Outline

- Role of aggregate planning in a supply chain
- The aggregate planning problem
- Aggregate planning strategies
- Implementing aggregate planning in practice

Role of Aggregate Planning

- Capacity has a cost, lead times are greater than zero
- Aggregate planning:
  - process by which a company determines levels of capacity, production, subcontracting, inventory, stockouts, and pricing over a specified time horizon
  - goal is to maximize profit
  - decisions made at a product family (not SKU) level
  - time frame of 3 to 18 months
  - how can a firm best use the facilities it has?

Role of Aggregate Planning

- Specify operational parameters over the time horizon:
  - production rate
  - workforce
  - overtime
  - machine capacity level
  - subcontracting
  - backlog
  - inventory on hand
- All stages should work together on an aggregate plan that will optimize supply chain performance
Aggregate Planning Problem

Given the demand forecast, determine the best
- production level,
- inventory level,
- capacity level.

Specify the
- planning horizon
- duration of each period
- key required information

Information Needed

- Demand forecast in each period
- Production costs
  - labor costs: regular time and overtime
  - subcontracting costs
  - cost of changing capacity: hiring or layoff
  - cost of adding or reducing machine capacity
- Labor/machine hours required per unit
- Inventory holding cost
- Stockout or backlog cost
- Constraints: limits on overtime, layoffs, capital available, stockouts and backlogs

Outputs

- Production quantity
  - regular time, overtime, and subcontracted time
  - to determine number of workers and supplier purchase levels
- Inventory
  - to determine required warehouse space and working capital
- Backlog/stockout quantity:
  - to determine what customer service levels will be
- Machine capacity increase/decrease:
  - to find if new production equipment needs to be purchased
- A poor aggregate plan can
  - lost sales, lost profits, excess inventory, or excess capacity

Strategies

- Trade-off
  - between capacity, inventory, backlog/lost sales
- Chase strategy
  - using capacity as the lever
- Time flexibility: workforce or capacity
  - using utilization as the lever
- Level strategy
  - using inventory as the lever
- Mixed strategy
Chase Strategy

- Production rate is synchronized with demand
  - varying machine capacity
  - hiring and laying off workers
- Cons
  - difficult to vary capacity and workforce on short notice
  - Expensive if cost of varying capacity is high
  - Negative effect on workforce confidence
- Pros
  - low levels of inventory
- Used when
  - Inventory costs are high and changing capacity is flexible

Time Flexibility Strategy

- Working hours synchronize production and demand
  - Fixed workforce and variable number of hours worked
  - Excess machine capacity is available
- Pros
  - Use a flexible work schedule
  - Avoids morale problems
  - Low levels of inventory,
- Cons
  - Lower utilization
  - Used when
  - Inventory costs are high and capacity is inexpensive.

Level Strategy

- Constant output rate
  - Stable machine capacity and workforce levels
- Pros
  - Better for worker confidence
  - High utilization
- Cons
  - Fluctuations in inventory levels over time
  - Large inventories and backlogs may accumulate
    - Inventories are built up in anticipation of future demand
    - Backlogs are carried over from high to low demand periods
- Used when
  - Inventory holding and backlog costs are relatively low

Case Study: Red Tomato Tools

- Produce gardening tools
  - peaking in the spring
- To overcome the seasonality,
  - add workers during the peak season,
  - subcontract out some of the work,
  - build up inventory during the slow months,
  - build up a backlog of orders that will be delivered later.
- How to best use these options through an aggregate plan?
Demand

<table>
<thead>
<tr>
<th>Month</th>
<th>Demand Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1,600</td>
</tr>
<tr>
<td>February</td>
<td>3,000</td>
</tr>
<tr>
<td>March</td>
<td>3,200</td>
</tr>
<tr>
<td>April</td>
<td>3,800</td>
</tr>
<tr>
<td>May</td>
<td>2,200</td>
</tr>
<tr>
<td>June</td>
<td>2,200</td>
</tr>
</tbody>
</table>

