

Supply chain Management

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Lecture 6

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PMG 660

NETWORK DESIGN IN AN UNCERTAIN
ENVIRONMENT



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Learning Objectives

After reading this chapter, you will be able to:

- 1. Identify uncertainties that influence supply chain performance and network design.**
- 2. Understand the methodologies used to evaluate supply chain design decisions under uncertainty.**
- 3. Analyze supply chain network design decisions in an uncertain environment.**

UNCERTAINTY ON NETWORK DESIGN



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we emphasized that network design decisions have a long-term impact on a supply chain's performance. As a result, managers must account for demand, macroeconomic, and financial uncertainties over the long term when designing a supply chain network.

In this chapter, we discuss the methodologies used to evaluate network design decisions under uncertainty and show how they improve supply chain decisions.

THE IMPACT OF UNCERTAINTY ON NETWORK DESIGN



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Supply chain design decisions such as the number and size of plants to build, the size and scope of a distribution system, and whether to buy or lease one's facilities involve significant investment.

These decisions, once made, cannot be altered in the short term. They remain in place for several years and define the constraints within which the supply chain must compete. Thus, it is important that these decisions be evaluated as accurately as possible.

Over the life of a supply chain network, a company experiences fluctuations in demand, prices, exchange rates, and the competitive environment. A decision that looks very good under the current environment may be quite poor if the situation changes.

For example, long-term contracts for warehousing are more attractive if the demand and price of warehousing do not change in the future or if the price of warehousing goes up.



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In contrast, a short-term contract is more attractive if either demand or the price of warehousing drops in the future. The degree of demand and price uncertainty has a significant influence on the appropriate portfolio of long- and short-term warehousing space that a firm should carry



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Uncertainty of demand and price drives the value of building flexible production capacity at a plant. If price and demand do vary over time in a global network, flexible production capacity can be reconfigured to maximize, profits in the new environment.

In the late 1990s, Toyota made its global assembly plants more flexible so that each plant could supply multiple markets. One of the main benefits of this flexibility is that

it allows Toyota to react to fluctuations in demand, exchange rates, and local prices by altering production to maximize profits. A firm may choose to build a flexible global supply chain even in the presence of little demand or supply uncertainty if uncertainty exists in exchange rates or prices.

Thus, supply, demand, and financial uncertainty must be considered when making network design decisions. In the next section we discuss a methodology for evaluating any supply chain decision that will be in place for an extended duration.

methodologies used to evaluate supply chain design decisions under uncertainty

DISCOUNTED CASH FLOW ANALYSIS

Supply chain design decisions should be evaluated as a sequence of cash flows over the duration of time that they will be in place.

The present value of a stream of cash flows is what that stream is worth in today's dollars.

Discounted cash flow (DCF) analysis evaluates the present value of any stream of future cash flows and allows management to compare two streams of cash flows in terms of their financial value.

DCF analysis is based on the fundamental premise that "a dollar today is worth more than a dollar tomorrow" because a dollar today may be invested and earn a return in addition to the dollar invested.

This premise provides the basic tool for comparing the relative value of future cash flows that will arrive during different time periods

to obtain its present value. The rate of return **k** is also referred to as the discount rate, hurdle rate, or opportunity cost of capital.

Given a stream of cash flows $C_0, C_1, \dots, C_T$ over the next **T** periods, and a rate of return **k**, the net present value (NPV) of this cash flow stream is given by
$$NPV = C_0 + \sum_{t=1}^T \frac{C_t}{(1+k)^t}$$
 (6.2)

The NPV of different options should be compared when making supply chain decisions.

A negative NPV for an option indicates that the option will lose money for the supply chain.

The decision with the highest NPV will provide a supply chain with the highest financial return

EXAMPLE 6-1 Trips Logistics, a third-party logistics firm that provides warehousing and other logistics services, is facing a decision regarding the amount of space to lease for the upcoming three-year period. The general manager has forecast that Trips Logistics will need to handle a demand of 100,000 units for each of the next three years..

Historically, Trips Logistics has required 1,000 square feet of warehouse space for every 1,000 units of demand.

