

# 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



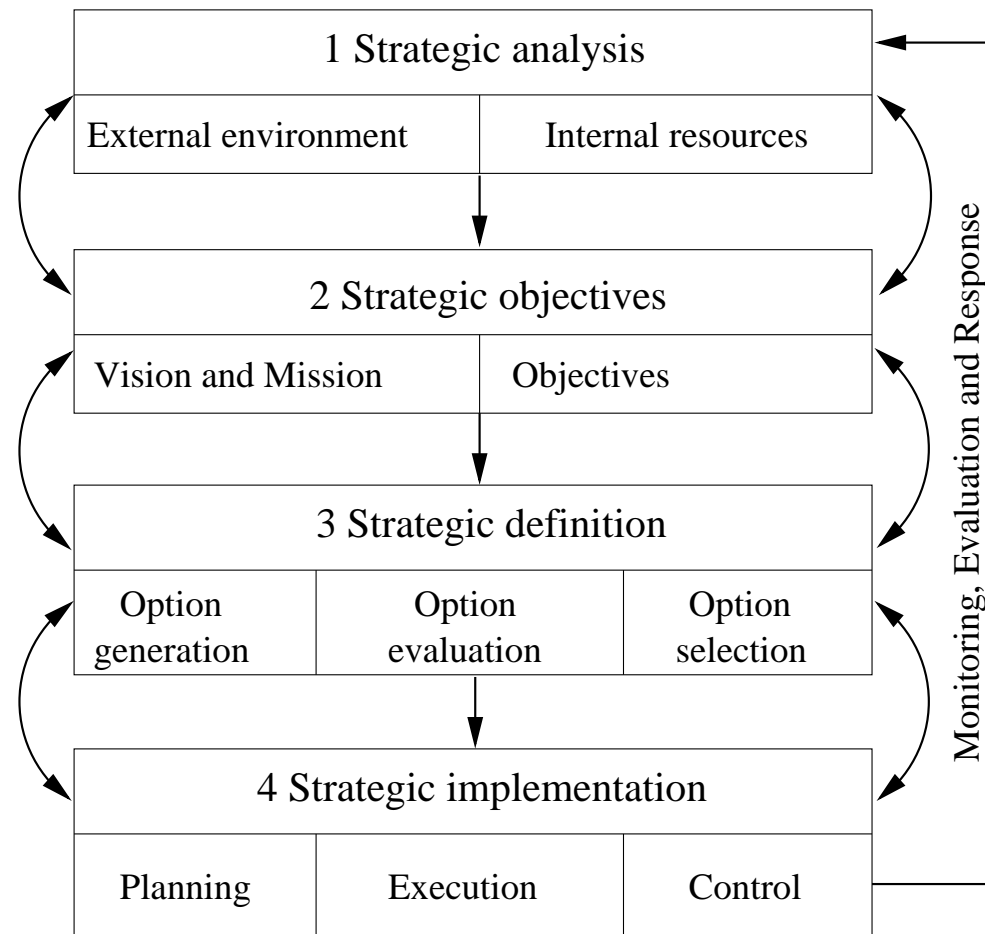
## The Generic Four-Stage Strategy Process Model

