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Multicriteria decision model for outsourcing contracts selection based on utility function and ELECTRE method

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Abstract

An outsourcing contract problem has been analyzed. This is a typical problem when dealing with outsourcing vendor selection. For each alternative of an outsourcing contract there is an evaluation of both cost and quality of service. The latter may include probabilistic delivery time and confidence in quality commitment. The decision-maker takes into account multicriteria evaluation through ELECTRE method. Besides, each criterion is evaluated through a utility function. The model integrates both approaches to indicate a contract proposal. This paper presents the formulation for the decision model and a numerical application to illustrate the use of the model.

Keywords: Outsourcing vendor selection; Outsourcing service selection; Multicriteria decision; Utility theory; ELECTRE method

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1. Introduction

Several studies have been conducted on the process of outsourcing dealing with different aspects of this matter. Smith et al. [1] have presented a framework that addresses issues that arise in the context of the offshore outsourcing of software development. The proposed framework links projects and sites, including environmental aspects. Krause et al. [2] have developed a process model for supplier development based on an exploratory study.

Regarding the outsourcing contract or supplier selection little research has been found in the literature. Almeida [3] has dealt with maintenance contract selection based on a multicriteria model, which uses contributions from multiattribute utility theory (MAUT). Dulmin and Mininno [4] have presented a multicriteria decision aid method, so called PROMETHEE/GAIA to approach a suppliers selection model, which is applied in the context of the rail transportation. Valluri and Croson [5] have studied the performance of a supplier selection model, which displays a reward and punishment profile under incomplete information. The model separates sellers capable of producing high-quality goods from those incapable of doing so. Their study is based on outsourcing of tangible products and is not adequate for service outsourcing.

Multicriteria decision aid methods such as PROMETHEE/GAIA and MAUT allow the decision-maker to quantify multiple objectives even when these objectives contain conflicting attributes or when they are subjective.

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The present paper presents results of research dealing with a multicriteria decision model for outsourcing vendor selection, using contributions from utility theory associated with the ELECTRE method. The problem consists of selecting the most appropriate alternative for an outsourcing contract taking several criteria into account.

The formulation of the problem answers the question: "What types of services can be outsourced?" and addresses strategic concerns such as ownership versus outsourcing. This can be done by including, among the alternatives to be analyzed an alternative that consists of the ownership of the service function instead of outsourcing.

Each contract alternative implies a specific contract cost and service quality characteristics. Probabilistic delivery time, confidence commitment regarding deadlines and service quality are among these service quality characteristics. The decision-maker has to choose the best alternative taking into account the consequences modeled through a multicriteria method. Utility function [6] and ELECTRE method [7] have been taken into account to model this problem.

2. Outsourcing contract selection problem

Outsourcing is a popular business strategy nowadays, and requires close attention to the outsourcing contract selection process. The outsourcing contract price is no longer the only aspect to be taken into account regarding decisions on outsourcing selection. That is, different aspects have to be considered by the decision-maker, such as cost of the contract and performance of the service. In general, delivery time is a formal commitment written in the outsourcing contract. Normally a different delivery time implies a specific condition of resources, personal skills and service availability and may result in a different cost.

The outsourcing contract is assumed to have basic variables related to multiple objectives. These multiple objectives may be represented through the performance objectives of a production strategy plan, such as quality, speed, dependability, flexibility, and cost [8]. Other approaches for multiple objectives may be obtained from multidimensional quality views [9–11].

The Action Space corresponds to the set of alternatives available to the decision-maker. An action element of the set is represented by a. The set of all actions is discrete with m elements: $\{a_1, a_2 \ldots, a_m\}$. Each element of this set corresponds to a possible outsourcing service contract to be adopted by the decision-maker that faces the problem. If the problem addresses strategic concerns such as ownership versus outsourcing, then the set of alternatives must include ownership of the service function as one of the alternatives.

In this paper the outsourcing service problem is analyzed with respect to the following criteria: cost, delivery time and dependability. Thus, for each action a_i there is a related cost c_i, and specific conditions associated to the delivery time t_i and its dependability d_i.

For each action a_i, c_i is assumed to be a constant value and t_i is a random variable. So, the decision model incorporates the uncertainty associated with t_i through the probability density function $f_i(t_i)$. Dependability is represented by the probability d_i for achievement of contract conditions.

