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

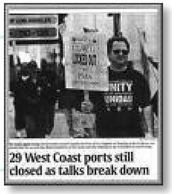
COSO – Enterprise Risk Management Integrated Framework (2004)

SOX – Sarbanes Oaxley Act (2002)

BaFin Circular (2009)

West Coast Port Lockout (2002)

- 10 days strike
- Inventories run empty



Containership Piracy (2009)

- „Hansa Stanvanger"
- „Buccaneer"

Eyjafjallajökull

- Europe: no-fly zone
- material shortages

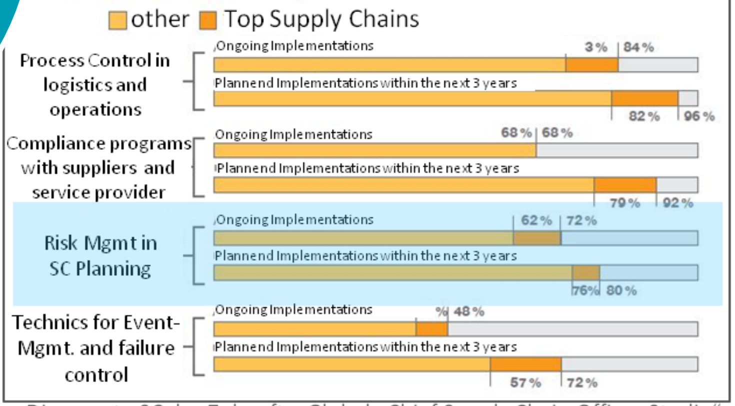
Earthquake Japan

- …

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

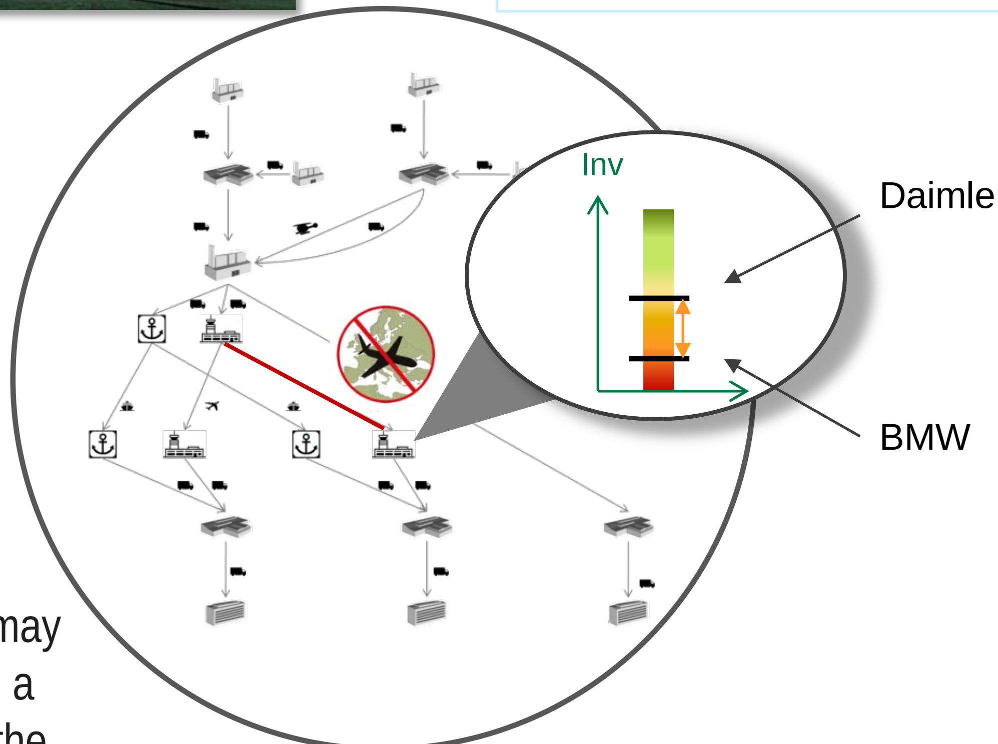


„ Die smarte SC der Zukunft – Globale Chief Supply Chain Officer Studie"
© IBM 2009

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



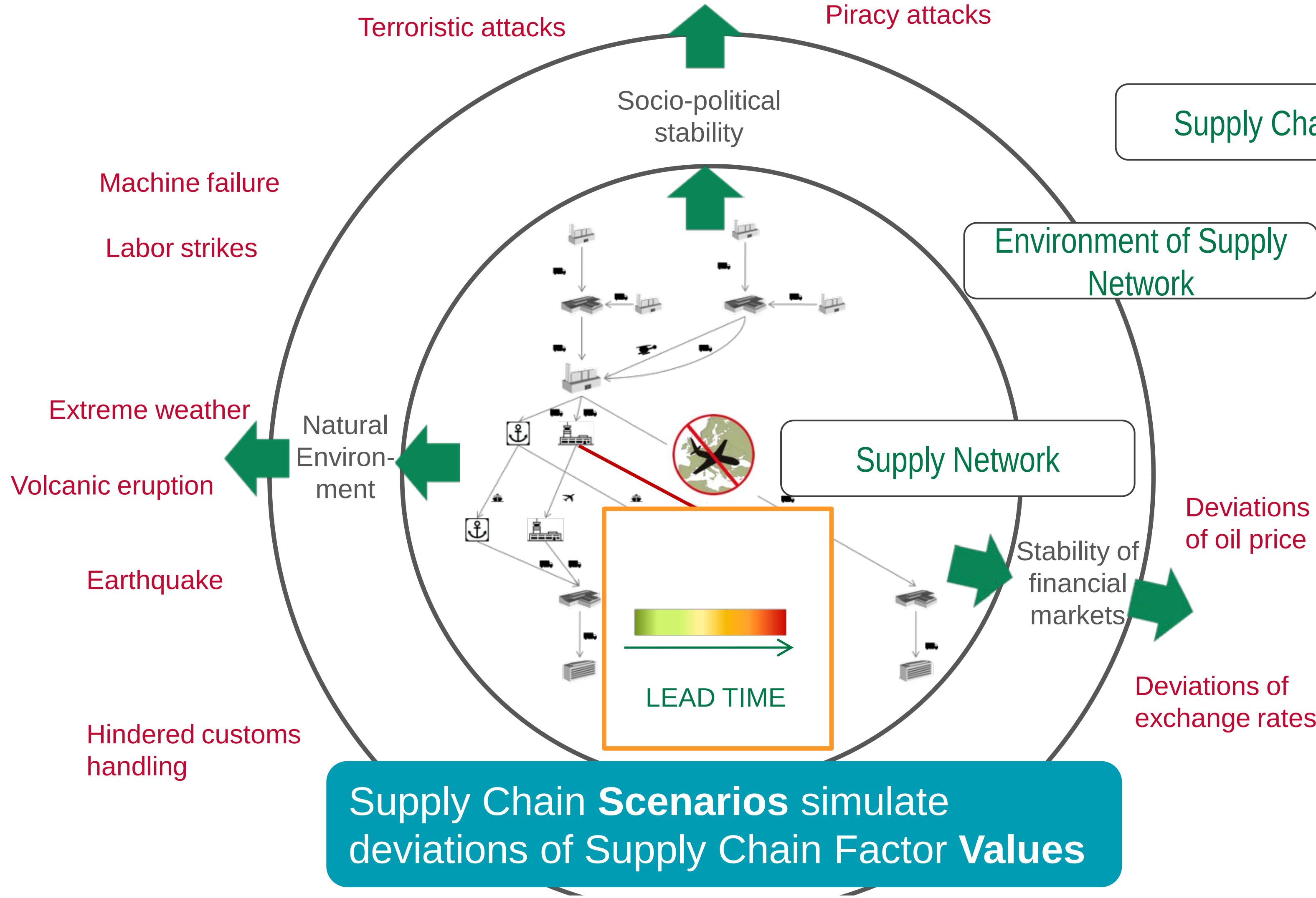
Which factors increase the vulnerability of the underlying supply chain?

Which factors are critical?

