Identifying Risks and Mitigating Disruptions in the Automotive Supply Chain

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Keith Combs, Yao Ge, Oleg Gusikhin, Michael Sanders, Don Zhang

Talk Outline

- Introduction
- The Risk Exposure Index
- The Mathematical Model
- Ford's implementation
- The Impact

Risks in Today's Supply Chains

- 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

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 had struck Japan.

***New York Times,* 2011**

Risks in Today's Supply Chains

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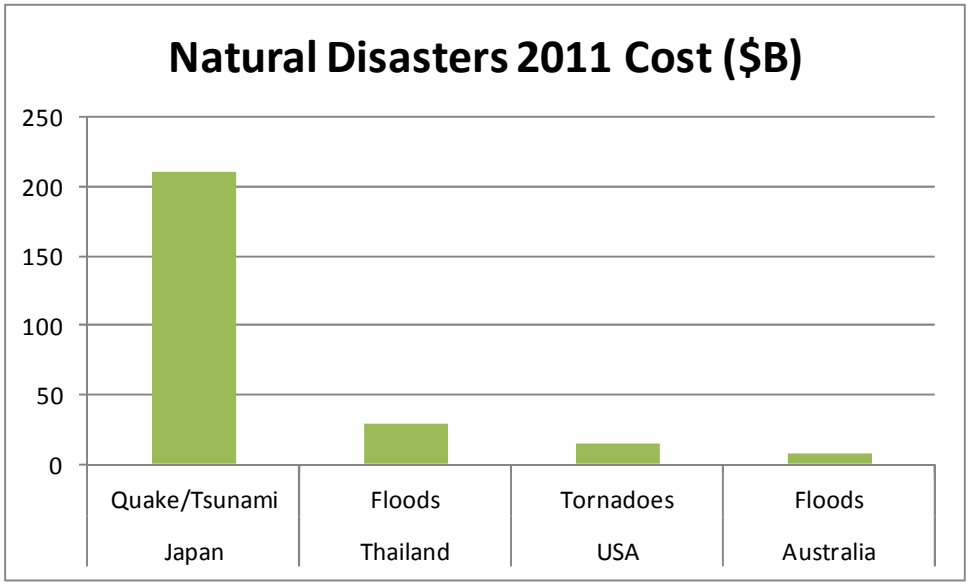
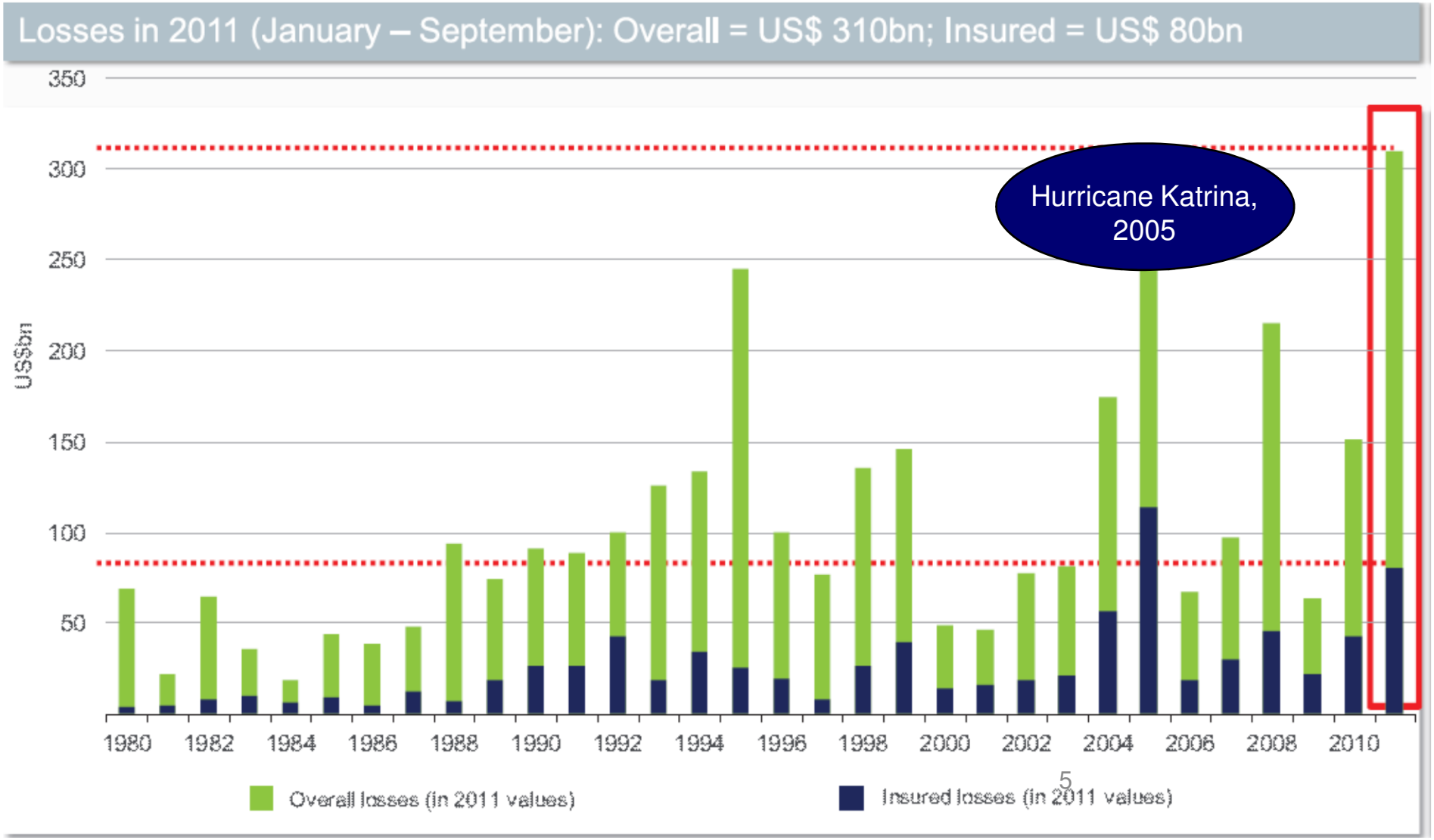
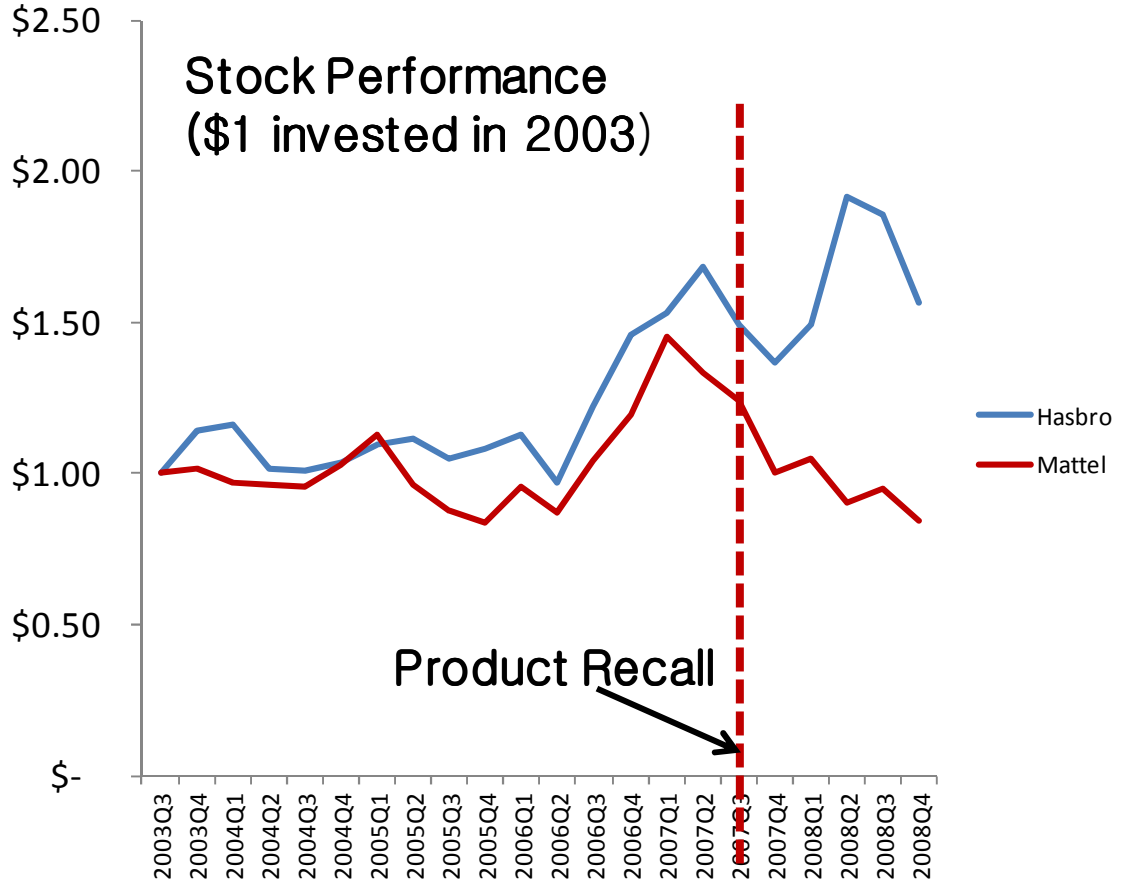


Worldwide Natural Disasters 1980-2011 Source: Munich Re



Supply Chain Disruption and Stock Performance

- **Mattel, the world's largest toy maker;**
- **Recalled 18 million toys made in China on August 2007;**
- **The reason: hazards such as lead paint**



