

Supply Chain Management

Prepared by Dr. Tarek Mohamed

MGM 660

Lecture 7



Aggregate planning in a supply chain

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Learning Objectives

- 1. Identify the decisions that are best solved by aggregate planning.**
- 2. Understand the importance of aggregate planning as a supply chain activity.**
- 3. Describe the information needed to produce an aggregate plan.**
- 4. Explain the basic trade-offs to consider when creating an aggregate plan.**



Role of Aggregate Planning in a Supply Chain

- **Aggregate planning** is a process by which a company determines planned levels of capacity, production, subcontracting, inventory, stockouts, and even pricing over a specified time horizon.
- The goal of aggregate planning is to build a plan that satisfies demand while maximizing profit.

Role of Aggregate Planning in a Supply Chain

- **Aggregate planning**, as the name suggests, solves problems involving aggregate decisions rather than stock-keeping unit (SKU)-level decisions.
- **For example**, aggregate planning determines the total production level in a plant for a given month, but it does so without determining the quantity of each individual SKU that will be produced

Role of Aggregate Planning in a Supply Chain

- This level of detail makes aggregate planning a useful tool for thinking about decisions with an intermediate time frame of between roughly 3 and 18 months.
- In this time frame, it is too early to determine production levels by SKU, but it is also generally too late to arrange for additional capacity.
- Therefore, aggregate planning answers the question: How should a firm best utilize the facilities that it currently has?
- **To be effective**, aggregate planning requires inputs from all stages of the supply chain, and its results have a tremendous impact on supply chain performance.

Role of Aggregate Planning in a Supply Chain

- **Collaborative forecasts** are created by multiple supply chain enterprises and are an important input for aggregate planning.
- In addition, many constraints that are key inputs to aggregate planning come from supply chain partners outside the enterprise.
- Without these inputs from both up and down the supply chain, aggregate planning cannot realize its full potential to create value.
- The output from aggregate planning is also of value to both upstream and downstream partners.
- Production plans for a firm define demand for suppliers and establish supply constraints for customers.

Role of Aggregate Planning in a Supply Chain

- **As an example,**
 - Consider how a premium paper supply chain uses aggregate planning to maximize profit.
 - Many types of paper mills face seasonal demand that ripples up from customers to printers to distributors and, finally, to the manufacturers.
 - Many types of premium paper have demand peaks in the spring, when annual reports are printed, and in the fall, when new-car brochures are released.
 - Building a mill with capacity to meet demand in the spring and fall on an as-needed basis is too costly, because of the high cost of mill capacity.

Role of Aggregate Planning in a Supply Chain

- On the other side of the supply chain, premium papers often require special additives and coatings that may be in short supply.
- The paper manufacturer must deal with these constraints and maximize profit around them.
- The mills use aggregate planning to determine production levels and inventory levels that they should build up in the slower months for sale in the spring and fall, when demand is greater than the mill's capacity.
- By taking into account the inputs from throughout the supply chain, aggregate planning allows the mill and the supply chain to maximize profit.

Role of Aggregate Planning in a Supply Chain

- **Capacity** has a cost and lead times are often long
- **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**
 - Subcontracting
 - **Workforce**
 - Backlog
 - **Overtime**
 - Inventory on hand
 - **Machine capacity level**
- All supply chain stages should work together on an aggregate plan that will optimize supply chain performance

The aggregate planner's main objective

- **The aggregate planner's main objective** is to identify the following operational parameters over the specified time horizon:
- **Production rate:** the number of units to be completed per unit time (such as per week or per month)
- **Workforce:** the number of workers or units of labor capacity required
- **Overtime:** the amount of overtime production planned

The aggregate planner's main objective

- **Machine capacity level:** the number of units of machine capacity needed for production
- **Subcontracting:** the subcontracted capacity required over the planning horizon
- **Backlog:** demand not satisfied in the period in which it arises, but is carried over to future periods
- **Inventory on hand:** the planned inventory carried over the various periods in the planning horizon

