Ch 25 Production Planning and Control

Sections:

1. **Aggregate Production Planning and the Master Production Schedule**
2. **Material Requirements Planning**
3. **Capacity Planning**
4. **Shop Floor Control**
5. **Inventory Control**
6. **Extensions of MRP**
Production Planning and Control

- Production planning and control (PPC) is concerned with the logistics problems that are encountered in manufacturing, that is, managing the details of what and how many products to produce and when to produce those products by obtaining the raw materials, parts, and resources.

- PPC solves these logistics problems by managing information.

- Computers are essential for processing the tremendous amounts of data involved to define the products and the manufacturing resources to produce them, and for reconciling (to compare and adjust so that the figures agree) these technical details with the desired production schedule.
Production Planning and Control

- **In a very real sense, PPC is the integrator in computer-integrated manufacturing.**
- **Planning and control in PPC must themselves be integrated functions.**
- **It is insufficient to plan production if there is no control of the factory resources to achieve the plan; and it is ineffective to control production if there is no plan with which to compare factory progress.**
- **Both planning and control must be accomplished, and they must be coordinated with each other and with other functions in the manufacturing firm, such as process planning, concurrent engineering, and advanced manufacturing planning (Chapter 24).**
Production Planning and Control

- Concerned with the logistics problems in manufacturing:
  - Managing the details of what, when, and how many products to produce, and
  - Obtaining the raw materials, parts, and resources to produce them.

- PPC solves these logistics problems by managing information.

- PPC is the integrator in computer integrated manufacturing.
Production Planning

- **Concerned with:**
  1. *Deciding which products to make, how many of each, and when they should be completed,*
  2. *Scheduling the delivery and/or production of the parts and products,*
  3. *Planning the manpower and equipment resources needed to accomplish the production plan.*
Activities in Production Planning

- **Aggregate production planning** – planning the production output levels for major product lines.
  - Must be coordinated with product design, production, marketing, and sales.
- **Master production planning** – specific schedule (master production schedule) of the quantities of individual models in each major product line.
- **Material requirements planning (MRP)** – detailed schedule of raw materials and parts production for models in master schedule.
- **Capacity planning** – planning labor and equipment resources to achieve the master schedule.
Production Planning Activities

- Production planning activities divide into two stages:
  (1) aggregate planning, which results in the MPS, and
  (2) detailed planning, which includes MRP and capacity planning.

Aggregate planning involves planning six months or more into the future, whereas detailed planning is concerned with the shorter term (weeks to months).

**MPS: Master Production Schedule**

**MRP: Materials Requirement Planning**
Production Control

- Concerned with determining whether the necessary resources to implement the production plan have been provided.
  - If not, it attempts to take corrective action to address the deficiencies.

- Major topics in production control:
  - Shop floor control,
  - Manufacturing execution systems,
  - Inventory control,
  - Manufacturing Resource Planning (MRP II),
  - Enterprise resource planning.

(MRP: Materials Requirement Planning)
Manufacturing Resource Planning

MRP II

- Manufacturing resource planning evolved from material requirements planning in the 1980s.

- It came to be abbreviated MRP II to distinguish it from the original abbreviation and to indicate that it was second generation, that is, more than just a material planning system.

- Manufacturing resource planning can be defined as a computer-based system for planning, scheduling, and controlling the materials, resources, and supporting activities needed to meet the master production schedule.
Production Control

- Shop floor control systems compare the actual progress and status or production orders in the factory with the production plans (MPS and MRP schedule).

- A Manufacturing Execution System (MES) is a computerized system that accomplishes shop floor control using automated data collection techniques.

- Inventory control includes a variety of techniques for managing the inventory of a firm.
  - One of the important tools in inventory control is the economic order quantity formula.
Production Control

- Manufacturing Resource Planning, also known as MRP II, combines MRP and capacity planning as well as shop floor control and other functions related to PPC.

- Enterprise Resource Planning (ERP) is an extension of MRP II that includes all of the functions of the organization, including those unrelated to manufacturing.

- The activities in a modern PPC system and their interrelationships are depicted in Figure 25.1.

