FROM PANDEMIC DISRUPTION TO GLOBAL SUPPLY CHAIN RECOVERY

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• Introduction

• The Risk Exposure Model

• A Recovery Plan

• The Impact

• Appendix
Last Ten Years: Supply Chain Risk

- Significant increase in supply chain risk
  - Outsourcing and offshoring
    - Supply chain is geographically more diverse
  - Lean manufacturing
    - Just-in-time (JIT) manufacturing and low inventory levels

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**Ash in the Supply Chain**

The tentacles of the crisis have already stretched into the global supply chain. Auto factories in China that use electronic parts flown in from Germany faced a sudden halt in shipments.

*The Washington Post, 2010*

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**Intel Sales are down**

Giant blames Thai flood for $1B drop in sales goals. Toyota, Honda, Goodyear, Canon, Nikon, Sony... have cut production and lowered financial forecasts because of the flooding in Thailand.

*The Wall Street Journal, 2011*

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**General Motors truck plant was shutting down**

General Motors truck plant in Louisiana announced that it was shutting down temporarily for lack of Japanese-made parts because of the earthquake and tsunami had struck Japan.

*New York Times, 2011*
Last Five Weeks

- HBR on February 28:
  - “...the peak of the impact of Covid-19 on global supply chains will occur in mid-March, forcing thousands of companies to throttle down or temporarily shut assembly and manufacturing plants in the U.S. and Europe.”

- FORTUNE on March 17:
  - “The European automotive industry is shutting down...”
  - This includes Volkswagen, Renault, PGA Group, Fiat, etc

- MIT News on March 25:
  - “In the U.S., most major automakers announced last week (week of March 17) they were temporarily closing plants”
For Most Companies

• **Right Now**: trying to find their way through these tough supply and demand challenges

• **Short Term**: need to prepare for the recovery that will surely arrive in the not too distant future

• **Long Term**: consider significant supply chain restructuring and risk mitigation strategies and technologies
For Most Companies

• **Right Now**: trying to find their way through these tough supply and demand challenges

• **Short Term**: need to prepare for the recovery that will surely arrive in the not too distant future
  
  • How can a firm fashion a recovery plan given the huge uncertainties that now exist on both the demand and supply sides?

• **Long Term**: Consider significant supply chain restructuring and risk mitigation strategies and technologies
Three Scenarios

- **Worst-Case**: no vaccine/cure is available for a long time, a prolonged need to maintain social distancing measures, and a significant impact on demand and supply
  - Growing number of bankruptcies
- **Best-Case**: NA and EU are able to control and reduce the pandemic and life is back to normal by the end of the second quarter
  - Significant pressure on logistics capacity
- **Most-Likely**: the peaks in various regions will differ in time and magnitude with perhaps second waves
  - The pandemic effects will stretch out beyond the second quarter
  - Supplier’s factory may be running one time period and then closed the next period
Challenges

• Understand the impact of a supplier downtime on business
  • Estimate backlogs; run-down time; when to expedite & for how long
• Take advantage of the fact that peaks will happen at different times in different regions
• Reposition inventory in anticipation of certain regions or facilities being under quarantine
• Reconfigure supply chains since some critical, but vulnerable, suppliers will go out of business
• Address supply chain blocking
  • Chinese manufacturers are faced with a second shockwave associated with canceled or delayed orders from all over the world
• Estimate consumer demand.
Talk Outline

• Introduction

• The Risk Exposure Model

• A Recovery Plan

• The Impact
The Risk Exposure Model: Objectives

- Identify exposure to risk associated with parts and suppliers
- Prioritize and allocate resources effectively
- Develop mitigation strategies.
Illustrating the Approach

Steel Bar Suppliers
Raw Chemical Suppliers
Sheet Steel Suppliers
Contract Manufacturers
Assembly Suppliers
Stamping Plants
Engine Plants
Assembly Plants

• Time-To-Recover (TTR): The time it takes to recover to full functionality after a disruption
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Illustrating the Approach

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- Performance Impact (PI): Impact of a disruption for the duration of TTR on a given performance measure
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• Performance Impact (PI): Impact of a disruption for the duration of TTR on a given performance measure
• Risk Exposure: Impact of disruption anywhere on business performance after optimally allocating resources
Time-to-Recover (TTR): The time for a node (region) in the supply chain to return to full functionality after a disruption

- Apply TTR to estimate parts and plants impacted, to allocate remaining resources...

