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Introduction to Supply Chain Dynamics

Summary
Supply chain dynamics illustrates how reality can impact supply chains. We introduce the idea of complexity and we identify five main drivers of supply chain complexity. Supply chains are complex systems. However, a system is more than just the sum of its components, but rather also involves the product of their interactions and the need for their alignment. To grapple with this, we must understand the limitations of event based thinking, feedback or casual loop diagrams, and time lags and delays.

Key Concepts

Complexity

<table>
<thead>
<tr>
<th>Product complexity</th>
<th>Customer complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small batch sizes</td>
<td>Customized products</td>
</tr>
<tr>
<td>Long set-up times</td>
<td>Short lead times</td>
</tr>
<tr>
<td>Unique components</td>
<td>Unpredictable orders</td>
</tr>
<tr>
<td>Special tests/inspections</td>
<td>Extensive technical support</td>
</tr>
<tr>
<td>Extensive material handling</td>
<td>Extensive post-sales support</td>
</tr>
<tr>
<td>Special vendors</td>
<td>Special tests or requirements</td>
</tr>
</tbody>
</table>

Table 1-1. Source of complexity

Two types of complexity (Senge, 1990):
- Detail complexity: Distinct number of processes or parts within the system
- Dynamic complexity: Unpredictability of response of the system due to interactions

According to Herbet Simon (1962): “A system is complex if it is made up of a large number of parts that interact in a non-simple way”.

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Drivers of Complexity

Drivers of SC complexity (complexity increases according to these drivers):

- Numerousness - number of suppliers, products, customers...
- Variety/diversity of the different entities or components
- Interconnections/interactions between those entities
- Opacity of interactions
- Dynamic effects

Drivers of profitability:

- Increase revenue per unit
- Increase the number of customers
- Increase number of units sold
- Decrease cost per unit

Source of Complexity

Most complexity enters from the ends!

Any initiative to reduce complexity in the SC needs to involve people from marketing and sales as well as from new product development under the R&D process.

**Complexity-adjusted margin**

\[
\text{Complexity ROI} = \frac{(\text{Incremental Margin} - \text{Variable Complexity Cost})}{(\text{Fixed Complexity Cost})}
\]

**Variable Complexity Cost**

Low volume of a SKU drives costs
- Volume discounts for procurement
- Excess costs (obsolescence, storage, etc.)
- Shortage costs (expedite, lost sales, etc.)

**Fixed Complexity Cost**

High SKU variety drives costs
- Resource costs (R&D, testing, etc.)
Supply Chains as Complex Systems
Event-oriented thinking to solve problems:

Moving from linear to circular thinking

Feedback or Causal Loop Diagrams

- Causal link (arrows): captures causal relationship between two variables along with polarity, to indicate how the dependent variable changes when the independent variable changes
- Positive link (+): the cause increases, then the effect increases above what it would have otherwise been
- Reinforcing loop: a collection of links that form a loop that is positive
- Negative link (-): the cause increases, then the effect decreases below what it would have otherwise been
Stock and Flow Diagrams

<table>
<thead>
<tr>
<th>Stocks</th>
<th>Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define the “state” of the system</td>
<td>Define the rate of change of system states</td>
</tr>
<tr>
<td>Examples:</td>
<td>Examples:</td>
</tr>
<tr>
<td>• Balance sheet</td>
<td>• Cash flow statement</td>
</tr>
<tr>
<td>• Wealth</td>
<td>• Income –Expenses</td>
</tr>
<tr>
<td>• Water in a bath tub</td>
<td>• Flows in through faucet and out drain</td>
</tr>
<tr>
<td>• Inventory in a DC</td>
<td>• Throughput (replenishment – shipments)</td>
</tr>
<tr>
<td>• Integrals</td>
<td>• Derivatives</td>
</tr>
</tbody>
</table>

Table: Stocks and Flows

Stocks characteristics:
- Stocks have memory
- Stocks change the time path of flows
- Stocks decouple flows
- Stocks create delays

Balancing loop: a collection of links that form a loop that is negative

Figure: Causal Loop Diagram notation
Learning Objectives

- Understand how to manage complexity in supply chains
- Help understand the dynamics within a system
- Introduce System Dynamics and System Thinking concepts
- Understand feedback or causal loop diagrams
- Introduce stock and flow diagrams

References

For Supply Chain Systems


For Supply Chains as Complex Systems

- [http://www.systemdynamics.org/](http://www.systemdynamics.org/)
Process Analysis

Summary
Process analysis is an important perspective in supply chain management. We start with understanding a simple process than move on to different metrics for characterizing and measuring the performance of any process, supply chain or otherwise are presented, including Throughput (TH), Work in Process (WIP), Cycle Time (CT), Capacity, and Utilization. Little’s Law is introduced as a way to connect TH, WIP, and CT. Finally, queuing theory is described and performance metrics to quantify the impact of variability on a queue are presented.

Key Concepts

Simple process
Processes convert inputs into outputs. The items or entities processed can be items, people, jobs, financial units, etc.

According to Wallace Hopp (2011), “a supply chain is a goal-oriented network of processes and stock points used to deliver goods and services to customers.”

Key process performance measures
- Throughput (TH): rate at which items are processed by the system (items/time)
- Work in Process (WIP): Number of items in the system (items)
- Cycle Time (CT): Time required for an item to traverse the system (time)
- Capacity: Maximum average rate at which items can flow through the system (items/time); the output of a system cannot equal or exceed its capacity
- Utilization: Rate of flow into a process divided by its capacity
- Bottleneck: The process in a system with the highest utilization

Little’s Law
Little’s Law states that the long-term average of WIP is equal to the long-term average of the Throughput multiplied by the long-term average Cycle Time:

\[ \text{WIP} = \text{TH} \times \text{CT} \]

\[ (\text{items}) = (\text{items/time}) \times (\text{time}) \]
Impact of variability
Variability within a process occurs due to either arrival and/or process variability.

Sources of input or arrival variability include:
- Scheduling
- Transportation delays
- Quality issues
- Upstream processing
- Random demand

Sources of process variability include:
- Variety of items
- Operator speed
- Failures
- Set ups
- Quality problems

To describe this variability, we use central tendency (typically the mean, $\mu$) and dispersion around the mean (typically the standard deviation, $\sigma$). The coefficient of variation (ratio of dispersion to mean, $CV = \sigma/\mu$) is used in order to compare across different distributions. As a general rule:
- $0 \leq CV \leq 0.75$, low variability
- $0.75 \leq CV \leq 1.33$, moderate variability
- $CV > 1.33$, high variability

Increasing variability of the arrival and/or process times always degrades the performance of a production system, which leads to increases in both WIP and CT. Queues form because of this.

