Chapter 7

Aggregate Planning

Operations Management

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Agenda

➢ **Role of aggregate planning in operations management**

➢ Aggregate planning strategies

➢ Solving an example problem

Role of Aggregate Planning in a Supply Chain

◆ 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 in a Supply Chain

◆ Specify operational parameters over the time horizon:

- – production rate
- – workforce
- – overtime
- – machine capacity level
- – subcontracting
- – backlog
- – inventory on hand

◆ All supply chain stages should work together on an aggregate plan that will optimize supply chain performance

Information Needed for an Aggregate Plan

◆ Demand forecast in each period

◆ Production costs

  – labor costs, regular time ($/hr) and overtime ($/hr)

  – subcontracting costs ($/hr or $/unit)

  – cost of changing capacity: hiring or layoff ($/worker) and cost of adding or reducing machine capacity ($/machine)

◆ Inventory holding cost ($/unit/period)

◆ Stockout or backlog cost ($/unit/period)

◆ Labor/machine hours required per unit

◆ Constraints: limits on overtime, layoffs, capital available, stockouts and backlogs

Outputs of Aggregate Plan

◆ Production quantity from regular time, overtime, and subcontracted
  – used to determine number of workers and supplier, purchase levels

◆ Inventory held
  – used to determine how much warehouse space and working capital is needed

◆ Backlog/stockout quantity:
  – used to determine what customer service levels will be

◆ Machine capacity increase/decrease:
  – used to determine if new production equipment needs to be purchased

Outputs of Aggregate Plan

◆ A poor aggregate plan can result in

- – lost sales,
- – lost profits,
- – excess inventory, or
- – excess capacity.

Agenda

➢ Role of aggregate planning in operations management

➢ **Aggregate planning strategies**

➢ Solving an example problem

Aggregate Planning Strategies

◆ Trade-off between capacity, inventory, backlog/lost sales

◆ Chase strategy – using capacity as the lever

◆ Time flexibility from workforce or capacity strategy – using utilization as the lever

◆ Level strategy – using inventory as the lever

◆ Mixed strategy – a combination of one or more of the first three strategies

Chase Strategy

◆ Production rate is synchronized with demand by varying machine capacity or hiring and laying off workers as the demand rate varies

◆ However, in practice, it is often difficult to vary capacity and workforce on short notice

◆ Expensive if cost of varying capacity is high

◆ Negative effect on workforce morale

◆ Results in low levels of inventory

◆ Should be used when inventory holding costs are high and costs of changing capacity are low

Time Flexibility Strategy

◆ Can be used if there is excess machine capacity

◆ Workforce is kept stable, but the number of hours worked is varied over time to synchronize production and demand

◆ Can use overtime or a flexible work schedule

◆ Requires flexible workforce, but avoids morale problems of the chase strategy

◆ Low levels of inventory, lower utilization

◆ Should be used when inventory holding costs are high and capacity is relatively inexpensive

Level Strategy

◆ Maintain stable machine capacity and workforce levels with a constant output rate

◆ Shortages and surpluses result in fluctuations in inventory levels over time

◆ Inventories that are built up in anticipation of future demand or backlogs are carried over from high to low demand periods

◆ Better for worker morale

◆ Large inventories and backlogs may accumulate

◆ Should be used when inventory holding and backlog costs are relatively low

Agenda

➤ Role of aggregate planning in operations management

➤ Aggregate planning strategies

➤ **Solving an example problem**

Aggregate Planning Example

Month	Demand Forecast
January	1,600
February	3,000
March	3,200
April	3,800
May	2,200
June	2,200

Fundamental Tradeoffs in Aggregate Planning

◆ Capacity (regular time, overtime, subcontract)

◆ Inventory

◆ Backlog / lost sales

Basic Strategies

◆ Chase strategy

◆ Time flexibility from workforce or capacity

◆ Level strategy

Aggregate Planning Costs

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

Aggregate Planning (Define Decision Variables)

W_t = Workforce size for month t, $t = 1, ..., 6$

H_t = Number of employees hired at the beginning of month t, $t = 1, ..., 6$

L_t = Number of employees laid off at the beginning of month t, $t = 1, ..., 6$

P_t = Production in month t, $t = 1, ..., 6$

I_t = Inventory at the end of month t, $t = 1, ..., 6$

S_t = Number of units stocked out at the end of month t, $t = 1, ..., 6$

C_t = Number of units subcontracted for month t, $t = 1, ..., 6$

O_t = Number of overtime hours worked in month t, $t = 1, ..., 6$

Aggregate Planning
(Define Objective Function)

$$Min \sum_{t=1}^{6} 640\, W_t + \sum_{t=1}^{6} 300\, H_t$$

$$+ \sum_{t=1}^{6} 500\, L_t + \sum_{t=1}^{6} 6\, O_t + \sum_{t=1}^{6} 2\, I_t$$

$$+ \sum_{t=1}^{6} 5\, S_t + \sum_{t=1}^{6} 10\, P_t + \sum_{t=1}^{6} 30\, C_t$$

Aggregate Planning (Define Constraints Linking Variables)

◆ Workforce size for each month is based on hiring and layoffs

$$W_t = W_{t-1} + H_t - L_t, \quad or$$

$$W_t - W_{t-1} - H_t + L_t = 0$$

$$for\ t = 1,...,6,\ where\ W_0 = 80.$$

Aggregate Planning (Constraints)

◆Production for each month cannot exceed capacity

$$P_t \le 40W_t + O_t/4,$$

$$40W_t + O_t/4 - P_t \ge 0,$$

$$for \ t = 1,...,6.$$

Aggregate Planning (Constraints)

◆ Inventory balance for each month

$$I_{t-1} + P_t + C_t = D_t + S_{t-1} + I_t - S_t,$$

$$I_{t-1} + P_t + C_t - D_t - S_{t-1} - I_t + S_t = 0,$$

$$for \ t = 1,...,6, where \ I_0 = 1,000,$$

$$S_0 = 0, and \ I_6 \geq 500.$$

Aggregate Planning (Constraints)

◆ Over time for each month

$$O_t \leq 10W_t,$$

$$10W_t - O_t \geq 0,$$

$$for\ t = 1,...,6.$$

Scenarios

◆ Increase in holding cost (from $2 to $6)

◆ Overtime cost drops to $4.1 per hour

◆ Increased demand fluctuation

Increased Demand Fluctuation

Month	Demand Forecast
January	1,000
February	3,000
March	3,800
April	4,800
May	2,000
June	1,400