As the figure indicates, PPC ultimately extends to the company’s supplier base and customer base. This expanded scope of PPC control is known as supply chain management.

PPC: Production Planning and Control
Activities in a Production Planning and Control System

- Aggregate planning
- Master production schedule
- Material requirements planning
- Engineering & manufacturing database
- Purchasing department
- Shop floor control
- Supplier base
- Factory
- Customer base

Flowchart:
- Sales and marketing
- Product design
- Sales orders
- Sales forecasts
- Inventory records
- Capacity planning

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Aggregate Production Planning

Planning the production output levels for major product lines.

- High-level corporate planning activity.
- Must be coordinated with the plans of the sales and marketing departments.
  - Includes products that are currently in production.
    - Must consider current and future inventory levels of those products.
  - Also includes new products currently being developed.
- Marketing plans for current and new products must be reconciled against total capacity resources of the company.
### Aggregate Production Plan

<table>
<thead>
<tr>
<th>Product line</th>
<th>Week</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
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<tr>
<td>M model line</td>
<td>200</td>
</tr>
<tr>
<td>N model line</td>
<td>80</td>
</tr>
<tr>
<td>P model line</td>
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</tr>
</tbody>
</table>

- Indicates production output levels for the major product lines of the company.
Master Production Schedule

The specific schedule of individual products and models that is derived from the aggregate production plan.

- It is a list of the products to be manufactured, when they should be completed and delivered, and in what quantities.

- Master production schedule includes three categories of items:
  1. Firm customer orders
  2. Forecasted demand
  3. Spare parts
## Master Production Schedule

<table>
<thead>
<tr>
<th>Product line</th>
<th>Week</th>
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</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>N model line</td>
<td>80</td>
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<td>P model line</td>
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<table>
<thead>
<tr>
<th>Product line models</th>
<th>Week</th>
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<td>Model M4</td>
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<td>Model N8</td>
<td>80</td>
</tr>
<tr>
<td>Model P1</td>
<td></td>
</tr>
<tr>
<td>Model P2</td>
<td></td>
</tr>
</tbody>
</table>

Specific schedule of individual products, quantities and times.
Material Requirements Planning (MRP)

Computational technique that converts the master production schedule for end products into a detailed schedule for the raw materials and components used in the end products.

MRP is the appropriate technique for determining quantities of dependent demand items.

For independent demand items, inventory control is often accomplished using order point systems (Section 25.5.1).
Material Requirements Planning (MRP)

- **Independent demand** - demand for a product is unrelated to demand for other items.
- **Independent demand patterns must usually be forecasted.**
  - e.g. Final products and spare parts.
- **Dependent demand** - demand for the item is directly related to the demand for some other item, usually a final product.
  - The dependency usually derives from the fact that the item is a component of the other product.
  - These items constitute the inventory of manufacturing, raw materials, work-in-process (WIP), component parts, and subassemblies.
Material Requirements Planning (MRP)

- Once the delivery schedule for end products is established, the requirements for components and raw materials can be directly calculated.

- e.g. Even though demand for automobiles in a given month can only be forecasted, once the quantity is established and production is scheduled it is known that five tires will be needed to deliver the car.

- Thus, MRP is the appropriate technique for determining quantities of dependent demand items.
Structure of an MRP System

- Master production schedule
  - Sales orders
  - Sales forecast
  - Spare parts requirements

- Inventory record file

- Material requirements planning

- Capacity planning

- Bill-of-materials and other design & manufacturing data

- Product design

- Manufacturing engineering

- Planned order releases for (1) purchasing and (2) manufacturing, and other output reports
How MRP Works

- The MRP processor operates on data contained in the **MPS**, the **BOM file**, and the **inventory record file**.

- The master production schedule (MPS) specifies the period-by-period list of final products required, the **bill of materials (BOM) file** defines what materials and components are needed for each product.

- The inventory record file gives the current and future inventory status of each product, component, and material.

