Supplier - Manufacturer Relationship Modeling through Satisficing Games ⋆

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Abstract: In this paper we propose a framework to analyze supplier - manufacturer relationship within a supply chain in two steps: the first step put the manufacturer in the position of a decision maker who want to select a short list of suppliers from a prospective and possibly huge list to respond to some of its primary objectives; in a second stage a negotiation process will be engaged between manufacturer and a selected supplier in order to establish the most mutual profitable contract. Bipolar analysis that is evaluating a possible alternative decision by assessing its degree of achieving pursued objectives and its degree of preventing that achievement or degree of resources consumption is highlighted as the main paradigm that guid decision process in the two steps. By so doing, satisficing games theory is used as the mathematical tool to modelize and analyze these decision making situations.

Keywords: Decision Evaluation, Multiobjectives Optimisation, Multiattributes Optimisation, Satisficing Game Theory, Analytic Hierarchy Process, BOCR Analysis, Supplier selection, Negotiation Process.

1. INTRODUCTION

Supply chain management is one of the fastest growing subject in management science, particularly in today globalized economy. Supply chain management include different activities such as purchasing management, transportation management, warehouse management, inventory management, strategic sourcing, and partners relationships management. One important issue raised by the globalization of activities is how to identify and assess opportunities and risks related to these activities among which possible failure of quality of final product sold to customers. For long time, the primary concern in supply chain management, mainly in the selection of suppliers has been the costs of raw material that count up to 50% of the final price of a product in some industry such as automotive industry, see Weber (1993), so that purchasing activity with suppliers selection has been considered as the capital decision, see Nydick and Hill (1992) and Mobolurin (1995), that determines the long term viability of the company, see Thompson (1990). But quality issues nowadays are becoming a real concern for companies; as a proof of this statement, let us mention the 2007 recall of Berko Electric Toe-Space Heaters made in US, the recall of backpack blowers made in Japan, the recall of toys and pet food made in China and recently largely mediatized problem of Fauteil or Bottes made in China that cause skin harms to their owners in France, to name few. Such events are very destabilizing for companies that have their main market in developed countries where standards and norms as well as the public opinion are highly developed. Hence, along with classical criteria or attributes such as raw materials price and transportation price, companies must include another dimension related to the risk of quality failure and/or opportunity of quality improvement in their relationship with their suppliers. Along with quality failure of the final product, there may exist other sources including operational failure of the manufacturer process including packaging of the final product to be supplied to customers and/or transportation from manufacturer to customers conditions, quality failure of supplied components and part that can have origin in the failure of suppliers operations, transportation system from suppliers to manufacturer or from manufacturer to customers. Managing risk related to quality failure in supply chain on the manufacturer side is twofold: manage the upstream risk that is its relationship with its suppliers and the downstream risk related to customers. Another concerns in relation with sourcing and production location among others are oil price volatility and labor costs in emerging markets; a short discussion regarding these issues has been considered in Simchi-Levi *et al.* (2012). Relation with customers is mainly in one way that is customers desires act as constraints for manufac-

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turer so that risk management strategy on this side will consist in warranties manufacturer will offer to customers. In this paper we will concentrate in analyzing activities around the suppliers - manufacturer relationships with the manufacturer as the main partner. On the suppliers side, things are more complex as a certain common objectives of doing business may lead to cooperation strategies; two main approaches are used in this case: performance based contracts and multi-sourcing and closer collaboration. Whereas, the first approach is a matter of the manufacturer who must select and diversify its partners, the second approach necessitate a collaboration of both the manufacturer and the supplier where each partner must act when considering the concerns of the other partner. These approaches can be considered sequentially where the manufacturer will first select a set of potential partners and then engage a close collaboration procedure with each selected partner. Of course the context that is the business environment of each partner will have a great influence on these strategies. This framework is summarized as the following:

- the supplier is characterized by some *attributes* that constitute valuable information for manufacturer during selection process; his *objectives* that are concerns manufacturer must take into account during collaboration phase and *actions or decisions* he may set up to respond to manufacturer concerns;
- the manufacturer have *objectives* that are balanced with suppliers attributes during selection process and constitute concerns supplier must consider during collaboration and *decisions* to set up in order to respond eventually to suppliers concerns.

