

FROM PANDEMIC DISRUPTION TO GLOBAL SUPPLY CHAIN RECOVERY

David Simchi-Levi | April 8, 2020



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Talk Outline

- 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

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

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

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 that 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, PSA 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**.

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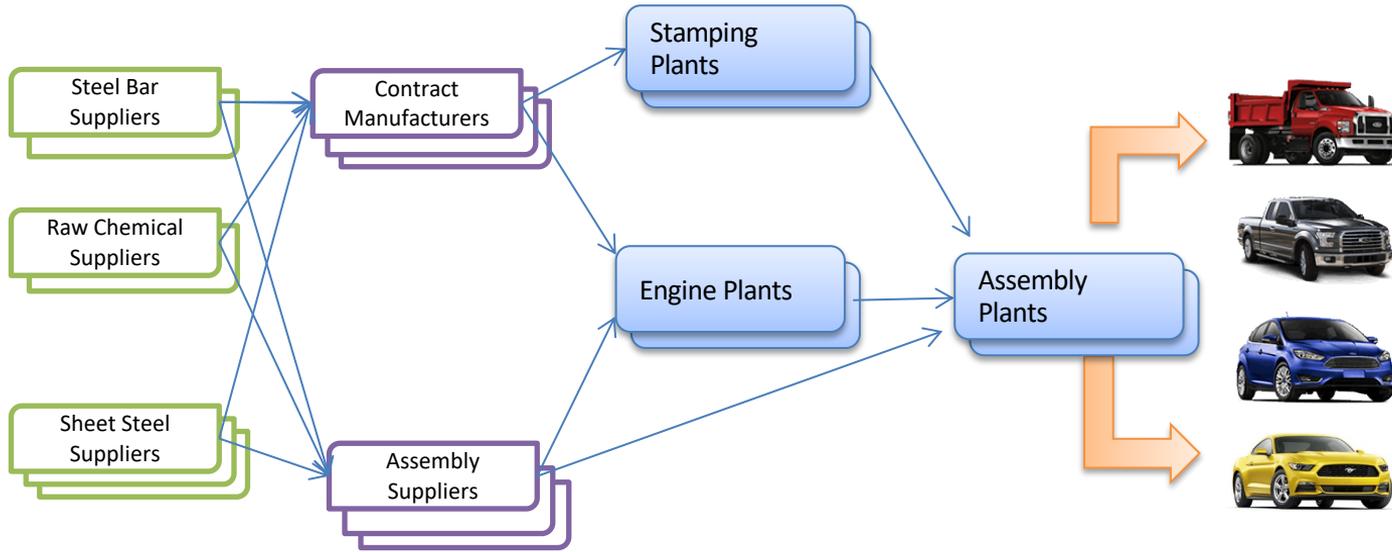