Many Sources of Risks

Unknown-Unknown

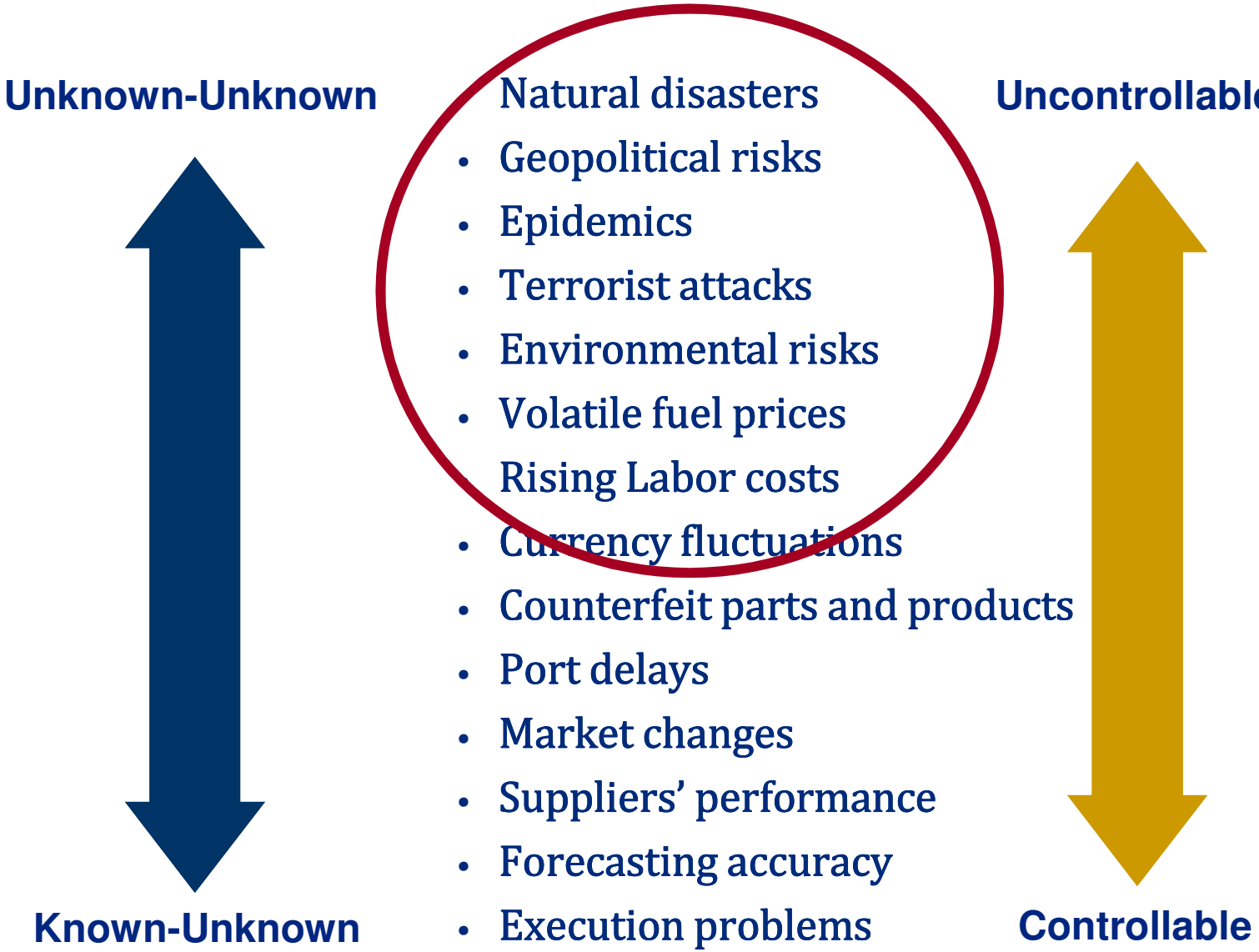
Known-Unknown

- Natural disasters
- Geopolitical risks
- Epidemics
- Terrorist attacks
- Environmental risks
- Volatile fuel prices
- Rising Labor costs
- Currency fluctuations
- Counterfeit parts and products
- Port delays
- Market changes
- Suppliers' performance
- Forecasting accuracy
- Execution problems

Uncontrollable

Controllable

Many Sources of Risks



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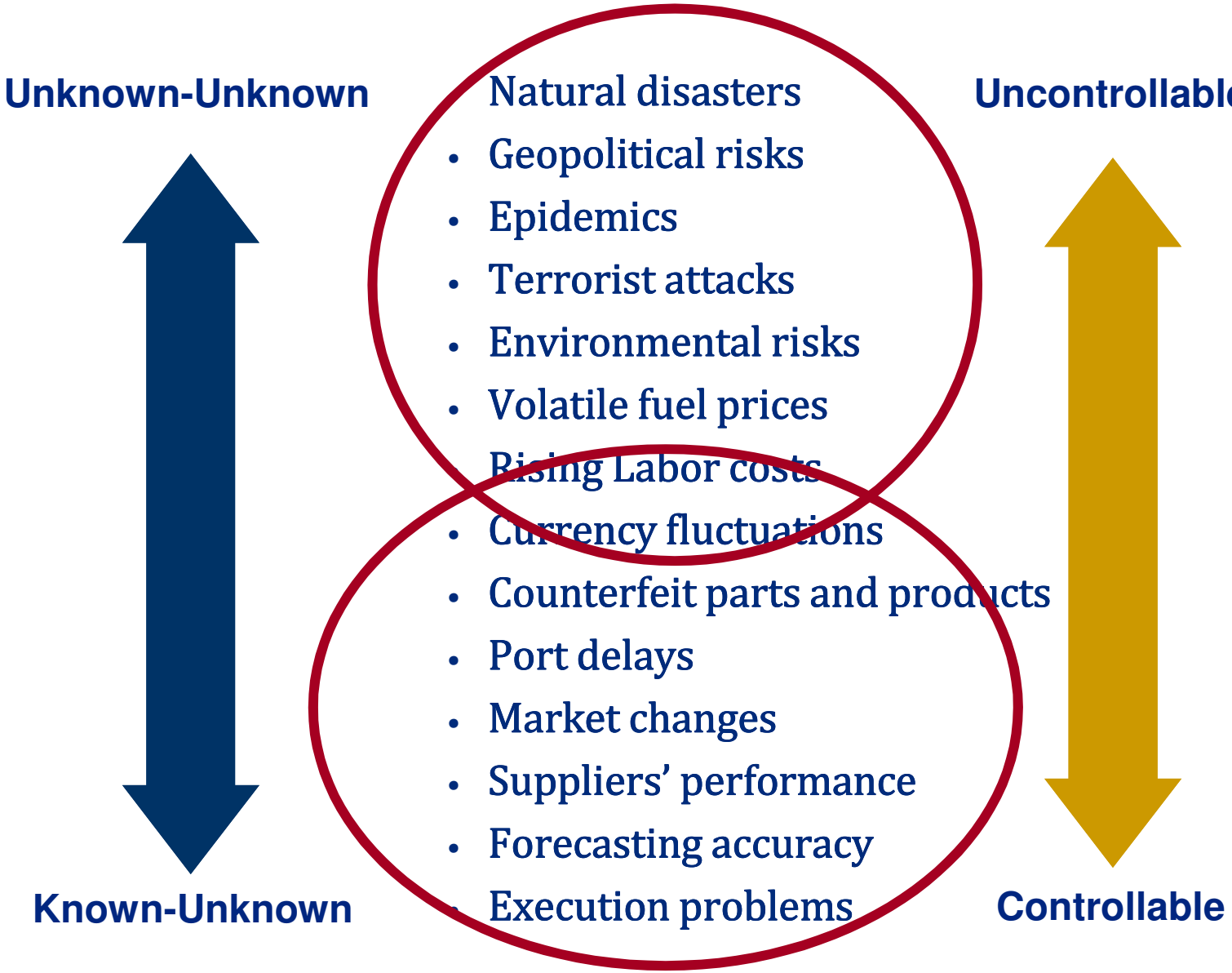
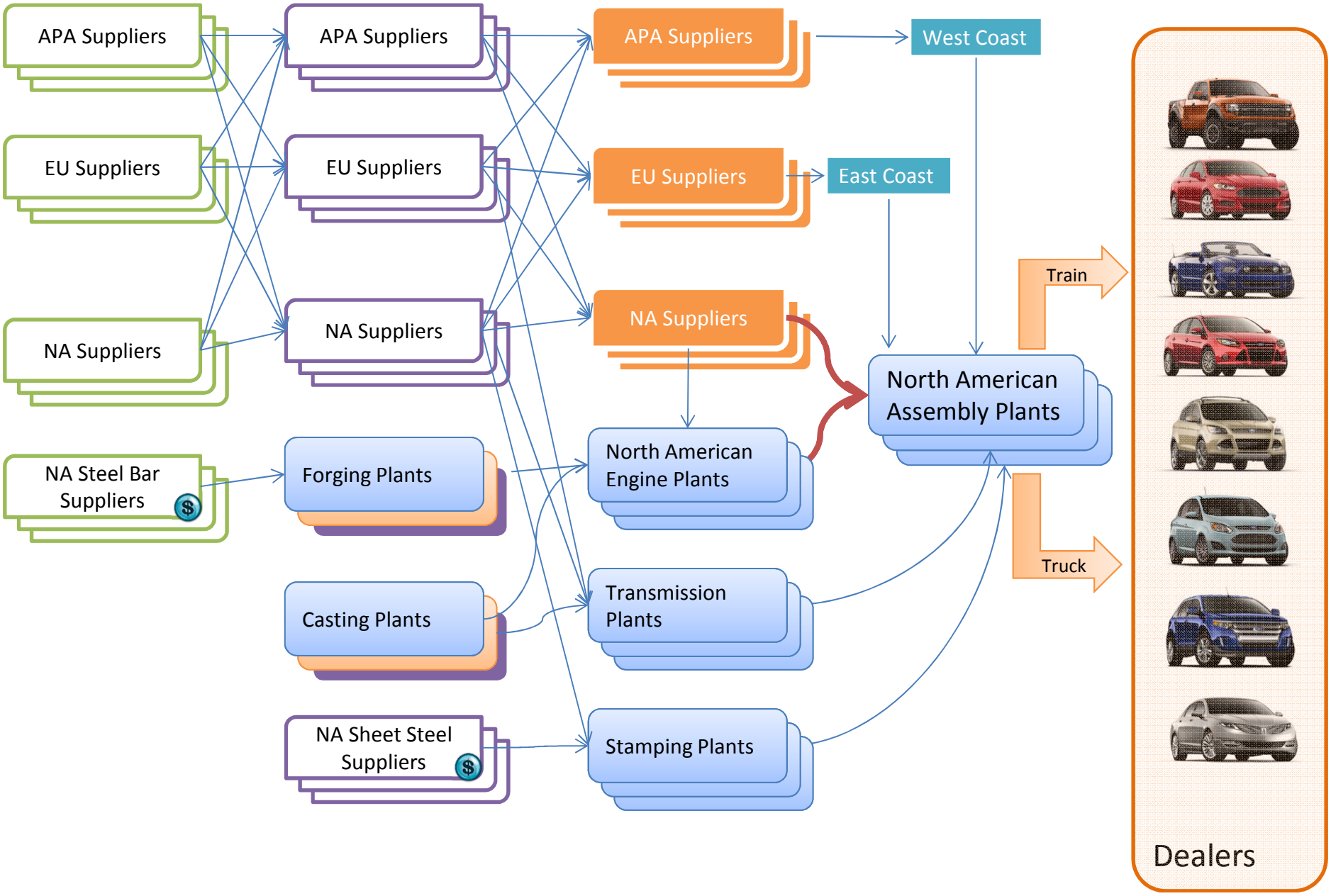


Managing Supply Chain Risk: The Challenge

- Very difficult to predict many sources of risk, especially the unknown-unknown
- Impact of disruption can be devastating
- Large investment in identifying every possible risk in the supply chain
- Existing tools and techniques have been inadequate
  - Mostly ad-hoc, intuition, gut feeling
  - Exposure to risk may reside in unlikely places
  - May lead to the wrong actions and waste resources
  - No ability to prioritize mitigation investment

