

Material Requirements Planning (MRP) and ERP



Outline

- Global Company Profile: Wheeled Coach***
- Dependent Demand***
- Dependent Inventory Model Requirements***
 - Master Production Schedule***
 - Bills of Material***
 - Accurate Inventory Records***
 - Purchase Orders Outstanding***
 - Lead Times for Components***

Outline – Continued

- MRP Structure***
- MRP Management***
 - MRP Dynamics***
 - MRP and JIT***
- Lot-Sizing Techniques***

Outline – Continued

✓ *Extensions of MRP*

**✓ *Material Requirements Planning II
(MRP II)***

✓ *Closed-Loop MRP*

✓ *Capacity Planning*

✓ *MRP In Services*

**✓ *Distribution Resource Planning
(DRP)***

Outline – Continued

- Enterprise Resource Planning (ERP)***
 - Advantages and Disadvantages of ERP Systems***
 - ERP in the Service Sector***

Learning Objectives

When you complete this chapter you should be able to:

- 1. Develop a product structure***
- 2. Build a gross requirements plan***
- 3. Build a net requirements plan***
- 4. Determine lot sizes for lot-for-lot, EOQ, and PPB***

Learning Objectives

***When you complete this chapter you
should be able to:***

- 5. Describe MRP II***
- 6. Describe closed-loop MRP***
- 7. Describe ERP***

Wheeled Coach

- 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*



Wheeled Coach

Four Key Tasks

- Material plan must meet both the requirements of the master schedule and the capabilities of the production facility*
- Plan must be executed as designed*
- Minimize inventory investment*
- Maintain excellent record integrity*

Benefits of MRP

- 1. Better response to customer orders***
- 2. Faster response to market changes***
- 3. Improved utilization of facilities and labor***
- 4. Reduced inventory levels***

Dependent Demand

- The demand for one item is related to the demand for another item***
- Given a quantity for the end item, the demand for all parts and components can be calculated***
- In general, used whenever a schedule can be established for an item***
- MRP is the common technique***

Dependent Demand

Effective use of dependent demand inventory models requires the following

- 1. Master production schedule***
- 2. Specifications or bill of material***
- 3. Inventory availability***
- 4. Purchase orders outstanding***
- 5. Lead times***

Master Production Schedule (MPS)

- Specifies what is to be made and when***
- Must be in accordance with the aggregate production plan***
- Inputs from financial plans, customer demand, engineering, supplier performance***
- As the process moves from planning to execution, each step must be tested for feasibility***
- The MPS is the result of the production planning process***

Master Production Schedule (MPS)

- MPS is established in terms of specific products***
- Schedule must be followed for a reasonable length of time***
- The MPS is quite often fixed or frozen in the near term part of the plan***
- The MPS is a rolling schedule***
- The MPS is a statement of what is to be produced, not a forecast of demand***

The Planning Process

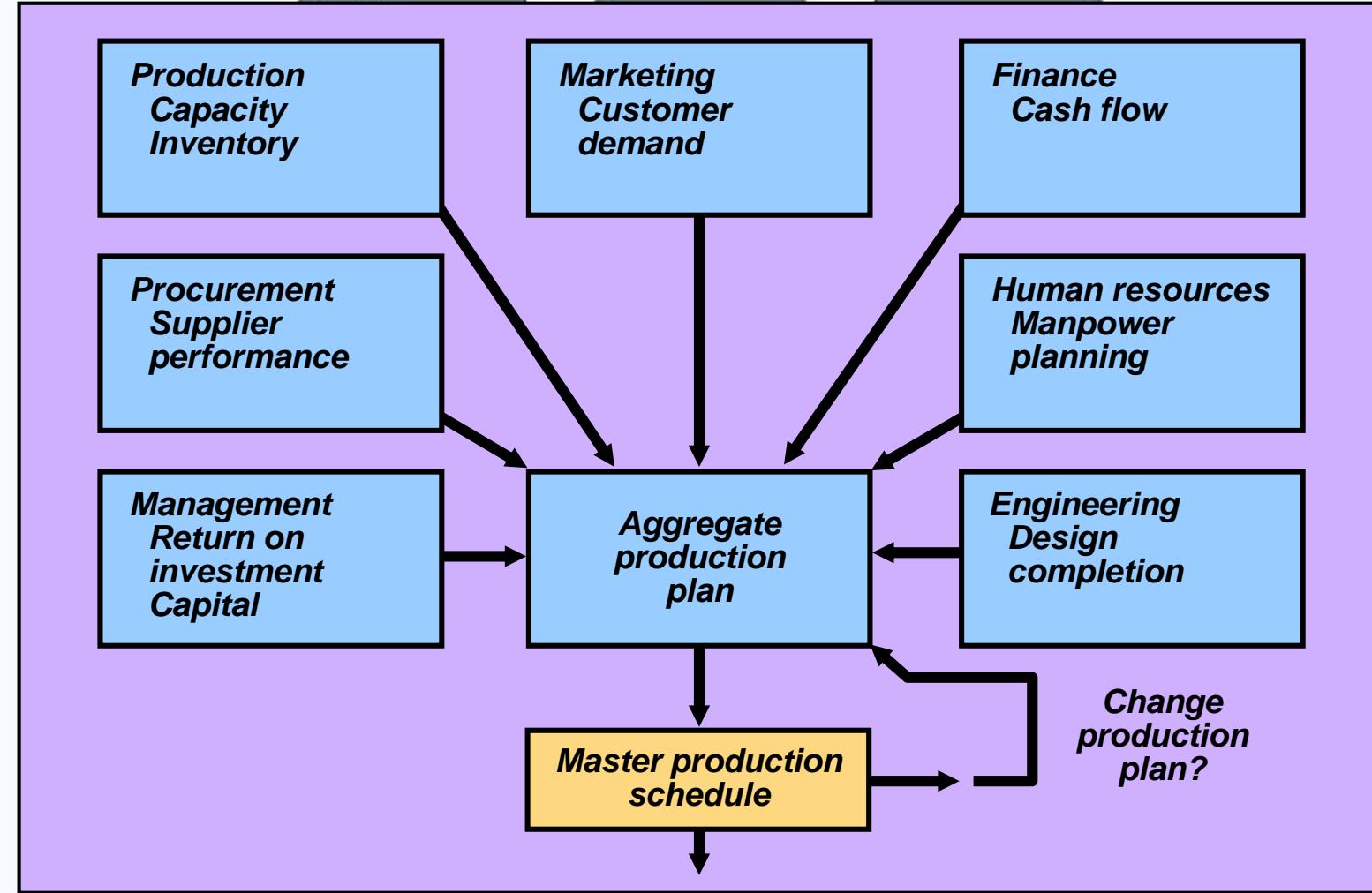


Figure 14.1

The Planning Process

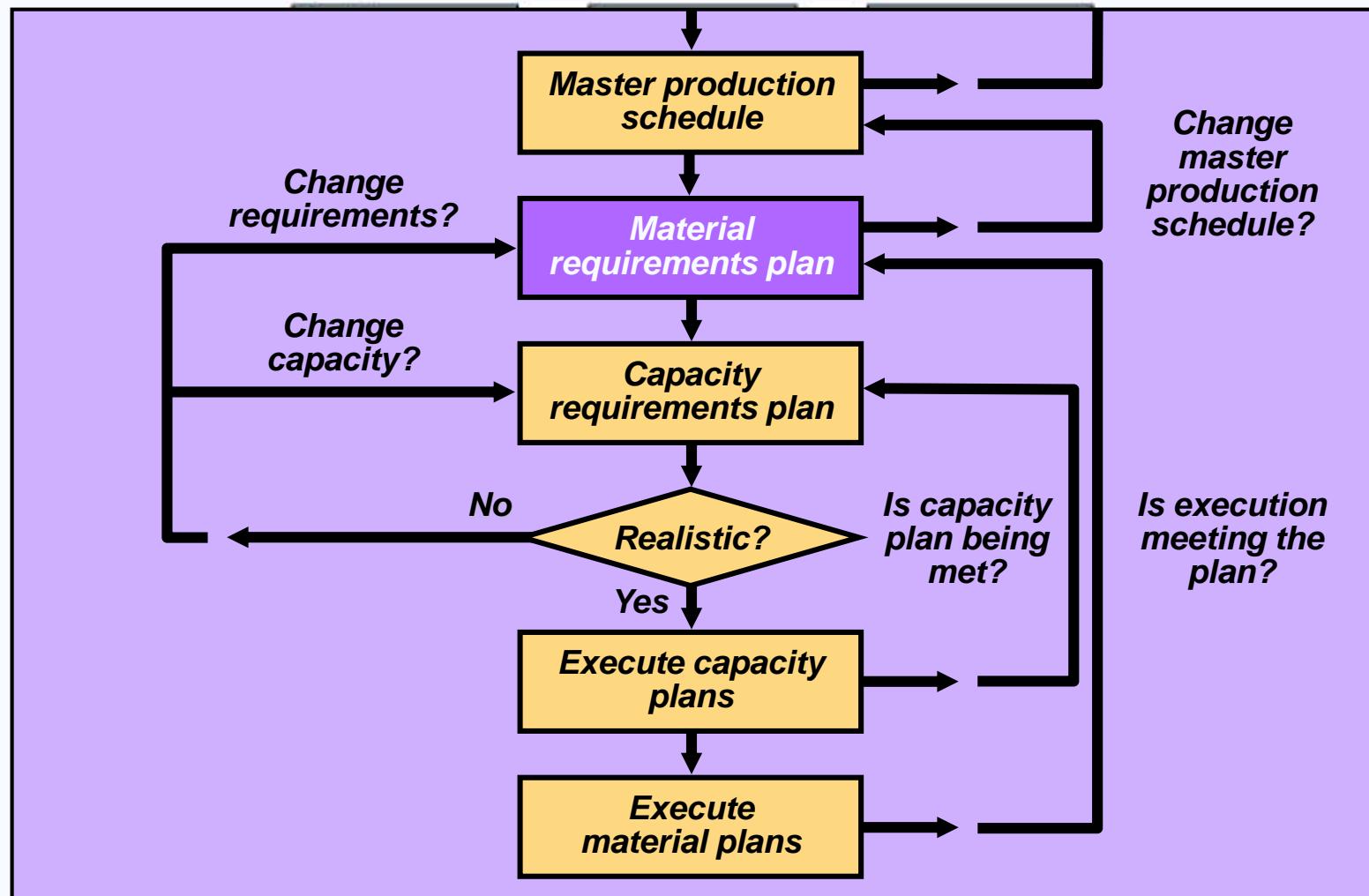


Figure 14.1

Aggregate Production Plan

Months	January				February			
Weeks	1	2	3	4	5	6	7	8
Aggregate Production Plan (Shows the total quantity of amplifiers)	1,500				1,200			
Master Production Schedule (Shows the specific type and quantity of amplifier to be produced)								
240-watt amplifier	100		100		100		100	
150-watt amplifier		500		500		450		450
75-watt amplifier			300				100	

Figure 14.2

Master Production Schedule (MPS)

Can be expressed in any of the following terms:

- A customer order in a job shop (make-to-order) company***
- Modules in a repetitive (assemble-to-order or forecast) company***
- An end item in a continuous (stock-to-forecast) company***