The Risk Exposure Model: Objectives

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

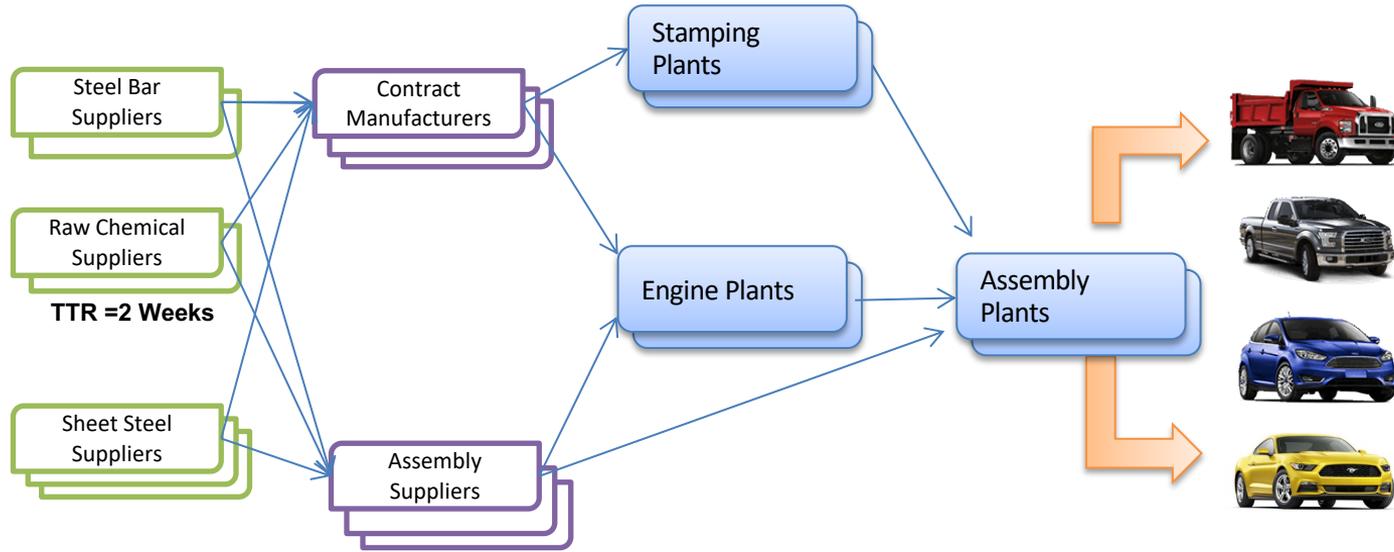


Illustrating the Approach



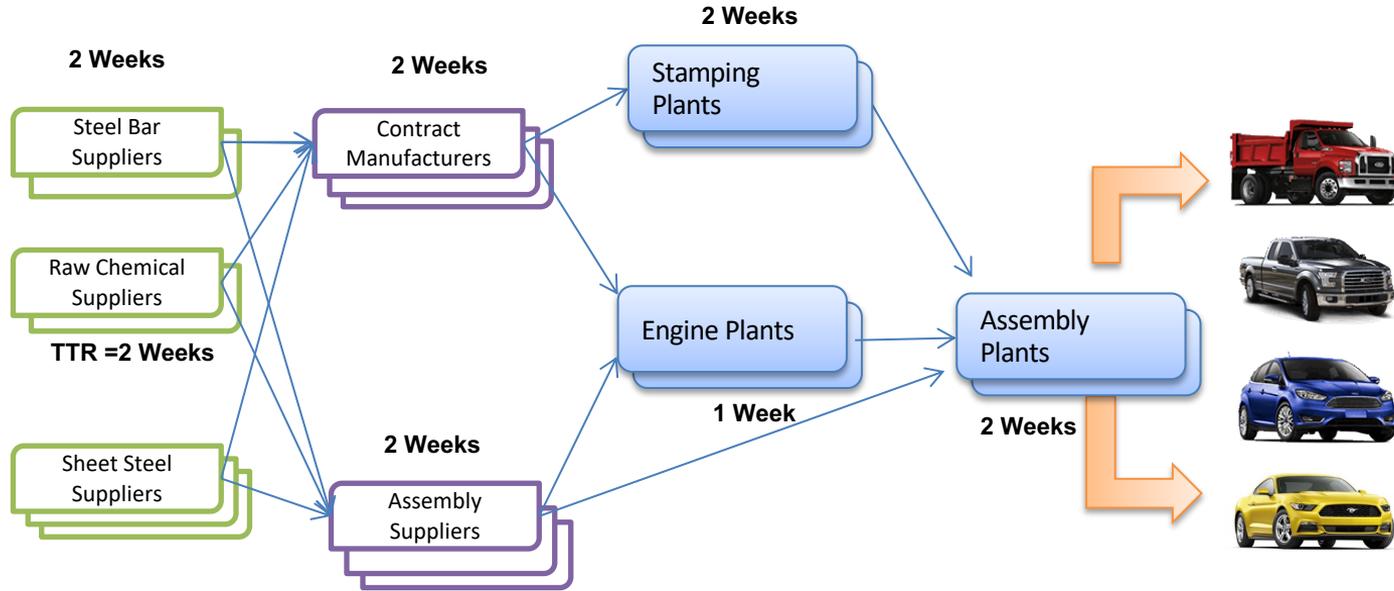
- **Time-To-Recover (TTR):** The time it takes to recover to full functionality after a disruption