Queueing Theory
Queueing theory allows us to quantify how variability impacts the performance of a queue. Queueing Theory is also known as the study of the “science of waiting”. The system can be thought of as having an arrival process, a service process, and a queue of entities waiting to be serviced (see Figure 2-2).
Nomenclature

<table>
<thead>
<tr>
<th>Definition</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_a$ Rate of arrivals</td>
<td>items/time</td>
</tr>
<tr>
<td>$t_a$ Mean time between arrivals = $1/r_a$</td>
<td>time/item</td>
</tr>
<tr>
<td>$CV_a$ Coefficient of variation of inter arrivals</td>
<td></td>
</tr>
<tr>
<td>$b$ Buffer size or maximum number of items allowed in system</td>
<td>items</td>
</tr>
<tr>
<td>$m$ number of parallel servers</td>
<td></td>
</tr>
<tr>
<td>$r_p$ rate or capacity of work station</td>
<td>(items/time)</td>
</tr>
<tr>
<td>$t_p$ mean effective process time = $m/r_p$</td>
<td>(time/item)</td>
</tr>
<tr>
<td>$CV_p$ coefficient of variation of process time</td>
<td></td>
</tr>
</tbody>
</table>

Table: Notation adopted in queueing theory

Performance metrics

<table>
<thead>
<tr>
<th>Definition</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_q$ Expected waiting time in the queue</td>
<td>time</td>
</tr>
<tr>
<td>$CT$ Expected time in system = $t_q + t_p$</td>
<td>time</td>
</tr>
<tr>
<td>WIP Average work in process at station</td>
<td>items</td>
</tr>
<tr>
<td>WIP Average work in process in queue</td>
<td>items</td>
</tr>
<tr>
<td>$u$ Utilization of the server = $r_a/r_p$</td>
<td></td>
</tr>
</tbody>
</table>

Table: Performance metrics in queueing theory

Kendall’s notation (X/Y/m/b)

<table>
<thead>
<tr>
<th>Definition</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X$ Distribution of the interarrival times</td>
<td>D = Deterministic</td>
</tr>
<tr>
<td>$Y$ Distribution of the effective process times</td>
<td>M = Exponential</td>
</tr>
<tr>
<td>$m$ Number of servers at the station</td>
<td>items</td>
</tr>
<tr>
<td>$b$ System capacity at any one time</td>
<td>items</td>
</tr>
</tbody>
</table>

Table: Performance metrics in queueing theory

M/M/1/$\infty$ Queue

M stands for exponential. So M/M/1/$\infty$ has exponential arrival and processing time with one server and infinite system capacity at any one time. It is usually written as M/M/1.

Performance metrics:

$$WIP = \frac{u}{(1 - u)}$$

$$CT = \frac{t_p}{(1 - u)}$$
\[
\begin{align*}
t_q &= \frac{u}{(1-u)} t_p \\
WIP_q &= \frac{u^2}{(1-u)}
\end{align*}
\]

**VUT Equations**

Kingman’s or VUT equation includes three terms: the V (variation), the U (utilization) and the T (processing time). The general case is for the G/G/m/\(\infty\) queue:

\[
t_q = \left(\frac{CV_a^2 + CV_p^2}{2}\right) \left(\frac{u}{1-u}\right) t_p
\]

**The G/G/1/\(\infty\) queue:**

For any general distribution for interarrivals and process time and a single server (m=1).

\[
t_q = \left(\frac{CV_a^2 + CV_p^2}{2}\right) \left(\frac{u}{1-u}\right) t_p
\]

**The M/M/1/\(\infty\) queue:**

For Exponentially distributed (Poisson) interarrivals and process times. This means that CV\(_a\) = CV\(_p\) = 1.

\[
t_q = \left(\frac{u}{1-u}\right) t_p
\]

**The M/D/1/\(\infty\) queue:**

For Exponentially distributed (Poisson) interarrivals and Deterministic process times.
This means that CV\(_a\) = 1 and CV\(_p\) = 0.

\[
t_q = \left(\frac{1}{2}\right) \left(\frac{u}{1-u}\right) t_p
\]

**The D/D/1/\(\infty\) queue:**

For Deterministic interarrivals and process times.
This means that CV\(_a\) = CV\(_p\) = 0.

\[
t_q = 0
\]

**Multiple Servers**

We can have: i) separate queues with dedicated servers or ii) parallel servers with a single queue. Parallel servers with single queue always outperform dedicated ones, mainly due to the pooling effect.

**Process Analysis in Practice**

Supply chain process variability

One of the key problems in Supply Chains is dealing with variability. There are two main sources of variability: interarrival variability and process variability.
Coefficient of variation of arrivals (CVa)
Coefficient of variation of process (CVp)

Reducing variability
There are several approaches for reducing variability:
- Identify & measure sources of variability and defects
- Develop plans and courses of action
- Segmentation

In addition, the approaches for buffering against variability are:
- Inventory
- Capacity
- Time

Core Supply Chain Processes
Main actors and processes in a supply chain:

![Diagram of supply chain processes]

Processes follow the work flow so coordination across functions is the key to SCM.

According to Lambert (2014) there are seven core supply chain processes. We can categorize them in internal and external processes.
Internal facing processes:
- Demand management
- Order fulfillment
- Manufacturing flow management
- New product development
- Returns management

External facing processes:
- Customer management
- Supplier relationship management

Demand management

<table>
<thead>
<tr>
<th>Source</th>
<th>Potential problems</th>
<th>Possible solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promotions</td>
<td>Creates lumpy demand; Cannibalizes future demand; Misdirects scarce resources</td>
<td>Plan and coordinate timing, duration, and level with operations and customers in advance</td>
</tr>
<tr>
<td>Sales metrics</td>
<td>Creates hockey stick effect at end of periods; Creates surges and lumpy demand</td>
<td>Design sales metrics to lessen end of quarter effect</td>
</tr>
<tr>
<td>Minimum order quantities</td>
<td>Creates lumpy demand; Increases potential for obsolescence and spoilage</td>
<td>Incorporate all costs when determining MOQ; Work to minimize the MOQ in order to speed up inventory velocity</td>
</tr>
</tbody>
</table>

Table: Main sources of variability for demand management
Manufacturing flow management

Figure: Type of manufacturing processes

Process map
A process map is a model that is a symbolic representation of the workflow used to better understand, communicate, level-set, codify, and converge on how a process works. There are different types: flowcharts, relationship maps, cross-functional (swimlane) maps, value stream maps, etc.

