Material Requirements Planning (MRP) and ERP

14

PowerPoint presentation to accompany
Heizer and Render
Operations Management, Global Edition, Eleventh Edition
Principles of Operations Management, Global Edition, Ninth Edition

PowerPoint slides by Jeff Heyl

Outline

- **Global Company Profile:** Wheeled Coach
- Dependent Demand
- Dependent Inventory Model Requirements
- MRP Structure
- MRP Management

Outline - Continued

- Lot-Sizing Techniques
- Extensions of MRP
- MRP In Services
- Enterprise Resource Planning (ERP)

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 POQ

Learning Objectives

When you complete this chapter you should be able to:

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

MRP for 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

MRP for 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

Dependent Demand

For any product for which a schedule can be established, dependent demand techniques should be used

Dependent Demand

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 Inventory Model Requirements

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

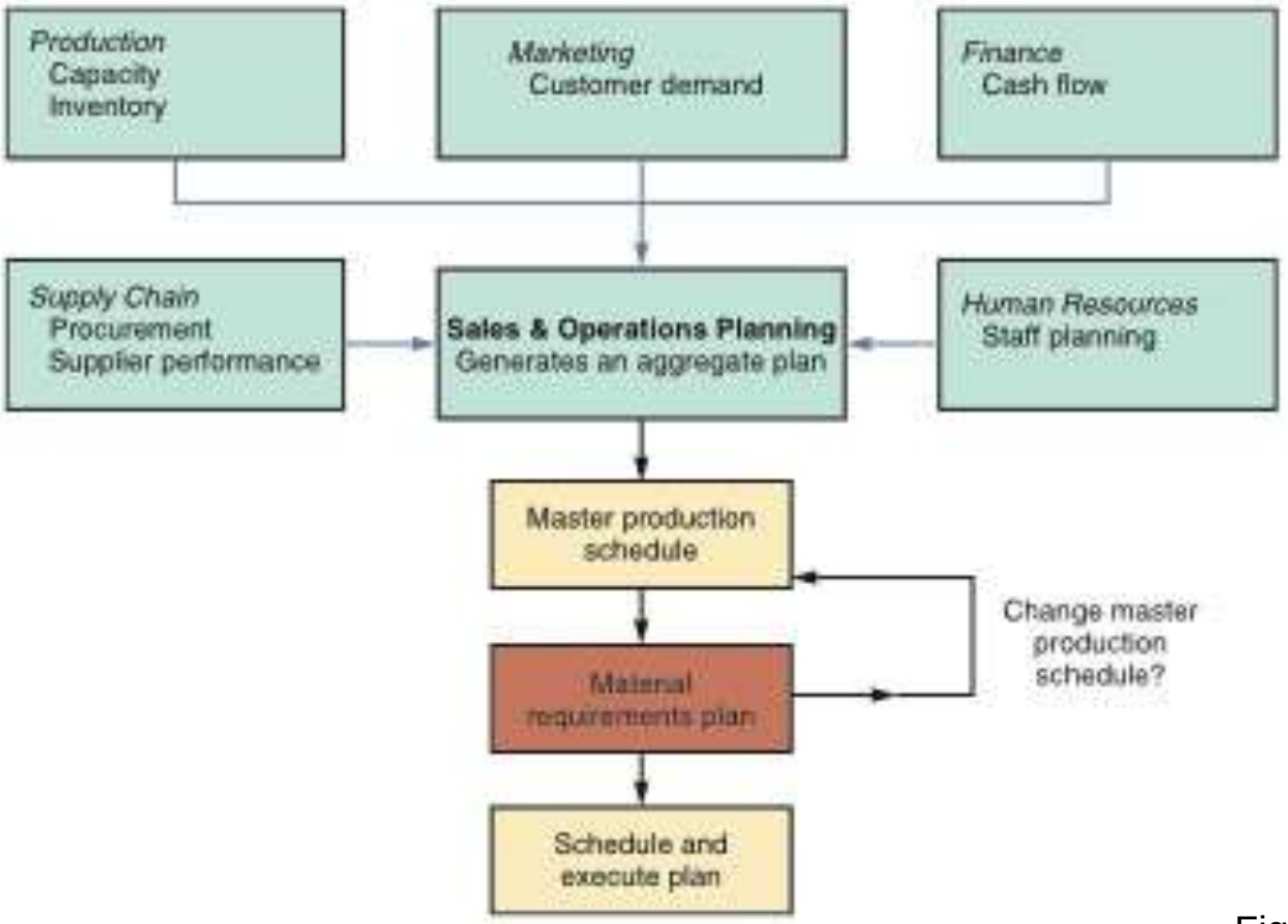


Figure 14.1

The Planning Process

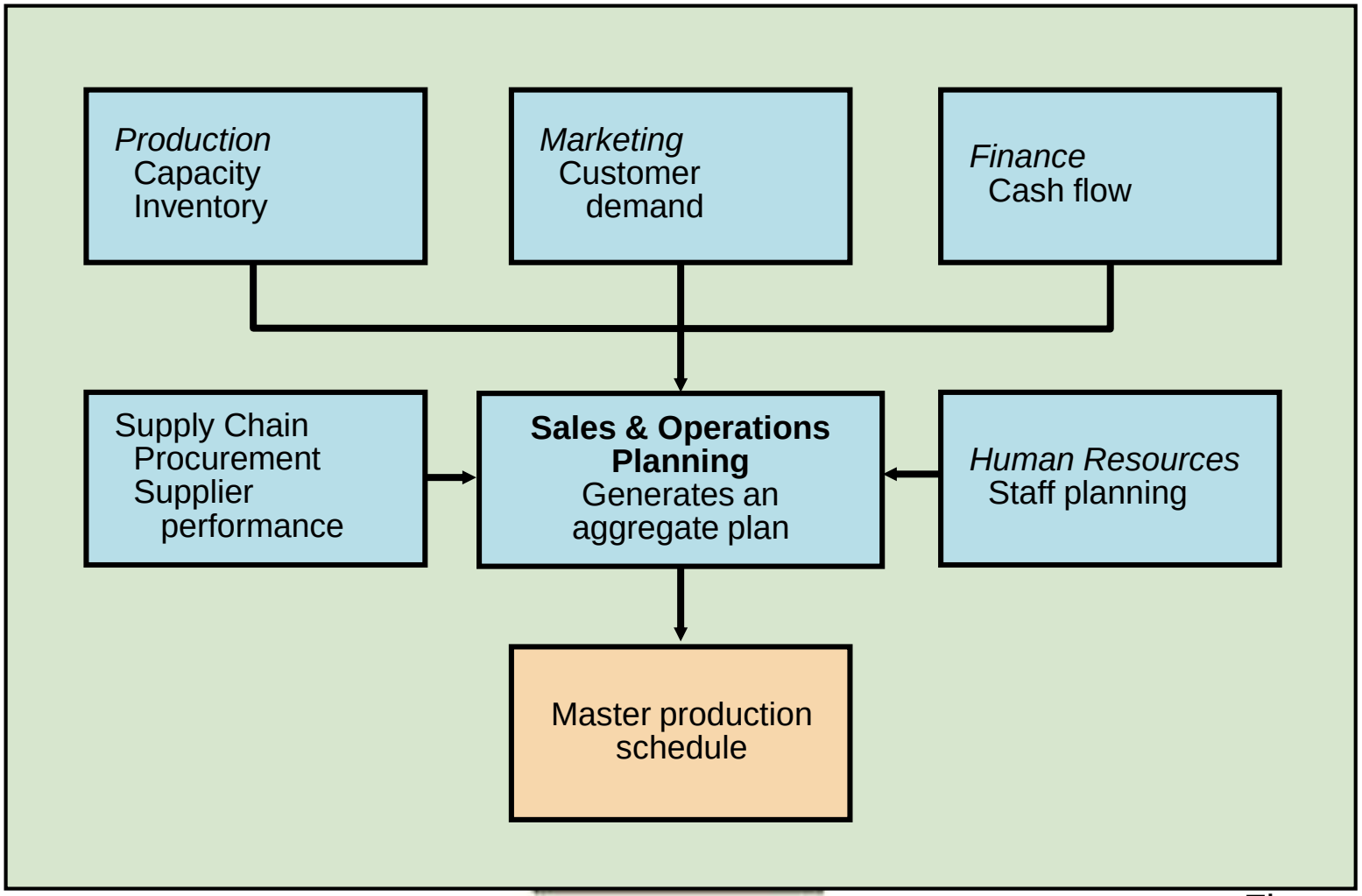


Figure 14.1

The Planning Process

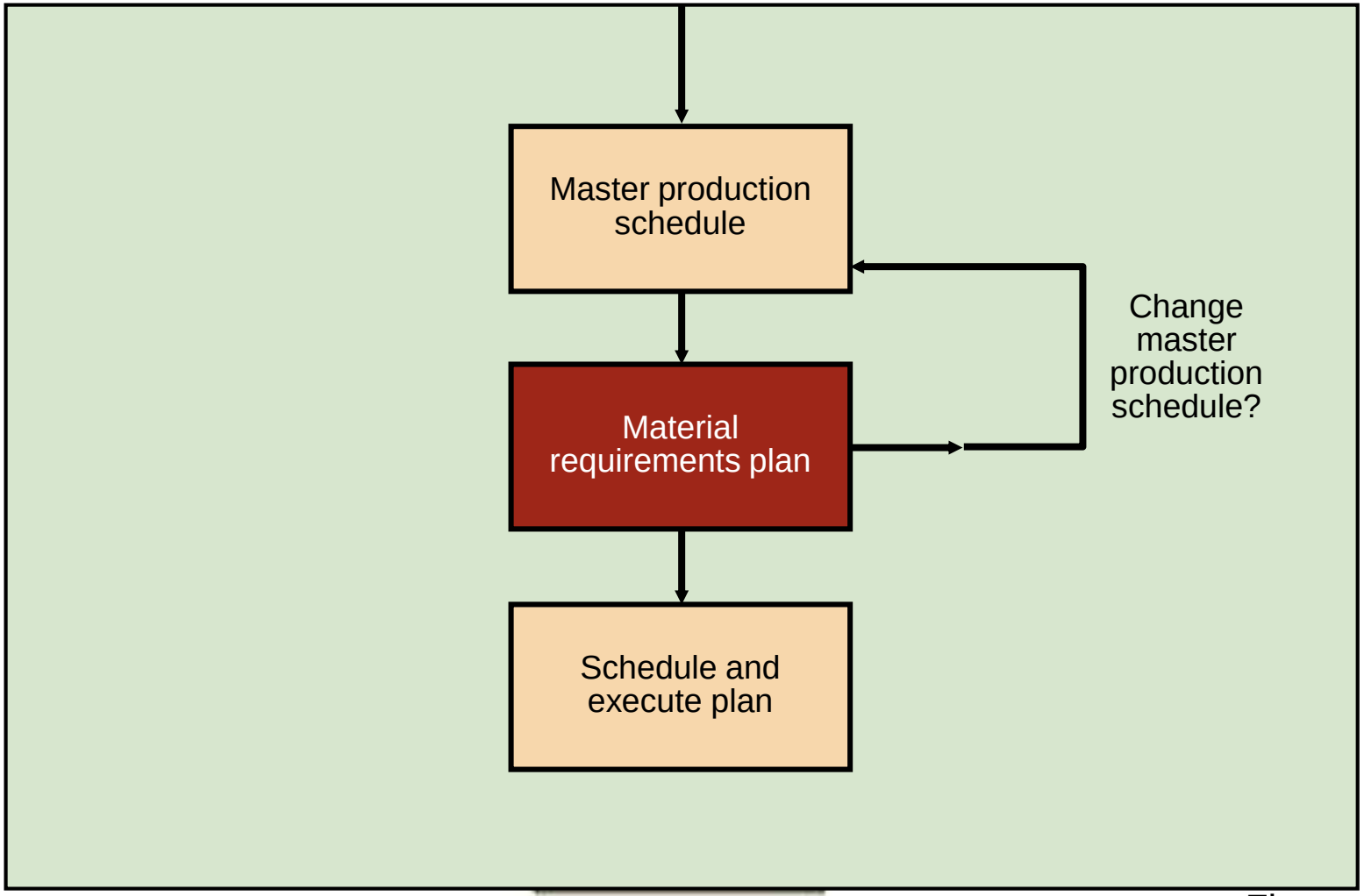


Figure 14.1

Aggregate Production Plan

Figure 14.2

Months	January				February			
Aggregate Plan (Shows the total quantity of amplifiers)	1,500				1,200			
Weeks	1	2	3	4	5	6	7	8
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	

Master Production Schedule (MPS)

Can be expressed in any of the following terms:

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

