Agenda

1. Supply chain risk and disruptions: Why should we care?
2. Response stages, strategies, and behaviors
3. Summary
A defect in a small part prolonged along the supply chain and resulted in substantial costs

**Supply chain disruption at Robert Bosch (January 2005)**

- DuPont
- Federal Mogul
- Bosch
- Automotive OEMs
- Final customer

- Teflon granulate
- Teflon-coated socket
- Diesel injection pump
- Cars

**Consequences**

The small “defect” in the **upstream supply chain** resulted in:

- **Standstill of assembly lines** at several automotive OEMs
- **Product recalls** of more than 1,000 cars
- **Consequential costs** in the three-digit million Euro range
- **Damaged brand image** of Bosch and the involved OEMs
Supply chain risk is an umbrella term for a large set of heterogeneous issues

|---------------------------------|------------------|

### Environmental
- Natural disasters: 59%
- Extreme weather: 30%
- Pandemic: 11%

### Geopolitical
- Conflict and political unrest: 46%
- Export/import restrictions: 33%
- Terrorism: 32%
- Corruption: 17%
- Illicit trade and organized crime: 15%
- Maritime piracy: 9%
- Nuclear/biological/chemical weapons: 6%

### Economic
- Sudden demand shocks: 44%
- Extreme volatility in commodity prices: 30%
- Border delays: 26%
- Currency fluctuations: 26%
- Global energy shortages: 19%
- Ownership/investment restrictions: 17%
- Shortage of labour: 17%

### Technological
- Information and communications disruptions: 30%
- Transport infrastructure failures: 6%

### Controllability
- Uncontrollable
- Influenceable
- Controllable

Environmental: Natural disasters 59%
- Extreme weather 30%
- Pandemic 11%

Geopolitical: Conflict and political unrest 46%
- Export/import restrictions 33%
- Terrorism 32%
- Corruption 17%
- Illicit trade and organized crime 15%
- Maritime piracy 9%
- Nuclear/biological/chemical weapons 6%

Economic: Sudden demand shocks 44%
- Extreme volatility in commodity prices 30%
- Border delays 26%
- Currency fluctuations 26%
- Global energy shortages 19%
- Ownership/investment restrictions 17%
- Shortage of labour 17%

Technological: Information and communications disruptions 30%
- Transport infrastructure failures 6%
Alright, but these issues are as old as supply chains…

East India Company

Wells Fargo & Company

… so why the recent interest?
Complexity and inter-connectedness of modern supply chains have created conditions for disruptions to become more widespread and severe.

- More dependencies ("Tight coupling")
- Increasingly complex supply networks

- Shorter product life cycles
- Explosion of product variety
- Mass customization
- Smaller margins of error

- Globalization of supply and demand markets
- Longer paths in supply chains

- Outsourcing
- Single Sourcing
- Lean Production
- Focus on cost efficiency but not on robustness
Supply base complexity

Example

- **Porsche 991** (*7th* generation 911; SOP: 2011; Facelift: 2015)
- External value added < 20%
- ~ 150 major direct suppliers; many of them deliver on a JIT or JIS basis
Supply chain risk management seeks to address these issues

- Risk identification
- Risk assessment
- Risk handling
Two different areas of risk handling can be distinguished

Proactive

- Powerful approach, if based on correct risk identification and assessment
- But, in dynamic, complex, and tightly coupled systems, it is impossible to address all risks proactively

Reactive

- Reactive risk management is about developing and applying arrangements and procedures that enable a firm to...
  - anticipate a disruption early and
  - respond to the disruption in such a manner that business functions continue with little interruption
Agenda

1. Supply chain risk and disruptions: Why should we care?

2. Response stages, strategies, and behaviors

3. Summary
Context, process, and content

Event

Response formation

Supply chain disruption

Context

Response content

Response process

Research questions

What factors affect the response content?
How do firms devise a response?
How does the responses look like?

1. Response stages
2. Response strategies
3. Response behavior

Source: Bode, Wagner, Petersen, & Ellram (2011)
When looking at the response: Which stages are most important?