Illustrating the Approach



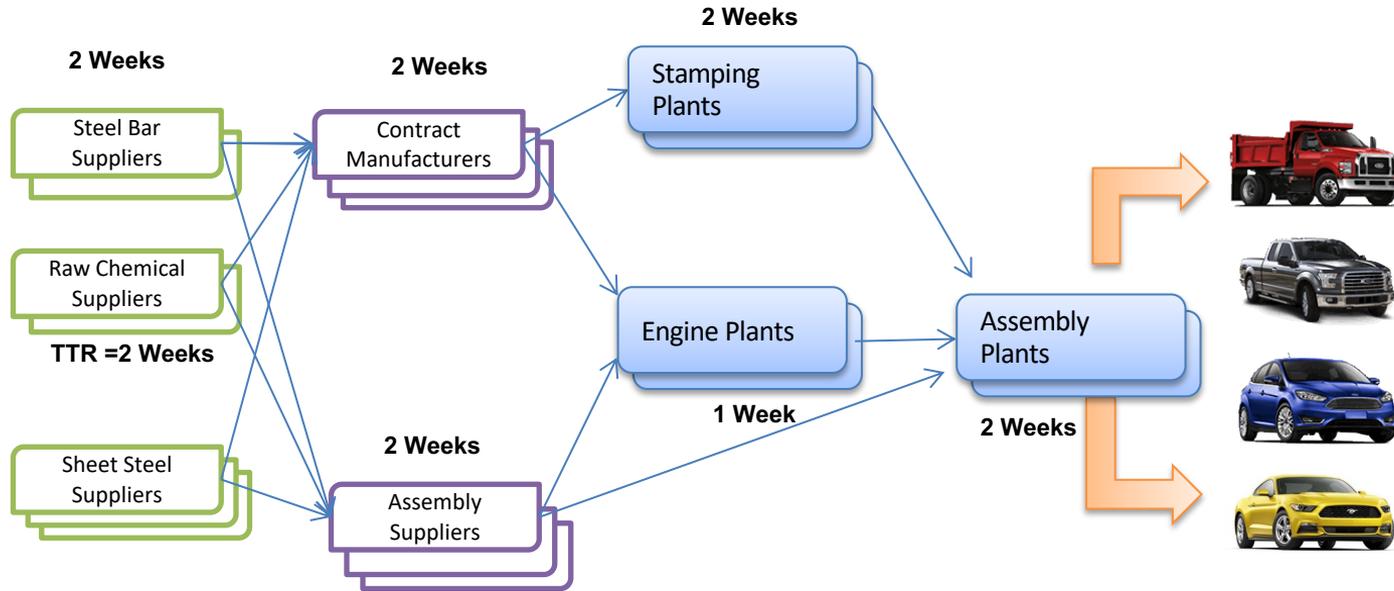
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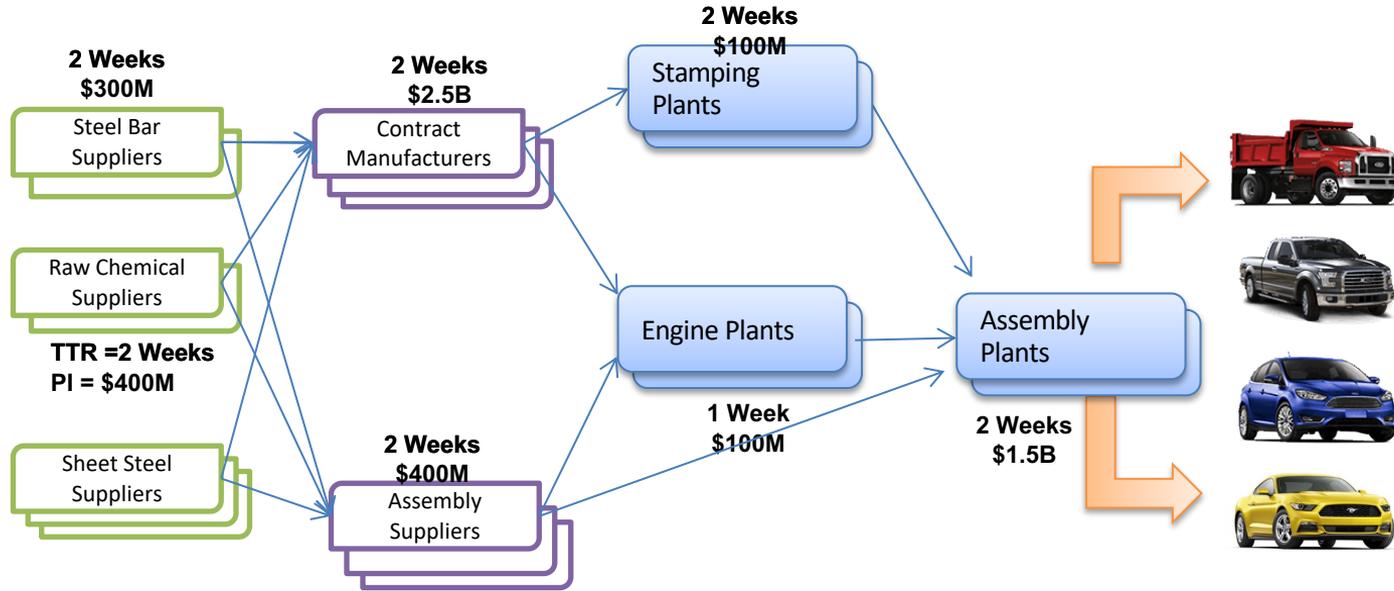
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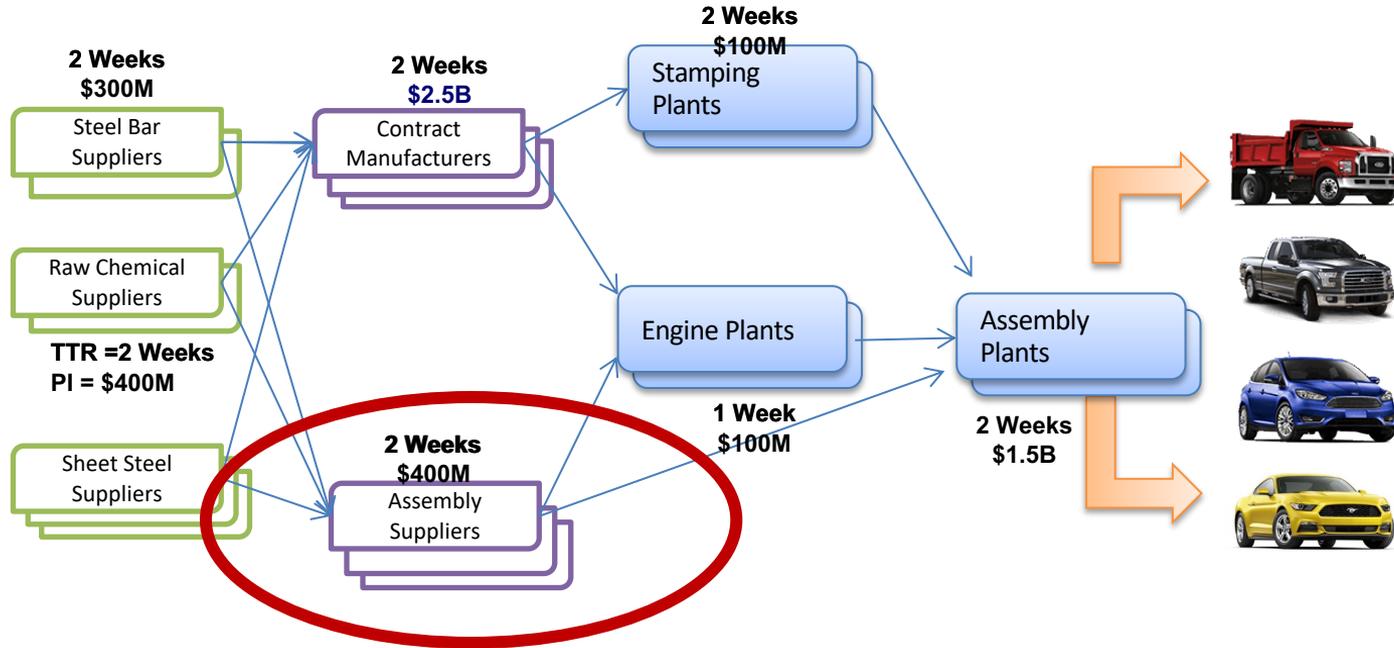
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- **Performance Impact (PI):** Impact of a disruption for the duration of TTR on a given performance measure

