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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

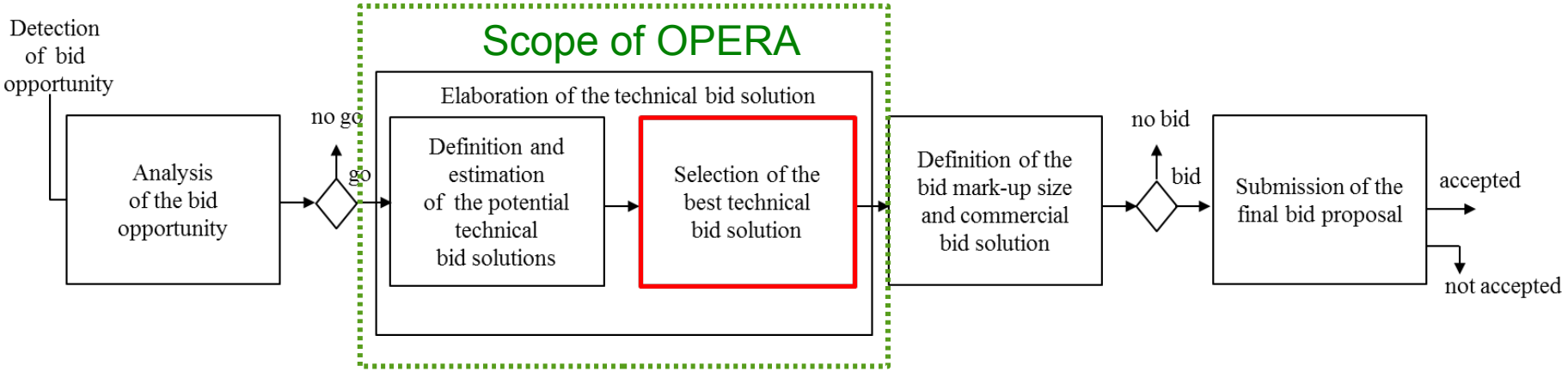
Context, problematic and propositions (1/3)

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):



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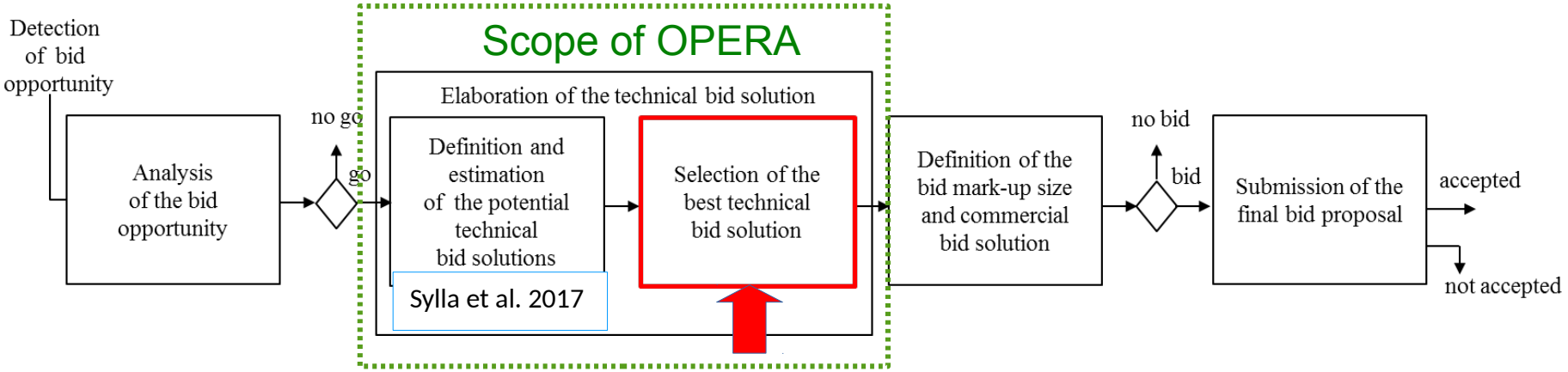


Context, problematic and propositions (2/3)

