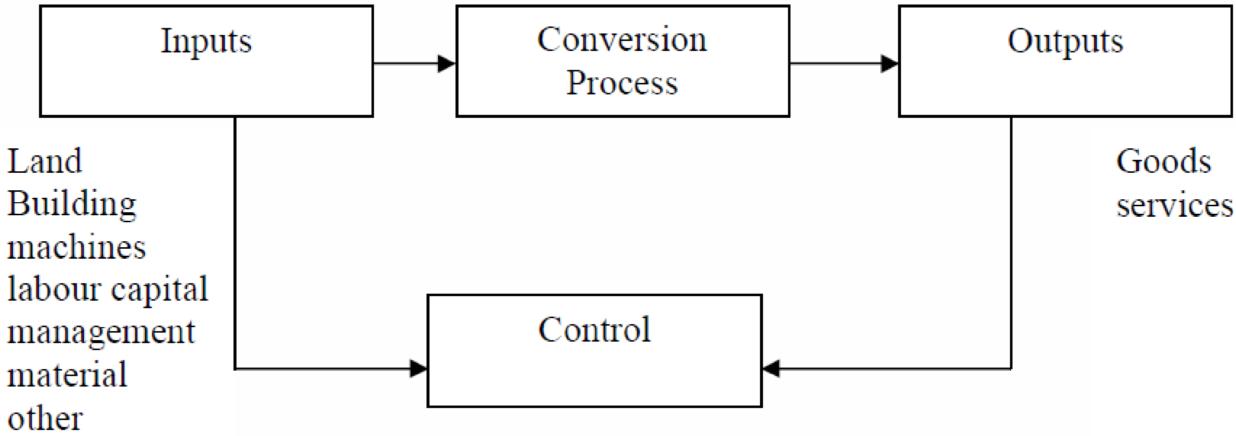
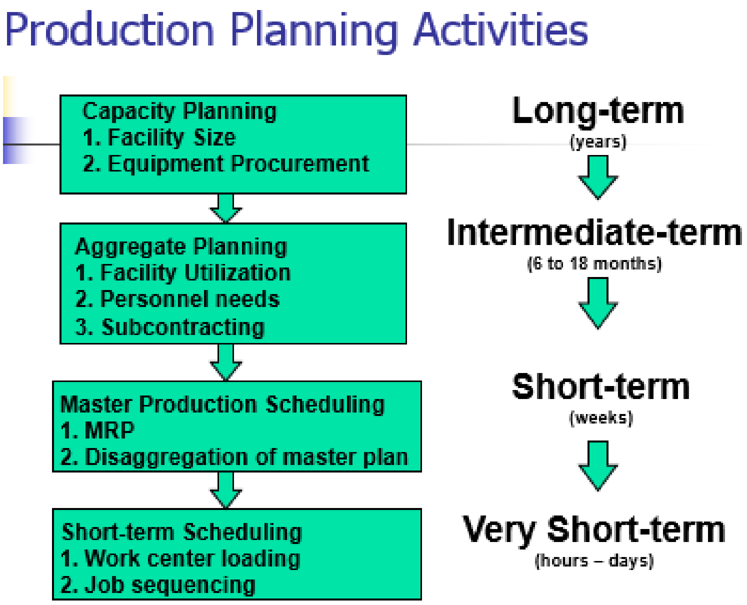
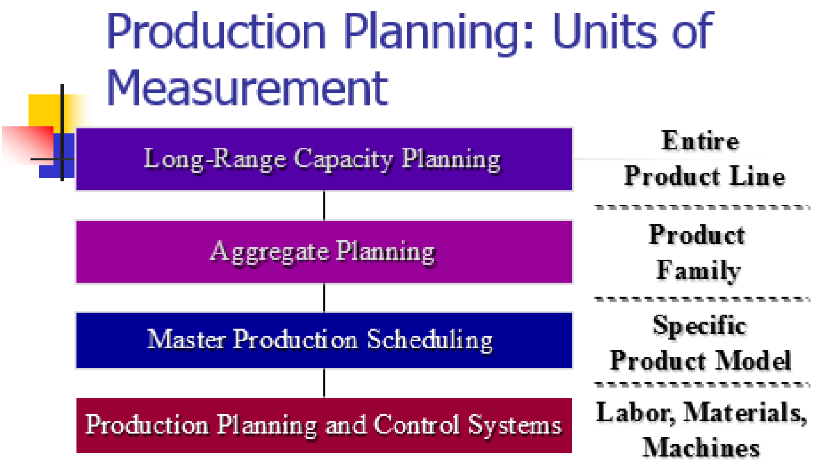
PRODUCTION PLANNING ANDCONTROL AND COMPUTER AIDED PRODUCTION PLANNING

Production is a process whereby raw material is converted into semi-finished products and thereby adds to the value of utility of products, which can be measured as the difference between the value of inputs and value of outputs



➢ The purpose of the production planning is to ensure that manufacturing run effectively and efficiently and produces products as required by customers





MANUFACTURING PLANNING AND CONTROL SYSTEM:

The primary objective of a *manufacturing planning and control system* (MPCS) in any organization is to ensure that the desired products are manufactured

- at the right time,
- in the right quantities,
- meeting quality specifications, and
- at minimum cost.

