Learning Objectives

1. Identify factors that need to be included in total cost when making global sourcing decisions.
2. Define uncertainties that are particularly relevant when designing global supply chains.
3. Explain different strategies that may be used to mitigate risk in global supply chains.
4. Understand decision tree methodologies used to evaluate supply chain design decisions under uncertainty.
Impact of Globalization on Supply Chain Networks

• Opportunities to simultaneously increase revenues and decrease costs
• Accompanied by significant additional risk
• Difference between success and failure often ability to incorporate suitable risk mitigation into supply chain design
• Uncertainty of demand and price drives the value of building flexible production capacity
## Impact of Globalization on Supply Chain Networks

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Percentage of Supply Chains Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural disasters</td>
<td>35</td>
</tr>
<tr>
<td>Shortage of skilled resources</td>
<td>24</td>
</tr>
<tr>
<td>Geopolitical uncertainty</td>
<td>20</td>
</tr>
<tr>
<td>Terrorist infiltration of cargo</td>
<td>13</td>
</tr>
<tr>
<td>Volatility of fuel prices</td>
<td>37</td>
</tr>
<tr>
<td>Currency fluctuation</td>
<td>29</td>
</tr>
<tr>
<td>Port operations/custom delays</td>
<td>23</td>
</tr>
<tr>
<td>Customer/consumer preference shifts</td>
<td>23</td>
</tr>
<tr>
<td>Performance of supply chain partners</td>
<td>38</td>
</tr>
<tr>
<td>Logistics capacity/complexity</td>
<td>33</td>
</tr>
<tr>
<td>Forecasting/planning accuracy</td>
<td>30</td>
</tr>
<tr>
<td>Supplier planning/communication issues</td>
<td>27</td>
</tr>
<tr>
<td>Inflexible supply chain technology</td>
<td>21</td>
</tr>
</tbody>
</table>

TABLE 6-1
The Offshoring Decision: Total Cost

• Comparative advantage in global supply chains
• Quantify the benefits of offshore production along with the reasons
• Two reasons offshoring fails
  1. Focusing exclusively on unit cost rather than total cost
  2. Ignoring critical risk factors
The Offshoring Decision: Total Cost

• A global supply chain with offshoring increases the length and duration of information, product, and cash flows

• The complexity and cost of managing the supply chain can be significantly higher than anticipated

• Quantify factors and track them over time

• Big challenges with offshoring is increased risk and its potential impact on cost
## The Offshoring Decision: Total Cost

<table>
<thead>
<tr>
<th>Performance Dimension</th>
<th>Activity Affecting Performance</th>
<th>Impact of Offshoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order communication</td>
<td>Order placement</td>
<td>More difficult communication</td>
</tr>
<tr>
<td>Supply chain visibility</td>
<td>Scheduling and expediting</td>
<td>Poorer visibility</td>
</tr>
<tr>
<td>Raw material costs</td>
<td>Sourcing of raw material</td>
<td>Could go either way depending on raw material sourcing</td>
</tr>
<tr>
<td>Unit cost</td>
<td>Production, quality (production and transportation)</td>
<td>Labor/fixed costs decrease; quality may suffer</td>
</tr>
<tr>
<td>Freight costs</td>
<td>Transportation modes and quantity</td>
<td>Higher freight costs</td>
</tr>
<tr>
<td>Taxes and tariffs</td>
<td>Border crossing</td>
<td>Could go either way</td>
</tr>
<tr>
<td>Supply lead time</td>
<td>Order communication, supplier production scheduling, production</td>
<td>Lead time increase results in poorer forecasts and higher inventories</td>
</tr>
<tr>
<td></td>
<td>time, customs, transportation, receiving</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 6-2
# The Offshoring Decision: Total Cost

<table>
<thead>
<tr>
<th>Performance Dimension</th>
<th>Activity Affecting Performance</th>
<th>Impact of Offshoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-time delivery/lead time uncertainty</td>
<td>Production, quality, customs, transportation, receiving</td>
<td>Poorer on-time delivery and increased uncertainty resulting in higher inventory and lower product availability</td>
</tr>
<tr>
<td>Minimum order quantity</td>
<td>Production, transportation</td>
<td>Larger minimum quantities increase inventory</td>
</tr>
<tr>
<td>Product returns</td>
<td>Quality</td>
<td>Increased returns likely</td>
</tr>
<tr>
<td>Inventories</td>
<td>Lead times, inventory in transit and production</td>
<td>Increase</td>
</tr>
<tr>
<td>Working capital</td>
<td>Inventories and financial reconciliation</td>
<td>Increase</td>
</tr>
<tr>
<td>Hidden costs</td>
<td>Order communication, invoicing errors, managing exchange rate risk</td>
<td>Higher hidden costs</td>
</tr>
<tr>
<td>Stockouts</td>
<td>Ordering, production, transportation with poorer visibility</td>
<td>Increase</td>
</tr>
</tbody>
</table>

TABLE 6-2 continued
The Offshoring Decision: Total Cost

• Key elements of total cost
  1. Supplier price
  2. Terms
  3. Delivery costs
  4. Inventory and warehousing
  5. Cost of quality
  6. Customer duties, value added-taxes, local tax incentives
  7. Cost of risk, procurement staff, broker fees, infrastructure, and tooling and mold costs
  8. Exchange rate trends and their impact on cost
Key Point