Ford's Supply Chain: The Challenge



Ford's Supply Chain: The Challenge

Large multi-tier supply chain network

- Complex bill of materials and supply chain structure
- Over 50 manufacturing plants
- 10 tiers of suppliers
- 1400 tier 1 supplier companies with 4,400 manufacturing sites in over 60 countries
- 55,000 different parts
- 6 million vehicles produced annually

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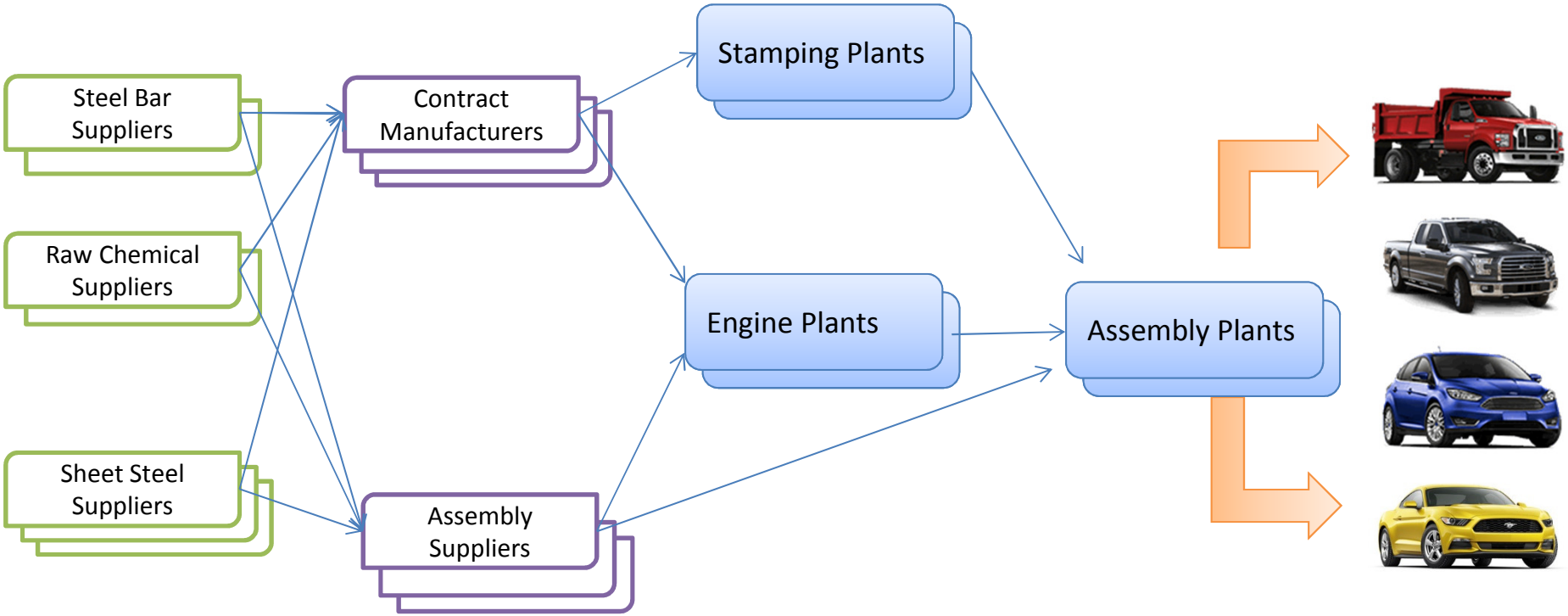
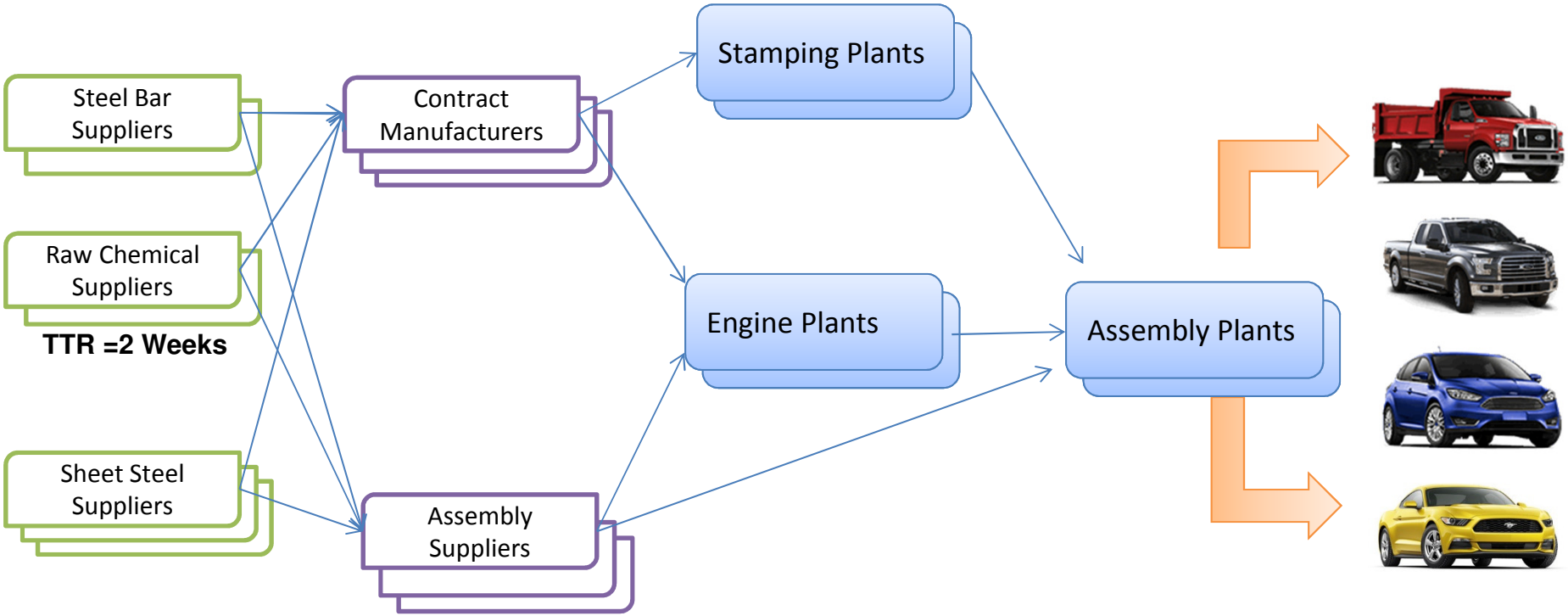
Illustrating Our Approach



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

Illustrating Our Approach



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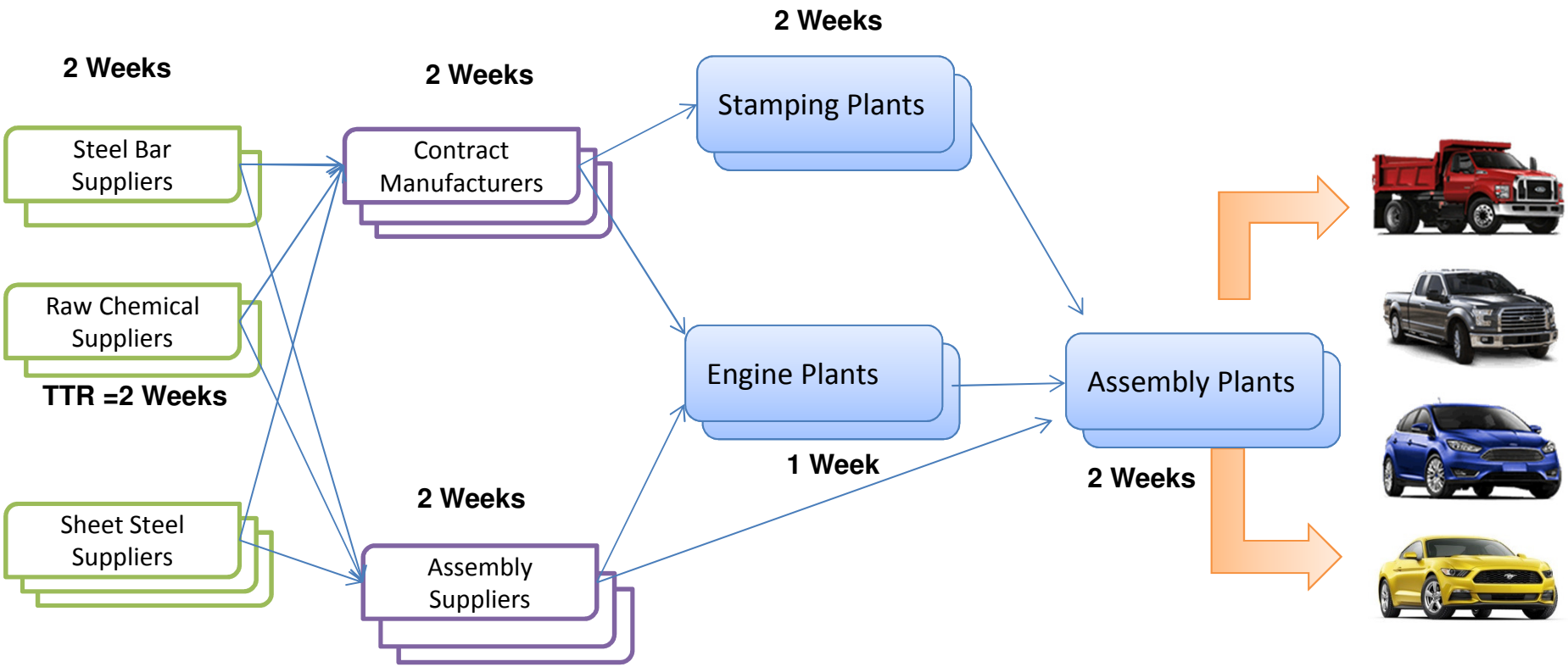