This paper is mainly concerned by selection and negotiation processes. Indeed, we consider that from a prospective search process, a manufacturer has identified a list of potential suppliers from which he will select a short list of suppliers with which he wants to work. Short list selection process is typically a multi-criteria / multiobjectives decision making problem that will be considered in BOCR analysis framework, see Tchangani and Pérès (2010); BOCR stands for a decision process that evaluates available options, given an objective, in terms of benefit (B) and opportunity (O) by aggregating certain (respectively uncertain) attributes that support (work towards the achievement of the objective) this objective on one side and cost (C) and risk (R) by aggregating certain (respectively uncertain) attributes that reject (work against the achievement of the objective) that objective; a method to evaluate risk component can be found in Tchangani (2011). Negotiation process is a multi-agent decision making problem where the suited paradigm is game theory. Classically, game theory framework has been established with pure competition assumption whereas in practice (mainly in our supplier chain management problem) players that are actually partners may have interest to cooperate. Main issues in classical cooperative game theory have concerned how to share the created value from cooperation; to this purpose some power indices such as Shapley index are introduced; in supply chain literature this index is used, for instance, by Pan (2010) to share value from reduction of CO_2 emission when enterprises form a pool for their logistics activities. In Talluri (2002), a model to evaluate alternative bids in buyer-seller negotiation and selection process is formulated. Satisficing game theory is a well suited tool to tackle cooperation problem because it highlights bipolar nature of human decision making, that is given an alternative, one evaluates its positive aspects and its negative aspects separately and then balance them. Satisficing notion has been already considered in supply chain management literature; for instance, He and Khouja (2011) and Shi and Chen (2007) employed this notion in supplier-retailer contracts evaluation. But one must notice that satisficing notion considered in these publications differ from that being considered in this paper in the sense that satisficing in this paper is a point of view that highlights bipolarity of attributes with regard to objectives whereas in the former publications satisficing is related to the attainment of a threshold of a certain indicator. Collaborative planning between supply chain partners based on a negotiation scheme using integer programming method has been considered in Dutek and Stadtler (2005). The remainder of this paper is organized as follows: in the second section the problem of selecting a short list of suppliers by a manufacturer is considered with a recall of relevant basics of a single decision maker satisficing game theory; the third section presents the negotiation procedure with a prior recall of multi persons satisficing game; the fourth section considers an illustration and section fives concludes the paper.

2. SHORT LIST SELECTION OF SUPPLIERS BY A MANUFACTURER

Supplier selection problems have been treated in supply chain management literature using techniques such as AHP and QFD analysis, see for instance Bhattacharya *et al.* (2010); other authors raised the issues of supplier-supplier relationships as a strategic objective for the buyer, see Wu and Choi (2005) where theories of these issues have been built from case studies. In this section we consider the following problem: a manufacturer wants to select a short list of potential suppliers; for this end the manufacturer will determine attributes of suppliers that will be used; the evaluation process will be based on bipolarity analysis in the framework of satisficing game so that we will recall in the following subsection materials of this framework that are relevant to our approach.

2.1 Single decision maker satisficing game

Let us consider a universe $\mathcal{U}$ of alternatives; then for each alternative $u \in \mathcal{U}$, a *selectability measure* $\mu_S(u)$ and a *rejectability measure* $\mu_R(u)$ are defined to measure the degree to which u works towards success in achieving the decision maker's goal and costs associated with this alternative respectively. This pair of measures called *satisfiability measures* are *mass functions* (they have the mathematical structure of the probabilities Stirling (2003)): they are non negative and sum to one on $\mathcal{U}$. The following definition then gives the set of options arguable to be satisficing because for these options, the "benefit" expressed by the measure μ_S exceeds the cost expressed by the measure μ_R with regard to the index of boldness q.

Definition 1. The satisficing set $\Sigma_q \subseteq \mathcal{U}$ with the index of boldness q is the set of alternatives defined by equation (1)

$$\Sigma_q = \{u \in \mathcal{U} : \mu_S(u) \geq q\mu_R(u)\}. \quad (1)$$

The boldness index q can be used to adjust the aspiration level: increase q if Σ_q is too large or on the contrary decrease q if Σ_q is empty for instance.

But for a satisficing alternative there can exist other satisficing alternatives that are better (having more selectability and at most the same rejectability or having less rejectability and at least the same selectability) than the previous one; it is obvious that in this case any rational decision maker will prefer the later alternatives and we say that the later alternatives dominate the former one. So the interesting set is that containing good enough alternatives that are not dominated. Let us define by $\mathcal{D}(u)$ the set of alternatives that dominate u, that is, equation (2)

$$\mathcal{D}(u) = \{v \in \mathcal{U} : \mu_R(v) \leq \mu_R(u) \text{ and } \mu_S(v) \geq \mu_S(u)\} \quad (2)$$

with at least one strict inequality; then the set $\mathcal{E}$ of non dominated alternatives known as *equilibria* is given by equation

$$\mathcal{E} = \{u \in \mathcal{U} : \mathcal{D}(u) = \varnothing\} \quad (3)$$

and *non dominated or good enough* alternatives at boldness index of q set $\mathcal{S}_q$ is given as (4)

$$\mathcal{S}_q = \mathcal{E} \cap \Sigma_q. \quad (4)$$

Notice that this set can always be rendered non empty as one can always adjust the size of Σ_q and as the equilibria set $\mathcal{E}$ cannot be empty by construction. $\mathcal{S}_q$ or Σ_q constitute the short list of selected suppliers. Formulating the selection problem as a satisficing game to obtain the short list return to defining the satisfiability measures μ_S and μ_R. This process must take into account two things: manufacturer objectives and suppliers attributes.