- When an unexpected supply chain disruption occurs, managers face a situation that can involve the following characteristics:
  - Ambiguity of causes and effects
  - Decisions have to be made swiftly
  - Might involve surprise

- Which is more important, working through all decision stages quickly, or are some stages more important than others?

Source: Bode & Macdonald (2016)
Response stages: Individual effects

### Direct effects

**Model 1:** Direct effect of response speed
- \[ IMCT = a_0 + a_1 \text{SIZE} + a_2 \text{COMP} + a_3 \text{RCAT} + a^A \text{RSPD}^A + \varepsilon \]

**Model 2:** Direct effects of individual response stages
- \[ IMCT = a_0 + a_1 \text{SIZE} + a_2 \text{COMP} + a_3 \text{RCAT} + a^{S1} \text{RSPD}^{S1} + a^{S2} \text{RSPD}^{S2} + a^{S3} \text{RSPD}^{S3} + a^{S4} \text{RSPD}^{S4} + \varepsilon \]

### DV: Disruption impact

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.78</td>
<td>2.78</td>
</tr>
<tr>
<td>Firm size</td>
<td>-0.06†</td>
<td>-0.06†</td>
</tr>
<tr>
<td>Competitive intensity</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Reaction category</td>
<td>0.31***</td>
<td>0.31***</td>
</tr>
<tr>
<td>Response speed</td>
<td>-0.16***</td>
<td></td>
</tr>
<tr>
<td>Response stage 1: Recognition</td>
<td></td>
<td>-0.09*</td>
</tr>
<tr>
<td>Response stage 2: Diagnosis</td>
<td></td>
<td>-0.01</td>
</tr>
<tr>
<td>Response stage 3: Development</td>
<td></td>
<td>-0.03</td>
</tr>
<tr>
<td>Response stage 4: Implementation</td>
<td></td>
<td>-0.10*</td>
</tr>
</tbody>
</table>

- Both total response speed and the speed of the individual response stages reduce impact
- However only the effects of response speed and of recognition and implementation are significantly different from zero.
- Model 2 does not explain more variance than Model 1.

Note: Except for the binary dummy variables, all variables were standardized. *p < 0.05, **p < 0.01, ***p < 0.001 (two-tailed). n = 438.
Response stages: Constraining effects

**Constraining effects**

- **Recognition (Stage 1)**
- **Diagnosis (Stage 2)**
- **Development (Stage 3)**
- **Implementation (Stage 4)**