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

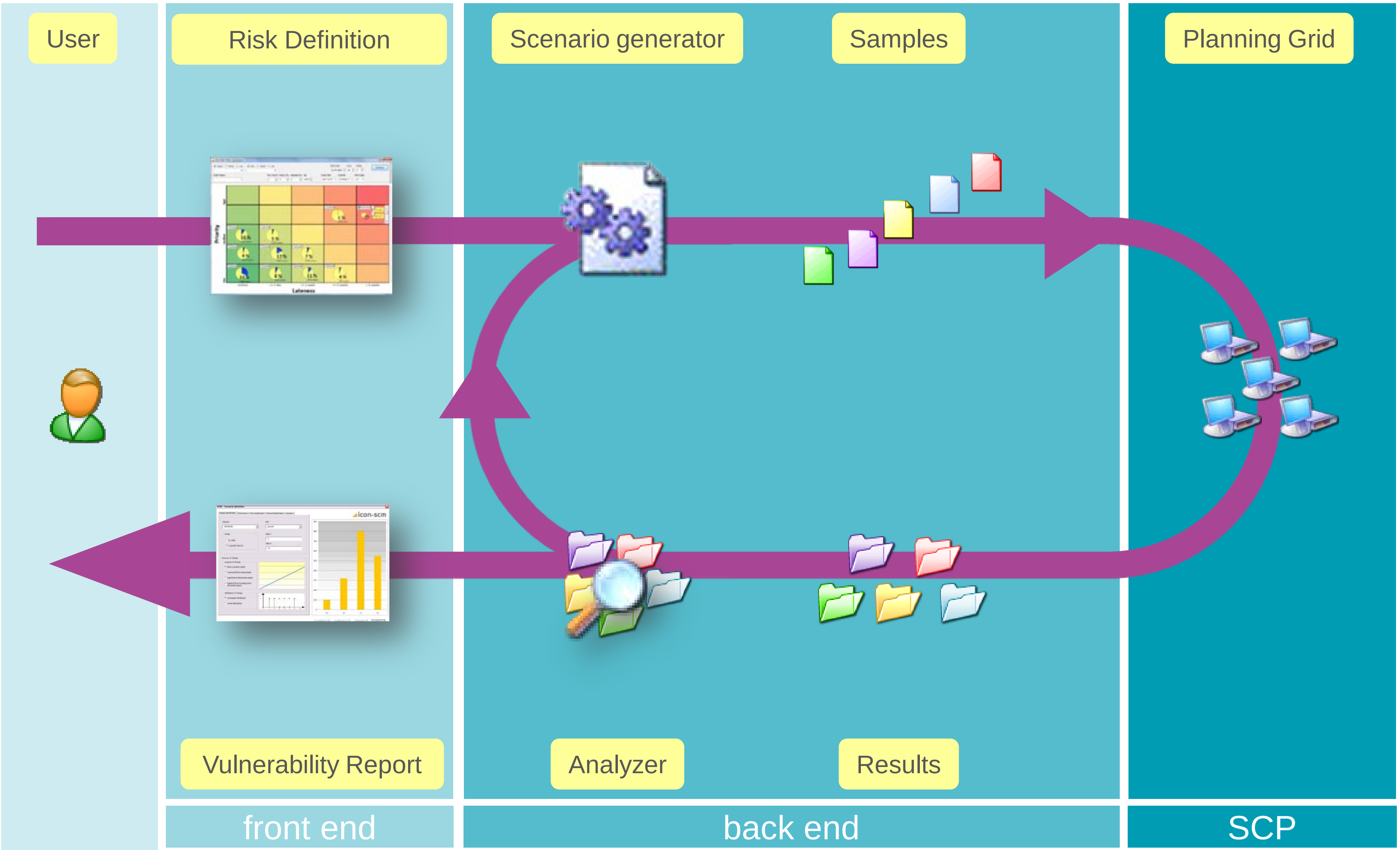
What is the action control limit for factor levels?

The impact of Supply Chain Risks on the Supply Network and its Environment is reflected by value changes of Supply Chain Factors

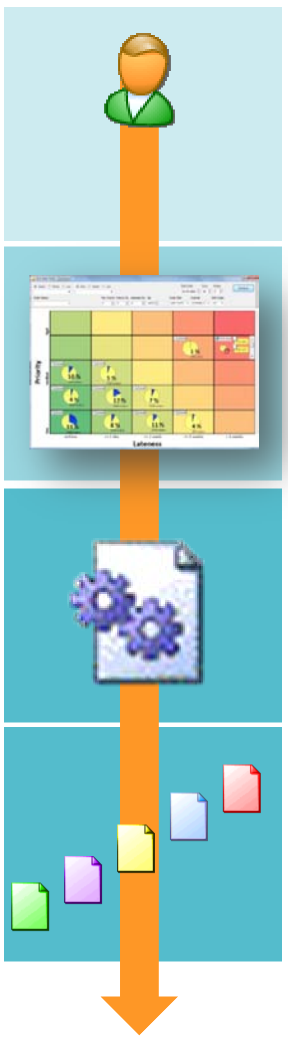


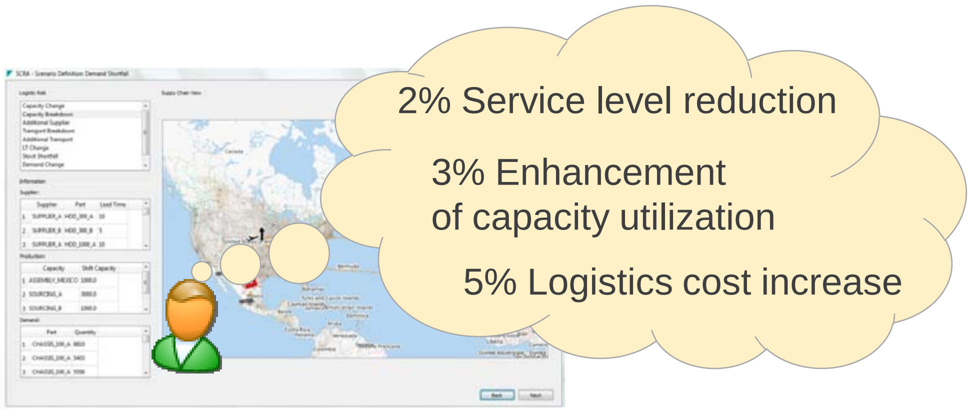
Supply Chain **Scenarios** simulate deviations of Supply Chain Factor **Values**

Our approach combines simulation with operational supply chain planning and consists of two integrated stages: Factor screening and Response Surface Approximation

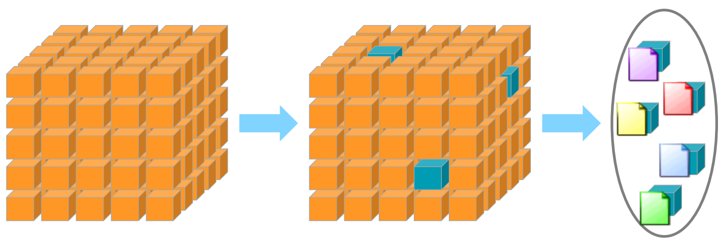


From risk definition to scenario generation: What kind of risk and how much of it are you willing to take?





