A Decision Support Model for Intermediary Selection in the Supply Chain

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Outline

- Intermediary Selection in the Supply Chain
- A Conceptual Process Model for Intermediary Selection
- Decision Support from Artificial Intelligence Tools
- Conclusion and Future Work
Intermediary Selection in the Supply Chain

- intermediary: third party offering services between two trading parties
- supply chain management (SCM):
  - traditionally focused on purchasing and logistics
  - more emphasis on value creation as source of competitive advantage
  - customer service, profit generation, asset utilization, cost reduction
- effective selection of intermediaries is essential to achieve these goals
  - combinations of traditional channels, dis-, re- and cyber-mediation
- supply chain design: complex decision that involves
  - strategic choice of the appropriate channel structure, and
  - tactical selection of the appropriate intermediaries
  - \(2^n\) potential chains for \(n\) candidates, not a one-time process
- supply chain coordinators require assistance in the selection process
  - advice by available experts or automated decision support, or
  - process model guiding the intermediary selection process
The Generic Four-Stage Strategy Process Model

- intermediary selection
  part of third phase

- to define business
  strategy, options
  for intermediaries are

  → generated,
  → evaluated, and
  → selected
A Conceptual Process Model for Intermediary Selection

*Divide and Conquer*

- Iterative with each iteration consisting of four phases
  - Iterations triggered by events, support of target chain’s *agility*
  - Changes in supply/demand, revised strategic objectives or disasters
- Phase 1: Fragmentation of Candidates and Allocation of Experts
  - Each intermediary candidate covered by some fragment
  - Coordinator allocates domain experts to champion fragments
  - Fragmentation could be based on scope of expert domain knowledge
- Phase 2: Development of Local Plans (Black Box here)
  - Experts develop local plans for selection within their fragments
  - Recommendations in some formal language (example later)
  - Consist of specific or conditional selections
  - Aim to *adapt* target chain to local market situations or changes
A Conceptual Process Model for Intermediary Selection

Alignment and Preference Selection

Phase 3: Strategy or Approximation Inference

- selection of intermediaries that meet all local plans
- recommendations of different local plans may be inconsistent
- experts must align local plans, possibly by collaboration
- iterated until consistency achieved or inconsistency unresolvable
- approximations of strategy developed in latter case
- several tactics of either strategy or approximation available

Phase 4: Selection of Preferred Tactics

- heuristics narrow down choices of tactics available
- heuristics based on corporate strategies (minimize intermediaries)
- preferred tactic identifies a unique selection of intermediaries
Summary of
Conceptual Process Model for Intermediary Selection
Automated Assistance

- process model suggests to have automated assistance for:
  - the decision whether local plans can be integrated into strategy
  - inferring all tactics available for a strategy
  - approximating a strategy as closely as possible
  - choosing tactics available for strategy or approximation

- require a formal language
  - expressive enough for domain experts to specify local plans, and
  - which enables efficient reasoning about consistency
  - coordination mechanism forcing experts to express key insights

- showcase for language here: Boolean propositional logic
  - expressive enough to accommodate recommendations for fragments
  - off-the-shelf tools available to assist with problems above
Candidate Fragmentation

- set $SCC = \{I_1, \ldots, I_n\}$ of intermediary candidates $I_j$

- fragmentation of $SCC$ is collection $\mathcal{F}(SCC) \subseteq 2^{SCC}$ such that for every $I \in SCC$ there is some $F \in \mathcal{F}(SCC)$ such that $I \in F$

- example: down-stream supply chain $SCC = \{W_1, W_2, R_1, R_2\}$
  - two wholesalers $W_1$ and $W_2$, and two retailers $R_1$ and $R_2$
  - four fragments based on geographical location & domain knowledge
  - $F_1 = \{W_1, R_1\}$, $F_2 = \{W_2, R_2\}$, $F_3 = \{W_1, W_2\}$, $F_4 = \{R_1, R_2\}$
Example of Fragmentation and Allocation

F_1
Expert: Geographic Region 1

F_2
Expert: Geographic Region 2

F_3
Expert: Wholesalers

F_4
Expert: Retailers

W_1
R_1

W_2
R_2
Local Plans

- \(LS_{F_1}\): if \(W_1\) is selected as an intermediary, then \(R_1\) as well
  \(\lambda_{F_1} = W_1 \Rightarrow R_1\),

- \(LS_{F_2}\): if \(W_2\) is selected as an intermediary, then \(R_2\) as well
  \(\lambda_{F_2} = W_2 \Rightarrow R_2\),

- \(LS_{F_3}\): select either \(R_1\) or \(R_2\)
  \(\lambda_{F_3} = R_1 \Leftrightarrow \neg R_2\), and

- \(LS_{F_4}\): select both \(W_1\) and \(W_2\)
  \(\lambda_{F_4} = W_1 \land W_2\)

- can be complex: select precisely two manufacturers out of three when the distributor is not selected
  \(\neg D \Rightarrow (M_1 \land M_2 \land \neg M_3) \lor (M_1 \land \neg M_2 \land M_3) \lor (\neg M_1 \land M_2 \land M_3)\)
Tactics and Strategies

- A **plan** for selection wrt $\mathcal{F}(SCC')$ is the union $\pi = \bigcup_{F \in \mathcal{F}(SCC')} \{ \lambda_F \}$.