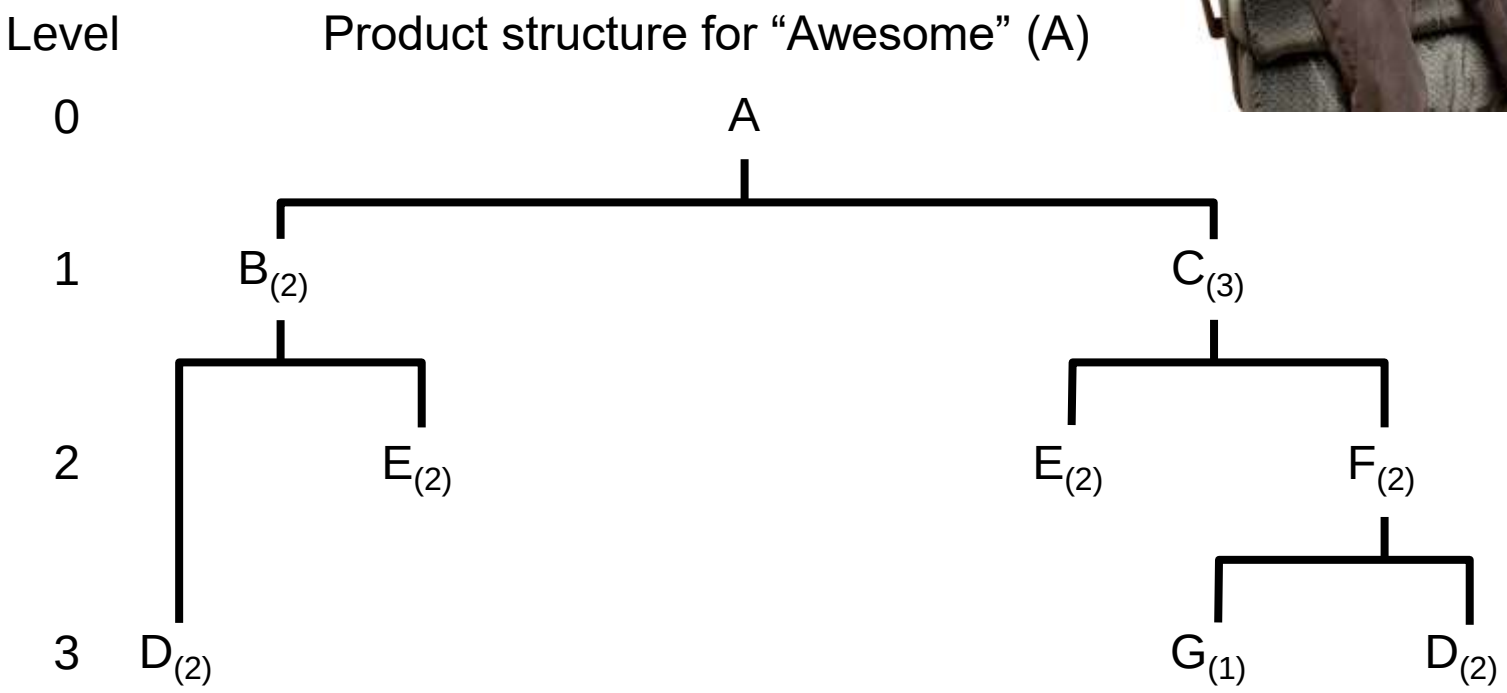
MPS Example

TABLE 14.1	Master Production Schedule for Chef John's Buffalo Chicken Mac & Cheese									
GROSS REQUIREMENTS FOR CHEF JOHN'S BUFFALO MAC & CHEESE										
Day	6	7	8	9	10	11	12	13	14	And so on
Quantity	450		200	350	525		235	375		

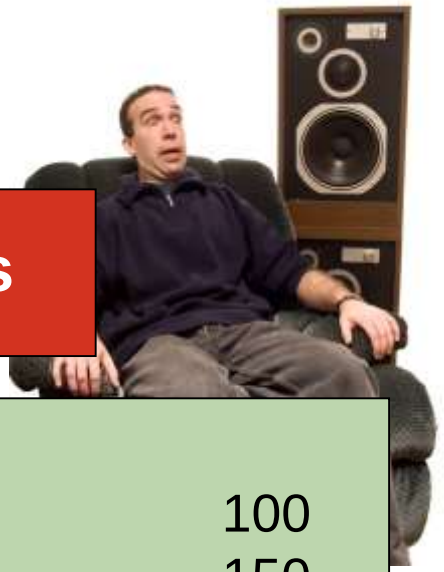
Bills of Material

- 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 components or children

BOM Example



BOM Example



For an order of 50 Awesome speaker kits

Part B:	2 x number of As =	(2)(50) =	100
Part C:	3 x number of As =	(3)(50) =	150
Part D:	2 x number of Bs		
	+ 2 x number of Fs =	(2)(100) + (2)(300) =	800
Part E:	2 x number of Bs		
	+ 2 x number of Cs =	(2)(100) + (2)(150) =	500
Part F:	2 x number of Cs =	(2)(150) =	300
Part G:	1 x number of Fs =	(1)(300) =	300

3 $D_{(2)}$ $G_{(1)}$ $D_{(2)}$

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
  - Also called “pseudo” or super 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 Inventory Records

- Accurate inventory records are absolutely required for MRP (or any dependent demand system) to operate correctly
- Generally MRP systems require more than 99% accuracy

Purchase Orders Outstanding

- A by-product of well-managed purchasing and inventory control department
- Outstanding purchase orders must accurately reflect quantities and scheduled receipts

Lead Times for Components

- The time required to purchase, produce, or assemble an item
  - For production – the sum of the *move*, *setup*, and *assembly* or *run times*
  - For purchased items – the time between the recognition of a need and when its available for production

