Material Requirements Planning (MRP)
Outline

DEPENDENT INVENTORY MODEL

REQUIREMENTS

- Master Production Schedule
- Bills of Materials
- Accurate Inventory records
- Purchase Orders Outstanding
- Lead Times for Each Component

MRP STRUCTURE
Collins Industries

- Largest manufacturer of ambulances in the world
- International competitor
- 12 major ambulance designs
  - 18,000 different inventory items
    - 6,000 manufactured parts
    - 12,000 purchased parts
- MRP: IBM’s MAPICS
Collins Industries

- Collins requires:
  - Material plan must meet both the requirements of the master schedule and the capabilities of the production facility
  - Plan must be executed as designed
  - Effective “time-phased” deliveries, consignments, and constant review of purchase methods
  - Maintenance of record integrity
Material Requirements Planning (MRP)

- Manufacturing computer information system
- Determines *quantity & timing* of dependent demand items

<table>
<thead>
<tr>
<th>Gross Requirements</th>
<th>2</th>
<th>20</th>
<th>25</th>
<th>15</th>
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<tr>
<td>Planned Order Releases</td>
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</tbody>
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MRP: Types of Items

- **Independent demand** items; complete product ready for use

- **Dependent demand** items; sub-assemblies, components
MRP Requirements

- Computer system
- Mainly discrete products
- Accurate bill-of-material
- Accurate inventory status
  - 99% inventory accuracy
- Stable lead times
MRP Benefits

- Increased customer satisfaction due to meeting delivery schedules
- Faster response to market changes
- Improved labor & equipment utilization
- Better inventory planning & scheduling
- Reduced inventory levels without reduced customer service
Structure of the MRP System

- Master Production Schedule
- BOM
- Lead Times (Item Master File)
- Inventory Data
- Purchasing data
- MRP planning programs (computer and software)
- MRP by Period Report
- MRP by date report
- Planned order report
- Purchase advice
- Exception report
The Planning Process

1. Aggregate production plan
   - Change production plan?
2. Master production schedule
   - Change master production schedule?
3. Material requirements plan
   - Change requirements?
   - Change capacity?
   - Is capacity plan being met?
4. Detail capacity plan
   - Realistic
     - No
     - Yes
5. Execute capacity plans
6. Execute material plans
   - Is execution meeting the plan?
Inputs to the Production Plan

- **Production**
  - Capacity
  - Inventory

- **Procurement**
  - Supplier
  - Performance

- **Marketing**
  - Customer
  - Demand

- **Finance**
  - Cash Flow

- **Human Resources**
  - Manpower
  - Planning

- **Management**
  - Return on
  - Investment
  - Capital

- **Engineering**
  - Design
  - Completion
MRP and The Production Planning Process

- Forecast & Firm Orders
- Aggregate Production Planning
- Resource Availability
- Material Requirements Planning
- Master Production Scheduling
- No, modify CRP, MRP, or MPS
- Realistic?
- Yes
- Shop Floor Schedules
- Capacity Requirements Planning
MRP modeling requires that the operations manager know the:

- master production schedule (MPS)
- specifications or bills-of-material (BOM)
- inventory availability
- purchase orders outstanding
- lead times
MRP Systems - Input and Output

- Bill of Materials
- Item Master
- Master Production Schedule
- Material Requirements Planning System
- Planned Order & Other Reports
- Inventory Status
- Purchasing Data
Inventory Classifications

- Process stage
  - Raw Material
  - WIP
  - Finished Goods

- Number & Value
  - A Items
  - B Items
  - C Items

- Demand Type
  - Independent
  - Dependent

- Other
  - Maintenance
  - Operating
WHY INVENTORIES ARE CENTRAL?