For the purposes of this discussion, the only cost Trips Logistics faces is the cost for the warehouse. Trips Logistics receives revenue of \$1.22 for each unit of demand

Analysis The general manager decides to compare the NPV of signing a three-year lease for 100,000 square feet of warehouse space with obtaining the space from the spot market each year.

If the general manager obtains warehousing space from the spot market each year, Trips Logistics will earn \$1.22 for each unit and pay \$1.20 for one square foot of warehouse space required.

The expected annual profit for Trips Logistics in this case is given by the following: Expected annual profit if warehousing = $(100,000 * \$1.22)$ space is obtained from spot market - $(100,000 * \$1.20) = \$2,000$ Obtaining warehouse space from the spot market provides Trips Logistics with an expected positive cash flow of \$2,000 in each of the three years. The NPV may be evaluated as follows: $NPV_{1\text{No lease}2} = C_0 + C_1 / (1 + k) + C_2 / (1 + k)^2 = 2,000 + 2,000 / 1.1 + 2,000 / 1.1^2 = \$5,471$

If the general manager leases 100,000 sq. ft. of warehouse space for the next three years, Trips Logistics pays \$1 per square foot of space leased each year.

The expected annual profit for Trips Logistics in this case is given by the following:

Expected annual profit with three-year lease = $(100,000 * \$1.22) - (100,000 * \$1.00) = \$22,000$ Signing a lease for three years provides Trips Logistics with a positive cash flow of \$22,000 in each of the three years. The NPV may be evaluated as $NPV_{Lease} = C_0 + \frac{C_1}{(1 + k)} + \frac{C_2}{(1 + k)^2} = 22,000 + \frac{22,000}{1.1} + \frac{22,000}{1.1^2} = \$60,182$

The NPV of signing the lease is $\$60,182 - \$5,471 = \$54,711$ higher than obtaining warehousing space on the spot market

Based on this simple analysis, a manager may opt to sign the lease. However, this does not tell the whole story because we have not yet included the uncertainty in spot prices and valued the greater flexibility to adjust to uncertainty that the spot market provides the manager .

In the next section, we introduce methodology that allows for uncertainty and discuss how the inclusion of uncertainty of future demand and costs may cause the manager to rethink the decision

In any global supply chain, demand, prices, exchange rates, and several other factors are uncertain and are likely to fluctuate during the life of any supply chain decision.

In an uncertain environment, the problem with using a simple DCF analysis is that it typically undervalues flexibility. The result is often a supply chain that performs well if everything goes according to plan but becomes terribly expensive if something unexpected happens.

A manager makes several different decisions when designing a supply chain network. For instance:

- **Should the firm sign a long-term contract for warehousing space or get space from the spot market as needed?**
- **What should the firm's mix of long-term and spot market be in the portfolio of transportation capacity?**
- **How much capacity should various facilities have? What fraction of this capacity should be flexible?**

Cont.

If uncertainty is ignored, a manager will always sign long-term contracts (because they are typically cheaper) and avoid all flexible or backup capacity (because it is more expensive). Such decisions can hurt the firm, however, if future demand or prices are not as forecast at the time of the decision. including global currency instability, unpredictable commodities costs, uncertainty about customer demand, political or social unrest in key markets, and potential changes in government regulations.”

It is thus important to provide a methodology that allows managers to incorporate this uncertainty into their network design process.

In this section, we describe such a methodology and show that accounting for uncertainty can have a significant impact on the value of network design decisions.

Decision Tree Analysis



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The Basics of Decision Tree Analysis A decision tree is a graphic device used to evaluate decisions under uncertainty. Decision trees with DCFs can be used to evaluate supply chain design decisions given uncertainty in prices, demand, exchange rates, and inflation. The first step in setting up a decision tree is to identify the number of time periods into the future that will be considered when making the decision. The decision maker should also identify the duration of a period—a day, a month, a quarter, or any other time period.

The duration of a period should be the minimum period of time over which factors affecting supply chain decisions may change by a significant amount. “Significant” is hard to define, but in most cases it is appropriate to use as a period the duration over which an aggregate plan holds. If planning is done monthly, for example, we set the duration of a period at a month. In the following discussion, **T** will represent the number of time periods over which the supply chain decision is to be evaluated.