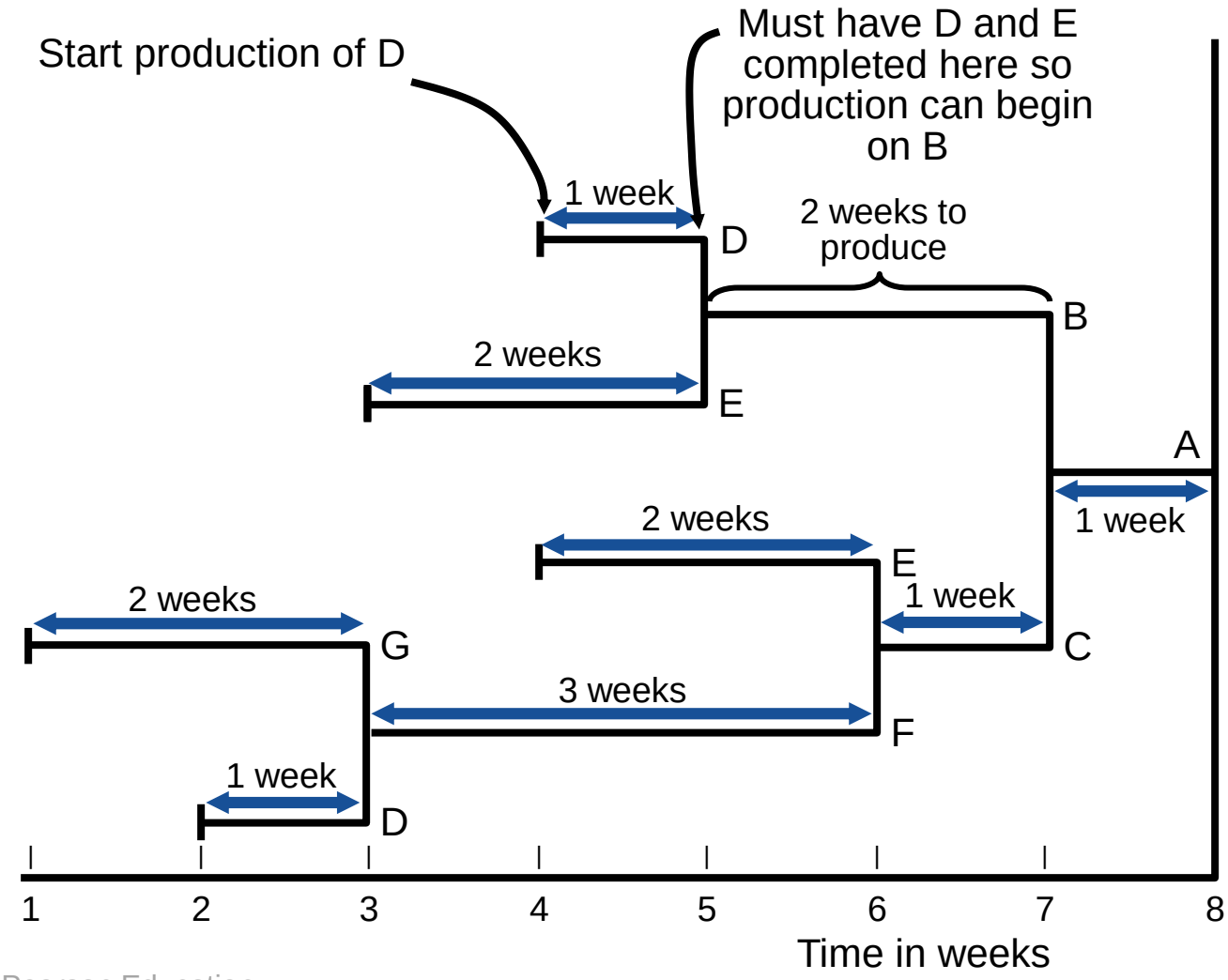
TABLE 14.2

Lead Times for Awesome Speaker Kits (As)

COMPONENT	LEAD TIME
A	1 week
B	2 weeks
C	1 week
D	1 week
E	2 week
F	3 weeks
G	2 weeks

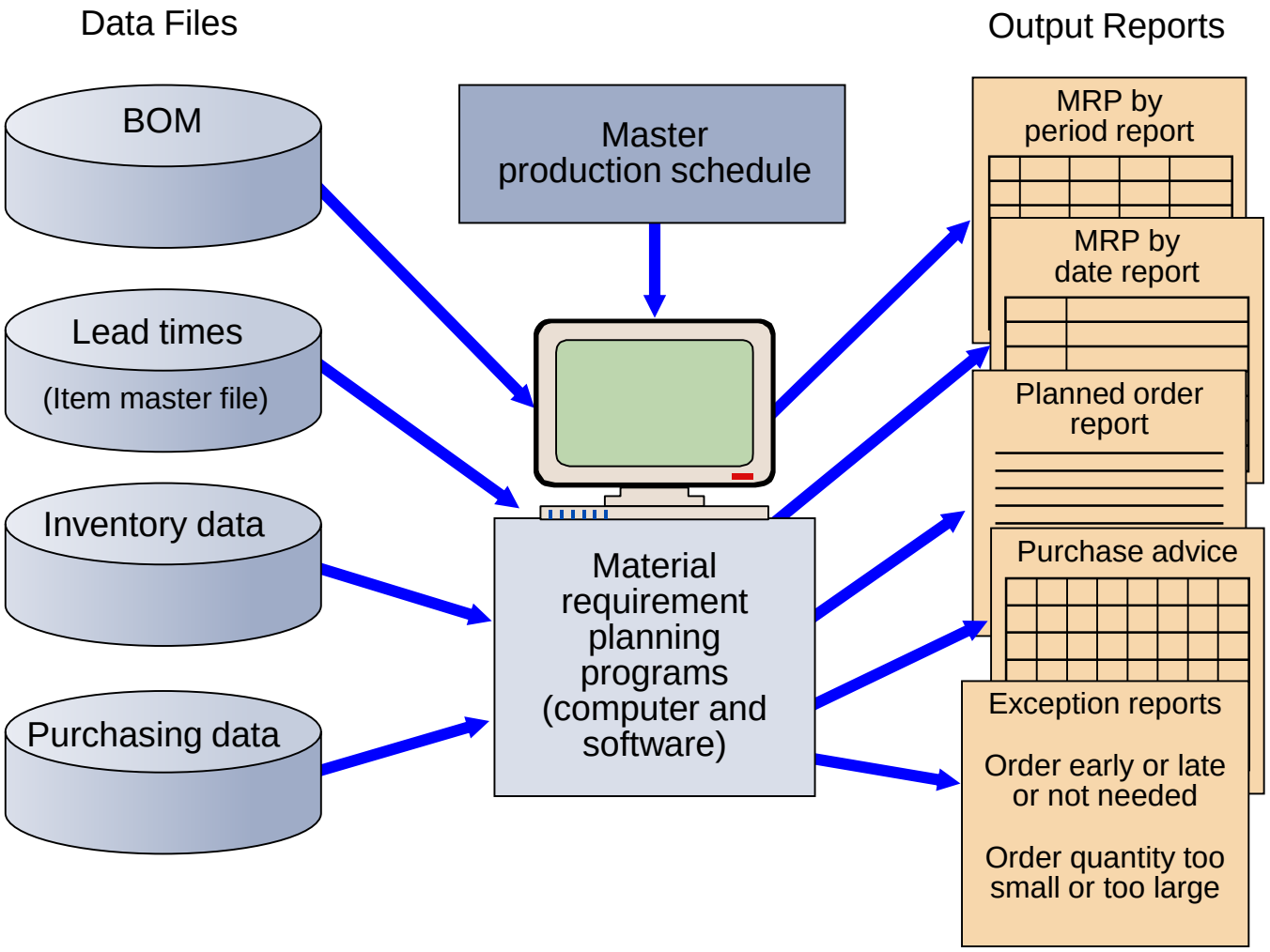
Time-Phased Product Structure

Figure 14.3



MRP Structure

Figure 14.4



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

TABLE 14.3 Gross Material Requirements Plan for 50 Awesome Speaker Kits (As) with Order Release Dates Also Shown

	WEEK								LEAD TIME
	1	2	3	4	5	6	7	8	
A. Required date								50	
Order release date							50		1 week
B. Required date							100		
Order release date					100				2 weeks
C. Required date							150		
Order release date						150			1 week
E. Required date					200	300			
Order release date			200	300					2 weeks
F. Required date						300			
Order release date			300						3 weeks
D. Required date			600		200				
Order release date		600		200					1 week
G. Required date			300						
Order release date	300								2 weeks

Net Requir

ITEM	ON HAND	ITEM	ON HAND
A	10	E	10
B	15	F	5
C	20	G	0
D	10		

Lot Size	Lead Time (weeks)	On Hand	Safety Stock	Allo-cated	Low-Level Code	Item Identi-fication		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	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	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	20	
							Net Requirements							100	
							Planned Order Receipts							100	
							Planned Order Releases						100		