- Purpose of any production system is creation of finished product right on time at right place in right quantity at low cost with best quality
- Inventories are finished products created earlier than their demand time
## Dependent versus Independent Demand

<table>
<thead>
<tr>
<th>Item</th>
<th>Materials With Independent Demand</th>
<th>Materials With Dependent Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Source</td>
<td>Company Customers</td>
<td>Parent Items</td>
</tr>
<tr>
<td>Material Type</td>
<td>Finished Goods</td>
<td>WIP &amp; Raw Materials</td>
</tr>
<tr>
<td>Method of Estimating Demand</td>
<td>Forecast &amp; Booked Customer Orders</td>
<td>Calculated</td>
</tr>
<tr>
<td>Planning Method</td>
<td>EOQ &amp; ROP</td>
<td>MRP</td>
</tr>
</tbody>
</table>
Typical Focus of the Master Production Schedule

- **Make to Order**: (Process Focus)
  - Assemble to Order or Forecast: (Repetitive)
  - Stock to Forecast: (Product Focus)

  Schedule finished product

Examples:
- Print shop
- Machine shop
- Motorcycles, autos, TVs, fast-food restaurant
- Steel, Pepsi, Bread, Light bulbs, Paper

Number of end items

Number of inputs

Typical focus of the master production schedule
## Aggregate Production Plan Leads to Master Production Schedule (MPS)

<table>
<thead>
<tr>
<th>Months</th>
<th>January</th>
<th>February</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Production Plan</td>
<td></td>
<td></td>
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<tr>
<td>(shows the total quantity of</td>
<td>1,500</td>
<td>1,200</td>
</tr>
<tr>
<td>amplifiers)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeks</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6</td>
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<tr>
<td></td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Master Production Schedule</td>
<td></td>
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</tr>
<tr>
<td>(Shows the specific type and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>quantity of amplifier to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>be produced)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>240 watt amplifier</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>150 watt amplifier</td>
<td>500</td>
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<tr>
<td>75 watt amplifier</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>450</td>
</tr>
</tbody>
</table>
Master Production Schedule

- Shows items to be produced
  - End item, customer order, module
- Derived from aggregate plan

**Example**

<table>
<thead>
<tr>
<th>Item/Week</th>
<th>Oct 3</th>
<th>Oct 10</th>
<th>Oct 17</th>
<th>Oct 24</th>
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</thead>
<tbody>
<tr>
<td>Drills</td>
<td>300</td>
<td>200</td>
<td>310</td>
<td>300</td>
</tr>
<tr>
<td>Saws</td>
<td>300</td>
<td>450</td>
<td>310</td>
<td>330</td>
</tr>
</tbody>
</table>
Derivation of Master Schedule

A and S are End Items

B and C are used to make A and S

Lead time = 4 for A
Master schedule for A

Lead time = 6 for S
Master schedule for S
Derivation of Master Schedule

A is required
Week 6  : 40  
 8   : 50  
11  : 15

S is required
Week 9  : 40  
11   : 20  
13  : 13
Derivation of Master Schedule

Periods

A

B

C

S

Lead time = 4 for A
Master schedule for A

Periods

5 6 7 8 9 10 11

40 50 15

Lead time = 6 for S
Master schedule for S

Periods

8 9 10 11 12 13

40 20 30

10 10

Therefore, these are the gross requirements for B

B Requirements

Gross requirements: B

10 40+10 = 50 40 50 20 15+30 = 45
Bill-of-Material (BOM)

- List of components & quantities needed to make product
- Provides product structure (tree)
  - Parents: Items above given level
  - Children: Items below given level
- Shows low-level coding
  - Lowest level in structure item occurs
  - Top level is 0; next level is 1 etc.
Bill-of-Material
Product Structure Tree

Bicycle (1)
P/N 1000

Handle Bars (1)
P/N 1001

Frame Assembly (1)
P/N 1002

Wheels (2)
P/N 1003

Frame (1)
P/N 1004
Special Bills-of-Material

- **Modular bills**
  - Modules are final components used to make assemble-to-stock end items

- **Planning bills**
  - Used to assign artificial parent
  - Reduces number of items scheduled