Main steps to create a process map:
- Determine the scope and level of detail
- Based on scope, identify and list the people or functions involved
- Using sticky pads, brainstorm the steps involved
- Work through the process chronologically, placing the sticky pads in the appropriate swim lanes
- Discuss and debate the draft process map and adjust accordingly
- Do functions touch the same items multiple times?
- Are there repeated and redundant handoffs?
- Are steps missing or extraneous?
- Transfer the diagram to paper; add a date and version

Process improvement tools

Tools for checking variability
- Histograms: help understand outliers
- Time series charts: help understand where to focus

Tools for identifying causes of variability
- 5 Whys: encourage brainstorming
- Cause and effect diagrams (fishbone / Ishiwaka): provide structure for understanding root causes

**Learning Objectives**

- Understand the Supply Chain as a process
- Learn how to measure the performance of a process
- Identify sources of process variability
- Quantify how process variability impacts the performance of a queue
- Understand supply chain processes and variability
- Identify strategies to reduce variability
- Describe the seven core processes in a supply chain
- Learn tools and techniques to help with process analysis

**References**


**For In Practice**

Supply Chain Strategy

Summary
Strategy is key to an effective supply chain. To understand this, we review the most common business strategy frameworks and methodologies. We provide some examples that help to understand how supply chains need to align to the selected company’s strategy in order to enable it. There is not a single best supply chain for every firm. Typically, each company should develop and utilize a portfolio of different supply chains.

We also introduce a novel way of thinking about supply chain strategy. It demonstrates a way of tackling the problem of supply chain strategizing. Our primary resource for this lesson is the material developed by the MIT CTL Supply Chain Strategy Lab led by Dr. Roberto Perez Franco. We discuss the nature of the problem that supply chain strategizing presents to supply chain practitioners and present ten supply chain strategy evaluation criteria.

Key Concepts
Strategy is an “art”, not exactly a science, this means focusing on the big picture and overall results of an effort. Here are some definitions:

According to the Oxford English Dictionary: “The art of a commander-in-chief; the art of projecting and directing the larger military movements and operations of a campaign.” Perspectives and challenges of the general and soldier are very different.

According to Merriam-Webster: “The science and art of military command exercised to meet the enemy in compact under advantageous conditions.”

Supply chain strategy
The importance of strategy for supply chain management has been recognized for a long time. Shapiro and Heskett (1985) highlighted that “logistics’ most important role is strategic”. They recommended that logistics managers apply a variety of perspectives while running their logistics systems:

- **Internal perspective**: understand structure, economics and requirements of the logistics systems as well as constraints and components
- **Interfunctional perspective**: interact constantly with other functional managers in areas such as marketing, production, and finance
- **Channel perspective**: think in terms of maximizing the total channel benefit, considering that the firm’s decisions affect and is affected by channel partners
• **Strategic perspective:** well designed logistics management can influence company’s strategy and has the potential to “advance a company’s strategic goals”

A dichotomy: The two faces of logistics (supply chain management)
Successful supply chain management requires attention to detail, to day-to-day control and coordination, and to the tactical and analytic. However, managers should also be able to see “the big picture,” and be cognizant of the broad, qualitative, long-term aspects of supply chain management. This awareness will ensure that the firm’s supply chain function, combined with the other functional areas, can further the overall objectives of the organization.

Figure: “A difficult, yet fundamental dichotomy”. Based on Shapiro and Heskett (1985)

Shapiro and Heskett (1985) point out that this “ever-present tension between the strategic and the tactical, the broad and the detailed”, “all conspire to make the job of a supply chain manager a challenging one.”

Two strategic roles for the supply chain

**As input to formulate new overall strategy**
Supply chain must be an input when formulating a new overall strategy. Organizations usually have – and should have – an *overall strategy* that gives them direction and helps them succeed. This overall strategy is called by many names, depending on the type of organization we are referring to. In the case of organizations that compete against others, this is often called their *competitive strategy*. In the case of business units, it is often called their *business strategy*. But in all cases, the overall strategy seeks to provide the organization with a path or direction to success.

**As enabler of an existing overall strategy**
Implementing an overall strategy means translating objectives into decisions, goals into action. An overall strategy that provides a set of high-level strategic objectives has to be elaborated into more specific objectives, policies and choices across a wide range of areas of activity. This may include many diverse functions that are relevant to the supply chain, such as purchasing, logistics, operations and sales. The means that the strategy executed has to be in line with the principles and values the organization embraces, across a series of areas of interest such as quality, sustainability, service level, safety, etc. There is a gap between the overall strategy of an organization and the execution of this strategy. Supply chain strategy helps to bridge this gap.

### Strategic tools

**Porter’s Five Forces**

Porter argues that a company’s ability to increase profit is affected not only by rivalry of immediate competitors but also by four other forces, which determine the intensity of competition and the attractiveness of an industry. These five forces are:

1. **Internal rivalry** among existing competitors, which is influenced by different factors such as number of existing competitors, rate of market growth, balance between supply and demand, among others.
2. **Threat of new entrants**, which refers to how difficult it is to become a competitor in a given market and is influenced by access to specific technology, brand credibility and recognition, laws and regulations, etc.
3. **Ease of substitution**, which depends on alternative products or services available that customers could choose to buy instead.
4. **Relative power of suppliers**, which is influenced by the number of suppliers available, availability of substitutes for the material or component you are procuring, number of customers the supplier has, cost of switching to another supplier, among others.
5. **Relative power of customers**, which is determined by the quantity bought by each customer, availability of similar products from competitors, cost of switching from one seller to another, amount of information that is available to customers, customers’ profit margin, etc.
The Growth-Share Matrix is a tool that was developed by the Boston Consulting Group in the 70’s, used to manage a portfolio of businesses within a firm. It is important to understand the categorizations for each business line because the supply chain required for each category will be very different. According to the market share and the business potential growth rate, we can classify the lines of businesses in a 2x2 matrix. The four types of businesses are:

- **Stars**: are lines of business with high growth rate and high market share, which generate a lot of cash and require investments to maintain the market share.
- **Cash Cows**: are lines of business with high market share but low growth rate. Like the stars, cash cows generate a lot of cash but, because of the low growth rate, investments do not make sense.
- **Dogs**: are lines of business with low market share and low growth rate, which do not generate any profit; the strategy for these is to divest.
- **Question marks**: are lines of business with high growth rate and low market share, there are two potential strategies for these lines of businesses: invest to increase market share or divest and reallocate your resources.
The SWOT analysis, developed by Kenneth Andrews, is used to categorize internal and external factors that influence strategic decisions. SWOT is an easy way to have a structured brainstorming session with a team to better understand the lay of the land. SWOT stands for Strengths, Weaknesses, Opportunities and Threats.