Net Requirements Plan

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

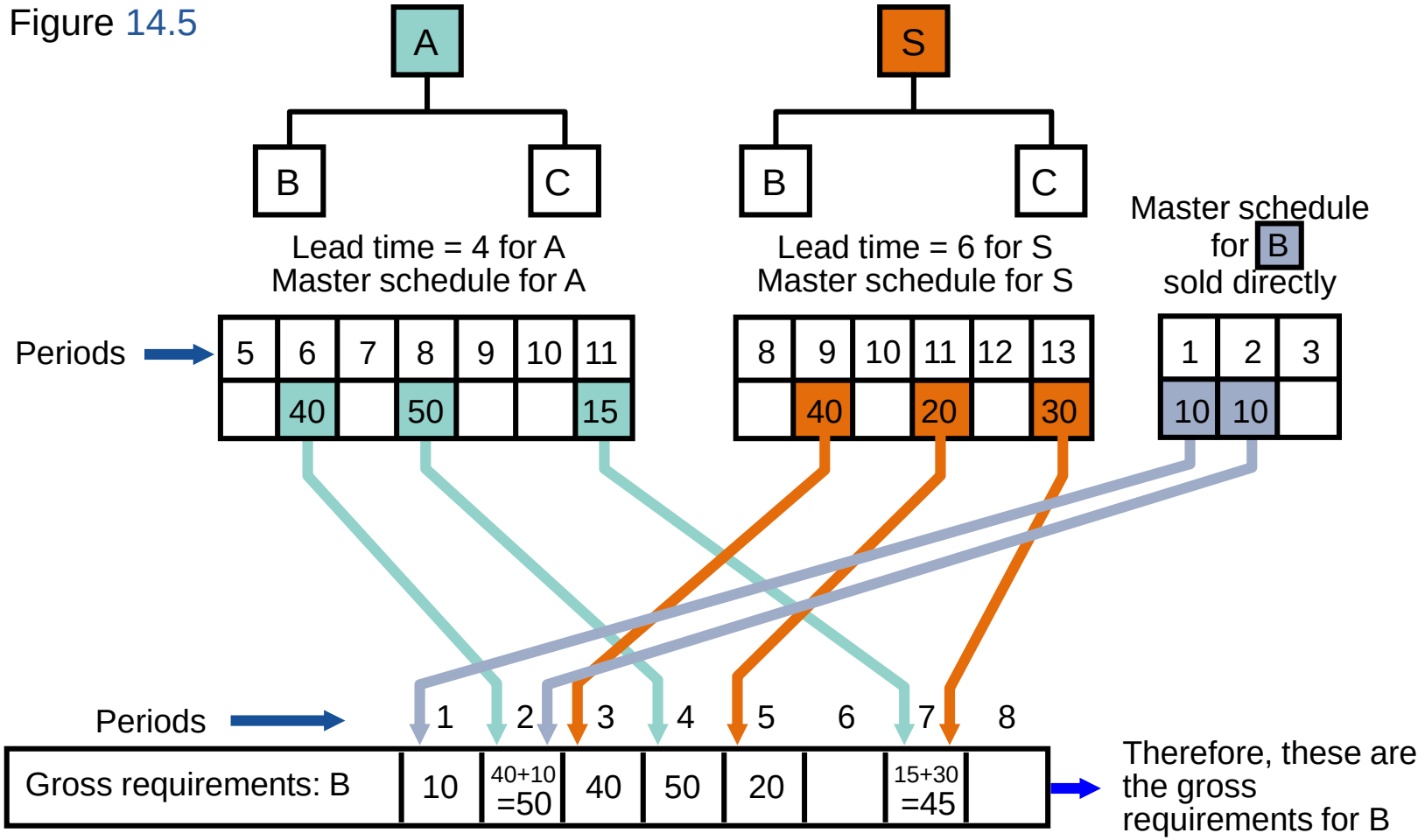
- Following the lead time offset procedure, the planned order release for Item A is now 40 units in week 7
- The gross requirement for Item B is now 80 units in week 7
- There are 15 units of Item B on hand, so the net requirement is 65 units in week 7
- A planned order receipt of 65 units in week 7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

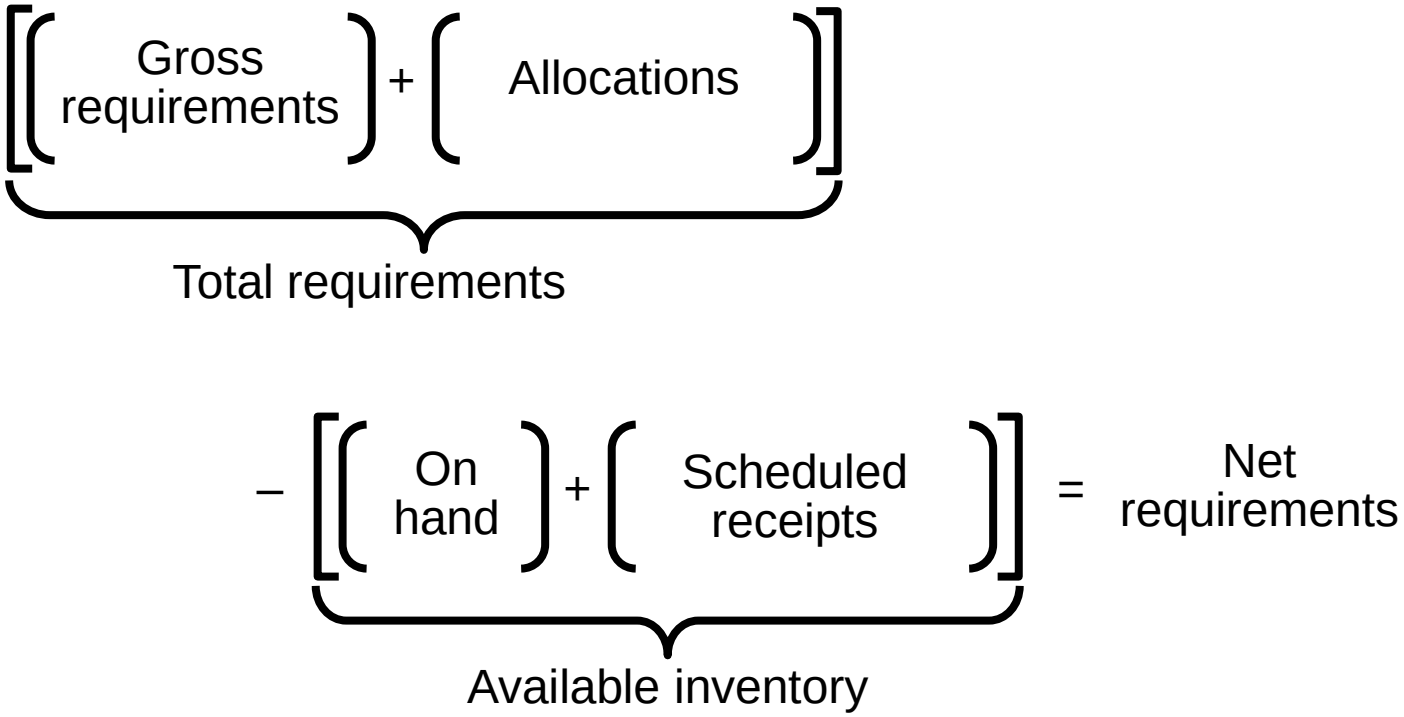
Gross Requirements Schedule

Figure 14.5



Net Requirements Plan

The logic of net requirements



MRP Planning Sheet

Lot Size	Lead Time	On Hand	Safety Stock	Allocated	Low-Level Code	Item ID
Lot For Lot	1	0	0	10	0	Z

	Period							
	1	2	3	4	5	6	7	8
Gross Requirements								~~80~~ 90
Scheduled Receipts								0
Projected On Hand 0	0	0	0	0	0	0	0	0
Net Requirements								90
Planned Order Receipts								90
Planned Order Releases							90	

Figure 14.6

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 dynamics
  - 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 Management

- MRP limitations
  - MRP does not do detailed scheduling–it plans
  - Works best in product-focused, repetitive environments
  - Requires fixed lead time and infinite size time **buckets**

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

- **Periodic order quantity** (POQ) orders quantity needed for a predetermined time period
  - Interval = EOQ / average demand per period
  - Order quantity set to cover the interval
  - Order quantity calculated when order is released
  - No extra inventory

Lot-Sizing Techniques

- Dynamic lot sizing techniques
  - Balance lot size and setup costs
  - Part period balancing (least total cost)
  - Least unit cost
  - Least period cost (Silver-Meal)
- Dynamic programming approach
  - Wagner-Whitin

Lot-for-Lot Example

WEEK		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	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

Lot for Lot Example

No on-hand inventory is carried through the system
Total holding cost = $0

There are seven setups for this item in this plan
Total ordering cost = 7 x $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

WEEK		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	39
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 Size Example

Annual demand D = 1,404
Holding cost = 375 units x $1 (including 57 units on hand at end of week 10)
Ordering cost = 4 x $100 = $400
Total cost = $375 + $400 = $775

Projected on hand	35	35	0	43	3	3	66	26	69	69	39
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

POQ Lot Size Example

WEEK		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	40	0	0	70	30	0	0	55
Net requirements		0	30	0	0	10	0		0	55	0
Planned order receipts			70			80		0		85	0
Planned order releases		70			80				85		

EOQ = 73 units; Average weekly gross requirements = 27;
POQ interval = 73/27 ≅ 3 weeks

POQ Lot Size Example

Setups = 3 x $100 = $300
Holding cost = (40 + 70 + 30 + 55) units x $1 = $195
Total cost = $300 + $195 = $495

Projected on hand	35	35	0	40	0	0	70	30	0	0	55
Net requirements		0	30	0	0	10	0		0	55	0
Planned order receipts			70			80		0		85	0
Planned order releases		70			80				85		

EOQ = 73 units; Average weekly gross requirements = 27;
POQ interval = 73/27 ≅ 3 weeks

Lot-Sizing Summary

For these three examples

	COSTS		
	SETUP	HOLDING	TOTAL
Lot-for-lot	$700	$0	$700
EOQ	$400	$375	$775
POQ	$300	$195	$495

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 setups 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, POQ or EOQ should give reasonable results

Extensions of MRP

- MRP II
- Closed-Loop MRP
- Capacity Planning

Material Requirements Planning II

- Requirement data can be enriched by other resources
- Generally called **MRP II** or Material Resource Planning
- Outputs can include scrap, packaging waste, effluent, carbon emissions

- Data used by purchasing, production scheduling, capacity planning, inventory, warehouse management