- The MRP processor computes how many of each component and raw material are needed each period by “exploding” the end product requirements into successively lower levels in the product structure.
Inputs to the MRP System

1. Master production schedule
   - Expressed in terms of time buckets.

2. Bill of materials (BOM) file – product structure and list of component parts in each product.

3. Inventory record file (item master file) – includes:
   - Item master data – part number, order quantities, lead times.
   - Inventory status – time-phased record of inventory status.
   - Subsidiary data – purchase orders, engineering changes.
Typical Product Structure

Figure 25.4 Product structure for product P1.
Typical Product Structure

Figure 25.6 Product structure for product P2.
### Inventory Record File

<table>
<thead>
<tr>
<th>Period</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
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<td>Scheduled receipts</td>
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<td>50</td>
<td>50</td>
<td></td>
<td>90</td>
<td></td>
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<tr>
<td>Net requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned order releases</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Complicating Factors in MRP

- **Net requirements** = gross requirements less on-hand inventories and less quantities on order.
- **Common use items** – raw materials and components used on more than one product.
- **Lead times** – scheduled delivery of end products must be translated into time-phased requirements of components and materials by factoring in lead times.
  - **Ordering lead times** – time between purchase requisition and receipt from vendor.
  - **Manufacturing lead times** – time between order release and completion.
MRP Outputs

1. **Planned order releases**
   - *Purchase orders* – to buy raw materials and parts
   - *Work orders* – to make parts and products

2. **Report of planned order releases in future periods**

3. **Rescheduling notices**

4. **Cancellation notices**

5. **Inventory status reports**

6. **Performance reports**

7. **Exception reports**

8. **Inventory forecasts**
MRP Benefits Reported by Users

1. Reduction in inventory,
2. Quicker response to changes in demand,
3. Reduced setup and changeover costs,
4. Better machine utilization,
5. Improved capacity to respond to changes in master production schedule,
6. Aid in developing the master schedule.
Why Some MRP Systems Do Not Succeed

1. Application was not appropriate,
   - Usually because product structure did not fit data requirements of MRP.

2. MRP computations based on inaccurate data,

3. Master production schedule was not coupled with capacity planning.
   - MRP generated an unrealistic schedule of work orders that overloaded the factory.
Capacity Planning

The original MRP systems that were developed in the 1970s created schedules that were not necessarily consistent with the production capabilities and limitations of the plants that were to produce the products.

In many instances, the MRP system developed the detailed schedule based on a master production schedule that was unrealistic.

**A successful production schedule must consider production capacity.**

In cases where current capacity is inadequate, the firm must make plans for changes in capacity to meet the changing production requirements specified in the schedule.
Capacity Planning

Concerned with determining labor and equipment resources required to meet the current master schedule as well as long-term future production needs of the firm.

- Also serves to identify the limitations of the available production resources so that an unrealistic master schedule is not planned.

- Accomplished in two stages:
  1. Rough-cut capacity planning (RCCP) – to assess feasibility of master production schedule.
  2. Capacity requirements planning (CRP) – detailed capacity calculation for individual departments and work cells.
Two Stages of Capacity Planning

1. Master production schedule
2. Material requirements planning
3. Capacity requirements planning (CRP)
4. Rough-cut capacity planning (RCCP)
Short Term Capacity Adjustments

- **Employment levels** – employment in the plant can be increased or decreased in response to changes in capacity requirements.
- **Temporary workers**
- **Number of work shifts per period**
- **Labor hours per shift** – overtime or reduced hours.
- **Inventory stockpiling** – accumulate and store a reserve supply in order to smooth production and maintain steady employment.
Short Term Capacity Adjustments

- **Order backlogs** – deliveries of the product to the customer could be delayed during busy periods when production resources are insufficient to keep up with demand.

- **Subcontracting** – involves the letting of jobs to other shops during busy periods, or the taking in of extra work during slack periods.
Long Term Capacity Adjustments

- New equipment investments
- New plant construction
- Purchase of existing plants from other companies
- Acquisition (purchase) of existing companies
- Plant closings
Shop Floor Control

Concerned with releasing production orders to the factory, monitoring and controlling the progress of the orders through the plant, and acquiring current information on the status of the orders.