The decision tree analysis methodology is summarized as follows:

- 1. Identify the duration of each period (month, quarter, etc.) and the number of periods T over which the decision is to be evaluated.**
- 2. Identify factors such as demand, price, and exchange rate whose fluctuation will be considered over the next T periods.**
- 3. Identify representations of uncertainty for each factor; that is, determine what distribution to use to model the uncertainty**

4. Identify the periodic discount rate k for each period.

5. Represent the decision tree with defined states in each period, as well as the transition probabilities between states in successive periods.

6. Starting at period T , work back to Period 0, identifying the optimal decision and the expected cash flows at each step. Expected cash flows at each state in a given period should be discounted back when included in the previous period.

Evaluating Flexibility at Trips Logistics We illustrate the decision tree analysis methodology by using the lease decision facing the general manager at Trips Logistics. The manager must decide whether to lease warehouse space for the coming three years and the quantity to lease. The manager anticipates uncertainty in demand and spot prices for warehouse space over the coming three years. The long-term lease is cheaper but the space could go unused if demand is lower than anticipated. The long-term lease may also end up being more expensive if future spot market prices come down.

The manager is considering three options:

- 1. Get all warehousing space from the spot market as needed.**
- 2. Sign a three-year lease for a fixed amount of warehouse space and get additional requirements from the spot market.**
- 3. Sign a flexible lease with a minimum charge that allows variable usage of warehouse space up to a limit, with additional requirements from the spot market.**

We now discuss how the manager can evaluate each decision, taking uncertainty into account.

One thousand square feet of warehouse space is required for every 1,000 units of demand, and the current demand at Trips Logistics is for 100,000 units per year. The manager forecasts that from one year to the next, demand may go up by 20 percent, with a probability of 0.5, or go down by 20 percent, with a probability of 0.5.

The probabilities of the two outcomes are unchanged from one year to the next. The general manager feels that prices of warehouse space and demand for the product fluctuate independently. Each unit Trips Logistics handles results in revenue of \$1.22 and Trips Logistics is committed to handling all demand that arises. Trips Logistics uses a discount rate of $k = 0.1$ for each of the three years.

The general manager assumes that all costs are incurred at the beginning of each year and thus constructs a decision tree with $T = 2$., with each node representing demand (D) in thousands of units and price (p) in dollars.

The probability of each transition is 0.5 3 ,0.5 5 ,0.25 because price and demand fluctuate independently.

The manager first analyzes the option of not signing a lease and obtaining all warehouse space from the spot market. He starts with Period 2 and evaluates the profit for Trips Logistics at each node. At the node $D = 144, p = \$1.45$, Trips Logistics must satisfy a demand of 144,000 and faces a spot price of \$1.45 per square foot for warehouse space in Period 2.

The cost incurred by Trips Logistics in Period 2 at the node $D = 144, p = \$1.45$ is represented by $C(D = 144, p = 1.45, 2)$ and is given by $C(D = 144, p = 1.45, 2) =: 144,000 \times 1.45 = \$208,800$

The profit at Trips Logistics in Period 2 at the node

**$D = 144, p = \$1.45$ is represented by $P(D = 144, p = 1.45, 2)$
and is given by**

$$\begin{aligned} P(D = 144, p = 1.45, 2) &= 144,000 \times 1.22 - C(D = 144, p = 1.45, 2) \\ &= 175,680 - 208,800 = -\$33,120 \end{aligned}$$

A global supply chain network is exposed to a variety of risks, including supply disruption, supply delays, demand fluctuations, price fluctuations, and exchange-rate fluctuations. hurt supply chain performance. For example, contamination at one of the two suppliers of flu vaccine to the United States led to a severe shortage at the beginning of the 2004 flu season. This shortage led to rationing in most states and severe price gouging in some cases. Similarly, the significant strengthening of the euro has hurt firms that have most of their supply sources located in Western Europe.

categorization of supply chain risks and their drivers that must be considered during network design

Disruptions :Natural disaster, war, terrorism Labor disputes
Supplier bankruptcy .

