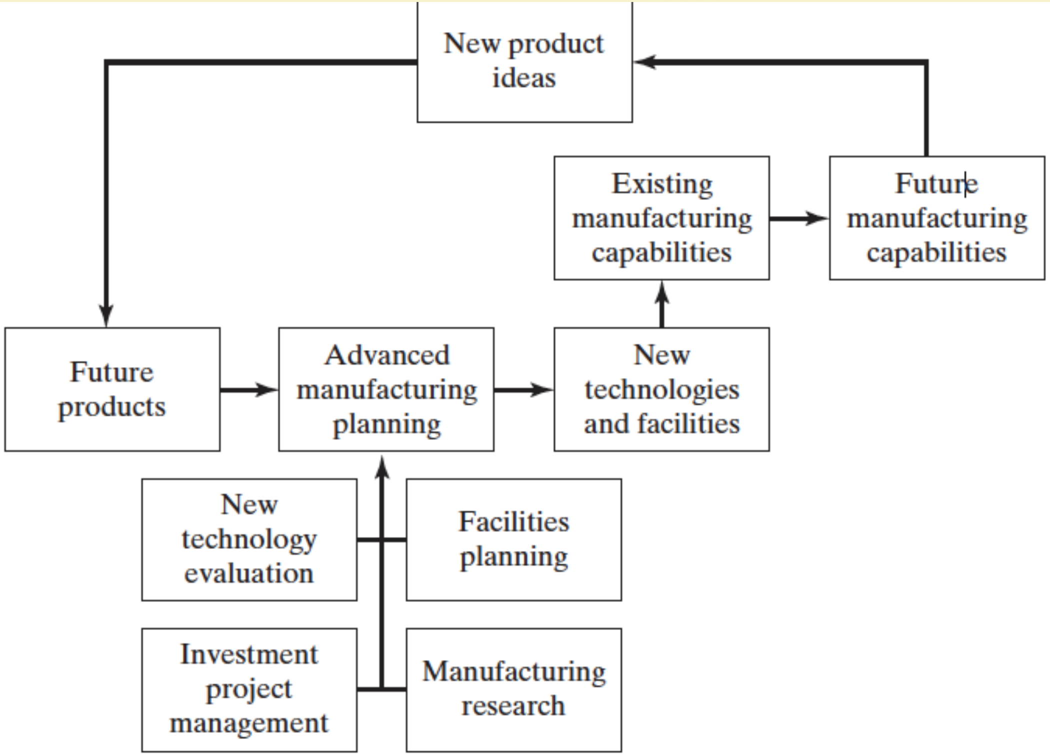

Figure 24.5 Advanced manufacturing planning cycle.

Automated CAPP (Part-II)

✓ **Autonomation**

Autonomation

- The word seems like a misspelling of "automation." Taiichi Ohno referred to autonomation as "automation with a human touch".
- The notion is that the machines operate autonomously as long as they are functioning properly.
- When they do not function properly, for example, when they produce a defective part, they are designed to stop immediately.
- Another aspect of autonomation is that the machines and processes are designed to prevent errors.

Autonomation

- Finally, machines in the Toyota production system must be reliable, which requires an effective maintenance program.

- This section covers these three aspects of autonomation:

  (1) stopping the process automatically when something goes wrong,
  (2) preventing mistakes, and
  (3) total productive maintenance.

Autonomation

- **Stop the Process**

- Much of autonomation is embodied in the Japanese word jidoka, which refers to machines that are designed to stop automatically when something goes wrong, such as a defective part being processed.
- Production machines in Toyota plants are equipped with automatic stop devices that activate when a defective work unit is produced.
- Therefore, when a machine stops, it draws attention to the problem, requiring corrective action to be taken to avoid future recurrences.