- Manufacturing execution system (MES) - the computer software that supports shop floor control.
  - Typically includes capability to respond to on-line inquiries about the status of orders in the shop.
  - Other MES functions may include generation of process instructions, real-time inventory control, and labor tracking.
Three Phases of Shop Floor Control

1. Order release
2. Order scheduling
3. Order progress
Three Phases in Shop Floor Control

1. Master production schedule
2. Material requirements planning
3. Order release
4. Order scheduling
5. Order progress
6. Management reports

- Engineering & manufacturing data base
- Raw materials and components
- Work centers
- Work-in-process
- Finished products
- Factory data collection system
- Dispatch list
- Shop packet
- Factory

Order Release

Provides documentation to process a production order through the factory

- Documentation (shop packet):
  - Route sheet – process plan
  - Material requisitions – to draw raw materials from inventory
  - Job cards – to report direct labor hours expended on order and track progress of order
  - Move tickets – to authorize transport of parts between work centers
  - Parts list (if assembly)
Order Scheduling

Assigns production orders to work centers in the plant

- Executes the dispatching function in production planning and control.

- Solves two problems in production control:
  1. **Machine loading** – allocating orders to work centers.
     - **Shop loading** – loading all machines in the plant
  2. **Job sequencing** – determining the sequence in which orders will be processed through each work center.
Priority Control

Sets appropriate priority levels for production orders

- Possible dispatching rules in priority control are:
  - **First-come-first-serve**
    Jobs are processed in the order in which they arrive at the machine. One might argue that this rule is the most fair.
  - **Earliest due date**
    Orders with earlier due dates are given higher priorities.
  - **Shortest processing time**
    Orders with shorter processing times are given higher priorities.
Priority Control

- **Least slack time**
  
  Slack time is defined as the difference between the time remaining until due date and the process time remaining.
  
  Orders with the least slack in their schedule are given higher priorities.

- **Critical ratio**
  
  The critical ratio is defined as the ratio of the time remaining until due date divided by the process time remaining.
  
  Orders with the lowest critical ratio are given higher priorities.
Priority Control

When an order is completed at one work center, it enters the queue at the next machine in its process routing. That is, the order becomes part of the machine loading for the next work center, and priority control is utilized to determine the sequence of processing among the jobs at that machine.
Priority Control

The relative priorities of different orders may change over time. Reasons behind these changes include:

1. lower or higher than expected demand for certain products,
2. equipment breakdowns that cause delays in production,
3. cancellation of an order by a customer, and
4. defective raw materials that delay an order.

The priority control function reviews the relative priorities of the orders and adjusts the dispatch list accordingly.
Order Progress

Monitors the status of the orders in the plant, WIP, and other parameters that indicate production progress and performance.

- **Purpose** is to provide information useful to manage the factory based on data collected from the factory.

- **Reports generated by order progress module:**
  - *Work order status reports* – whether orders are on schedule or behind.
  - *Progress reports* – number of orders completed vs. number that should have been completed.
  - *Exception reports* – An exception report identifies deviations from the production schedule [e.g. Overdue (past due; not done at the scheduled time) jobs and similar exception information.]
Factory Data Collection System

Consists of the various paper documents, terminals, and automated devices throughout plant for collecting data on shop floor operations.

- Includes methods to compile and process the data
- Functions of factory data collection system:
  1. To supply status and performance data to the shop floor control system,
  2. To provide current information to production foremen, plant management, and production control personnel.
Types of Data Collected

- Direct labor time on each order
- Parts scrapped or needing rework
- Piece counts completed at each work center
- Equipment utilization and downtime
- Time clocks for employees
Manual (Clerical)
Data Input Techniques

Production workers read and fill out paper forms indicating order progress data - examples:

- **Job traveler** – workers must record their time spent, piece counts, rejects, etc., onto log sheet that travels with shop packet.

- **Employee time sheets** – workers fill out daily time sheet indicating orders worked on, pieces completed.

- **Operation tear strips** – preprinted sheets that can be separated from shop packet, filled out, and turned in.