The manufacturing planning and control system (MPCS) in a company is achieved by integrating the activities as:

- determining product demand,
- translating product demand into feasible manufacturing plans,
- establishing detailed planning of material flows,
- capacity to support the overall manufacturing plans, and
- helping to execute these plans by such actions as

  ⇒*detailed cell scheduling*

  ⇒*purchasing*

The benefits achieved through the use of integrated MPCS are:

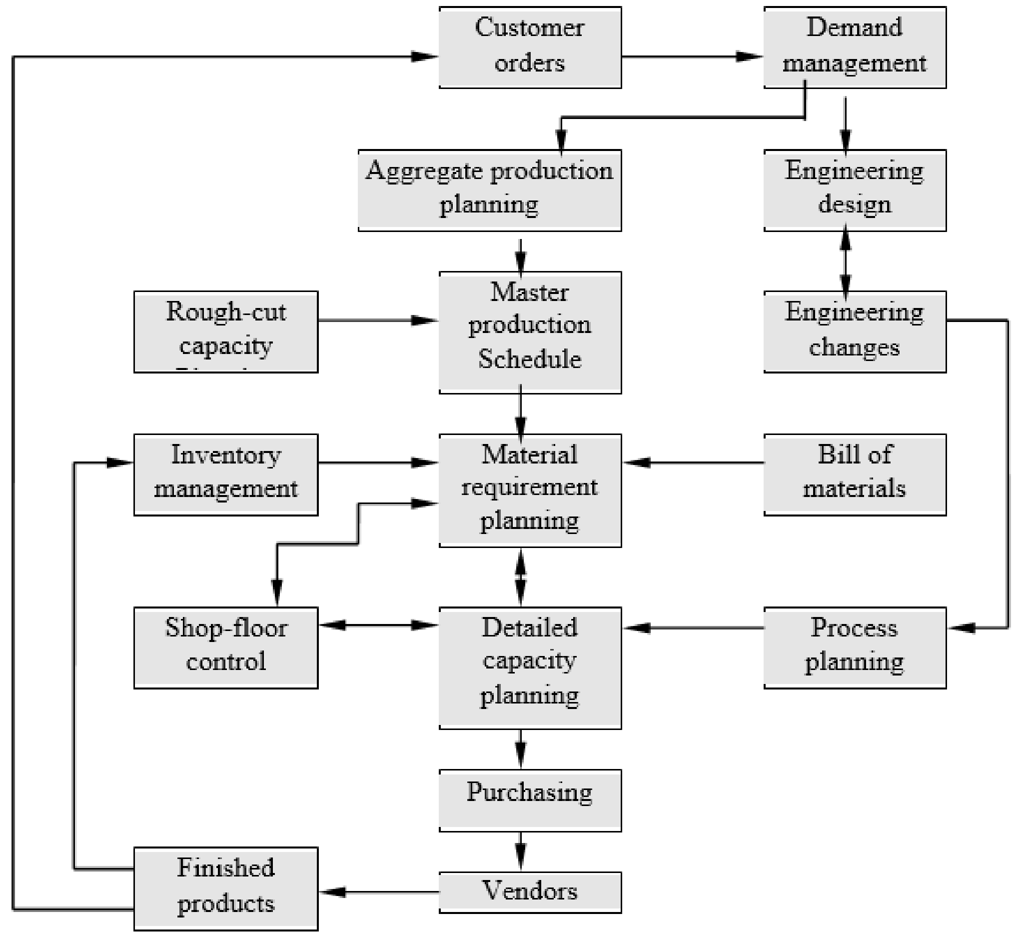
- reduced inventories
- reduced capacity
- reduced labor costs
- reduced overtime costs
- shorter manufacturing lead time
- faster responsiveness to internal and external changes as:

⇒*machine and other equipment failure*
⇒*product mix*
⇒*demand changes*
⇒*etc.*

The major elements of a integrated MPCS are:

- Demand management
- Aggregate production planning
- Master production scheduling
- Rough-cut capacity planning
- Material requirement planning
- Capacity planning
- Order release
- Shop floor scheduling and control

<u>The flow of information among various elements of an MPCS:</u>



DEMAND MANAGEMENT:

Demand for products is the driving force for any production activity.

Demand management is therefore an important input to *production planning*.

Demand managementcontains activities as:

- demand forecasting
- order transaction entry
- customer-contact activities
- physical distribution management

Demand forecasting:

Forecasting is concerned with estimating future demand (or requirement) for products.

Forecasting is necessary for production planning.

There are three approaches to forecasting:

1. The qualitative approach
2. The explanatory approach
3. The descriptive approach

AGGREGATE PRODUCTION PLANNING:

In a high-variety, discrete manufacturing environment, demand for product may fluctuate considerably. On the other end, the resources of the company *(number of machines, number of workers, etc.)* remain constant during the planning horizon *(normally 12 months).* The best approach to obtain feasible solutions is to aggregate the information being processed.

For aggregation purposes the product demand should be expressed in a common measurement unit such as **production hours**. Production planning is concerned primarily with determining optimal production, inventory, and work force levels to meet demand fluctuation.

Basic strategies to absorb the demand fluctuations are:

* Maintain uniform production rate and absorb demand fluctuations.
* Maintain work force but change the production rate by permitting planned overtime, idle time and subcontracting.
* Change the production rate by changing the size of the work force through planned hiring and layoffs.
* Explore the possibility of planned backlogs if customers are willing to accept delays in delivery of products.

A suitable combination of these strategies should be explored to develop an optimal aggregate production plan.

EXAMPLE:

Data on the expected aggregated sales of three products, A, B, and C, over planning horizon of six 4-week periods are as follows:

	Product A		Product B		Product C	
Period	Units	Eq. Cell-hours	Units	Eq. Cell-hours	Units	Eq. Cell-hours
1	60	120	40	80	100	100
2	70	140	50	100	160	160
3	50	100	70	140	210	210
4	55	110	65	130	170	170
5	45	90	55	110	100	100
6	40	80	40	80	80	80

The company has the regular production capacity of 300 *units/period.*

Overtime is allowed up to 60 *units/period*.

