Sales and Capacity Planning

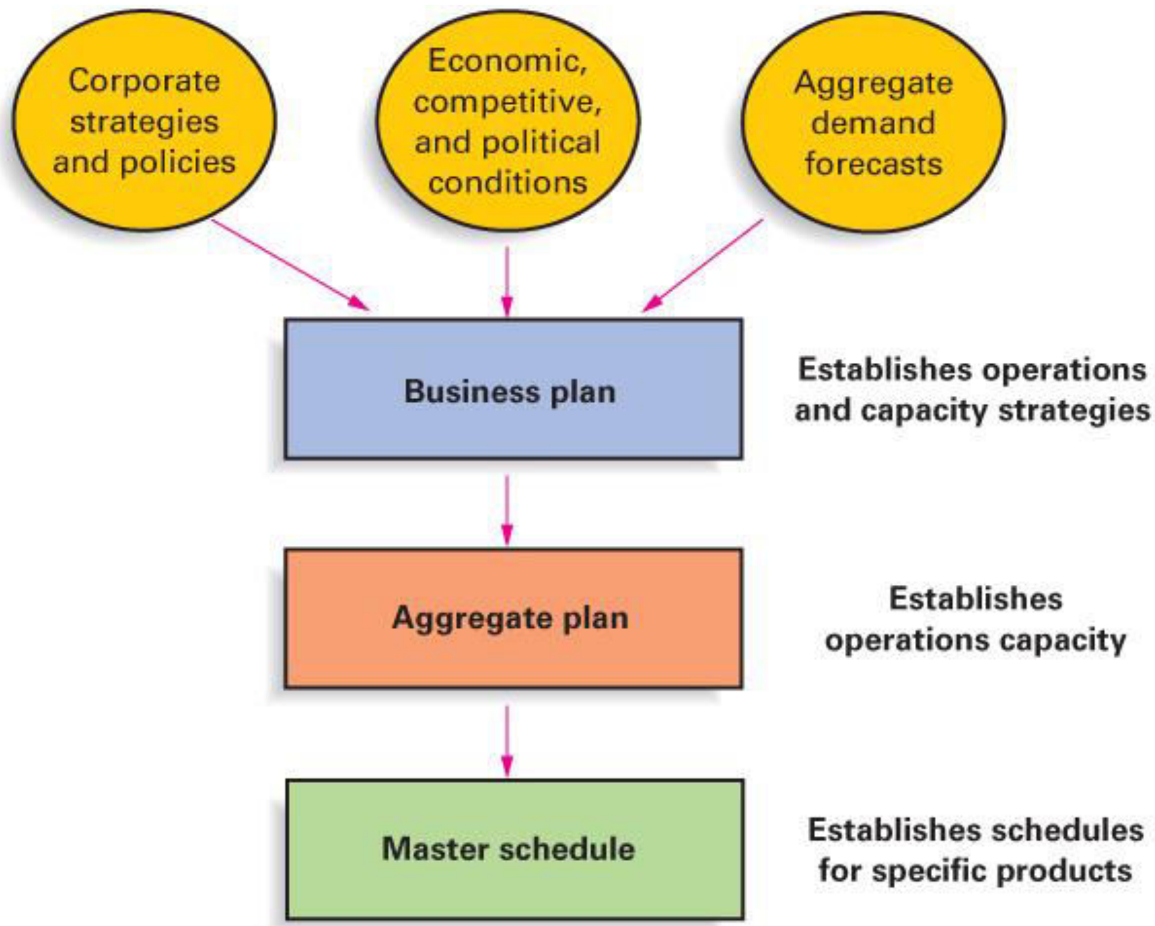
Lecture Outline

- **The Sales and Operations Planning Process**
- Strategies for Adjusting Capacity
- Strategies for Managing Demand
- Quantitative Techniques for Aggregate Planning
- Hierarchical Nature of Planning
- Aggregate Planning for Services

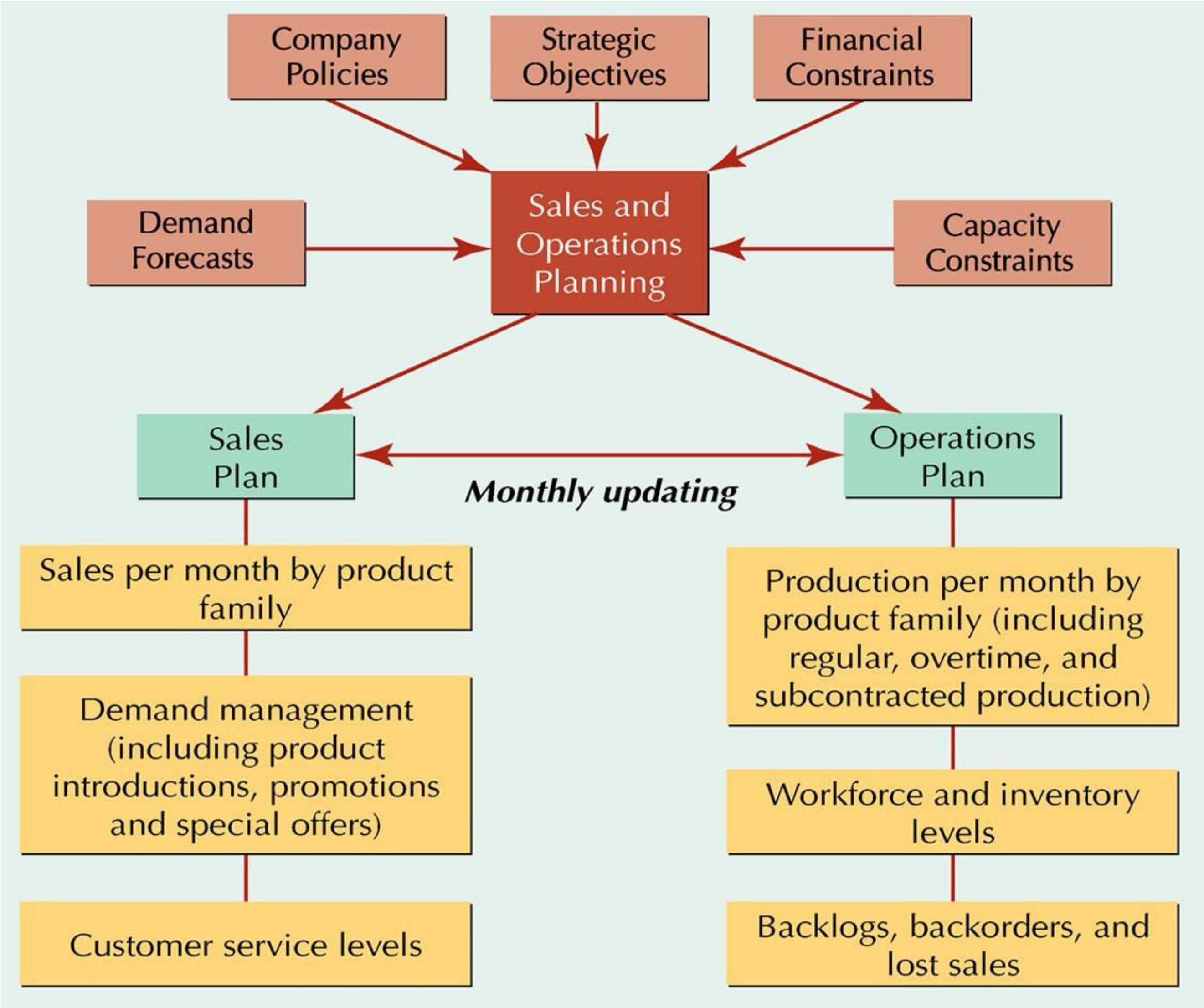
Sales and Operations Planning

- Determines resource capacity to meet demand over an intermediate time horizon
  - *Aggregate* refers to sales and operations planning for product lines or families
  - *Sales and Operations planning (S&OP)* matches supply and demand
- Objectives
  - Establish a company wide plan for allocating resources
  - Develop an economic strategy for meeting demand