Illustrating the Approach



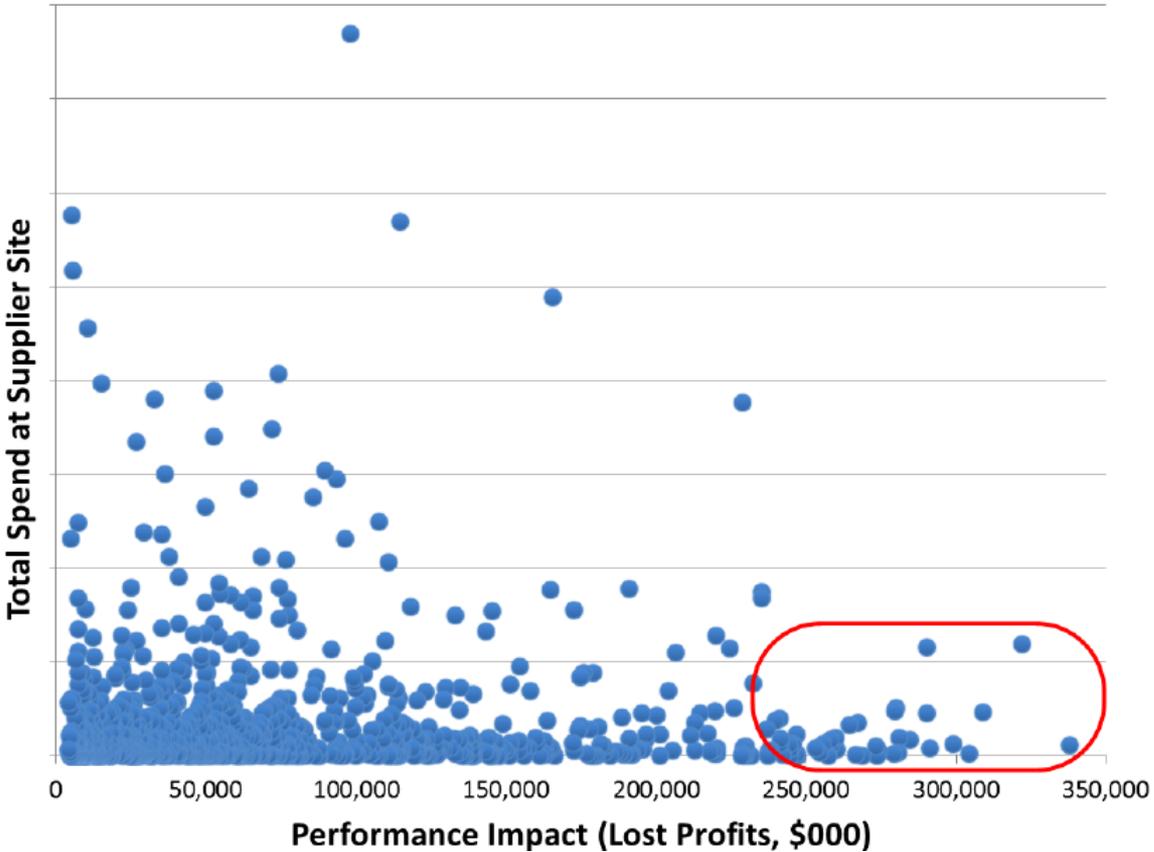
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Illustrating the Approach