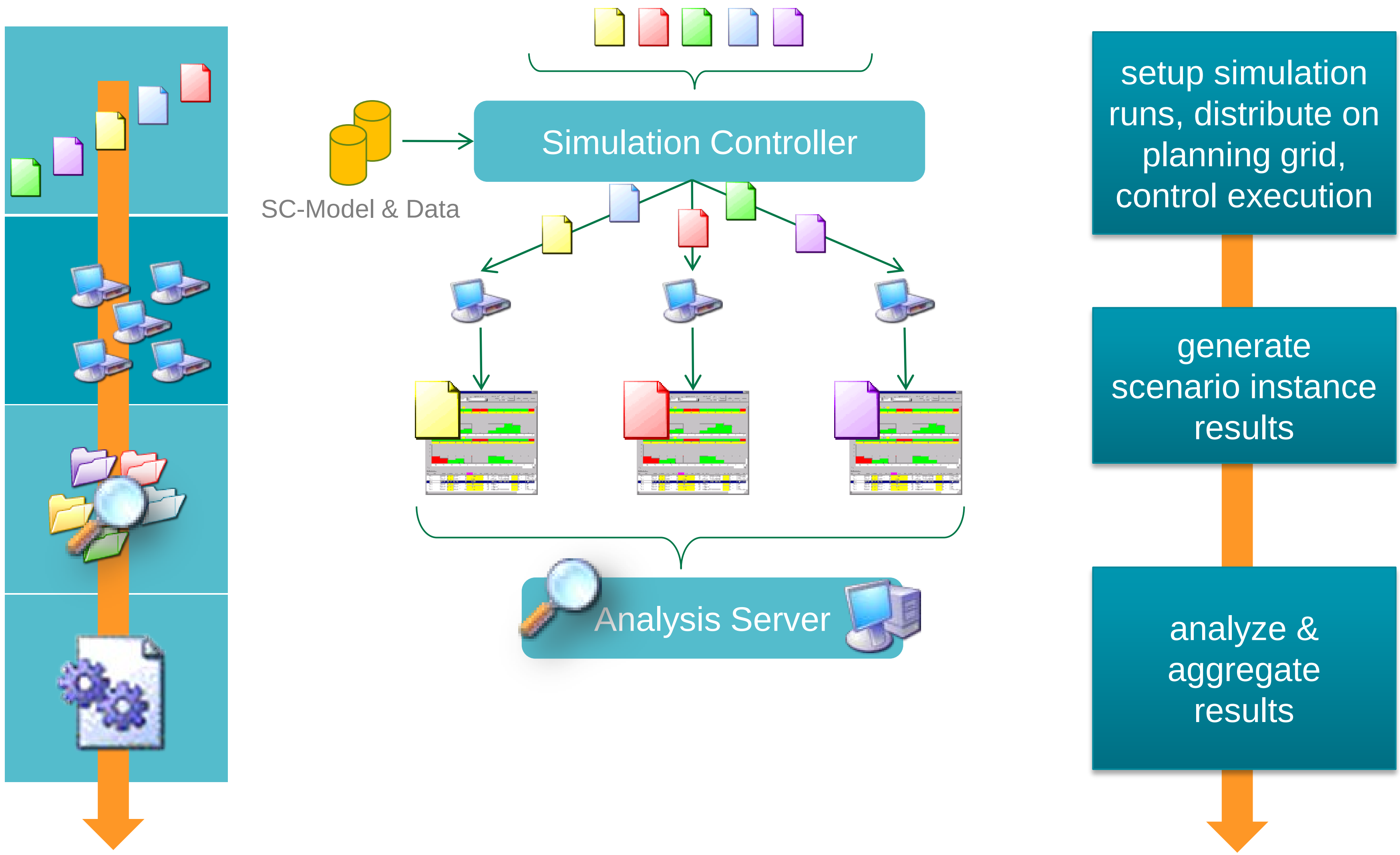
GUI assists in formulating risk definition



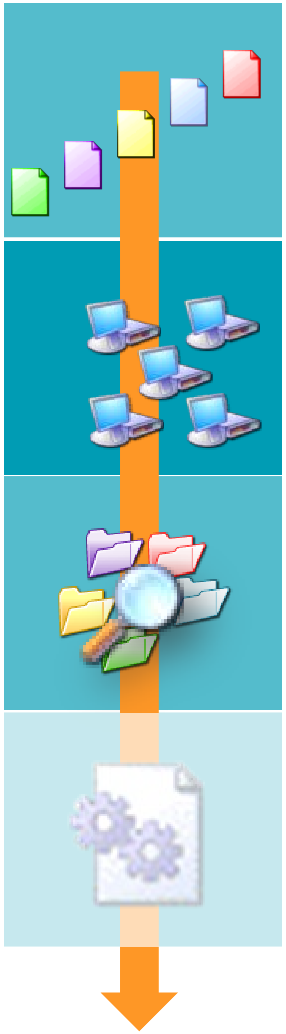
Generation of screening sample

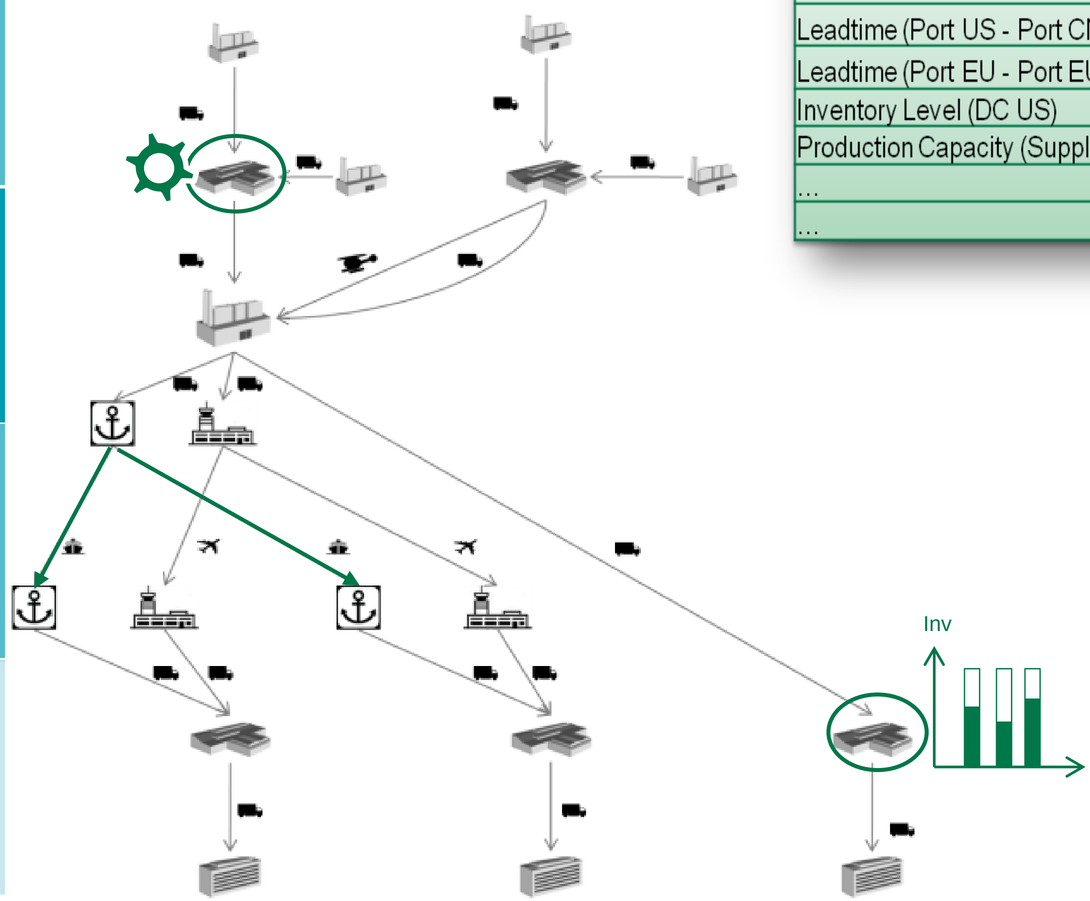
Internal transformation to supply chain model changes

From scenarios to results: Running the experiment



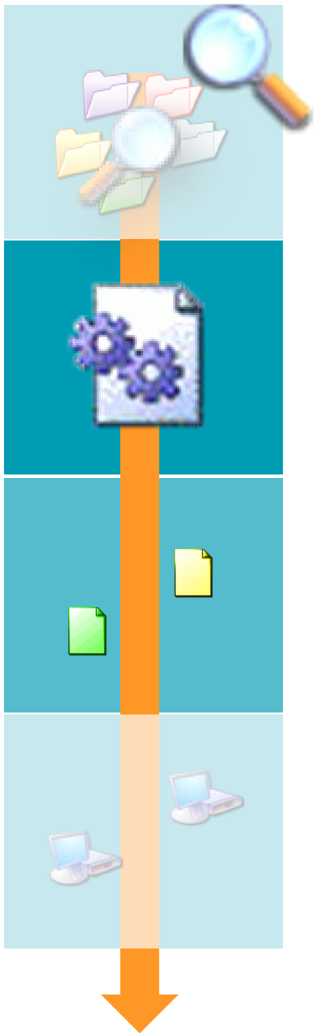
“Factor Screening” identifies those Supply Chain Factors – i.e. vulnerability drivers – which have relevant effects on KPI levels