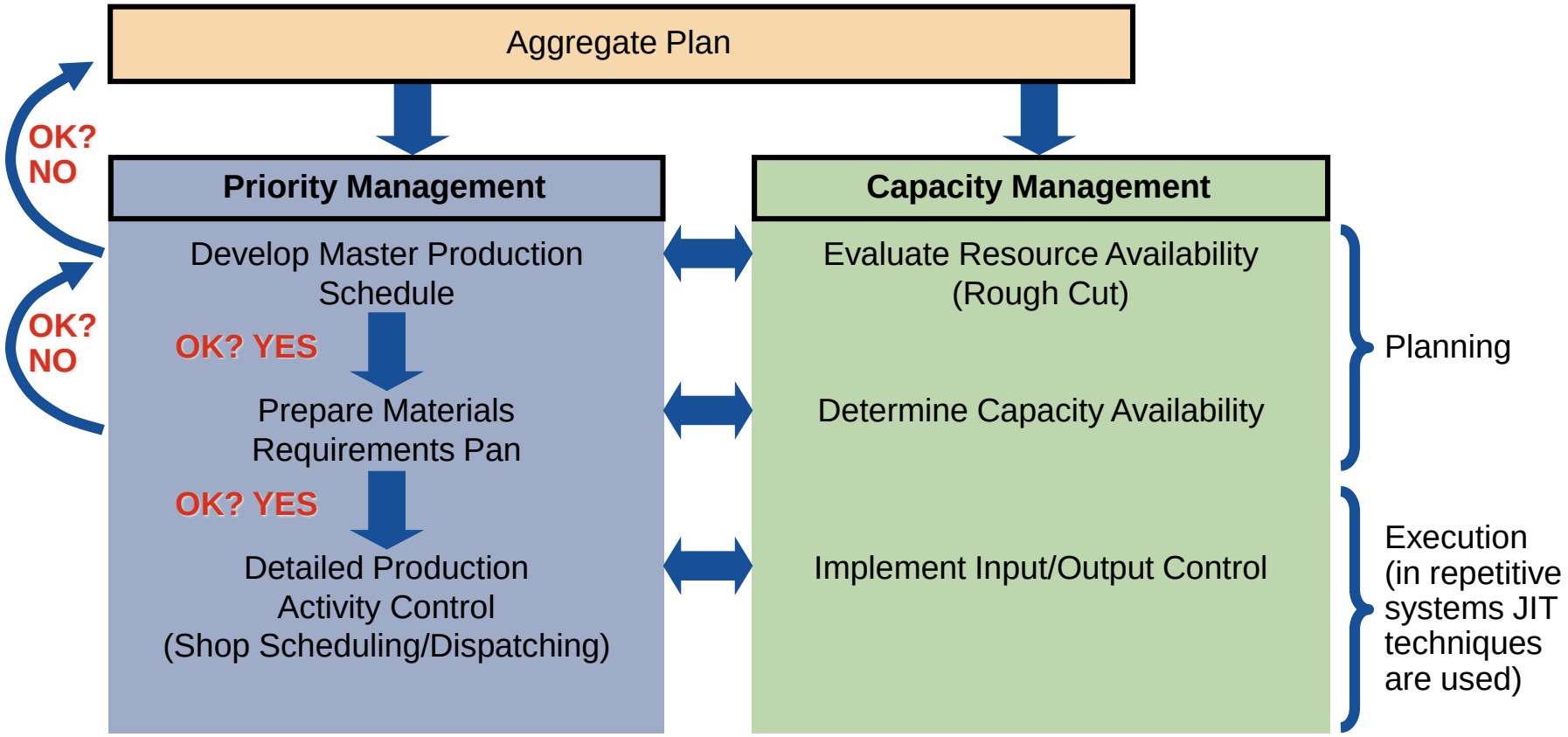
Material Resource Planning

TABLE 14.4 Material Resource Planning (MRP II)

		Weeks			
	LT	5	6	7	8
Computer	1				100
Labor Hrs: .2 each					20
Machine Hrs: .2 each					20
Scrap: 1 ounce fiberglass each					6.25 lb
Payables: $0 each					$0
PC Board (1 each)	2			100	
Labor Hrs: .15 each				15	
Machine Hrs: .1 each				10	
Scrap: .5 ounces copper each				3.125 lb	
Payables: raw material at $5 each				$500	
Processors (5 each)	4	500			
Labor Hrs: .2 each		100			
Machine Hrs: .2 each		100			
Scrap: .01 ounces of acid waste each		0.3125 lb			
Payables: processors at $10 each		$5,000			

Closed-Loop MRP System

Figure 14.7



Capacity Planning

- Feedback from the MRP system
- **Load reports** show resource requirements for work centers
- Work can be moved between work centers to smooth the load or bring it within capacity

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 earlier (or later) in the schedule

Order Splitting

- Develop a capacity plan for a work cell at Wiz Products
- There are 12 hours available each day
- Each order requires 1 hour

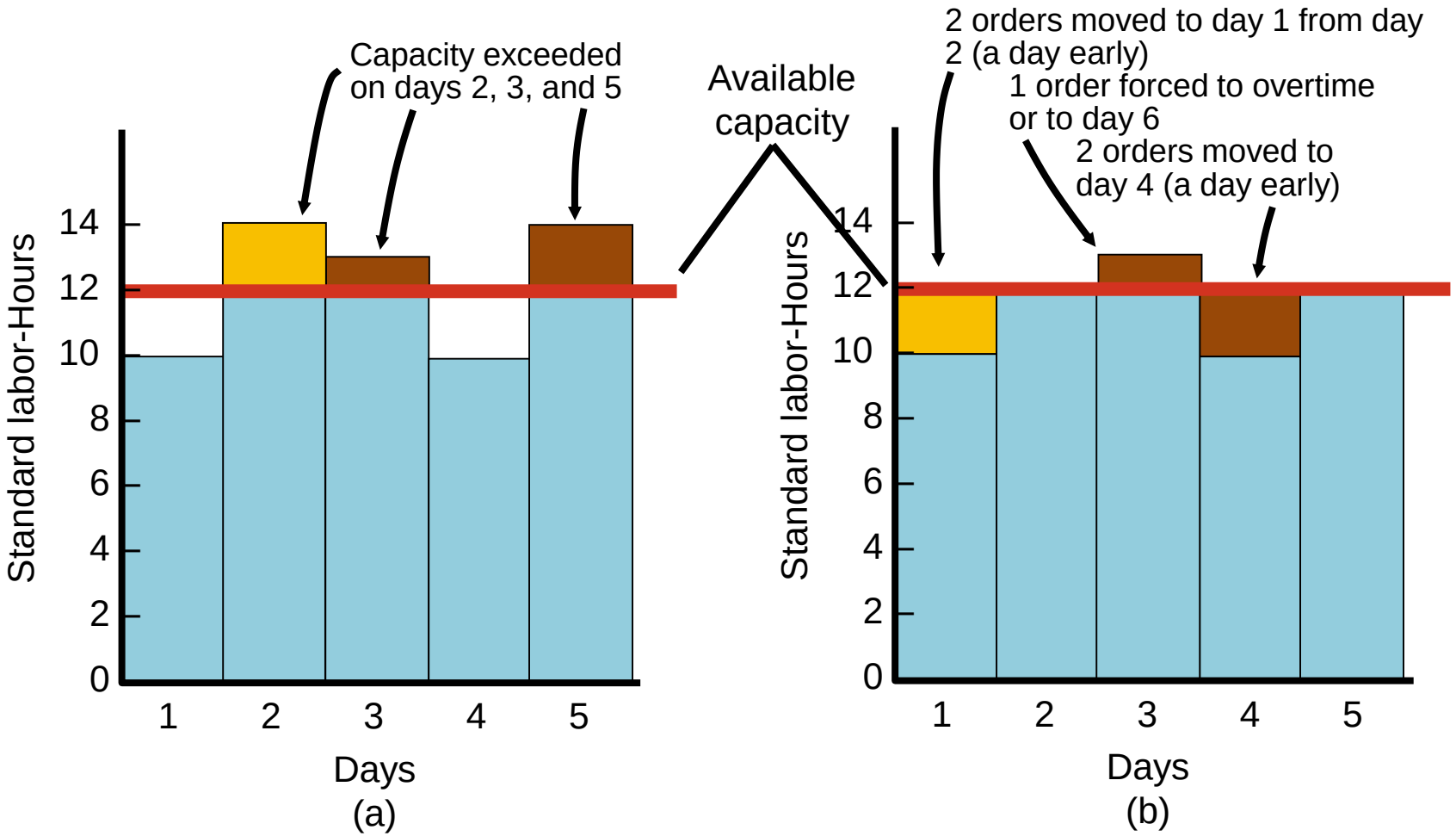
Day	1	2	3	4	5
Orders	10	14	13	10	14

Order Splitting

DAY	UNITS ORDERED	CAPACITY REQUIRED (HOURS)	CAPACITY AVAILABLE (HOURS)	UTILIZATION: OVER/ (UNDER) (HOURS)	PRODUCTION PLANNER'S ACTION	NEW PRODUCTION SCHEDULE
1	10	10	12	(2)		12
2	14	14	12	2	Split order: move 2 units to day 1	12
3	13	13	12	1	Split order: move one unit to day 6 or request overtime	13
4	10	10	12	(2)		12
5	14	14	12	2	Split order: move 2 units to day 4	12
	61					