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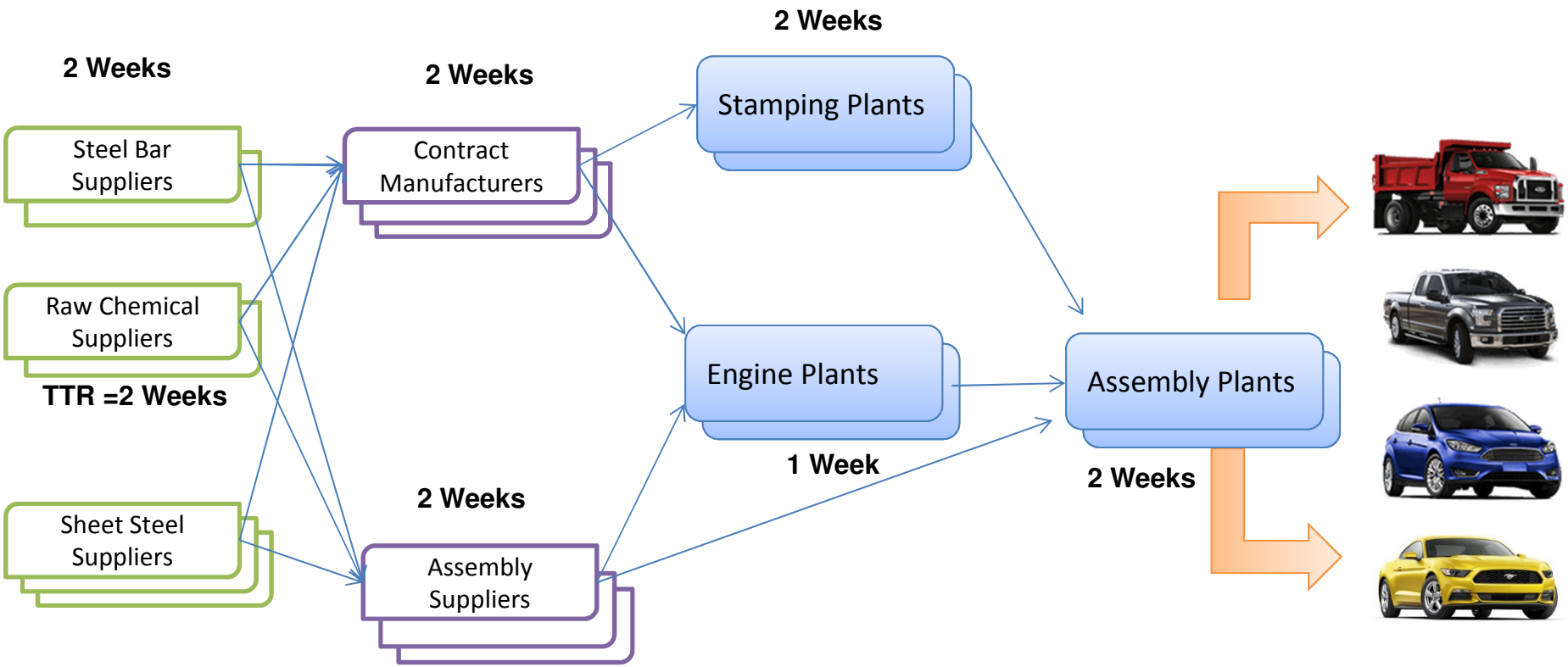

- Time-To-Recover (TTR): The time it takes to recover to full functionality after a disruption
- Performance Impact (PI): Impact of a disruption for the duration of TTR on a given performance measure

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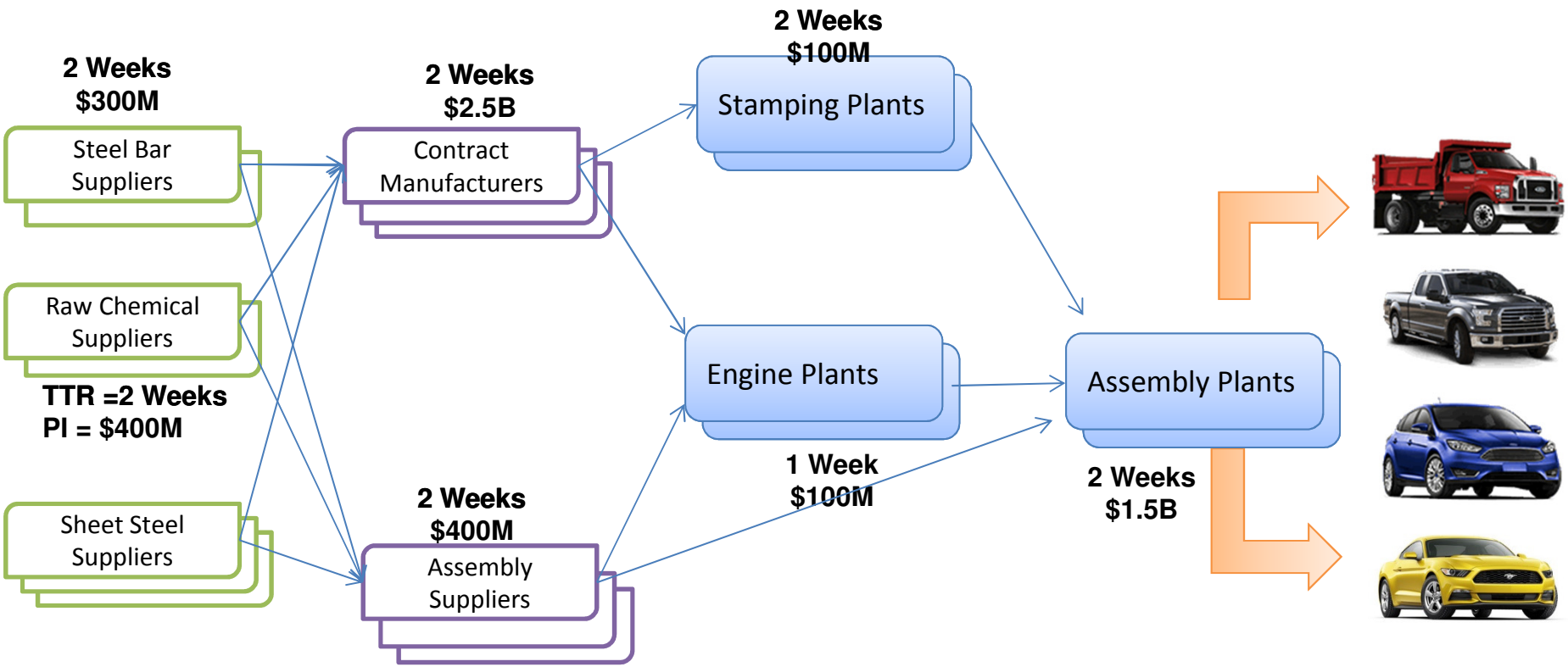

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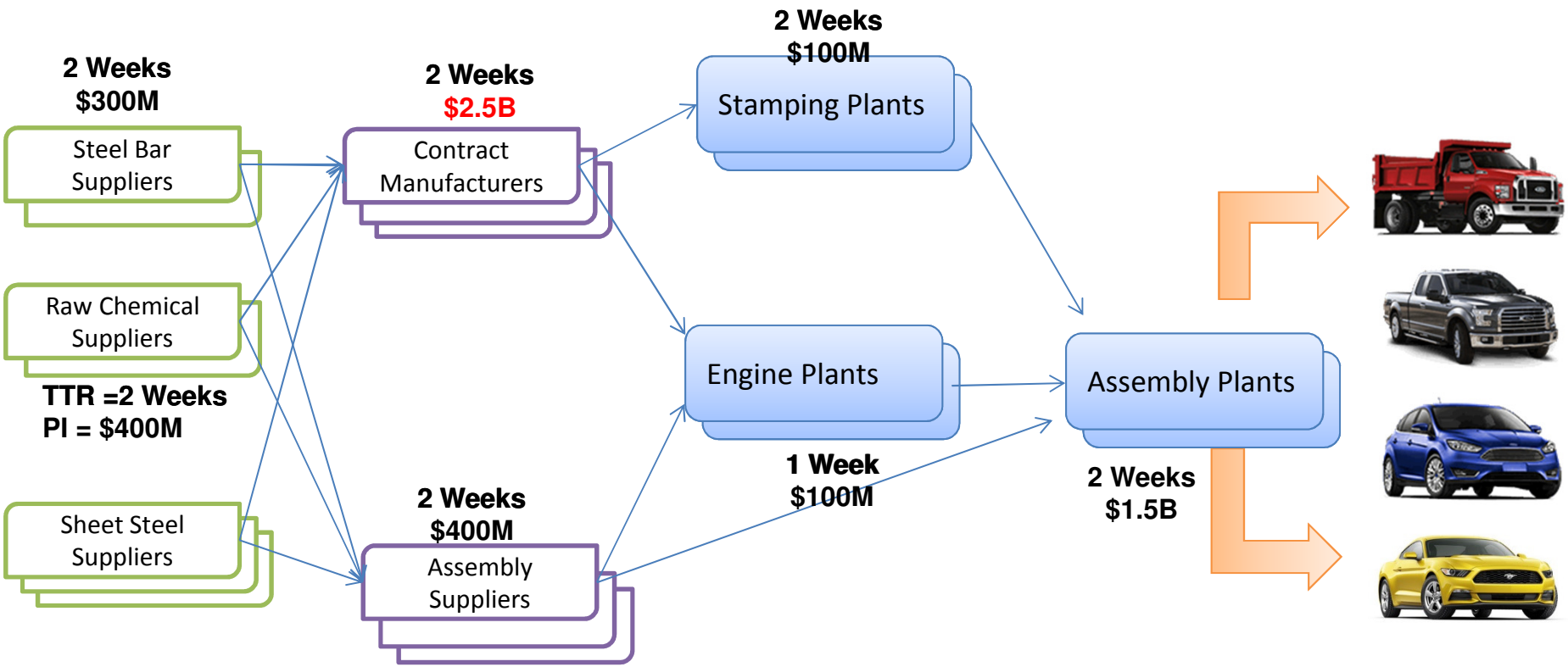