The company has developed machining cell-hours as a common unit for aggregation purposes.

Product A &B :2 *cell-hours/unit* Product C : 1 *cell-hours/unit*

Data on the aggregate demand forecast in cell-hours is given in the table below:

Period	Expected Aggregate Demand *(Equivalent Cell-hours)*	Cumulative Aggregate Demand *(Cell-hours)*
1	300	300
2	400	700
3	450	1150
4	410	1560
5	300	1860
6	240	2100

Requirements exceeding overtime capacity may be satisfied by subcontracting.

Two alternative production policies are developed as follows:

PLAN 1: Produce at the constant rate of 350 *units/period* for the entire planning horizon

PLAN 2: Produce at the rate of 400 *units/period* for the first 4 periods and then at the rate of 250 *units/period* for the subsequent periods.

Analyze these two aggregate production plans.

PLAN 1: Uniform Regular Production Rate Policy

Period	Production rate	Inventory	Back orders	Change in capacity	Overtime	Subcontract
1	350	50	0	+50	50	0
2	350	0	0	0	50	0
3	350	0	100	0	50	0
4	350	0	160	0	50	0
5	350	0	110	0	50	0
6	350	0	0	0	50	0

PLAN 2: Varying Regular Production Rate Policy

Period	Production rate	Inventory	Back orders	Change in capacity	Overtime	Subcontract
1	400	100	0	+100	60	40
2	400	100	0	0	60	40
3	400	50	0	0	60	40
4	400	40	0	0	60	40
5	250	0	10	-50	50	0
6	250	0	0	0	50	0

MASTER PRODUCTION SCHEDULE:

The primary use of *an aggregate production plan* is to level the production schedule so that the production costs are minimized.

However, the output of an aggregate plan does not indicate individual product. This means that the aggregated plan must be *disaggregated* into individual product. The result of such a disaggregation methodologies is what is known as **master production schedule**.

Master production schedule does not present an executable manufacturing plan. Because the capacities and the inventories have not been considered in this stage. Therefore, further analysis for the material and capacity requirements is required to develop an executable manufacturing plan.

ROUGH-CUT CAPACITY PLAN:

The objective of rough-cut capacity planning is to ensure that the master production schedule is feasible. For each product family the average amount of work needed an key work centers per unit per unit can be calculated from each item's bill of materials and production routings *(process planning sheets).*

EXAMPLE:

Consider two families of steel cylinders and the resource profile developed in standard hours of resources per 200 units of end-product family as follows:

Work center	Product Family 1 *(Standard Hours per 200 Units)*	Product Family 2 *(Standard Hours per 200 Units)*	Total resources required for all families
1100	14	7	21
2100	7	20	27
3100	6	14	20
4500	25	9	34
6500	9	16	25

The available resources are compared with the resource requirements profile obtained for all the work centers considering all the product families. If the available resources are less than required, then decisions related to *overtime, subcontracting, hiring workers* must be made.

MATERIAL REQUIREMENTS PLANNING:

The *material requirements planning system is* system essentially an information system consisting of logical procedure for managing inventories of component assemblies, subassemblies, parts, and raw materials in a manufacturing environment.

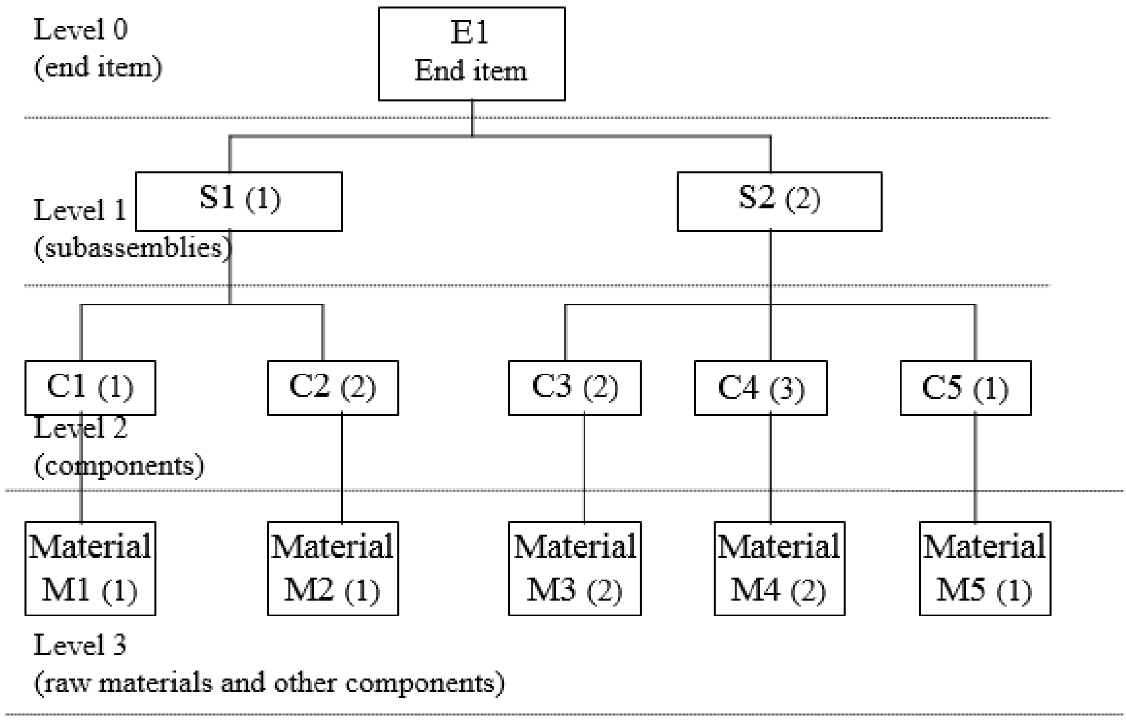
The primary objective of an MRP system is to determine how many of each item in the bill of materials must be manufactured or purchased and when.