2.2 Short list selection process

As stated in previous section, when selecting suppliers, a manufacturer will consider achieving some objectives; therefore attributes of a supplier he/she will use to evaluate it will be in relation with these objectives. Many attributes can characterize suppliers, see for instance Beyoucef *et al.* (2003) for a comprehensive study of such attributes and Mohanty and Gahan (2011) where an important list of possible attributes that can be used in suppliers selection process has been established from an empirical study of Indian manufacturing industry. To structure the elicitation and assessment of these attributes we propose BOCR framework built around the notions of supportability and rejectability of attributes with regard to pursued objectives, see Tchangani (2010), and the uncertainty. By so doing, the selectability measure μ_S and the rejectability measure μ_R will be obtained by aggregating positive aspects that is benefit and opportunity and negative aspects, costs and risk respectively to fulfill the single decision maker satisficing game theory framework. We will not completely describe how to obtain parameters μ_S and μ_R; interested reader may refer to Tchangani *et al.* (2012) for this purpose .

3. MUTUAL PROFITABLE CONTRACT ESTABLISHMENT

Once a short list of suppliers has been constituted, manufacturer will consider establishing a contract with each one in a win-win way. It means that each partner must take into account objectives or desires of other partners. A framework that permit such decision making analysis is the multi-persons satisficing game theory, see Stirling (2003). To this end, we introduce in the following subsection basics of this theory that will permit us to formulate manufacturer - supplier contracting problem in a second subsection.

3.1 Multi - persons satisficing game

Previous satisficing game definition concerns only one decision maker case; but in general a decision problem will involve many decision makers or actors that could interact. In this case the satisficing game is defined as given by the following definition.

Definition 2. A satisficing game involving n actors or decision makers is defined by the following data, equation (5)

$$\left\langle \mathcal{D} = \mathcal{D}_1 \times \mathcal{D}_2 \times ... \times \mathcal{D}_n,\ \mu_{S_1S_2..S_n},\ \mu_{R_1R_2..R_n} \right\rangle \quad (5)$$

where

- $\mathcal{D} = \mathcal{D}_1 \times \mathcal{D}_2 \times ... \times \mathcal{D}_n$ is the set of the joint options and $\mathcal{D}_i$ is the options set of actor i, and
- $\mu_{\mathcal{S}} = \mu_{S_1S_2..S_n}$ and $\mu_{\mathcal{R}} = \mu_{R_1R_2..R_n}$ are joint selectability and joint rejectability measures respectively.

Let us denote by (see equation (6)),

$$\mathbf{d} = (\, d_1,\, d_2,\, ...,\, d_n\,), \quad (6)$$

where $d_i \in \mathcal{D}_i$, the joint option and $\mathbf{d}_{-i}$ the joint option where that of actor i is fixed. Given the former joint measures, one can deduce the marginal measures μ_{S_i}/μ_{R_i} for each actors as given by equations (7) - (8)

$$\mu_{S_i}(d_i) = \sum_{d_j^l \in \mathcal{D}_j, j \neq i} \mu_{\mathcal{S}}(\mathbf{d}_{-i}) \quad (7)$$

$$\mu_{R_i}(d_i) = \sum_{d_j^l \in \mathcal{D}_j, j \neq i} \mu_{\mathcal{R}}(\mathbf{d}_{-i}). \quad (8)$$

But as actors will generally influence each other, one define in fact an interdependency measure $\mu_{\mathcal{SR}}$ as shown by equation (9)

$$\mu_{\mathcal{SR}}(\mathbf{d}; \boldsymbol{\delta}) \quad (9)$$

where $\mathbf{d}, \boldsymbol{\delta} \in \mathcal{D}$ which can be elicited using praxeic network (see Stirling (2003)) that are similar to Bayesian network (see Jensen (2001)) because of the probabilistic nature of satisfiability measures. From this interdependency measure, the joint selectability and rejectability measures are determined by marginalization as given by equations (10)-(11),

$$\mu_{\mathcal{S}}(\mathbf{d}) = \sum_{\boldsymbol{\delta} \in \mathcal{D}} \mu_{\mathcal{SR}}(\mathbf{d}; \boldsymbol{\delta}); \quad (10)$$

$$\mu_{\mathcal{R}}(\boldsymbol{\delta}) = \sum_{\mathbf{d} \in \mathcal{D}} \mu_{\mathcal{SR}}(\mathbf{d}; \boldsymbol{\delta}). \quad (11)$$

Negotiation scheme For the multi - persons satisficing case, the analysis in terms of satisficing sets can be carried up in the point of view of the community or in the point of view of an individual actor. Each member i of the community comes with his own boldness index q_i and let us denote by $\mathbf{q} = (\ q_1,\ q_2,\ ...,\ q_n\ )$ the boldness indices vector and $q_L = \min\{\ q_1,\ q_2,\ ...,\ q_n\ \}$ the least bold value then the following materials that can be used for negotiation are obtained. Let us denote by $\Sigma^i_{q_i}$ the satisficing set of member i as given by the following equation (12)

$$\Sigma^i_{q_i} = \left\{d_i \in \mathcal{D}_i : \mu_{S_i}(d_i) \geq q_i \mu_{R_i}(d_i)\right\}; \quad (12)$$

the joint satisficing set at an arbitrary boldness index q is then given by the following definition.

