

# Chapter 9

## **Sales and Operations Planning: Planning Supply and Demand in a Supply Chain**

# Learning Objectives

- Manage supply to improve synchronization in a supply chain in the face of predictable variability.
- Manage demand to improve synchronization in a supply chain in the face of predictable variability.
- Use sales and operations planning to maximize profitability when faced with predictable variability in a supply chain.

# Responding to Predictable Variability in a Supply Chain

- Predictable variability is change in demand that can be forecasted
- Can cause increased costs and decreased responsiveness in the supply chain
- Two broad approaches
  - Manage supply using capacity, inventory, subcontracting, and backlogs
  - Manage demand using short-term price discounts and trade promotions

# Managing Supply

- Managing capacity
  - ↪ Time flexibility from workforce
  - ↪ Use of seasonal workforce
  - ↪ Use of subcontracting
  - ↪ Use of dual facilities – specialized and flexible
  - ↪ Designing product flexibility into production processes
- Managing inventory
  - ↪ Using common components across multiple products
  - ↪ Build inventory of high demand or predictable demand products

# Inventory/Capacity Trade-off

- Leveling capacity forces inventory to build up in anticipation of seasonal variation in demand
- Carrying low levels of inventory requires capacity to vary with seasonal variation in demand or enough capacity to cover peak demand during season

# Managing Demand

- Promotion at Red Tomato and Green Thumb

Item	Cost
Material cost	\$10/unit
Inventory holding cost	\$2/unit/month
Marginal cost of stockout/backlog	\$5/unit/month
Hiring and training costs	\$300/worker
Layoff cost	\$500/worker
Labor hours required	4/unit
Regular time cost	\$4/hour
Overtime cost	\$6/hour
Cost of subcontracting	\$30/unit

Table 9-1

# Managing Demand

	A	B	C	D	E	F	G	H	I	J	K
1	<b>Aggregate Plan Decision Variables</b>										
2		H <sub>t</sub>	L <sub>t</sub>	W <sub>t</sub>	O <sub>t</sub>	I <sub>t</sub>	S <sub>t</sub>	C <sub>t</sub>	P <sub>t</sub>		
3	<b>Period</b>	<b># Hired</b>	<b># Laid off</b>	<b># Workforce</b>	<b>Overtime</b>	<b>Inventory</b>	<b>Stockout</b>	<b>Subcontract</b>	<b>Production</b>	<b>Demand</b>	<b>Price</b>
4	0	0	0	80	0	1,000	0	0			
5	1	0	15	65	0	1,983	0	0	2,583	1,600	40
6	2	0	0	65	0	1,567	0	0	2,583	3,000	40
7	3	0	0	65	0	950	0	0	2,583	3,200	40
8	4	0	0	65	0	0	267	0	2,583	3,800	40
9	5	0	0	65	0	117	0	0	2,583	2,200	40
10	6	0	0	65	0	500	0	0	2,583	2,200	40
22	<b>Total Cost =</b>		<b>\$422,275</b>								
23						<b>Base Price</b>	<b>\$</b>		<b>40</b>		
24	<b>Total Revenue =</b>	<b>\$640,000</b>		<b>Promote? (0/1</b>	<b>0</b>		<b>Consumption</b>	<b>0.10</b>			
25	<b>Profit =</b>	<b>\$217,725</b>		<b>Month (1/4)</b>	<b>1</b>		<b>Forward buy</b>	<b>0.20</b>			

Figure 9-1

# Managing Demand

Total cost over planning horizon = \$422,275

Revenue over planning horizon = \$640,000

Profit over planning horizon = \$217,725

$$\begin{aligned} \text{Average seasonal inventory} &= \frac{(I_0 + I_6) / 2 + \left( \dot{a}_{t=1}^5 I_t \right)}{T} = \frac{5,367}{6} = 895 \end{aligned}$$

$$\begin{aligned} \text{Average flow time} &= \frac{\text{average inventory}}{\text{average sales}} = \frac{895}{2,667} = 0.34 \text{ months} \end{aligned}$$



# The Timing of a Promotion

- Impact of the promotion on demand
- Cost of holding inventory
- Cost of changing the level of capacity
- Product margins
- Increase in demand from
  - ↗ Market growth
  - ↗ Stealing share
  - ↗ Forward buying

# When to Promote

- Is it more effective to promote during the peak period of off-peak?
- Analyze the impact of a promotion on demand and the resulting optimal aggregate plan