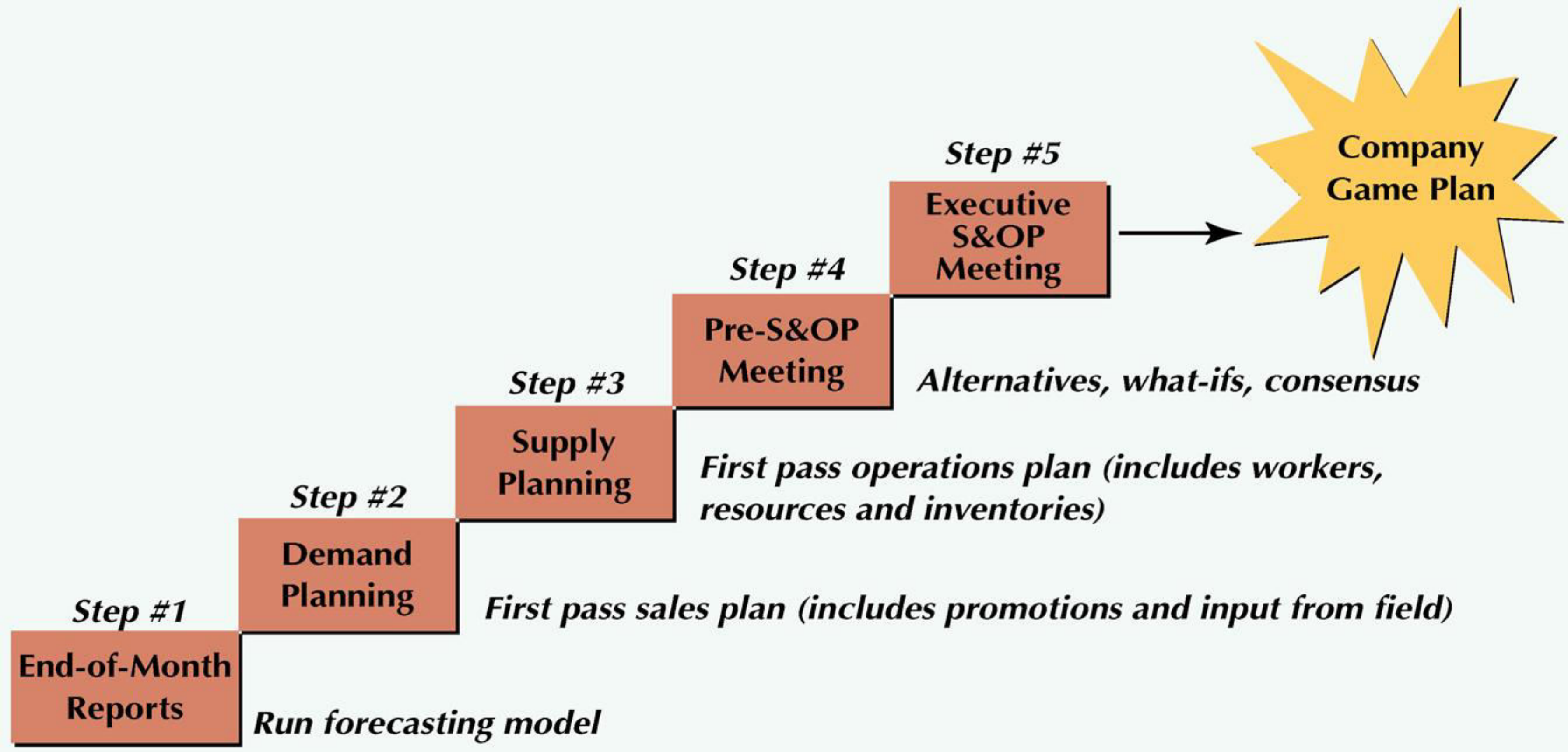
The Planning Sequence



Sales and Operations Planning Process



Monthly S&OP Planning Process



Lecture Outline

- The Sales and Operations Planning Process
- **Meeting Demand**
  - **Strategies for Adjusting Capacity**
  - Strategies for Managing Demand
- Quantitative Techniques for Aggregate Planning
- Hierarchical Nature of Planning
- Aggregate Planning for Services

Meeting Demand Strategies

- Adjusting capacity
  - Resources to meet demand are acquired and maintained over the time horizon of the plan
  - Minor variations in demand are handled with overtime or under-time
- Managing demand
  - Proactive demand management

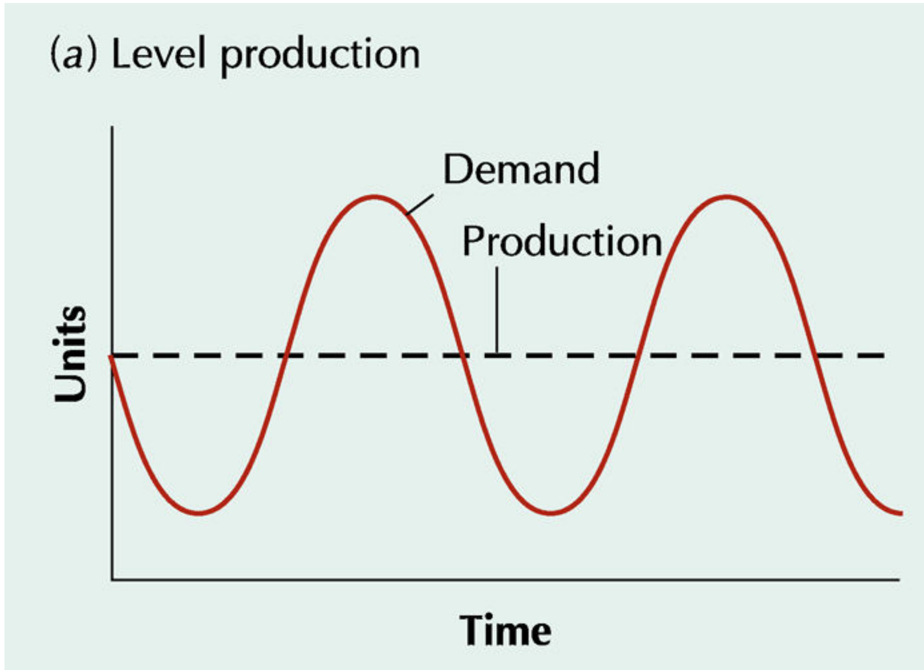
Strategies for Adjusting Capacity

- Level production
  - Producing at a constant rate and using inventory to absorb fluctuations in demand
- Chase demand
  - Hiring and firing workers to match demand
- Peak demand
  - Maintaining resources for high-demand levels