Focus for Different Process Strategies

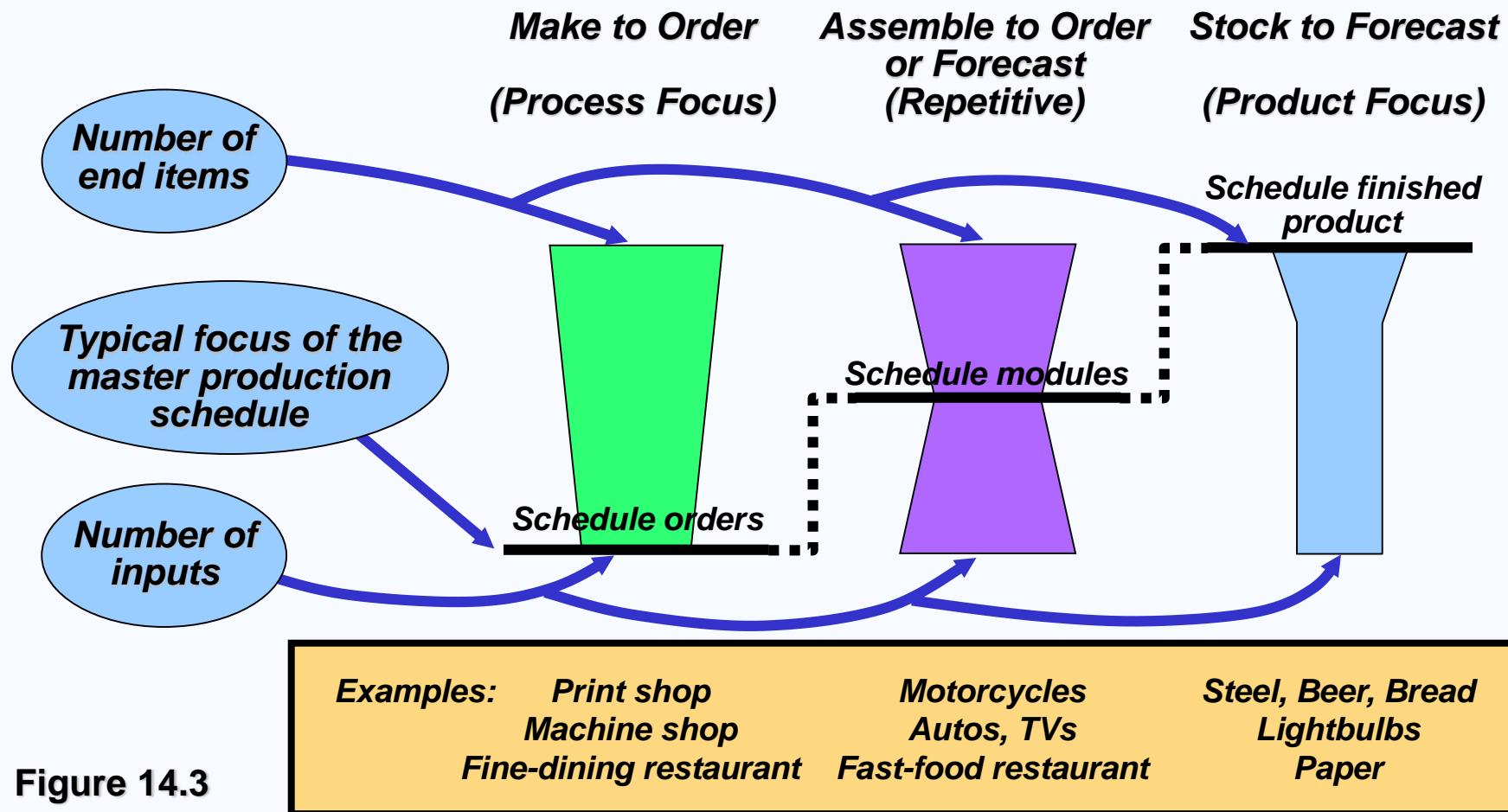


Figure 14.3

MPS Examples

For Nancy's Specialty Foods

Gross Requirements for Crabmeat Quiche									
Day	6	7	8	9	10	11	12	13	14 and so on
Amount	50		100	47	60		110	75	

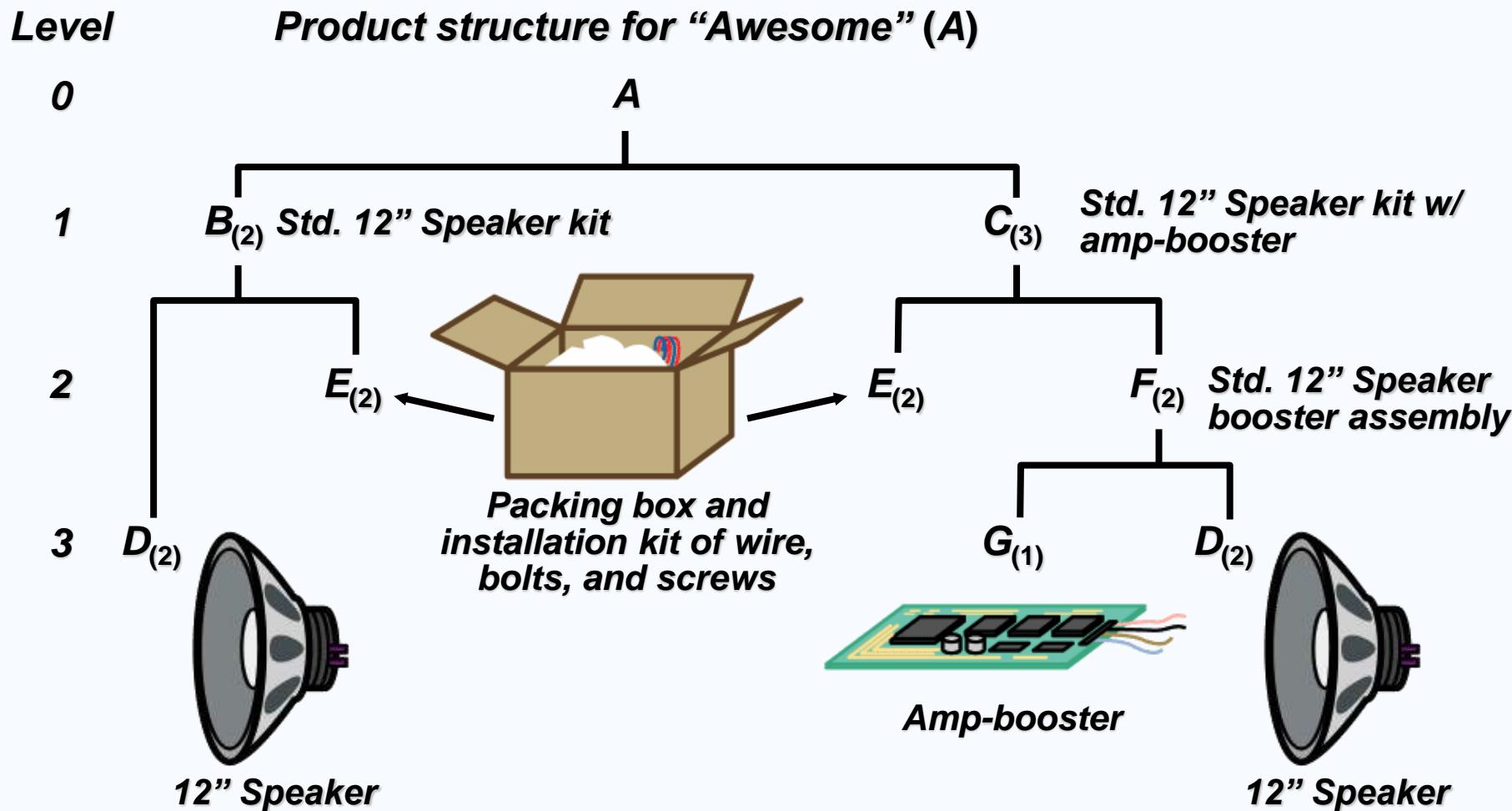
Gross Requirements for Spinach Quiche									
Day	7	8	9	10	11	12	13	14	15 and so on
Amount	100	200	150			60	75		100

Table 14.1

Bills of Material

- ❑ *List of components, ingredients, and materials needed to make product*
- ❑ *Provides product structure*
 - ❑ *Items above given level are called parents*
 - ❑ *Items below given level are called children*

BOM Example



BOM Example



12" Speaker



Amp-booster



12" Speaker

Bills of Material

Modular Bills

- Modules are not final products but components that can be assembled into multiple end items*
- Can significantly simplify planning and scheduling*

Bills of Material

- Planning Bills (Pseudo Bills)*
 - Created to assign an artificial parent to the BOM*
 - Used to group subassemblies to reduce the number of items planned and scheduled*
 - Used to create standard “kits” for production*

Bills of Material

Phantom Bills

Describe subassemblies that exist only temporarily

Are part of another assembly and never go into inventory

Low-Level Coding

Item is coded at the lowest level at which it occurs

BOMs are processed one level at a time

Accurate Records

- Accurate inventory records are absolutely required for MRP (or any dependent demand system) to operate correctly***
- Generally MRP systems require 99% accuracy***
- Outstanding purchase orders must accurately reflect quantities and scheduled receipts***

Lead Times

- The time required to purchase, produce, or assemble an item***
 - For production – the sum of the order, wait, move, setup, store, and run times***
 - For purchased items – the time between the recognition of a need and the availability of the item for production***