- **Time-To-Recover (TTR):** The time it takes to recover to full functionality after a disruption
- **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

Performance Impact and Total Spent at Supplier Site



Time-to-Recover & Time-to-Survive

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

$TTR(j) < TTS(j)$ \rightarrow Supply is not disrupted

$TTR(j) > TTS(j)$ \rightarrow Shutdown plants*

$TTR(j) = TTS(j)$ \rightarrow 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”



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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

The Last Step

- 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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FOR MORE INFORMS MEMBER RESOURCES FOR COVID-19, PLEASE VISIT:

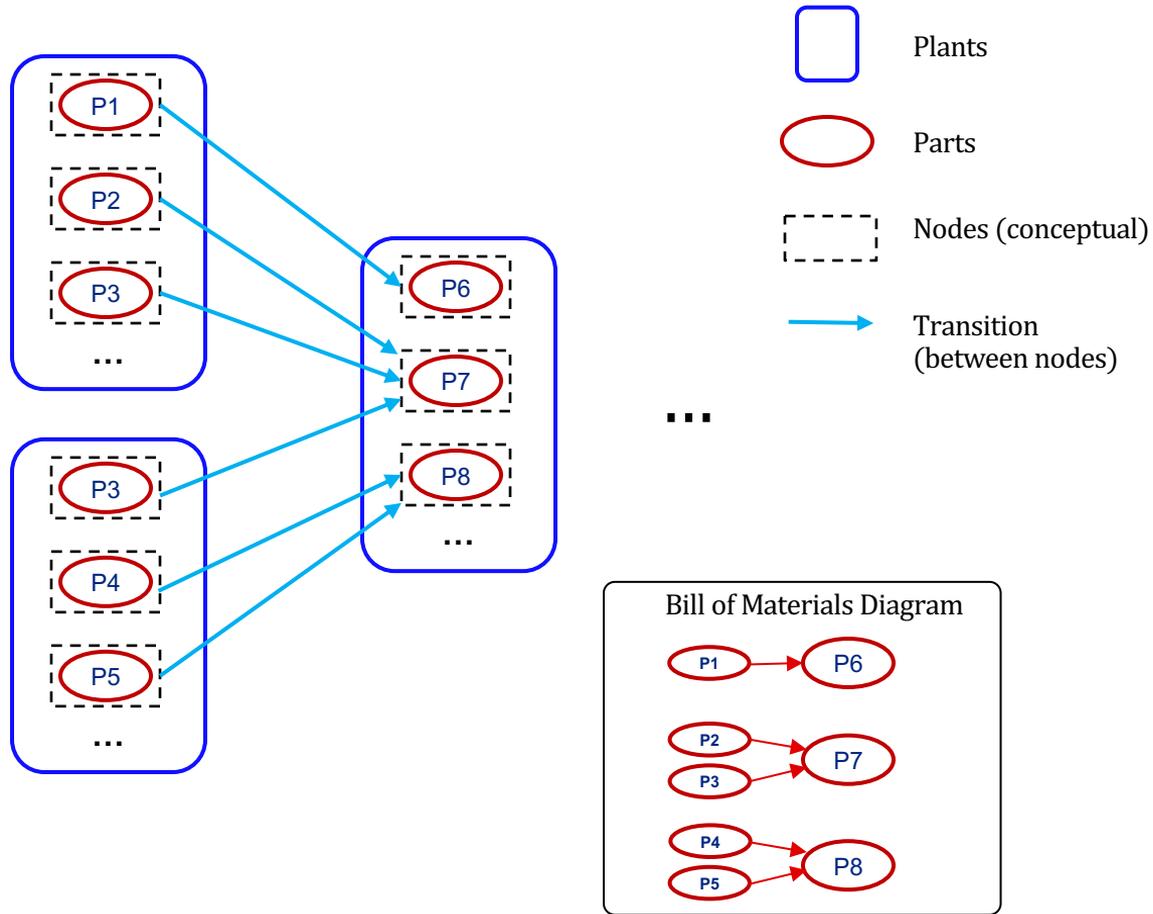
informs.org/COVID19



Appendix

- The TTR Model
- The TTS Model
- Ford Implementation

Visualizing a Simple Model



TTR Model Formulation

Model Formulation:

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

- 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

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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

TTR Model Formulation

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Parts Allocation Constraint

Total allocation volume of node i is constrained by its production and its pipeline inventory

TTR Model Formulation

Model Formulation:

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

Disruption Constraint

Production of node j is halted due to disruption

TTR Model Formulation

Model Formulation:

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

Demand loss constraints

Loss of production for vehicle j is lower bounded by the demand minus the production over the TTR duration

TTR Model Formulation

Model Formulation:

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Production capacity constraints