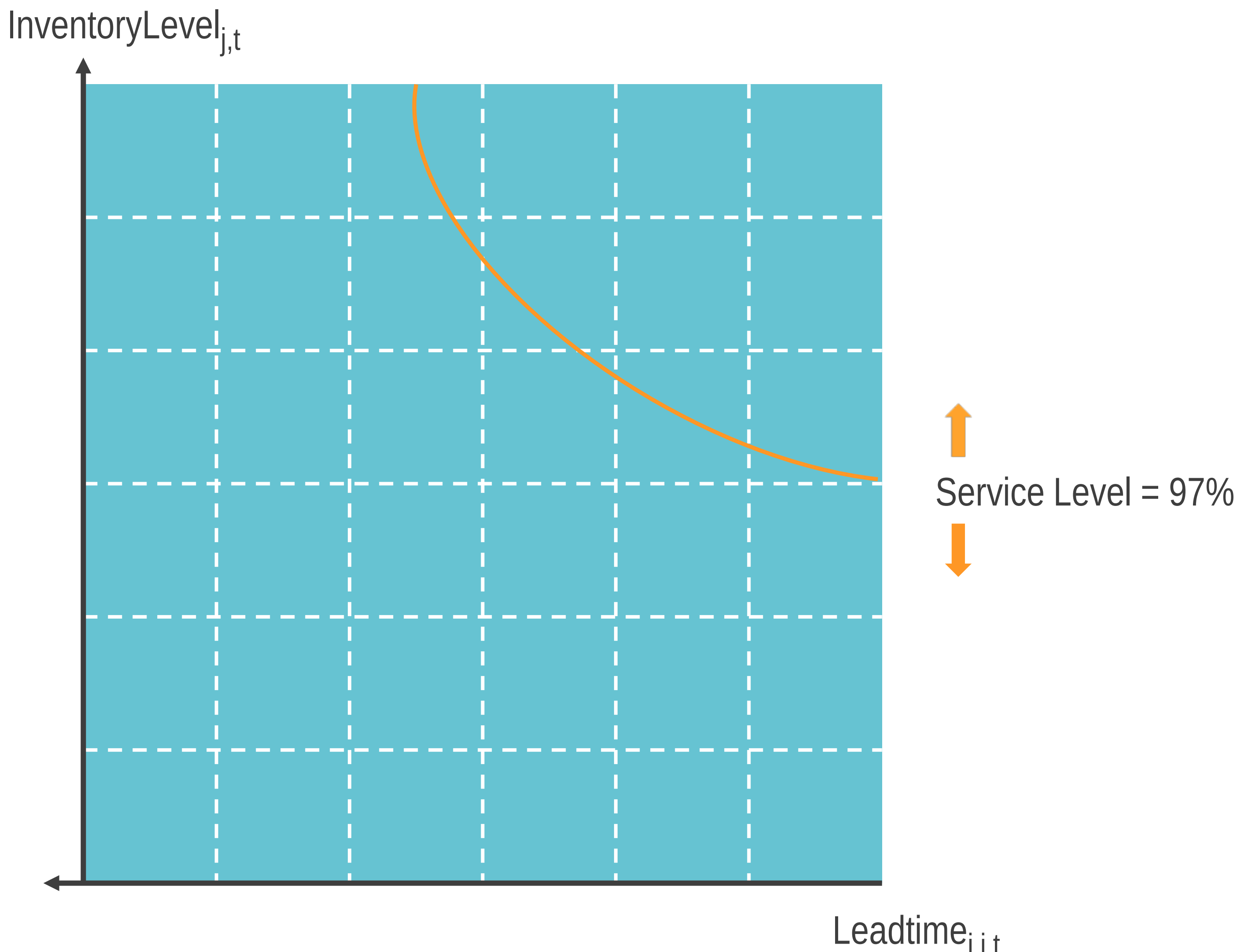




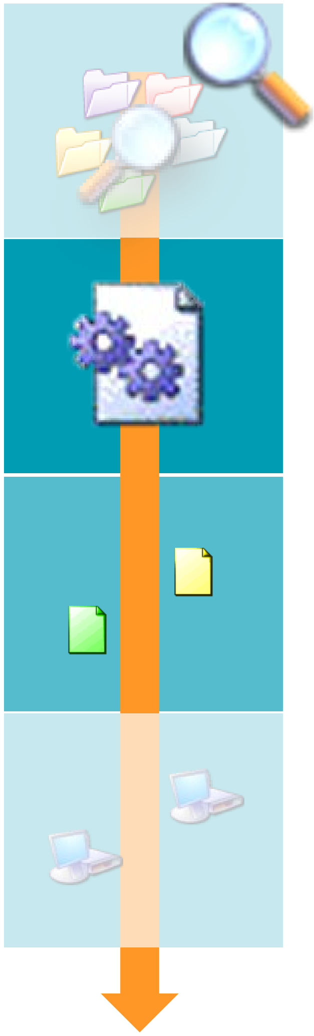
Factor	Mean
Leadtime (Port US - Port CN)	-4.85
Leadtime (Port EU - Port EU)	-4.41
Inventory Level (DC US)	-3.61
Production Capacity (Supplier 2)	-1.04
…	-0.98
…	-0.92

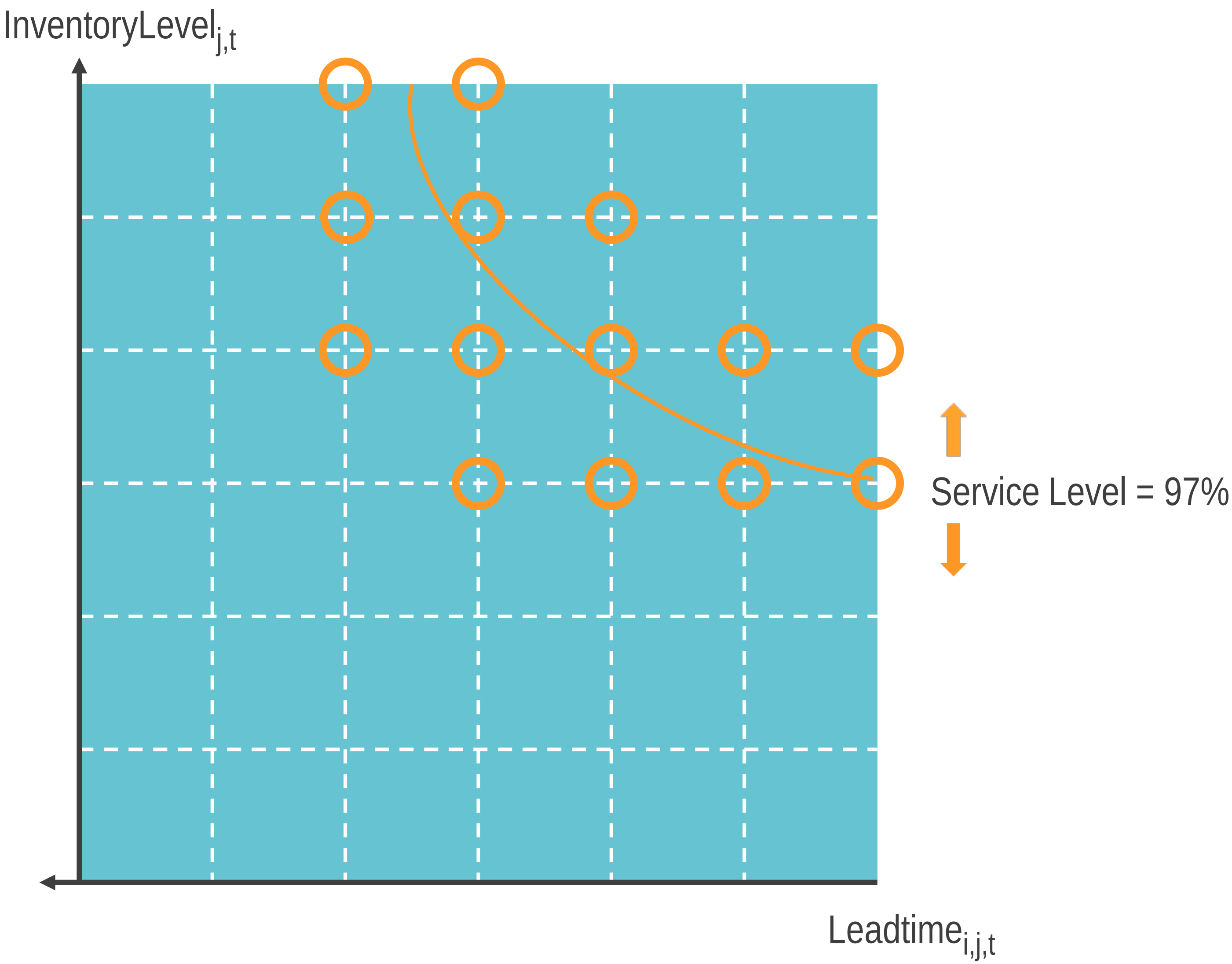
From screening results to a sequential algorithm for response surface approximation: Finding the KPI boundary





From screening results to a sequential algorithm for response surface approximation: Finding the KPI boundary