Time-Phased Product Structure

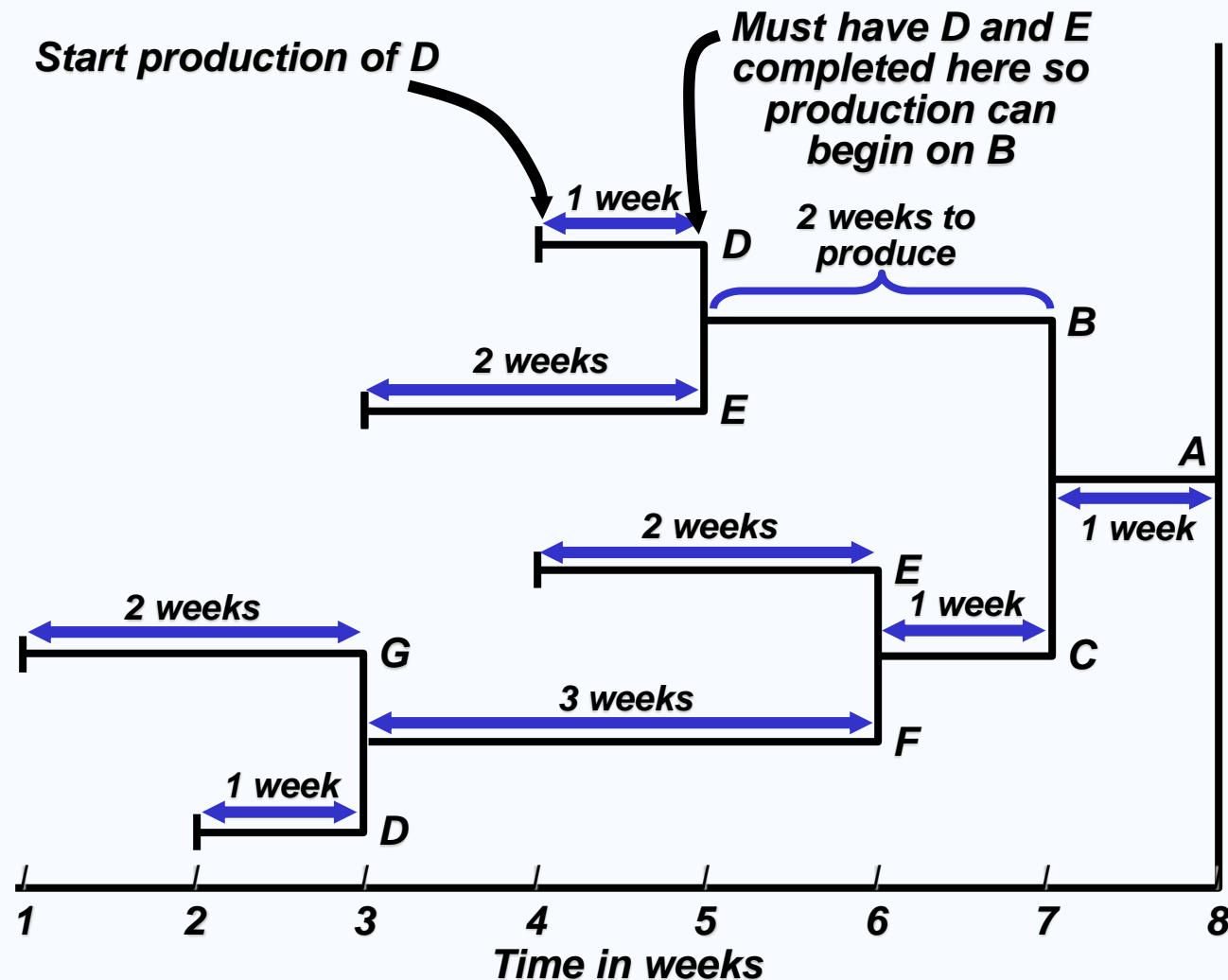


Figure 14.4

MRP Structure

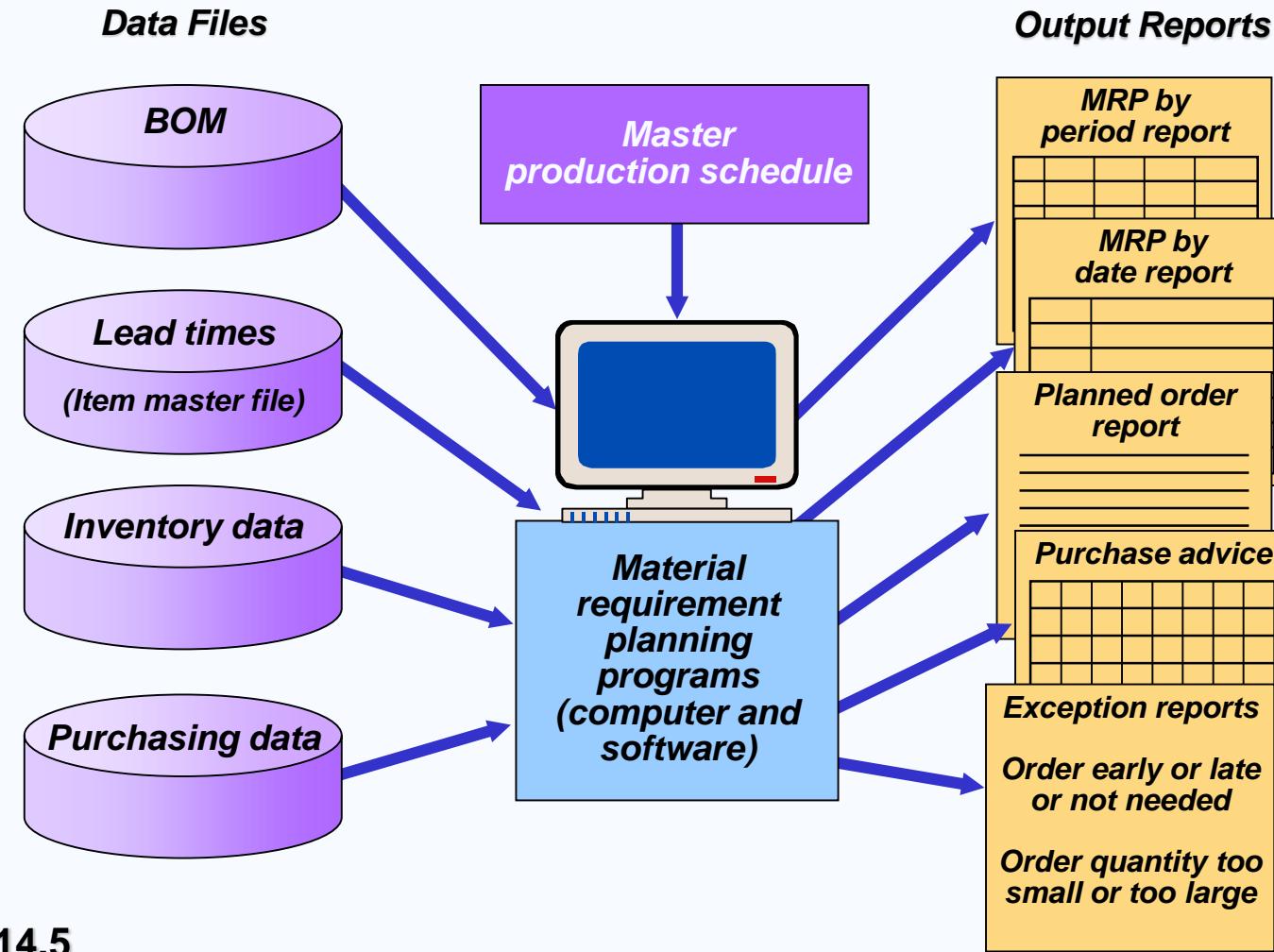


Figure 14.5

Determining Gross Requirements

- Starts with a production schedule for the end item – 50 units of Item A in week 8***
- Using the lead time for the item, determine the week in which the order should be released – a 1 week lead time means the order for 50 units should be released in week 7***
- This step is often called “lead time offset” or “time phasing”***

Determining Gross Requirements

- From the BOM, every Item A requires 2 Item Bs – 100 Item Bs are required in week 7 to satisfy the order release for Item A***
- The lead time for the Item B is 2 weeks – release an order for 100 units of Item B in week 5***
- The timing and quantity for component requirements are determined by the order release of the parent(s)***

Determining Gross Requirements

- The process continues through the entire BOM one level at a time – often called “explosion”*
- By processing the BOM by level, items with multiple parents are only processed once, saving time and resources and reducing confusion*
- Low-level coding ensures that each item appears at only one level in the BOM*

Gross Requirements Plan

	Week								
	1	2	3	4	5	6	7	8	Lead Time
A. Required date Order release date								50	
B. Required date Order release date						50		1 week	
C. Required date Order release date					100		100		
D. Required date Order release date				100				2 weeks	
E. Required date Order release date						150		150	
F. Required date Order release date					150			1 week	
G. Required date Order release date			200	300	200	300		2 weeks	
H. Required date Order release date		200	300					3 weeks	
I. Required date Order release date	600	600	200	200				1 week	
J. Required date Order release date	300	300						2 weeks	

Table 14.3

Net Requirements Plan

Lot Size	Lead Time (weeks)	On Hand	Safety Stock	Allocated	Low-Level Code	Item Identification		Week							
								1	2	3	4	5	6	7	8
Lot-for-Lot	1	10	—	—	0	A	Gross Requirements								50
							Scheduled Receipts								
							Projected On Hand	10	10	10	10	10	10	10	10
							Net Requirements								40
							Planned Order Receipts								40
							Planned Order Releases								40
Lot-for-Lot	2	15	—	—	1	B	Gross Requirements							80 ^A	
							Scheduled Receipts								
							Projected On Hand	15	15	15	15	15	15	15	
							Net Requirements								65
							Planned Order Receipts								65
							Planned Order Releases								65
Lot-for-Lot	1	20	—	—	1	C	Gross Requirements								120 ^A
							Scheduled Receipts								
							Projected On Hand	20	20	20	20	20	20	20	
							Net Requirements								100
							Planned Order Receipts								100
							Planned Order Releases								100

Net Requirements Plan

Lot-for-Lot	E	2	10	—	—	2	Gross Requirements					130 ^B	200 ^C		
							Scheduled Receipts								
							Projected On Hand	10	10	10	10	10			
							Net Requirements						120	200	
							Planned Order Receipts						120	200	
							Planned Order Releases			120	200				
Lot-for-Lot	F	3	5	—	—	2	Gross Requirements						200 ^C		
							Scheduled Receipts								
							Projected On Hand	5	5	5	5	5	5		
							Net Requirements						195		
							Planned Order Receipts						195		
							Planned Order Releases			195					
Lot-for-Lot	D	1	10	—	—	3	Gross Requirements				390 ^F	130 ^B			
							Scheduled Receipts								
							Projected On Hand	10	10	10	10				
							Net Requirements				380	130			
							Planned Order Receipts				380	130			
							Planned Order Releases		380		130				
Lot-for-Lot	G	2	0	—	—	3	Gross Requirements				195 ^F				
							Scheduled Receipts								
							Projected On Hand				0				
							Net Requirements				195				
							Planned Order Receipts				195				
							Planned Order Releases	195							

Determining Net Requirements

- Starts with a production schedule for the end item – 50 units of Item A in week 8***
- Because there are 10 Item As on hand, only 40 are actually required – (net requirement) = (gross requirement - on-hand inventory)***
- The planned order receipt for Item A in week 8 is 40 units – 40 = 50 - 10***

Determining Net Requirements

- Following the lead time offset procedure, the planned order release for Item A is now 40 units in week 7***
- The gross requirement for Item B is now 80 units in week 7***
- There are 15 units of Item B on hand, so the net requirement is 65 units in week 7***
- A planned order receipt of 65 units in week 7 generates a planned order release of 65 units in week 5***

Determining Net Requirements

- A planned order receipt of 65 units in week 7 generates a planned order release of 65 units in week 5**
- The on-hand inventory record for Item B is updated to reflect the use of the 15 items in inventory and shows no on-hand inventory in week 8**
- This is referred to as the Gross-to-Net calculation and is the third basic function of the MRP process**

Net Requirements Plan

The logic of net requirements

$$\left[\begin{array}{c} \text{Gross} \\ \text{requirements} \end{array} \right] + \left[\text{Allocations} \right]$$

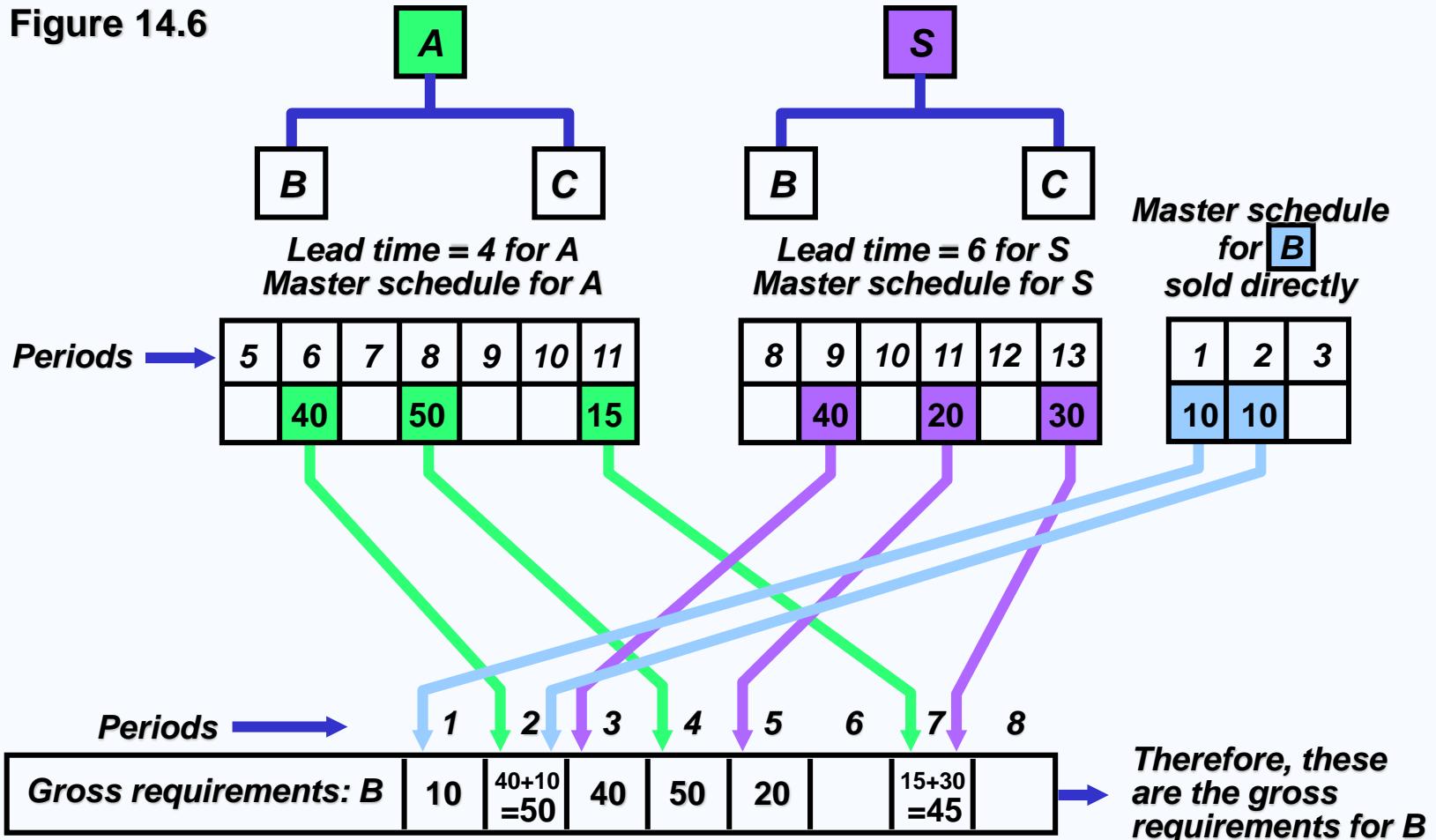
Total requirements

$$- \left[\begin{array}{c} \text{On} \\ \text{hand} \end{array} \right] + \left[\begin{array}{c} \text{Scheduled} \\ \text{receipts} \end{array} \right] = \text{Net requirements}$$