Total production of all nodes at site/plant α is bounded by its capacity

TTS Formulation

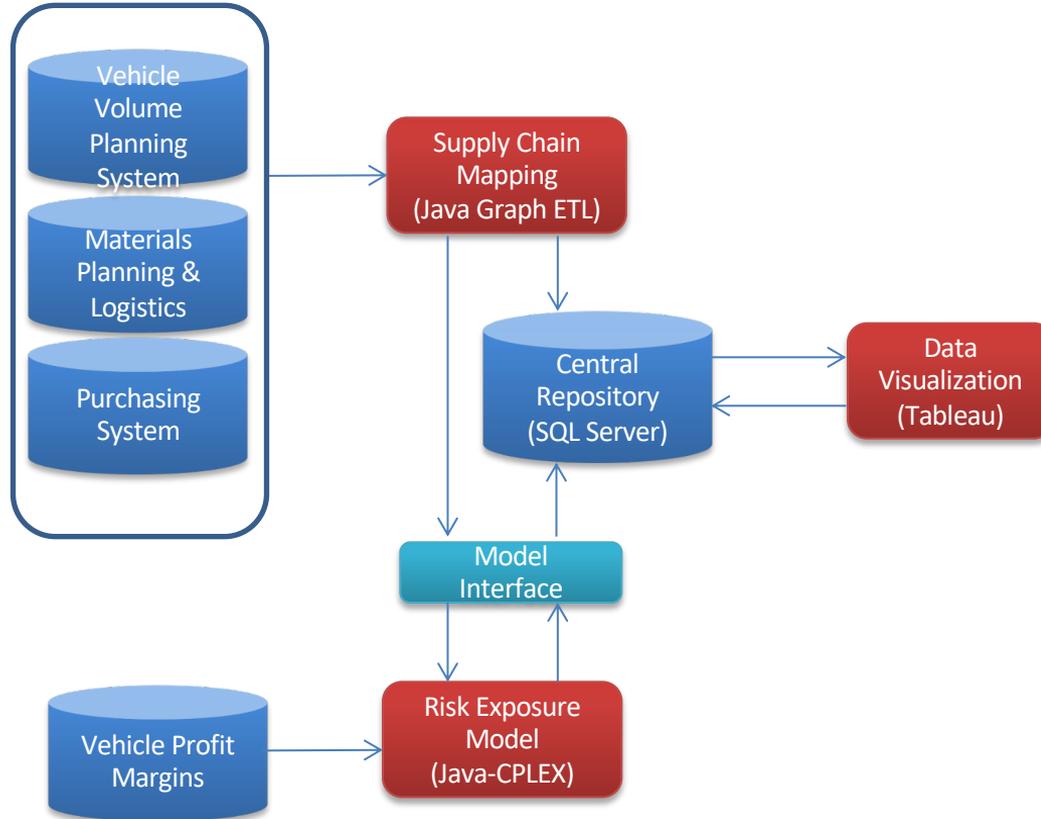
$$\begin{aligned} & \text{maximize } t^{(n)} \\ & \text{s.t. } u_j - y_{ij}/r_{ij} \leq 0, \quad \forall i \in \mathcal{N}^-(j), \forall j \in \mathcal{D} \\ & \quad \sum_{j \in \mathcal{N}^+(i)} y_{ij} - u_i \leq s_i, \quad \forall i \in \mathcal{U} \\ & \quad u_j = 0, \quad \forall j \in \mathcal{S}^{(n)} \\ & \quad u_j \geq d_j t^{(n)}, \quad \forall j \in \mathcal{V} \\ & \quad \sum_{k \in A_\alpha} u_k \leq c_\alpha t^{(n)}, \quad \forall \alpha \in \mathcal{A} \\ & \quad u_j, y_{ij}, t^{(n)} \geq 0. \end{aligned}$$

In the TTS formulation, $t^{(n)}$ changes from a constant to a variable, and is being maximized.