The key concept used in determining material requirements are:

- Product structure and bill of materials
- Independent versus dependent demand
- Parts explosion
- Gross requirement
- Common-use items
- Scheduled receipts
- On-hand inventories
- Net requirements
- Plant order releases
- Lead time

Product structure and Bill of Materials:

Product is the single most important identity in an organization. A product may be made from one or more assemblies, subassemblies and components. A **bill of material** is an engineering document that specifies that the components and subassemblies required to make each end item *(product).*



Independent versus Dependent Demand:

The demand for the end item originates from customer order and forecasts.

Such a demand for end items and spare parts is called **independent demand**.The demand by a parent item for its components is called **dependent demand**.

Parts Explosion:

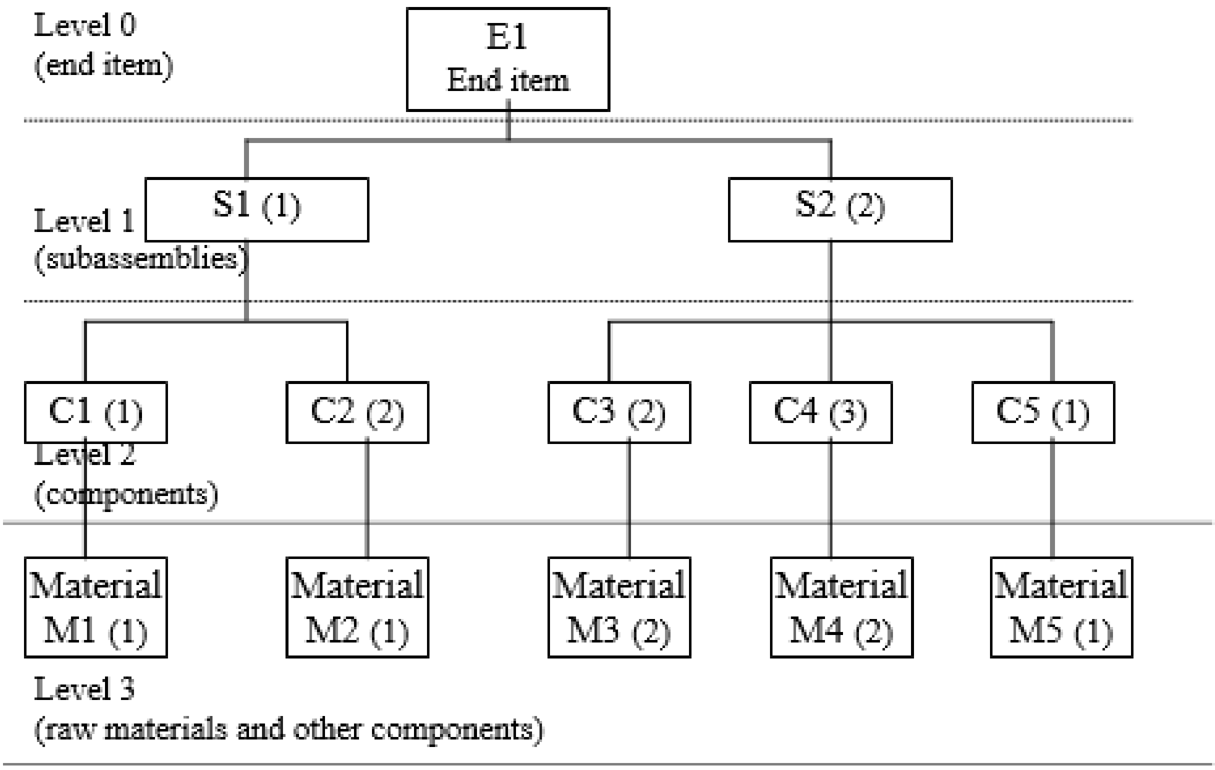
The process of determining gross requirements for component items that *is requirements for the subassemblies, components, and raw materials* for a given number of end-item units is known as **parts explosion**.

Part explosion represents the explosion of *parents* into their *components*.

Gross Requirements of Component Items:

Gross requirement of component items is the total number of component items required to manufacture the end products. Gross requirement of component items is computed by using the information from the *product information* and the *bill of materials.*

EXAMPLE:
If the demand for end-item E1 is 50, determine the gross requirements for the item components.



Demand of S1 = 1 x demand of E1 = 50 units
Demand of S2 = 2 x demand of E1 = 100 units
Demand of C1 = 1 x demand of S1 = 50 units
Demand of C2 = 2 x demand of S1 = 100 units
Demand of C3 = 2 x demand of S2 = 200 units
Demand of C4 = 3 x demand of S2 = 300 units
Demand of C5 = 1 x demand of S2 = 100 units

Common-Use Items:

They are the component items which are used different subassemblies of different end-products. These items must be added to have more economic purchasing.

On-Hand Inventory, Scheduled Receipts, and Net Requirements:

On-hand inventory is the available items in stock from the previous period. **Scheduled receipt** is the items already been ordered but not been received from the vendors yet.**Net requirements** is found by subtracting the *on-hand inventoryand scheduled receipts* from the *gross requirements*.