Available inventory

Gross Requirements Schedule

Figure 14.6



MRP Planning Sheet

Lot Size	Lead Time	On Hand	Safety Stock	Allocated	Low-Level Code	Item ID	Period							
							1	2	3	4	5	6	7	8
Lot For Lot	1	0	0	10	0	Z	Gross Requirements							80 90
							Scheduled Receipts							0
							Projected On Hand	0	0	0	0	0	0	0
							Net Requirements							90
							Planned Order Receipts							90
							Planned Order Releases							90

Figure 14.7

Safety Stock

- BOMs, inventory records, purchase and production quantities may not be perfect***
- Consideration of safety stock may be prudent***
- Should be minimized and ultimately eliminated***
- Typically built into projected on-hand inventory***

MRP Management

- MRP is a dynamic system*
- Facilitates replanning when changes occur*
- System nervousness can result from too many changes*
- Time fences put limits on replanning*
- Pegging links each item to its parent allowing effective analysis of changes*

MRP and JIT

- MRP is a planning system that does not do detailed scheduling***
- MRP requires fixed lead times which might actually vary with batch size***
- JIT excels at rapidly moving small batches of material through the system***

Finite Capacity Scheduling

- MRP systems do not consider capacity during normal planning cycles***
- Finite capacity scheduling (FCS) recognizes actual capacity limits***
- By merging MRP and FCS, a finite schedule is created with feasible capacities which facilitates rapid material movement***

Small Bucket Approach

- 1. MRP “buckets” are reduced to daily or hourly***
 - The most common planning period (time bucket) for MRP systems is weekly***
- 2. Planned receipts are used internally to sequence production***
- 3. Inventory is moved through the plant on a JIT basis***
- 4. Completed products are moved to finished goods inventory which reduces required quantities for subsequent planned orders***
- 5. Back flushing based on the BOM is used to deduct inventory that was used in production***

Balanced Flow

- Used in repetitive operations*
- MRP plans are executed using JIT techniques based on “pull” principles*
- Flows are carefully balanced with small lot sizes*



Supermarket

- Items used by many products are held in a common area often called a supermarket***
- Items are withdrawn as needed***
- Inventory is maintained using JIT systems and procedures***
- Common items are not planned by the MRP system***

Lot-Sizing Techniques

- Lot-for-lot techniques order just what is required for production based on net requirements***
 - May not always be feasible***
 - If setup costs are high, lot-for-lot can be expensive***
- Economic order quantity (EOQ)***
 - EOQ expects a known constant demand and MRP systems often deal with unknown and variable demand***

Lot-Sizing Techniques

- Part Period Balancing (PPB) looks at future orders to determine most economic lot size***
- The Wagner-Whitin algorithm is a complex dynamic programming technique***
 - Assumes a finite time horizon***
 - Effective, but computationally burdensome***

Lot-for-Lot Example

	1	2	3	4	5	6	7	8	9	10
<i>Gross requirements</i>	35	30	40	0	10	40	30	0	30	55
<i>Scheduled receipts</i>										
<i>Projected on hand</i>	35	35	0	0	0	0	0	0	0	0
<i>Net requirements</i>	0	30	40	0	10	40	30	0	30	55
<i>Planned order receipts</i>		30	40		10	40	30		30	55
<i>Planned order releases</i>	30	40		10	40	30		30	55	

Holding cost = \$1/week; Setup cost = \$100; Lead time = 1 week

Lot-for-Lot Examples

No on-hand inventory is carried through the system

Total holding cost = \$0

There are seven setups for this item in this plan

Total setup cost = $7 \times \$100 = \700

Projected on hand	35	35	0	0	0	0	0	0	0	0	0
Net requirements	0	30	40	0	10	40	30	0	30	55	
Planned order receipts		30	40		10	40	30		30	55	
Planned order releases	30	40		10	40	30		30	55		

Holding cost = \$1/week; Setup cost = \$100; Lead time = 1 week

EOQ Lot Size Example

	1	2	3	4	5	6	7	8	9	10
Gross requirements	35	30	40	0	10	40	30	0	30	55
Scheduled receipts										
Projected on hand	35	35	0	43	3	3	66	26	69	69
Net requirements	0	30	0	0	7	0	4	0	0	16
Planned order receipts		73			73		73			73
Planned order releases	73			73		73			73	

Holding cost = \$1/week; Setup cost = \$100; Lead time = 1 week
Average weekly gross requirements = 27; EOQ = 73 units

EOQ, Lot Sizing Examples

Annual demand = 1,404

Total cost = setup cost + holding cost

Total cost = (1,404/73) x \$100 + (73/2) x (\$1 x 52 weeks)

Total cost = \$3,798

*Cost for 10 weeks = \$3,798 x (10 weeks/52 weeks) =
\$730*

<i>Projected on hand</i>	35	35	0	0	0	0	0	0	0	0	0
<i>Net requirements</i>	0	30	0	0	7	0	4	0	0	0	16
<i>Planned order receipts</i>		73			73		73			73	
<i>Planned order releases</i>	73			73		73			73		

*Holding cost = \$1/week; Setup cost = \$100; Lead time = 1 week
Average weekly gross requirements = 27; EOQ = 73 units*

PPB Example

	1	2	3	4	5	6	7	8	9	10
Gross requirements	35	30	40	0	10	40	30	0	30	55
Scheduled receipts										
Projected on hand	35									
Net requirements										
Planned order receipts										
Planned order releases										

**Holding cost = \$1/week; Setup cost = \$100; Lead time = 1 week
EPP = 100 units**

Periods Combined	Trial Lot Size (cumulative net requirements)	Part Periods	Costs		
			Setup	Holding	Total
2	30	0			
2, 3	70	$40 = 40 \times 1$			
2, 3, 4	70	40			
2, 3, 4, 5	80	$70 = 40 \times 1 + 10 \times 3$	100	+ 70	= 170
2, 3, 4, 5, 6	120	$230 = 40 \times 1 + 10 \times 3$ + 40×4			
Combine periods 2 - 5 as this results in the Part Period closest to the EPP					
6	40	0			
6, 7	70	$30 = 30 \times 1$			
6, 7, 8	70	$30 = 30 \times 1 + 0 \times 2$			
6, 7, 8, 9	100	$120 = 30 \times 1 + 30 \times 3$	100	+ 120	= 220
Combine periods 6 - 9 as this results in the Part Period closest to the EPP					
10	55	0	100	+ 0	= 100
Total cost			300	+ 190	= 490

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PPB Example

	1	2	3	4	5	6	7	8	9	10
<i>Gross requirements</i>	35	30	40	0	10	40	30	0	30	55
<i>Scheduled receipts</i>										
<i>Projected on hand</i>	35	35	0	50	10	10	0	60	30	0
<i>Net requirements</i>	0	30	0	0	0	40	0	0	0	55
<i>Planned order receipts</i>	80					100				55
<i>Planned order releases</i>	80				100					55

**Holding cost = \$1/week; Setup cost = \$100; Lead time = 1 week
EPP = 100 units**

Lot-Sizing Summary

For these three examples

<i>Lot-for-lot</i>	\$700
<i>EOQ</i>	\$730
<i>PPB</i>	\$490

***Wagner-Whitin would have yielded a
plan with a total cost of \$455***

Lot-Sizing Summary

- In theory, lot sizes should be recomputed whenever there is a lot size or order quantity change***
- In practice, this results in system nervousness and instability***
- Lot-for-lot should be used when low-cost JIT can be achieved***



Lot-Sizing Summary

- Lot sizes can be modified to allow for scrap, process constraints, and purchase lots***
- Use lot-sizing with care as it can cause considerable distortion of requirements at lower levels of the BOM***
- When setup costs are significant and demand is reasonably smooth, PPB, Wagner-Whitin, or EOQ should give reasonable results***

Extensions of MRP

Closed-Loop MRP

- MRP system provides input to the capacity plan, MPS, and production planning process*

Capacity Planning

- MRP system generates a load report which details capacity requirements*
- This is used to drive the capacity planning process*
- Changes pass back through the MRP system for rescheduling*

Material Requirements Planning II

- Once an MRP system is in place, inventory data can be augmented by other useful information**

- Labor hours**
- Material costs**
- Capital costs**
- Virtually any resource**



- System is generally called MRP II or Material Resource Planning**

Material Resource Planning

	Week			
	5	6	7	8
A. Units (lead time 1 week)				100
<i>Labor: 10 hours each</i>				1,000
<i>Machine: 2 hours each</i>				200
<i>Payable: \$0 each</i>				0
B. Units (lead time 2 weeks, 2 each required)				200
<i>Labor: 10 hours each</i>				2,000
<i>Machine: 2 hours each</i>				400
<i>Payable: Raw material at \$5 each</i>				1,000
C. Units (lead time 4 weeks, 3 each required)	300			
<i>Labor: 2 hours each</i>	600			
<i>Machine: 1 hour each</i>	300			
<i>Payable: Raw material at \$10 each</i>	3,000			