Order Splitting

Figure 14.8



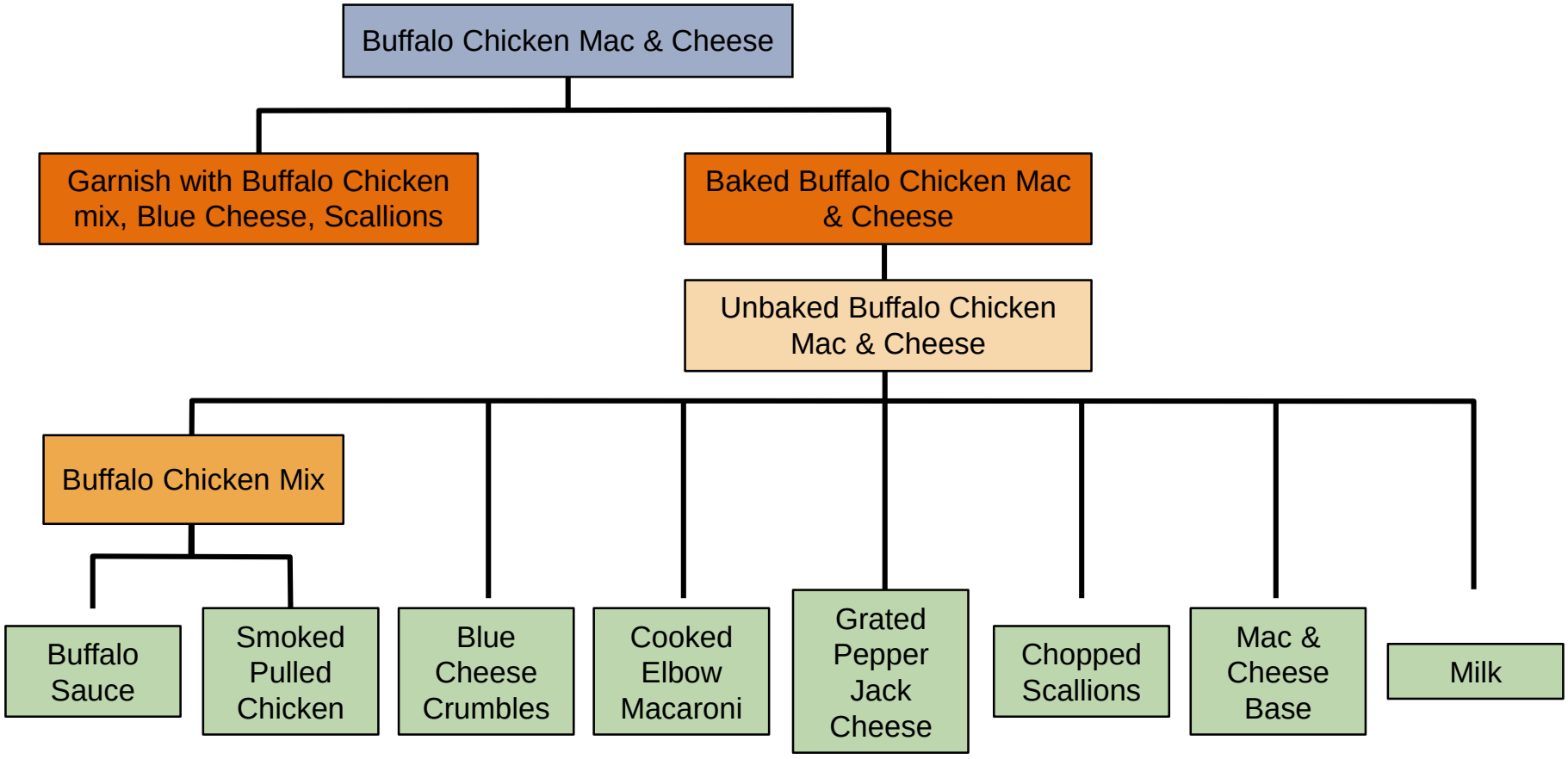
MRP in Services

- 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 14.9



MRP in Services

(b) BILL OF MATERIALS

Production Specifications	**Buffalo Chicken Mac & Cheese (6 portions)**				
Ingredients	*Quantity*	*Measure*	*Unit Cost*	*Total Cost*	*Labor Hrs.*
Elbow Macaroni (large, uncooked)	20.00	oz.	$ 0.09	$ 1.80	
Cheese-Pepper Jack (grated)	10.00	oz.	0.17	1.70	
Mac and Cheese Base (from refrigerator)	32.00	oz.	0.80	25.60	
Milk	4.00	oz.	0.03	0.12	
Smoked Pulled Chicken	2.00	lb.	2.90	5.80	
Buffalo Sauce	8.00	oz.	0.09	0.72	
Blue Cheese Crumbles	4.00	oz.	0.19	0.76	
Scallions	2.00	oz.	0.18	0.36	
					0.2 hrs

Distribution Resource Planning (DRP)

Using dependent demand techniques through the supply chain

- Expected demand or sales forecasts become gross requirements
- All other levels are computed
- DRP pulls inventory through the system
- Small and frequent replenishments

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)
  - Sustainability

Figure 14.10

ERP and MRP

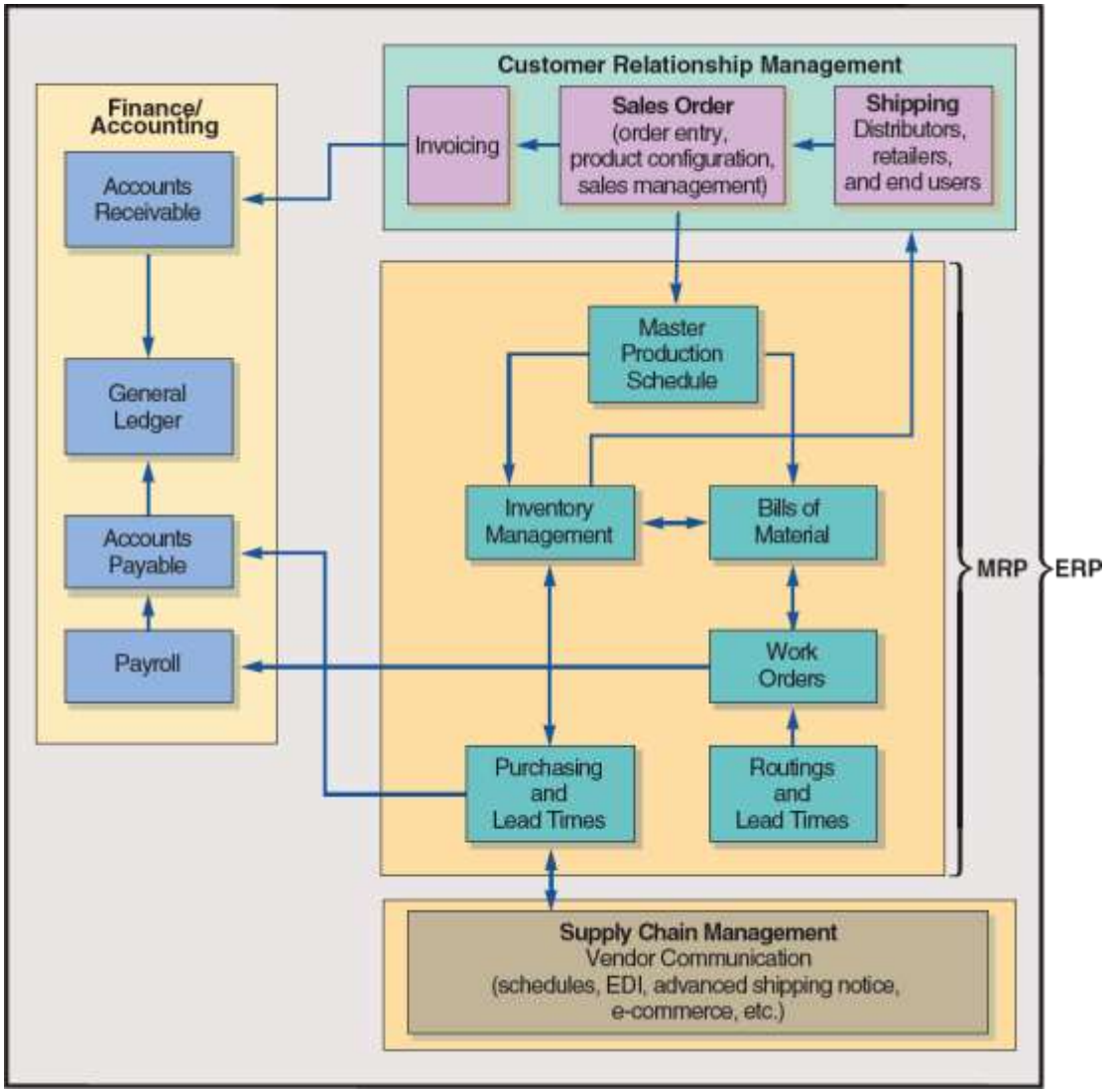
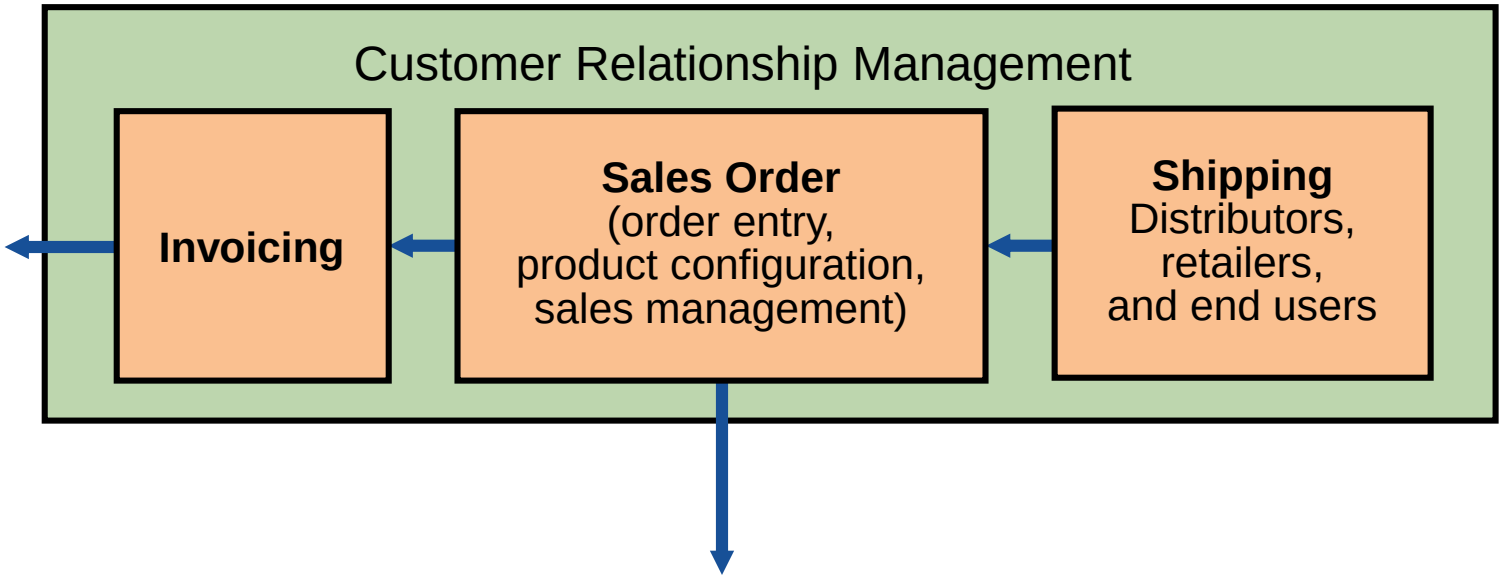
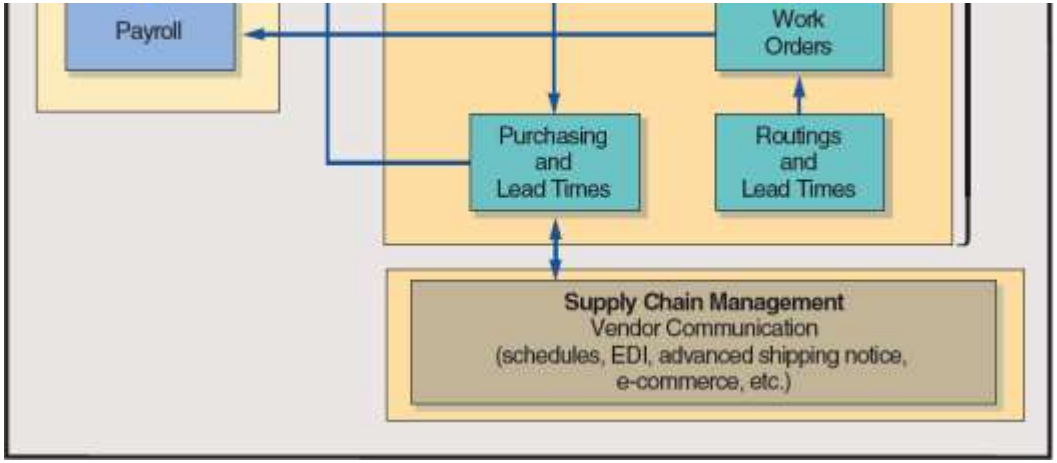