**Internal Factors**

**Strengths**
- What does the organization do well?
- What areas of expertise does it have?
- Examples: low cost manufacturing, product design, technical capabilities

**Weaknesses**
- What does the organization not do well?
- What does it lack?
- Examples: weak brand identity, ineffective sales group, customization

**External Factors**

**Opportunities**
- What future opportunities are there for the organization?
- Examples: expansion to new region, extend product line to new purposes

**Threats**
- What future threats are looming for the organization?
- Examples: changes in regulations, new competing technology, shifting consumer tastes

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**Figure: SWOT Analysis**

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**Figure: Growth share matrix. Source: adapted from Hedley (1977)**

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Strategic Fit
Porter introduces the concept of “fit”, which means that activities are consistent with each other and reinforce each other to create a competitive advantage and superior profitability.

Porter identifies three types of “fit”, which “are not mutually exclusive”:
- First order fit ensures that “competitive advantage of activities cumulate and do not erode”
- Second Order fit “occurs when activities are reinforcing”
- Third order fit is “optimization effort”

What is Strategy?
According to Porter’s famous paper:
- Strategy is creating fit among a company’s activities
- Successful strategy is a result of doing many things well, and integrating them
- If there’s no fit among activities, there’s no distinctive strategy and the strategy will be unsustainable

Supply Chain Strategy
According to Narasimhan et al. (2008): “supply chain strategy can be viewed as the pattern of decisions related to sourcing products, capacity planning, conversion of raw materials, demand management, communication across the supply chain, and delivery of products and services.”

According to Cigloni et al. (2004): “what companies actually did, rather than what they claimed their strategic intent to be, is the best clue to reveal their very supply chain management strategies.”

Match and Mismatch in Supply Chain Strategies
Marshall Fisher introduced the concept of match and mismatch of supply chain strategies in 1997. Figure 3-5 includes his 2x2 matrix.
Lee’s Matched Strategies
Lee (2002) uses the uncertainty framework as a way to classify risks. Figure 3-6 presents this 2x2 matrix.

![Diagram](Figure: Lee’s matched strategies. Source: Lee, 2002)

Rethinking your Supply Chain Strategy

The Basic Challenges
Supply chain strategy presents a set of interrelated challenges:

- **Challenge 1**: Assess your current supply chain strategy
- **Challenge 2**: Anticipate future supply chain needs
- **Challenge 3**: Craft an improved supply chain strategy

Ten supply chain strategy evaluation criteria
The first challenge is to assess the current supply chain strategy, which means understanding what you have in place today. To understand the strategy, you must map the current supply
chain strategy and evaluate it. To evaluate whether the current supply chain strategy is good enough there are 10 evaluation criteria.

First criterion is **coverage**. A good supply chain strategy must be comprehensive and cover every area that matters for a company’s supply chain. It must have **clarity** – policies and choices in a supply chain strategy must be unambiguous and understood by all of the decision makers. It must be **feasible**, realistic and able to be achieved. **Internal consistency** is key to supply chain strategy with different objectives, policies and choices and can be thought in three different levels: **compatibility**, **coherence**, and **synergy**.

Each component of a good supply chain strategy must **support**, enable, advance or help realize some element of the overall organization’s strategy.

Supply chain strategy must also have: **sufficiency**, **external consistency**, **advantageousness**, **parsimony**, and **riskiness**.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coverage</td>
</tr>
<tr>
<td>2</td>
<td>Clarity</td>
</tr>
<tr>
<td>3</td>
<td>Feasibility</td>
</tr>
<tr>
<td>4</td>
<td>Internal Consistency</td>
</tr>
<tr>
<td>5</td>
<td>Support</td>
</tr>
<tr>
<td>6</td>
<td>Sufficiency</td>
</tr>
<tr>
<td>7</td>
<td>External Consistency</td>
</tr>
<tr>
<td>8</td>
<td>Advantageousness</td>
</tr>
<tr>
<td>9</td>
<td>Parsimony</td>
</tr>
<tr>
<td>10</td>
<td>Riskiness</td>
</tr>
</tbody>
</table>

Table: Supply chain strategy evaluation criteria

Evaluation criteria can be summarized as: “a good supply chain strategy should be comprehensive, clear, feasible, consistent both internally and externally, sufficiently supportive, competitively advantageous, not wasteful, and not riskier than is acceptable to the organization.”

**Scenario Planning**

The second challenge is anticipating future supply chain needs, which in a short-term timeline are identified using forecasting techniques. However, for a longer timeline we use the scenario planning technique. Scenario planning is a method that shifts from predicting events to preparing for multiple potential futures. It is defined as: “a structured brainstorming methodology that immerses decision makers of an organization in different potential future scenarios in order to better understand potential risks, blind spots, opportunities, and future needs.”

**Creating scenarios**
A scenario is essentially a story about a future based on a set of driving forces. They have high impact and high uncertainty for your selected time frame. Some criteria for creating a good set of scenarios are:

- Avoid the preferred and/or probable future
- Capture the right decision
- Plausible, within realistic limits
- Include real alternatives
- Consistent
- Different
- Memorable names
- Challenge the status quo

In addition to creating scenarios, we need to translate events into effects and apply the scenarios.

