RAPHAEL – An analysis system for the quantitative identification of supply chain risks

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Disruptions, regulations and executive’s needs require quantitative risk analysis

West Coast Port Lockout (2002)
- 10 days strike
- Inventories run empty

Containership Piracy (2009)
- "Hansa Stanvanger"
- "Buccaneer"

Eyjafjallajökull
- Europe: no-fly zone
- Material shortages

Earthquake Japan
- ...

Integrated analysis tool supporting quantitative identification and assessment of supply chain risks

LEADING SUPPLY CHAINS ARE ON TOP IN ALL RISK MANAGEMENT CATEGORIES
Discrepancy between Top Supply Chains and other examples concerning ongoing and planned implementations

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The chief cause of a supply chain being prone to unexpected events is that the supply chain is in a vulnerable state.

Eyjafjallajökull
- Europe no-fly zone
- material shortages

Supply chain factors affected:
1. Capacity of air freight transportation
2. Lead time of air freight transportation

Which factors increase the vulnerability of the underlying supply chain?
Which factors are critical?

How far factor levels may change without having a negative influence on the supply chain performance?

What is the action control limit for factor levels?
The impact of Supply Chain Risks on the Supply Network and its Environment is reflected by value changes of Supply Chain Factors. Supply Chain Scenarios simulate deviations of Supply Chain Factor Values.
Our approach combines simulation with operational supply chain planning and consists of two integrated stages: Factor screening and Response Surface Approximation.
From risk definition to scenario generation: What kind of risk and how much of it are you willing to take?

- GUI assists in formulating risk definition
- Generation of screening sample
- Internal transformation to supply chain model changes

2% Service level reduction
3% Enhancement of capacity utilization
5% Logistics cost increase
From scenarios to results: Running the experiment

- **Simulation Controller**
  - SC-Model & Data
  - Generate scenario instance
  - Setup simulation runs, distribute on planning grid, control execution

- **Analysis Server**
  - Analyze & aggregate results
  - Generate scenario instance results
“Factor Screening” identifies those Supply Chain Factors – i.e. vulnerability drivers – which have relevant effects on KPI levels.
From screening results to a sequential algorithm for response surface approximation: Finding the KPI boundary

Service Level = 97%
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\[ \text{Service Level} = 97\% \]
From screening results to a sequential algorithm for response surface approximation: Finding the KPI boundary
From screening results to a sequential algorithm for response surface approximation: First sample & result evaluation
From screening results to a sequential algorithm for response surface approximation: Next step

Service Level = 97%
RAPHAEL System uses MRP-II planning but allows for pluggable Supply Chain Planning engines to meet specific environments.
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\[
\begin{align*}
\text{Min} & \sum \sum \sum \sum \sum \text{Backlog Minimization} \\
\text{Min} & \sum \text{Demand Coverage} \\
\text{Min} & \sum \text{Inventory Balance at DC} \\
\sum \text{Transportation Definition} \\
\text{Min} & \sum \text{Inventory Balance at OEM} \\
\sum \text{Grossdemand for Preproducts} \\
\text{Min} & \sum \text{Alternative Preproducts} \\
\text{Min} & \sum \text{Inventory Balance of Preproducts} \\
\sum \text{Transportation Definition} \\
\text{Min} & \sum \text{Inventory at n ber Supplier} \\
\end{align*}
\]
Response variable: Service Level
Results

- Factor screening:
  - Factors analyzed: 123 Lead Times
  - Solution:
    - Relevant factors: 10 factors unambiguously identifiable (including lead times of ship transports)

- Approximation verified with different response functions:
  - \( r_1 = \sum_{i=0}^{19} \beta_i x_i \), \( \beta_i = 2i+10 \)
  - \( r_2 = r_1 + \sum_{i=0}^{9} \beta_{2i,2i+1} x_{2i} x_{2i+1} + \sum_{i=2}^{4} \beta_{i,i^2} x_i x_{i^2} \), \( \beta_{i,j} = (i+j)/2c \), \( c > 0 \)
  - \( r_3 = a \cdot \text{floor}(r_2/a) \), \( a \in N \)
  - \( r_4 = \min(x_0,x_1) + \ldots + \min(x_6,x_7) + \min(x_8,x_9,x_{10}) + \min(x_{11},x_{12}) + \ldots + \min(x_{15},x_{16}) + \min(x_{17},x_{18},x_{19}) \)
  - \( r_6 = r_1 + r_2 - r_3 + r_4 \)
Next Steps

- Screening Design
- Advanced approximation algorithm
- Mitigation Programming