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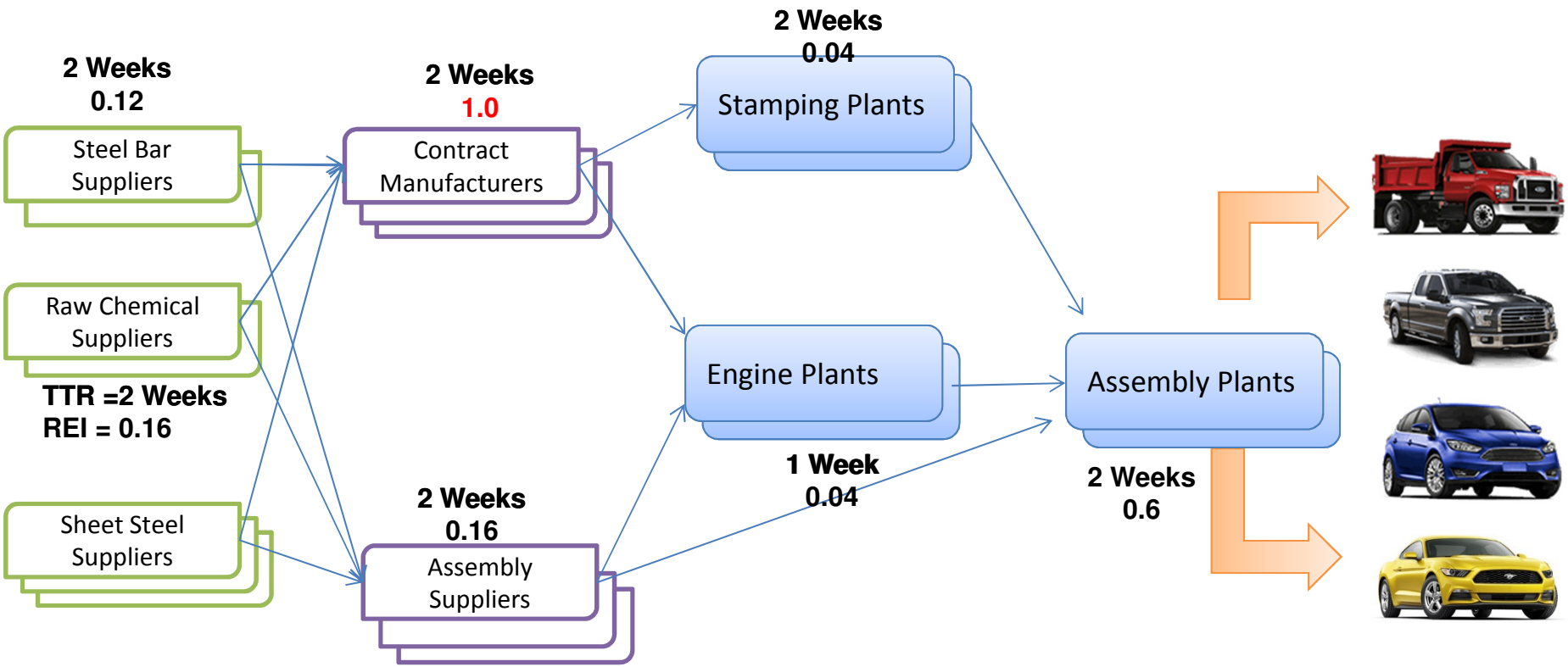
- Risk Exposure Index (REI): Normalizes the PI by the maximum PI over all disruption scenarios

Illustrating Our Approach



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Features Captured in Our Model

Key features captured in our risk exposure model:

- Ford and its supplier sites' production portfolio and volume of production
- Bill of materials for each vehicle and its corresponding parts
- Volumes and profit margins of different vehicle lines
- Pipeline inventories
- Time duration of a disruption
- Firm's response after a disruption
  - The response is simulated via optimization

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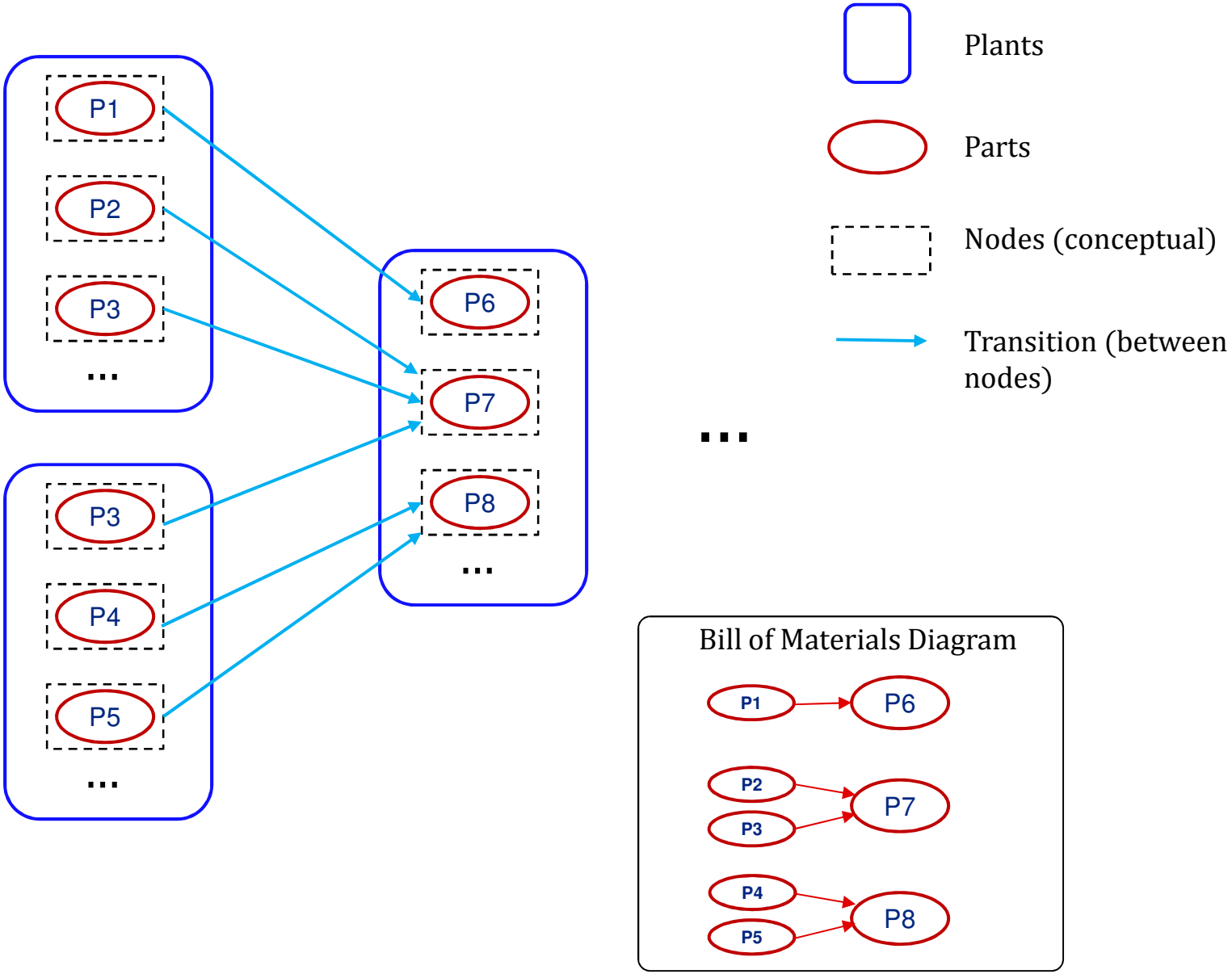
Visualizing a Simple Model



Model Formulation

Model Formulation:

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

- Each optimization problem corresponds to a single disruption scenario
- The optimization problems are linear programs
  - important because Ford is looking at tens of thousands of possible disruption scenarios

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\end{aligned}
$$

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

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$$

Parts Allocation Constraint

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

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Disruption Constraint

Production of node j is halted due to disruption

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$$

Demand loss constraints

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

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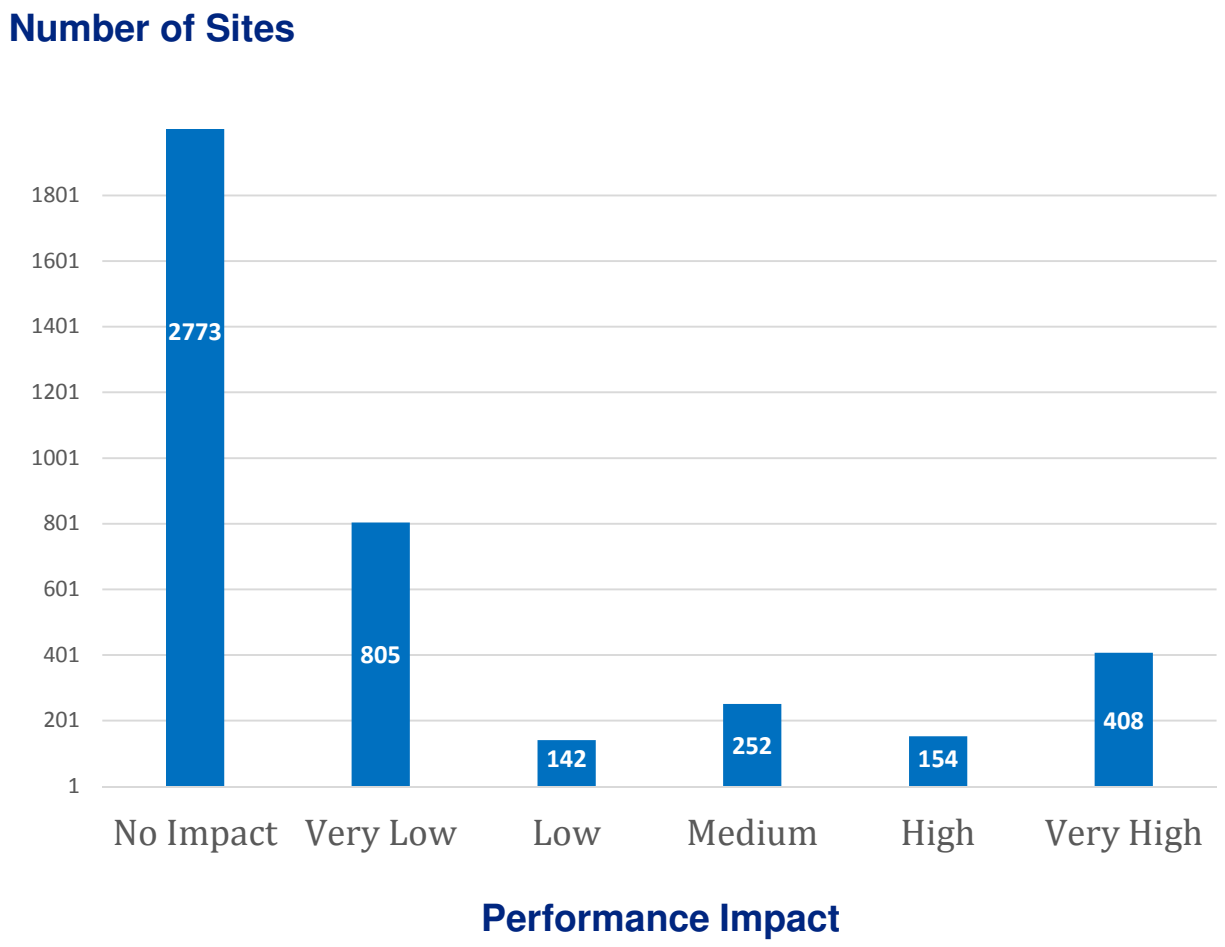
\end{aligned}
$$