**DV: Disruption impact**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Impact</th>
<th>Net eff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.01 ***</td>
<td></td>
</tr>
<tr>
<td>Firm size</td>
<td>-0.05</td>
<td></td>
</tr>
<tr>
<td>Competitive intensity</td>
<td>0.07 †</td>
<td></td>
</tr>
<tr>
<td>Reaction categorya</td>
<td>0.28 ***</td>
<td></td>
</tr>
<tr>
<td><strong>Stage 1 is constraining factor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response stage 1</td>
<td>0.06</td>
<td>-</td>
</tr>
<tr>
<td>Response stage 2</td>
<td>0.05</td>
<td>-</td>
</tr>
<tr>
<td>Response stage 3</td>
<td>-0.24 *</td>
<td>-</td>
</tr>
<tr>
<td>Response stage 4</td>
<td>-0.13</td>
<td>-</td>
</tr>
<tr>
<td><strong>Stage 2 is constraining factor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \theta_{cf2} )</td>
<td>-0.71 **</td>
<td></td>
</tr>
<tr>
<td>( \theta_{cf2} \times \text{Response stage 1} )</td>
<td>-0.12</td>
<td>-0.06</td>
</tr>
<tr>
<td>( \theta_{cf2} \times \text{Response stage 2} )</td>
<td>-0.56 **</td>
<td>-0.51 ***</td>
</tr>
<tr>
<td>( \theta_{cf2} \times \text{Response stage 3} )</td>
<td>0.47 **</td>
<td>0.23 *</td>
</tr>
<tr>
<td>( \theta_{cf2} \times \text{Response stage 4} )</td>
<td>0.36 *</td>
<td>0.22 *</td>
</tr>
<tr>
<td><strong>Stage 3 is constraining factor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \theta_{cf3} )</td>
<td>-0.53</td>
<td></td>
</tr>
<tr>
<td>( \theta_{cf3} \times \text{Response stage 1} )</td>
<td>-0.15</td>
<td>-0.09</td>
</tr>
<tr>
<td>( \theta_{cf3} \times \text{Response stage 2} )</td>
<td>0.15</td>
<td>0.21</td>
</tr>
<tr>
<td>( \theta_{cf3} \times \text{Response stage 3} )</td>
<td>-0.02</td>
<td>-0.26</td>
</tr>
<tr>
<td>( \theta_{cf3} \times \text{Response stage 4} )</td>
<td>0.03</td>
<td>-0.11</td>
</tr>
<tr>
<td><strong>Stage 4 is constraining factor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \theta_{cf4} )</td>
<td>-0.27</td>
<td></td>
</tr>
<tr>
<td>( \theta_{cf4} \times \text{Response stage 1} )</td>
<td>-0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>( \theta_{cf4} \times \text{Response stage 2} )</td>
<td>-0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>( \theta_{cf4} \times \text{Response stage 3} )</td>
<td>0.10</td>
<td>-0.14</td>
</tr>
<tr>
<td>( \theta_{cf4} \times \text{Response stage 4} )</td>
<td>-0.04</td>
<td>-0.18</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>( F )</td>
<td>3.75 ***</td>
<td></td>
</tr>
</tbody>
</table>

**Note**: Except for the binary dummy variables, all variables were standardized. * \( p < 0.05 \), ** \( p < 0.01 \), *** \( p < 0.001 \) (two-tailed). \( n = 438 \).

\[ IMCT = b_1 \text{SIZE} + b_2 \text{COMP} + b_3 \text{RCAT} + 1(b_{cf1} + b_{cf1} \text{RSPD}^{S1} + b_{cf1} \text{RSPD}^{S2} + b_{cf1} \text{RSPD}^{S3} + \]

- Only when stage 2 (diagnosis) is the constraining factor do the results suggest that relaxing this bottleneck has a strong and significant mitigating effect on disruption impact (\( b_{cf1} + \theta_{cf2} \times b_{cf2} = -0.51, p < 0.001 \))
- For the other stages, the results do not support the notion of constraining factors
Two basic decision-making styles when uncertainty is involved: Ready-aim-fire and ready-fire-aim

**Ready-aim-fire**
(Cox 1995, Stevahn and King 2010)

- Bias for planning/information collection
- Requires additional time and resources
- Reduction of uncertainty via information which enables **more precise actions**

**Ready-fire-aim**
(Weick 1949, Zenie 2011)

- Action orientation/bias
- Unresolved uncertainty promotes inaccuracy
- **Irreversibility of actions** may lead to unsatisfactory outcomes

Source: Merath & Bode (2016)
Characteristics of ready-aim-fire and ready-fire-aim

**Ready-aim-fire (RAF)**
- In response to a disruption, firms use the first period to "wait" and collect information.
- After one period of waiting and collecting information, the firms pursue local search with undistorted performance values.
- Firms may perfectly predict the consequences of response alternatives.

**Ready-fire-aim (RFA)**
- In response to a disruption, firms immediately start local hill-climbing.
- For a certain number of periods $D$, performance values are distorted by a random error term (linearly decreasing over time, uniformly distributed; cf. Levinthal, 1997).
- Re-evaluation of choice configuration in subsequent period.

