Offer elaboration and selection under uncertainty using a multi-criteria approach in a bidding process

Abdourahim Sylla, Thierry Coudert, Elise Vareilles, Laurent Geneste and Michel Aldanondo
Agenda

- Context and problematic
- Representation of imprecise and uncertain values for a criterion
- Mono-criterion dominance relations
- Multi-criteria dominance relations and Pareto-front
- Illustrative application
- Conclusion
Context, problematic and propositions (1/3)

Context: OPERA Project (funded by ANR – 2016-2020)

Goal: To help systems contractors to elaborate, to evaluate and to select bids
- Tool based on the use of formalized knowledge and experience feedbacks
- Multicriteria decision making to select one technical bid solution to propose

Bidding Process (adapted from Chalal et al. 2008):
Context, problematic and propositions (1/3)

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Bidding Process (adapted from Chalal et al. 2008):

Scope of OPERA

- Detection of bid opportunity
- Analysis of the bid opportunity
- Elaboration of the technical bid solution
  - Definition and estimation of the potential technical bid solutions
  - Selection of the best technical bid solution
  - Definition of the bid mark-up size and commercial bid solution
- Submission of the final bid proposal
  - Accepted
  - Not accepted

Sylla et al. 2017
Context, problematic and propositions (2/3)

Context and problematic

Engineer To Order (ETO)

- Relevant potential technical bid solutions are not completely defined
- Knowledge is not fully available to estimate the potential solutions
- There are a lot of uncertainties related to the performances of the potential solutions
  → Confidence of the bidder is generally low – Issue: How to evaluate it and choose a solution under uncertainty
- A multi-criteria decision support approach is required
  → To help the bidder to select one solution within a multi-criteria decision space under uncertainty
Context, problematic and propositions (3/3)

- Propositions
  - A three steps approach

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Engineer To Order

1. Representation of the values of the decision criteria as possibility distributions
2. Computation of mono-criterion dominance relations
3. Computation of multi-criteria dominance relations
   → Solutions comparison
   → Construction of a Pareto front