Production capacity constraints

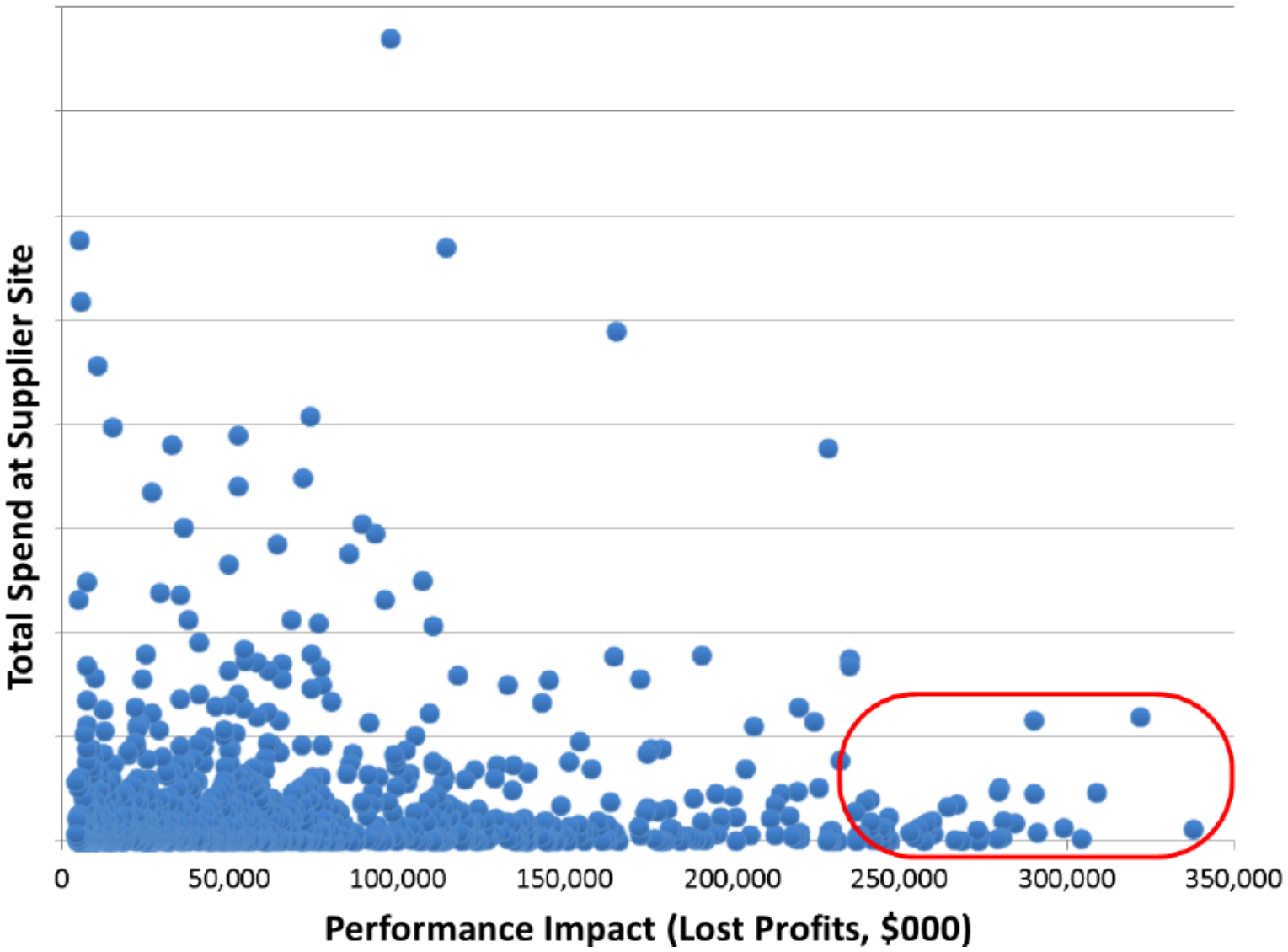
Total production of all nodes at site/plant α is bounded by its capacity

Performance Impact of Different Supplier's Sites

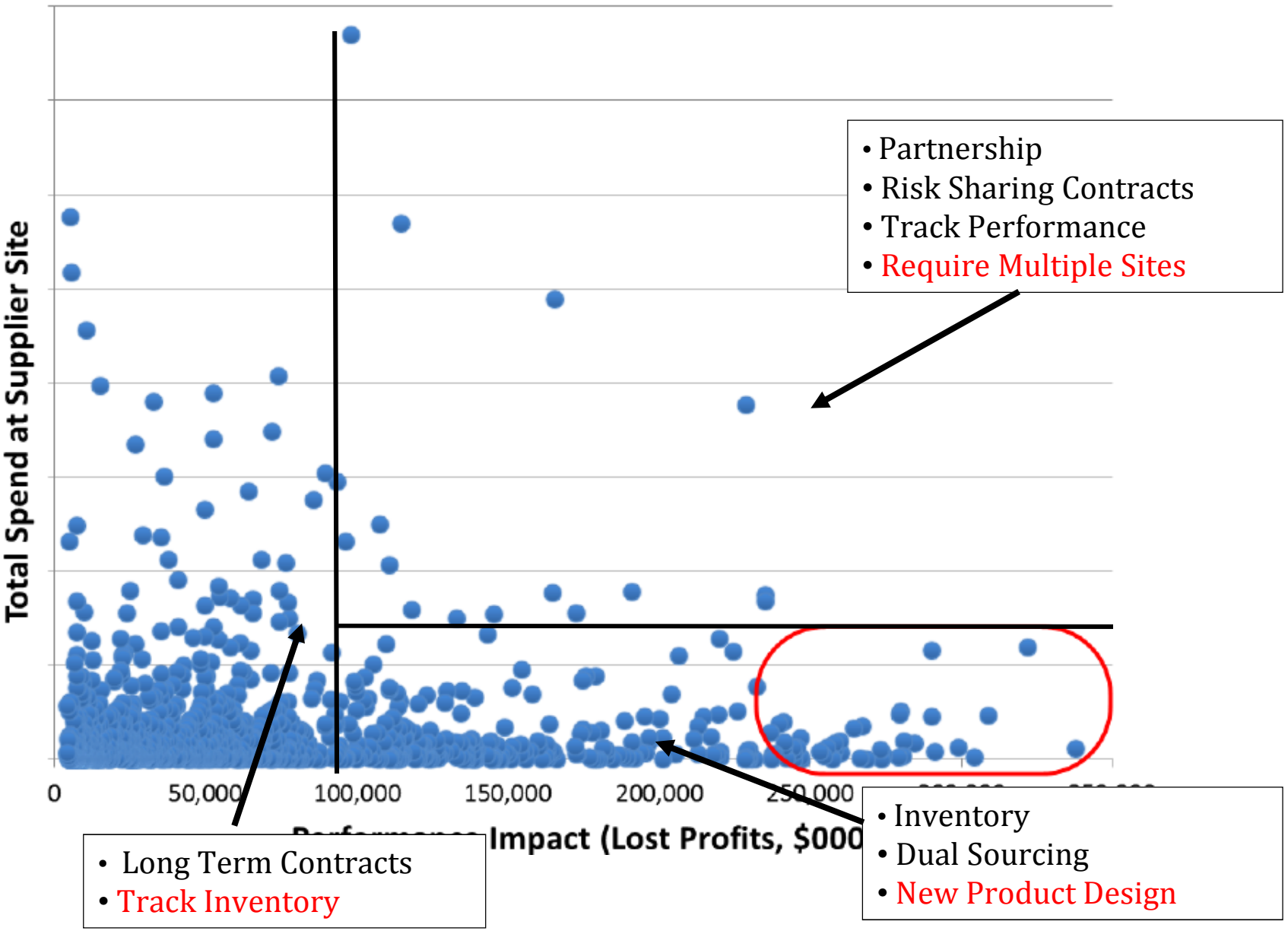


Another 2773 sites with No Impact

Performance Impact and Total Spent at Supplier Site



Supplier Sites Segmentation



Time –to-Recover & Time-to-Survive

Time-to-Recover (TTR): The time for a node in the supply chain to return to full functionality after a disruption.

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

$$TTR(j) < TTS\ (j) \text{ for all nodes } (j)$$

Robust Supply Chain

TTS Formulation

$$
\begin{aligned}
\text{maximize } & t^{(n)} \\
\text{s.t. } & u_j - y_{ij}/r_{ij} && \leq 0, && \forall i \in \mathcal{N}^-(j), \forall j \in \mathcal{D} \\
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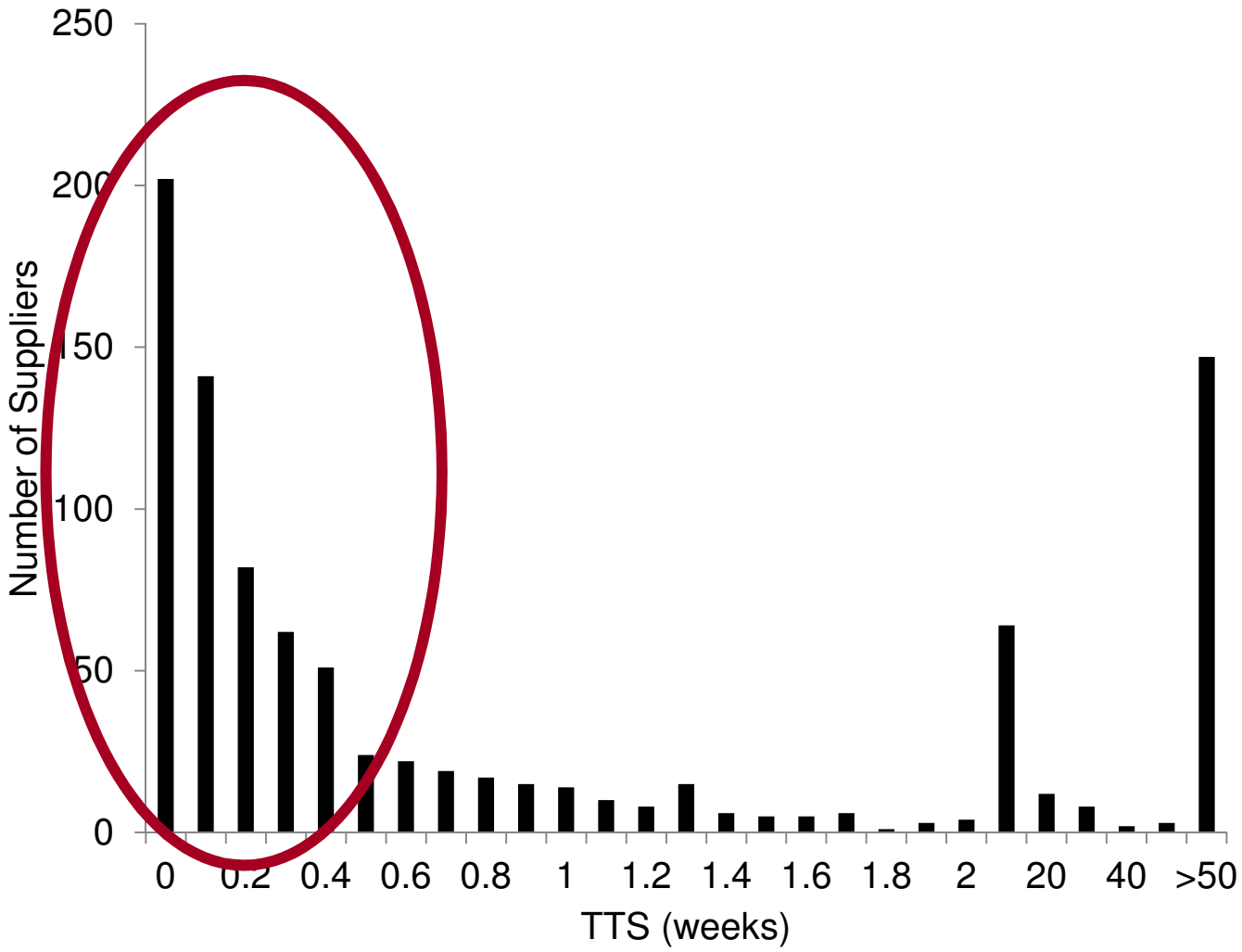
& u_j, y_{ij}, t^{(n)} && \geq 0.
\end{aligned}
$$