3. Multicriteria decision approaches

Several multicriteria decision methods are available [6,7,12–14] to deal with this kind of problem. The method should be chosen considering the nature of the problem and the model building process. Regarding the model presented in this paper, two of these methods are briefly described.

MAUT [6,14] allows the decision-maker to quantify and aggregate multiple objectives even when these objectives are composed of conflicting attributes. The decision-maker's preferences are modeled in order to obtain a multiattribute utility function, for instance $U(c_i, t_i, d_i)$. This function aggregates utility functions for all criteria or attributes. That is, an analytical function is obtained which combines all criteria through a synthesis function. Each particular analytical form for this function has preferential independence conditions to be evaluated, in order to guarantee that the decision-maker's preferences are associated to the basic axioms of the theory [3,6].

ELECTRE method provides a different approach. This method concentrates the analysis on the dominance relations among the alternatives. That is, this method is based on the study of outranking relations, exploiting notions of concordance [7,12,14]. These outranking relations are built in such a way that it is possible to compare alternatives. The information required by ELECTRE consists of information among the criteria and information within each criterion [7].

The method uses concordance and discordance indexes to analyze the outranking relations among the alternatives. These indexes are obtained through the following relations, considering two actions: a and b [7,12,14]:

$$C(a,b)=\frac{\sum(W^{+}+W^{=})}{\sum(W^{+}+W^{=}+W^{-})}, \tag{1}$$

$$D(a,b)=\mathrm{Max}\left[\frac{(Z_{bk}-Z_{ak})}{Z_k^{*}-Z_k^{-}}\right], \quad \text{for all } k \text{ where } Z_{bk}>Z_{ak}, \tag{2}$$

$$a\,S\,b \text{ if } C(a,b)\geqslant p \text{ and } D(a,b)\leqslant q, \quad \text{so called outranking relation}, \tag{3}$$

where, $C(a,b)$ is the concordance index that action a outranks action b, $D(a,b)$ is the discordance index that action a outranks action b, $a\,S\,b$ corresponds to the outranking relation; it means that action a outranks b, p is the concordance index threshold, q is the discordance index threshold, W^{+} corresponds to the sum of weights for criteria where a is preferable to b, $W^{=}$ corresponds to the sum of weights for criteria where $a=b$, W^{-} corresponds to the sum of weights for criteria where b is preferable to a, Z_{ak} is the evaluation or utility of action a related to criteria k, Z_k^{*} is the best degree of evaluation obtained for criteria k and Z_k^{-} is the worst degree of evaluation obtained for criteria k. In order to facilitate the procedure, the evaluation of alternatives are normalized such that $Z_k^{*}=1$ and $Z_k^{-}=0$.

The outranking relation is obtained by applying both Eq. (3) and the procedure to obtain the kernel, which is the sub-set of the best alternatives [7,12,14]. The kernel includes a sub-set of alternatives where any other alternative is outranked by at least one of the kernel and the alternatives of the kernel are incomparable.

4. Decision model

The decision-maker's preferences for each criterion is modeled in order to obtain the utility function for each objective of the contract. Then, the utility function is obtained from the decision-maker for each consequence: $U(t)$, $U(c)$ and $U(d)$. These utility functions are obtained by applying one of the classical elicitation procedures [15,16].

The final solution depends on the utility function for each criterion. The analytical form of this utility function may represent one of the three basic conditions for the decision-maker behavior. That is, aversion, neutral or prone condition may be considered [15,16].

For $U(t)$ it is assumed that the decision-maker behavior is accordingly of exponential analytical form given below:

$$U(t)=\mathrm{e}^{-A1t}. \tag{4}$$

The exponential utility function is a typical function often found in practice [6,16] for unidimensional utility functions. In previous work [3] the exponential utility function has been found for $U(t)$ and $U(c)$. This means that higher values of t or c are much more undesirable for the decision-maker.