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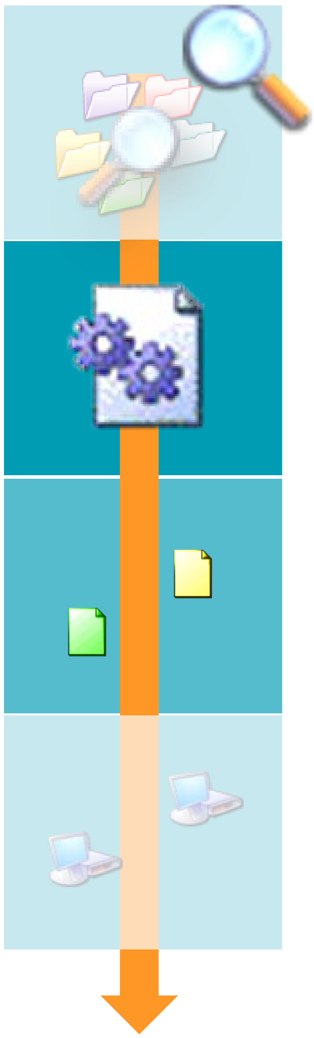

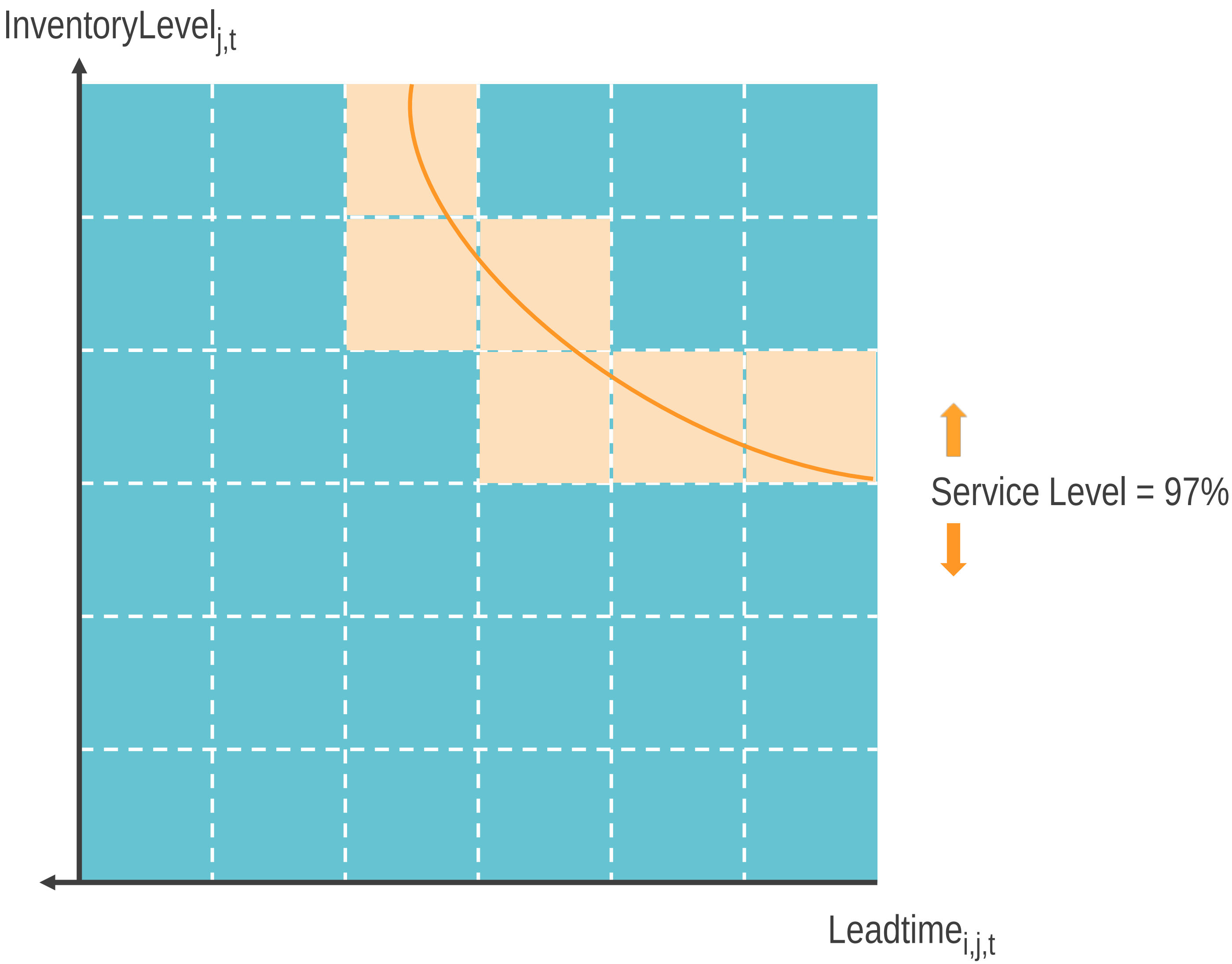

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