Definition 3. The joint satisficing set $\mathbf{\Sigma}_q$ at the boldness index q is given by equation (13)

$$\mathbf{\Sigma}_q = \{\mathbf{d} \in \mathcal{D} : \mu_{\mathcal{S}}(\mathbf{d}) \geq q\mu_{\mathcal{R}}(\mathbf{d})\} \quad (13)$$

For negotiation purpose it is important to characterize for each partner what can be considered to be a compromise set, this is given by the following definition.

Definition 4. The set of all decision vectors $\mathbf{d}$ that are jointly satisficing at boldness index q_L and also satisficing for decision maker i denoted $\mathbf{C}_i$ is called his compromise set given by the following equation (14)

$$\mathbf{C}_i = \left\{\mathbf{d} = (\ d_1,\ d_2,\ ...,\ d_n\ ) \in \mathbf{\Sigma}_{q_L} : d_i \in \Sigma^i_{q_i}\right\}. \quad (14)$$

It is known that the compromise set is always non empty, (see Stirling (2003)); the intersection of compromise set is known as the satisficing imputation set at the boldness index vector $\mathbf{q}$ and given by the following definition.

Definition 5. A joint decisions vector $\mathbf{d} = (\ d_1,\ d_2,\ ...,\ d_n\ )$ is a satisficing imputation at boldness index vector $\mathbf{q}$ if the following equation (15) is valide

$$\mu_{\mathcal{S}}(\mathbf{d}) \geq q_L \mu_{\mathcal{R}}(\mathbf{d}) \text{ and } \mu_{S_i}(d_i) \geq q_i \mu_{R_i}(d_i)\ \forall\ i = 1,\ 2,\ ..,\ n. \quad (15)$$

The set of satisficing imputation set at boldness index vector $\mathbf{q}$ denoted $\mathbf{N}_q$ is given by equation (16)

$$\mathbf{N}_q = \cap_{i=1}^n \mathbf{C}_i. \quad (16)$$

The set $\mathbf{N}_q$ contains joint decision that provides benefit to the group while ensuring that each decision makers preferences are not compromised. If $\mathbf{N}_q = \varnothing$ then no compromise is possible and some decision makers must lower their standards in order to reach a compromise. The algorithm of finding an imputation set is as follows:

1. each actor i forms $\Sigma^i_{q_L}$ and $\Sigma^i_{q_i}$, $i = 1,\ 2,\ ..,\ n$;
2. each actor forms its compromise set $\mathbf{C}_i$;
3. each actor broadcasts $\mathbf{C}_i$ and q_i;
4. compute the imputation set $\mathbf{N}_q = \cap_{i=1}^n \mathbf{C}_i$; if $\mathbf{N}_q = \varnothing$, decrease q_i, $i = 1,\ 2,\ ..,\ n$, and repeat previous steps until $\mathbf{N}_q \neq \varnothing$;
5. select final imputation joint decision using some criterion.

In practice and with many decision makers having huge possible decisions, interdependency satisfiability measure elicitation may be infeasible so that one may need simplified procedure that we will consider in the following paragraph to establish supplier - manufacturer negotiation procedure.

3.2 Manufacturer - supplier negotiation model

Model building In practice, manufacturer and suppliers may have a common interest in cooperating. In terms of quality assurance for instance, a supplier may accept to undertake some actions (undergo certification procedure, invest in operations improvement program, etc.) to improve its product so that the likelihood of the manufacturer quality failure is reduced whereas manufacturer will be disposed to integrate some concerns (agreement on a certain level of command per year, exclusive contract, etc.) of its suppliers in a win-win strategy. Each partner is then characterized by the following sets of decisions and objectives

$$\mathcal{D}_m = \left\{d^1_m,\ d^2_m,\ ...,\ d^{n_m}_m\right\} \text{ and } \mathcal{O}_m = \left\{o^1_m,\ o^2_m,\ ...,\ o^{p_m}_m\right\} \quad (17)$$

corresponding to manufacturer decisions and objectives, equation (17), and

$$\mathcal{D}_s = \left\{d^1_s,\ d^2_s,\ ...,\ d^{n_s}_s\right\} \text{ and } \mathcal{O}_s = \left\{o^1_s,\ o^2_s,\ ...,\ o^{p_s}_s\right\} \quad (18)$$

as decisions and objectives sets for supplier, equation (18). In a win - win strategy procedure, each partner must know options other partner is considering but not necessary their pursued objectives, so we suppose that $\mathcal{D}_m$ and $\mathcal{D}_s$ are public information at community level. The following items are necessary in order to fully define the satisficing game to analyze manufacturer - supplier relationship.