- A **policy** $\vartheta$ of a plan $\pi$ is a truth assignment $\vartheta : SCC \rightarrow \{true, false\}$.

- A policy $\vartheta$ of a plan $\pi$ is a **tactic** of $\pi$ if $\vartheta$ is a model of $\pi$.

- A plan is a **strategy**, usually denoted by $\zeta$, if there is some tactic for $\zeta$.

- A tactic $\vartheta$ of strategy $\zeta$ **defines** selection $\iota_\vartheta = \{ I \in SCC \mid \models_\vartheta I \}$.

- A **selection of intermediaries** from $SCC$ wrt $\mathcal{F}(SCC)$ is a subset $\iota \subseteq SCC$ such that:
  - There is a strategy $\zeta$ wrt $\mathcal{F}(SCC')$ and
  - A tactic $\vartheta$ of $\zeta$ such that $\iota = \iota_\vartheta$. 
**The Decision Problem** *Strategy*

**Problem:** Strategy

**INPUT:** A plan $\pi$

**QUESTION:** Is $\pi$ a strategy?

<table>
<thead>
<tr>
<th>Policy</th>
<th>Intermediary $\vartheta$</th>
<th>Plan $\pi = {\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi, \lambda_{F_4}^\pi}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$W_1$</td>
<td>$W_2$</td>
</tr>
<tr>
<td>$\vartheta_1$</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>$\vartheta_2$</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>$\vartheta_3$</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>$\vartheta_4$</td>
<td>true</td>
<td>true</td>
</tr>
<tr>
<td>$\vartheta_5$</td>
<td>true</td>
<td>false</td>
</tr>
<tr>
<td>$\vartheta_6$</td>
<td>true</td>
<td>false</td>
</tr>
<tr>
<td>$\vartheta_7$</td>
<td>true</td>
<td>false</td>
</tr>
<tr>
<td>$\vartheta_8$</td>
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<td>false</td>
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<tr>
<td>$\vartheta_9$</td>
<td>false</td>
<td>true</td>
</tr>
<tr>
<td>$\vartheta_{10}$</td>
<td>false</td>
<td>true</td>
</tr>
<tr>
<td>$\vartheta_{11}$</td>
<td>false</td>
<td>true</td>
</tr>
<tr>
<td>$\vartheta_{12}$</td>
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<td>$\vartheta_{13}$</td>
<td>false</td>
<td>false</td>
</tr>
<tr>
<td>$\vartheta_{14}$</td>
<td>false</td>
<td>false</td>
</tr>
<tr>
<td>$\vartheta_{15}$</td>
<td>false</td>
<td>false</td>
</tr>
<tr>
<td>$\vartheta_{16}$</td>
<td>false</td>
<td>false</td>
</tr>
</tbody>
</table>
The Enumeration Problem All Tactics

Problem: All-Tactics
INPUT: A plan \( \pi \)
QUESTION: What are all tactics of \( \pi \)?

▶ plan \( \zeta = \{\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi\} \) input

▶ table

<table>
<thead>
<tr>
<th>Tactic ( \vartheta_i )</th>
<th>( W_1 )</th>
<th>( W_2 )</th>
<th>( R_1 )</th>
<th>( R_2 )</th>
<th>Selection ( \iota_{\vartheta_i} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \vartheta_6 )</td>
<td>true</td>
<td>false</td>
<td>true</td>
<td>false</td>
<td>{( W_1 ), ( R_1 )}</td>
</tr>
<tr>
<td>( \vartheta_{11} )</td>
<td>false</td>
<td>true</td>
<td>false</td>
<td>true</td>
<td>{( W_2 ), ( R_2 )}</td>
</tr>
<tr>
<td>( \vartheta_{14} )</td>
<td>false</td>
<td>false</td>
<td>true</td>
<td>false</td>
<td>{( R_1 )}</td>
</tr>
<tr>
<td>( \vartheta_{15} )</td>
<td>false</td>
<td>false</td>
<td>false</td>
<td>true</td>
<td>{( R_2 )}</td>
</tr>
</tbody>
</table>

shows all four tactics \( \vartheta_i \) of \( \zeta \), and the associated selections \( \iota_{\vartheta_i} \).
The Enumeration Problem *All Best Approximations*

- **approximation** of plan $\pi$: a subset $\varsigma \subseteq \pi$ such that
  $\hookrightarrow \varsigma$ is a strategy and no strategy $\varsigma' \subseteq \pi$ is a proper superset of $\varsigma$

- **best approximation** of plan $\pi$: approximation $\varsigma$ of $\pi$ such that
  $\hookrightarrow$ no approximation $\varsigma'$ of $\pi$ has more local plans than $\varsigma$