Planned Order Release:

Planned order releases refer to the process of releasing a lot of every component item for production or purchase. Determination of lot size is an economic issue. The trade-off is between *the inventory holding costs* and the *set up costs*.

Lot sizes in MRP system are determined for component items for each stage sequentially starting with *level 1*, then *level 2* and so on.

Lead Time and Lead Time Offsetting:

The **lead time** is the time it takes to produce or purchase a part. The lead time depends on:

1. setup time
2. production time
3. lot size
4. sequence of machines on which operations are performed
5. queuing delays

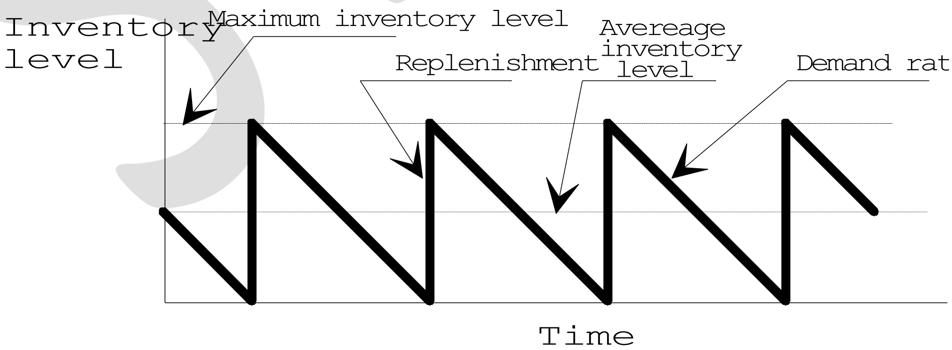
The **purchasing lead time** is the time between placing an order with a vendor and receipt of the order.

The manufacture or purchase of component items must be **offset** by at least their *lead times* to ensure availability of these items for assembly into their parent items at the desired time.

Economic Order Quantity:

In order to balance the costs of keeping the items in inventory and the costs of setup, the concept of *Economic Order Quantity* (EOQ) is introduced.

Normally, the ordering policy is set as displayed below, where the demand is fairly constant:



MRP EXAMPLE:

Period (weeks)									
1	2	3	4	5	6	7	8	9	10

End item E1; lead time 3 weeks										
Gross requirements			20	30	10	40	50	30	30	40
On-hand inventory	(50)									
Scheduled receipt										
Net requirements					10	40	50	30	30	40
Planned order release		10	40	50	30	30	40			

CAPACITY PLANNING:

The output of MRP does not produce an executable manufacturing plan, because it contains material requirement information only but does not contain information about the manufacturing capacity of the plant.

To develop an executable manufacturing plan, it is essential to establish the feasibility of the planned order releases obtained from the MRP system.

Capacity planning is concerned with ensuring the feasibility of production plans by determining resources such as labour and equipment with a view to developing what is known as an executable manufacturing plan.

The process of capacity planning is complex and involves a number of decisions:

- Exploring overtime/multiple shifts/subcontracting options
- Developing alternative process plans for effective resource utilization
- Splitting lots
- Increasing or decreasing employment levels to respond to capacity changes
- Inventory options
- Increasing capacity by adding capital equipment such as machine tools

ORDER RELEASE:

Once an executable manufacturing plans are obtained, the orders are released to the shop floor. Order release documents should include:

- Material inventories allocated to the order.
- Routing sheets having information on:
  - ⇒operation sequences,
  - ⇒machines,
  - ⇒work centers,
  - ⇒tool and fixture allocations,
  - ⇒batch sizes,
  - ⇒standard machine time allowed for each operation, etc.
- Appropriate shop floor records such as cards, move cards, and part lists for assembly jobs.

The order release triggers a number of activities at the shop floor:

- Scheduling of job orders on the work centers.
- Sequencing of jobs on a work center.
- Allocation of jigs and fixture.
- Loading of work centers considering optimal cutting conditions *(cutting speeds, feed rates, depth of cuts)*.
- Coordination of material handling, storage, warehousing, and machine tools.

SHOP FLOOR CONTROL:

When the planned orders are released to the shop floor for manufacturing, the primary objective is to deliver the product at the right time, in the right quantities, meeting quality specifications. But some unexpected event *(machine breakdown for example)* may cause delays.

In order to take action *(changing the scheduling for example)*, the up to date information from the shop floor must be send to the management a fast and a steady manner.

A number of methods are used for data collection in industries, such as:

* Hand written reports.
* Manual data entry terminals.
* Bar code readers and sensors such as optical and magnetic reading devices that automatically update an item's progress through the shop floor.
* Voice data entry system.

The major functions of a shop-floor control system are

* to schedule job orders on the work centers,
* to sequence the jobs in order on a work center,
* to provide accurate and timely order status information.

The work order status information includes:

* order batch sizes
* job completion
* remaining jobs and operations

The work order status information is used:

* To monitor the progress of manufacturing activities.
* To determine priorities for scheduling jobs in the shop in response to changes in job order status.

* To maintain and control work in process.
* To provide output data for capacity control purposes.

PROCESS PLANNING

Concurrent engineering requires the integration of all aspects of the product life cycle, that is:

- design,
- manufacturing,
- assembly,
- distribution,
- service,
- disposal

Two important areas in the life cycle of a product are ***design*** and ***manufacturing***. Process planning serves as an ***integration link*** between *design* and *manufacturing*.