**Five categories of effects for supply chains:**

- Impact on sourcing patterns
- Impact on flow destination
- Impact on routing
- Impact on flow volume
- Impact on value density

**Applying Scenarios**

1. Immerse a large group of people in each scenario
2. Bring everyone together and evaluate, compare and contrast the solutions/strategies proposed across the different scenarios
3. Eliminate the no gainer strategies
4. Monitor with sensors in the ground whether to apply strategies that are only applicable to some scenarios

**Progressive formulation**

The third challenge is to craft an improved supply chain strategy. These are the steps to perform a progressive formulation:

- Identify a starting point: a revised overall strategy
- Identify areas of decision or activity and interest, add or drop areas accordingly
- Identify sequence of events that you want to follow
- Use evaluation criteria on each area of decision
- Repeat this process in each level of abstraction

**Learning Objectives**

- Learn basic concepts of business and supply chain strategy
- Identify the most common business strategy frameworks
• Understand that there is not a single best supply chain for every firm
• Outline a process to develop and improve a supply chain strategy
• Learn how to tackle the problem of supply chain “strategizing”
• Identify the main criteria for evaluating a supply chain strategy

References
• Perez-Franco, R. (2016) Rethinking your supply chains strategy. A brief guide. MIT Supply Chain Strategy Lab
• Additional references can be found here: strategy.mit.edu
Global Supply Chain Management

Summary
This review covers global supply chain management concepts and explain the challenges and opportunities of trading between countries. Since most supply chains are global, it is important to consider the many factors that will influence your supply chain.

Global Supply Chain Management Concepts

World Trade Organization (WTO)
The World Trade Organization (WTO) was founded in 1995 to promote fair trade. Its principals include trade without discrimination, freer trade, predictable, more competitive and more beneficial for less developed countries.

Duty determination
Duty is the amount of tax paid on an imported good. The amount of duty that an importer has to pay is determined by three factors:

- The type of goods (their classification)
  - Harmonized Tariff Schedule (HTS) is a 10-digit code used to describe all goods in trade for duty, quota, etc. The first 6 digits are standardized internationally; the last 4 digits are country specific.
- The value of the goods (their valuation)
- The country from which the goods originated (the rules of origin)

Duty Drawbacks
There are three types of duty drawbacks:

- Same condition drawback: when you import an item and then re-export this item in the same condition
- Different condition drawback: or sometimes also called manufacturing drawback, when you use an imported item in the assembly of another product
- Domestic goods returned in different condition: when an item that was previously exported comes back as part of an assembly of another product

Valuation
Valuation is important because most of the duties are collected as a percentage of the value of goods, this is called *ad valorem*. For Customs’ purposes, valuation is generally the amount billed by the exporter and shown on the invoice. However, there are situations were the amount shown in the invoice may not represent an “arms-length transaction.” This occurs when the exporter and importer are “related parties” such as a parent company and its subsidiary. There
are four alternative methods used by Customs authorities worldwide to determine the value of goods:
  
  • Comparative method: use the value of similar goods  
  • Deductive method: work backwards from price  
  • Computed or reconstructive method: build up from manufacturing cost  
  • Method of last resort: make an educated guess

Rules of Origin

Rules of origin are important because duties may differ by origin countries. There are two methods used to figure out the rules of origin:

  • Substantial transformation: last country where the product underwent a substantial transformation  
  • Change in Harmonized System Code: last country where the harmonized system code of the product changed

Generalized System of Preferences

Developed countries usually provide opportunities to developing countries to grow their economies by designating them as Generalized System of Preference (GSP). Countries designated as GSP benefit from reduced duty rates and quotas for their goods.

Free Trade Zone and Bonded Warehouses

<table>
<thead>
<tr>
<th>Free Trade Zone</th>
<th>Bonded Warehouses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main purpose: duty-free access to low cost labor</td>
<td>Main purpose is to delay the paying of duties</td>
</tr>
<tr>
<td>No duty paid if re-exported</td>
<td>No duty paid if re-exported</td>
</tr>
<tr>
<td>Duty delayed if imported</td>
<td>Duty delayed if imported</td>
</tr>
<tr>
<td>Work can be performed on the goods</td>
<td>Little / no work can be performed on the goods</td>
</tr>
<tr>
<td>Great for processing goods in low cost labor countries</td>
<td>Great for delaying duty on imported $$$ goods</td>
</tr>
<tr>
<td>Great for showing off products to international buyers</td>
<td></td>
</tr>
</tbody>
</table>

Table: Free Trade Zones and Bonded Warehouses

Dumping

Dumping is a form of predatory pricing where producers charge a high price in the home market but a very low price in another market to gain market share. In international trade there are two types of penalties:

  • **Anti-dumping Duty:** import duty to bring the price up to the price charged at the home market  
  • **Countervailing Duty:** or anti-subsidy duty, import duty to products that have subsidies at home
Trade Barriers
Trade Barriers are measures that countries use to slow down international trade and protect domestic markets:

- Duties (see above)
- Trade-Related Investment Measures (TRIMS)
- Local Content Requirements
- Quotas:
  - Absolute
  - Tariff-based
- Other Import Taxes
  - Punitive Tariffs
  - Border Traffic Tax
  - Safeguard Tax
  - Temporary Protection Tax
- National Standards
- Pre-Shipment Inspections
- Various stalling tactics

Trading Blocs
The term Trade Bloc is the umbrella term used to refer to all of the various types of arrangements, which are:

- **Preferential Trade Area**: reduced tariffs between member countries
- **Free Trade Area**: zero tariffs between member countries
- **Customs Union**: zero tariffs between member countries AND the same external tariffs
- **Common Market**: a free trade area with relatively free movement of capital and of services between countries
- **Single Market**: a free trade area with common product regulations and freedom of movement of capital, labor, enterprise, and services
- **Economic Union**: combination of a Customs Union and a Single Market
- **Monetary (Currency) Union**: countries who share the same currency
International Transportation

International transportation differs significantly from domestic transportation. The main ways are reviewed including INCO terms, transportation options, and ports.

INCO terms

INCO stands for International Chamber of Commerce. These terms define which responsibilities belong to the buyer and which responsibilities belong to the seller during an international shipment. They also define who pays for freight cost, insurance, duties, cost of goods, and other various fees. There are four main groups of INCO terms: E, F, C, and D.

**Figure: Four main groups of INCO terms**

Air Freight vs. Ocean Freight

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Air Freight</th>
<th>Ocean Freight</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-time reliability</td>
<td>Very reliable, 1-2 day delivery window</td>
<td>Not reliable, 1-2 week delivery window</td>
</tr>
<tr>
<td>Freight Cost (ignoring inventory)</td>
<td>Expensive 5 to 10+ times Ocean</td>
<td>Cheaper</td>
</tr>
<tr>
<td>Basis of Freight cost</td>
<td>Weight is most important</td>
<td>Volume is most important factor</td>
</tr>
<tr>
<td>Transit time</td>
<td>1-3 days to (almost) anywhere</td>
<td>5 to 40 days</td>
</tr>
<tr>
<td>Pollution</td>
<td>Very high</td>
<td>Much lower</td>
</tr>
</tbody>
</table>

**Table: Air Freight vs Ocean Freight**

Type of ships

The most common types of ships are presented below.