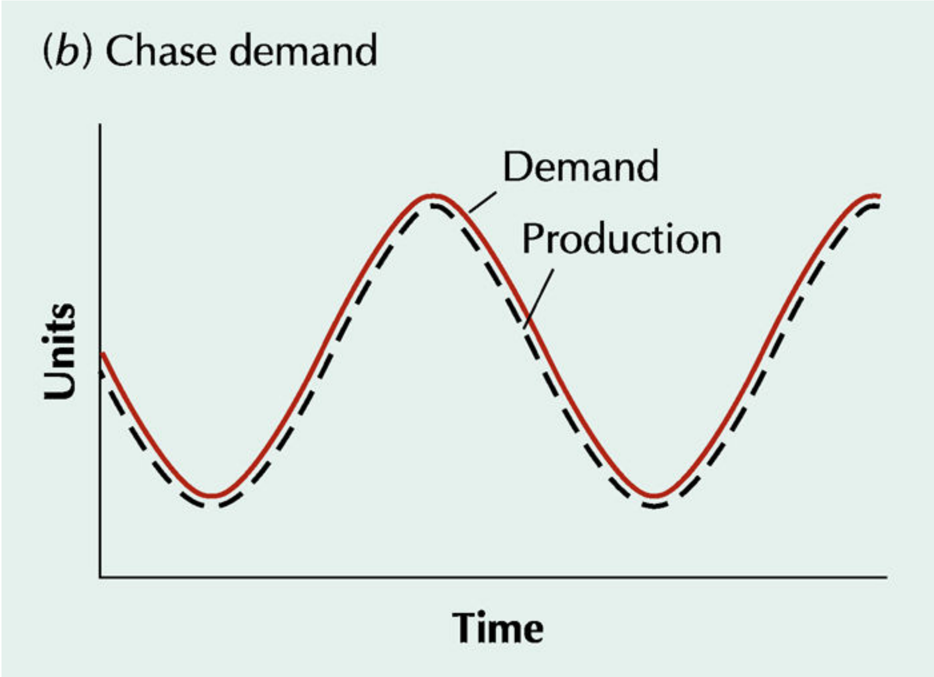
Strategies for Adjusting Capacity

- Overtime and under-time
  - Increase or decrease working hours
- Subcontracting
  - Let outside companies complete the work
- Part-time workers
  - Hire part-time workers to complete the work
- Backordering
  - Provide the service or product at a later time period

Level Production



Chase Demand



Lecture Outline

- The Sales and Operations Planning Process
- Meeting Demand
  - Strategies for Adjusting Capacity
  - **Strategies for Managing Demand**
- Quantitative Techniques for Aggregate Planning
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Strategies for Managing Demand

- Shifting demand into other time periods
  - Incentives
  - Sales promotions
  - Advertising campaigns
- Offering products or services with counter-cyclical demand patterns
- Partnering with suppliers to reduce information distortion along the supply chain

Lecture Outline

- The Sales and Operations Planning Process
- Meeting Demand
  - Strategies for Adjusting Capacity
  - Strategies for Managing Demand
- **Quantitative Techniques for Aggregate Planning**
- Hierarchical Nature of Planning
- Aggregate Planning for Services

Quantitative Techniques For AP

- Pure Strategies
- Mixed Strategies
- Linear Programming
- Transportation Method
- Other Quantitative Techniques

Pure Strategies

QUARTER	SALES FORECAST (LB)
Spring	80,000
Summer	50,000
Fall	120,000
Winter	150,000

Hiring cost	= $100 per worker
Firing cost	= $500 per worker
Inventory carrying cost	= $0.50 pound per quarter
Regular production cost per pound	= $2.00
Production per employee	= 1,000 pounds per quarter
Beginning work force	= 100 workers

Level Production Strategy

Level production

QUARTER	SALES FORECAST	PRODUCTION PLAN	INVENTORY
Spring	80,000		
Summer	50,000		
Fall	120,000		
Winter	150,000		

Cost of Level Production Strategy

Level Production Strategy

Level production

$$\frac{(50{,}000 + 120{,}000 + 150{,}000 + 80{,}000)}{4} = 100{,}000 \text{ pounds}$$

QUARTER	SALES FORECAST	PRODUCTION PLAN	INVENTORY
Spring	80,000	100,000	20,000
Summer	50,000	100,000	70,000
Fall	120,000	100,000	50,000
Winter	150,000	100,000	0
		400,000	140,000

Cost of Level Production Strategy

(400,000 X \$2.00) + (140,00 X \$.50) = \$870,000

Chase Demand Strategy

QUARTER	SALES FORECAST	PRODUCTION PLAN	WORKERS NEEDED	WORKERS HIRED	WORKERS FIRED
Spring	80,000				
Summer	50,000				
Fall	120,000				
Winter	150,000				

Cost of Chase Demand Strategy

Chase Demand Strategy

QUARTER	SALES FORECAST	PRODUCTION PLAN	WORKERS NEEDED	WORKERS HIRED	WORKERS FIRED
Spring	80,000	80,000	80	0	20
Summer	50,000	50,000	50	0	30
Fall	120,000	120,000	120	70	0
Winter	150,000	150,000	150	30	0
				100	50

Cost of Chase Demand Strategy

(400,000 X \$2.00) + (100 x \$100) + (50 x \$500) = \$835,000

Level Production with Excel

Exhibit 14

F12 =F11+E12-D12

	A	B	C	D	E	F	G
1							
2							
3		**Example 14.1a - Level Production**				***Cost***	**$870,000**
4							
5		**Beg Wkforce**	**100**	**Prod. Cost**	**$2.00**	**Firing cost**	**$500**
6		**Units/wker**	**1000**	**Inv. Cost**	**$0.50**	**Hiring cost**	**$100**
7		**Beg Inv.**	**0**				
8							
9							
10			***Quarter***	***Demand***	***Production***	***Inventory***	
11			**Spring**	**80,000**	**100,000**	**20,000**	
12			**Summer**	**50,000**	**100,000**	**70,000**	
13			**Fall**	**120,000**	**100,000**	**50,000**	
14			**Winter**	**150,000**	**100,000**	**0**	
15			***Total***	**400,000**	**400,000**	**140,000**	

Cost of level production = inventory costs + production costs

Input by user =400,000/4

Inventory at end of summer

Chase Demand with Excel

Exhibit 14.1

F13 `=IF(E13-E12<0,0,E13-E12)`

No. of workers hired in fall

Example 14.1b - Chase Demand				***Cost***	**$835,000**
Beg Wkforce	**100**	**Prod. Cost**	**$2.00**	**Firing cost**	**$500**
Units/wker	**1000**	**Inv. Cost**	**$0.50**	**Hiring cost**	**$100**
Beg Inv.	**0**				
Quarter	***Demand***	***Production***	***Workers Needed***	***Workers Hired***	***Workers Fired***
Spring	**80,000**	**80,000**	**80**	**0**	**20**
Summer	**50,000**	**50,000**	**50**	**0**	**30**
Fall	**120,000**	**120,000**	**120**	**70**	**0**
Winter	**150,000**	**150,000**	**150**	**30**	**0**
Total	**400,000**	**400,000**		**100**	**50**

Workforce requirements calculated by system

Production input by user; production =demand

Cost of chase demand = hiring + firing + production

Mixed Strategy

- Combination of Level Production and Chase Demand strategies
- Example policies
  - no more than *x*% of workforce can be laid off in one quarter
  - inventory levels cannot exceed *x* dollars
- Some industries may shut down manufacturing during the low demand season and schedule employee vacations during that time

General Linear Programming (LP) Model

- LP gives an optimal solution, but demand and costs must be linear
- *Let*
  - W_t = workforce size for period t
  - P_t =units produced in period t
  - I_t =units in inventory at the end of period t
  - F_t =number of workers fired for period t
  - H_t = number of workers hired for period t