❑ 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

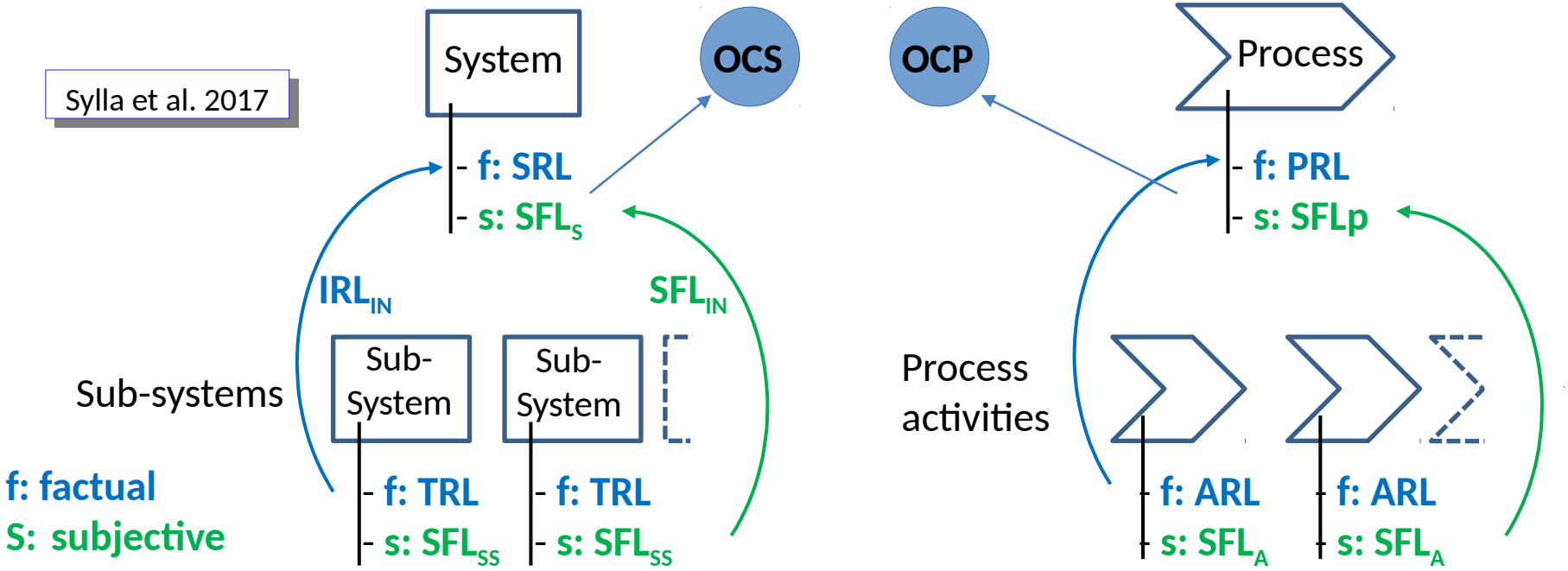
Engineer To Order

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).



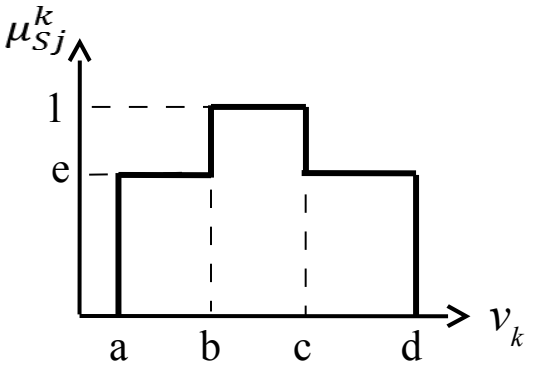
Sylla, A., Vareilles E., Coudert, T., Aldanondo M., Geneste, L., Readiness, feasibility and confidence: how to help bidders to better develop and assess their offers, **International Journal of Production Research**, 2017, Vol. 55, No. 23, pp. 7204–7222.

Representing values of a criterion as a possibility distribution

The possibility distribution for the possible values of a criterion

For a solution S_j, μ_{Sj}^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] U [c, d]**
  - **– it depends on the confidences OCS and OCP**



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

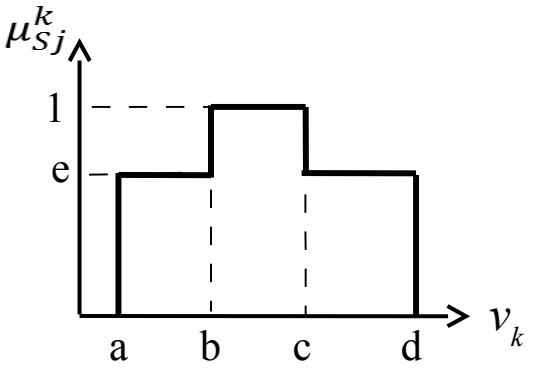
$$\alpha = \begin{cases} 0 & if \quad \text{k} \; characterizes \, the \, process \\ 1 & if \quad \text{k} \; characterizes \, the \, system \\ 0.5 & if \quad \text{k} \; characterizes \, both \end{cases}$$