<table>
<thead>
<tr>
<th>Type of ship</th>
<th>Type of Cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll-On/Roll-Off or Ro-Ro ship</td>
<td>Wheeled cargo</td>
</tr>
<tr>
<td>Break-Bulk Ship</td>
<td>General cargo</td>
</tr>
</tbody>
</table>
### Ocean Shipment Overview

<table>
<thead>
<tr>
<th>Oil tanker</th>
<th>Oil in bulk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Carrier</td>
<td>Chemicals in bulk</td>
</tr>
<tr>
<td>Dry-Bulk Carrier</td>
<td>Unpackaged bulk cargo</td>
</tr>
<tr>
<td>LNG ship or Gas Carrier</td>
<td>Liquefied natural gas (LNG)</td>
</tr>
<tr>
<td>Container Ship</td>
<td>Non-bulk cargo</td>
</tr>
</tbody>
</table>

#### Table: Types of Ships

- **Dray**: local haul to the port
- **Demurrage**: penalty for extra days that containers stay at a dock
- **Cabotage**: when a foreign-flagged vessel picks up and drops off in the same country
- **TEU**: twenty-foot equivalent unit
- **Weekly service**: string of ships following each other

### The Steamship Industry

The steamship industry is a volatile industry in which few carriers handle most of the freight. Carriers collaborate and cooperate among each other, there are known as alliances. This industry is characterized by having very different freight rates depending on the direction of the trip. Because of volume discount pricing, this industry attracts consolidators and Non-Vessel Operating Common Carrier (NVOCC). Historically the steamship industry has faced the Bull-Whip effect, which is the time lag in carrier response to the demand curve.
Altman’s Z-Score
The Altman’s Z-Score is a financial measure of a company’s vulnerability to bankruptcy that uses information that can be found in the income statement and balance sheet. Z score bankruptcy model is given by:

\[ Z = 1.2T1 + 1.4T2 + 3.3T3 + 0.6T4 + .999T5 \]

Where,
T1 = Working Capital / Total Assets
T2 = Retained Earnings / Total Assets
T3 = Earnings Before Interest and Taxes / Total Assets
T4 = Market Value of Equity / Total Liabilities
T5 = Sales/ Total Assets

According to the Z-Score there are three different zones of discrimination: Safe zone: \( Z > 2.99 \)
Grey zone: \( 1.81 < Z < 2.99 \)
Distress zone: \( Z < 1.81 \)

International Surface Transport
International Surface transports are railroads and trucks that cross international borders.
- Biggest challenges
  - Truck transportation: safety standards, protecting local jobs
  - Railroad transportation: different safety requirements, work rules and interoperability (different widths between tracks)

Ports and Terminals
A port is a general term referring to a big community of players, which include:
- Port Authority
- Terminal Operators
- Warehouse Operators
- Consolidators / De-consolidators
- Customs Officials
- Railroads
- Dray Operators
- Freight Forwarders
- Customs Brokers

A terminal is the location within a port where ships load & unload, it has:
- Quay, ship to shore cranes, RTG cranes
- Container storage yard
- Administration buildings
Currency Issues and Financing

In global supply chains it is essential to understand currency issues and financing. To understand this we must review several important concepts including: exchange rate risk, transfers pricing, and profit repatriation and its effects on corporate income taxes. We also briefly review description of trade finance and international trade payment methods.

Exchange Rate Risks

There are two factors that will trigger exchange rate risk when together:

- Two different currencies (i.e., buy in one currency but get paid in another)
- Time delay between beginning and end of transaction

The most common ways to protect against exchange rate risk are:

- Use only one currency
- Use a bank to hedge the transaction - pay a fee to the bank to guarantee the price you will get paid
- Hedge yourself:
  - Currency Futures Contract: a contract to exchange one currency for another at some future point in time at a pre-specified exchange rate (this usually requires a fee)
  - Foreign currency hedging: is a risk reducing strategy where two offsetting, opposite positions, are taken in two different parallel markets. The positions are such, that their end results offset each other.

Internal ways to hedge foreign currencies within your own company:

- Leading Expenditure: to pay in advance if currency is expected to rise
- Lagging Expenditure: to pay late if currency is expected to fall
- Netting Receipts and Payments: to hedge the net exposure

External ways to hedge currencies:

- Forward Contracts: a contract where a buyer and seller agree on an exchange rate in advance
- Currency Swaps: two parties with two different currencies take an equivalent loan in their home currency and trade the cash
- Foreign Currency Options: pay a fee to have the optional right to buy or sell a specific amount of a specific currency at a specific price at a specific future time
- Spot Contracts: contracts that are completed in 1-3 days to avoid high fluctuations

Corporate Income Taxes

International Income Taxes

Taxes in each country are charged based on how much profit was made in that country. The tax rate varies significantly from country to country. Profitability varies significantly by type of product and profit margins can vary significantly from region to region.
Tax Haven
A Tax Haven is a country with a low corporate income tax rate such as Ireland, Switzerland, Singapore, or Puerto Rico.

Permanent Establishment
A Permanent Establishment (PE) is a fixed place of business that generates income or value added tax liability in a particular jurisdiction. The tax systems in some civil law countries impose income and value added taxes only where an enterprise maintains a PE in the country. These are the things that may get a business labeled as having a PE in a country:

- A branch
- A warehouse
- A factory
- A mine or oil or gas well
- A management office
- Owning inventory in a country
- Buying or selling in the country
- Being the importer of record, being the exporter of record
- Owning property in the country
- Having employees in the country

Types of Tax Relief
Foreign Tax Credit (FTC): when countries allow companies to deduct the amount of tax paid in another country.
Participation Exemption (PEX): a partial to full exemption of taxes for companies that are subsidiaries of companies with a certain level of ownership in a specific country.
Double taxation agreement (DTA): treaties between a pair of countries to provide partial or full tax exemption.

Transfer Price
A transfer price is a “market price” for intracompany transfer of goods. It is needed because duties are charged based on the value of the goods being imported. This means that the invoice amount between related parties is not always a good indication of the value of the good. Transfer price is also a way to shift profit from one country to another, given that income tax rates might be very different.