Delays High capacity utilization at supply source Inflexibility of
supply source Poor quality or yield at supply source

Systems risk Information infrastructure breakdown System
integration or extent of systems being networked

Forecast risk Inaccurate forecasts due to long lead times,
seasonality, product variety, short life cycles, small customer
base Bullwhip effect or information distortion

Intellectual property risk Vertical integration of supply chain
Global outsourcing and markets

Cont.

Procurement risk Exchange-rate risk Fraction purchased from a single source Industry-wide capacity utilization .

Receivables risk Inventory Number of customers Financial strength of customers

Inventory risk: Rate of product obsolescence Inventory holding cost Product value Demand and supply uncertainty

Capacity risk: Cost of capacity
Capacity flexibility

Good network design can play a significant role in mitigating supply chain risk. For instance, having multiple suppliers mitigates the risk of disruption from any one supply source.

An excellent example is the difference in impact on Nokia and Ericsson when a plant owned by Royal Phillips Electronics, located in New Mexico, caught fire in March 2000. Nokia adjusted to the disruption quickly using several other supply plants in its network.

In contrast, Ericsson had no backup source in its network and was unable to react. Ericsson estimated that it lost revenues of \$400 million as a result. Similarly, having flexible capacity mitigates the risks of global demand, price, and exchange-rate fluctuations.

For example, Hino Trucks uses flexible capacity at its plants to change production levels for different products by shifting workforce between lines. As a result, the company keeps a constant workforce in the plant even though the production at each line varies to best match supply and demand.

Every mitigation strategy, however, comes at a price and may increase other risks. For example, increasing inventory mitigates the risk of delays but increases the risk of obsolescence. Acquiring multiple suppliers mitigates the risk of disruption but increases costs because each supplier may have difficulty achieving economies of scale. Thus, it is very important to develop tailored mitigation strategies during network design that achieve a good balance between the amount of risk mitigated and the increase in cost. Some tailored mitigation strategies are outlined below

tailored mitigation strategies



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Increase capacity: Focus on low cost, decentralized capacity for predictable demand. Build centralized capacity for unpredictable demand. Increase decentralization as cost of capacity drops.

Get redundant suppliers: More redundant supply for high-volume products, less redundancy for low-volume products. Centralize redundancy for low-volume products in a few flexible suppliers.

Increases responsiveness: Favor cost over responsiveness for commodity products. Favor responsiveness over cost for short-life-cycle products.

Cont.

Increase inventory: Decentralize inventory of predictable, lower-value products. Centralize inventory of less predictable, higher-value products.

Increase flexibility: Favor cost over flexibility for predictable, high-volume products. Favor flexibility for unpredictable, low-volume products. Centralize flexibility in a few locations if it is expensive.

Pool or aggregate demand Increase aggregation as unpredictability grows.

Increase source capability Prefer capability over cost for high-value, high-risk products. Favor cost over capability for low-value commodity products. Centralize high capability in flexible source if possible.

Summarize



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1. Identify uncertainties that influence supply chain performance and network design. The main financial measurement for evaluating supply chain alternatives is the present value of the stream of cash flows generated by each alternative.

These streams are affected by uncertainty of demand, price, exchange rates, and other economic factors. These uncertainties and any flexibility in the supply chain network must be taken into account when valuing the cash flows. evaluations on the decision alternatives.

Cont.

2. Understand the methodologies used to evaluate supply chain decisions under uncertainty. When valuing the streams of cash flows, decision trees are a basic approach to valuing alternatives under uncertainty.

Incorporating a binomial representation of uncertainty allows the decision tree to value alternatives given uncertainty. When decision trees become too complex to solve reasonably, simulation can be used to perform financial

Cont.



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3. Analyze supply chain network design decisions in an uncertain environment. The basic steps in analyzing network design decisions involve gathering financial data on the alternatives, determining what the uncertainties affecting the decision are, quantifying the cash flows for each alternative in each time period, quantifying the uncertainties' impact on the cash flows, and using one of the methodologies to calculate a financial valuation for the different alternatives.