It is critical that offshoring decisions be made while accounting for total cost. Offshoring typically lowers labor and fixed costs but increases risk, freight costs, and working capital. Before offshoring, product design and process design should be carefully evaluated to identify steps that may lower freight content and the need for working capital. Including an onshore option can lower the cost associated with covering risk from an offshore facility.
Risk Management In Global Supply Chains

• Risks include supply disruption, supply delays, demand fluctuations, price fluctuations, and exchange-rate fluctuations

• Critical for global supply chains to be aware of the relevant risk factors and build in suitable mitigation strategies
## Risk Management In Global Supply Chains

<table>
<thead>
<tr>
<th>Category</th>
<th>Risk Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disruptions</td>
<td>Natural disaster, war, terrorism</td>
</tr>
<tr>
<td></td>
<td>Labor disputes</td>
</tr>
<tr>
<td></td>
<td>Supplier bankruptcy</td>
</tr>
<tr>
<td>Delays</td>
<td>High capacity utilization at supply source</td>
</tr>
<tr>
<td></td>
<td>Inflexibility of supply source</td>
</tr>
<tr>
<td></td>
<td>Poor quality or yield at supply source</td>
</tr>
<tr>
<td>Systems risk</td>
<td>Information infrastructure breakdown</td>
</tr>
<tr>
<td></td>
<td>System integration or extent of systems being networked</td>
</tr>
<tr>
<td>Forecast risk</td>
<td>Inaccurate forecasts due to long lead times,</td>
</tr>
<tr>
<td></td>
<td>seasonality, product variety, short life cycles,</td>
</tr>
<tr>
<td></td>
<td>small customer base</td>
</tr>
<tr>
<td></td>
<td>Information distortion</td>
</tr>
</tbody>
</table>

**TABLE 6-3**
### Risk Management In Global Supply Chains

<table>
<thead>
<tr>
<th>Category</th>
<th>Risk Drivers</th>
</tr>
</thead>
</table>
| Intellectual property risk | Vertical integration of supply chain  
                           | Global outsourcing and markets                                                 |
| Procurement risk      | Exchange-rate risk  
                           | Price of inputs  
                           | Fraction purchased from a single source  
                           | Industry-wide capacity utilization                                              |
| Receivables risk      | 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                                                           |

**TABLE 6-3**
Risk Management In Global Supply Chains

• Good network design can play a significant role in mitigating supply chain risk
• Every mitigation strategy comes at a price and may increase other risks
• Global supply chains should generally use a combination of rigorously evaluated mitigation strategies along with financial strategies to hedge uncovered risks
Risk Management In Global Supply Chains

<table>
<thead>
<tr>
<th>Risk Mitigation Strategy</th>
<th>Tailored Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase capacity</td>
<td>Focus on low-cost, decentralized capacity for predictable demand. Build centralized capacity for unpredictable demand. Increase decentralization as cost of capacity drops.</td>
</tr>
<tr>
<td>Increase responsiveness</td>
<td>Favor cost over responsiveness for commodity products. Favor responsiveness over cost for short–life cycle products.</td>
</tr>
</tbody>
</table>

TABLE 6-4
## Risk Management In Global Supply Chains

<table>
<thead>
<tr>
<th>Risk Mitigation Strategy</th>
<th>Tailored Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase inventory</td>
<td>Decentralize inventory of predictable, lower value products. Centralize inventory of less predictable, higher value products.</td>
</tr>
<tr>
<td>Increase flexibility</td>
<td>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.</td>
</tr>
<tr>
<td>Pool or aggregate demand</td>
<td>Increase aggregation as unpredictability grows.</td>
</tr>
<tr>
<td>Increase source capability</td>
<td>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.</td>
</tr>
</tbody>
</table>
Flexibility, Chaining, and Containment

• Three broad categories of flexibility
  – New product flexibility
    • Ability to introduce new products into the market at a rapid rate
  – Mix flexibility
    • Ability to produce a variety of products within a short period of time
  – Volume flexibility
    • Ability to operate profitably at different levels of output
Flexibility, Chaining, and Containment

Dedicated Network

Fully Flexible Network

Chained Network with One Long Chain

Chained Network with Two Short Chains

FIGURE 6-1
Flexibility, Chaining, and Containment

• As flexibility is increased, the marginal benefit derived from the increased flexibility decreases
  – With demand uncertainty, longer chains pool available capacity
  – Long chains may have higher fixed cost than multiple smaller chains
  – Coordination more difficult across with a single long chain

• Flexibility and chaining are effective when dealing with demand fluctuation but less effective when dealing with supply disruption
Key Point

Appropriate flexibility is an effective approach for a global supply chain to deal with a variety of risks and uncertainties. Whereas some flexibility is valuable, too much flexibility may not be worth the cost. Strategies such as chaining and containment should be used to maximize the benefit from flexibility while keeping costs low.
Discounted Cash Flow Analysis

• Supply chain decisions should be evaluated as a sequence of cash flows over time
• Discounted cash flow (DCF) analysis evaluates the present value of any stream of future cash flows and allows managers to compare different cash flow streams in terms of their financial value
• Based on the time value of money – a dollar today is worth more than a dollar tomorrow
Discounted Cash Flow Analysis

\[
\text{discount factor} = \frac{1}{1 + k}
\]

\[
\text{NPV} = C_0 + \sum_{t=1}^{T} \left( \frac{1}{1 + k} \right)^t C_t
\]

where

- \(C_0, C_1, \ldots, C_T\) is stream of cash flows over \(T\) periods
- \(\text{NPV}\) = net present value of this stream
- \(k\) = rate of return