- The manufacturer will elicit the following parameters

$$\theta^S_{ms}(d^k_m/d^l_s) = \mu_{S_m/S_s}(d^k_m/d^l_s) \quad (19)$$

$$\theta^R_{ms}(d^k_m/d^l_s) = \mu_{R_m/R_s}(d^k_m/d^l_s); \quad (20)$$

representing the degree to which the manufacturer is disposed to select (equation (19)), respectively to reject (equation (20)) its decision d^k_m if supplier selects (respectively rejects) its decision d^l_s; the elicitation of this parameters may be carried up in BOCR analysis framework; one simple way to elicit them is to use an AHP analysis, see Saaty (2005), by answering questions of the form "how selectable (respect. rejectable) is option d^k_m compared to option d^j_m for manufacturer if supplier does select (respect. reject) its option d^l_s using standard AHP scale to obtain the scores $\nu^l_{S_m}(k,j)$ and $\nu^l_{R_m}(k,j)$ respectively" and finally obtain $\theta^S_{ms}(d^k_m/d^l_s)$ and $\theta^R_{ms}(d^k_m/d^l_s)$ by equations (21) and (22)

$$\theta^S_{ms}(d^k_m/d^l_s) = \frac{1}{n_m}\sum_{j=1}^{n_m}\left(\frac{\nu^l_{S_m}(k,j)}{\sum_{p=1}^{n_m}\left(\nu^l_{S_m}(p,j)\right)}\right) \quad (21)$$

$$\theta^R_{ms}(d^k_m/d^l_s) = \frac{1}{n_m}\sum_{j=1}^{n_m}\left(\frac{\nu^l_{R_m}(k,j)}{\sum_{p=1}^{n_m}\left(\nu^l_{R_m}(p,j)\right)}\right) \quad (22)$$

These parameters, of course sum to one over manufacturer decision set $\mathcal{D}_m$. The conditional rejectability $\mu_{R_m/S_s}(d^k_m/d^l_s)$ of the manufacturer for option d^k_m given the selection of option d^l_s by the supplier is complementary to $\theta^S_{ms}(d^k_m/d^l_s)$ and so is the conditional selectability $\mu_{S_m/R_s}(d^k_m/d^l_s)$ of the manufacturer for option d^k_m given the rejection of option d^l_s by the supplier to parameter $\theta^R_{ms}(d^k_m/d^l_s)$; that is they are given by the following equations (23) - (24)

$$\mu_{S_m/R_s}(d^k_m/d^l_s) = \frac{1 - \theta^R_{ms}(d^k_m/d^l_s)}{n_m - 1} \quad (23)$$

$$\mu_{R_m/S_s}(d^k_m/d^l_s) = \frac{1 - \theta^S_{ms}(d^k_m/d^l_s)}{n_m - 1} \quad (24)$$

We see then that in terms of elicitation it is not equivalent to elicit $\theta^S_{ms}(d^k_m/d^l_s)$ or $\mu_{R_m/S_s}(d^k_m/d^l_s)$; indeed we consider the situation where selection goes with selection and rejection with rejection so that parameters $\theta^S_{ms}(d^k_m/d^l_s)$ and $\theta^R_{ms}(d^k_m/d^l_s)$ must be elicited first. The same thing will be done on supplier side to define parameters $\theta^S_{sm}(d^k_s/d^l_m)$ and $\theta^R_{sm}(d^k_s/d^l_m)$.

- Each partner will propose his a priory selectability and rejectability measures $\mu^0_{S_m}(d^k_m)$ and $\mu^0_{R_m}(d^k_m)$ for manufacturer and $\mu^0_{S_s}(d^l_s)$ and $\mu^0_{R_s}(d^l_s)$ for supplier; once again this can be done in the BOCR analysis framework to obtain these parameters as (25) and (26)

$$\mu^0_{S_\times}(d^k_\times) = \frac{\alpha_\times B(d^k_\times) + (1-\alpha_\times)O(d^k_\times)}{\sum_{d^j_\times \in \mathcal{D}_\times}\left(\alpha_\times B(d^j_\times) + (1-\alpha_\times)O(d^j_\times)\right)} \tag{25}$$

$$\mu^0_{R_\times}(d^k_\times) = \frac{(1-\alpha_\times)C(d^k_\times) + \alpha_\times R(d^k_\times)}{\sum_{d^j_\times \in \mathcal{D}_\times}\left((1-\alpha_\times)C(d^j_\times) + \alpha_\times R(d^j_\times)\right)} \tag{26}$$

where $\times$ stands for m or s and $B(d^k_\times)$, $O(d^k_\times)$, $C(d^k_\times)$, and $R(d^k_\times)$ stand for benefit measure, opportunity measure, cost measure, and risk measure respectively for option $d^k_\times$, see Tchangani *et al.* (2012); $\alpha_\times$ is the risk aversion degree of actor $\times$; indeed, a risk aversion decision maker will privileged certain component for positive aspect (benefit for selectability) and penalize uncertain component for negative aspect (risk for rejectability); of course some of these measures may be not defined or ignore because of lack of information or assessment difficulties.