LP MODEL

$$\text{Minimize } Z = \$100\,(H_1 + H_2 + H_3 + H_4) + \$500\,(F_1 + F_2 + F_3 + F_4) + \$0.50\,(I_1 + I_2 + I_3 + I_4) + \$2\,(P_1 + P_2 + P_3 + P_4)$$

Subject to

Demand constraints

$$P_1 - I_1 = 80{,}000 \quad (1)$$
$$I_1 + P_2 - I_2 = 50{,}000 \quad (2)$$
$$I_2 + P_3 - I_3 = 120{,}000 \quad (3)$$
$$I_3 + P_4 - I_4 = 150{,}000 \quad (4)$$

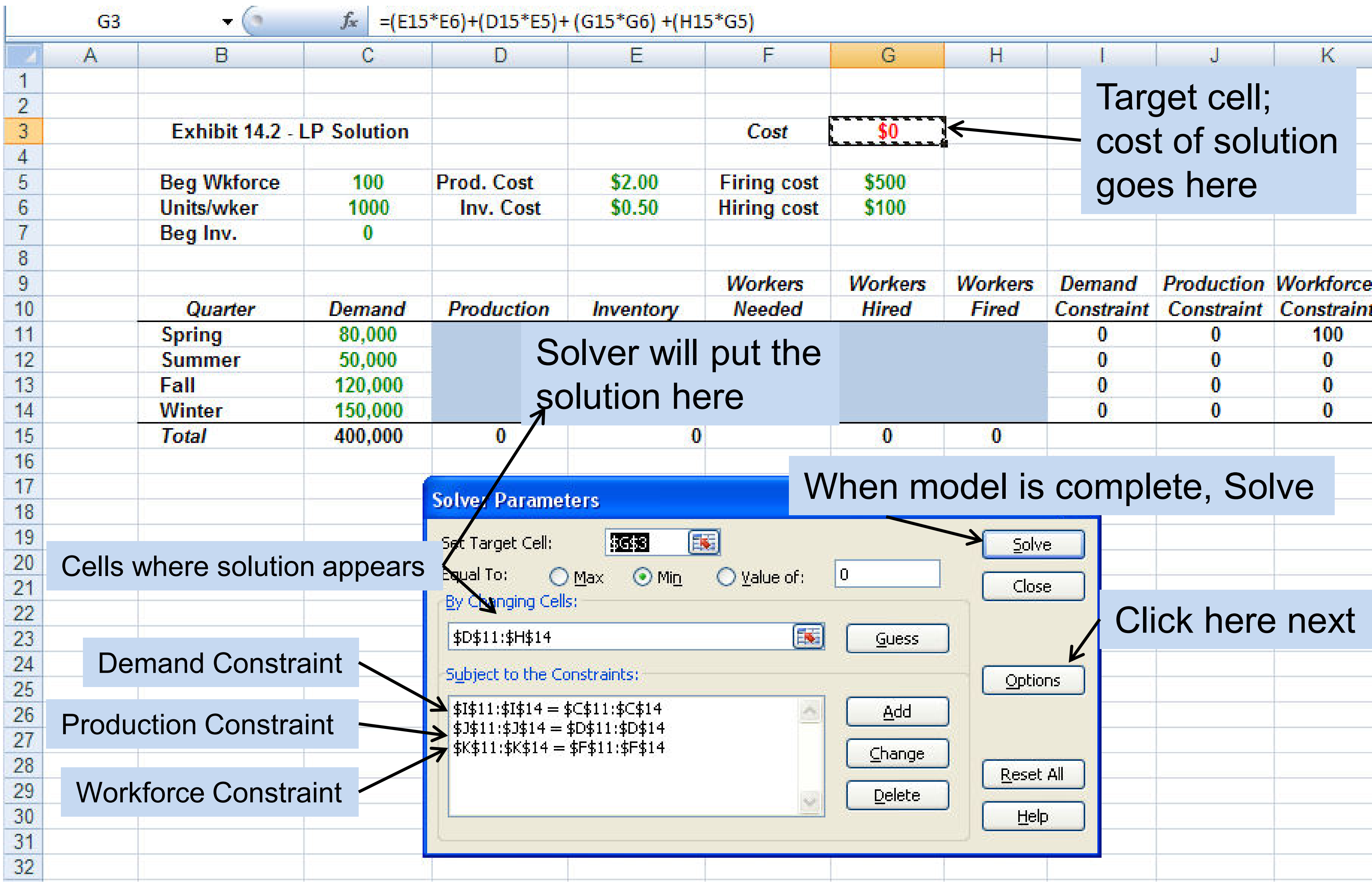
Production constraints

$$1000\,W_1 = P_1 \quad (5)$$
$$1000\,W_2 = P_2 \quad (6)$$
$$1000\,W_3 = P_3 \quad (7)$$
$$1000\,W_4 = P_4 \quad (8)$$

Work force constraints

$$100 + H_1 - F_1 = W_1 \quad (9)$$
$$W_1 + H_2 - F_2 = W_2 \quad (10)$$
$$W_2 + H_3 - F_3 = W_3 \quad (11)$$
$$W_3 + H_4 - F_4 = W_4 \quad (12)$$

Setting up the Spreadsheet



G3 =(E15*E6)+(D15*E5)+ (G15*G6) +(H15*G5)

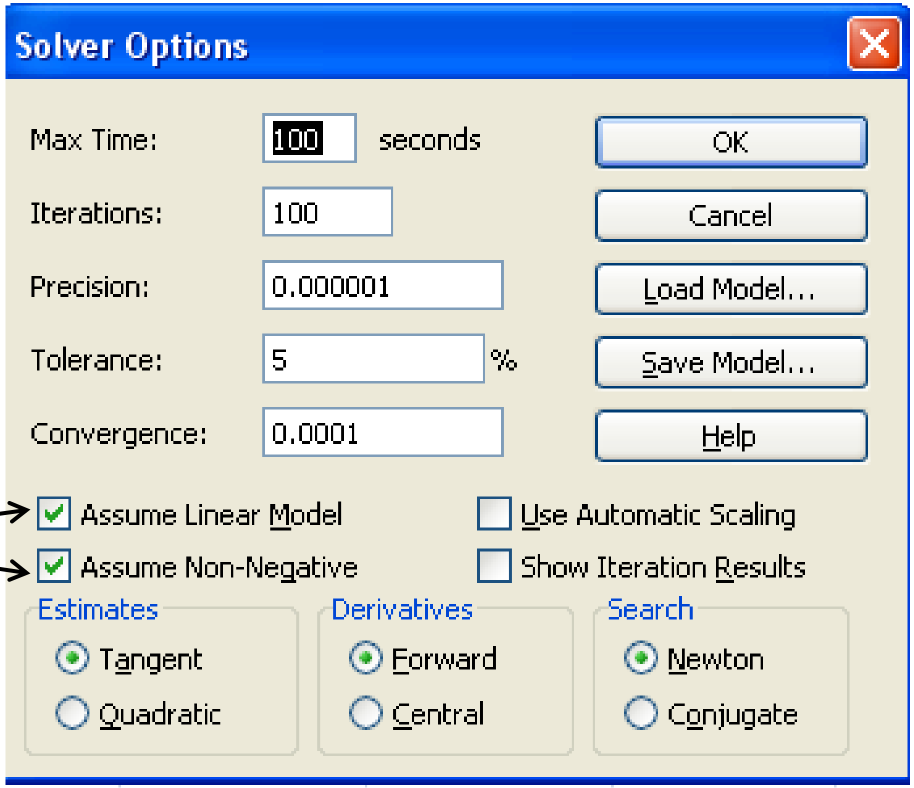
Exhibit 14.2 - LP Solution Cost $0

Beg Wkforce	100	Prod. Cost	$2.00	Firing cost	$500		
Units/wker	1000	Inv. Cost	$0.50	Hiring cost	$100		
Beg Inv.	0						