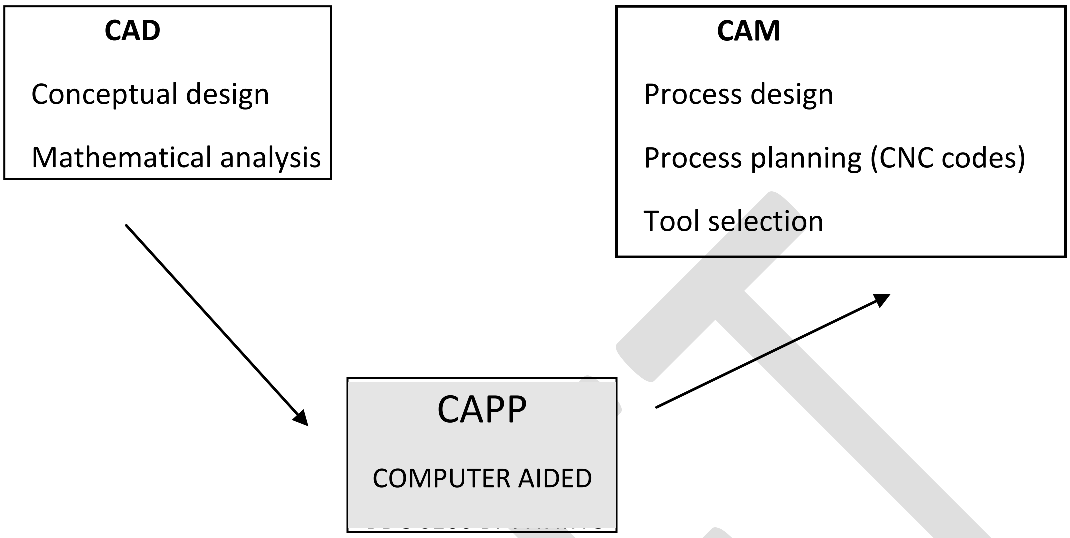
Process planning consists of preparing a set of instructions that describe how to fabricate a part or build an assembly which will satisfy engineering design specifications.

The resulting set of instructions may include any or all of the following:

- operation sequence,
- machines,
- tools,
- materials,
- tolerances,
- cutting parameters,
- processes (such as how to heat-treat),
- jigs,
- fixtures,
- time standards,
- setup details,
- inspection criteria,
- gauges,
- graphical representations of the part in various stages of completion

Process planning emerges as a key factor in CAD/CAM integration because it is the link between CAD and CAM. After engineering designs are communicated to manufacturing, either on paper or electronic media, the process planning function converts the designs into instructions used to make the specified part.

CIM cannot occur until this process is automated; consequently, automated process planning is the link between CAD and CAM.



Some typical **benefits of automated process planning** include:

- 50% increase in process planner productivity
- 40% increase in capacity of existing equipment
- 25% reduction in setup costs
- 12% reduction in tooling
- 10% reduction in scrap and rework
- 10% reduction in shop labor
- 6% reduction in work in process
- 4% reduction in material

If the process **planner's productivity is significantly improved**:

- More time can be spent on methods, improvements and cost-reduction activities.
- Routings can be consistently optimized.
- Manufacturing instructions can be provided in greater detail
- Preproduction lead times can be reduced.
- Responsiveness to engineering charges can be increased.

The **development of process plans** involves a number of activities:

- Analysis of part requirement
- Selection of raw work piece
- Determining manufacturing operations and their sequences
- Selection of machine tools
- Selection of tools, work holding devices, and inspection equipment
- Determining machining conditions and manufacturing time

ANALYSIS OF PART REQUIRENTS:

The part requirements can be defined as:

- part features
  - ◊ *process determination*
  - ◊ *steps of processes*
- dimensions
  - ◊ *machine tool size*
- tolerance specifications
  - ◊ *machine tool capability*
  - ◊ *CNC code generation*

SELECTION OF RAW WORKPIECE:

It involves such attributes as:

- shape
  - ◊ *standard materials*
    - ⇒ *rod*
    - ⇒ *blank*
    - ⇒ *slab*
    - ⇒ *profile*
  - ◊ *pre-shaped materials*
    - ⇒ *cast*
    - ⇒ *extruded*
    - ⇒ *forged*
- size
  - ◊ *machine tool size*
- material
  - ◊ *cutting conditions*
  - ◊ *tool selection*

DETERMINING MANUFACTURING OPTIONS AND THEIR SEQUENCES:

- selection of processes
  - ◊ *availability*
  - ◊ *suitability*
  - ◊ *accuracy requirement*
  - ◊ *cost*
- sequence of operations
  - ◊ *work holding method*
  - ◊ *cutting tool availability*

SELECTION OF MACHINE TOOLS:

- work piece related attributes
  - ◊ *part features*
  - ◊ *dimensions*
  - ◊ *dimensional tolerances*
  - ◊ *raw material form*
- machine tool related attributes
  - ◊ *process capability*
  - ◊ *size*
  - ◊ *mode of operation*
    - ⇒*manual*
    - ⇒*semiautomatic*
    - ⇒*automatic*
    - ⇒*CNC*
  - ◊ *tooling capabilities*
    - ⇒*type of tool*
    - ⇒*size of tool*
  - ◊ *tool changing capability*
    - ⇒*manual*
    - ⇒*automatic*
- production volume related information
  - ◊ *production quantity*
  - ◊ *order frequency*