Time-to-Survive (TTS): The maximum duration that the supply chain can match supply with demand after a node disruption

- Apply TTS to estimate run-down time, backlog level,
- Apply TTS/TTR to estimate how much and how long to reserve logistics capacity

$TTR(j) < TTS(j) \quad \text{Supply is not disrupted}$

$TTR(j) > TTS(j) \quad \text{Shutdown plants*}$

$TTR(j) = TTS(j) \quad \text{Expedite}$
Features Captured in Our Model

Key features captured of the risk exposure model:

- The firm and its supplier production portfolio and volume of production by site
- Bill of materials for each product and its corresponding parts
- Volumes and profit margins of different product lines
- Pipeline inventories
- Time duration of a disruption, by scenario
- **Firm’s response during and after a disruption**
  - The response is simulated via optimization
Risk Exposure Impact

- Risk Exposure method implemented in industries such as Telecommunications, High-Tech, Pharmaceutical, Aerospace and Automotive
- Winner of the 2014 INFORMS Wagner Award - Ford Motor Company
- Received the Ford 2015 Engineering Excellence Award
- The UN Office of Disaster Risk Reduction applied the Risk Exposure method in developing countries
  - Haraguchi, M, and U. Lall, “Flood Risks and Impacts”
Talk Outline

- Introduction
- The Risk Exposure Model
- A Recovery Plan
- The Impact
A 5-Step Plan for Recovery

- **Step 1**: Map out your supply chain and estimate time-to-recover by scenario.
- **Step 2**: For each scenario, estimate demand and assess which products and assembly facilities will be impacted by effected suppliers.
- **Step 3**: Determine when and for how long you should shut down, or significantly reduce, manufacturing activities.
- **Step 4**: Determine when to ramp up capacity. Allocate the available resources to products that allow you to achieve specific objectives during recovery period.
- **Step 5**: Determine when to expedite and for how long. Book logistics capacity as soon as possible.
The First Step

- It is not enough to focus on strategic suppliers
  - Small suppliers that provide low-cost components may be even more crucial, as a short supply of certain components might force production shut-downs.

- Therefore, this step is about **supply chain mapping**
  - Requires connecting with tier-1 suppliers and identifying their suppliers and, if possible, their suppliers’ suppliers.
  - A few technology companies can help accelerate this process, see for example Interos or resilinc.
  - **This step needs to be done immediately!**
The Second Step

- Evaluate each scenario
  - Estimate demand: use external data, in particular Hubei China, Henan China and S. Korea recovery info, to estimate demand volume
    - Epidemic modeling can help
  - Understand the impact of disruptions in various regions on products and assembly facilities.

- Identify which suppliers/regions in the network create the greatest risk exposure
  - Often highlighting previously hidden or overlooked areas of high risk.

- Estimate Time-to-Survive.
The Third and Fourth Steps

• Determine the best response to a node or several nodes being disrupted during the TTR duration.
  ♦ Compare the costs and benefits of various alternatives for mitigating impact
  ♦ Identify the best allocation of available resources to finished goods.
  ♦ Decide which subset of products to focus on

• Apply TTR and TTS to determine when to shut down a facility and for how long

• Take advantage of the fact that the peaks in various regions will differ in time and magnitude
• Apply the model to identify how much and for how long the firm needs airfreight
  ‣ Compare TTR to TTS
• The sooner transportation capacity is reserved, the lower the cost is likely to be since once recovery starts, competition on this capacity will be intense.
Consider Creative Solutions

- Paying more for certain components from alternative suppliers
- Financially helping out small critical suppliers
- Using different materials, if applicable
- Sharing blueprints of certain critical components with suppliers who can modify existing tools and machines and enable the production of these components.
The Impact

• **Supply Chain Executives:** Need to run the model multiple times, not only to analyze different scenarios, but also to (i) update demand estimate and (ii) take advantage of the shifting peaks over time and book logistics capacity.

• **Business Executives:** For many companies, the expected decline in sales and revenue in 2020 will require significant **cost-cutting measures everywhere** in the organization.

• **Consumers:** Likely to face shortages and longer delivery times for many products, as well as **smaller product variety**.
THANK YOU!