Profit Repatriation
Profit repatriation is bringing profits earned in a foreign country back to the home country. Mechanics of Profit Repatriation:

- Transfer Pricing: charge a foreign-subsidiary a high price to keep the profits in the home country
- Royalty Payments: charge a fee to foreign-subsidiary for the use of the parent company’s name and brand
- Leading and Lagging Payments: use currency fluctuations to favor the home country
Managing Working Capital

Figure 1-1. Example of a Cash Flow Model

Cash-to-Cash Cycle Time

CTC=IDS+DSO-DPO

Where,
CTC is Cash to Cycle Time
IDS is Inventory Days of Supply
DSO is Days of Sales Outstanding (Accounts Receivable)
DPO is Days of Payables Outstanding (Accounts Payable)

Ways to Free Up Working Capital
These are ways to free up working capital. Although their effect is to decrease working capital, a thorough analysis of the side effects of each one of these should be performed.
Most common ways used:
- Lower transit time
- Return excess to suppliers
- Lower inventory targets, increase deliveries and runs
- Improve manufacturing cycle time
- Use smaller lots
- Sell off excess and obsolete
- Use shorter payment terms with customers
• Have vigorous collection of past due payments
• Ask for longer payment terms to suppliers (not usually recommended)
• Delay payments to suppliers (not usually recommended)

Innovative Ways
• Bill on receipt
• Use vendor-owned adjusted time inventory
• Implement Lean Manufacturing techniques
• Build to order
• Offer early payment discount
• Offer a pay by credit card option
• Ask about payments prior to due date
• Electronics Funds Transfer (EFT)

Trade Financing Actions
• Early Payment Program:
  o Offered by OEM: OEM pays Supplier early but charges the Supplier at a discounted rate
  o Using a Funder: Funder pays supplier immediately, and charges a percentage to supplier, the OEM also gets a discount for using the Funder

• A/R Financing - Selling Receivables: Supplier sells its receivables to a Funder who pays the Supplier immediately but gets a discount, this method is very similar to the Early Payment Program Using a Funder but the OEM is not involved in this scheme

• Revolving Line of Credit:
  o Supplier goes alone: Supplier borrows cash from a Funder, which charges an interest rate (based on the supplier’s financial health) and takes supplier’s invoices as collateral for the loan
  o OEM helps supplier: OEM publishes a list of “approved invoices” to show that it is committed to pay. Therefore, when the supplier borrows cash from the Funder the interest rate is lower as the interest rate is based on the OEM’s financial health

• Early Payment Program to Extend DPO: Funder is used to pay to the Supplier immediately and to extend the payment terms to the OEM, the Funder charges to both Supplier and OEM

Methods of Payment in International Trade
• Cash-in-Advance: means that the buyer pays before receiving the goods; this method is used in high-risk trade relationships or export markets.
• **Letters of Credit**: is a document issued by the buyer’s bank committing to pay to the seller even if the buyer fails to pay to the bank; this method is used in new or less-established trade relationships.

• **Documentary Collections**: occurs when the Seller’s bank collects all the export documents (BOL, Commercial Invoice, etc.) of the goods shipped by the buyer, the Seller’s bank sends these documents to the Buyer’s bank demanding payment. The Buyer’s bank will hold these documents until the payment is made, this method is used in established trade relationships.

• **Open Account**: is when goods are shipped before payment along with all the export documents. This arises in secure trading relationships or markets or in competitive markets to win customers.

![Payment Risk Diagram](source: US. Gov. Trade Finance Guide 2007)

**Sourcing and Shoring**

In a global world, the topics of sourcing and shoring are hotly debated. To break apart these topics, we identify the motivations and the challenges to move manufacturing abroad. Beyond the initial decision to move abroad, there are additional key elements on social responsibility that companies lose grasp of when work moves farther away such as slavery or conflict minerals. Finally, we provide examples of different global supply chain strategies.

**Approaches for Manufacturing Internationally**

- **Contract Manufacturing**: a company hires another company to manufacture goods, usually in a foreign country
- **Licensing**: a company allows another firm to use its intellectual property to make products in exchange for a royalty
- Franchising: a company gives another firm a “bundle” of intellectual property items and allow the firm to reproduce its entire business model in exchange for royalties
- Joint Venture: two or more companies join to set up a new company to enter a new marketplace
- Subsidiary: a wholly owned foreign company that is independent from the parent company and gives total control to the foreign company

Motivations and challenges of offshoring
Here are some of the reasons that explains why manufacturing moved to Asia & China:
- Very low labor cost, huge labor pool
- Very few restrictions on pollution, working conditions, quality, and exports
- New factories, new equipment
- New infrastructure
- Herd mentality
- Supply based moved - self-fulfilling trend.
- Corporate profit motive & competitive pressure outweighed loyalty to community
- Consumer savings outweighed loyalty to community

Some of the challenges related to the previous decision are:
- Very long lead times
- Long supply lines --- long distance ocean transportation
- Time zone challenges
- Communication challenges --- language differences
- Need for higher inventory levels
- Intellectual property theft, counterfeiting of products
- Extra cargo security
- Emergency air shipments are now a very long way

Social Issues in Global Supply Chains
A supply chain manager needs to make sure that its supply chain is free of the following social issues, as the presence of any of these could affect the brand of the company:
- Child labor
  - Children in employment: all children engaged in any economic activity for at least one hour/week, paid or not, part time or full time, inside or outside the family setting
  - Children in child labor: subset of children in employment, workers below the minimum age allowed not doing the light simple work?
  - Hazardous work: subset of children in child labor, children who are doing work that is harmful to their health, safety and moral development
- Dangerous working conditions: poor occupational safety and health practices, which vary among the different countries
• Modern slavery instances that represent the biggest risks for supply chains:
  o Bonded labor: people who work to pay off debt
  o Forced labor: people who are forced to work and cannot escape
  o Migrant workers: people who work to survive and don't have any other alternative
• Conflict minerals: mined by armed groups, which force people to dig for these minerals and to use them to support their gangs. These come from Congo’s Mineral-rich area, the four minerals are:
  o Tin from cassiterite ore
  o Tungsten from wolframite ore
  o Tantalum from coltan ore (columbite + tantalite)
  o Gold ore