Autonomation

- In either case, it consists of the following control devices: (1) sensors to detect abnormal operation that would result in a quality defect, (2) a device to count the number of parts that have been produced, and (3) a means to stop the machine or production line when abnormal operation is detected or the required batch quantity has been completed.
- The alternative to autonomation occurs when a production machine is not equipped with these control mechanisms and continues to operate abnormally, possibly completing an entire batch of defective parts before the quality problem is even noticed, or producing more parts than the quantity required at the downstream workstation.

Autonomation

- To avoid such a calamity in a plant that does not have automatic stop mechanisms on its machines, each machine must have a worker in continuous attendance to monitor its operation.

- Machines equipped with autonomation do not require a worker to be present all the time when they are functioning correctly. Only when a machine stops must the worker attend to it.

- This allows one worker to oversee the operation of multiple machines, thereby increasing worker productivity.

Autonomation

- Because workers are called upon to service multiple machines, and the machines are frequently of different types, the workers must be willing and able to develop a greater variety of skills than those who are responsible for only a single machine type.

- The net effect of more versatile workers is that the plant becomes more flexible in its ability to shift workers around among machines and jobs to respond to changes in workload mix.

- At Toyota, the jidoka concept is extended to its final assembly lines.

Autonomation

- Workers are empowered to stop the assembly line when a quality problem is discovered, using pull cords located at regular intervals along the line.
- Downtime on final assembly lines in the automotive industry is expensive. Managers desperately want to avoid it.
- They accomplish this by making sure that the problems that cause it are eliminated.
- Pressure is applied on the parts fabrication departments and suppliers to prevent defective parts and subassemblies from reaching the final assembly area.

Autonomation

- **Error Prevention**

- This aspect of autonomation is derived from two Japanese words: poka, which means error, and yoke, which means prevention.
- Together, poka-yoke means prevention of errors through the use of low-cost devices that detect and/or prevent them.
- The poka-yoke concept was developed by Shigeo Shingo, who also pioneered the single minute exchange of dies (SMED).
- The use of poka-yoke devices relieves the worker of constantly monitoring the process for errors that might cause defective parts or other undesirable consequences.

Autonomation

- Mistakes in manufacturing are common, and they often result in the production of defects.
- Examples include omission of processing steps, incorrectly locating a work part in a fixture, using the wrong tool, not aligning jigs and fixtures properly on the machine tool table (this can result in the entire batch of parts being processed incorrectly), and neglecting to add a component part in an assembly.
- Most of the functions performed by poka-yoke devices in production can be classified into the following categories:

Autonomation

- **Detecting work part deviations:** The function is to detect abnormalities in a work part, such as its weight, dimensions, and shape. The detection may apply to the starting piece or the final piece or both (before and after).

- **Detecting processing and methods deviations:** This type of poka-yoke is designed to detect mistakes made during an assembly or processing operation. The mistake is usually associated with manual operations. For example, did the worker correctly position the work part in the fixture?

Autonomation

- **Counting and timing functions:** In batch production, counting can be used to stop the production machine after a specified number of parts have been made. Tool changes in machining operations are often predicated on the length of time that the cutting tool has been in use. Many operations require a certain number of repetitions of a given work element during the cycle. For example, did the spot-welder apply the correct number of spot-welds during the work cycle? Timing or counting devices can monitor these kinds of situations.

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Autonomation

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- **Verification functions:** This function is concerned with the verification of a desired status or condition during the work cycle. For example, is the work part present or absent in the clamping device?

Autonomation

When a poka-yoke finds that an error or other exception has occurred, it responds in either or both of the following ways:

- **Stop the process:** The poka-yoke stops the mechanized or automated cycle of a production machine when it detects a problem. For example, a limit switch installed in a workholder detects that the workpiece is incorrectly located and is interlocked with the milling machine to prevent the process from starting.

Autonomation

- **Provide an alert:** This response is an audible or visible warning signal that an error has occurred. This signal alerts the operator and perhaps other workers and supervisors about the problem. The use of andon boards is a means of implementing this type of response.

List of Reference Textbooks

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Thank You!!