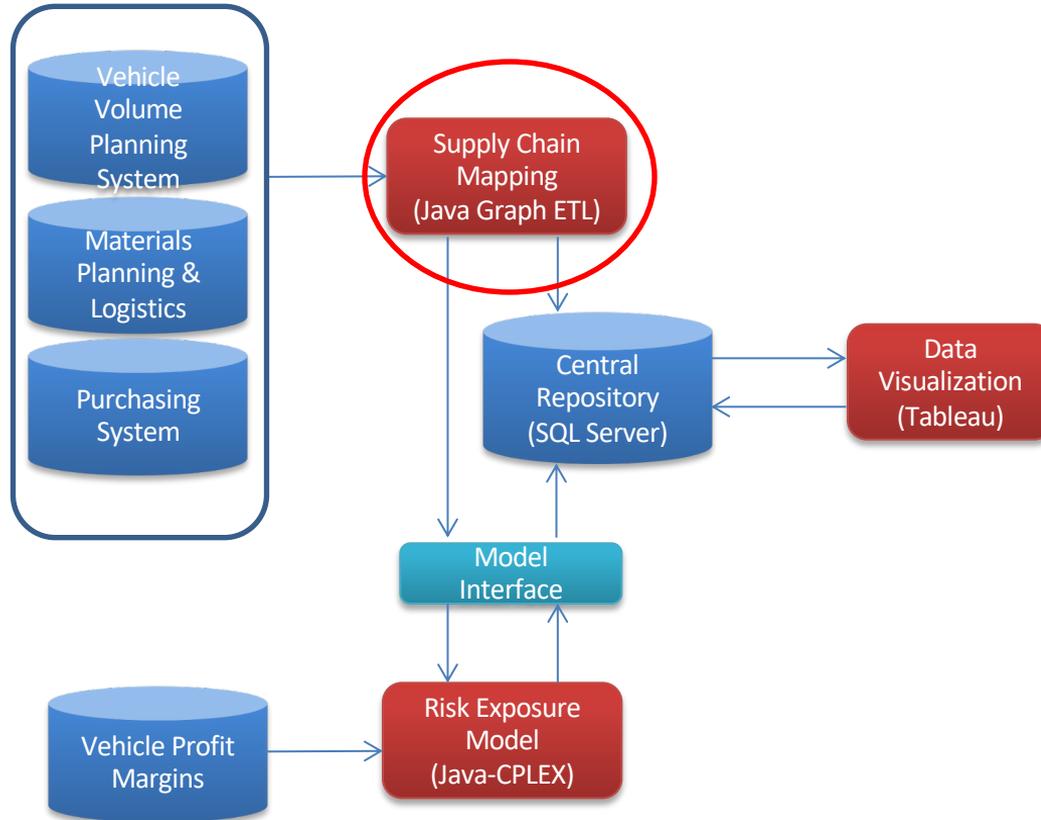
Ford Implementation

- 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

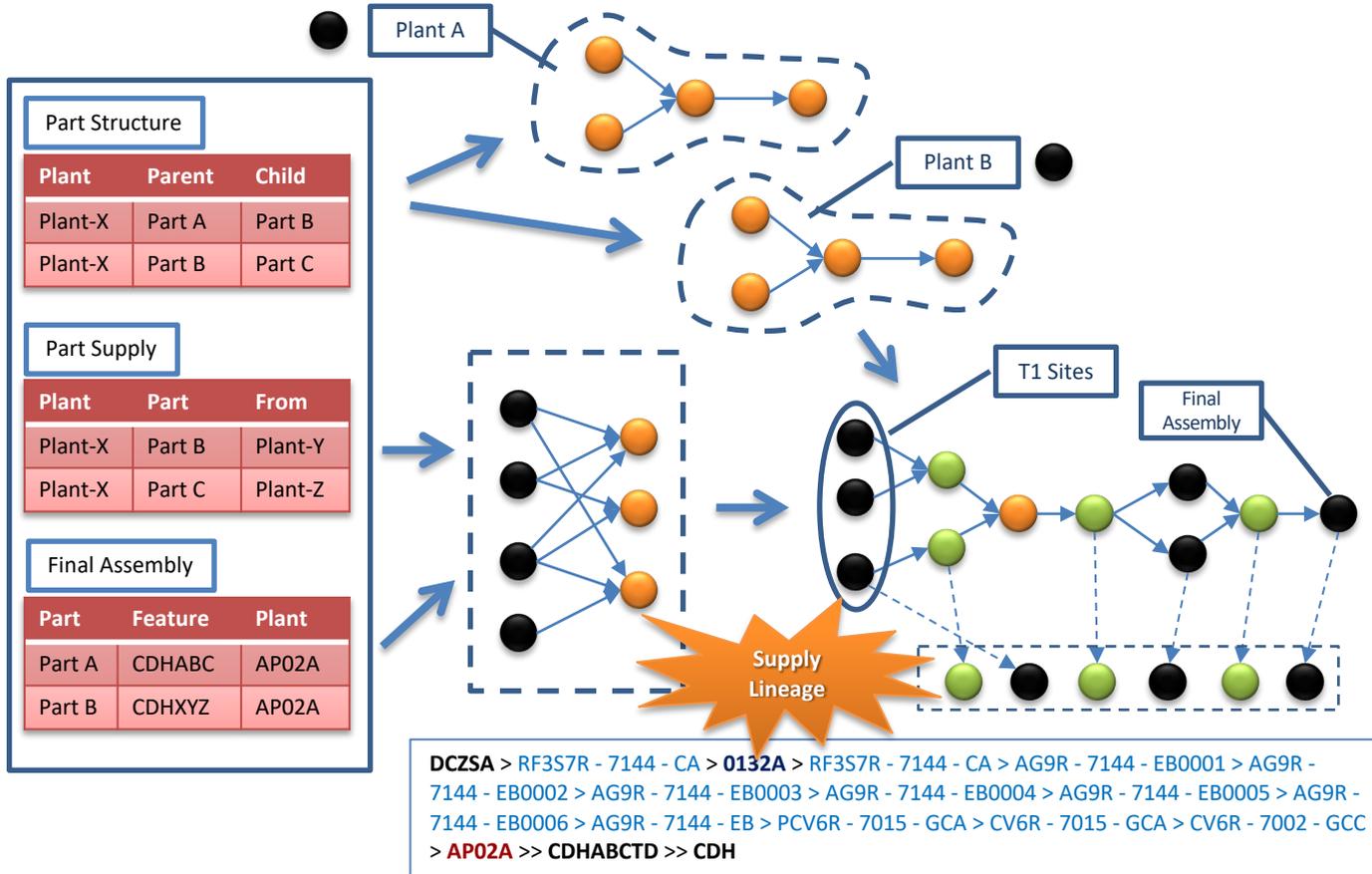
System Architecture



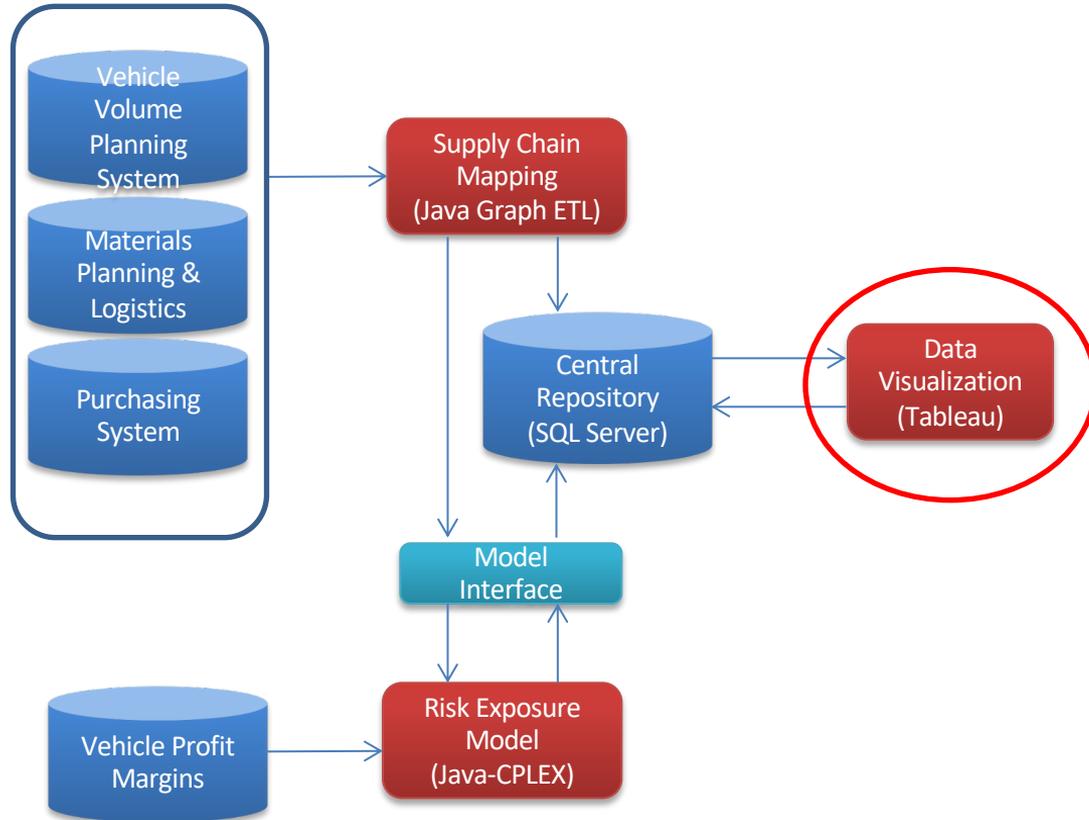
System Architecture



Mapping Ford Supply Chain – Graph ETL



System Architecture



Generating Critical Supplier List



Supplier	Vehicle Impacted	Total Part Cost	Financial Impact	Volume Impact
x11	cc1	\$\$\$	\$\$\$	ww
x12	cc2	\$\$\$	\$\$\$	ww
x13	cc3	\$\$\$	\$\$\$	ww
x14	cc4	\$\$\$	\$\$\$	ww
x15	cc5	\$\$\$	\$\$\$	ww
x16	cc6	\$\$\$	\$\$\$	ww
x17	cc7	\$\$\$	\$\$\$	ww
x18	cc8	\$\$\$	\$\$\$	ww
x19	cc9	\$\$\$	\$\$\$	ww
x20	cc10	\$\$\$	\$\$\$	ww

Supplier	Part Names
x11	y11
x11	y12
x11	y13
x12	y21
x12	y22
x13	y31
x13	y32
x13	y33
x13	y34
x14	y41

Critical Suppliers in Japan



Supplier	Vehicle Impacted	Total Part Cost	Financial Impact	Volume Impact
x11	cc1	\$\$\$	\$\$\$	ww
x20	cc10	\$\$\$	\$\$\$	ww
x21	cc11	\$\$\$	\$\$\$	ww

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x20	y31
x20	y32
x20	y33
x20	y34
x20	y35