- Compare NPV of different supply chain design options
- The option with the highest NPV will provide the greatest financial return
Trips Logistics Example

• Demand = 100,000 units
• 1,000 sq. ft. of space for every 1,000 units of demand
• Revenue = $1.22 per unit of demand
• Sign a three-year lease or obtain warehousing space on the spot market?
• Three-year lease cost = $1 per sq. ft.
• Spot market cost = $1.20 per sq. ft.
• $k = 0.1
Trips Logistics Example

Expected annual profit if warehouse space is obtained from the spot market

\[ \text{Expected annual profit} = (100,000 \times \$1.22) - (100,000 \times \$1.20) = \$2,000 \]

NPV (No lease) = \( C_0 + \frac{C_1}{1 + k} + \frac{C_2}{(1 + k)^2} \)

\[ = 2,000 + \frac{2,000}{1.1} + \frac{2,000}{1.1^2} = \$5,471 \]
Trips Logistics Example

Expected annual profit with three year lease

\[ \text{Expected annual profit} = (100,000 \times $1.22) - (100,000 \times $1.00) \]
\[ = $22,000 \]

NPV(Lease) = \( C_0 + \frac{C_1}{1+k} + \frac{C_2}{(1+k)^2} \)

\[ = 22,000 + \frac{22,000}{1.1} + \frac{22,000}{1.1^2} = $60,182 \]

• NPV of signing lease is $60,182 – $5,471 = $54,711 higher than spot market
Using Decision Trees

• Several different decisions
  – 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?
Using Decision Trees

• Executives need a methodology that allows them to estimate global currency instability, unpredictable commodities costs, uncertainty about customer demand, political or social unrest in key markets, and potential changes in government regulations the uncertainty in demand and price forecast
Basics of Decision Tree Analysis

• A decision tree is a graphic device used to evaluate decisions under uncertainty
  – Identify the number and duration of time periods that will be considered
  – Identify factors that will affect the value of the decision and are likely to fluctuate over the time periods
  – Evaluate decision using a decision tree
Decision Tree Methodology

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 whose fluctuation will be considered
3. Identify representations of uncertainty for each factor
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
Decision Tree – Trips Logistics

• Three warehouse lease 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 requirement from the spot market
Decision Tree – Trips Logistics

• 1000 sq. ft. of warehouse space needed for 1000 units of demand
• Current demand = 100,000 units per year
• Binomial uncertainty: Demand can go up by 20% with \( p = 0.5 \) or down by 20% with \( 1 - p = 0.5 \)
• Lease price = $1.00 per sq. ft. per year
• Spot market price = $1.20 per sq. ft. per year
• Spot prices can go up by 10% with \( p = 0.5 \) or down by 10% with \( 1 - p = 0.5 \)
• Revenue = $1.22 per unit of demand
• \( k = 0.1 \)
FIGURE 6-2

Decision Tree
Decision Tree – Trips Logistics

• Analyze the option of not signing a lease and using the spot market
• Start with Period 2 and calculate the profit at each node

For $D = 144$, $p = $1.45, in Period 2:

$$C(D = 144, \ p = 1.45, 2) = 144,000 \times 1.45$$

$$= $208,800$$

$$P(D = 144, \ p = 1.45, 2) = 144,000 \times 1.22$$

$$– C(D = 144, \ p = 1.45, 2)$$

$$= 175,680 – 208,800$$

$$= –$33,120$$
## Decision Tree – Trips Logistics

<table>
<thead>
<tr>
<th></th>
<th>Revenue</th>
<th>Cost $C(D =, p =, 2)$</th>
<th>Profit $P(D =, p =, 2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D = 144, p = 1.45$</td>
<td>$144,000 \times 1.22$</td>
<td>$144,000 \times 1.45$</td>
<td>$-33,120$</td>
</tr>
<tr>
<td>$D = 144, p = 1.19$</td>
<td>$144,000 \times 1.22$</td>
<td>$144,000 \times 1.19$</td>
<td>$4,320$</td>
</tr>
<tr>
<td>$D = 144, p = 0.97$</td>
<td>$144,000 \times 1.22$</td>
<td>$144,000 \times 0.97$</td>
<td>$36,000$</td>
</tr>
<tr>
<td>$D = 96, p = 1.45$</td>
<td>$96,000 \times 1.22$</td>
<td>$96,000 \times 1.45$</td>
<td>$-22,080$</td>
</tr>
<tr>
<td>$D = 96, p = 1.19$</td>
<td>$96,000 \times 1.22$</td>
<td>$96,000 \times 1.19$</td>
<td>$2,880$</td>
</tr>
<tr>
<td>$D = 96, p = 0.97$</td>
<td>$96,000 \times 1.22$</td>
<td>$96,000 \times 0.97$</td>
<td>$24,000$</td>
</tr>
<tr>
<td>$D = 64, p = 1.45$</td>
<td>$64,000 \times 1.22$</td>
<td>$64,000 \times 1.45$</td>
<td>$-14,720$</td>
</tr>
<tr>
<td>$D = 64, p = 1.19$</td>
<td>$64,000 \times 1.22$</td>
<td>$64,000 \times 1.19$</td>
<td>$1,920$</td>
</tr>
<tr>
<td>$D = 64, p = 0.97$</td>
<td>$64,000 \times 1.22$</td>
<td>$64,000 \times 0.97$</td>
<td>$16,000$</td>
</tr>
</tbody>
</table>