- **Prepunched cards** – similar to tear strips.
Automated and Semi-Automated Data Collection Systems

- **Hardware and technology includes:**
  - Specialized keypads or conventional keyboards
  - Optical bar code readers
  - Other AIDC systems
    (e.g. RFID-Radio Frequency Identification)

- **Configurations:**
  - One centralized terminal
  - Satellite terminals
  - Workstation terminals

**AIDC: Automatic Identification and Data Collection**
Inventory Control

- Concerned with achieving an appropriate **compromise** between two opposing objectives:
  1. **Minimizing the cost of holding inventory,**
     - Implies keeping inventory to a minimum
  2. **Maximizing customer service.**
     - Implies keeping large stocks on hand so the customer can immediately take possession
Costs of Holding Inventory

1. **Investment costs**
   - *Cost of money tied up in inventory until the customer pays for the finished product.*

2. **Storage costs**
   - *Cost of space to store the inventory.*

3. **Cost of possible obsolescence or spoilage**
   - *Reduction in value of inventory when it cannot be used.*

*Collectively, these costs are referred to as carrying costs or holding costs.*
Order Point Inventory Systems

- Concerned with two related problems that must be solved when managing inventories of independent demand items:
  1. How many units should be ordered?
     - Often solved by using economic order quantity formulas.
  2. When should the order be placed?
     - Can be solved using reorder point methods.

Two topics will be covered:
- Economic order quantity formula
- Reorder point systems
Inventory Model in Make-to-Stock

Figure 25.10 Model of inventory level over time in the typical make-to-stock situation.
Economic Order Quantity Formula

- Situations when EOQ formula is appropriate:
  1. Demand rate for the item is fairly constant,
  2. Rate of production is significantly greater than the demand rate.

- The same basic problem occurs with dependent demand items when usage of the item is relatively constant over time due to a steady production rate of the final product with which the item is correlated.
Total Inventory Cost Equation

- Total annual cost of inventory includes two terms:
  1. Cost of holding inventory,
  2. Cost of reordering or setup.

- Equation for total inventory cost TIC:

\[
TIC = \frac{C_h Q}{2} + \frac{C_{su} D_a}{Q}
\]

- \(C_h\) - holding cost ($/piece/year),
- \(Q\) - order quantity (piece/order) \((Q/2: \text{Average inventory level})\),
- \(C_{su}\) - setup (or ordering) cost ($/setup, $/order), and
- \(D_a\) - annual demand for the item (piece/year).
**EOQ Formula**

- **By taking the derivative of TIC with respect to Q and setting the derivative equal to zero, the minimum cost order quantity can be determined as:**

**Economic Order Quantity formula:**

\[
Q = EOQ = \sqrt{\frac{2D_a C_{su}}{C_h}}
\]

- \(D_a\) - annual demand for the item (piece/year),
- \(C_{su}\) - setup (or ordering) cost ($/setup, $/order), and
- \(C_h\) - holding cost ($/piece/year).
EOQ Formula

EXAMPLE 25.3 Economic Order Quantity Formula

The annual demand for a certain item made-to-stock = 15,000 pc/yr. One unit of the item costs $20.00, and the holding cost rate = 18%/yr. Setup time to produce a batch = 5 hr. The cost of equipment downtime plus labor = $150/hr. Determine the economic order quantity and the total inventory cost for this case.

Solution: Setup cost $C_{su} = 5 \times $150 = $750$. Holding cost per unit = 0.18 $\times$ $20.00 = $3.60$. Using these values and the annual demand rate in the EOQ formula, we have

$$Q = EOQ = \sqrt{\frac{2D_a C_{su}}{C_h}}$$

$$EOQ = \sqrt{\frac{2(15000)(750)}{3.60}} = 2500 \text{ units}$$

Total inventory cost is given by the TIC equation:

$$TIC = \frac{C_h Q}{2} + \frac{C_{su} D_a}{Q}$$

$$TIC = 0.5(3.60)(2,500) + 750(15,000/2,500) = $9,000$$

Including the actual production costs in the annual total, by Eq (25.4) we have

$$TC = 15,000(20) + 9,000 = $309,000$$
Reorder Point Systems

- Determining the economic order quantity is not the only problem that must be solved in controlling inventories in make-to-stock situations.
- The other problem is deciding when to reorder.
- One of the most widely used methods is the reorder point system.
- The reality is that there are usually variations in demand rate during the inventory order cycle, as illustrated in Figure 25.11.
- Accordingly, when to reorder cannot be predicted with the precision that would exist if demand rate were a known constant value.
Operation of Reorder Point System

When inventory level reaches the reorder point, the next order for quantity Q is placed.