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

Time-to-Survive across all Ford Tier 1 suppliers



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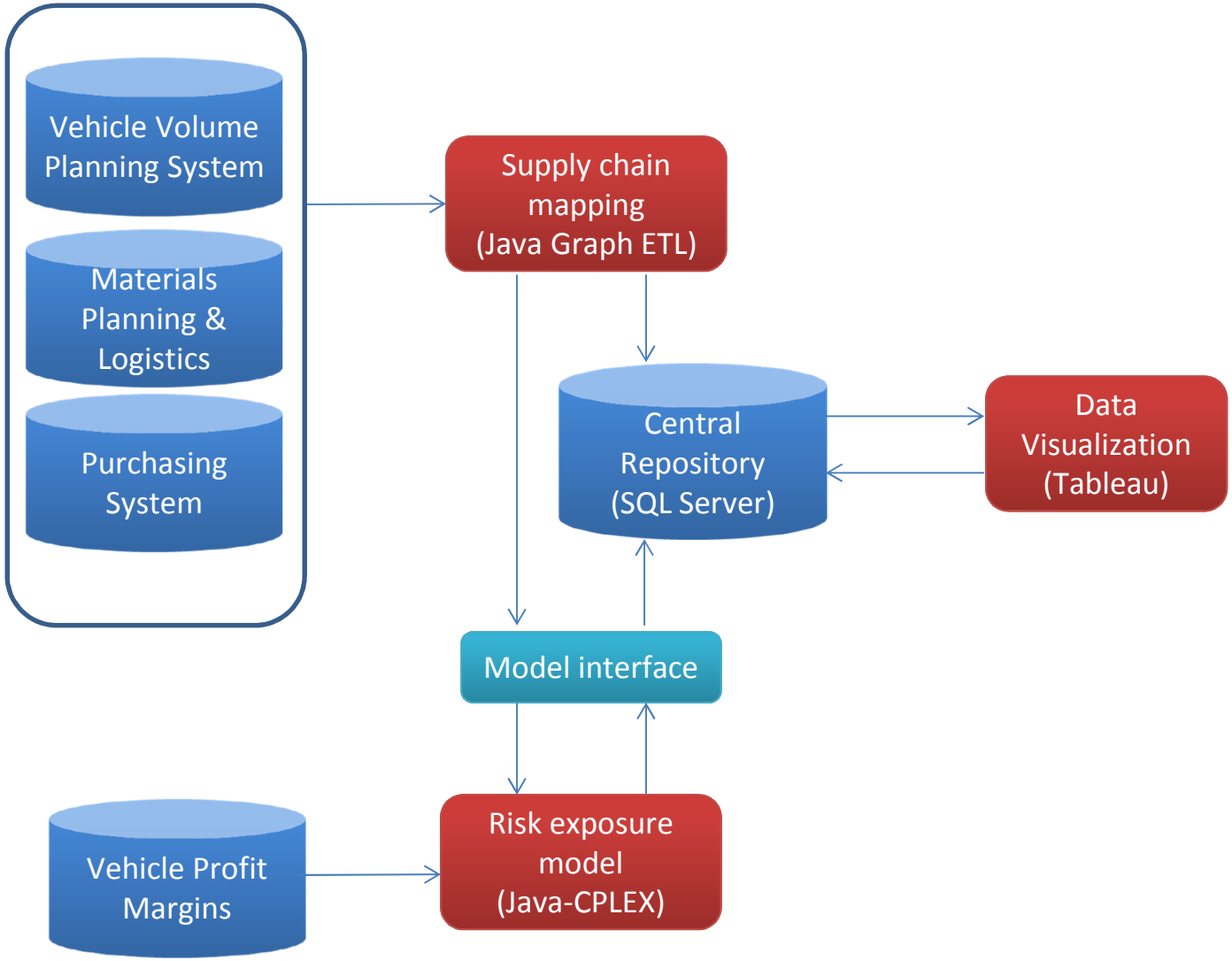
Ford Implementation

- 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



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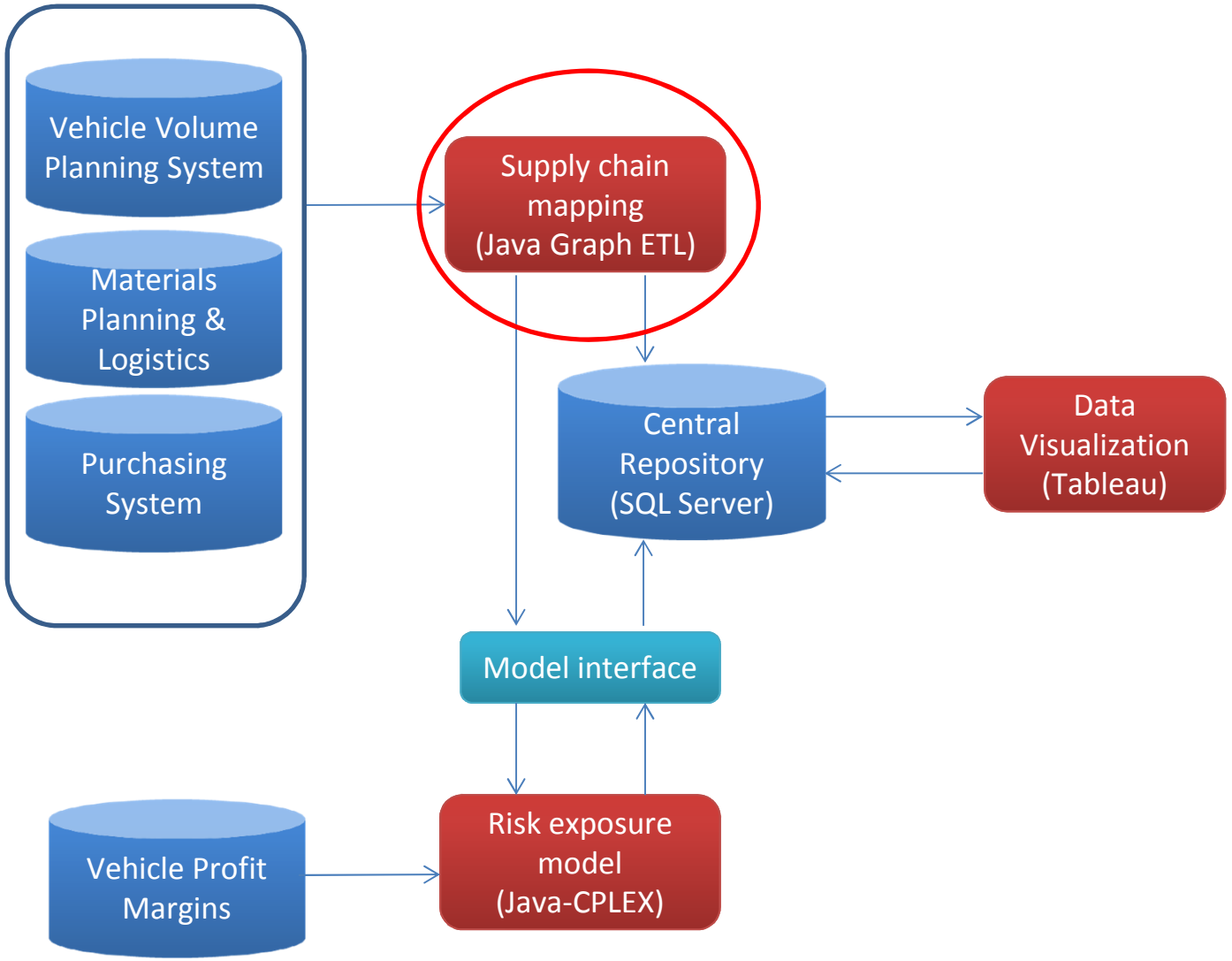
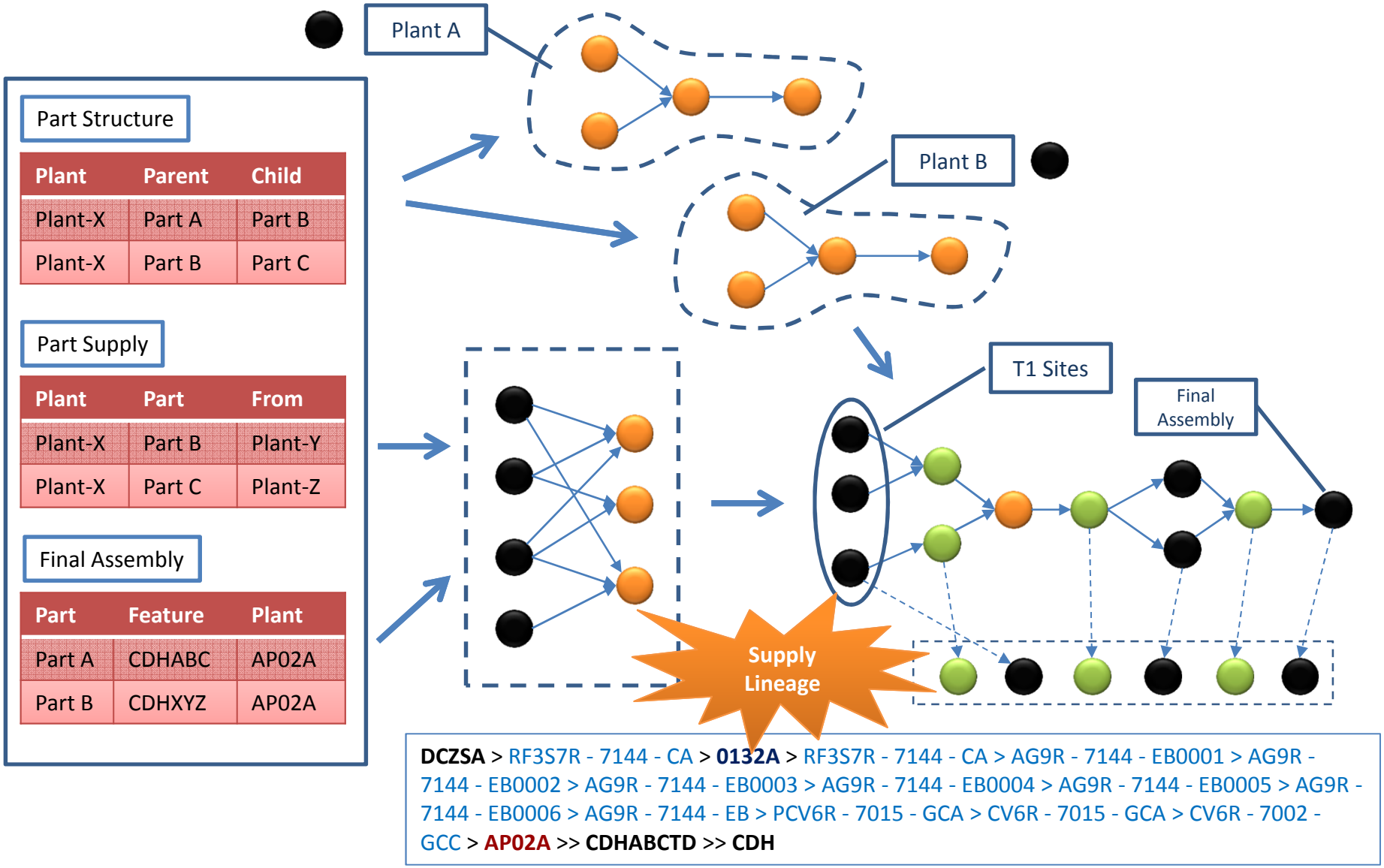


