Risk Management in Supply Chain Management Using Probability and Game Theory

Overview

Supply Chain Management (SCM) involves coordinating various entities like suppliers, manufacturers, and distributors to ensure the efficient production and distribution of goods. Game Theory helps in strategizing the interactions among these entities, while Probability aids in managing uncertainties related to demand, supply, and disruptions. Here, we provide a detailed explanation using a specific example.

Scenario: Multiple Suppliers and a Manufacturer

Problem Setup

- **Entities Involved:**
  - Two suppliers (Supplier 1 and Supplier 2)
  - One manufacturer
- **Objectives:**
  - **Suppliers:** Maximize their profits by determining the quantity and pricing of raw materials supplied to the manufacturer.
  - **Manufacturer:** Minimize costs while ensuring a steady supply of raw materials to meet production demands.

Game Theory Application

1. **Players:** Supplier 1 and Supplier 2.
2. **Strategies:** Each supplier can choose to supply a high quantity (HQ) or a low quantity (LQ) of raw materials.
3. **Payoffs:** The payoffs for each player depend on the strategies chosen by both suppliers and the resulting costs and profits.
4. **Payoff Matrix:**

	Supplier 2: HQ	**Supplier 2: LQ**
Supplier 1: HQ	(8, 8)	(4, 6)
Supplier 1: LQ	(6, 4)	(2, 2)

- **Interpretation:**
  - If both suppliers choose HQ, they both get a moderate profit (8, 8) due to competition.
  - If Supplier 1 chooses HQ and Supplier 2 chooses LQ, Supplier 1 gets a higher profit (4, 6) due to reduced competition.
  - Similarly, the other combinations lead to different payoffs.

Probability Application

1. **Modeling Demand and Supply Uncertainties:**
   - The manufacturer faces uncertain demand for its products. This uncertainty can be modeled using probability distributions (e.g., normal distribution).
   - Supply uncertainties (e.g., delays, quality issues) are also modeled probabilistically.
2. **Risk Management:**
   - The manufacturer uses these probabilistic models to estimate the likelihood of different scenarios (e.g., high demand, supply disruptions).
   - Strategies are developed to mitigate these risks, such as maintaining safety stock or diversifying suppliers.

Detailed Example

Let's assume the manufacturer produces electronic devices and needs semiconductor chips from the suppliers.

- **Supplier 1 and Supplier 2** can each supply up to 1000 chips per month.
- The **manufacturer's demand** for chips is uncertain and follows a normal distribution with a mean of 1500 chips and a standard deviation of 300 chips.

Game Theory Analysis:

- Both suppliers aim to maximize their profit by deciding how many chips to supply (HQ or LQ) and at what price.
- The manufacturer's goal is to minimize costs while ensuring a steady supply to avoid production halts.

Probability Analysis:

- The manufacturer calculates the probability of different demand levels using the normal distribution.
- For example, the probability that the demand will be between 1200 and 1800 chips can be calculated using the cumulative distribution function (CDF).

Combined Strategy

1. **Negotiation:**
    - The manufacturer negotiates contracts with both suppliers considering the game-theoretic payoffs.
    - For instance, the manufacturer might offer a higher price per chip for a guaranteed supply (HQ) and a lower price for a less guaranteed supply (LQ).
2. **Optimal Order Quantity:**
    - Based on the probabilistic demand model, the manufacturer determines the optimal order quantity from each supplier.
    - If the demand is likely to be high, the manufacturer might order HQ from both suppliers. If the demand is uncertain or likely low, the manufacturer might order HQ from one supplier and LQ from the other.
3. **Risk Mitigation:**
    - The manufacturer maintains a safety stock to buffer against demand fluctuations and supply disruptions.
    - They also diversify their supplier base to reduce the risk of dependency on a single supplier.

Conclusion

By combining Game Theory and Probability, the manufacturer can develop robust strategies to manage the supply chain effectively. Game Theory helps in understanding the competitive dynamics between suppliers, while Probability aids in managing uncertainties and risks.

Resources

- **Books:**
    - *Supply Chain Management: Strategy, Planning, and Operation* by Sunil Chopra and Peter Meindl
    - *Game Theory for Applied Economists* by Robert Gibbons
- **Research Papers:**
    - *Game Theory in Supply Chain Analysis* by Gerard P. Cachon and Serguei Netessine
    - *Risk Management in Supply Chains: A Game Theoretic Analysis* by Alan Scheller-Wolf and Alper Atamturk