- From previous information, one can consider the selectability/rejectability degree, $\mu_{S_m/s}(d^k_m/d^l_s)$ and $\mu_{R_m/s}(d^k_m/d^l_s)$, of option d^k_m by manufacturer given the attitude of supplier towards its option d^l_s to be proportional to the following parameters, equations (27) and (28) respectively

$$\mu_{S_m/S_s}(d^k_m/d^l_s)\mu^0_{S_s}(d^l_s) + \mu_{S_m/R_s}(d^k_m/d^l_s)\mu^0_{R_s}(d^l_s) \tag{27}$$

$$\mu_{R_m/R_s}(d^k_m/d^l_s)\mu^0_{R_s}(d^l_s) + \mu_{R_m/S_s}(d^k_m/d^l_s)\mu^0_{S_s}(d^l_s). \tag{28}$$

To have normalized measures we define these parameters $\mu_{S_m/s}(d^k_m/d^l_s)$ and $\mu_{R_m/s}(d^k_m/d^l_s)$ as given by equations (29) and (30) respectively

$$\mu_{S_m/s}(d^k_m/d^l_s) = \frac{\theta^S_{ms}(d^k_m/d^l_s)\mu^0_{S_s}(d^l_s) + \left(\frac{1-\theta^R_{ms}(d^k_m/d^l_s)}{n_m-1}\right)\mu^0_{R_s}(d^l_s)}{\mu^0_{S_s}(d^l_s) + \mu^0_{R_s}(d^l_s)} \tag{29}$$

$$\mu_{R_m/s}(d^k_m/d^l_s) = \frac{\theta^R_{ms}(d^k_m/d^l_s)\mu^0_{R_s}(d^l_s) + \left(\frac{1-\theta^S_{ms}(d^k_m/d^l_s)}{n_m-1}\right)\mu^0_{S_s}(d^l_s)}{\mu^0_{R_s}(d^l_s) + \mu^0_{S_s}(d^l_s)} \tag{30}$$

with similar consideration on supplier side.

- One can then define the total influence degrees of supplier on the selectability and rejectability degrees for option d^k_m of manufacturer by (31) and (32)

$$\mu_{S_m/s}(d^k_m) = \sum_{l=1}^{n_s}\omega_{sl}\mu_{S_m/s}(d^k_m/d^l_s) \tag{31}$$

$$\mu_{R_m/s}(d^k_m) = \sum_{l=1}^{n_s}\omega_{sl}\mu_{R_m/s}(d^k_m/d^l_s) \tag{32}$$

where the weights ω_{sl} verify $\sum_{l=1}^{n_s}\omega_{sl} = 1$ and represent the relative importance of each decision of supplier; with similar equations on supplier side.

- Finally one can consider defining global selectability and rejectability measures taking into account interaction, as given by equations (33)-(34)

$$\mu_{S_m}(d^k_m) = \delta_m\mu^0_{S_m}(d^k_m) + (1-\delta_m)\mu_{S_m/s}(d^k_m) \tag{33}$$

$$\mu_{R_m}(d^k_m) = \delta_m\mu^0_{R_m}(d^k_m) + (1-\delta_m)\mu_{R_m/s}(d^k_m) \tag{34}$$

for manufacturer and equations (35)-(36)

$$\mu_{S_s}(d^l_s) = \delta_s\mu^0_{S_s}(d^l_s) + (1-\delta_s)\mu_{S_s/m}(d^l_s) \tag{35}$$

$$\mu_{R_s}(d^l_s) = \delta_s\mu^0_{R_s}(d^l_s) + (1-\delta_s)\mu_{R_s/m}(d^l_s) \tag{36}$$

for supplier where $\delta_\times$ verifying $0 \le \delta_\times \le 1$ is the egoism degree of the considered partner $\times$. The joint selectability and rejectability are then considered as if partners do not interact that is they are given by equations (37) and (38) respectively.

$$\mu_{S_mS_s}(d^k_m, d^l_s) = \mu_{S_m}(d^k_m)\mu_{S_s}(d^l_s) \tag{37}$$

$$\mu_{R_mR_s}(d^k_m, d^l_s) = \mu_{R_m}(d^k_m)\mu_{R_s}(d^l_s). \tag{38}$$

Remark 1. One can easily verifies that μ_{S_m} and μ_{R_m} (respectively μ_{S_s} and μ_{R_s}) are mass functions over $\mathcal{D}_m$ (respectively over $\mathcal{D}_s$) and and that $\mu_{S_mS_s}$ and $\mu_{R_mR_s}$ are mass functions over $\mathcal{D}_m \times \mathcal{D}_s$.