Thus,

$$U(c)=\mathrm{e}^{-A2c}. \tag{5}$$

For $U(d)$ is assumed to be a linear function:

$$U(d)=A3d: \tag{6}$$

Therefore, the evaluation of variable t is given by the decision-maker through the utility function $U(t)$. However, the evaluation of alternatives is based on the probabilistic characteristics of t. Thus, a probability density function $f(t)$ for t is taken into account. The assumption of $f(t)$ implies different results, given the decision-maker's preferences for this probabilistic criterion. Gamma probability function, with parameter $n=2$, is assumed for $f(t)$. This condition may be found in practical situations where delivery time is concentrated around a modal value. Thus,

$$f(t)=u^{2}t\mathrm{e}^{-ut}. \tag{7}$$

Once $U(t)$ gives the evaluation for variable t, the evaluation of the alternatives is based on parameter u. Then, $U(u)$ is derived based on $U(t)$. Applying the linearity property of utility theory [15] for utility of t, it follows that

$$E_t U(u) = \int_0^\infty U(t) f(t)\,\mathrm{d}t. \tag{8}$$

Applying (4) and (7) into (8), it follows that

$$E_t U(u) = \int_0^\infty [tu^2 \mathrm{e}^{-ut} \mathrm{e}^{-A1t}]\,\mathrm{d}t,$$

$$E_t U(u) = \frac{u^2}{(A1+u)^2} \tag{9}$$

Therefore, in order to incorporate the probabilistic aspect related to t, this variable is represented by its parameter u. Thus, for each action a_i, a parameter u_i is applied.

Once the utility function is obtained for all criteria $U(u)$, $U(d)$ and $U(c)$, the ELECTRE method may be applied. In this case, the decision-maker establishes the relative weights for the criteria, taking into account framework of the non-compensatory ELECTRE method [7,12].

In the MAUT approach the decision-maker preferences are modeled in order to obtain a multiattribute utility function $U(u, c, d)$, when aggregates [6] all utility functions $U(c)$, $U(d)$ and $U(u)$. The function $U(u, c, d)$ has to be evaluated in order to guarantee that the axioms of the theory (MAUT) conform to the decision-maker's preferences.

A different approach is employed by the ELECTRE method. This method exploits some characteristics of dominance regarding the multiple criteria analyzed. In this method a concordance notion allows the ranking of alternatives, analyzing outranking relations among alternatives [12]. This allows a decision support approach avoiding rigid assumptions required by MAUT from the decision-maker [12]. The ELECTRE method is based on the study of outranking relations, using a non-compensatory logic.

Each alternative of contract can be evaluated through:

- contract cost c,
- parameter u, associated to the probability density function of t, and
- contract dependability d.

The ELECTRE method may now be applied to (5), (6) and (9) given to the decision-maker the best alternatives of contract.

5. Numerical application

In order to illustrate the use of the decision model, there follows a presentation of a numerical application. This application is based on a case regarding service outsourcing related to transportation. In this context the cost and the response time t has characteristics suitable to the exponential utility function previously discussed.

The cost is given in monetary units for each contract alternative as follows:

1) Action a_1—most expensive ($c_1 = 100$) and reduced t, such that $u = 0.95$; $d = 0.95$.
2) Action a_2—medium cost ($c_2 = 60$) and medium t, such that $u = 0.65$; $d = 0.90$.
3) Action a_3—least expensive cost ($c_3 = 10$) and the large t, such that $u = 0.03$; $d = 0.75$.
4) Action a_4—below medium cost ($c_4 = 30$) and t, such that $u = 0.15$; $d = 0.8$.
5) Action a_5—below medium cost ($c_5 = 50$) and t, such that $u = 0.70$; $d = 0.75$.
6) Action a_6—expensive cost ($c_6 = 85$) and reduced t, such that $u = 0.9$; $d = 0.8$.

The following weights have been applied: for c: 0.40; for d: 0.25; t: 0.35.

Table 1
Outsourcing alternatives

Action	u	C	d
a_1	0.95	100	0.95
a_2	0.65	60	0.90
a_3	0.03	10	0.75
a_4	0.15	30	0.80
a_5	0.70	50	0.75
a_6	0.90	85	0.80

Table 2
Normalized utilities for alternatives

Action	$U'(u)$	$U'(C)$	$U'(d)$
a_1	1.00	0.00	1.00
a_2	0.91	0.24	0.75
a_3	0.00	1.00	0.00
a_4	0.40	0.61	0.25
a_5	0.93	0.34	0.00
a_6	0.99	0.07	0.25

Outsourcing alternatives are given in Table 1. Values of criteria are assigned to all alternatives a_i, where $i = 1, 2, \ldots, 6$.