Information Needed for an Aggregate Plan

- Aggregate demand forecast F_t for each Period t over T periods
- Production costs
 - Labor costs, regular time (\$/hr) and overtime (\$/hr)
 - Subcontracting costs (\$/hr or \$/unit)
 - Cost of changing capacity – hiring or layoff (\$/worker), adding or reducing machine capacity (\$/machine)
- Labor/machine hours required per unit
- Inventory holding cost (\$/unit/period)
- Stockout or backlog cost (\$/unit/period)
- Constraints – overtime, layoffs, capital available, stockouts, backlogs, from suppliers

Outputs of Aggregate Plan

- Production quantity from regular time, overtime, and subcontracted time
- Inventory held
- Backlog/stockout quantity
- Machine capacity increase/decrease
- A poor aggregate plan can result in lost sales, lost profits, excess inventory, or excess capacity

Identifying Aggregate Units of Production

- An important first step in aggregate planning is the identification of a suitable aggregate unit of production.
- When planning is done at the aggregate level, it is important that the aggregate unit be identified in a way that when the final production schedule is built (this has to be at the disaggregate product level), the results of the aggregate plan reflect approximately what can be accomplished in practice.

Identifying Aggregate Units of Production

- Given that the bottleneck is likely to be the most constraining area in any manufacturing facility, it is important to focus on the bottleneck when selecting the aggregate unit and identifying capacity as well as production times.
- When evaluating production times, it is also important to account for activities—such as setups and maintenance—that use up capacity but do not result in any production.

Identifying Aggregate Units of Production

- Aggregate unit should be identified in a way that the resulting production schedule can be accomplished in practice
- Focus on the bottlenecks when selecting the aggregate unit and identifying capacity and production times
- Account for activities such as setups and maintenance

Identifying Aggregate Units of Production

Consider, **for example**,

- **Red Tomato Tools**, a small manufacturer of gardening equipment with manufacturing facilities in Mexico.
- The company makes six product families at its manufacturing plant.
- The costs, revenues, production times, setup times, and historical batch sizes of production for each family

Red Tomato Tools

Family	Material Cost/ Unit (\$)	Revenue/ Unit (\$)	Setup Time/Ba tch (hour)	Average Batch Size	Production Time/ Unit (hour)	Net Production Time/Unit (hour)	Percentage Share of Units Sold
A	15	54	8	50	5.60	5.76	10
B	7	30	6	150	3.00	3.04	25
C	9	39	8	100	3.80	3.88	20
D	12	49	10	50	4.80	5.00	10
E	9	36	6	100	3.60	3.66	20
F	13	48	5	75	4.30	4.37	15

Red Tomato Tools

- **Weighted average approach**

$$\begin{aligned} \text{Material cost per aggregate unit} \\ &= 15 \times 0.10 + 7 \times 0.25 + 9 \times 0.20 \\ &\quad + 12 \times 0.10 + 9 \times 0.20 + 13 \times 0.15 = \$10 \end{aligned}$$

- **Similarly**

Revenue per aggregate unit = \$40

Net production time per aggregate unit = 4.00 hours

Aggregate Planning Strategies

- **The aggregate planner** must make **trade-offs** among capacity, inventory, and backlog costs.
- An aggregate plan that increases one of these costs typically results in reduction of the other two.
- In this sense, the costs represent **a trade-off**:
To lower inventory cost, a planner must increase capacity cost or delay delivery to the customer. Thus, the planner trades inventory cost for capacity or backlog cost.
- Arriving at the most profitable combination of trade-offs is the goal of aggregate planning.

Aggregate Planning Strategies

- Given that demand varies over time, the relative level of the three costs leads to one of them being the key lever the planner uses to maximize profits.
- If the cost of varying capacity is low, a company may not need to build inventory or carry backlogs.
- If the cost of varying capacity is high, a company may compensate by building some inventory and carrying some backlogs from peak demand periods to off-peak demand periods.