Mapping Ford Supply Chain – Graph ETL



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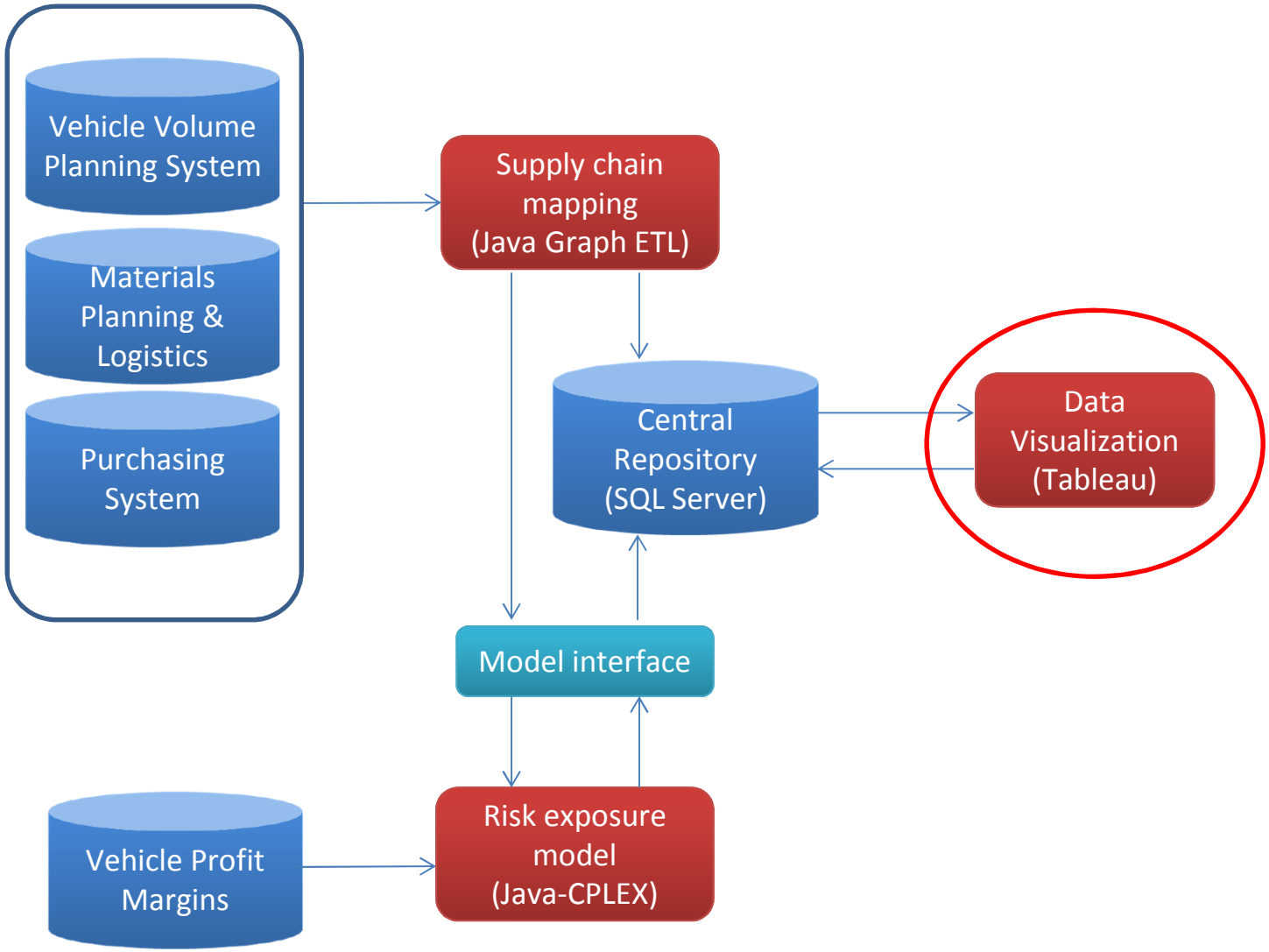
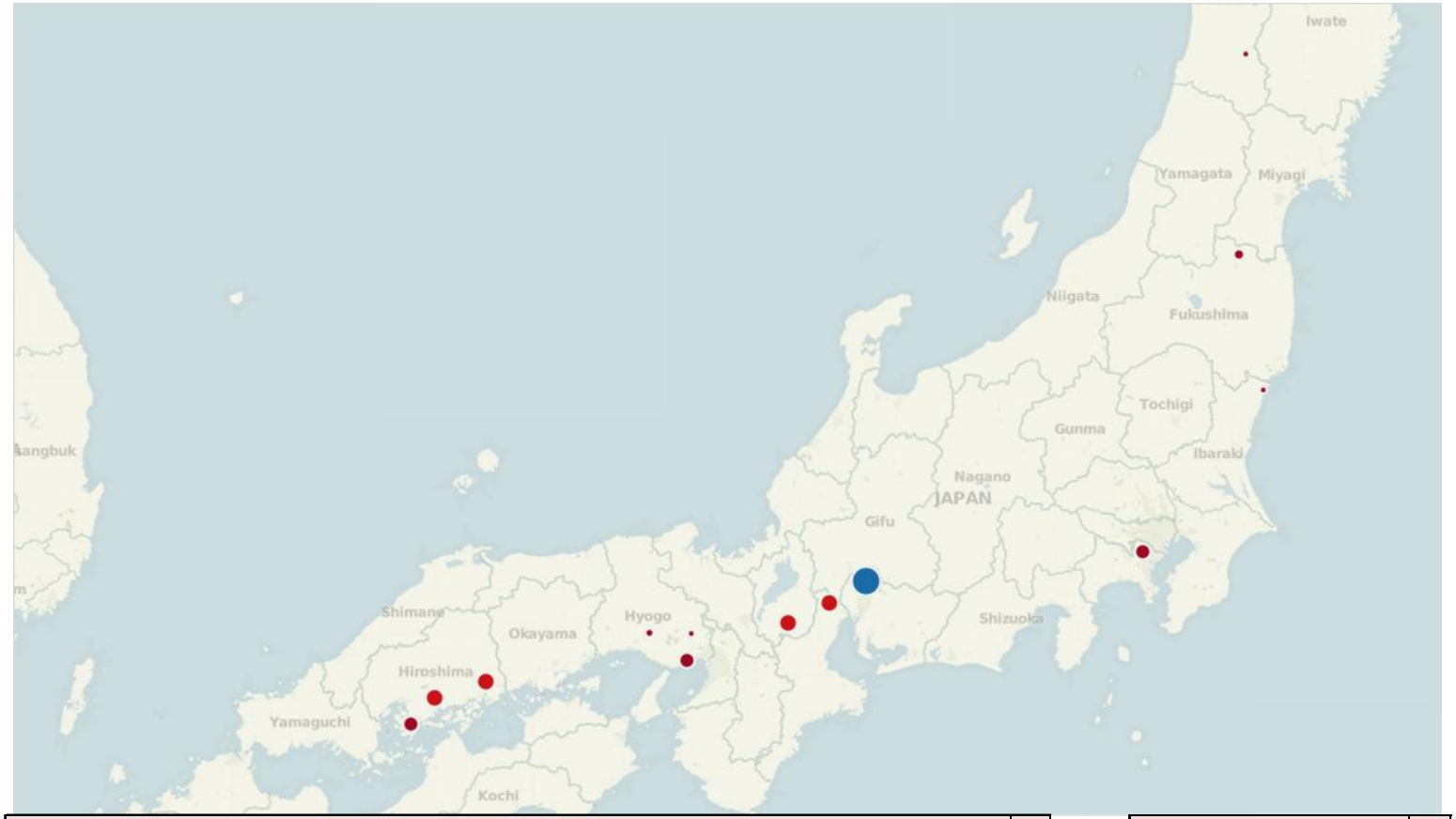


Generating Critical Supplier List

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

Supplier	Part Names
x11	y11
x11	y12
x11	y13
x20	y21
x20	y22
x20	y31
x20	y32
x20	y33
x20	y34
x20	y35

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Benefits to Ford

- Provided an internal proactive tool for risk management
- Generated critical supplier list / part list
  - Previously, Ford monitored 1500 supplier sites
  - The model identified 2600 suppliers' sites, up to $2.5 billion risks on revenue
  - Among the 2600 sites, 1100 sites were monitored by Ford
    - Identified 1500 new sites that are not currently monitored
    - About 400 sites has been assessed as low risks
- Examples of the model in practice
  - Risk model identified a sensor that has high vehicle exposure and is being supplied by two sites globally. The commodity team acknowledged the sourcing concentration and has investigated alternatives
  - For the fastener commodity, the model enabled Ford to prioritize parts based on exposure level and triggered further investigation. Our investigation segment industry standard parts with short TTR into low-risk while special or unique fasteners into potential high-risk category
  - Ford Supply Risk Specialists use the model routinely to prioritize commodities and supplier sites that represent the highest level of exposure during potential disruption events (i.e. Natural disasters, Labor Strikes, Political Unrest, etc.), enabling efficient use of resources

Acknowledgement

- Ford Purchasing – Steve Faraci
- Ford IT – John Knowles and Dong Ruan
- Ford Research – John Ginder
- Ford – MIT Alliance

Thank you!

Any Questions?