Quarter	Demand	Production	Inventory	Workers Needed	Workers Hired	Workers Fired	Demand Constraint	Production Constraint	Workforce Constraint
Spring	80,000						0	0	100
Summer	50,000						0	0	0
Fall	120,000						0	0	0
Winter	150,000						0	0	0
Total	400,000	0	0		0	0			

Setting up the Spreadsheet

Click these boxes



The LP Solution

G3 =(E15*E6)+(D15*E5)+ (G15*G6) +(H15*G5)

Cost of optimal solution

Exhibit 14.2 - LP Solution — *Cost* $832,000

Beg Wkforce	100	Prod. Cost	$2.00	Firing cost	$500
Units/wker	1000	Inv. Cost	$0.50	Hiring cost	$100
Beg Inv.	0				

Solution is a mix of inventory, hiring and firing

Quarter	Demand	Production	Inventory	Workers Needed	Workers Hired	Workers Fired	Demand Constraint	Production Constraint	Workforce Constraint
Spring	80,000	80,000	0	80	0	20	80,000	80,000	80
Summer	50,000	80,000	30,000	80	0	0	50,000	80,000	80
Fall	120,000	90,000	0	90	10	0	120,000	90,000	90
Winter	150,000	150,000	0	150	60	0	150,000	150,000	150
Total	400,000	400,000	30,000		70	20			

Optimal production plan

Solver Results

Solver found a solution. All constraints and optimality conditions are satisfied.

- Keep Solver Solution
- Restore Original Values

Reports: Answer, Sensitivity, Limits

OK | Cancel | Save Scenario... | Help

Extra report options

Level Production for Quantum

Example 14.3 (a) - Level Production

Input:	Beg. Wkrs	10	Regular	$10	Hiring	$1,000	
	Units/wkr	100	Overtime	$15	Firing	$500	*Cost:* $146,000
	Beg. Inv.	0	Subk	$25	Inventory	$1	

Month	*Demand*	*Reg*	*OT*	*Subk*	*Inv*	*#Wkrs*	*#Hired*	*#Fired*
Jan	1000	1,000	0	0	0	10	0	0
Feb	400	1,000	0	0	600	10	0	0
Mar	400	1,000	0	0	1,200	10	0	0
Apr	400	1,000	0	0	1,800	10	0	0
May	400	1,000	0	0	2,400	10	0	0
[illegible]	[illegible]	1,000	0	0	3,000	10	0	0
[illegible]	[illegible]	1,000	0	0	3,500	10	0	0
Aug	500	1,000	0	0	4,000	10	0	0
Sept	1000	1,000	0	0	4,000	10	0	0
Oct	1500	1,000	0	0	3,500	10	0	0
Nov	2500	1,000	0	0	2,000	10	0	0
Dec	3000	1,000	0	0	0	10	0	0
Total	12,000	12,000	0	0	26,000		0	0

Cost of level production

Excel calculates these

Input by user

Level = 12,000/12 = 1,000

Chase Demand for Quantum

No. workers hired in Feb.

f_x =MAX(H8-H9,0)

Cost of chase demand

Example 14.3 (b) - Chase Demand

Input:	Beg. Wkrs	10	Regular	$10	Hiring	$1,000		
	Units/wkr	100	Overtime	$15	Firing	$500	*Cost:*	$149,000
	Beg. Inv.	0	Subk	$25	Inventory	$1		

Month	*Demand*	*Reg*	*OT*	*Subk*	*Inv*	*#Wkrs*	*#Hired*	*#Fired*
Jan	1000	1000	0	0	0	10	0	0
Feb	400	400	0	0	0	4	0	6
Mar	400	400	0	0	0	4	0	0
Apr	400	400	0	0	0	4	0	0
May	400	400	0	0	0	4	0	0
[illegible]	[illegible]	400	0	0	0	4	0	0
[illegible]	[illegible]	500	0	0	0	5	1	0
Aug	500	500	0	0	0	5	0	0
Sept	1000	1000	0	0	0	10	5	0
Oct	1500	1500	0	0	0	15	5	0
Nov	2500	2500	0	0	0	25	10	0
Dec	3000	3000	0	0	0	30	5	0
Total	12,000	12,000	0	0	0		26	6

Input by user

Excel calculates these

LP Solution for Quantum

J4 | =SUM((E3*C20)+(E4*D20)+(E5*E20)+(G5*F20)+(G3*H20)+(G4*I20))

	A	B	C	D	E	F	G	H	I	J	K	L
1				**Example 14.3 - LP Model**								
2												
3	***Input:***	Beg. Wkrs	10	Regular	$10	Hiring	$1,000					
4		Units/wkr	100	Overtime	$15	Firing	$500		***Cost:***	$142,500		
5		Beg. Inv.	0	Subk	$25	Inventory	$1					
6										*Demand*	*Production*	*Wkforce*
7	*Month*	*Demand*	*Reg*	*OT*	*Subk*	*Inv*	*#Wkrs*	*#Hired*	*#Fired*	*Constraint*	*Constraint*	*Constraint*
8	Jan	1000	1,000	0	0	0	10	0	0	1,000	1,000	10
9	Feb	400	400	0	0	0	4	0	6	400	400	4
10	Mar	400	400	0	0	0	4	0	0	400	400	4
11	Apr	400	400	0	0	0	4	0	0	400	400	4
12	May	400	400	0	0	0	4	0	0	400	400	4
[illegible]	[illegible]	400	400	0	0	0	4	0	0	400	400	4
[illegible]	[illegible]	500	500	0	0	0	5	1	0	500	500	5
[illegible]	Aug	500	500	0	0	0	5	0	0	500	500	5
16	Sept	1000	2,000	0	0	1,000	20	15	0	1,000	2,000	20
17	Oct	1500	2,000	0	0	1,500	20	0	0	1,500	2,000	20
18	Nov	2500	2,000	0	0	1,000	20	0	0	2,500	2,000	20
19	Dec	3000	2,000	0	0	0	20	0	0	3,000	2,000	20
20	**Total**	**12,000**	**12,000**	**0**	**0**	**3,500**		**16**	**6**			

Optimal solution

Constraint equations in these cells

Solver found this solution

Transportation Method

QUARTER	EXPECTED DEMAND	REGULAR CAPACITY	OVERTIME CAPACITY	SUBCONTRACT CAPACITY
1	900	1000	100	500
2	1500	1200	150	500
3	1600	1300	200	500
4	3000	1300	200	500

Regular production cost	\$20/unit
Overtime production cost	\$25/unit
Subcontracting cost	\$28/unit
Inventory holding cost	\$3/unit-period
Beginning inventory	300 units

Burruss' Production Plan

PERIOD	DEMAND	REGULAR PRODUCTION	OVERTIME	SUB-CONTRACT	ENDING INVENTORY
1	900	1000	100	0	500
2	1500	1200	150	250	600
3	1600	1300	200	500	1000
4	3000	1300	200	500	0
Total	7000	4800	650	1250	2100

