Value-based Modeling of Supply Chains for Disclosure Risk Assessment

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Disclosure risk assessment

- **Risk assessment** is not a key component of methodologies for supply chain (SC) management.
- Still, certain characteristics of a SC might increase or decrease the risk of negative outcomes [11, 13].
- Further, the available procedures do not focus on risks related to information disclosure.
- As in any collaborative alliance, SCs need to be founded on trust among parties.
- The perception of a risk by the actors could lead to their abandoning the SC.
- In a risky configuration, actors may be reluctant to share information [7].
Disclosure risk assessment

- **Collaborative SC management** is the combined optimization of supply and delivery.
- **SC optimization** is necessary to sustain competition with SCs in the same business area.
- Optimization is based on data provided by each partner in the SC.
- The risks to be identified are internal to the SC.
- Misuse of shared information may damage the other partners.

**Example:** The introduction of fake information may direct the distribution of orders in favor of the disrupter.
Disclosure risk assessment

- Each actor participates to the coalition with its own objectives.
- These need to be reconciled with the achievement of the common good.
- If achieving such common good requires completely missing their objectives, actors may be tempted to adopt a non-cooperative behavior.
- This conflict of interest and the resulting risk can be described as an information sharing problem.
- A third party may not be equally trusted by all the actors for the SC master planning.
Our framework for disclosure risk assessment in the enactment of SCs is comprising:

- The **SCM model** describing the relationships among actors and the information exchanged by them;
- the corresponding **value model** enriched with the parameters that are not already featured by the e³ value ontology;
- the **key performance indicators** (KPI) ontology describing the entities and functions for risk assessment.

Indicators allows to point out how far an actor is from the optimum and prone to behave opportunistically.
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Modeling supply chains

- Traditional SC modeling techniques may be awkward for the average business analyst to fully grasp.

<table>
<thead>
<tr>
<th>Material flow level</th>
<th>Configuration of nodes and arcs has been determined through Supply chain configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i =$Stage Index ($i=1,...,4$)</td>
<td>$i = 1$</td>
</tr>
<tr>
<td>Process at stage $i$</td>
<td>Production of intermediate products</td>
</tr>
<tr>
<td>$K_i =$ Set of locations at stage $i$</td>
<td>$k \in K_1 = {1,2,3}$ Production facilities (Supplier)</td>
</tr>
<tr>
<td>Nodes $V_{i,k}$</td>
<td>$V_{1,k \in K_1}$</td>
</tr>
<tr>
<td>Arcs $(V_{i,k}, V_{i+1,l})$</td>
<td>$(V_{1,k \in K_1}, V_{2,l \in K_2})$</td>
</tr>
</tbody>
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![Diagram of supply chain model](image-url)
Modeling supply chains

- Topological features of the supply chain important for determining the probability and consequences of deviant behavior.
- Consequently, a prerequisite to an effective monitoring is a sound model for representing the coalition’s value interchanges.
- As opposed to BPM, *value models* [14, 6] describe business coalitions at a higher level of abstraction.
- Value models depict always which entities of value are exchanged between stakeholders. Business decisions can thus be based on estimates of the economic behavior of the different parties.
We selected a modeling technique which also allows for a graphical representation, the e³-value model [8].

The primary motivation for adopting this formalism is the one-to-one correspondence of the model with logic-based data structures.

The e³-value ontology allows for the extension of its constructs with the data items characterizing the supply chain.
Modeling supply chains

In the ontology-based representation of the SC we integrate:

- The SC description (here shown expanded);
- the value model expressing it;
- the performance indicators to be applied in the analysis.

For the time being, we are using the Shapley Value:

\[ u_i = \sum_c \frac{1}{n(n-1)} \left[ v(C) - v(C - i) \right] \quad (1) \]
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Supply chain analysis example

- We want to evaluate which actor is prone to adopt an opportunistic behavior by knowing a certain information.
- In a whiteboard scenario all actors share the data that are necessary for the SC optimization.
- In this scenario, it is possible for R to calculate its Shapley value and decide that the supply chain configuration is unfair to it.

<table>
<thead>
<tr>
<th>NAME</th>
<th>R</th>
<th>R</th>
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<tbody>
<tr>
<td>UID</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>profit</td>
<td>e3[#35.\text{V}]</td>
<td>135</td>
</tr>
<tr>
<td>capacity</td>
<td>60.00000</td>
<td>60</td>
</tr>
<tr>
<td>revenue</td>
<td>e3[#35.\text{V}]</td>
<td>270</td>
</tr>
<tr>
<td>declared_price</td>
<td>9.000000</td>
<td>9</td>
</tr>
<tr>
<td>shapley_value</td>
<td>(e3[#4.\text{c}]</td>
<td>180</td>
</tr>
</tbody>
</table>
Supply chain analysis example

- By knowing the manufacturer’s allocation strategy (favoring resellers with the highest declared price), R may decide to adopt an opportunistic behavior.

- One possible attack by actor R could be lying on the sale price that is applied to the product.

- By declaring a price equal to 13, the actor would increase the overall profit toward its Shapley value.

Then, the parameter declared_price cannot be shared among actors without increasing the risk of actor R to misbehave.
Supply chain analysis example

- In real-world SC the analysis we carry out is more complex.
- The *delta* between profit and Shapley value is weighted according to the *impact* of individual actors (e.g., upstream Vs. downstream actors).
- The normalized result leads to a *ranking* of actors according to the criticality of deviant behavior by them.
- The costs associated with the application of *secure computation* in SC optimization are evaluated.
- Alternative *incentive strategies* are also evaluated.
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Conclusions and outlook

- Our approach may serve more general purposes in the modeling of business coalitions and social behavior.
- The architecture aims at integrating with existing tools to enrich the range of results that may be presented to the business analyst.

Example: The profitability sheet generated by value modeling tools could be enriched by adding the calculation of the Shapley value.

- We are currently deploying our Java routine for calculating the Shapley value as an easily accessible web service.
- We also want to develop interfaces customizing the input to our web service according to specific data formats (e.g., the e³ value ontology).
Conclusions and outlook

Two possible integration scenarios:

• The e³ value editor introduces as built-ins the parameters for KPI evaluation.

• By doing this, SecureSCM-enabled supply chains can be created without relying on the underlying data model.

• The web service is invoked during calculation of profitability sheets, introducing a new, objective indicator for evaluating risk.

Alternatively, the other way around:

• SecureSCM data are translated into an e³ value ontology instance, embedding KPIs as custom properties.

• The generated profitability sheets will include the evaluation of KPIs.

• A custom application (or the human agent) derives the ranking of actors according to information disclosure risk.
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