Global Supply Chain Design Strategies

Vertical integration
The following metrics are helpful to analyzing the effect of vertical integration:

\[
\text{Inventory Turn} = \frac{\text{Annual Sales}}{\text{Average Inventory}}
\]

\[
\text{Combined Inventory Turn} = \frac{1}{\sum_{i=1}^{n} \text{Inventory Turn}_i}
\]

where \( n \) is the number of plants vertically integrated

Outsourcing
• Typical Situation
  o Companies import with Transfer Price from subsidiary to parent or to another subsidiary
  o They have a PERMANENT ESTABLISHMENT (PE) in each country
  o They pay taxes in each country
• Tax avoiding strategy:
  o Design a network that complies with export restrictions, minimizes taxes, and provides the flexibility to ship from and to anywhere
  o Avoid PE in all but one country (headquarters location)
  o Use subcontractors for manufacturing and exporting, use distributors for importing and distributing
  o OEM buys from manufacturers and sells to distributors only in international airspace or international waters

Learning Objectives
• Understand most common practices used in global supply chain management
• Introduce international trade concepts and understand challenges and opportunities
• Understand the basics of international transportation
• Identify the main challenges faced in Air Freight, Ocean Freight and Surface transport
• Understand currency issues and how to prepare against exchange rate risks
• Overview concepts related to corporate income taxes, transfer pricing and profit repatriation
• Understand trade financing and how companies can help each other
• Identify four methods of international trade payment and letters of credit
• Understand different ways for manufacturing internationally
• Identify social issues, slavery and conflict minerals

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For All

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• US. Gov. Trade Finance Guide 2007 pp3-28

For Sourcing and Shoring
• Trafficking in Persons Report, US Dept of State, July 2015
Enterprise Resilience

Summary
Companies are reliant on their supply chains, as a result of this, they are vulnerable to disruptions which pose a risk to their business. While all businesses are at risk, there are some more resilient than others, meaning that they recover quickly. To understand these two concepts, we focus on how to estimate risks, how to deal with them in terms of prioritizing and how to prepare companies for disruptions. Finally, we analyze how to respond and mitigate the problems once a disruption occurs.

There are two different ways to look at disruptions, i) thinking about causes and ii) thinking about effects or modes of failures. Cause thinking helps estimate likelihoods, while effects thinking helps estimate impacts and consequences.

Key Concepts

Risks and Disruptions

Causes of Disruptions
These are different types of risks or causes of disruptions:

- **Random Phenomena**: weather phenomena or natural disasters
- **Accidents**: any undesirable event, such as explosions
- **Governments & Politics**: trade barriers, trade embargo, military coups, political instability, changes in regulations
- **Non-Compliance**: non-compliance of standards such as air pollution, water contamination, safety, etc.
- **Competition**: technological innovation, process innovation
- **Economy**: macroeconomic shocks that lead to economic contractions such as financial economic recessions and depressions
- **Social disconnect**: companies not connecting with customers’ will and desire
- **Intentional disruptions**: when there is a smart attacker on the other side, who will attack in the worst time and worst place, including terrorist attacks, strikes, cyber attacks

Modes of failure
These are ways how supply chains can fail and/or effects of disruptions:

- Inability to acquire supplies
- Inability to ship/loss of shipment
- Inability to communicate
- Inability to convert
- Loss of personnel
• Unavailable credit
• Brand/Trust diminution

Figure: Causes and Effects of Disruptions
Bow-Tie Risk Analysis Framework

One of the classical frameworks for thinking about risk and disruption is the Bow-Tie Risk Analysis Framework:

Disruption Profile
Classification of Risks

The traditional classification used to prioritize risk, includes two dimensions: probability of disruption and consequences. Usually supply chain managers focus on the severe consequences-high probability quadrant (upper right). However, the most dangerous events are those in the severe consequences-low probability quadrant because companies are typically not prepared and do not know how to prepare for these events.

![Figure: Two dimensional classification: Disruption Probability vs Consequences](image)

In addition to disruption probability and consequences, a three dimensional classification includes detectability. Dependability is defined as how long it takes from the time we know that an event is going to happen until it happens.

- **Probability**: investigate the causes and estimate their likelihoods
- **Consequences**: identify impact, prepare options, drills, mitigate options and ways to “bounce back”
- **Detection**: develop detection ability and define decision rules

A **black swan** is an event or occurrence that deviates beyond what is normally expected of a situation and is extremely difficult to predict. **Black swan** events are typically random and are unexpected.

**Power Law: Likelihood and Impact**

Likelihood and impact of many disruptions obey the power law, which can be used to estimate the relationship between the frequency and damage of events.

$$f(x) = x^{-k}$$

**Detectability and Preparation**

There is a third dimension to characterize disruptions: detectability. The warning signs to identify suppliers are presented. the three types of elements to prepare for disruption are discussed: redundancy, flexibility and preparation.
Warning Lag

The warning lag is the time between alarm and event. It can occur:

- **After the attack**: in this case the time of detection is negative, you discover that something happened only after the event occurred
- **Immediate**: the time between the alarm and the event is zero, you realize that the event is happening when it's occurring
- **Short term**: there is some time between the alarm and the event but not much to prepare
- **Medium term**: there is time between the alarm and the event, allowing the company to prepare
- **Long term**: the time between the alarm and the event is long so there is opportunity, enough time to prepare and take actions

Warning Signs of Supplier Failure

These might be signals that will allow you to sense that something is happening with the supplier:

- **Financial**: failure to prepare timely financial reports, multiple adjustments to annual reports, frequent negotiations of banking covenants, deteriorating working capital ratios, lengthening accounts payable
- **Operational**: high employee turnover in key positions, failed projects/failed acquisitions, operating loss, lack of capital investment, late/missed deliveries, quality issues, billing and invoicing errors, carrier selection errors

Resilience Fundamentals

Companies should weigh the benefits of uncertain future cost against certain current costs. Current costs are derived from the three ways to prepare for disruption:

- **Redundancy**: is creating/having some extra capacity, inventory, suppliers
- **Flexibility**: means interchangeability, is being able to change processes fast, cross-training people to be able to perform more than one task, using postponement and standardization
- **Readiness/preparation**: is having real options or the tools to respond
Safety management

Figure: Safety Pyramid

Du Pont Bradley Curve

Figure: Du Pont Bradley Curve
Ways to deal with limited supply

- Allocation: use some criteria to allocate what is available
- Auctions: give the product to the customer who wants it most
- Dilution
- Substitution
- Demand shaping

Learning Objectives

- Understand the concept of warning lag
- Learn resilience fundamentals
- Understand how to prepare for disruptions
- Learn how to think to prioritize and to prepare for risks
- Distinguish between different causes of disruptions and effects

References