Excel and Transportation Method

Exhibit 14.4 [Compatibility M

Home | Insert | Page Layout | Formulas | Data | Review | View | Add-Ins

K28 =K27+SUM(E28:I28)-C28

Exhibit 14.4 - The Transportation Method of Aggregate Planning

		Period of Use								*Units Produced*	*Capacity*	*Unused Capacity*
		1		2		3		4				
		300	0	0	3	0	6		9	300	300	0
		600	20	300	23	100	26		29	1,000	1,000	0
			25	0	28	0	31	100	34	100	100	0
	Subk	0	28	0	31	0	34	0	37	0	500	500
2	Regular	0		1,200							1,200	0
	Overtime	0									150	0
	Subk	0									500	250
3	Regular	0		0		1,300		0		1,300	1,300	0
	Overtime	0		0		200	25	0	28	200	200	0
	Subk	0		0		0	28	500	31	500	500	
4	Regular	0		0		0		1,300	20	1,300	1,300	
	Overtime	0		0		0		200	25	200	200	
	Subk	0		0		0		500	28	500	500	0
	Units Produced	900		1,500		1,600		3,000		7,000	7,000	750
	Demand	900		1,500		1,600		3,000		7,000		
	Unmet Demand	0		0		0		0			Total Cost =	$153,550

There are multiple optimum solutions to this problem.

Production Plan

Period	*Demand*	*Reg. Prod.*	*Overtime*	*Subk*	*Ending Inventory*
1	900	1,000	100	0	500
2	1,500	1,200	150	250	600
3	1,600	1,300	200	500	1,000
4	3,000	1,300	200	500	0
Total	7,000	4,800	650	1,250	2,100

Total Cost = $153,550

Period 2's ending inventory

Regular production for period 1

Cost of solution

Other Quantitative Techniques

- Linear decision rule (LDR)
- Search decision rule (SDR)
- Management coefficients model

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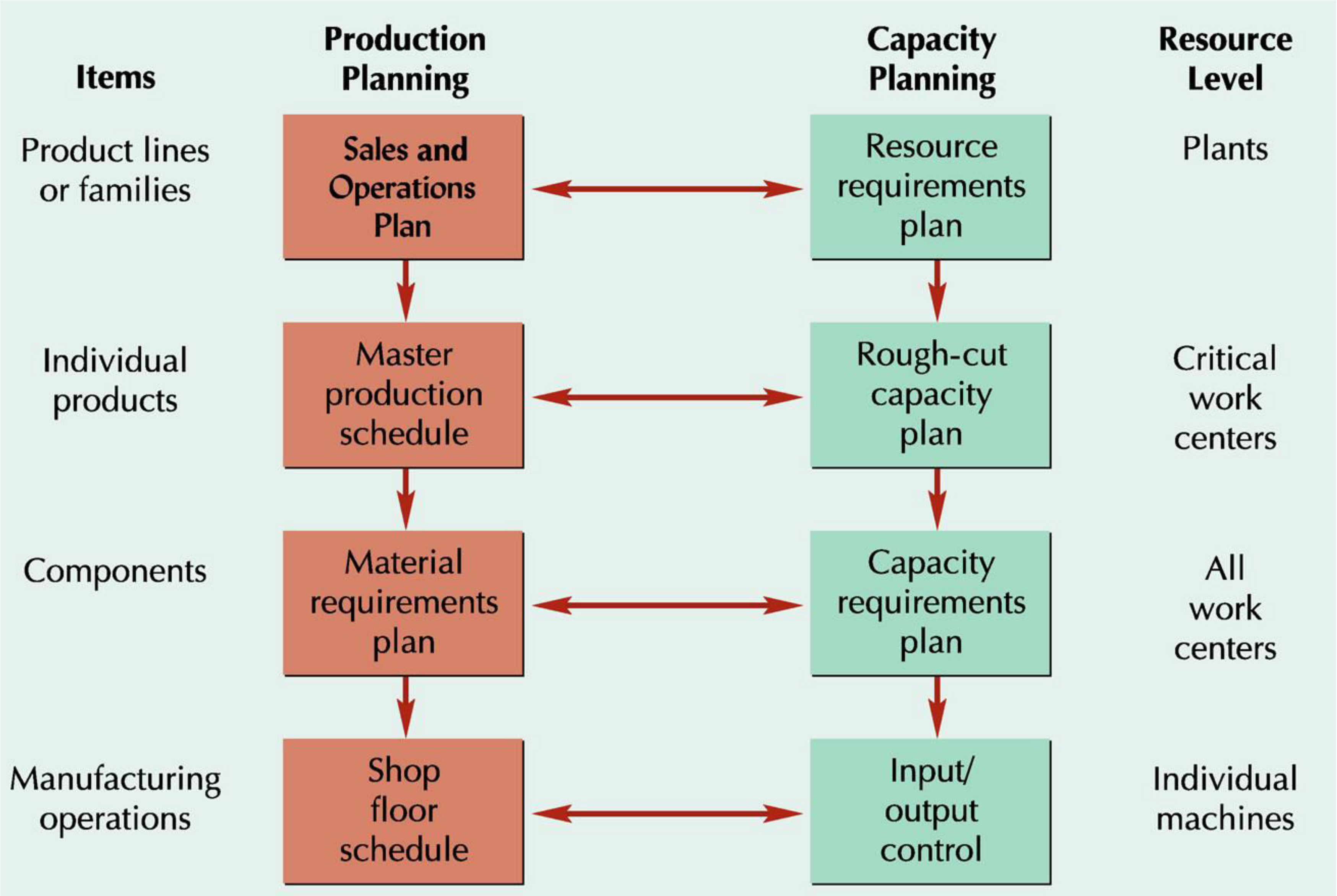
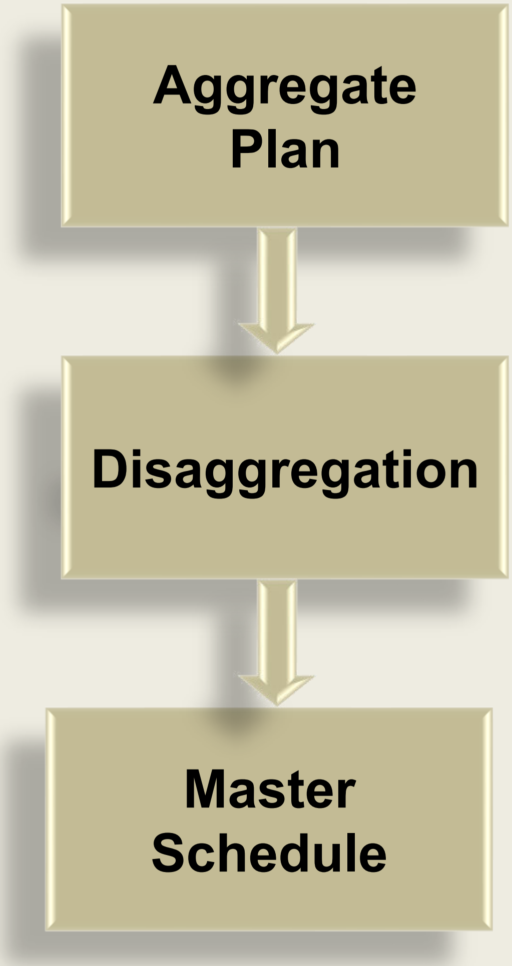
  - Strategies for Managing Demand
- Quantitative Techniques for Aggregate Planning
- **Hierarchical Nature of Planning**
- Aggregate Planning for Services