Satisficing negotiation procedure Once joint selectability and rejectability has been obtained negotiation process can be considered using the procedure presented in the previous section for many decision makers case. When a non empty imputation set $C_m \cap C_s$ is obtained the final joint selected option can be obtained as given by equation (39) or using any other criterion

$$(d^i_m, d^j_s)^* = \arg\left\{\max_{(d^i_m, d^j_s)\in C_m\cap C_s}\left(\frac{\mu_{S_mS_s}(d^i_m, d^j_s)}{\mu_{R_mR_s}(d^i_m, d^j_s)}\right)\right\}. \tag{39}$$

4. ILLUSTRATIVE APPLICATION OF NEGOTIATION PROCESS

As selection process is just a single person multiattributes and multiobjectives decision making problems for which selection process described in this paper has been used to solve real world problems in literature, see for instance Tchangani (2010), Tchangani (2011), Tchangani *et al.* (2012) and references therein, we consider here an illustrative example of how a negotiation problem between a manufacturer and a supplier can be solved in practice by the approach proposed in this paper.

Let us consider the following situation: a manufacturer and its supplier are engaged in a negotiation process to establish collaborative relationship. The supplier main objective is to have a stable and long term partnership with the manufacturer whereas the manufacturer want to have high qualified and reliable suppliers. Given these objectives each partner consider analyzing the possibility to make some decisions or actions. The supplier consider the following actions:

d_s^1 : undergo a deep amelioration of his production process confirmed by certification process such ISO certification for instance; this will necessitate a great financial and human investment;
d_s^2 : just improve existing procedure by ameliorating its documentation process to keep an easy traceability of potential mistakes for example;
d_s^3 : keep actual situation.

and the manufacturer is disposed to study following options that obviously may present benefit, opportunity, cost and risk for him,

d_m^1 : sign an exclusive long term contract with the supplier;
d_m^2 : sign an exclusive short term contract;
d_m^3 : sign a simple contract not exclusive nor long term.

4.1 Prior selectability and rejectability measures elicitation

As stated previously, each partner may do a BOCR analysis taking into account available information and then his prior selectability $\mu^0_{S_\times}(d^k_\times)$ and rejectability $\mu^0_{R_\times}(d^k_\times)$ using equations (25) and (26). To this end let us consider the following scenario:

- Manufacturer is not able to estimate or pair compare benefit and cost of his options whereas he consider all options to be equally opportune because of some open possibilities in each case but that d_m^2 is "strongly more important" and d_m^1 is "very strongly more important" than d_m^3 in the standard AHP scales, see Saaty (2005).
- Supplier does consider that in terms of cost, his option d_s^2 is "strongly more important" and d_s^1 is "extremely more important" than d_s^3 whereas in terms of opportunity, d_s^2 is "moderately more important" and d_s^1 is "strongly more important" than d_s^3; he is not able to assess benefit nor risk of these options at the moment.

This consideration leads to the following prior selectability and rejectability measures (Table I):

	$\mu^0_{S_m}(d^k_m)$	$\mu^0_{R_m}(d^k_m)$		$\mu^0_{S_s}(d^k_s)$	$\mu^0_{R_s}(d^k_s)$
d_m^1	$\frac{1}{3}$	$\frac{7}{13}$	d_s^1	$\frac{5}{9}$	$\frac{9}{15}$
d_m^2	$\frac{1}{3}$	$\frac{5}{13}$	d_s^2	$\frac{3}{9}$	$\frac{5}{15}$
d_m^3	$\frac{1}{3}$	$\frac{1}{13}$	d_s^3	$\frac{1}{9}$	$\frac{1}{15}$

Table I: prior satisfiability measures for the two partners

4.2 Interaction parameters elicitation

Let us consider that if manufacturer rejects his decision d_m^1 then supplier decision d_s^2 and d_s^3 are "strongly more rejectable" and "very strongly more rejectable" than decision d_s^1 respectively whereas if decision d_m^2 is rejected by the manufacturer then all supplier decisions are equally rejectable, and in the case where manufacturer rejects d_m^3, decisions d_s^2 and d_s^3 are respectively "moderaly more rejectable" and "strongly more rejectable" than decision d_s^1. If manufacturer selects his option d_m^1 then the selectability of options d_s^1 and d_s^2 are respectively "extremely more selectable" and "strongly more selectable" than option d_s^3; if option d_m^2 is preferred by the manufacturer then the strength of selectability of options d_s^1 and d_s^2 compare to option d_s^3 by the supplier are "moderaly more selectable" and "strongly more selectable" respectively and finally if manufacturer selects option d_m^3 then options d_s^3 and d_s^2 are respectively "very strongly more selectable" and "strongly more selectable" than d_s^1 for supplier. This information leads to the following table in terms of parameters $\theta^R_{sm}(d^k_s/d^l_m)$ and $\theta^S_{sm}(d^k_s/d^l_m)$, see Table II.