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informs.org/COVID19
Appendix

- The TTR Model
- The TTS Model
- Ford Implementation
TTR Model Formulation

Model Formulation:

\[
\begin{align*}
\text{minimize} & \quad \sum_{j \in \mathcal{V}} f_j l_j \\
\text{s.t.} & \quad u_j - \sum_{i \in \mathcal{P}_j} y_{ij} r_{kj} \leq 0, \quad \forall k \in \mathcal{N}^-(j), \forall j \in \mathcal{D} \\
\sum_{j \in \mathcal{N}^+(i)} y_{ij} - u_i & \leq s_i, \quad \forall i \in \mathcal{U} \\
\sum_{k \in \mathcal{V}_j} u_k & = 0, \quad \forall j \in \mathcal{S}^{(n)} \\
l_j + \sum_{k \in \mathcal{A}_\alpha} u_k & \geq d_j t^{(n)}, \forall j \in \mathcal{V} \\
\sum_{k \in \mathcal{A}_\alpha} u_k & \leq c_\alpha t^{(n)}, \forall \alpha \in \mathcal{A} \\
l_j, u_j, y_{ij} & \geq 0.
\end{align*}
\]

- Each optimization problem corresponds to a single disruption scenario.

- The optimization problems are linear programs
  - important because a firm maybe looking at tens of thousands of possible disruption scenarios.
TTR Model Formulation

Model Formulation:

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\begin{align*}
\text{minimize} & \quad \sum_{j \in \mathcal{N}} f_j l_j \\
\text{subject to} & \quad u_j - \sum_{i \in \mathcal{P}_{j,k}} y_{ij} / r_{kj} \leq 0, \quad \forall k \in \mathcal{N}^-(j), \forall j \in \mathcal{D} \\
& \quad \sum_{j \in \mathcal{N}^+(i)} y_{ij} - u_i \leq s_i, \quad \forall i \in \mathcal{U} \\
& \quad u_j = 0, \quad \forall j \in \mathcal{S}^{(n)} \\
& \quad l_j + \sum_{k \in \mathcal{V}_j} u_k \geq d_j t^{(n)}, \forall j \in \mathcal{V} \\
& \quad \sum_{k \in \mathcal{A}_\alpha} u_k \leq c_\alpha t^{(n)}, \forall \alpha \in \mathcal{A} \\
& \quad l_j, u_j, y_{ij} \geq 0.
\end{align*}
\]

Bill of Material Constraint

Total production at node \( j \) (corresponding to a part at a particular facility) is bounded by the volumes allocated from its upstream nodes.
Model Formulation:

\[
\begin{align*}
\text{minimize} & \quad \sum_{j \in V} f_j l_j \\
\text{st.} & \quad u_j - \sum_{i \in P_{jk}} y_{ij} / r_{ki} \leq 0, \quad \forall k \in N^-(j), \forall j \in D \\
& \quad \sum_{i \in N^+(i)} y_{ij} - u_i \leq s_i, \quad \forall i \in U \\
& \quad u_j = 0, \quad \forall j \in S^{(n)} \\
& \quad l_j + \sum_{k \in V_j} u_k \geq d_j t^{(n)}, \forall j \in V \\
& \quad \sum_{k \in A_{\alpha}} u_k \leq c_{\alpha} t^{(n)}, \forall \alpha \in A \\
& \quad l_j, u_j, y_{ij} \geq 0.
\end{align*}
\]

Parts Allocation Constraint

Total allocation volume of node \( i \) is constrained by its production and its pipeline inventory.
### TTR Model Formulation

**Model Formulation:**

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\text{minimize} & \quad \sum_{j \in \mathcal{V}} f_j l_j \\
\text{s.t.} & \quad u_j - \sum_{i \in \mathcal{P}_{jk}} y_{ij} / r_{kj} \leq 0, \quad \forall k \in \mathcal{N}^-(j), \forall j \in \mathcal{D} \\
& \quad \sum_{j \in \mathcal{N}^+(i)} y_{ij} - u_i \leq s_i, \quad \forall i \in \mathcal{U} \\
& \quad u_i = 0, \quad \forall i \in \mathcal{S}^{(n)} \\
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& \quad l_j, u_j, y_{ij} \geq 0.
\end{align*}
\]