Hierarchical Nature of Planning



Disaggregation



Disaggregating the Aggregate Plan

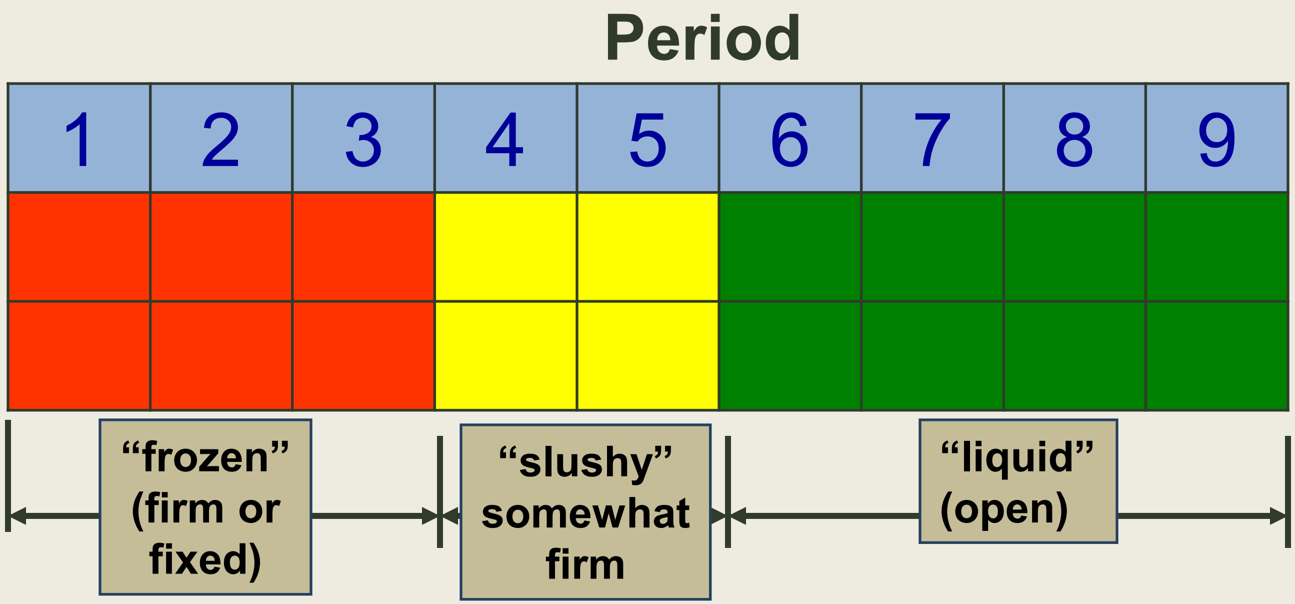
- **Master schedule:**
  - The result of disaggregating an aggregate plan
  - Shows quantity and timing of specific end items for a scheduled horizon

Master Scheduling

- **The heart of production planning and control**
  - It determines the quantity needed to meet demand from all sources
  - It interfaces with
    - Marketing
    - Capacity planning
    - Production planning
    - Distribution planning
  - Provides senior management with the ability to determine whether the business plan and its strategic objectives will be achieved

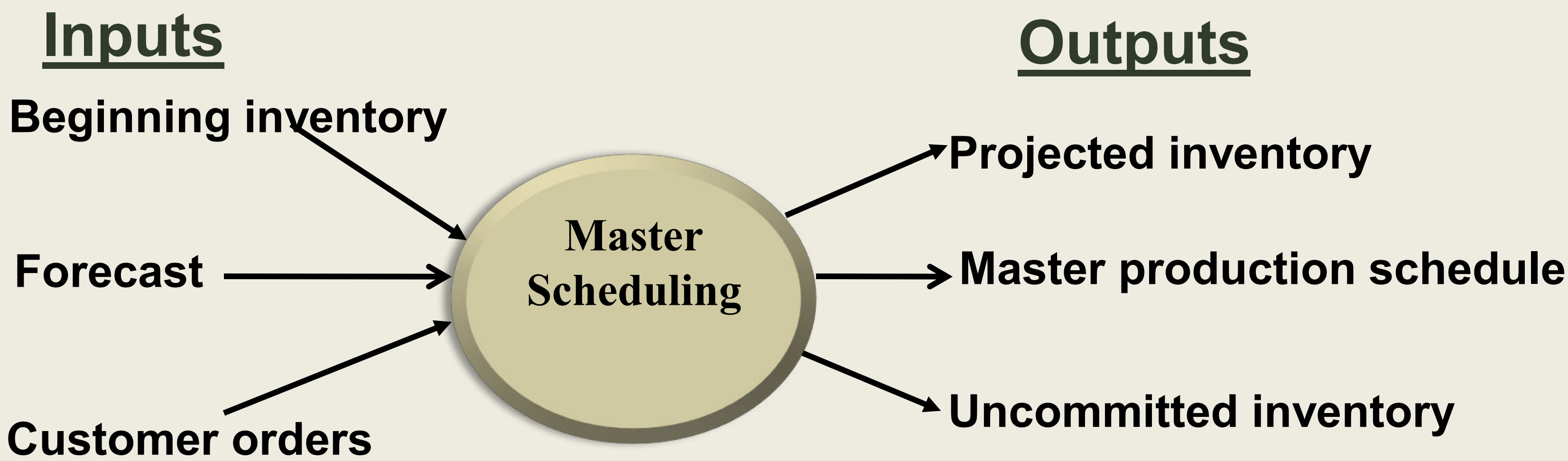
LO 11.7

Time Fences



LO 11.7

The Master Scheduling Process



Master Scheduling Process

- **The master production schedule (MPS) is one of the primary outputs of the master scheduling process**
  - Once a *tentative* MPS has been developed, it must be validated
- **Rough cut capacity planning (RCCP) is a tool used in the validation process**
  - Approximate balancing of capacity and demand to test the feasibility of a master schedule
  - Involves checking the capacities of production and warehouse facilities, labor, and vendors to ensure no gross deficiencies exist that will render the MPS unworkable

MPS – Forecasts and Customer Orders

	June				July			
	1	2	3	4	5	6	7	8
Forecast	30	30	30	30	40	40	40	40

Beginning inventory	June				July			
64	1	2	3	4	5	6	7	8
Forecast	30	30	30	30	40	40	40	40
Customer orders (committed)	33	20	10	4	2			

MPS – Projected On Hand

Beginning inventory 64	June				July			
	1	2	3	4	5	6	7	8
Forecast	30	30	30	30	40	40	40	40
Customer orders (committed)	33	20	10	4	2			
Projected on-hand inventory	31	1	−29					

Customer orders are larger than forecast in week 1; projected on-hand inventory is 64 − 33 = 31

Forecast is larger than customer orders in week 2; projected on-hand inventory is 31 − 30 = 1

Forecast is larger than customer orders in week 3; projected on-hand inventory is 1 − 30 = −29

LO 11.8

Determining MPS and Projected On Hand

Week	Inventory from Previous Week	Requirements	Inventory before MPS	(70) MPS	Projected Inventory
1	64	33	31		31
2	31	30	1		1
3	1	30	-29	+ 70	= 41
4	41	30	11		11
5	11	40	-29	+ 70	= 41
6	41	40	1		1
7	1	40	-39	+ 70	= 31
8	31	40	-9	+ 70	= 61