Table 14.4

Closed-Loop MRP System

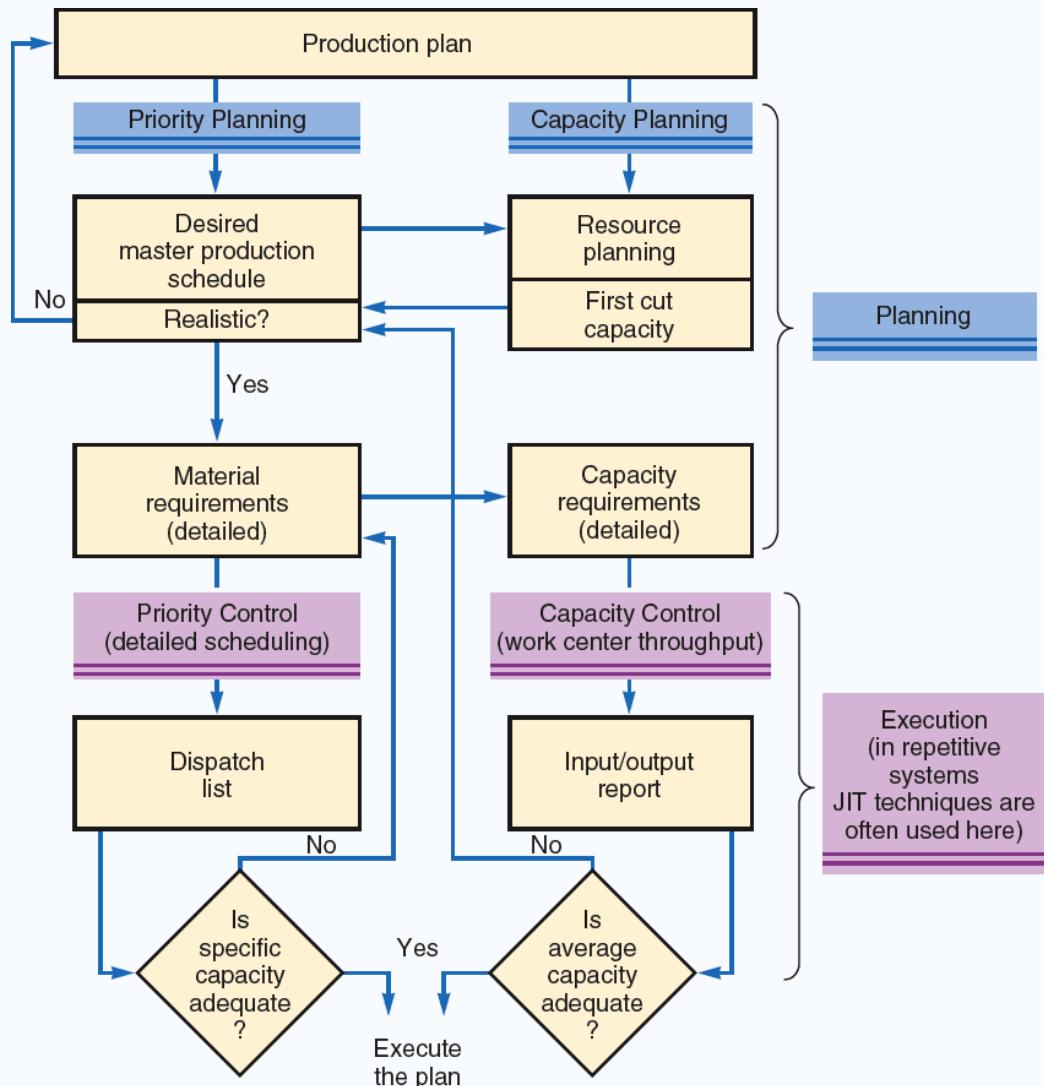


Figure 14.8

Closed-Loop MRP System

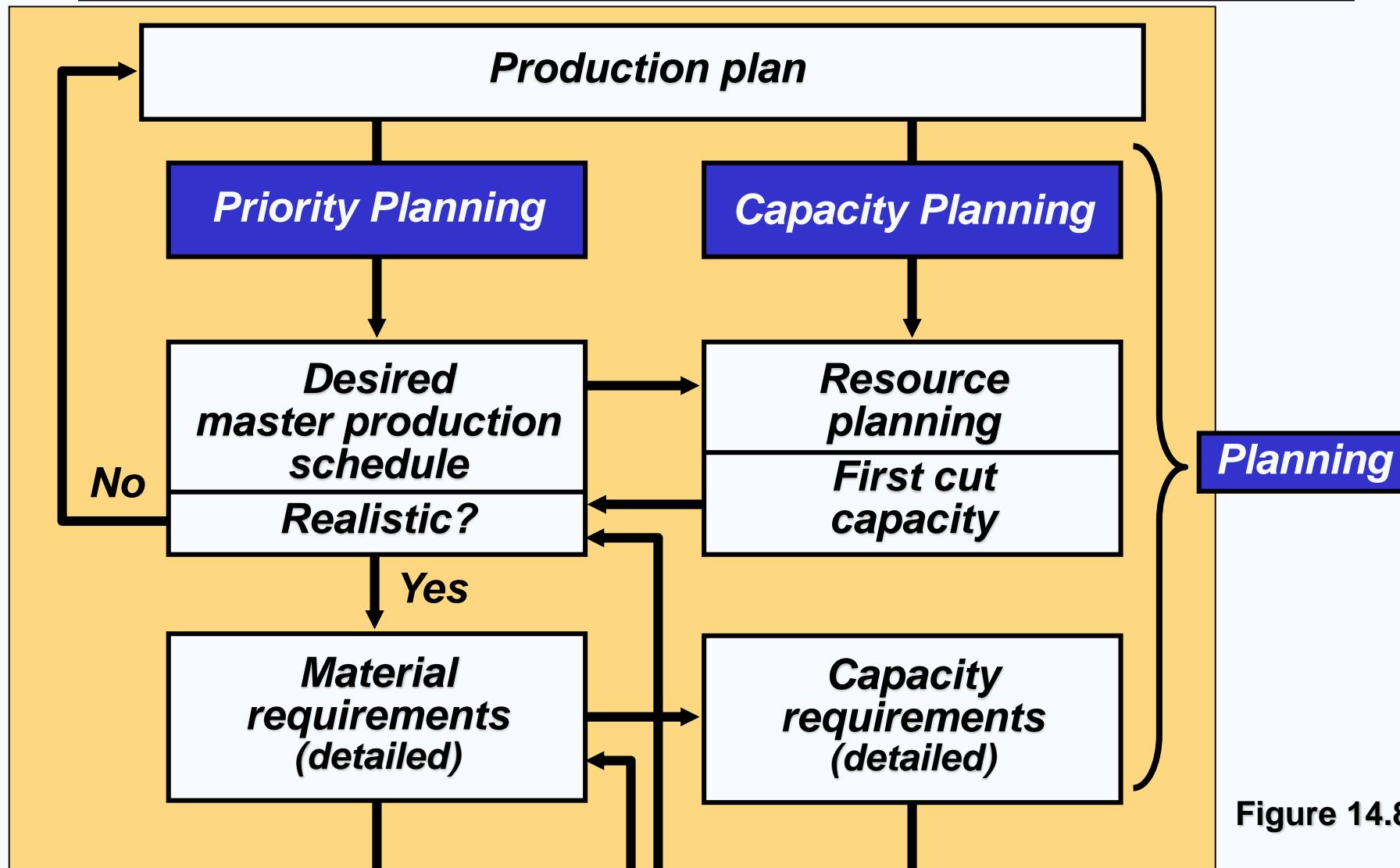


Figure 14.8

Closed-Loop MRP System

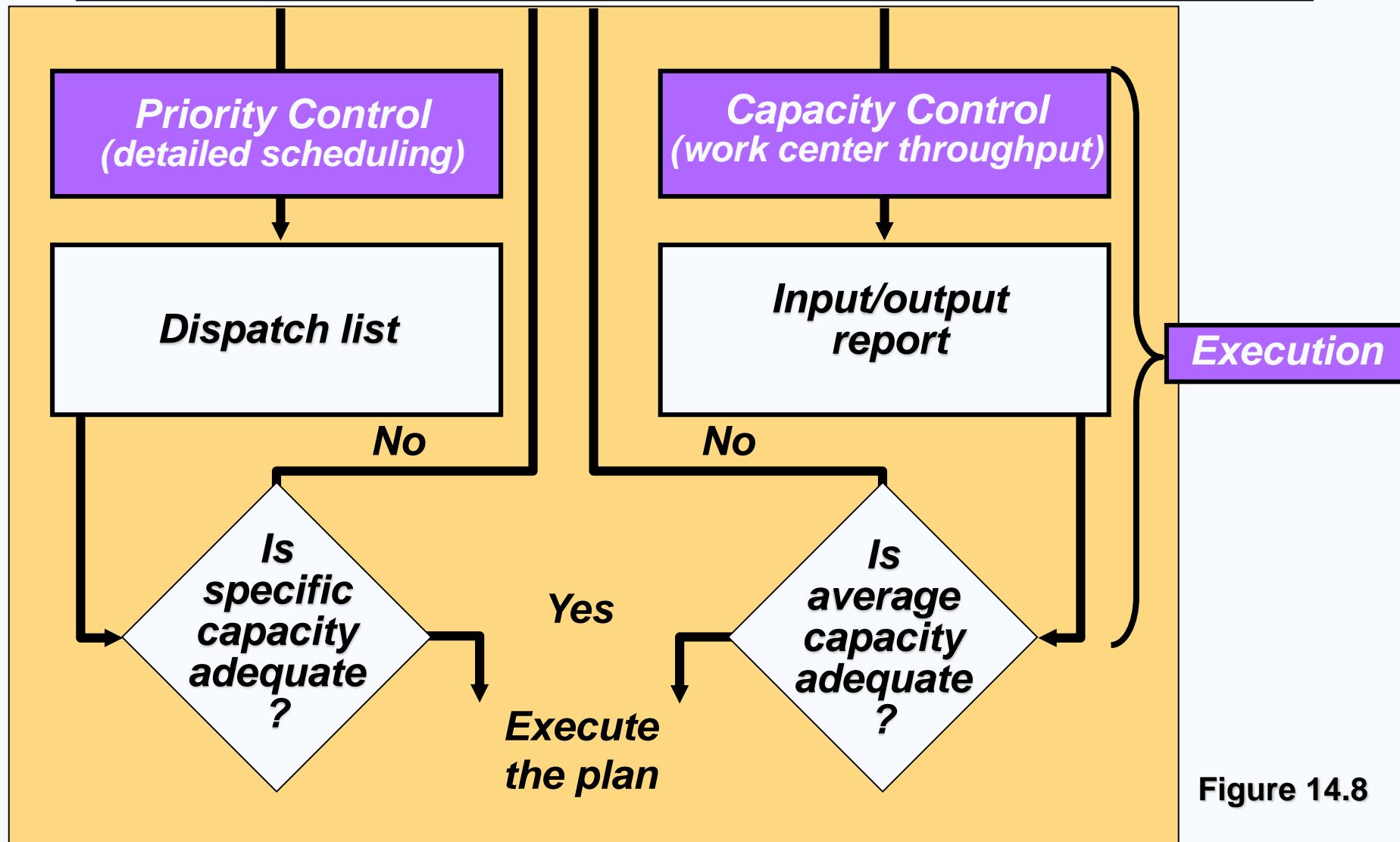


Figure 14.8

Resource Requirements Profile

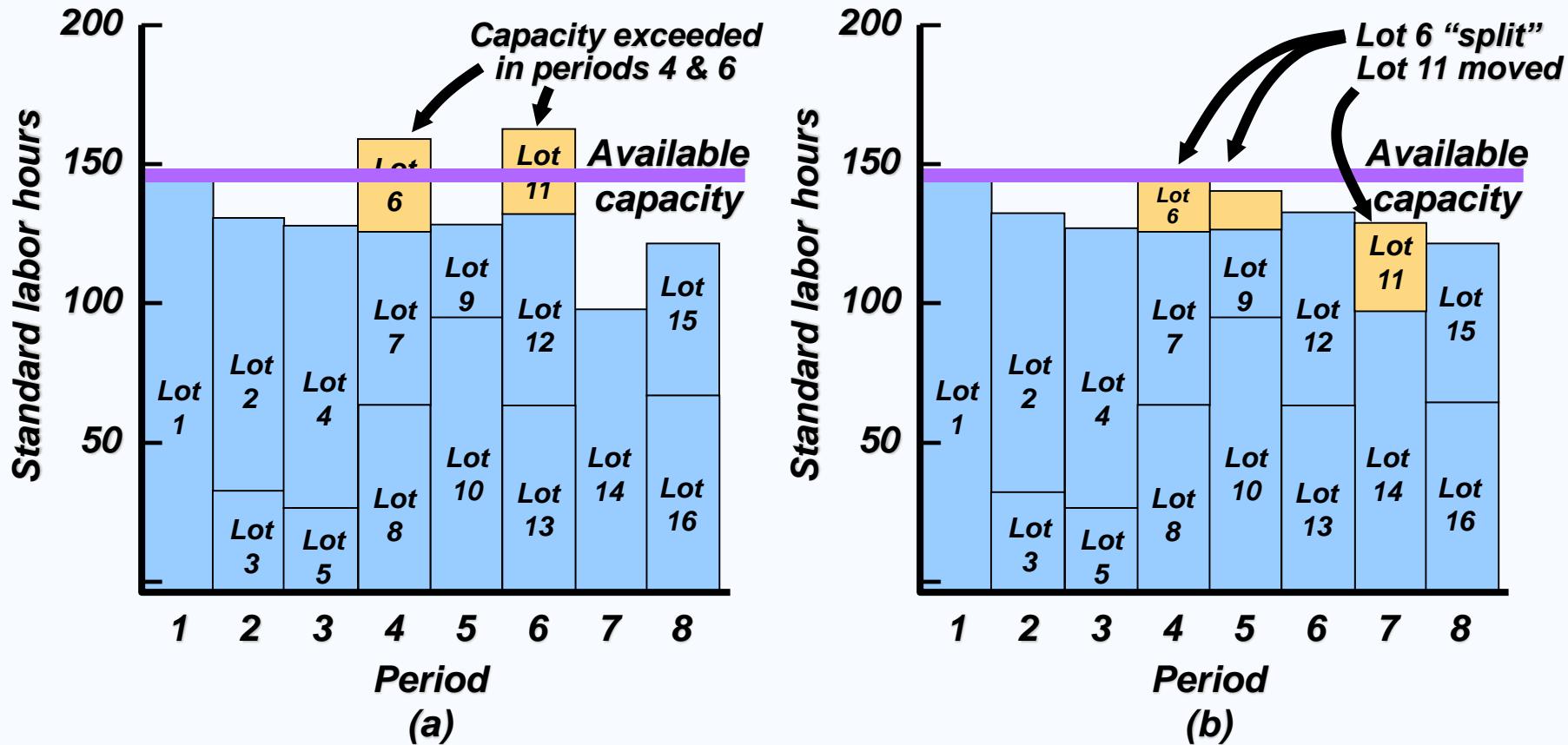


Figure 14.9

Resource Requirements Profile

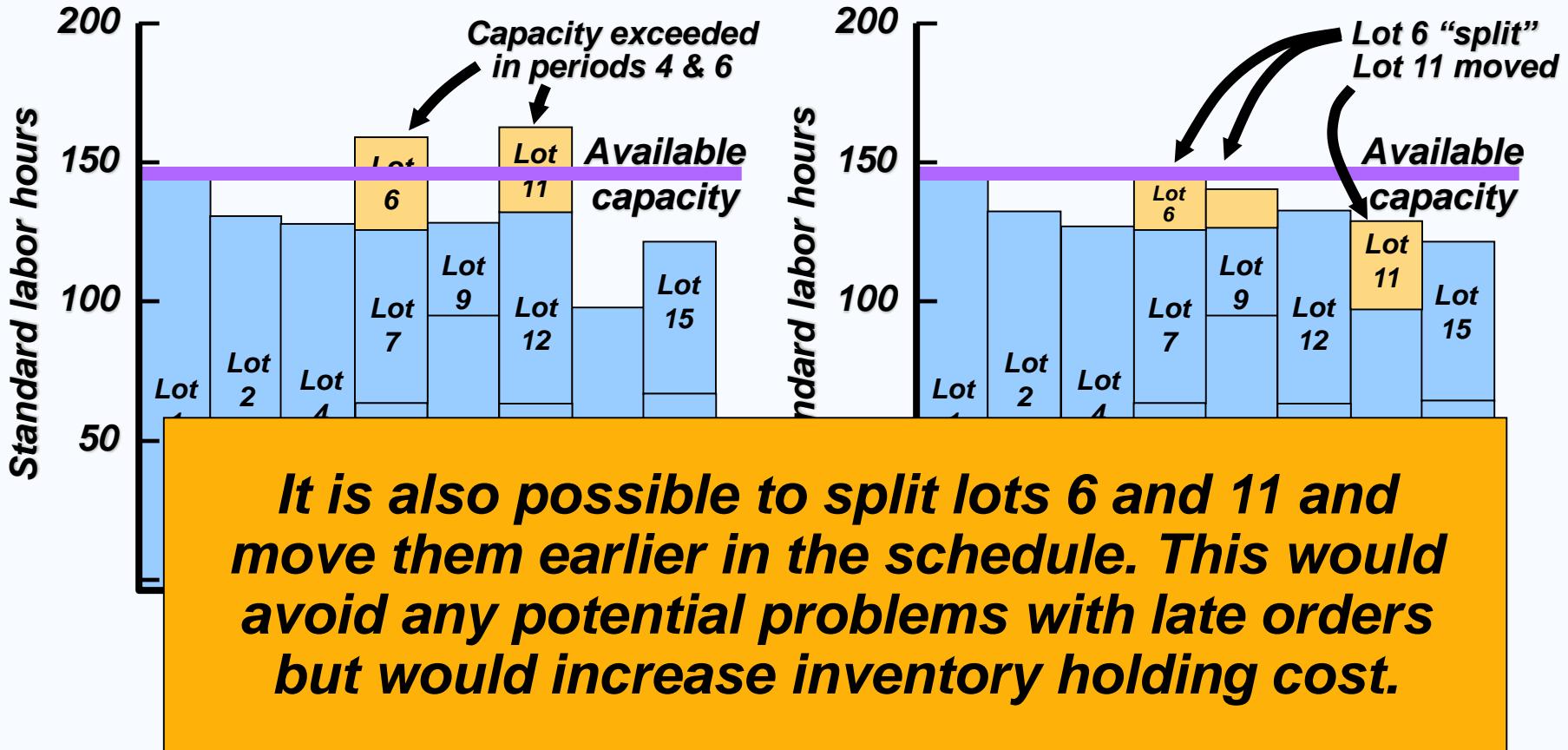


Figure 14.9

Smoothing Tactics

1. Overlapping

- ✓ Sends part of the work to following operations before the entire lot is complete***
- ✓ Reduces lead time***

2. Operations splitting

- ✓ Sends the lot to two different machines for the same operation***
- ✓ Shorter throughput time but increased setup costs***

3. Order or lot splitting

- ✓ Breaking up the order into smaller lots and running part ahead of schedule***

MRP in Services

- Some services or service items are directly linked to demand for other services***
- These can be treated as dependent demand services or items***
 - Restaurants***
 - Hospitals***
 - Hotels***

MRP in Services

(a) PRODUCT STRUCTURE TREE

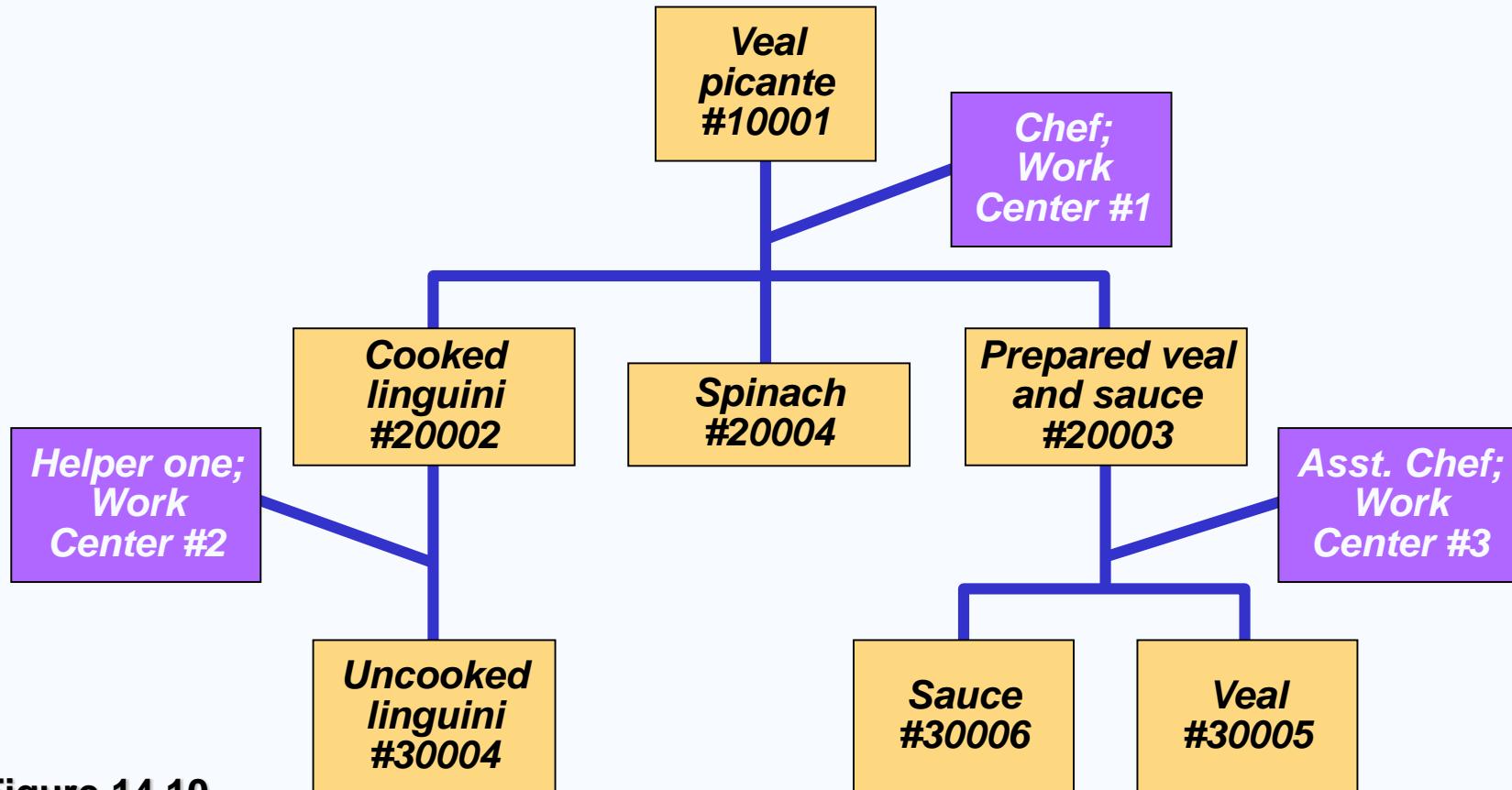


Figure 14.10

MRP in Services

(b) BILL OF MATERIALS

Part Number	Description	Quantity	Unit of Measure	Unit cost
10001	<i>Veal picante</i>	1	<i>Serving</i>	—
20002	<i>Cooked linguini</i>	1	<i>Serving</i>	—