# Promotion in January

	A	B	C	D	E	F	G	H	I	J	K
1	<b>Aggregate Plan Decision Variables</b>										
2		H <sub>t</sub>	L <sub>t</sub>	W <sub>t</sub>	O <sub>t</sub>	I <sub>t</sub>	S <sub>t</sub>	C <sub>t</sub>	P <sub>t</sub>		
3	<b>Period</b>	<b># Hired</b>	<b># Laid off</b>	<b># Workforce</b>	<b>Overtime</b>	<b>Inventory</b>	<b>Stockout</b>	<b>Subcontract</b>	<b>Production</b>	<b>Demand</b>	<b>Price</b>
4	0	0	0	80	0	1,000	0	0			
5	1	0	15	65	0	610	0	0	2,610	3,000	39
6	2	0	0	65	0	820	0	0	2,610	2,400	40
7	3	0	0	65	0	870	0	0	2,610	2,560	40
8	4	0	0	65	0	0	320	0	2,610	3,800	40
9	5	0	0	65	0	90	0	0	2,610	2,200	40
10	6	0	0	65	0	500	0	0	2,610	2,200	40
22	<b>Total Cost =</b>	<b>\$421,915</b>									
23							<b>Base Price</b>	<b>\$</b>	<b>40</b>		
24	<b>Total Revenue =</b>	<b>\$643,400</b>	<b>Promote? (0/1</b>	<b>1</b>	<b>Consumption</b>	<b>0.10</b>					
25	<b>Profit =</b>	<b>\$221,485</b>	<b>Month (1/4)</b>	<b>1</b>	<b>Forward buy</b>	<b>0.20</b>					

Figure 9-2

# Promotion in January

Total cost over planning horizon = \$421,915

Revenue over planning horizon = \$643,400

Profit over planning horizon = \$221,485

- Lower seasonal inventory
- A somewhat lower total cost
- A higher total profit

# Promotion in April

	A	B	C	D	E	F	G	H	I	J	K
1	<b>Aggregate Plan Decision Variables</b>										
2		H <sub>t</sub>	L <sub>t</sub>	W <sub>t</sub>	O <sub>t</sub>	I <sub>t</sub>	S <sub>t</sub>	C <sub>t</sub>	P <sub>t</sub>		
3	<b>Period</b>	<b># Hired</b>	<b># Laid off</b>	<b># Workforce</b>	<b>Overtime</b>	<b>Inventory</b>	<b>Stockout</b>	<b>Subcontract</b>	<b>Production</b>	<b>Demand</b>	<b>Price</b>
4	0	0	0	80	0	1,000	0	0			
5	1	0	14	66	0	2,047	0	0	2,647	1,600	40
6	2	0	0	66	0	1,693	0	0	2,647	3,000	40
7	3	0	0	66	0	1,140	0	0	2,647	3,200	40
8	4	0	0	66	0	0	1,273	0	2,647	5,060	39
9	5	0	0	66	0	0	387	0	2,647	1,760	40
10	6	0	0	66	0	500	0	0	2,647	1,760	40
22	<b>Total Cost =</b>		<b>\$ 438,857</b>								
23											
24	<b>Total Revenue =</b>	\$ 650,140	<b>Promote? (0/1</b>	1	<b>Base Price</b>	\$	40	<b>Consumption</b>	0.10		
25	<b>Profit =</b>	\$ 211,283	<b>Month (1/4)</b>	4	<b>Forward buy</b>		0.20				

Figure 9-3

# Promotion in April

Total cost over planning horizon = \$438,857

Revenue over planning horizon = \$650,140

Profit over planning horizon = \$211,283

- Higher seasonal inventory
- A somewhat higher total cost
- A slightly smaller total profit

# Discount Leads to Large Increase in Consumption

- Promotion in January

	A	B	C	D	E	F	G	H	I	J	K
1	<b>Aggregate Plan Decision Variables</b>										
2		H <sub>t</sub>	L <sub>t</sub>	W <sub>t</sub>	O <sub>t</sub>	I <sub>t</sub>	S <sub>t</sub>	C <sub>t</sub>	P <sub>t</sub>		
3	<b>Period</b>	<b># Hired</b>	<b># Laid off</b>	<b># Workforce</b>	<b>Overtime</b>	<b>Inventory</b>	<b>Stockout</b>	<b>Subcontract</b>	<b>Production</b>	<b>Demand</b>	<b>Price</b>
4	0	0	0	80	0	1,000	0	0			
5	1	0	0	80	0	0	240	0	3,200	4,440	39
6	2	0	10	70	0	140	0	0	2,780	2,400	40
7	3	0	0	70	0	360	0	0	2,780	2,560	40
8	4	0	0	70	0	0	660	0	2,780	3,800	40
9	5	0	0	70	0	0	80	0	2,780	2,200	40
10	6	0	0	70	0	500	0	0	2,780	2,200	40
22	<b>Total Cost =</b>			<b>\$456,750</b>							
23						<b>Base Price</b>		<b>\$</b>	<b>40</b>		
24	<b>Total Revenue =</b>	<b>\$699,560</b>	<b>Promote? (0/1</b>	<b>1</b>	<b>Consumption</b>				<b>1.00</b>		
25	<b>Profit =</b>	<b>\$242,810</b>	<b>Month (1/4)</b>	<b>1</b>	<b>Forward buy</b>				<b>0.20</b>		