LO 11.8

Adding MPS and Projected On Hand to the MPS

	June				July			
64	1	2	3	4	5	6	7	8
Forecast	30	30	30	30	40	40	40	40
Customer orders (committed)	33	20	10	4	2			
Projected on-hand inventory	31	1	41	11	41	1	31	61
MPS			70		70		70	70

Available-to-Promise

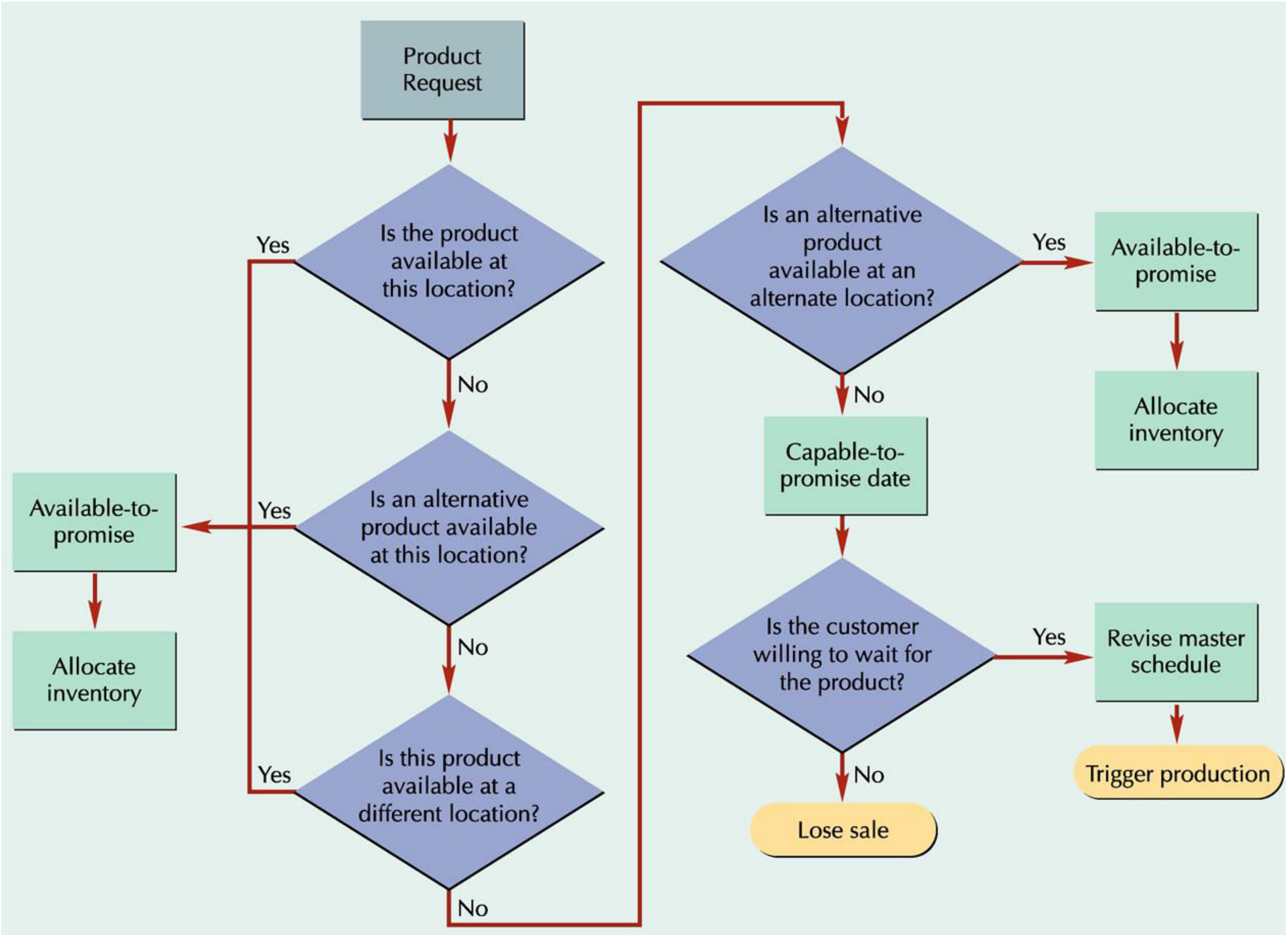
	June				July			
64	1	2	3	4	5	6	7	8
Forecast	30	30	30	30	40	40	40	40
Customer orders (committed)	33	20	10	4	2			
Projected on-hand inventory	31	1	41	11	41	1	31	61
MPS			70		70		70	70
Available-to-promise inventory (uncommitted)	11		56		68		70	70

LO 11.8

Collaborative Planning

- Sharing information and synchronizing production across supply chain
- Part of CPFR (collaborative planning, forecasting, and replenishment)
  - involves selecting products to be jointly managed, creating a single forecast of customer demand, and synchronizing production across supply chain

Rule Based ATP



Lecture Outline

- The Sales and Operations Planning Process
- Meeting Demand
  - Strategies for Adjusting Capacity
  - Strategies for Managing Demand
- Quantitative Techniques for Aggregate Planning
- Hierarchical Nature of Planning
- **Aggregate Planning for Services**

Aggregate Planning for Services

- Most services cannot be inventoried
- Demand for services is difficult to predict
- Capacity is also difficult to predict
- Service capacity must be provided at the appropriate place and time
- Labor is usually the most constraining resource for services

Yield Management

Type of Problem	Type of Business	Probability of Overestimating Demand or No-Shows, $P(N < X)$	Optimal Probability of Demand or No-Shows $\frac{C_u}{(C_u + C_o)}$	Cost Description
Overbooking	Hotel, airlines, restaurants	N = number of no-shows X = number of overbooked rooms or seats	C_o = cost of overbooking C_u = cost of understanding	Replacement cost Lost profit
Fare Classes	Airlines, cruise ships, passenger trains, extended stay hotel	N = number of full-fare tickets that can be sold X = seats reserved for full fare passengers	C_o = cost of overestimating full fare passengers C_u = cost of underestimating full fare passengers	Lost full-fare (Fulll-Fare − discounted fare)
Premium Seats	Stadiums, theaters	N = number of premium tickets that can be sold X = seats reserved for premium ticket holders	C_o = cost of overestimating premium ticket sales C_u = cost of underestimating premium ticket sales	Lost regular revenue (Premium ticket − regular ticket revenue)
Single Order Quantities	Newspapers, magazines, florists, nurseries, bakeries, sale items	N = number of items that can be sold X = number of items ordered	C_o = cost of overestimating demand C_u = cost of underestimating demand	(Cost − salvage value) Lost profit

Yield Management

NO-SHOWS	PROBABILITY	$P(N < X)$
0	.15	.00
1	.25	.15
2	.30	.40
3	.30	.70

Revenue = \$100/night

Maintenance = \$25/night

Overflow = \$70/night

Optimal probability of no-shows

$$P(n < x) \leq \frac{C_u}{C_u + C_o} =$$

$$C_o = \$70$$

$$C_u = \$100 - \$25 = \$75$$

Yield Management

NO-SHOWS	PROBABILITY	$P(N < X)$
0	.15	.00
1	.25	.15
$\boxed{2}$	.30	.40
3	.30	.70

$\leftarrow$ .517

Optimal probability of no-shows

$$P(n < x) \leq \frac{C_u}{C_u + C_o} = \frac{75}{75 + 70} = .517$$

Hotel should be overbooked by two rooms