**TABLE 6-5**
Decision Tree – Trips Logistics

• Expected profit at each node in Period 1 is the profit during Period 1 plus the present value of the expected profit in Period 2

• Expected profit $\text{EP}(D =, p =, 1)$ at a node is the expected profit over all four nodes in Period 2 that may result from this node

• $\text{PVEP}(D =, p =, 1)$ is the present value of this expected profit and $\text{P}(D =, p =, 1)$, and the total expected profit, is the sum of the profit in Period 1 and the present value of the expected profit in Period 2
Decision Tree – Trips Logistics

• From node $D = 120$, $p = $1.32 in Period 1, there are four possible states in Period 2

• Evaluate the expected profit in Period 2 over all four states possible from node $D = 120$, $p = $1.32 in Period 1 to be

$$EP(D = 120, p = 1.32,1) = 0.2 \times [P(D = 144, p = 1.45,2)$$
$$+ P(D = 144, p = 1.19,2)$$
$$+ P(D = 96, p = 1.45,2)$$
$$+ P(D = 96, p = 1.19,2)$$
$$= 0.25 \times [-33,120 + 4,320$$
$$- 22,080 + 2,880]$$
$$= -$12,000}
The present value of this expected value in Period 1 is

\[ PVEP(D = 120, p = 1.32,1) = EP(D = 120, p = 1.32,1) / (1 + k) \]
\[ = -$12,000 / (1.1) \]
\[ = -$10,909 \]

The total expected profit \( P(D = 120, p = 1.32,1) \) at node \( D = 120, p = 1.32 \) in Period 1 is the sum of the profit in Period 1 at this node, plus the present value of future expected profits possible from this node

\[ P(D = 120, p = 1.32,1) = (120,000 \times 1.22) - (120,000 \times 1.32) + PVEP(D = 120, p = 1.32,1) \]
\[ = -$12,000 - $10,909 = -$22,909 \]
Decision Tree – Trips Logistics

• For Period 0, the total profit $P(D = 100, p = 120,0)$ is the sum of the profit in Period 0 and the present value of the expected profit over the four nodes in Period 1

$EP(D = 100, p = 1.20,0) = 0.25 \times [P(D = 120, p = 1.32,1) + P(D = 120, p = 1.08,1) + P(D = 96, p = 1.32,1) + P(D = 96, p = 1.08,1)]$

$= 0.25 \times [–22,909 + 32,073 – 15,273] + 21,382$

$= $3,818
Decision Tree – Trips Logistics

\[
PVEP(D = 100, p = 1.20,1) = EP(D = 100, p = 1.20,0) / (1 + k)
= \$3,818 / (1.1) = \$3,471
\]

\[
P(D = 100, p = 1.20,0) = (100,000 \times 1.22) - (100,000 \times 1.20) + PVEP(D = 100, p = 1.20,0)
= \$2,000 + \$3,471 = \$5,471
\]

• Therefore, the expected NPV of not signing the lease and obtaining all warehouse space from the spot market is given by \(NPV(\text{Spot Market}) = \$5,471\)
Decision Tree – Trips Logistics

• Fixed Lease Option

<table>
<thead>
<tr>
<th>Node</th>
<th>EP(D =, p =, 1)</th>
<th>( P(D =, p =, 1) = D \times 1.22 - D \times p + EP(D =, p =, 1) / (1 + k) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D = 120, p = 1.32 )</td>
<td>(-$12,000)</td>
<td>(-$22,909)</td>
</tr>
<tr>
<td>( D = 120, p = 1.08 )</td>
<td>($16,000)</td>
<td>($32,073)</td>
</tr>
<tr>
<td>( D = 80, p = 1.32 )</td>
<td>(-$8,000)</td>
<td>(-$15,273)</td>
</tr>
<tr>
<td>( D = 80, p = 1.08 )</td>
<td>($11,000)</td>
<td>($21,382)</td>
</tr>
</tbody>
</table>

TABLE 6-6
## Decision Tree – Trips Logistics

<table>
<thead>
<tr>
<th>Node</th>
<th>Leased Space</th>
<th>Warehouse Space at Spot Price ($S$)</th>
<th>Profit $P(D = p = 2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D = 144, p = 1.45$</td>
<td>100,000 sq. ft.</td>
<td>44,000 sq. ft.</td>
<td>$11,880$</td>
</tr>
<tr>
<td>$D = 144, p = 1.19$</td>
<td>100,000 sq. ft.</td>
<td>44,000 sq. ft.</td>
<td>$23,320$</td>
</tr>
<tr>
<td>$D = 144, p = 0.97$</td>
<td>100,000 sq. ft.</td>
<td>44,000 sq. ft.</td>
<td>$33,000$</td>
</tr>
<tr>
<td>$D = 96, p = 1.45$</td>
<td>100,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$17,120$</td>
</tr>
<tr>
<td>$D = 96, p = 1.19$</td>
<td>100,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$17,120$</td>
</tr>
<tr>
<td>$D = 96, p = 0.97$</td>
<td>100,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$17,120$</td>
</tr>
<tr>
<td>$D = 64, p = 1.45$</td>
<td>100,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$-21,920$</td>
</tr>
<tr>
<td>$D = 64, p = 1.19$</td>
<td>100,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$-21,920$</td>
</tr>
<tr>
<td>$D = 64, p = 0.97$</td>
<td>100,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$-21,920$</td>
</tr>
</tbody>
</table>