- ▶ 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

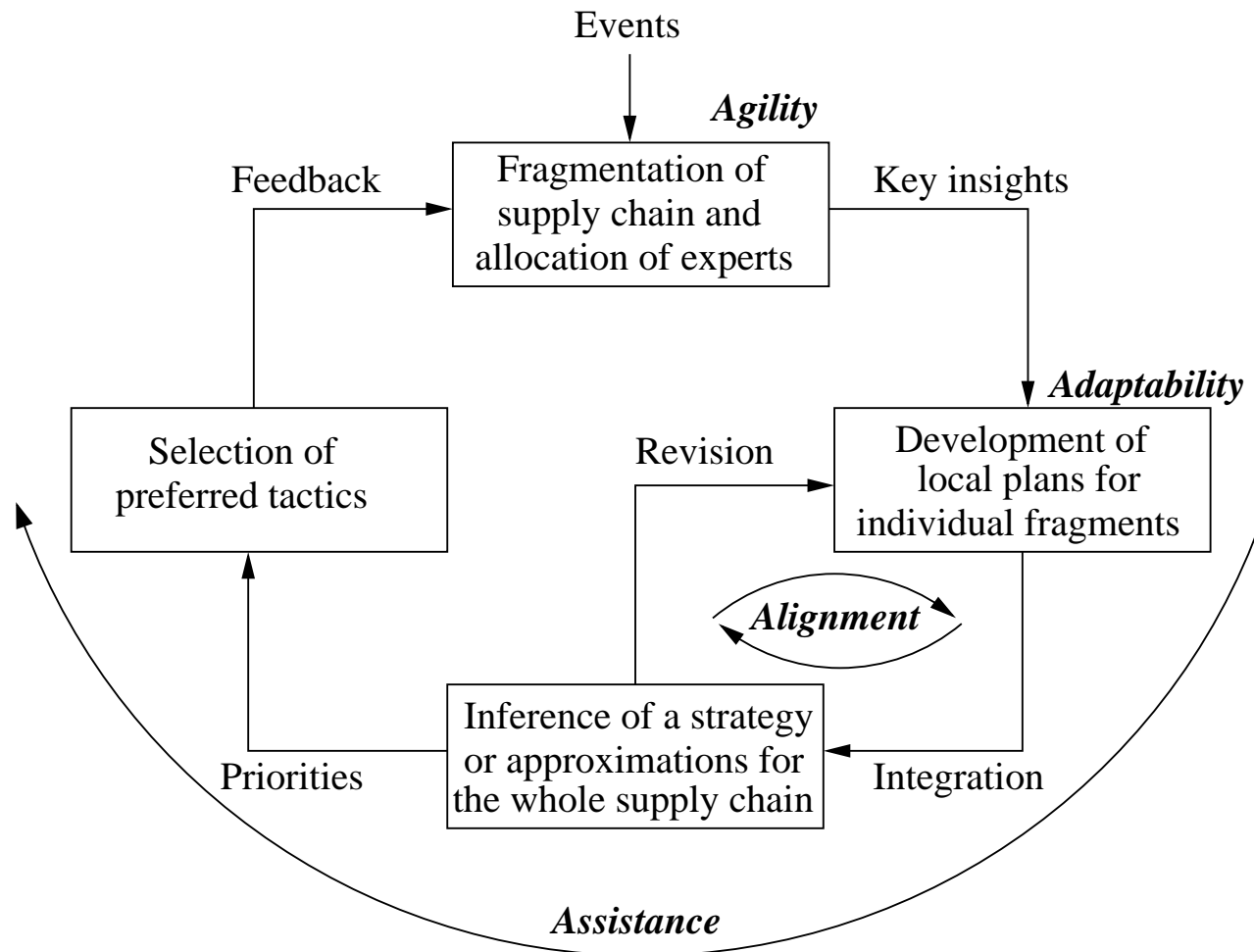


## A Conceptual Process Model for Intermediary Selection *Alignment and Preference Selection*

- ▶ 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

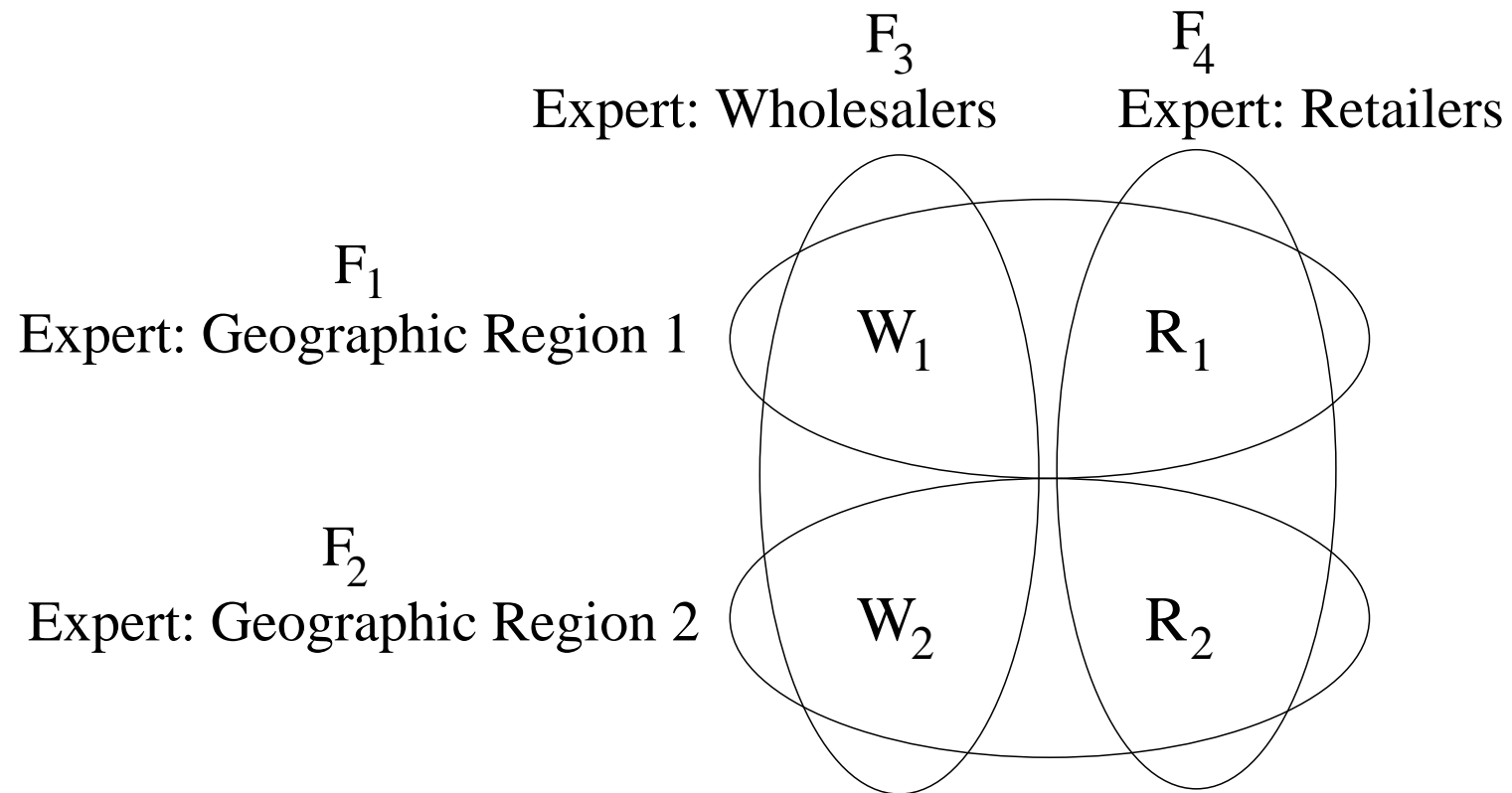


## Candidate Fragmentation

- ▶ set  $SCC = \{I_1, \dots, I_n\}$  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



## Local Plans

- ▶  $LS_{F_1}$ : if  $W_1$  is selected as an intermediary, then  $R_1$  as well  
 $\hookrightarrow \lambda_{F_1}^\pi = W_1 \Rightarrow R_1$ ,
- ▶  $LS_{F_2}$ : if  $W_2$  is selected as an intermediary, then  $R_2$  as well  
 $\hookrightarrow \lambda_{F_2}^\pi = W_2 \Rightarrow R_2$ ,
- ▶  $LS_{F_3}$ : select either  $R_1$  or  $R_2$   
 $\hookrightarrow \lambda_{F_3}^\pi = R_1 \Leftrightarrow \neg R_2$ , and
- ▶  $LS_{F_4}$ : select both  $W_1$  and  $W_2$   
 $\hookrightarrow \lambda_{F_4}^\pi = W_1 \wedge W_2$
- ▶ can be complex: select precisely two manufacturers out of three when the distributor is not selected  

$$\neg D \Rightarrow (M_1 \wedge M_2 \wedge \neg M_3) \vee (M_1 \wedge \neg M_2 \wedge M_3) \vee (\neg M_1 \wedge M_2 \wedge M_3)$$



## Tactics and Strategies

- ▶ *plan* for selection wrt  $\mathcal{F}(SCC)$  is the union  $\pi = \cup_{F \in \mathcal{F}(SCC)} \{\lambda_F^\pi\}$
- ▶ *policy*  $\vartheta$  of a plan  $\pi$  is a truth assignment  $\vartheta : SCC \rightarrow \{true, false\}$
- ▶ *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  $\zeta$
- ▶ 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*

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INPUT: A plan  $\pi$

QUESTION: Is  $\pi$  a strategy?