	$\theta^R_{sm}(d^k_s/d^l_m)$			$\theta^S_{sm}(d^k_s/d^l_m)$		
	d_m^1	d_m^2	d_m^3	d_m^1	d_m^2	d_m^3
d_s^1	$\frac{1}{13}$	$\frac{1}{3}$	$\frac{1}{9}$	$\frac{9}{15}$	$\frac{3}{9}$	$\frac{1}{13}$
d_s^2	$\frac{5}{13}$	$\frac{1}{3}$	$\frac{3}{9}$	$\frac{5}{15}$	$\frac{5}{9}$	$\frac{5}{13}$
d_s^3	$\frac{7}{13}$	$\frac{1}{3}$	$\frac{5}{9}$	$\frac{1}{15}$	$\frac{1}{9}$	$\frac{7}{13}$

Table II: conditional satisfiability measures for supplier

On the manufacturer side, let us suppose that a similar reasoning with regard to supplier attitude leads to conditional comparison matrices shown on the following Table III.

	$\theta^R_{ms}(d^k_m/d^l_s)$			$\theta^S_{ms}(d^k_m/d^l_s)$		
	d_s^1	d_s^2	d_s^3	d_s^1	d_s^2	d_s^3
d_m^1	$\frac{1}{15}$	$\frac{1}{3}$	$\frac{7}{22}$	$\frac{7}{13}$	$\frac{2}{6}$	$\frac{7}{79}$
d_m^2	$\frac{5}{15}$	$\frac{1}{3}$	$\frac{14}{22}$	$\frac{5}{13}$	$\frac{3}{6}$	$\frac{9}{79}$
d_m^3	$\frac{9}{15}$	$\frac{1}{3}$	$\frac{1}{22}$	$\frac{1}{13}$	$\frac{1}{6}$	$\frac{63}{79}$

Table III: conditional satisfiability measures of manufact.

4.3 Results

Considering egoism degrees to be equal to 0.5 for the two partners, we obtain from equations (35)-(36) following individual selectability and rejectability measures, see Table IV and from (37) and (38) joint selectability and rejectability are given by Table V.

	μ_{S_m}	μ_{R_m}		μ_{S_s}	μ_{R_s}
d_m^1	0.3230	0.4233	d_s^1	0.4170	0.4565
d_m^2	0.3262	0.3621	d_s^2	0.3468	0.3370
d_m^3	0.3508	0.2145	d_s^3	0.2363	0.2065

Table IV: satisfiability measures for the two partners

For a common index of caution $q_m = q_s = 1$, individual satisficing sets Σ^m_1 and Σ^s_1 as well as joint satisficing set Σ_1 along with necessary negotiation materials are given by equations (40) to (44)

$$\Sigma^m_1 = \{d^3_m\} \text{ and } \Sigma^s_1 = \{d^2_s,\ d^3_s\}, \tag{40}$$

$$\mathbf{\Sigma}_1 = \{(d^1_m, d^3_s),\ (d^2_m, d^3_s),\ (d^3_m, d^2_s), (d^3_m, d^3_s)\} \tag{41}$$

$$\mathbf{C}_m = \{(d^3_m, d^2_s), (d^3_m, d^3_s)\} \tag{42}$$

$$\mathbf{C}_s = \{(d^1_m, d^3_s),\ (d^2_m, d^3_s),\ (d^3_m, d^2_s), (d^3_m, d^3_s)\} \tag{43}$$

$$\mathbf{N}_{(1,1)} = C_m \cap C_s = \{(d^3_m, d^2_s), (d^3_m, d^3_s)\}\,. \tag{44}$$

As the satisficing imputation $\mathbf{N}_{(1,1)}$ set is not empty, one can choose the final decisions from this set using a criterion such as that of equation (39); this criterion leads to final decision (d_m^3, d_s^3) signifying that, given actual situa-tion, it is better to sign a simple contract for manufacturer and supplier keep its actual manufacturing process.

		$\mu_{S_m S_s}(d_m^x, d_s^y)$	$\mu_{R_m R_s}(d_m^z, d_s^w)$
d_m^1	d_s^1	0.1347	0.1933
d_m^1	d_s^2	0.1360	0.1653
d_m^1	d_s^3	0.1463	0.0979
d_m^2	d_s^1	0.1120	0.1427
d_m^2	d_s^2	0.1131	0.1220
d_m^2	d_s^3	0.1216	0.0723
d_m^3	d_s^1	0.0763	0.0874
d_m^3	d_s^2	0.0771	0.0748
d_m^3	d_s^3	0.0829	0.0443

Table V: joint selectability and rejectability measures

5. CONCLUSION

A framework to analyze relationship between two actors (a manufacturer and a supplier) in a supply chain has been considered in this paper. Two steps process has been described: in a first step, manufacturer used a multiobjectives and multiattributes decision making framework to select a short list of suppliers from possibly huge potential suppliers list; this process is carried up in a structuring framework such as BOCR analysis using a single person satisficing game as an ultimate tool for evaluation. In a second step, a multi-persons satisficing game theory is used to establish a negotiation framework between manufacturer and a selected supplier for a contracting purpose. A simplified method for eliciting joint selectability and rejectability measures has been proposed to overcome difficulties related to interdependency measure elicitation before obtaining joint selectability and rejectability by marginalization. An illustrative example of how negotiation process can be conducted is proposed. Future works will concentrate in applying this approach to solve real world problems.

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