### Profit Calculation

$$P(D = p = 2) = D \times 1.22 - (100,000 \times 1 + S \times p)$$

TABLE 6-7
### Decision Tree – Trips Logistics

<table>
<thead>
<tr>
<th>Node</th>
<th>$EP(D =, p =, 1)$</th>
<th>Warehouse Space at Spot Price ($S$)</th>
<th>$P(D =, p =, 1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D = 120, p = 1.32$</td>
<td>$0.25 \times (P(D = 144, p = 1.45, 2) + P(D = 144, p = 1.19, 2) + P(D = 96, p = 1.45, 2) + P(D = 96, p = 1.19, 2)) = 0.25 \times (11,880 + 23,320 + 17,120 + 17,120) = 17,360$</td>
<td>20,000</td>
<td>$35,782$</td>
</tr>
<tr>
<td>$D = 120, p = 1.08$</td>
<td>$0.25 \times (23,320 + 33,000 + 17,120 + 17,120) = 22,640$</td>
<td>20,000</td>
<td>$45,382$</td>
</tr>
<tr>
<td>$D = 80, p = 1.32$</td>
<td>$0.25 \times (17,120 + 17,120 – 21,920 – 21,920) = –2,400$</td>
<td>0</td>
<td>$–4,582$</td>
</tr>
<tr>
<td>$D = 80, p = 1.08$</td>
<td>$0.25 \times (17,120 + 17,120 – 21,920 – 21,920) = –2,400$</td>
<td>0</td>
<td>$–4,582$</td>
</tr>
</tbody>
</table>

**TABLE 6-8**
Decision Tree – Trips Logistics

• Using the same approach for the lease option, $\text{NPV}(\text{Lease}) = $38,364
• Recall that when uncertainty was ignored, the NPV for the lease option was $60,182
• However, the manager would probably still prefer to sign the three-year lease for 100,000 sq. ft. because this option has the higher expected profit
Decision Tree – Trips Logistics

• Flexible Lease Option

<table>
<thead>
<tr>
<th>Node</th>
<th>Warehouse Space at $1 (W)</th>
<th>Warehouse Space at Spot Price (S)</th>
<th>Profit $P(D =, p =, 2) = D \times 1.22 - (W \times 1 + S \times p)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D = 144, p = 1.45$</td>
<td>100,000 sq. ft.</td>
<td>44,000 sq. ft.</td>
<td>$11,880$</td>
</tr>
<tr>
<td>$D = 144, p = 1.19$</td>
<td>100,000 sq. ft.</td>
<td>44,000 sq. ft.</td>
<td>$23,320$</td>
</tr>
<tr>
<td>$D = 144, p = 0.97$</td>
<td>100,000 sq. ft.</td>
<td>44,000 sq. ft.</td>
<td>$33,000$</td>
</tr>
<tr>
<td>$D = 96, p = 1.45$</td>
<td>96,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$21,120$</td>
</tr>
<tr>
<td>$D = 96, p = 1.19$</td>
<td>96,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$21,120$</td>
</tr>
<tr>
<td>$D = 96, p = 0.97$</td>
<td>96,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$21,120$</td>
</tr>
<tr>
<td>$D = 64, p = 1.45$</td>
<td>64,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$14,080$</td>
</tr>
<tr>
<td>$D = 64, p = 1.19$</td>
<td>64,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$14,080$</td>
</tr>
<tr>
<td>$D = 64, p = 0.97$</td>
<td>64,000 sq. ft.</td>
<td>0 sq. ft.</td>
<td>$14,080$</td>
</tr>
</tbody>
</table>

TABLE 6-9

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## Decision Tree – Trips Logistics

<table>
<thead>
<tr>
<th>Node</th>
<th>$EP(D =, p =, 1)$</th>
<th>Warehouse Space at $1 (W)$</th>
<th>Warehouse Space at Spot Price (S)</th>
<th>$P(D =, p =, 1) = D \times 1.22 – (W \times 1 + S \times p) + EP(D =, p =, 1)(1 + k)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D = 120, p = 1.32$</td>
<td>$0.25 \times (11,880 + 23,320 + 21,120 + 21,120) = 19,360$</td>
<td>100,000</td>
<td>20,000</td>
<td>$37,600</td>
</tr>
<tr>
<td>$D = 120, p = 1.08$</td>
<td>$0.25 \times (23,320 + 33,000 + 21,120 + 21,120) = 24,640$</td>
<td>100,000</td>
<td>20,000</td>
<td>$47,200</td>
</tr>
<tr>
<td>$D = 80, p = 1.32$</td>
<td>$0.25 \times (21,120 + 21,120 + 14,080 + 14,080) = 17,600$</td>
<td>80,000</td>
<td>0</td>
<td>$33,600</td>
</tr>
<tr>
<td>$D = 80, p = 1.08$</td>
<td>$0.25 \times (21,920 + 21,920 + 14,080 + 14,080) = 17,600$</td>
<td>80,000</td>
<td>0</td>
<td>$33,600</td>
</tr>
</tbody>
</table>