Policy	Intermediary				Plan $\pi = \{\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi, \lambda_{F_4}^\pi\}$			
	$W_1$	$W_2$	$R_1$	$R_2$	$W_1 \Rightarrow R_1$	$W_2 \Rightarrow R_2$	$R_1 \Leftrightarrow \neg R_2$	$W_1 \wedge W_2$
$\vartheta_1$	true	true	true	true	true	true	false	true
$\vartheta_2$	true	true	true	false	true	false	true	true
$\vartheta_3$	true	true	false	true	false	true	true	true
$\vartheta_4$	true	true	false	false	false	false	false	true
$\vartheta_5$	true	false	true	true	true	true	false	false
$\vartheta_6$	true	false	true	false	true	true	true	false
$\vartheta_7$	true	false	false	true	false	true	true	false
$\vartheta_8$	true	false	false	false	false	true	false	false
$\vartheta_9$	false	true	true	true	true	true	false	false
$\vartheta_{10}$	false	true	true	false	true	false	true	false
$\vartheta_{11}$	false	true	false	true	true	true	true	false
$\vartheta_{12}$	false	true	false	false	true	false	false	false
$\vartheta_{13}$	false	false	true	true	true	true	false	false
$\vartheta_{14}$	false	false	true	false	true	true	true	false
$\vartheta_{15}$	false	false	false	true	true	true	true	false
$\vartheta_{16}$	false	false	false	false	true	true	false	false



## 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

Tactic $\vartheta_i$	$W_1$	$W_2$	$R_1$	$R_2$	Selection $\iota_{\vartheta_i}$
$\vartheta_6$	<i>true</i>	<i>false</i>	<i>true</i>	<i>false</i>	$\{W_1, R_1\}$
$\vartheta_{11}$	<i>false</i>	<i>true</i>	<i>false</i>	<i>true</i>	$\{W_2, R_2\}$
$\vartheta_{14}$	<i>false</i>	<i>false</i>	<i>true</i>	<i>false</i>	$\{R_1\}$
$\vartheta_{15}$	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>	$\{R_2\}$

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
  - ↳  $\varsigma$  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
  - ↳ 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  $\pi$ ?

Best Approximation $\alpha$	Tactic of $\alpha$ ( $W_1, W_2, R_1, R_2$ )	Selection $\iota$
$\{\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi\}$	( <i>true, false, true, false</i> ) ( <i>false, true, false, true</i> ) ( <i>false, false, true, false</i> ) ( <i>false, false, false, true</i> )	$\{W_1, R_1\}$ $\{W_2, R_2\}$ $\{R_1\}$ $\{R_2\}$
$\{\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_4}^\pi\}$	( <i>true, true, true, true</i> )	$\{W_1, W_2, R_1, R_2\}$
$\{\lambda_{F_1}^\pi, \lambda_{F_3}^\pi, \lambda_{F_4}^\pi\}$	( <i>true, true, true, false</i> )	$\{W_1, W_2, R_1\}$
$\{\lambda_{F_2}^\pi, \lambda_{F_3}^\pi, \lambda_{F_4}^\pi\}$	( <i>true, true, false, true</i> )	$\{W_1, W_2, R_2\}$



## The Enumeration Problem *All Minimal Tactics*

- ▶ *minimal tactic* of plan  $\pi$  is tactic  $\vartheta$  of  $\pi$  such that  
 $\hookrightarrow$  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  $\alpha = \{\lambda_{F_1}^\pi, \lambda_{F_2}^\pi, \lambda_{F_3}^\pi\}$

Tactic	Selection
$(W_1, W_2, R_1, R_2)$	$\iota$
$(false, false, true, false)$	$\{R_1\}$
$(false, false, false, true)$	$\{R_2\}$

- ▶  $(true, false, true, false)$  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  
 $\hookrightarrow$  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  $X = \{W_1, R_1\}$

Tactic	Selection
$(W_1, W_2, R_1, R_2)$	$\iota$
$(false, true, false, true)$	$\{W_2, R_2\}$
$(false, false, false, true)$	$\{R_2\}$

- $(false, false, true, false)$  is not  $X$ -minimal:  
 $\hookrightarrow (false, true, false, true)$  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:

Problem	Related AI Problem
Strategy	SAT
All-Best-Approximations	ALL-MC
All-Tactics	ALLSAT
All-Minimal-Tactics	ALL-MINIMAL
All-X-Minimal-Tactics	ALL-X-MINIMAL
Tactic	MODEL
Minimal Tactic	MIN-MODEL

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