- **Phantom bills**
  - Used for subassemblies that exist temporarily
Product Structure for “Awesome” A

Level | Product structure for “Awesome” (A) |
--- | --- |
0 | A |
1 | B<sub>(2)</sub> Std. 12” Speaker kit |
   | C<sub>(3)</sub> Std. 12” Speaker kit w/ amp-booster |
2 | E<sub>(2)</sub> Packing box and installation kit of wire, bolts, and screws |
   | E<sub>(2)</sub> |
3 | D<sub>(2)</sub> 12” Speaker |
   | F<sub>(2)</sub> Std. 12” Speaker booster assembly |
   | G<sub>(1)</sub> Amp-booster |
   | D<sub>(2)</sub> 12” Speaker |
Product Structure for “Awesome” A

Level 0

A

Level 1

B(2) Std. 12" Speaker kit

C(3) Std. 12" Speaker kit w/ amp-booster

Level 2

E(2) Packing box and installation kit of wire, bolts, and screws

Level 3

D(2) 12" Speaker

F(2) Std. 12" Speaker booster assembly

G(1) Amp-booster

D(2) 12" Speaker
Product Structure for “Awesome” A

Level 0: Product structure for “Awesome” (A)

Level 1: 
- B\(_{(2)}\) Std. 12” Speaker kit
- C\(_{(3)}\) Std. 12” Speaker kit w/ amp-booster

Level 2: 
- E\(_{(2)}\) Packing box and installation kit of wire, bolts, and screws

Level 3: 
- D\(_{(2)}\) 12” Speaker
Product Structure for “Awesome” A

Level 0: Product structure for “Awesome” (A)

Level 1: B(2) Std. 12" Speaker kit

Level 2: E(2) Packing box and installation kit of wire, bolts, and screws

Level 3: D(2) 12" Speaker

Level 2: C(3) Std. 12" Speaker kit w/ amp-boosted

Level 2: F(2) Std. 12" Speaker booster assembly

Level 3: G(1) Amp-booster

Level 3: D(2) 12" Speaker
Product Structure for “Awesome” A

Level 0: A

Level 1: B(2) Std. 12" Speaker kit

Level 2:
- D(2) 12" Speaker
- E(2) Packing box and installation kit of wire, bolts, and screws

Level 3:
- C(3) Std. 12" Speaker kit w/ amp-booster
- F(2) Std. 12" Speaker booster assembly
- G(1) Amp-booster
- D(2) 12" Speaker
Product Structure for “Awesome” A
Product Structure for “Awesome” A

Level 0

A

Level 1

B(2) Std. 12" Speaker kit

C(3) w/ amp-booster

Level 2

E(2) Packing box and installation kit of wire, bolts, and screws

E(2)

F(2) Std. 12" Speaker booster assembly

G(1)

D(2) Amp-booster

D(2)

Level 3

12" Speaker

12" Speaker
Product Structure for “Awesome” A
Product Structure for “Awesome” A

Level 0

A

Level 1

B(2) Std. 12" Speaker kit

C(3) w/ amp-booster

Level 2

E(2) Packing box and installation kit of wire, bolts, and screws

Level 3

D(2) 12" Speaker

E(2)

F(2) Std. 12" Speaker booster assembly

G(1) Amp-booster

D(2) 12" Speaker
Time-Phased Product Structure

Lead times:

- **D**: 2 weeks to produce
- **E**: 2 weeks
- **F**: 3 weeks
- **G**: 1 week

Must have D and E completed here so production can begin on B.
Time-Phased Product Structure

Start production of D

2 weeks

1 week

2 weeks to produce

2 weeks

E

Must have D and E completed here so production can begin on B

1 week

1 week

F

3 weeks

1 week
Time-Phased Product Structure

Start production of D

1 week

2 weeks to produce B

2 weeks

1 week

3 weeks

1 week

2 weeks

1 week

2 weeks

1 week

Product structure for "Awesome" (A)