**Problem: All-Best-Approximations**

**INPUT:** A plan $\pi$

**QUESTION:** What are *all* best approximations of $\pi$?

<table>
<thead>
<tr>
<th>Best Approximation $\alpha$</th>
<th>Tactic of $\alpha$ $(W_1, W_2, R_1, R_2)$</th>
<th>Selection $\iota$</th>
</tr>
</thead>
<tbody>
<tr>
<td>${\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi}$</td>
<td>$(\text{true, false, true, false})$</td>
<td>${W_1, R_1}$</td>
</tr>
<tr>
<td>${\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi}$</td>
<td>$(\text{false, true, false, true})$</td>
<td>${W_2, R_2}$</td>
</tr>
<tr>
<td>${\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi}$</td>
<td>$(\text{false, false, true, false})$</td>
<td>${R_1}$</td>
</tr>
<tr>
<td>${\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi}$</td>
<td>$(\text{false, false, false, true})$</td>
<td>${R_2}$</td>
</tr>
<tr>
<td>${\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi}$</td>
<td>$(\text{true, true, true, true})$</td>
<td>${W_1, W_2, R_1, R_2}$</td>
</tr>
<tr>
<td>${\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi}$</td>
<td>$(\text{true, true, true, false})$</td>
<td>${W_1, W_2, R_1}$</td>
</tr>
<tr>
<td>${\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_4}^\pi}$</td>
<td>$(\text{true, true, false, true})$</td>
<td>${W_1, W_2, R_2}$</td>
</tr>
</tbody>
</table>
The Enumeration Problem All Minimal Tactics

- minimal tactic of plan $\pi$ is tactic $\vartheta$ of $\pi$ such that
  $\ni$ no other $\vartheta'$ of $\pi$ defines $\iota_{\vartheta'}$ that is proper subset of $\iota_{\vartheta}$

Problem: All-Minimal-Tactics

INPUT: A plan $\pi$
QUESTION: What are all minimal tactics of $\pi$?

- with input $\alpha = \{\lambda^F_{\pi_1}, \lambda^F_{\pi_2}, \lambda^F_{\pi_3}\}$

<table>
<thead>
<tr>
<th>Tactic</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(W_1, W_2, R_1, R_2)$</td>
<td>$\iota$</td>
</tr>
<tr>
<td>(false, false, true, false)</td>
<td>${R_1}$</td>
</tr>
<tr>
<td>(false, false, false, true)</td>
<td>${R_2}$</td>
</tr>
</tbody>
</table>

- $\text{(true, false, true, false)}$ not minimal
The Enumeration Problem *All X-Minimal Tactics*

- **X \subseteq SCC**: an *X-minimal tactic* of \( \pi \) is tactic \( \vartheta \) of \( \pi \) such that
  - no \( \vartheta' \) of \( \pi \) satisfies \( \iota_{\vartheta'} \cap X \subset \iota_{\vartheta} \cap X \)

**Problem: All-X-Minimal-Tactics**

**INPUT**: A plan \( \pi \), a subset \( X \) of candidate intermediaries

**QUESTION**: What are all \( X \)-minimal tactics of \( \pi \)?

- **input** \( \alpha = \{ \lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi \} \) and \( X = \{ W_1, R_1 \} \)

<table>
<thead>
<tr>
<th>Tactic</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>((W_1, W_2, R_1, R_2))</td>
<td>(\iota)</td>
</tr>
<tr>
<td>((false, true, false, true))</td>
<td>{W_2, R_2}</td>
</tr>
<tr>
<td>((false, false, false, true))</td>
<td>{R_2}</td>
</tr>
</tbody>
</table>

- \((false, false, true, false)\) is not \( X \)-minimal:
  - \((false, true, false, true)\) does neither select \( W_1 \) nor \( R_1 \)
Conclusion and Future Work

▶ proposed conceptual process model to assist intermediary selection
  → iterative, four-stage, divide-and-conquer approach to support agility, adaptability, alignment, and automated assistance
▶ plug-in support for a suitable logic
▶ automated assistance by off-the-shelf AI tools:

<table>
<thead>
<tr>
<th>Problem</th>
<th>Related AI Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy</td>
<td>SAT</td>
</tr>
<tr>
<td>All-Best-Approximations</td>
<td>ALL-MC</td>
</tr>
<tr>
<td>All-Tactics</td>
<td>ALLSAT</td>
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<tr>
<td>All-Minimal-Tactics</td>
<td>ALL-MINIMAL</td>
</tr>
<tr>
<td>All-X-Minimal-Tactics</td>
<td>ALL-X-MINIMAL</td>
</tr>
<tr>
<td>Tactic</td>
<td>MODEL</td>
</tr>
<tr>
<td>Minimal Tactic</td>
<td>MIN-MODEL</td>
</tr>
</tbody>
</table>

▶ test process model in various case studies
▶ analyze the potential of other formal languages
  → first-order logic, modal logics, para-consistent logics