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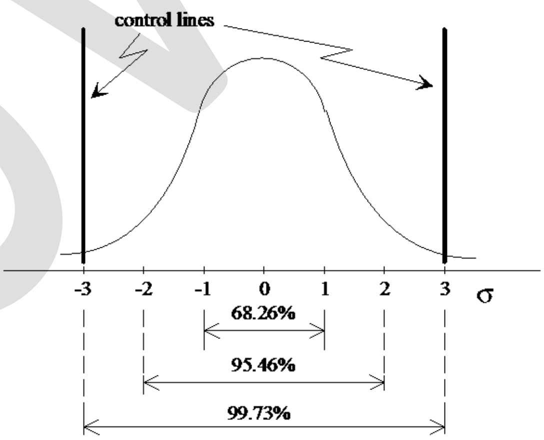
EVALUATION OF MACHINE TOOL ALTERNATIVES:

- Machine tool capability:



SELECTION OF TOOLS, WORKHOLDING DEVICES, AND INSPECTION EQUIPMENT:

- Tools
  - ◊ tool material
  - ◊ shape

- ◊ size
- ◊ tolerance
- ◊ nose radius

♦ Workholding devices

The primary purpose of a workholding device is to position the workpiece accurately and hold it securely.

- ◊ manually operated devices
  - ⇒*collets*
  - ⇒*mandrel*
  - ⇒*chucks*
  - ⇒*faceplates*
- ◊ designed devices
  - ⇒*power chucks*
  - ⇒*specially designed fixtures and jigs*
- ◊ flexible fixtures used in flexible manufacturing systems

♦ Inspection equipment

- ◊ on-line inspection equipment
- ◊ off-line inspection equipment

<u>DETERMINING CUTTING CONDITION AND MANUFACTURIN TIMES:</u>

Machining conditions

- cutting speed
- feed rate
- depth of cut

Object is to set the cutting conditions in such a way that the economically best production state is achieved.

What is the ***economically best production state?***

It is : 1- Minimum production cost or 2- Maximum production rate

CHOICE OF FEED

<u>Finishing cut</u>: Proper feed rate to provide desired surface quality *(relatively low)*

<u>Roughing cut</u>: Feed rate is not effective as cutting speed over tool life, therefore, feed should be set to maximum possible value

limitations:

maximum tool force that the machine or the tool can stand and the maximum power available

CHOICE OF CUTTING SPEED

Cutting speed is set to provide the optimum tool life.

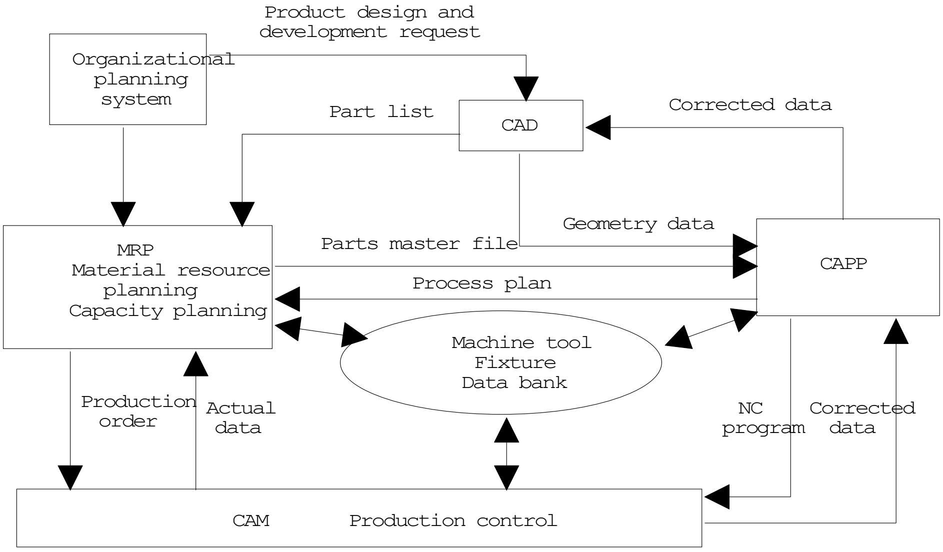
High V :	*low tool life*	**Low V**:	*high tool life*
	high tool cost		*low tool cost*
	high production rate		*low production rate*
	short production time		*long production time*

MANUAL *EXPERIENCE-BASED* PROCESS PLANNING METHOD:

- most widely used method
- time consuming
- inconsistent plans
- requires highly skilled, therefore, costly planners

COMPUTER-AIDED PROCESS PLANNING METHOD:

- it can systematically produce accurate and consistent process plans
- it can reduce the cost and lead time of process planning
- less skilled process planners may be employed
- it increases the productivity of process planners
- manufacturing cost, manufacturing lead time and work standards can easily be interfaced with the CAPP system



A computer-aided process planning framework

There are two basic methods used in *computer-aided process planning*:

- Variant CAPP method
- Generative CAPP method

The Variant CAPP Method:

- ♦ process plan is developed for a master part which represent the common features of a family of parts
- ♦ a process plan for a new part is created by recalling, identifying, and retrieving an existing plan for a similar part and making necessary modifications for the new part
- ♦ to use the method efficiently, parts classifying coding system must be used

<u>Advantages of variant process planning:</u>

- efficient processing and evaluation of complicated activities and decisions, thus reducing the time and labor requirements
- standardized procedures by structuring manufacturing knowledge of the process planers to company's needs
- lower development and hardware costs and shorter development times

<u>Disadvantages of variant process planning:</u>

- maintaining consistency in editing is difficult
- it is difficult to adequately accommodate various combinations of

⇒material,	⇒ quality, precision
⇒geometry,	⇒ alternative processing sequences,
⇒size,	⇒ machine loading

- The quality of the final process plan generated depends to a large extent on the knowledge and the experience of the process planners

The Generative CAPP Method:

In a generative approach, process plans are generated by means of

- decision logic
- formulas
- technology algorithm
- geometry based data

to perform uniquely the many processing decisions for converting a part from raw material to a finished state

There are basically two major components of generative process planning system:

- *a geometry based coding scheme*
- *process knowledge in the form of decision logic and data*

Geometry Based Coding Scheme:

The objective is to define all geometric features for all process-related surfaces together with feature dimensions, locations, and tolerances, and the surface finish desired on the features.