TABLE 6-10
### Decision Tree – Trips Logistics

<table>
<thead>
<tr>
<th>Option</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All warehouse space from the spot market</td>
<td>$5,471</td>
</tr>
<tr>
<td>Lease 100,000 sq. ft. for three years</td>
<td>$38,364</td>
</tr>
<tr>
<td>Flexible lease to use between 60,000 and 100,000 sq. ft.</td>
<td>$46,545</td>
</tr>
</tbody>
</table>

**TABLE 6-11**
Key Point

Uncertainty in demand and economic factors should be included in the financial evaluation of supply chain design decisions. The inclusion of uncertainty typically decreases the value of rigidity and increases the value of flexibility.
Onshore or Offshore

• D-Solar demand in Europe = 100,000 panels per year
• Each panel sells for €70
• Annual demand may increase by 20 percent with probability 0.8 or decrease by 20 percent with probability 0.2
• Build a plant in Europe or China with a rated capacity of 120,000 panels
Key Point

Flexibility should be valued by taking into account uncertainty in demand and economic factors. In general, the value of flexibility increases with an increase in uncertainty.
## D-Solar Decision

### European Plant

<table>
<thead>
<tr>
<th></th>
<th>Fixed Cost (euro)</th>
<th>Variable Cost (euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 million/year</td>
<td>40/panel</td>
</tr>
</tbody>
</table>

### Chinese Plant

<table>
<thead>
<tr>
<th></th>
<th>Fixed Cost (yuan)</th>
<th>Variable Cost (yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 million/year</td>
<td>340/panel</td>
</tr>
</tbody>
</table>

### Period 1

<table>
<thead>
<tr>
<th></th>
<th>Demand</th>
<th>Exchange Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>112,000</td>
<td>8.64 yuan/euro</td>
</tr>
</tbody>
</table>

### Period 2

<table>
<thead>
<tr>
<th></th>
<th>Demand</th>
<th>Exchange Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125,440</td>
<td>8.2944 yuan/euro</td>
</tr>
</tbody>
</table>

TABLE 6-12

TABLE 6-13
D-Solar Decision

• European plant has greater volume flexibility
• Increase or decrease production between 60,000 to 150,000 panels
• Chinese plant has limited volume flexibility
• Can produce between 100,000 and 130,000 panels
• Chinese plant will have a variable cost for 100,000 panels and will lose sales if demand increases above 130,000 panels
• Yuan, currently 9 yuan/euro, expected to rise 10%, probability of 0.7 or drop 10%, probability of 0.3
• Sourcing decision over the next three years
• Discount rate $k = 0.1$
D-Solar Decision

Period 0 profits = (100,000 x 70) – 1,000,000 – (100,000 x 40) = €2,000,000
Period 1 profits = (112,000 x 70) – 1,000,000 – (112,000 x 40) = €2,360,000
Period 2 profits = (125,440 x 70) – 1,000,000 – (125,440 x 40) = €2,763,200

Expected profit from onshoring = 2,000,000 + 2,360,000/1.1
+ 2,763,200/1.21
= €6,429,091

Period 0 profits = (100,000 x 70) – (8,000,000/9) – (100,000 x 340/9)
= €2,333,333
Period 1 profits = (112,000 x 70) – (8,000,000/8.64) – (112,000 x 340/8.64)
= €2,506,667
Period 2 profits = (125,440 x 70) – (8,000,000/7.9524) – (125,440 x 340/7.9524)
= €2,674,319

Expected profit from off-shoring = 2,333,333 + 2,506,667/1.1
+ 2,674,319/1.21
= €6,822,302
Decision Tree

FIGURE 6-3
D-Solar Decision

- Period 2 evaluation – onshore

Revenue from the manufacture and sale of 144,000 panels = 144,000 x 70
= €10,080,000

Fixed + variable cost of onshore plant = 1,000,000 + (144,000 x 40)
= €6,760,000

\[ P(D = 144, \ E = 10.89, 2) = 10,080,000 - 6,760,000 \]
= €3,320,000
# D-Solar Decision

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Sales</th>
<th>Cost</th>
<th>Quantity</th>
<th>Revenue (euro)</th>
<th>Cost (euro)</th>
<th>Profit (euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>144</td>
<td>10.89</td>
<td>144,000</td>
<td>144,000</td>
<td>10,080,000</td>
<td>6,760,000</td>
<td>3,320,000</td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>8.91</td>
<td>144,000</td>
<td>144,000</td>
<td>10,080,000</td>
<td>6,760,000</td>
<td>3,320,000</td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>10.89</td>
<td>96,000</td>
<td>96,000</td>
<td>6,720,000</td>
<td>4,840,000</td>
<td>1,880,000</td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>8.91</td>
<td>96,000</td>
<td>96,000</td>
<td>6,720,000</td>
<td>4,840,000</td>
<td>1,880,000</td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>7.29</td>
<td>144,000</td>
<td>144,000</td>
<td>10,080,000</td>
<td>6,760,000</td>
<td>3,320,000</td>
<td></td>
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<tr>
<td>96</td>
<td>7.29</td>
<td>96,000</td>
<td>96,000</td>
<td>6,720,000</td>
<td>4,840,000</td>
<td>1,880,000</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>10.89</td>
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<td>64,000</td>
<td>4,480,000</td>
<td>3,560,000</td>
<td>920,000</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>8.91</td>
<td>64,000</td>
<td>64,000</td>
<td>4,480,000</td>
<td>3,560,000</td>
<td>920,000</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>7.29</td>
<td>64,000</td>
<td>64,000</td>
<td>4,480,000</td>
<td>3,560,000</td>
<td>920,000</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 6-14**
D-Solar Decision