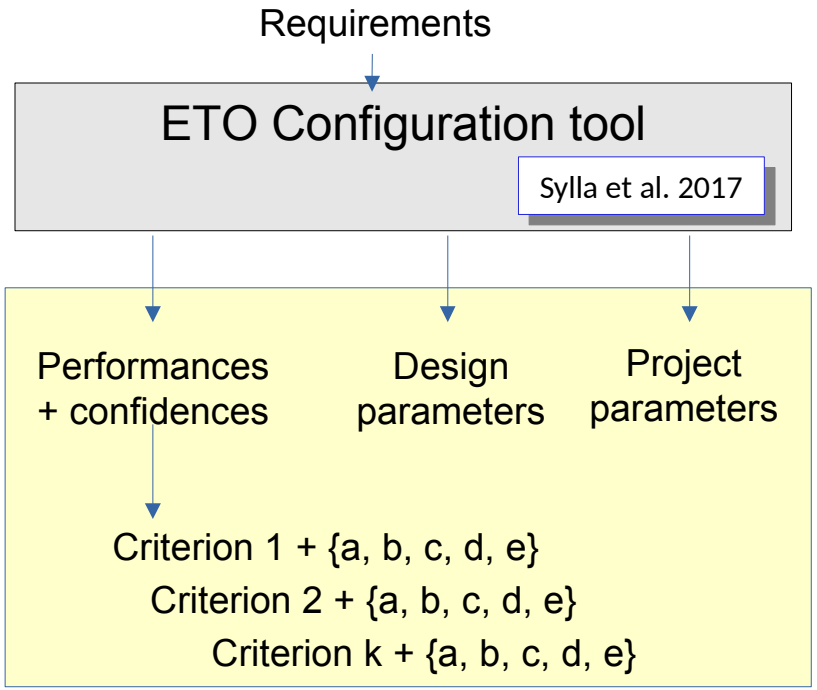
Representing values of a criterion as a possibility distribution

The possibility distribution for the possible values of a criterion

For each crierion 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}





Mono-criterion dominance relations (1/3)

Comparison of two solutions by means of the Dubois and Prade's dominance indexes

Dubois, Didier, and Henri Prade. 2012. *Possibility Theory: An Approach to Computerized Processing of Uncertainty*. Springer Science & Business Media.

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.

$$POD^k_{Sj \prec Si} = \sup_x \min(\mu^k_{Si}(x), \sup_{y \leq x} \mu^k_{Sj}(y))$$

Possibility of Strict Dominance (PSD)

It is the possibility that the values that can be affected to are smaller than those that can be affected to .

$$PSD^k_{Sj \prec Si} = \sup_x \min(\mu^k_{Si}(x), \inf_{y \geq x} (1 - \mu^k_{Sj}(y))$$

Necessity Of Dominance (NOD)

It is the necessity that the values that can be affected to are not greater than those that can be affected to .

$$NOD^k_{Sj \prec Si} = \inf_x \max((1 - \mu^k_{Si}(x)), \sup_{y \leq x} \mu^k_{Sj}(y))$$

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.

$$NSD^k_{Sj \prec Si} = \inf_x \max((1 - \mu^k_{Si}(x)), \inf_{y \geq x} (1 - \mu^k_{Sj}(y))$$

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

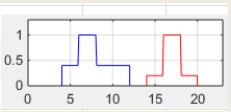
$$\begin{cases} D^k_{Sj \prec Si} = [POD^k_{Sj \prec Si}, PSD^k_{Sj \prec Si}, NOD^k_{Sj \prec Si}, NSD^k_{Sj \prec Si}] \\ D^k_{Si \prec Sj} = [POD^k_{Si \prec Sj}, PSD^k_{Si \prec Sj}, NOD^k_{Si \prec Sj}, NSD^k_{Si \prec Sj}] \end{cases}$$

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

Mono-criterion dominance relations (3/3)

The rules of the four mono-criterion dominance relations

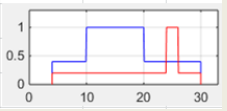
	PoD	PsD	NoD	NsD
$D_{Sj \prec Si}$	1	1	1	1
$D_{Si \prec Sj}$	0	0	0	0