Note: Performance levels are reported in relation to the global optimum of a landscape.
“Ready-fire-aim” becomes more beneficial in highly complex environments

—

Parameters

- **Complexity ($K$)**
  - low
  - high

- **Level of response uncertainty ($E$)**
  - low
  - medium
  - high

- **Duration of response uncertainty ($D$)**
  - short
  - long

- **Shadow of the past ($SOP$)**
  - no
  - stg

---

**Effectiveness**

- RFA
- RAF

**Speed**

- RFA
- RAF

---

*a* “no” refers to no path dependence ($SOP = 0$), “stg” refers to strong path dependence ($SOP = 4$).
But how do managers actually behave in response situations?

- **Vignettes** are short, carefully constructed descriptions of a situation (Atzmüller & Steiner, 2010)
- All vignettes begin with the **same introductory paragraph (common module)**
- The subsequent paragraphs contain **systematic manipulations** of our three variables of interest (**experimental cues module**):
  - Response uncertainty: low vs. high
  - Complexity: low vs. high
  - Path dependence: none vs. present
- After reading each vignette, participants are asked to report their **intention to act immediately (ITA)** subsequent to the described scenario (9 point Likert-type scale)

Source: Merath & Bode (2017)
Managers’ behaviors might deviate from how they should respond to disruptions

Main insights:
- High complexity tends to lead to a lower ITA than low complexity
- Path dependence does not drastically reduce participants’ ITA if response uncertainty is high
- Participants’ intentions deviate from how managers should behave (we conducted agent-based simulation experiments to analyze how managers should behave)
Agenda

1. Supply chain risk and disruptions: Why should we care?

2. Response stages, strategies, and behaviors

3. Summary
Supply chain disruption response: Summary

- **General:**
  - Modern **supply chains are vulnerable**. For this reason, supply chain risk management is important.
  - In dynamic, complex, and tightly coupled systems, it is impossible to address all risks proactively.

- **Stages:**
  - Recovering quickly reduces impact; in particular, speeding up the diagnosis stage is important if this is slowest stage

- **Strategies:**
  - RFA requires more changes to find a stable long-term configuration, but it is more effective if the environment is highly complex or if response uncertainty is neither high nor long-lasting

- **Behaviors:**
  - Managers’ behaviors might deviate from how they should respond to disruptions
SUPPLY CHAIN DISRUPTION RESPONSE: STAGES, STRATEGIES, AND BEHAVIORS

IAUP 2017 | Young Scientists Conference
Vienna, Austria | July-7, 2017

Christoph Bode
Endowed Chair of Procurement
University of Mannheim
Business School
Backup
“Anatomy” of a supply chain disruption

Prodromal stage  
Acute stage  
Resolution stage

Source: Sheffi (2005): The Resilient Enterprise
The “Albuquerque Fire” accident highlights the importance of reactive risk management

- Nokia and Ericsson were hit by the same disruption, but the outcome was different.
- The response of the involved firms is of significant relevance to the loss causes by the supply chain disruption.

Warning signals for supplier financial distress and default

Stakeholder Crisis
- Changes in ownership structure
- Loss of key employees
- Conflict in family-run businesses
- Threat by financial investors
- Strong influence of unions

Strategic Crisis
- Problems in the product portfolio
- Dependence on few customers / suppliers
- Extraordinarily high or low capital expenditures
- Worsening of competitive position
- Risks of M&A

Operative Crisis
- Quality issues
- High inventory levels
- Capacity issues
- Technical problems

Revenue Crisis
- Trouble with plant utilization
- Profit collapse
- Postponing investments
- Cost explosion: raw material, personal expenses, etc.
- Cost cutting programs
- Short time work
- Further financial requirements

Liquidity Crisis
- Postponing payment obligations
- Invitation to talks with banks and/ or sub-suppliers
- Requests for, e.g.:
  - Change in payment terms
  - Financing of tools
- Termination of trade credit insurances

Source: Bode, Hübner, Wagner (2014)
How to assess the performance of a supply disruption recovery process?

Performance dimensions

- **Effectiveness**
  (e.g., Handfield et al. 2007)

- **Speed**
  (e.g., Macdonald & Corsi 2013)

How to measure them in this setting?