Figure 25.11 Operation of a reorder point inventory system.
Reorder Point Systems

- In a reorder point system, when the inventory level for a given stock item falls to some point specified as the reorder point, then an order is placed to restock the item.
- The reorder point is specified at a sufficient quantity level to minimize the probability of a stock-out between when the reorder point is reached and the new order is received.
- Reorder point triggers can be implemented using computerized inventory control systems that continuously monitor the inventory level as demand occurs and automatically generate an order for a new batch when the level declines below the reorder point.
Extensions of MRP ➔ MRPII

Manufacturing Resource Planning (MRP II)

Manufacturing resource planning combines MRP and capacity planning as well as shop floor control and other functions related to PPC.

A computer-based system for planning, scheduling, and controlling the materials, resources, and supporting activities needed to meet the master production schedule.

(note: MRP is a computational technique that converts the master production schedule for end products into a detailed schedule for the raw materials and components used in the end products.)
Manufacturing Resource Planning

MRP II

MRP II can be considered to consist of three major modules:

(1) material requirements planning, or MRP
(2) capacity planning, and
(3) shop floor control.
Manufacturing Resource Planning

MRP II

**MRP** accomplishes the planning function for materials, parts, and assemblies, based on the master production schedule. In so doing it also provides a schedule for factory operations.

The **capacity planning module** interacts with the MRP module to ensure that the schedules created by MRP are feasible.

Finally, the **shop floor control module** performs the feedback control function using its factory data collection system to implement the three phases of order release, order scheduling, and order progress.
Manufacturing Resource Planning

MRP II

In general, functions of MRP II are:

- **Management planning** – aggregate production planning, master production scheduling.
- **Customer service** – sales forecasting, order entry, finished goods inventory.
- **Operations planning** – MRP enhanced with capacity requirements planning.
- **Operations execution** – purchasing, production scheduling and control, shop floor control.
Manufacturing resource planning represented an improvement over material requirements planning because it included production capacity and shop floor feedback in its computations.

But MRP II was limited to the manufacturing operations of the firm.

As further enhancements were made to MRP II systems, the trend was to consider all of the operations and functions of the enterprise rather than just manufacturing.

The final concept resulting from this trend in the 1990s was enterprise resource planning.
Extensions of MRP – ERP

- **Enterprise Resource Planning (ERP)**

  Enterprise resource planning is an extension of MRP II that includes all of the functions of the organization, including those unrelated to manufacturing.
Enterprise Resource Planning (ERP)

Defined as a computer software system that organizes and integrates all of the data and business functions of an organization through a single, central database.

- The functions include:
  
  Production and Materials Management (MRP II)  
  (MRP+Capacity planning+Shop floor control)  
  Master production scheduling, Process planning  
  Inventory control, Purchasing, Product costing  
  Interface with design (BOM, Part drawings, ...)  
  Sales and Marketing  
  Finance and Accounting  
  Human resources
ERP Systems Include Multiple Software Modules

- Each module is focused on a different business function or group of functions.
- Modules are integrated through the ERP framework.
- Modules can be classified into four main groups:
  1. Production and materials management - MRP II, master production scheduling, process planning, ...
  2. Sales and marketing - order input, customer service, delivery, invoicing, product returns.
  3. Finance and accounting - budgeting, cost control, asset management, accounts payable.
  4. Human resources - payroll, benefits, training, job descriptions, employee personal data.
ERP Uses a Single Database

- **ERP runs as a client-server system - users access the system through their PCs.**
- **ERP operates company-wide, not just plant-based.**
- **Avoids problems such as:**
  - Data redundancy or conflicting data in different databases,
  - Time delays in entering the data,
  - Communication issues between different databases.
- **Everyone in the organization has access to the same sets of data according to their individual job responsibilities.**
- **Not all of the data can be accessed by all employees.**