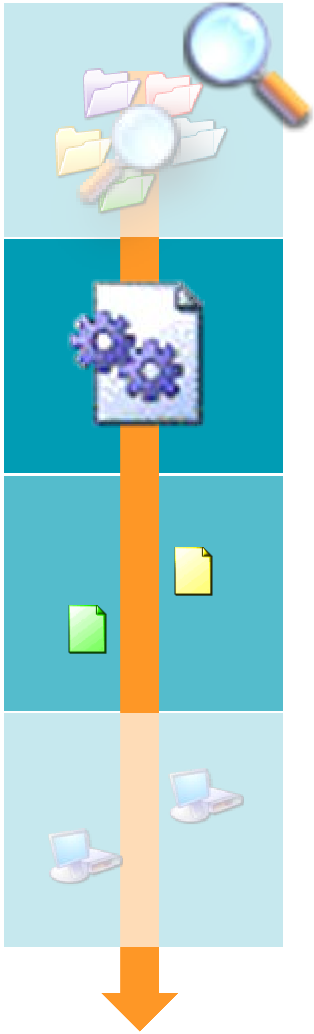
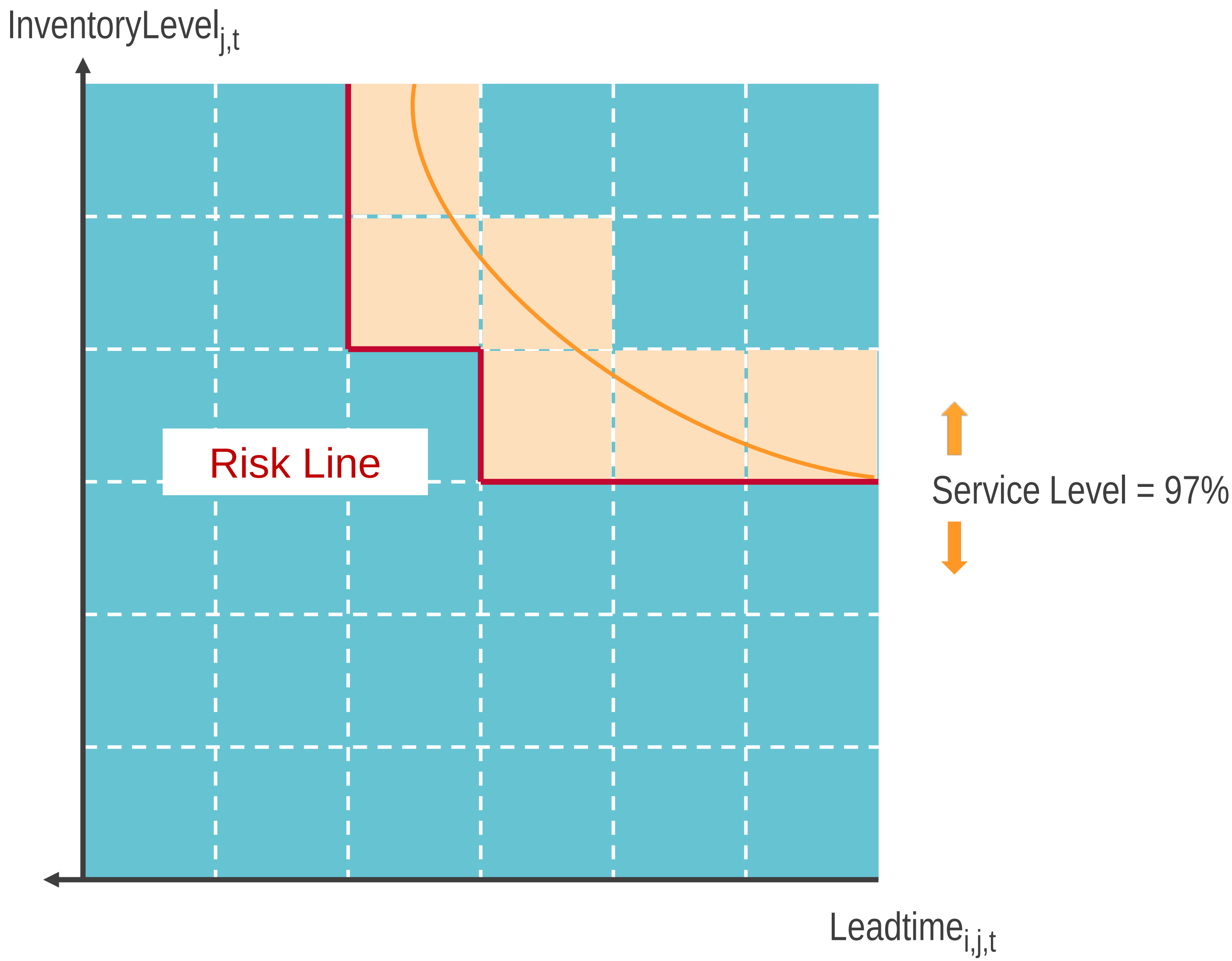
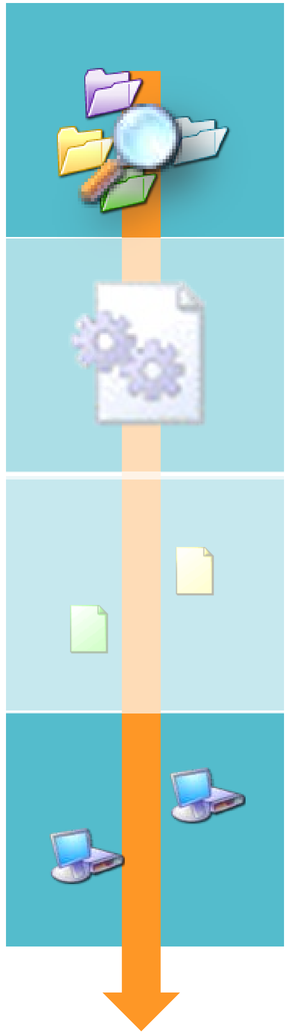
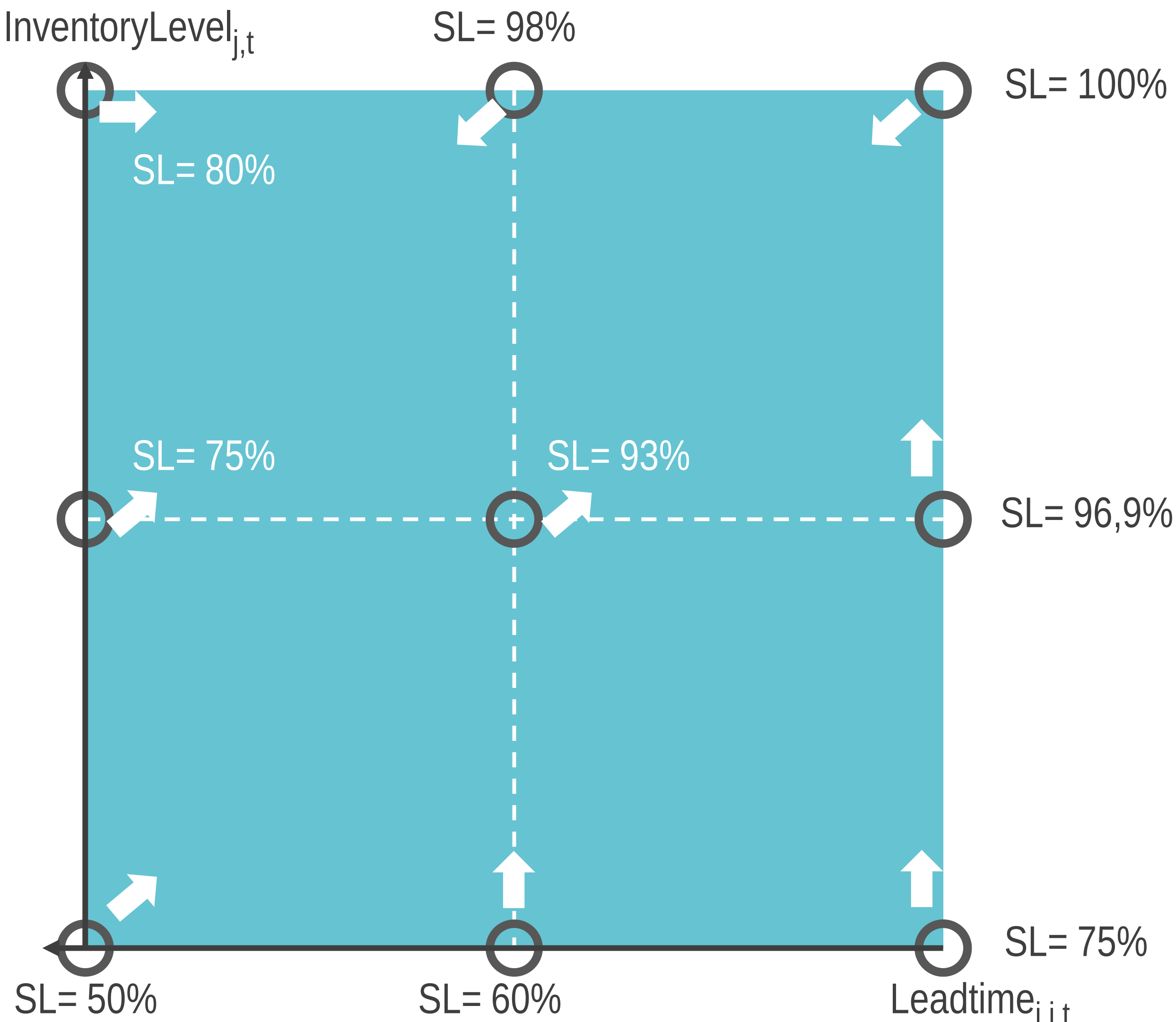