Fundamental Tradeoffs

- Capacity (regular time, overtime, subcontract)
- Inventory
- Backlog / lost sales

Basic Strategies

- Chase strategy
- Time flexibility from workforce or capacity
- Level strategy

Basic Information

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>$10/unit</td>
</tr>
<tr>
<td>Inventory holding cost</td>
<td>$2/unit/month</td>
</tr>
<tr>
<td>Marginal cost of a stockout</td>
<td>$5/unit/month</td>
</tr>
<tr>
<td>Hiring and training costs</td>
<td>$300/worker</td>
</tr>
<tr>
<td>Layoff cost</td>
<td>$500/worker</td>
</tr>
<tr>
<td>Labor hours required</td>
<td>4/unit</td>
</tr>
<tr>
<td>Regular time cost</td>
<td>$4/hour</td>
</tr>
<tr>
<td>Over time cost</td>
<td>$6/hour</td>
</tr>
<tr>
<td>Cost of subcontracting</td>
<td>$30/unit</td>
</tr>
</tbody>
</table>

Decision Variables

- $t = \text{Month (} t = 1, \ldots, 6\text{)}$
- $W_t = \text{Workforce size for month}$$
- $H_t = \text{Number of employees hired}$$
- $L_t = \text{Number of employees laid off}$$
- $P_t = \text{Production}$$
- $I_t = \text{Inventory at the end of month}$$
- $S_t = \text{Number of units stocked out at the end of month}$$
- $C_t = \text{Number of units subcontracted for month } t,$$
- $O_t = \text{Number of overtime hours worked in month } t,$$
### Objective Function

**Minimum**

- Regular-time labor cost \( \sum_{i=1}^{6} 640 W_i \)
- Overtime labor cost \( \sum_{i=1}^{6} 6 O_i \)
- Cost of hiring and layoffs \( \sum_{i=1}^{6} 300 H_i + \sum_{i=1}^{6} 500 L_i \)
- Cost of holding inventory \( \sum_{i=1}^{6} 2 I_i \)
- Cost of stocking out \( \sum_{i=1}^{6} 5 S_i \)
- Cost of subcontracting \( \sum_{i=1}^{6} 30 C_i \)
- Material cost \( \sum_{i=1}^{10} P_i \)

### Constraints

1. Workforce size for each month is based on hiring and layoffs

\[
W_t = W_{t-1} + H_t - L_t \quad \text{for } t = 1, \ldots, 6
\]

\[
W_0 = 80
\]

2. Production for each month cannot exceed capacity

\[
P_t \leq 40 W_t + O_t / 4, \quad \text{for } t = 1, \ldots, 6
\]

- Each worker can produce
  - 40 units per month on regular time
  - 1 unit for every four hours of overtime

3. Inventory balance for each month

\[
I_{t-1} + P_t + C_t = D_t + S_{t-1} + I_t - S_t, \quad \text{for } t = 1, \ldots, 6
\]

\[
I_0 = 1000
\]

\[
S_0 = 0
\]

\[
I_6 \geq 500
\]
Constraints

4. Over time for each month

\[ O_t \leq 10 W_t, \quad for \ t = 1, \ldots, 6 \]

No employee work more than 10 hours of overtime each month.

Scenarios

- Increase in holding cost (from $2 to $6)
- Overtime cost drops to $4.1 per hour
- Increased demand fluctuation

in Practice

- Think beyond the enterprise to the entire supply chain
- Make plans flexible because forecasts are always wrong
- Rerun the aggregate plan as new information emerges
- Use aggregate planning as capacity utilization increases

Summary

- What types of decisions are best solved by aggregate planning?
- What is the importance of aggregate planning as a supply chain activity?
- What kinds of information are needed to produce an aggregate plan?
- What are the basic trade-offs a manager makes to produce an aggregate plan?
- How are aggregate planning problems formulated and solved using Microsoft Excel?
Homework 4

Chapter 8

- Exercises:
  - 4
  - 5
  - 6