The utility function for cost is given in (5) with the parameter $A2 = 0.02$. The utility function for d is given in (6) with parameter $A3 = 1$. The utility function for t is given in (9) with parameter $A1 = 0.1$. Applying these Eqs. (5), (6) and (9), utilities are obtained for all alternatives. Table 2 presents $U'(u)$, $U'(C)$ and $U'(d)$, corresponding to normalized values for utilities. The normalization procedure is based on a linear transformation. For instance $U'(u) = aU(u) + b$, such that $a > 0$. According to the utility theory [6] this linear transformation insures that $U'(u)$ is strategically equivalent to $U(u)$. That is, $U'(u)$ preserves the same properties and the preference structure of $U(u)$.

Based on decision-maker's preferences, the weights of criteria have been assigned as previously mentioned and the admissible levels (thresholds) for concordance index and discordance index are as follows: $p = 0.5$ and $q = 0.45$.

Therefore, when (1) and (2) are applied, the concordance and discordance indexes are obtained. Then, the outranking relation is obtained by applying (3). Finally, by applying the procedure to obtain the kernel [7,12,14], alternatives a_1 and a_4 are identified. This result indicates that a_1 and a_4, although incomparable between themselves, are the two best alternatives for the preferences presented by the decision-maker and the assumptions underlying the model.

A sensitivity analysis of weights and admissible levels for the concordance index and the discordance index (varying by 10%) shows that the result remains the same. This analysis indicates that the recommendation for action a_1 and a_4 are sufficiently robust, regarding the limits of variation mentioned above.

6. Conclusion

Two different multicriteria approaches have been applied to deal with multiple criteria in similar problems: MAUT and the PROMETHEE method. The approach based on MAUT has been presented in Almeida [3] related to maintenance contracts. A model based on PROMETHEE has been applied in the rail transportation context [4] to approach a suppliers selection model. Dulmin and Mininno [4] use the classical approach based on PROMETHEE and associated with GAIA [13] to modeling a suppliers selection problem, applied to the context of rail transportation. The development of criteria scales to identify the intensity of preference for one alternative over another is based on deterministic way.

The problem approached in this paper is related to the context of service outsourcing, where uncertainties of some variables are relevant, such as: delivery time t_i and dependability d_i, for a given alternative a_i. Then, a utility function is introduced in order to incorporate the uncertainty evaluation of those variables. Theses utility functions are integrated into the ELECTRE framework in order to obtain multicriteria evaluation within a non-compensatory approach [12].

Another specific problem previously analyzed [17] is also based on contributions from utility theory [15,16] associated with ELECTRE method [7,12]. That problem has been analyzed for a particular context of maintenance problems using the exponential probability function assumption for repair time [17].

MAUT is the most appropriate multicriteria approach for decision problems under uncertainty, due to the structure of MAUT, which incorporates the probabilistic axiomatic structure of the utility theory [6,16]. Decision problems within this context are typically problems under uncertainty situations, requiring the appropriate multicriteria methodology. In most cases MAUT seems to accomplish this task. However, considering the requirements of this theory for multicriteria problems, it is not always possible to use MAUT. The main requirements of this theory imply a rationality that involves compensation among the criteria [12], which involves the procedure for aggregation of all criteria obtaining a synthesis multicriterion utility function. This rationality is not always accepted by the decision-maker.

The decision-maker rationality may require a non-compensatory method, where the decision support process does not require an aggregation of all criteria. The ELECTRE method may support decision process under this situation [12].

The model proposed in this paper presents an alternative approach for analyzing an outsourcing contract selection problem, such as those previously analyzed [3,4,17].

Using utility theory each criterion is represented by a utility function, incorporating the probabilistic structure of the problem. The probability function for the delivery time is assumed to be gamma probability density function. The evaluation of the criteria represented by each utility function is analyzed through the ELECTRE method. The paper includes the structure of the decision model to support the decision-maker and a numerical application illustrates the use of the model.

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