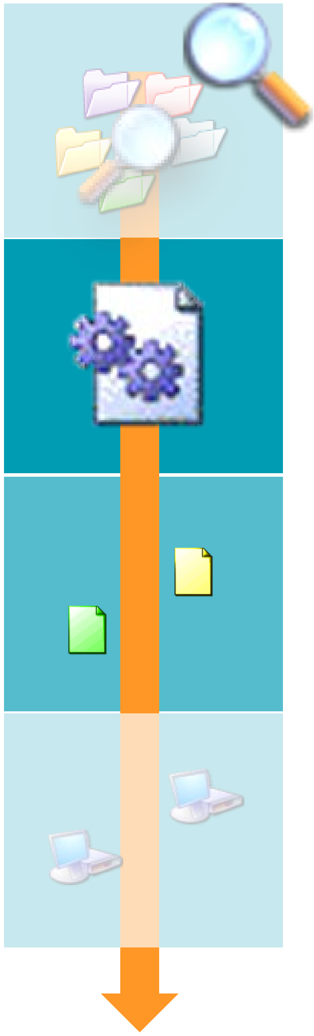


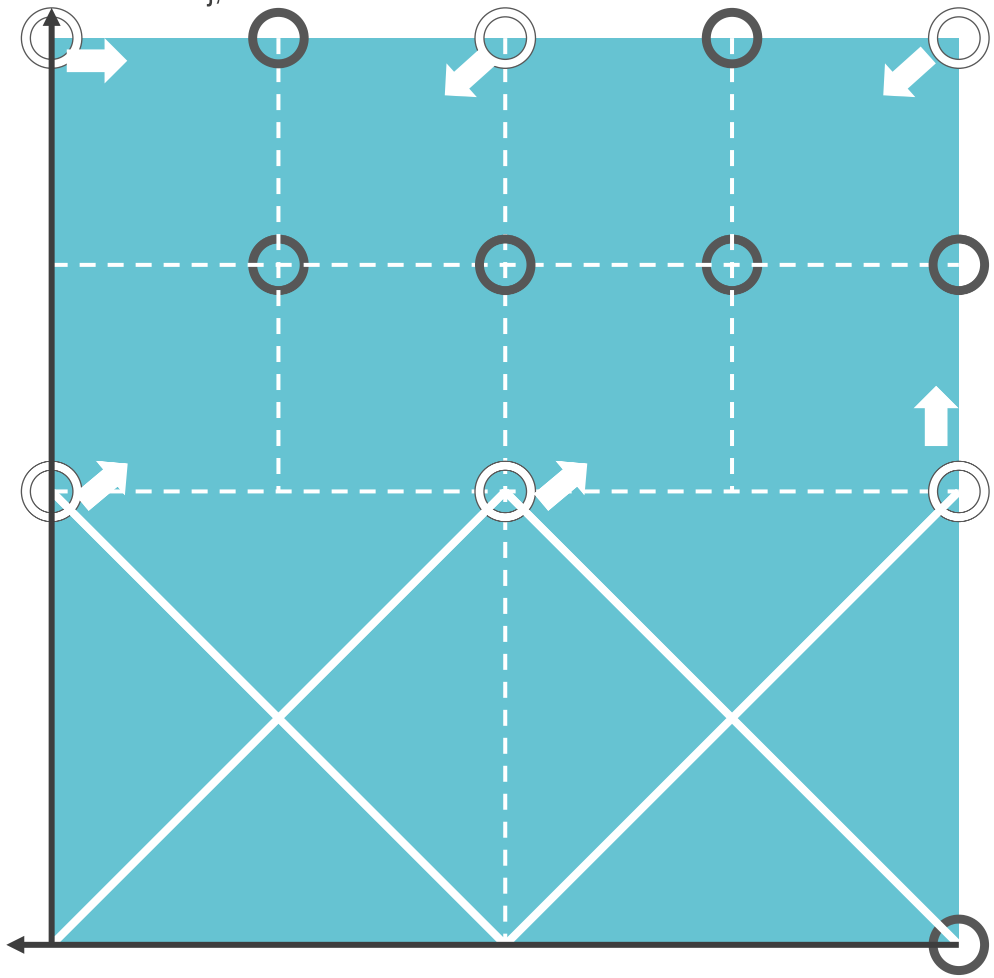
From screening results to a sequential algorithm for response surface approximation: First sample & result evaluation



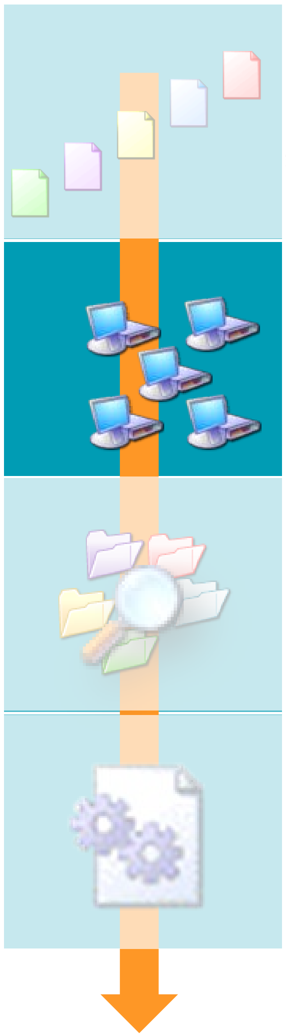


From screening results to a sequential algorithm for response surface approximation: Next step



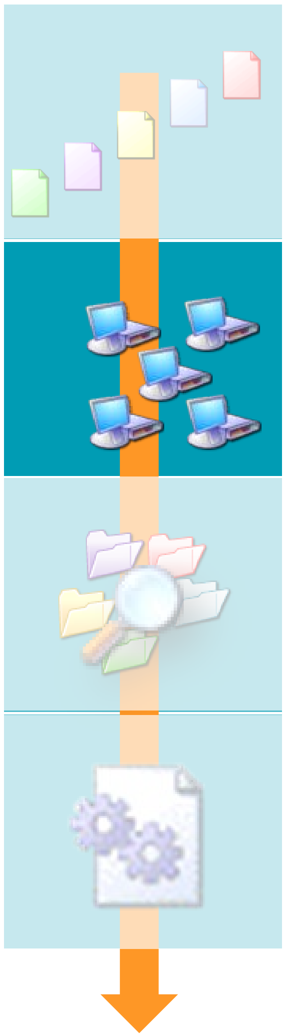


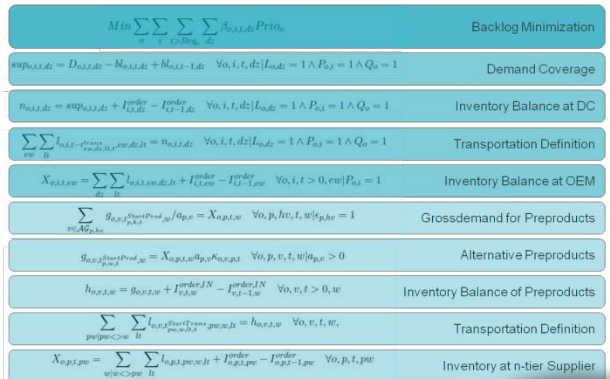
RAPHAEL System uses MRP-II planning but allows for pluggable Supply Chain Planning engines to meet specific environments

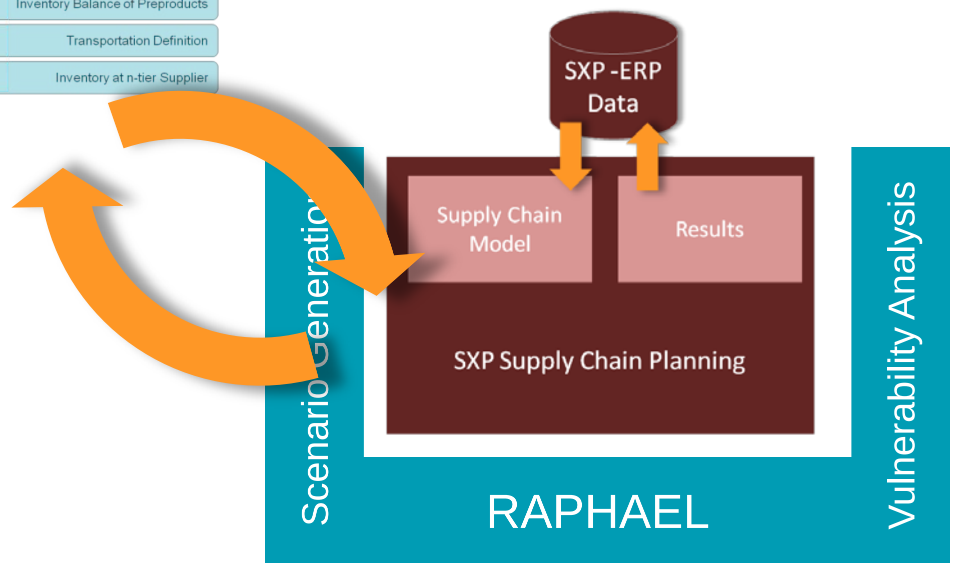


$Min \sum_{o} \sum_{i} \sum_{t>Req_o} \sum_{dz} \beta_{o,i,t,dz} Prio_o$	Backlog Minimization
$sup_{o,i,t,dz} = D_{o,i,t,dz} - bl_{o,i,t,dz} + bl_{o,i,t-1,dz} \quad \forall o,i,t,dz \mid L_{o,dz}=1 \wedge P_{o,i}=1 \wedge Q_o=1$	Demand Coverage
$n_{o,i,t,dz} = sup_{o,i,t,dz} + I^{order}_{i,t,dz} - I^{order}_{i,t-1,dz} \quad \forall o,i,t,dz \mid L_{o,dz}=1 \wedge P_{o,i}=1 \wedge Q_o=1$	Inventory Balance at DC
$\sum_{ew} \sum_{lt} l_{o,i,t-t^{trans}_{ew,dz,lt,t},ew,dz,lt} = n_{o,i,t,dz} \quad \forall o,i,t,dz \mid L_{o,dz}=1 \wedge P_{o,i}=1 \wedge Q_o=1$	Transportation Definition
$X_{o,i,t,ew} = \sum_{dz} \sum_{lt} l_{o,i,t,ew,dz,lt} + I^{order}_{i,t,ew} - I^{order}_{i,t-1,ew} \quad \forall o,i,t>0,ew \mid P_{o,i}=1$	Inventory Balance at OEM
$\sum_{v \in \mathcal{AG}_{p,hv}} g_{o,v,t^{StartProd}_{p,k,t},w} / a_{p,v} = X_{o,p,t,w} \quad \forall o,p,hv,t,w \mid \epsilon_{p,hv}=1$	Grossdemand for Preproducts
$g_{o,v,t^{StartProd}_{p,w,t},w} = X_{o,p,t,w} a_{p,v} \kappa_{o,v,p,t} \quad \forall o,p,v,t,w \mid a_{p,v}>0$	Alternative Preproducts
$h_{o,v,t,w} = g_{o,v,t,w} + I^{order,IN}_{v,t,w} - I^{order,IN}_{v,t-1,w} \quad \forall o,v,t>0,w$	Inventory Balance of Preproducts
$\sum_{pw \mid pw<>w} \sum_{lt} l_{o,v,t^{StartTrans}_{pw,w,lt,t},pw,w,lt} = h_{o,v,t,w} \quad \forall o,v,t,w,$	Transportation Definition
$X_{o,p,t,pw} = \sum_{w \mid w<>pw} \sum_{lt} l_{o,p,t,pw,w,lt} + I^{order}_{o,p,t,pw} - I^{order}_{o,p,t-1,pw} \quad \forall o,p,t,pw$	Inventory at n-tier Supplier