• Period 1 evaluation – onshore

\[
EP(D = 120, E = 9.90, 1) = 0.24 \times P(D = 144, E = 10.89, 2) \\
+ 0.56 \times P(D = 144, E = 8.91, 2) \\
+ 0.06 \times P(D = 96, E = 10.89, 2) \\
+ 0.14 \times P(D = 96, E = 8.91, 2) \\
= (0.24 \times 3,320,000) + (0.56 \times 3,320,000) \\
+ (0.06 \times 1,880,000) + (0.14 \times 1,880,000) \\
= €3,032,000
\]

\[
PVEP(D = 120, E = 9.90,1) = \frac{EP(D = 120, E = 9.90,1)}{(1 + k)} \\
= \frac{3,032,000}{1.1} = €2,756,364
\]
D-Solar Decision

- Period 1 evaluation – onshore

Revenue from manufacture and sale of 120,000 panels = 120,000 \times 70 = €8,400,000

Fixed + variable cost of onshore plant = 1,000,000 + (120,000 \times 40)
= €5,800,000

\[ P(D = 120, E = 9.90, 1) = 8,400,000 - 5,800,000 + PVEP(D = 120, E = 9.90, 1) \]
= 2,600,000 + 2,756,364
= €5,356,364
D-Solar Decision

<table>
<thead>
<tr>
<th>$D$</th>
<th>$E$</th>
<th>Sales</th>
<th>Production Cost</th>
<th>Quantity</th>
<th>Revenue (euro)</th>
<th>Cost (euro)</th>
<th>Expected Profit (euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>9.90</td>
<td>120,000</td>
<td>120,000</td>
<td>120,000</td>
<td>8,400,000</td>
<td>5,800,000</td>
<td>5,356,364</td>
</tr>
<tr>
<td>120</td>
<td>8.10</td>
<td>120,000</td>
<td>120,000</td>
<td>120,000</td>
<td>8,400,000</td>
<td>5,800,000</td>
<td>5,356,364</td>
</tr>
<tr>
<td>80</td>
<td>9.90</td>
<td>80,000</td>
<td>80,000</td>
<td>80,000</td>
<td>5,600,000</td>
<td>4,200,000</td>
<td>2,934,545</td>
</tr>
<tr>
<td>80</td>
<td>8.10</td>
<td>80,000</td>
<td>80,000</td>
<td>80,000</td>
<td>5,600,000</td>
<td>4,200,000</td>
<td>2,934,545</td>
</tr>
</tbody>
</table>

TABLE 6-15
D-Solar Decision

- Period 0 evaluation – onshore

\[
EP(D = 100, E = 9.00, 1) = 0.24 \times P(D = 120, E = 9.90, 1) \\
+ 0.56 \times P(D = 120, E = 8.10, 1) \\
+ 0.06 \times P(D = 80, E = 9.90, 1) \\
+ 0.14 \times P(D = 80, E = 8.10, 1)
\]
\[
= (0.24 \times 5,356,364) + (0.56 \times 5,5356,364) \\
+ (0.06 \times 2,934,545) + (0.14 \times 2,934,545)
\]
\[
= € 4,872,000
\]

\[
PVEP(D = 100, E = 9.00,1) = EP(D = 100, E = 9.00,1)/(1 + k)
\]
\[
= 4,872,000/1.1 = €4,429,091
\]
D-Solar Decision

• Period 0 evaluation – onshore

Revenue from manufacture and sale of 100,000 panels = 100,000 x 70 = €7,000,000

Fixed + variable cost of onshore plant = 1,000,000 + (100,000 x 40) = €5,000,000

\[ P(D = 100, E = 9.00, 1) = 8,400,000 - 5,800,000 \]
\[ + PVEP(D = 100, E = 9.00, 1) \]
\[ = 2,000,000 + 4,429,091 \]
\[ = €6,429,091 \]
D-Solar Decision

• Period 2 evaluation – offshore

Revenue from the manufacture and sale of 130,000 panels

\[= 130,000 \times 70\]
\[= €9,100,000\]