- Level 1: B, D, E
  - B: Std. 12" Speaker kit
  - D: 12" Speaker
  - E: Packing box and installation kit of wire, bolts, and screws

- Level 2: C
  - C: Std. 12" Speaker kit w/amp-booster

- Level 3: G
  - G: Std. 12" Speaker kit w/amp-booster

Must have D and E completed here so production can begin on B.
Time-Phased Product Structure

Start production of D

1 week to produce

2 weeks

2 weeks to produce

D

1 week

E

2 weeks

F

1 week

G

3 weeks

C

1 week

B

A

Must have D and E completed here so production can begin on B
Start production of:

**D**

- 1 week
- 2 weeks

**E**

- 2 weeks
- 2 weeks to produce

**B**

- 1 week

**A**

- 1 week

**C**

- 1 week
- 3 weeks

**F**

- 1 week
- 2 weeks

**G**

- 1 week
- 2 weeks

Must have D and E completed here so production can begin on B.
Time-Phased Product Structure

Must have D and E completed here so production can begin on B.

- D: Start production of D
- E: 2 weeks to produce
- B: 1 week
- C: 1 week
- F: 2 weeks
- G: 1 week
- 3 weeks
- A: 6 weeks

Legend:
- B: Std. 12" Speaker kit
- C: Std. 12" Speaker kit w/amp-booster
- D: 12" Speaker
- E: Packing box and installation kit of wire, bolts, and screws
- F: Amp booster
- G: 12" Speaker booster assembly

Timeline:
- Week 1: Start production of D
- Week 2: D
- Week 3: E
- Week 4: B
- Week 5: C
- Week 6: F
- Week 7: G
Time-Phased Product Structure

Must have D and E completed here so production can begin on B.

Start production of D.
Gross Material Requirements Plan for 50 “Awesome A” Speaker Kits

<table>
<thead>
<tr>
<th>Week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>C. Required date</td>
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</tbody>
</table>

You can interpret the gross material requirements shown in Table 14.3 as follows: If you want 50 units of A at week 8, you must start assembling A in week 7. Thus, in week 7, you will need 100 units of B and 150 units of C. These two items take 2 weeks and 1 week, respectively, to produce. Production of B, therefore, should start in week 5, and production of C should start in week 6 (lead time subtracted from the required date for these items). Working backward, we can perform the same computations for all of the other items. The material requirements plan shows when production of each item should begin and end in order to have 50 units of A at week 8.
# MRP TABLE STRUCTURE

<table>
<thead>
<tr>
<th>WEEKS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td></td>
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</tr>
</tbody>
</table>
MRP Table Parameters

- GR(t) : gross requirements
  total demand in a period t
- SR(t) :
  expected receipt of the item in period t from
  previous (outstanding) orders
- OHI(t) : on-hand inventory at beginning of t
- NR (t) : net requirements ; NR(t) = GR(t)-SR(t)-OHI(t)
- POT(t): planned order receipts
- POR(t): planned order release
MRP Table Calculations

- OHI(t) : on-hand inventory

\[
\text{OHI}(t) = 0; \quad \text{if } \text{GR}(t) - \{\text{SR}(t) + \text{OHI}(t)\} > 0
\]
\[
= \{\text{SR}(t) + \text{OHI}(t)\} - \text{GR}(t); \quad \text{otherwise}
\]
MRP Table Calculations

- NR(t) : net requirements is expected shortage

\[
NR(t) = 0; \quad \text{if } \{SR(t)+OHI(t)\} - GR(t) > 0
\]
\[
= GR(t) - \{SR(t)+OHI(t)\}; \quad \text{otherwise}
\]
MRP Table Calculations

- POR(t) : planned order release
  issue an order of manufacturing/buying
  according to NR(t+L)

where L = lead time of order replenishment
MRP Table Calculations

- POT(t) : planned order receipt receiving the consignment as a result of POR made in period (t+L)
<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>Projected on Hand</td>
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