Certain Dominance (CD)

S_j certainly dominates S_i if: $D^k_{Sj \prec Si}(4) = 1$

	PoD	PsD	NoD	NsD
$D_{Sj \prec Si}$	1	0,6	0,8	0,6
$D_{Si \prec Sj}$	0,4	0,4	0,2	0



Strong Possibility of Dominance (SPD)

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

$$[D^k_{Sj \prec Si}(4) < 1)] \wedge [\forall t \in \{1, ..., 4\}; D^k_{Sj \prec Si}(t) > D^k_{Si \prec Sj}(t)]$$

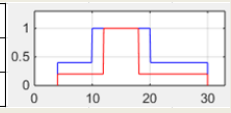
	PoD	PsD	NoD	NsD
$D_{Sj \prec Si}$	1	0,6	0,4	0,2
$D_{Si \prec Sj}$	0,8	0,2	0,8	0

Weak Possibility of Dominance (WPD)

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

$$[\exists t \in \{1, ..., 4\} : D^k_{Si \prec Sj}(t) \leq D^k_{Sj \prec Si}(t)] \wedge [\forall l \neq t : D^k_{Si \prec Sj}(l) > D^k_{Sj \prec Si}(l)]$$

	PoD	PsD	NoD	NsD
$D_{Sj \prec Si}$	1	0,2	0,8	0
$D_{Si \prec Sj}$	1	0,8	0,2	0



Indifference (IND)

S_j and S_i are indifferent if:

$$[\forall t \in \{1, 4\} : D^k_{Si \prec Sj}(t) = D^k_{Sj \prec Si}(t)] \wedge [D^k_{Si \prec Sj}(2) > D^k_{Sj \prec Si}(2)] \wedge [D^k_{Si \prec Sj}(3) < D^k_{Sj \prec Si}(3)]$$

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.

$$[\exists k \in \{1, ..., n\} : (S_j \prec_{CD} S_i) \vee (S_j \prec_{SPD} S_i)] \wedge [\forall l \neq k : (S_j \prec_{SPD} S_i) \vee (S_j \prec_{WUD} S_i) \vee (S_j \, IND \, S_i)]$$

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.

$$[\exists k \in \{1, ..., n\} : (S_j \prec_{WPD} S_i)] \wedge [\forall l \neq k : (S_j \prec_{WPD} S_i) \vee (S_j \, IND \, S_i)]$$

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}

Pareto-dominance requirement	Pareto-dominance condition of S_j over S_i
CPD	$S_j \prec_{CPD} S_i$
SPPD	$(S_j \prec_{CPD} S_i) \vee (S_j \prec_{SPPD} S_i)$
WPPD	$(S_j \prec_{CPD} S_i) \vee (S_j \prec_{SPPD} S_i) \vee (S_j \prec_{WPPD} S_i)$

⇨ Pareto-front

Illustrative application

Solutions	Criteria	
	Cost	Duration
1,2	SPD	SPD
1,3	SPD	SPD
2,3	WPD	IND

mono-criterion dominance relations

Sj	Pareto Dominance	Si
1	SPPD	2
1	SPPD	3
2	WPPD	3

PDR = SPD

PF = {1}

Solutions	Criteria		
	Cost	Duration	OCS = OCP
1	[6 8]	[6 8]	0.6
2	[10 20]	[10 20]	0.6
3	[20 24]	[12 18]	0.6

Dubois and Prade's indices

Solutions	Criteria							
	Cost				Duration			
	PoD	PsD	NoD	NsD	PoD	PsD	NoD	NsD
1,2	$D_{Sj<Si}$ 0,4	0,4	0,4	0	$D_{Sj<Si}$ 0,4	0,4	0,4	0
	$D_{Si<Sj}$ 1	0,6	0,6	0,6	$D_{Si<Sj}$ 1	0,6	0,6	0,6
1,3	$D_{Sj<Si}$ 0.4	0,4	0,4	0	$D_{Sj<Si}$ 0.4	0,4	0,4	0
	$D_{Si<Sj}$ 1	0,6	0,6	0.6	$D_{Si<Sj}$ 1	0,6	0,6	0.6
2,3	$DP_{y<x}$ 1	0,6	0,6	0	$D_{Sj<Si}$ 1	0,6	0,4	0
	$DP_{x<y}$ 1	0,4	0,4	0	$D_{Si<Sj}$ 1	0,4	0,6	0

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