Technical bid solution to propose to the customer
```
Representing values of a criterion as a possibility distribution

The confidence indicators: OCS and OCP: They provide information on the ability to finalize the design and implement the technical system according to the customer's expectations (e.g. Cost and delivery date).

The possibility distribution for the possible values of a criterion

For a solution $S_j$, $\mu_{S_j}^k$ is the possibility distribution of the values $v_k$ for the criterion $k$

- $[a, d]$ is the domain of the criterion (possible values)
- $[b, c]$ is the interval of the fully possible values for the criterion $k$,
- $e$ is the possibility to have a criterion value in $[a, b] \cup [c, d]$
- it depends on the confidences OCS and OCP

$$e = 1 - (\alpha \times OCS + (1 - \alpha) \times OCP) / 9$$

$$\alpha = \begin{cases} 
0 & k \text{ characterizes the process} \\
1 & k \text{ characterizes the system} \\
0.5 & k \text{ characterizes both} 
\end{cases}$$
Representing values of a criterion as a possibility distribution

The possibility distribution for the possible values of a criterion

For each criterion and each solution to evaluate, an ETO configuration tool allows:

- To determine the design parameters values
- To determine the project parameters values
- To evaluate the value of the criterion + uncertainty \{a, b, c, d, e\}

ETO Configuration tool

Requirements

Sylla et al. 2017

Criterion 1 + \{a, b, c, d, e\}
Criterion 2 + \{a, b, c, d, e\}
Criterion k + \{a, b, c, d, e\}
Comparison of two solutions by means of the Dubois and Prade’s dominance indexes


**Possibility Of Dominance (POD)**

It is the possibility that the values that can be affected to $S_j^k$ are not greater than those that can be affected to $S_i^k$.

$$POD_{S_j < S_i}^k = \sup_{x} \min(\mu_{S_i}^k(x), \sup_{y \leq x} \mu_{S_j}^k(y))$$

**Possibility of Strict Dominance (PSD)**

It is the possibility that the values that can be affected to $S_j^k$ are smaller than those that can be affected to $S_i^k$.

$$PSD_{S_j < S_i}^k = \sup_{x} \min(\mu_{S_i}^k(x), \inf_{y \geq x} (1 - \mu_{S_j}^k(y)))$$

**Necessity Of Dominance (NOD)**

It is the necessity that the values that can be affected to $S_j^k$ are not greater than those that can be affected to $S_i^k$.

$$NOD_{S_j < S_i}^k = \inf_{x} \max((1 - \mu_{S_i}^k(x)), \sup_{y \leq x} \mu_{S_j}^k(y))$$

**Necessity of Strict Dominance (NSD)**

It is the necessity that the values that can be affected to $S_j^k$ are smaller than those that can be affected to $S_i^k$.

$$NSD_{S_j < S_i}^k = \inf_{x} \max((1 - \mu_{S_i}^k(x)), \inf_{y \geq x} (1 - \mu_{S_j}^k(y)))$$
Mono-criterion dominance relations (2/3)

- Mono-criterion dominance relations

- Comparison of two distributions of possibilities $S_j$ and $S_i$

- Computation of the four indexes of Dubois and Prade

- Determination of the four mono-criterion dominance relations
  - **CD:** Certain Dominance
  - **SPD:** Strong Possibility of Dominance
  - **WPD:** Weak Possibility of Dominance
  - **IND:** Indifference

\[
\begin{align*}
D_{S_j < S_i}^k &= [POD_{S_j < S_i}^k, PSD_{S_j < S_i}^k, NOD_{S_j < S_i}^k, NSD_{S_j < S_i}^k] \\
D_{S_i < S_j}^k &= [POD_{S_i < S_j}^k, PSD_{S_i < S_j}^k, NOD_{S_i < S_j}^k, NSD_{S_i < S_j}^k]
\end{align*}
\]
Mono-criterion dominance relations (3/3)

- The rules of the four mono-criterion dominance relations

**Certain Dominance (CD)**

$S_j$ certainly dominates $S_i$ if:

$$D_{S_j < S_i}^k(4) = 1$$

**Strong Possibility of Dominance (SPD)**

$S_j$ dominates $S_i$, not certainly, but with strong possibility if:

$$[D_{S_j < S_i}^k(4) < 1] \land \forall t \in \{1, ..., 4\}; D_{S_j < S_i}^k(t) > D_{S_i < S_j}^k(t)$$

**Weak Possibility of Dominance (WPD)**

$S_j$ dominates $S_i$, not certainly, but with a weak possibility if:

$$\exists t \in \{1, ..., 4\}: D_{S_i < S_j}^k(t) \leq D_{S_j < S_i}^k(t) \land \forall l \neq t: D_{S_i < S_j}^k(l) > D_{S_j < S_i}^k(l)$$

**Indifference (IND)**

$S_j$ and $S_i$ are indifferent if:

$$\forall t \in \{1, 4\}: D_{S_i < S_j}^k(t) = D_{S_j < S_i}^k(t) \land [D_{S_i < S_j}^k(2) > D_{S_j < S_i}^k(2)] \land [D_{S_i < S_j}^k(3) < D_{S_j < S_i}^k(3)]$$
Multi-criteria dominance relations

- The three multi-criteria dominance relations

**Certain Pareto-Dominance (CPD)**
- \( S_j \) certainly Pareto-dominates \( S_i \) if:
  - for each criterion, \( S_j \) certainly dominates \( S_i \)
  \[
  \forall k \in \{1, ..., n\} : S_j \prec_{CD} S_i
  \]

**Strong Pareto-Dominance (SPD)**
- \( S_j \) Pareto-dominates \( S_i \), not certainly, but with strong possibility if:
  - \( S_j \) does not certainly Pareto-dominates \( S_i \), but there is at least one criterion for which: \( S_j \) certainly dominates \( S_i \) or \( S_j \) dominates \( S_i \) with strong possibility.
  \[
  \exists k \in \{1, ..., n\} : (S_j \prec_{CD} S_i) \lor (S_j \prec_{SPD} S_i) \lor (\forall l \neq k : (S_j \prec_{SPD} S_i) \lor (S_j \prec_{WPD} S_i) \lor (S_j \prec_{IND} S_i))
  \]

**Weak Pareto-Dominance (WPD)**
- \( S_j \) Pareto-dominates \( S_i \), not certainly, but with a weak possibility if:
  - \( S_j \) does not certainly Pareto-dominates \( S_i \), and \( S_j \) does not Pareto-dominates \( S_i \) with a strong possibility. But, there is at least one criterion for which \( S_j \) dominates \( S_i \) with weak possibility.
  \[
  \exists k \in \{1, ..., n\} : (S_j \prec_{WPD} S_i) \land (\forall l \neq k : (S_j \prec_{WPD} S_i) \lor (S_j \prec_{IND} S_i))
  \]
Construction of the Pareto-front

The Pareto-front is the set of non-dominated solutions

Pareto-Dominance Requirement → Acceptable level of uncertainty

- It is given by the decision maker, PDR = {CPD, SPD or WPD}

<table>
<thead>
<tr>
<th>Pareto-dominance requirement</th>
<th>Pareto-dominance condition of $S_j$ over $S_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPD</td>
<td>$S_j \prec_{CPD} S_i$</td>
</tr>
<tr>
<td>SPPD</td>
<td>$(S_j \prec_{CPD} S_i) \lor (S_j \prec_{SPPD} S_i)$</td>
</tr>
<tr>
<td>WPPD</td>
<td>$(S_j \prec_{CPD} S_i) \lor (S_j \prec_{SPPD} S_i) \lor (S_j \prec_{WPPD} S_i)$</td>
</tr>
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</table>
Illustrative application

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Solutions</th>
<th>Cost</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,2</td>
<td>SPD</td>
<td>SPD</td>
</tr>
<tr>
<td></td>
<td>1,3</td>
<td>SPD</td>
<td>SPD</td>
</tr>
<tr>
<td></td>
<td>2,3</td>
<td>WPD</td>
<td>IND</td>
</tr>
</tbody>
</table>

Pareto Dominance

<table>
<thead>
<tr>
<th>Sj</th>
<th>Pareto Dominance</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SPPD</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>SPPD</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>WPPD</td>
<td>3</td>
</tr>
</tbody>
</table>

PDR = SPD

PF = {1}
Conclusion and perspectives

• We have proposed an approach to support a multi-criteria decision making process when selecting the most interesting technical bid solution in a bidding process.

• The approach gathers three major propositions:
  • a method to represent the estimation of a decision criterion as a possibility distribution,
  • four possibilistic mono-criterion dominance relations to compare the solutions following a single criterion,
  • three possibilistic multi-criteria dominance relations to compare the solutions following several criteria and to determine the Pareto-front.

• In the bidding process, where the potential technical bid solutions are not completely defined, this approach enables the bidders to make good decisions while taking into account the uncertainty related to the estimation of the decision criteria.

• Experiments have been done by developing a tool on Matlab

• The next step is the integration within the OPERA mock-up and the end-users validation (four industrial partners)
Thank you for your attention