**Disruption Constraint**

Production of node $j$ is halted due to disruption
Model Formulation:

\[
\begin{align*}
\text{minimize} & \quad \sum_{j \in \mathcal{V}} f_j l_j \\
\text{subject to} & \quad u_j - \sum_{i \in \mathcal{P}_{j_k}} y_{ij} / r_{kj} \leq 0, & \forall k \in \mathcal{N}^-(j), \forall j \in \mathcal{D} \\
& \quad \sum_{j \in \mathcal{N}^+(i)} y_{ij} - u_i \leq s_i, & \forall i \in \mathcal{U} \\
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& \quad l_j, u_j, y_{ij} \geq 0.
\end{align*}
\]

Demand loss constraints

Loss of production for vehicle $j$ is lower bounded by the demand minus the production over the TTR duration.
Model Formulation:

\[
\begin{align*}
\text{minimize} & \quad \sum_{j \in \mathcal{V}} f_j l_j \\
\text{st.} & \quad u_j - \sum_{i \in \mathcal{P}_{j_k}} y_{ij} / \alpha_{k_j} \leq 0, \quad \forall k \in \mathcal{N}^{-}(j), \forall j \in \mathcal{D} \\
& \quad \sum_{j \in \mathcal{N}^{+}(i)} y_{ij} - u_i \leq s_i, \quad \forall i \in \mathcal{U} \\
& \quad u_j = 0, \quad \forall j \in \mathcal{S}^{(n)} \\
& \quad l_j + \sum_{k \in \mathcal{V}_j} u_k \geq d_j t^{(n)}, \quad \forall j \in \mathcal{V} \\
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& \quad l_j, u_j, y_{ij} \geq 0.
\end{align*}
\]

Production capacity constraints
Total production of all nodes at site/plant $\alpha$ is bounded by its capacity
In the TTS formulation, $t^{(n)}$ changes from a constant to a variable, and is being maximized.
• Development of a Decision Support System for Risk Management
  • Risk Analysis--Strategic
    ▶ Identify Exposure to Risk associated with parts and suppliers
    ▶ Prioritize and allocate resources effectively
    ▶ Segment suppliers and develop mitigation strategies
    ▶ Identify opportunities to reduce risk mitigation cost
  • Track changes in Risk Exposure--Tactical
    ▶ Alert procurement executives to changes in their risk position
  • Respond to a Disruption--Operational
    ▶ Identify an effective way to allocate resources after a disruption
System Architecture

Central Repository (SQL Server)
  \[\text{Supply Chain Mapping (Java Graph ETL)}\]
  \[\text{Data Visualization (Tableau)}\]
  \[\text{Model Interface}\]
  \[\text{Risk Exposure Model (Java-CPLEX)}\]
  \[\text{Vehicle Profit Margins}\]
  \[\text{Purchasing System}\]
  \[\text{Materials Planning & Logistics}\]
  \[\text{Vehicle Volume Planning System}\]
Mapping Ford Supply Chain – Graph ETL

Part Structure

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<thead>
<tr>
<th>Plant</th>
<th>Parent</th>
<th>Child</th>
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<td>Plant-X</td>
<td>Part A</td>
<td>Part B</td>
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<td>Plant-X</td>
<td>Part B</td>
<td>Part C</td>
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Part Supply

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Final Assembly

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System Architecture

- **Central Repository (SQL Server)**
- **Supply Chain Mapping (Java Graph ETL)**
- **Data Visualization (Tableau)**
- **Vehicle Volume Planning System**
- **Materials Planning & Logistics**
- **Purchasing System**
- **Model Interface**
- **Risk Exposure Model (Java-CPLEX)**
- **Vehicle Profit Margins**

**Flow:**
- Central Repository (SQL Server) connects to Supply Chain Mapping (Java Graph ETL).
- Supply Chain Mapping (Java Graph ETL) connects to Data Visualization (Tableau).
- Data Visualization (Tableau) connects to Vehicle Volume Planning System.
- Materials Planning & Logistics connects to Purchasing System.
- Purchasing System connects to Model Interface.
- Model Interface connects to Risk Exposure Model (Java-CPLEX).
- Risk Exposure Model (Java-CPLEX) connects to Vehicle Profit Margins.
## Generating Critical Supplier List

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### Critical Suppliers in Japan

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