Figure 9-4

# Discount Leads to Large Increase in Consumption

Total cost over planning horizon = \$456,750

Revenue over planning horizon = \$699,560

Profit over planning horizon = \$242,810

- Higher total profit than base case



# Discount Leads to Large Increase in Consumption

- Promotion in April

	A	B	C	D	E	F	G	H	I	J	K
1	<b>Aggregate Plan Decision Variables</b>										
2		H <sub>t</sub>	L <sub>t</sub>	W <sub>t</sub>	O <sub>t</sub>	I <sub>t</sub>	S <sub>t</sub>	C <sub>t</sub>	P <sub>t</sub>		
3	<b>Period</b>	<b># Hired</b>	<b># Laid off</b>	<b># Workforce</b>	<b>Overtime</b>	<b>Inventory</b>	<b>Stockout</b>	<b>Subcontract</b>	<b>Production</b>	<b>Demand</b>	<b>Price</b>
4	0	0	0	80	0	1,000	0	0			
5	1	0	0	80	0	2,600	0	0	3,200	1,600	40
6	2	0	0	80	0	2,800	0	0	3,200	3,000	40
7	3	0	0	80	0	2,800	0	0	3,200	3,200	40
8	4	0	0	80	0	0	2,380	100	3,200	8,480	39
9	5	0	0	80	0	0	940	0	3,200	1,760	40
10	6	0	0	80	0	500	0	0	3,200	1,760	40
22	<b>Total Cost =</b>	<b>\$ 536,200</b>									
23							<b>Base Price</b>	<b>\$</b>	<b>40</b>		
24	<b>Total Revenue =</b>	<b>\$ 783,520</b>	<b>Promote? (0/1)</b>	<b>1</b>	<b>Consumption</b>	<b>1.00</b>					
25	<b>Profit =</b>	<b>\$ 247,320</b>	<b>Month (1/4)</b>	<b>4</b>	<b>Forward buy</b>	<b>0.20</b>					

Figure 9-5

# Discount Leads to Large Increase in Consumption

Total cost over planning horizon = \$536,200

Revenue over planning horizon = \$783,520

Profit over planning horizon = \$247,320

- Much higher level of seasonal inventory
- Uses more stockouts and subcontracting
- Revenues increase
- Overall profits higher

# Supply Chain Performance

Regular Price	Promotion Price	Promotion Period	Percentage of Increase in Demand	Percentage of Forward Buying	Profit	Average Inventory
\$40	\$40	NA	NA	NA	\$217,725	895
\$40	\$39	January	10%	20%	\$221,485	523
\$40	\$39	April	10%	20%	\$211,283	938
\$40	\$39	January	100%	20%	\$242,810	208
\$40	\$39	April	100%	20%	\$247,320	1,492
\$31	\$31	NA	NA	NA	\$ 73,725	895
\$31	\$30	January	100%	20%	\$ 84,410	208
\$31	\$30	April	100%	20%	\$ 69,120	1,492

Table 9-2

# Impact on Promotion Timing

Factor	Impact on Timing of Promotion/Forward Buy
High forward buying	Favors promotion during low-demand periods
High ability to steal market share	Favors promotion during peak-demand periods
High ability to increase overall market	Favors promotion during peak-demand periods
High margin	Favors promotion during peak-demand periods
Low margin	Favors promotion during low-demand periods
High manufacturer holding costs	Favors promotion during low-demand periods
High costs of changing capacity	Favors promotion during low-demand periods
High retailer holding costs	Decreases forward buying by retailer
High promotion elasticity of consumer	Decreases forward buying by retailer

Table 9-3

# Conclusions on Promotion

- Average inventory increases if a promotion is run during the peak period and decreases if the promotion is run during the off-peak period
- Promoting during a peak-demand month may decrease overall profitability if there is a small increase in consumption and a significant fraction of the demand increase results from a forward buy

# Conclusions on Promotion

- As consumption increase from discounting grows and forward buying becomes a smaller fraction of the demand increase from a promotion, it is more profitable to promote during the peak period
- As the product margin declines, promoting during the peak-demand period becomes less profitable

# Implementing Sales and Operations Planning in Practice

- Coordinate planning across enterprises in the supply chain
- Take predictable variability into account when making strategic decisions
- Design S&OP to understand and manage the drivers of demand usage
- Ensure that the S&OP process modifies plans as the reality or forecasts change

# Summary of Learning Objectives

- Manage supply to improve synchronization in a supply chain in the face of predictable variability
- Manage demand to improve synchronization in a supply chain in the face of predictable variability
- Use sales and operations planning to maximize profitability when faced with predictable variability in a supply chain