The level of details is much greater in a *generative system* than a *variant system.*

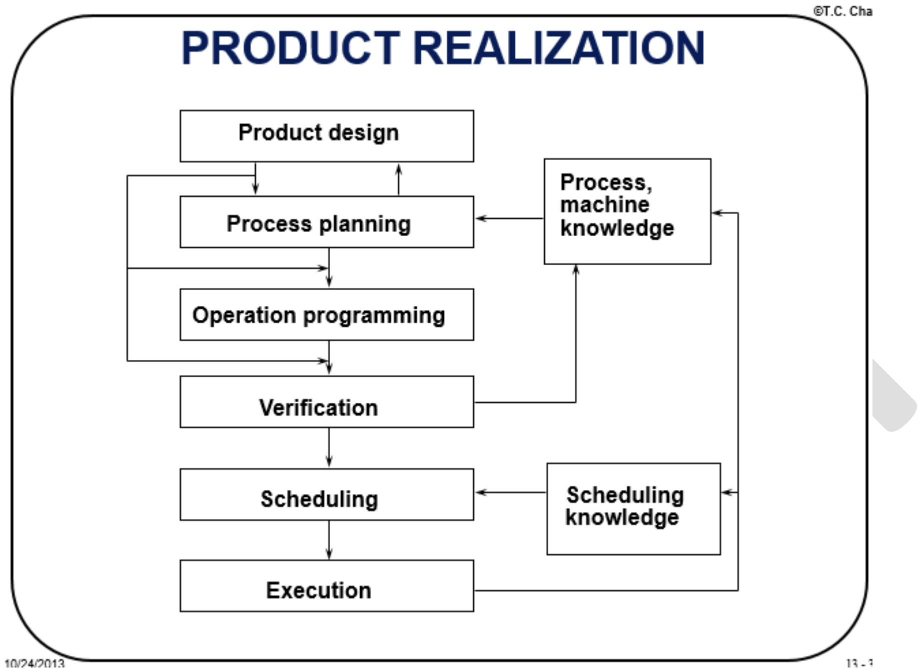
FUTURE TRENDS IN COMPUTER-AIDED PROGESS PLANNING:

One of the major strategies for reducing cost and lead time is to integrate various functional areas such as *design*, *process planning*, *manufacturing*, and *inspection*.

There are a number of difficulties in achieving the goal of complete integration.

For example, each functional area has its own stand-alone relational database and associated database management system. The software and hardware incompatibilities among these systems pose difficulties in full integration. There is a need to develop a single-database technology to address these difficulties.

Other challenges include automated translation of the design dimensions and tolerances into manufacturing dimensions and tolerances considering process capabilities and dimensional chains, automatic recognition of features, and making the CAPP systems affordable to the small and medium-scale manufacturing companies.



PROCESS PLAN

• Also called : operation sheet, route sheet, operation planning summary, or another similar name.

• The detailed plan contains:

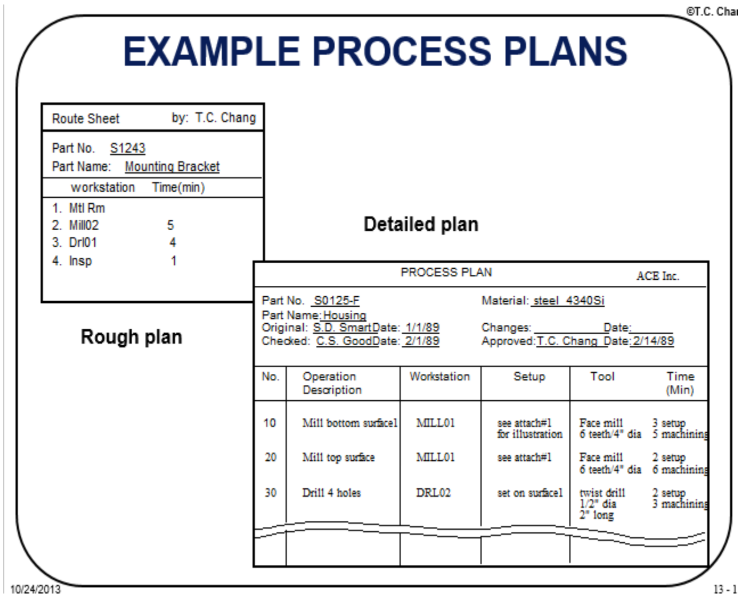
Route processes process parameters machine and tool selections fixtures

• How detail the plan is depends on the application.

• Operation: a process

- **Operation Plan (Op-plan): contains the description of an operation, includes tools, machines to be used, process parameters, machining time, etc.**

- **Op-plan sequence: Summary of a process plan**



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REQUIREMENTS IN MANUAL PROCESS PLANNING

- **ability to interpret an engineering drawing.**
- **familiar with manufacturing processes and practice.**
- **familiar with tooling and fixtures.**
- **know what resources are available in the shop.**
- **know how to use reference books, such as machinability data handbook.**
- **able to do computations on machining time and cost.**
- **familiar with the raw materials.**
- **know the relative costs of processes, tooling, and raw materials.**