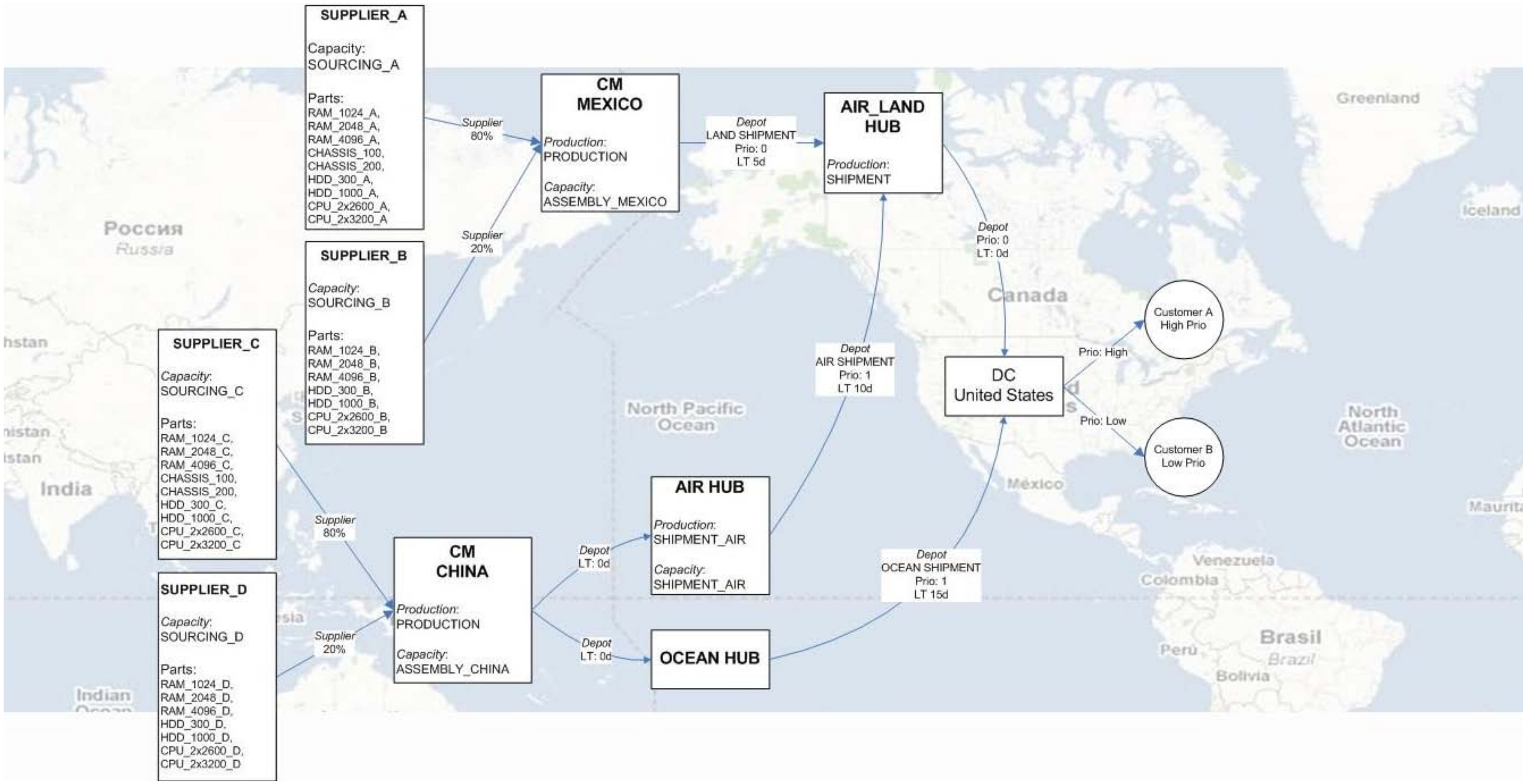
RAPHAEL System uses MRP-II planning but allows for pluggable Supply Chain Planning engines to meet specific environments







Example:

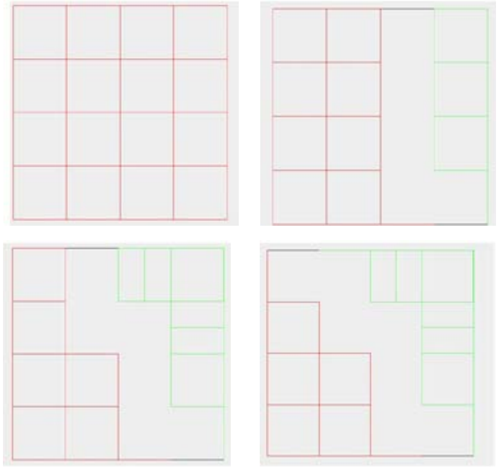


Response variable: Service Level

Results

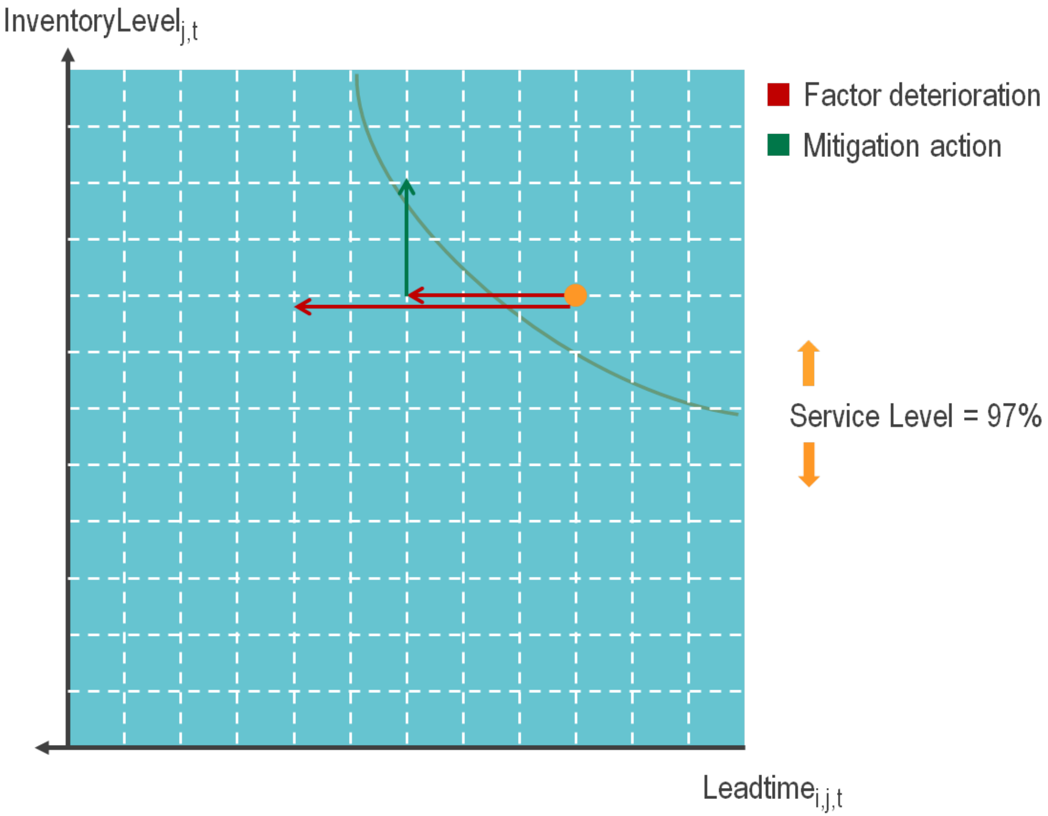
- Factor screening:
  - Factors analyzed: 123 Lead Times
  - Solution:
    - Relevant factors: 10 factors unambiguous identifiable (including lead times of ship transports)

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



Next Steps

- Screening Design
- Advanced approximation algorithm
- Mitigation Programming



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