Fixed + variable cost of offshore plant

\[= 8,000,000 + (130,000 \times 340)\]
\[= 52,200,000\] yuan

\[P(D = 144, E = 10.89,2)\]

\[= 9,100,000 – (52,200,000/10.89)\]
\[= €4,306,612\]
## D-Solar Decision

<table>
<thead>
<tr>
<th>D</th>
<th>E</th>
<th>Sales</th>
<th>Production Cost</th>
<th>Quantity</th>
<th>Revenue (euro)</th>
<th>Cost (yuan)</th>
<th>Profit (euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>144</td>
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<td>130,000</td>
<td>130,000</td>
<td>130,000</td>
<td>9,100,000</td>
<td>52,200,000</td>
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<tr>
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<td>8.91</td>
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<td>130,000</td>
<td>130,000</td>
<td>9,100,000</td>
<td>52,200,000</td>
<td>3,241,414</td>
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<td>10.89</td>
<td>96,000</td>
<td>100,000</td>
<td>100,000</td>
<td>6,720,000</td>
<td>42,000,000</td>
<td>2,863,251</td>
</tr>
<tr>
<td>96</td>
<td>8.91</td>
<td>96,000</td>
<td>100,000</td>
<td>100,000</td>
<td>6,720,000</td>
<td>42,000,000</td>
<td>2,006,195</td>
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<tr>
<td>144</td>
<td>7.29</td>
<td>130,000</td>
<td>130,000</td>
<td>130,000</td>
<td>9,100,000</td>
<td>52,200,000</td>
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<td>100,000</td>
<td>100,000</td>
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<td>8.91</td>
<td>64,000</td>
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<td>42,000,000</td>
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<td>10,000</td>
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<td>3,560,000</td>
<td>–1,281,317</td>
</tr>
</tbody>
</table>

TABLE 6-16
D-Solar Decision

• Period 1 evaluation – offshore

\[
EP(D = 120, E = 9.90, 1) = 0.24 \times P(D = 144, E = 10.89, 2) \\
+ 0.56 \times P(D = 144, E = 8.91, 2) \\
+ 0.06 \times P(D = 96, E = 10.89, 2) \\
+ 0.14 \times P(D = 96, E = 8.91, 2)
\]

\[
= (0.24 \times 4,306,612) + (0.56 \times 3,241,414) \\
+ (0.06 \times 2,863,251) + (0.14 \times 2,006,195)
\]

\[
= \€ 3,301,441
\]

\[
PVEP(D = 120, E = 9.90,1) = EP(D = 120, E = 9.90,1)/(1 + k)
\]

\[
= 3,301,441/1.1 = \€3,001,310
\]
D-Solar Decision

• Period 1 evaluation – offshore

Revenue from manufacture and sale of 120,000 panels = 120,000 x 70 = €8,400,000

Fixed + variable cost of offshore plant = 8,000,000 + (120,000 x 340) = 48,800,000 yuan

\[ P(D = 120, E = 9.90, 1) = 8,400,000 - \frac{48,800,000}{9.90} \]
\[ + PVEP(D = 120, E = 9.90, 1) \]
\[ = 3,470,707 + 3,001,310 \]
\[ = €6,472,017 \]
D-Solar Decision

<table>
<thead>
<tr>
<th>$D$</th>
<th>$E$</th>
<th>Sales</th>
<th>Production Cost</th>
<th>Quantity</th>
<th>Revenue (euro)</th>
<th>Cost (yuan)</th>
<th>Expected Profit (euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>9.90</td>
<td>120,000</td>
<td>120,000</td>
<td>8,400,000</td>
<td>48,800,000</td>
<td>6,472,017</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>8.10</td>
<td>120,000</td>
<td>120,000</td>
<td>8,400,000</td>
<td>48,800,000</td>
<td>4,301,354</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>9.90</td>
<td>80,000</td>
<td>100,000</td>
<td>5,600,000</td>
<td>42,000,000</td>
<td>3,007,859</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>8.10</td>
<td>80,000</td>
<td>100,000</td>
<td>5,600,000</td>
<td>42,000,000</td>
<td>1,164,757</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 6-17
D-Solar Decision

• Period 0 evaluation – offshore

\[ EP(D = 100, E = 9.00, 1) = 0.24 \times P(D = 120, E = 9.90, 1) \]
\[ + 0.56 \times P(D = 120, E = 8.10, 1) \]
\[ + 0.06 \times P(D = 80, E = 9.90, 1) \]
\[ + 0.14 \times P(D = 80, E = 8.10, 1) \]
\[ = (0.24 \times 6,472,017) + (0.56 \times 4,301,354) \]
\[ + (0.06 \times 3,007,859) + (0.14 \times 1,164,757) \]
\[ = € 4,305,580 \]

\[ PVEP(D = 100, E = 9.00, 1) = EP(D = 100, E = 9.00, 1)/(1 + k) \]
\[ = 4,305,580/1.1 = €3,914,164 \]
D-Solar Decision

• Period 0 evaluation – offshore

Revenue from manufacture and sale of 100,000 panels = 100,000 x 70 = €7,000,000

Fixed + variable cost of onshore plant = 8,000,000 + (100,000 x 340) = €42,000,000 yuan

\[
P(D = 100, E = 9.00, 1) = 7,000,000 - \left(\frac{42,000,000}{9.00}\right) + PVEP(D = 100, E = 9.00, 1)
\]

= 2,333,333 + 3,914,164
= €6,247,497
Decisions Under Uncertainty

1. Combine strategic planning and financial planning during global network design
2. Use multiple metrics to evaluate global supply chain networks
3. Use financial analysis as an input to decision making, not as the decision-making process
4. Use estimates along with sensitivity analysis
Summary of Learning Objectives

1. Identify factors that need to be included in total cost when making global sourcing decisions
2. Define uncertainties that are particularly relevant when designing global supply chains
3. Explain different strategies that may be used to mitigate risk in global supply chains
4. Understand decision tree methodologies used to evaluate supply chain design decisions under uncertainty