20003	<i>Prepared veal and sauce</i>	1	<i>Serving</i>	—
20004	<i>Spinach</i>	0.1	<i>Bag</i>	0.94
30004	<i>Uncooked linguini</i>	0.5	<i>Pound</i>	—
30005	<i>Veal</i>	1	<i>Serving</i>	2.15
30006	<i>Sauce</i>	1	<i>Serving</i>	0.80

MRP in Services

(c) BILL OF LABOR FOR VEAL PICANTE

Work Center	Operation	Labor Type	Labor Hours	
			Setup Time	Run Time
1	Assemble dish	Chef	.0069	.0041
2	Cook linguini	Helper one	.0005	.0022
3	Cook veal and sauce	Assistant Chef	.0125	.0500

Distribution Resource Planning (DRP)

***Using dependent demand techniques
through the supply chain***

- Expected demand or sales forecasts
become gross requirements***
- Minimum levels of inventory to meet
customer service levels***
- Accurate lead times***
- Definition of the distribution structure***

Enterprise Resource Planning (ERP)

- An extension of the MRP system to tie in customers and suppliers***
 - 1. Allows automation and integration of many business processes***
 - 2. Shares common data bases and business practices***
 - 3. Produces information in real time***
- Coordinates business from supplier evaluation to customer invoicing***

Enterprise Resource Planning (ERP)

- ERP modules include***
 - Basic MRP***
 - Finance***
 - Human resources***
 - Supply chain management (SCM)***
 - Customer relationship management (CRM)***