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
- **Tailored or hybrid strategy** – a combination of strategies

Chase Strategy

- Vary machine capacity or hire and lay off workers as demand varies
- 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
- Used when inventory holding costs are high and costs of changing capacity are low

Time Flexibility Strategy

- Use excess machine capacity
- Workforce stable, number of hours worked varies
- Use overtime or a flexible work schedule
- Flexible workforce, avoids morale problems
- Low levels of inventory, lower utilization
- Used when inventory holding costs are high and capacity is relatively inexpensive

Level Strategy

- Stable machine capacity and workforce levels, constant output rate
- Inventory levels fluctuate over time
- Inventories carried over from high to low demand periods
- Better for worker morale
- Large inventories and backlogs may accumulate
- Used when inventory holding and backlog costs are relatively low

Aggregate Planning Using Linear Programming

- **Red Tomato Tools**
 - Highly seasonal demand
 - Develop a forecast

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

Red Tomato Tools

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

Forecast Error in Aggregate Plans

- **Forecast errors** must be considered
- **Safety inventory**
- **Safety capacity**
 - Use overtime as a form of safety capacity
 - Carry extra workforce permanently as a form of safety capacity
 - Use subcontractors as a form of safety capacity
 - Build and carry extra inventories as a form of safety inventory
 - Purchase capacity or product from an open or spot market as a form of safety capacity

Building a Rough Master Production Schedule

- Disaggregate an aggregate plan

Family	Setup Time/Batch (hour)	Average Batch Size	Production Time/Unit (hour)	Production Quantity	Number of Setups	Setup Time (hours)	Production Time (hours)
A	8	50	5.60	258	5	40	1,445
B	6	150	3.00	646	4	24	1,938
C	8	100	3.80	517	5	40	1,965
D	10	50	4.80	258	5	50	1,238
E	6	100	3.60	517	5	30	1,861
F	5	75	4.30	387	5	25	1,664

The Role of IT in Aggregate Planning

- The ability to handle large problems
- The ability to handle complex problems (through either nonlinear optimization or linear approximations)
- The ability to interact with other core IT systems such as inventory management and sourcing

❑ Think beyond the enterprise to the entire supply chain

- Most aggregate planning today takes only the enterprise as its breadth of scope. However, many factors outside the enterprise and throughout the supply chain can affect the optimal aggregate plan dramatically.
- Therefore, avoid the trap of thinking only about your own enterprise when planning.
- Work with downstream partners to produce forecasts, with upstream partners to determine constraints, and with any other supply chain entities that can improve the quality of the inputs into the aggregate plan.

❑ Make plans flexible because forecasts are always inaccurate

- Aggregate plans are based on forecasts of future demand. Given that these forecasts are always inaccurate to some degree, the aggregate plan needs to have some flexibility built into it if it is to be useful.
- By building flexibility into the plan, when future demand changes or other changes occur, such as increases in costs, the plan can adjust appropriately to handle the new situation.

❑ Rerun the aggregate plan as new data emerge

- Aggregate plans provide a map for the next 3 to 18 months.
- This does not mean that a firm should run aggregate plans only once every 3 to 18 months.
- As inputs such as demand forecasts change, managers should use the latest values of these inputs and rerun the aggregate plan.
- Be careful, however, to modify plans in a way that limits volatility.

❑ Use aggregate planning as capacity utilization increases

- Many companies do not create aggregate plans and instead rely solely on orders from their distributors or warehouses to determine their production schedules.
- These orders are driven either by actual demand or through inventory management algorithms.
- If a company has no trouble meeting demand efficiently this way, then the lack of aggregate planning may not harm the company significantly.

❑ Use aggregate planning as capacity utilization increases

- However, when utilization becomes high and capacity is an issue, relying on orders to set the production schedule can lead to shortages and delays.
- When utilization is high, aggregate planning helps the firm effectively meet the forecasted demand.

Summary of Learning Objectives

- 1. Identify the decisions that are best solved by aggregate planning.**
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- 4. Explain the basic trade-offs to consider when creating an aggregate plan.**

Essential Reference

Chopra, S., & Meindl, P. (2016). Global Edition.
Pearson Education Limited

Chapter 8.



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Thank You