Figure 14.10

ERP and MRP





ERP and MRP

Figure 14.10

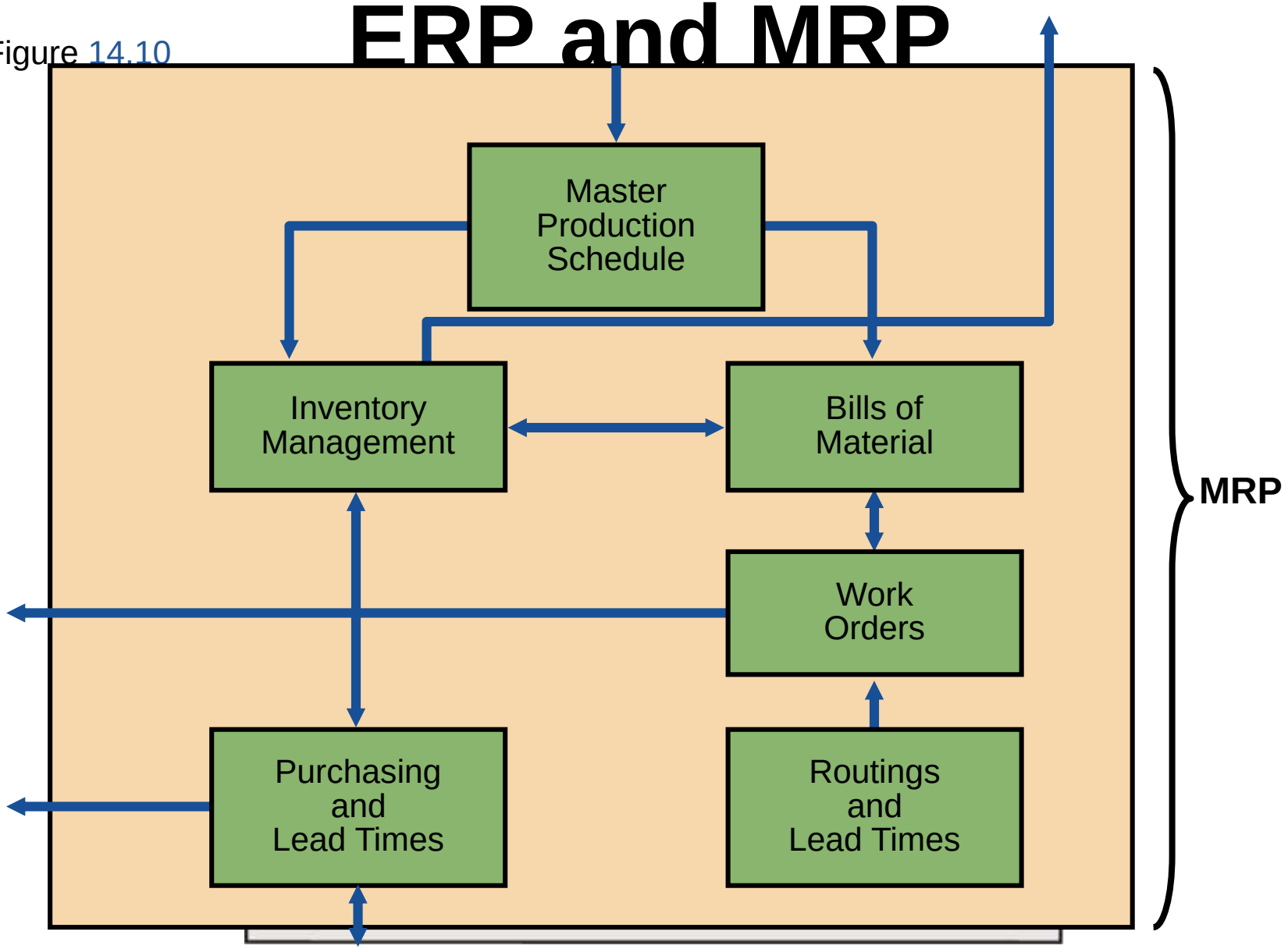
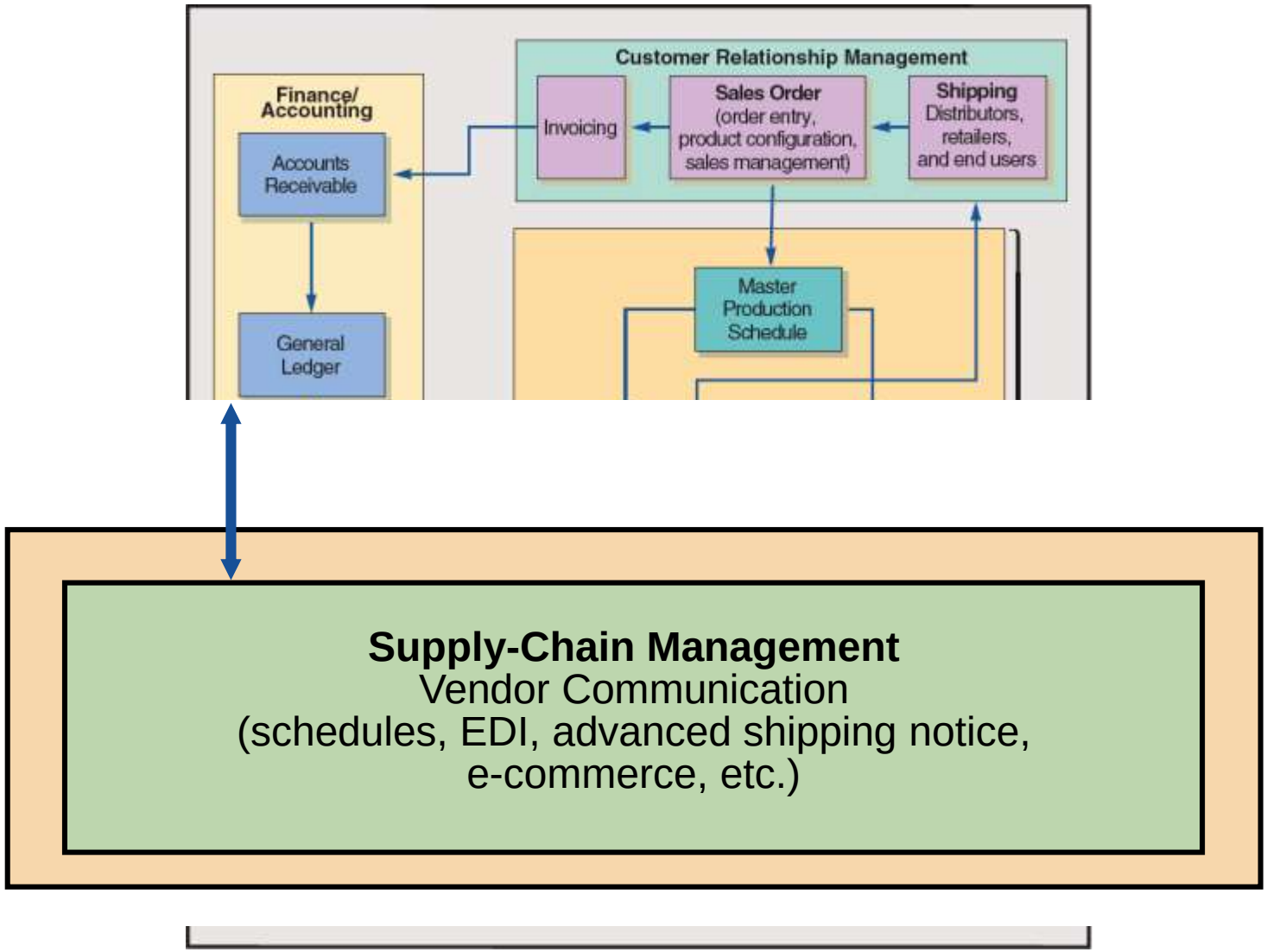