ERP and MRP

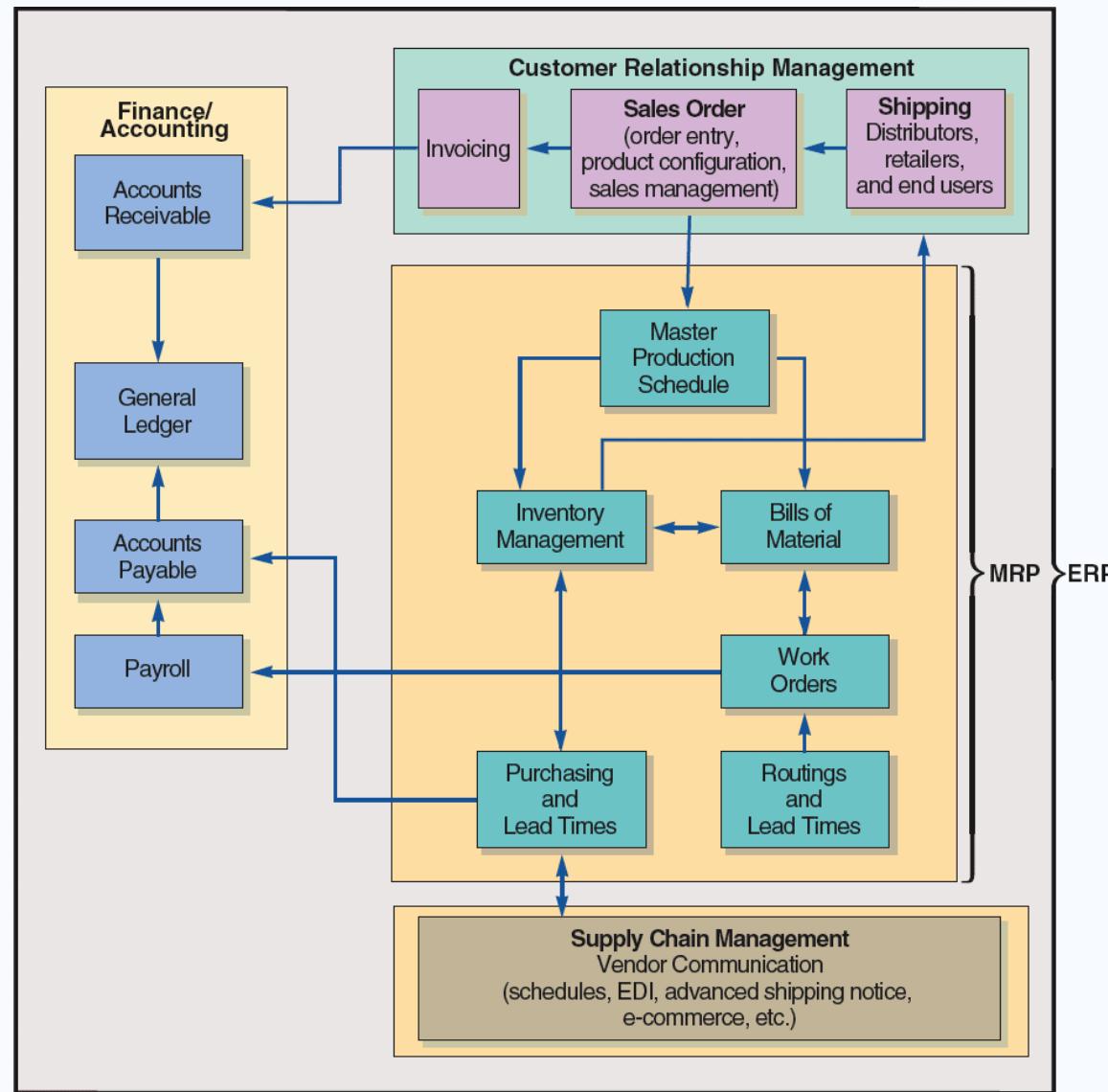


Figure 14.11

ERP and MRP

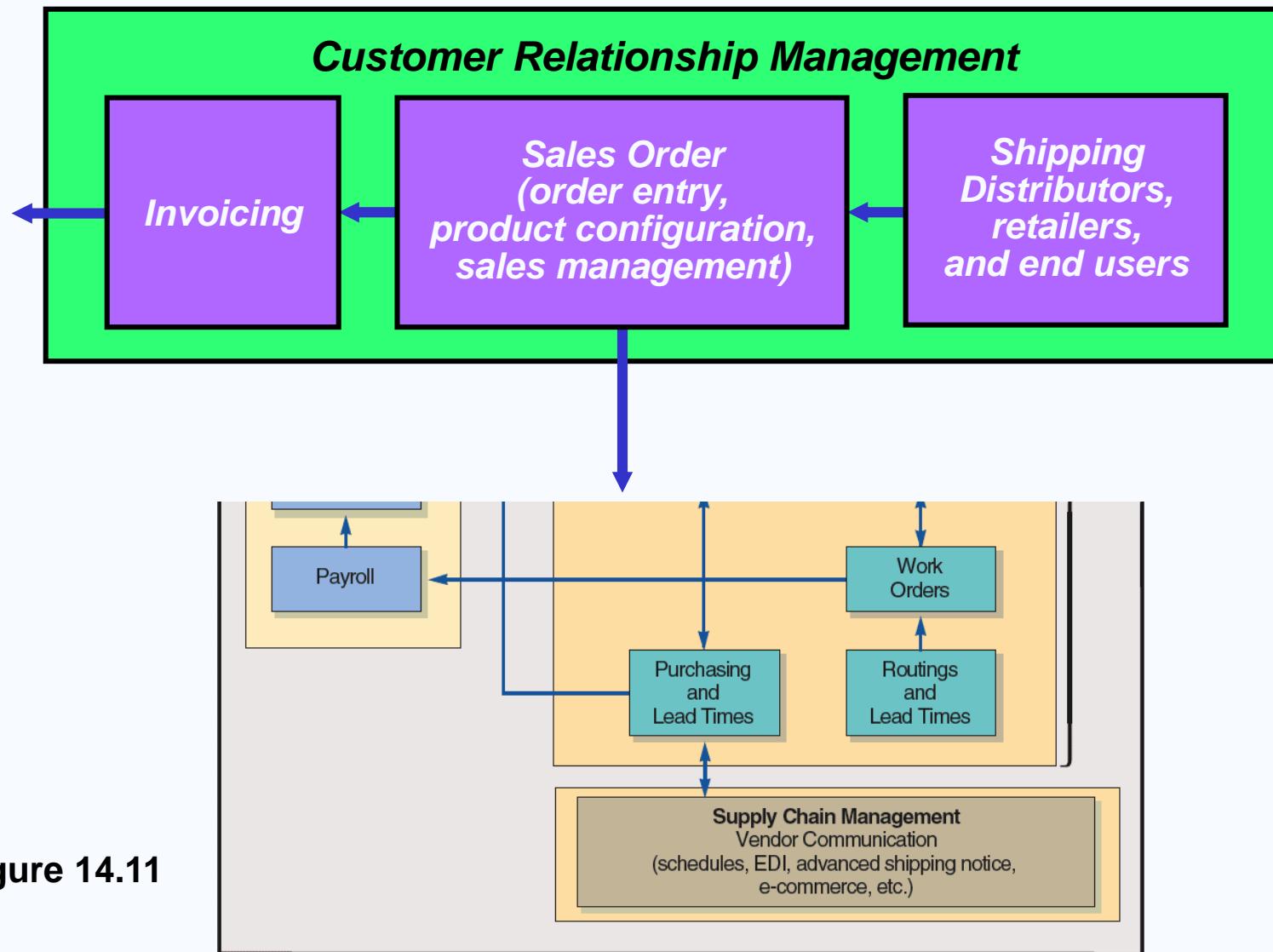
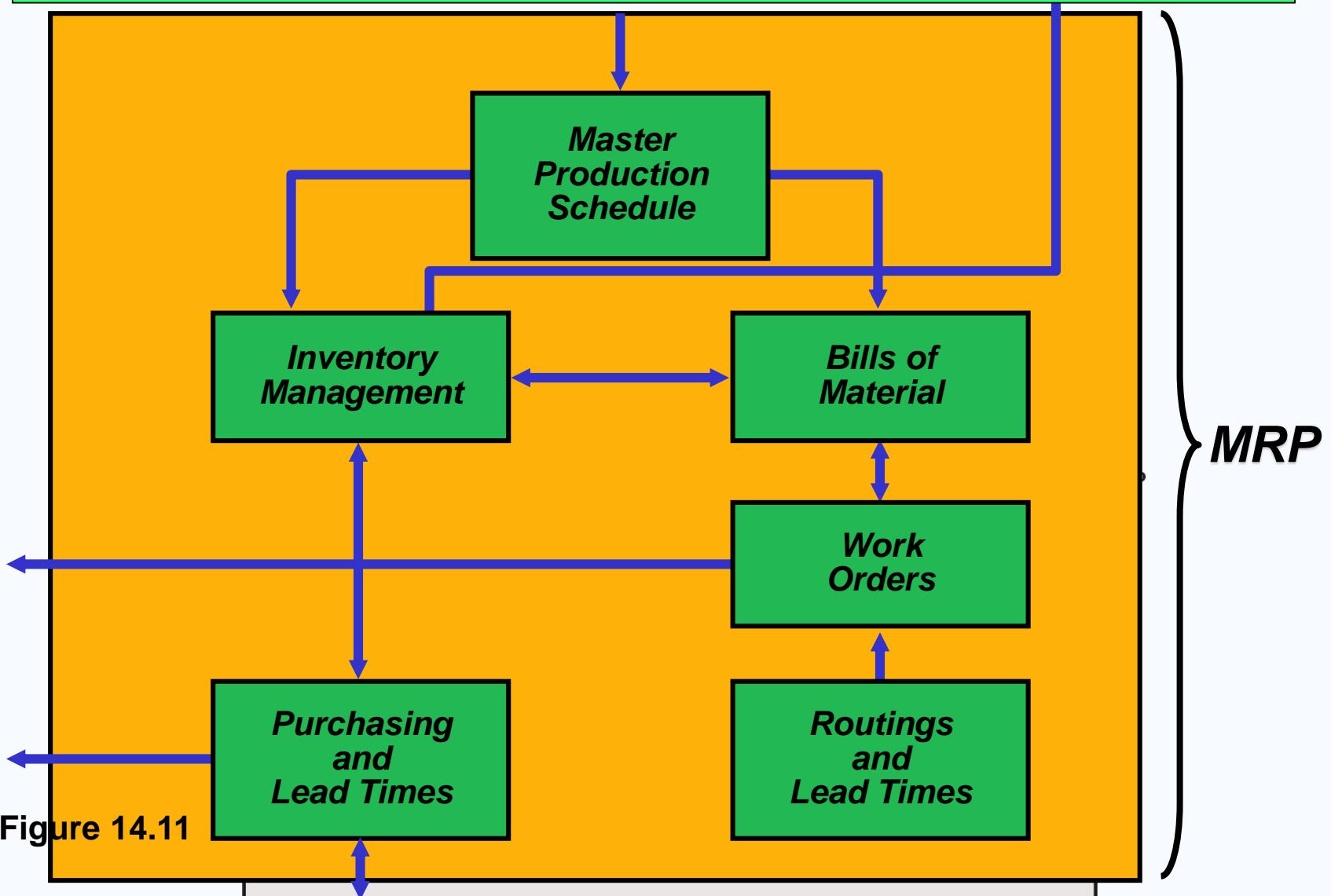
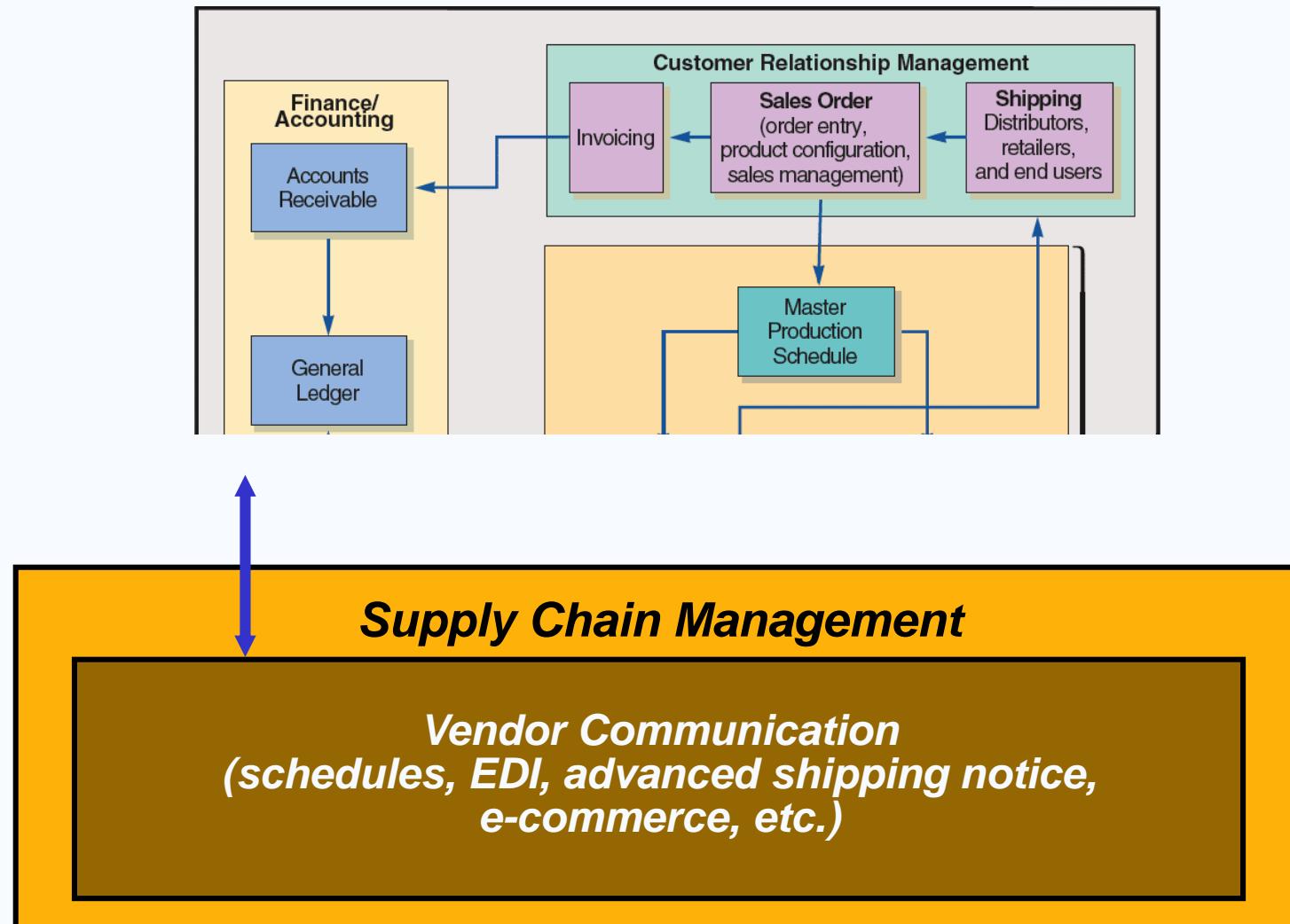