- **PDP**: Post-disruption performance (average from period 40 to 80)
- **FP**: Final performance (performance in period 80)
- **NTP**: Number of time periods required to reach long-term configuration
- **URP**: Performance when uncertainty has been resolved
- **FI**: Improvement during first period of search
- **NA**: Number of alterations required to reach long-term configuration

\(^{a} F_{\text{RAF}} > F_{\text{RFA}} \) and \( N_{\text{RFA}} > N_{\text{RAF}} \) in all settings, so both performance measures are not considered in the diagram on the following slide which focuses only on context-sensitive measures.
The NK model is a versatile approach to model search processes in organizational decision making

- A firm is viewed as a set of binary decisions that determines the overall firm performance, depending on the interdependencies among these decisions (Kauffman 1993, Milgrom & Roberts 1995). Key elements:
  - **Set of binary decisions** \( (N) \) a firm needs to take (technical specifications, sourcing strategy, etc.)
  - **Interdependencies** \( (K) \) among the decisions, which reflect the complexity of decision making:
    - If \( K = 0 \), contribution of each decision is independent from other decisions (no complexity)
    - If \( K = N - 1 \), contribution of each decision depends on the state of all other decisions (high complexity)

![Diagram showing binary decisions and their interdependencies]

- Each of the \( 2^N \) “choice configurations” \( d = (d_1, \ldots, d_i, \ldots, d_N) \) is evaluated by a fitness value function \( F: \{0, 1\}^N \to [0; 1] \) to a certain performance value \( F(d) \)

- The goal of organizational search is to identify and reach (e.g., via local hill climbing) a choice configuration that yields the highest possible performance value, given the given environment
Firms engage in “local search” which means that the immediate neighborhood of configurations is examined.

- Assume the initial configuration is:
  \[0.43 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1\]

- Period 1: Change of decision 4
  \[0.45 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1\]

- Period 2: Change of decision 3
  \[0.39 \quad 1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1\]

- Period 3: Change of decision 5
  \[0.64 \quad 1 \quad 0 \quad 0 \quad 0 \quad 1 \quad 1\]

Note: The parameters for the landscape shown above are \(N = 6\) and \(K = 2\).
The calculation of fitness values depends on the number of interdependencies $K$ among the $N$ decisions.

**$N = 3$ $K = 2$**

<table>
<thead>
<tr>
<th>Decisions</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>3</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

#### Contribution of each decision

<table>
<thead>
<tr>
<th>Configurations</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0.51</td>
<td>0.13</td>
<td>0.58</td>
</tr>
<tr>
<td>001</td>
<td>0.73</td>
<td>0.66</td>
<td>0.27</td>
</tr>
<tr>
<td>010</td>
<td>0.68</td>
<td>0.51</td>
<td>0.82</td>
</tr>
<tr>
<td>011</td>
<td>0.05</td>
<td>0.60</td>
<td>0.23</td>
</tr>
<tr>
<td>100</td>
<td>0.83</td>
<td>0.62</td>
<td>0.93</td>
</tr>
<tr>
<td>101</td>
<td>0.37</td>
<td>0.94</td>
<td>0.98</td>
</tr>
<tr>
<td>110</td>
<td>0.17</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>111</td>
<td>0.07</td>
<td>0.16</td>
<td>0.94</td>
</tr>
</tbody>
</table>

- Contribution values are **drawn randomly** from a **standard uniform distribution**

- **Different levels of complexity** lead to **different shapes** of landscapes
  - “Smooth” ($N = 6$ and $K = 0$)
  - “Rugged” ($N = 6$ and $K = 5$)

**First decision is changed from “0” to “1”**

**Firm A**

- $F("000") = \frac{C_1 + C_2 + C_3}{N} = \frac{0.51 + 0.13 + 0.58}{3} = 0.41$
- $F("100") = \frac{C_1 + C_2 + C_3}{N} = \frac{0.83 + 0.62 + 0.93}{3} = 0.79$
Responses to a supply chain disruption: Buffer or bridge?

Source: Bode, Wagner, Petersen, & Ellram (2011)