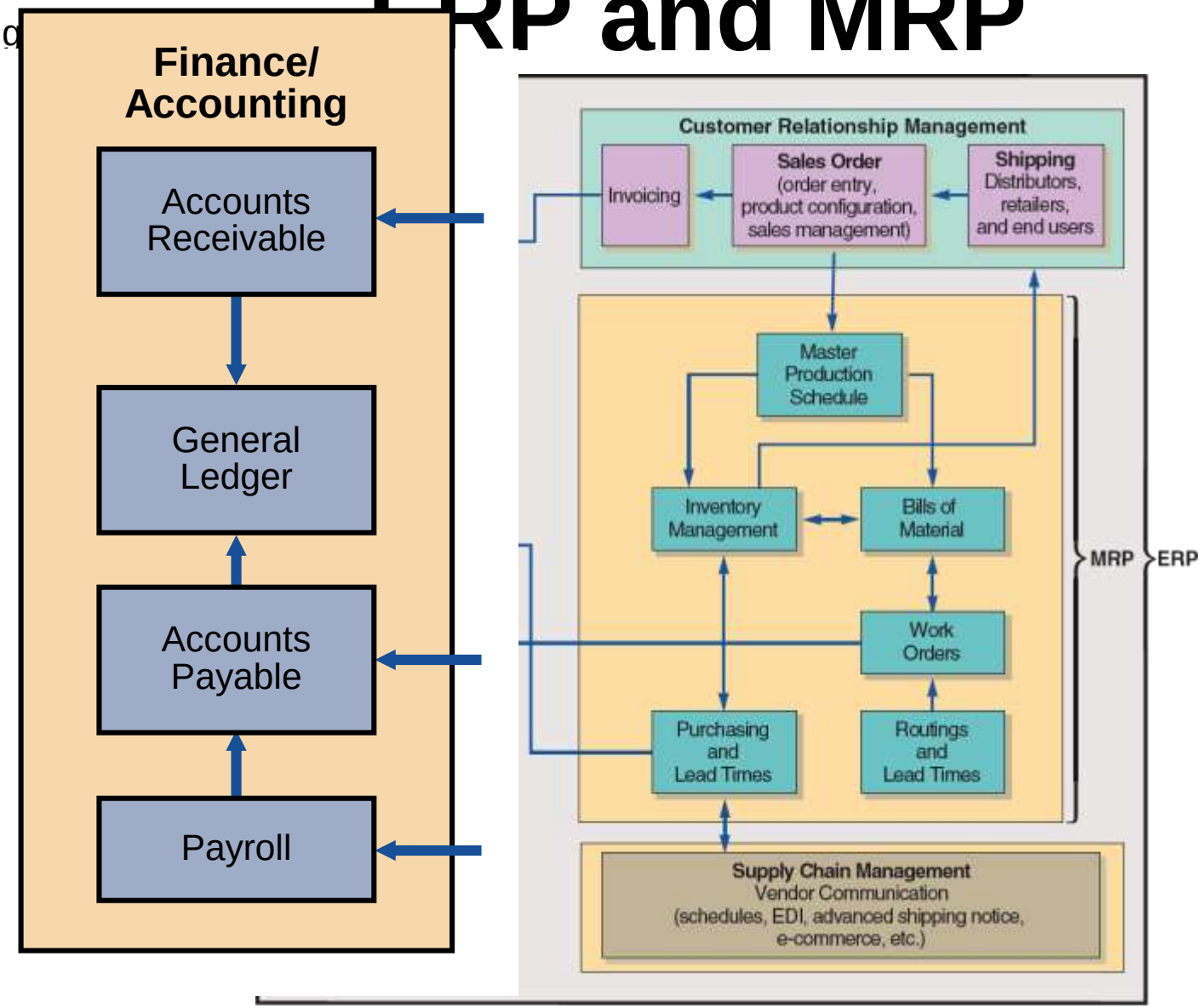
Figure 14.10

ERP and MRP



ERP and MRP

Fig



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 supply chain integration
- Can be expensive and time-consuming to install

SAP's ERP Modules

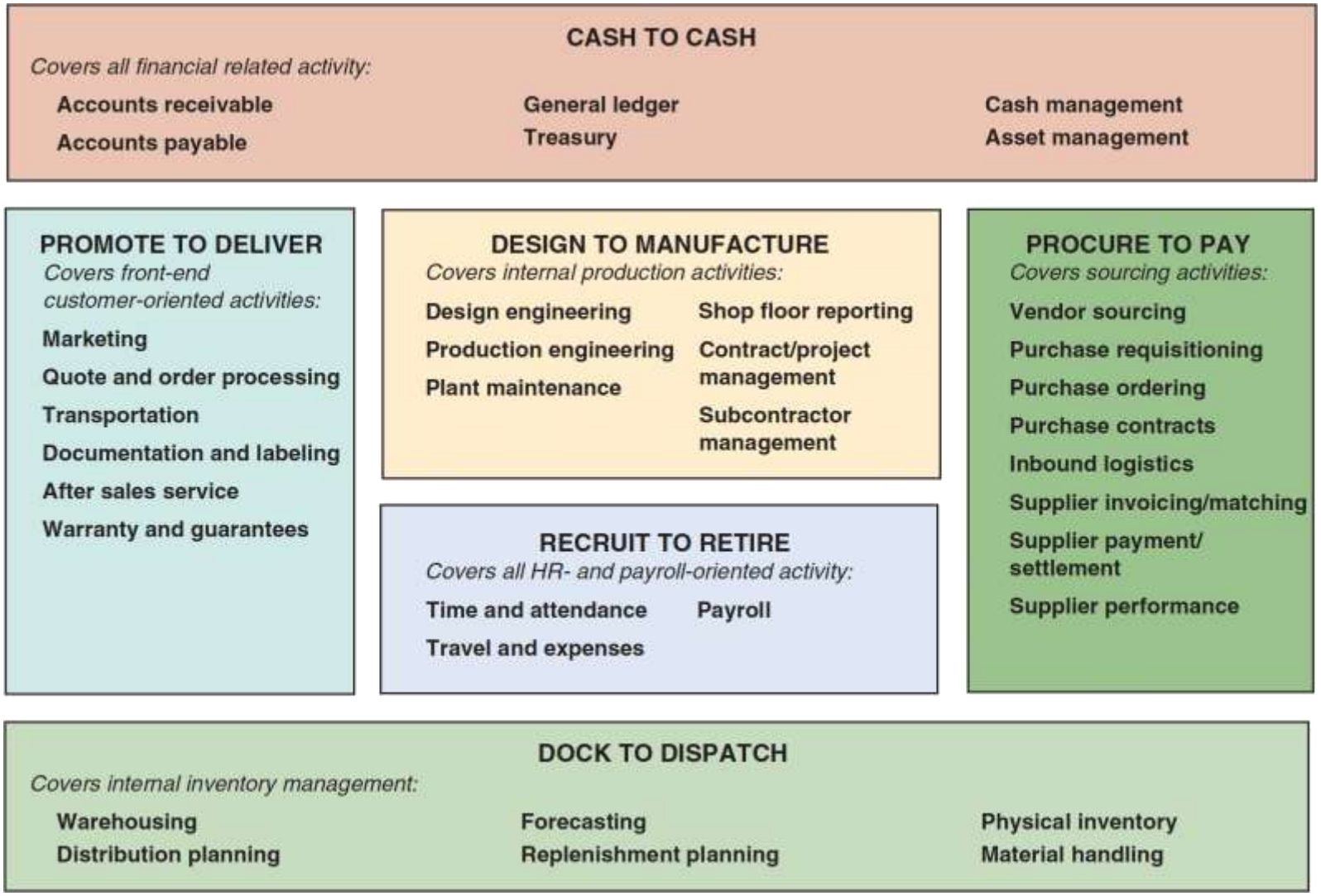


Figure 14.11

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