Figure 14.11

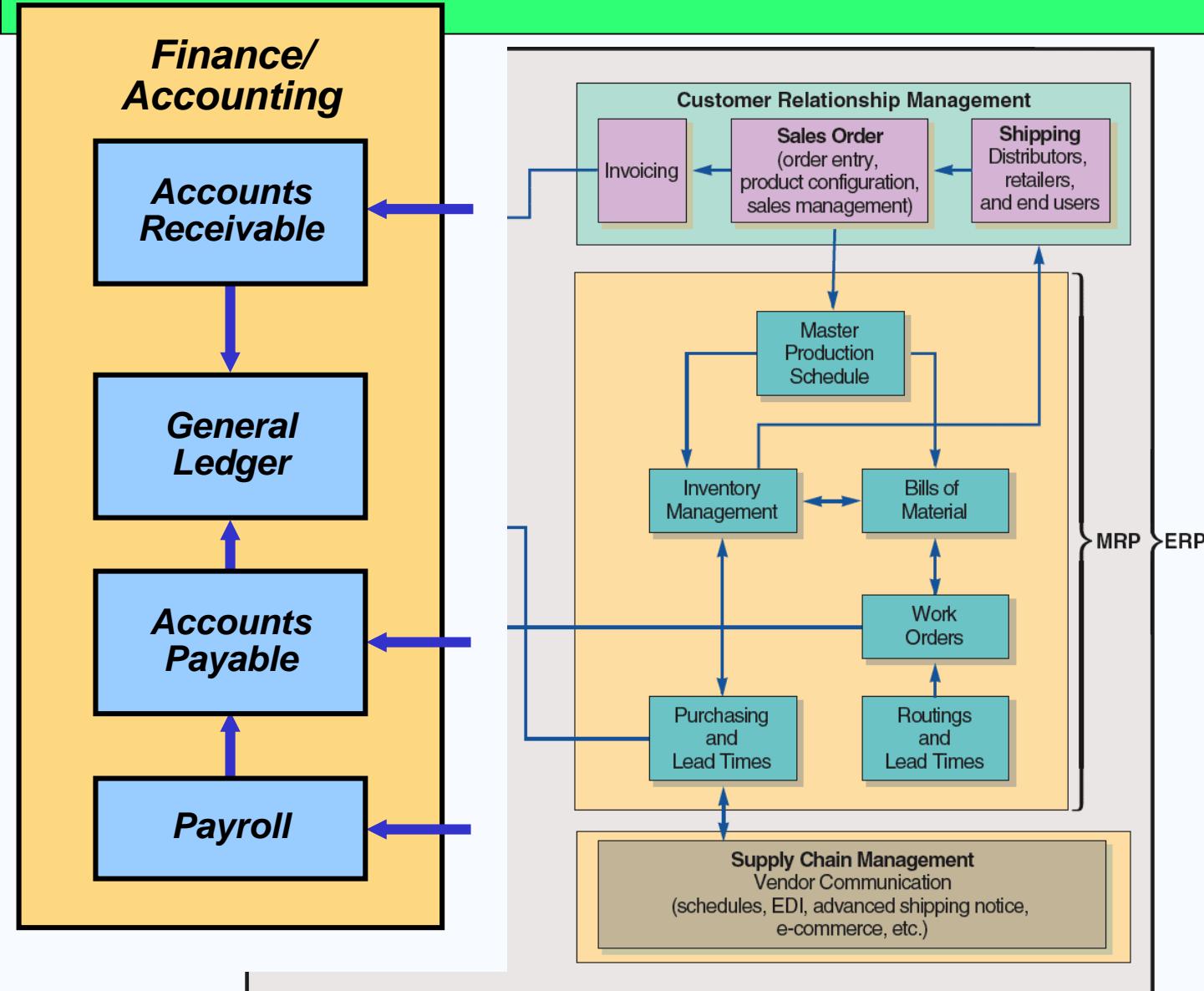
ERP and MRP



ERP and MRP



ERP and MRP



Enterprise Resource Planning (ERP)

- ERP can be highly customized to meet specific business requirements***
- Enterprise application integration software (EAI) allows ERP systems to be integrated with***
 - Warehouse management***
 - Logistics***
 - Electronic catalogs***
 - Quality management***

Enterprise Resource Planning (ERP)

- ERP systems have the potential to***
 - Reduce transaction costs***
 - Increase the speed and accuracy of information***
- Facilitates a strategic emphasis on JIT systems and integration***

Advantages of ERP Systems

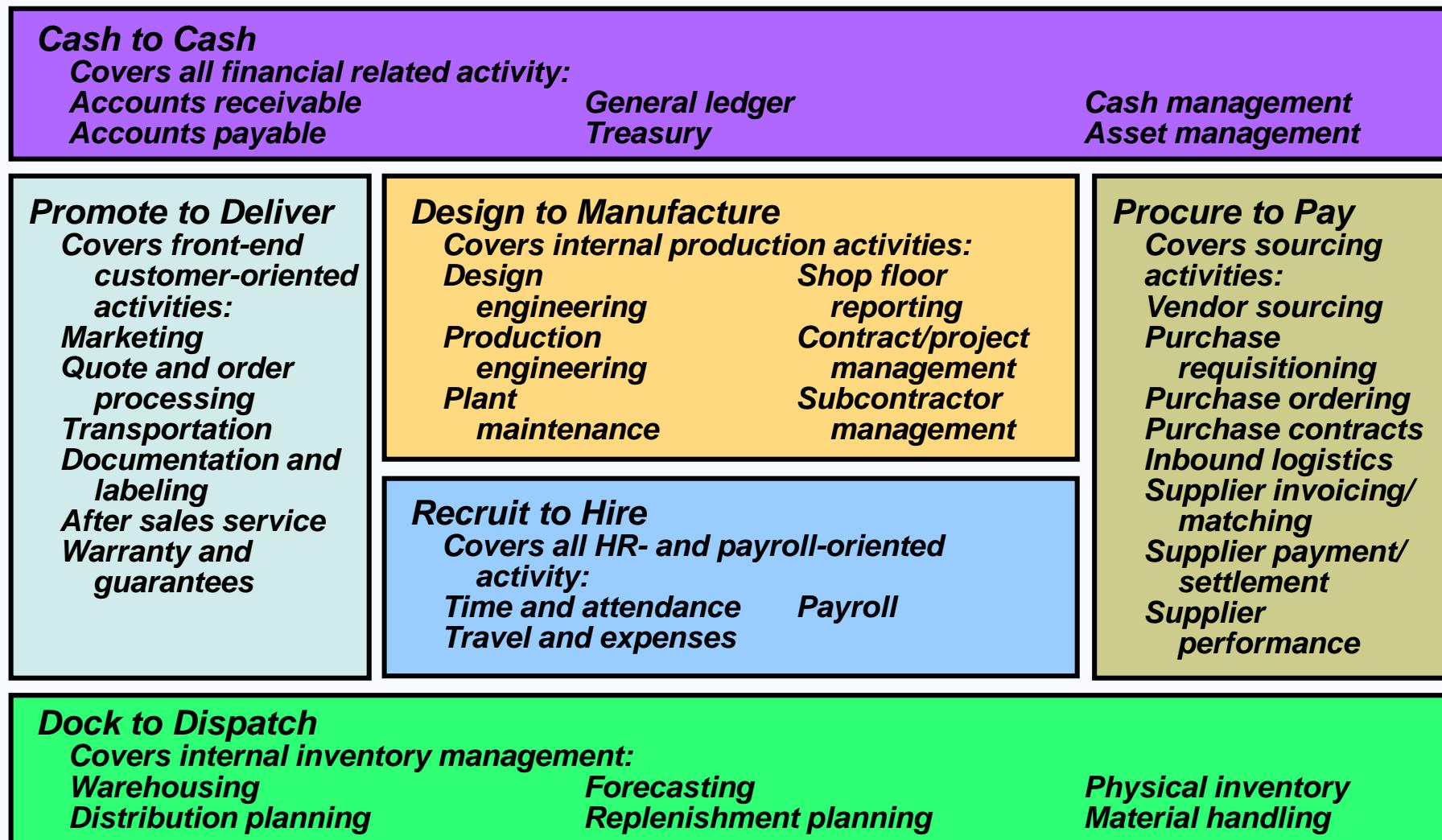
- 1. Provides integration of the supply chain, production, and administration***
- 2. Creates commonality of databases***
- 3. Can incorporate improved best processes***
- 4. Increases communication and collaboration between business units and sites***
- 5. Has an off-the-shelf software database***
- 6. May provide a strategic advantage***

Disadvantages of ERP Systems

- 1. Is very expensive to purchase and even more so to customize***
- 2. Implementation may require major changes in the company and its processes***
- 3. Is so complex that many companies cannot adjust to it***
- 4. Involves an ongoing, possibly never completed, process for implementation***
- 5. Expertise is limited with ongoing staffing problems***

SAP's ERP Modules

Figure 14.12



ERP in the Service Sector

- ❑ *ERP systems have been developed for health care, government, retail stores, hotels, and financial services*
- ❑ *Also called efficient consumer response (ECR) systems*
- ❑ *Objective is to tie sales to buying, inventory, logistics, and production*