PERGAMON

European Journal of Purchasing & Supply Management 4 (1998) 109–118

EUROPEAN JOURNAL OF PURCHASING & SUPPLY MANAGEMENT

Outranking methods in support of supplier selection

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Abstract

Initial purchasing decisions such as make-or-buy decisions and supplier selection are decisions of strategic importance to companies. The nature of these decisions usually is complex and unstructured. Management Science techniques might be helpful tools for this kind of decision making problems. So far, however, the application of outranking methods in purchasing decisions has not been suggested in purchasing or operations research literature. In this paper we show by means of a supplier selection example, that an outranking approach may be very well suited as a decision-making tool for initial purchasing decisions.

Keywords: Supplier selection; Multiple criteria decision aid; Outranking methods

1. Introduction

The purchasing function is increasingly seen as a strategic issue in organizations. This applies to industrial as well as service and government organizations. Many decisions concerning initial purchasing (e.g. make-or-buy and sourcing) decisions are consequently considered to be of great strategic importance. However, the nature of many of these decisions is unstructured and complex. Put together, this would plead for serious attention for the way these decisions are reached and justified and therefore suggests (among other things) the use of decision models in support of purchasing decision making.

However, the expected professionalization of initial purchasing decision-making is far from common practice. Decision support systems and information systems mainly support routine operational purchasing decisions (e.g. order-size) and administrative activities. Also in the literature, a lot of attention is given to models that have been developed for supporting these operational decisions (see De Boer et al., 1994). Furthermore, a majority of the relatively few models that have been developed for initial purchasing decisions are based on rather simplistic perceptions of decision making processes and do not seem to address the complex and unstructured nature and context of many present-day purchasing decisions. For example, a drawback of many existing decision models for supplier selection is the fact that only quantitative criteria are considered. Several factors that may complicate the decision making process such as incomplete information, additional qualitative criteria and imprecise preferences are often not taken into account. In this article we propose and illustrate a decision model for supplier selection that is based on the outranking approach (Roy, 1968). Using this approach it is possible to explicitly model the fuzziness inherent to many supplier selection decisions. The outranking model is well suited to deal with multiple criteria decisions with qualitative as well as quantitative attributes. Application of outranking methods enables the selection of a (small) number of attractive suppliers based on relatively limited information. These and other features such as the recognition of incomparability of suppliers are only implicitly or not at all present in traditional decision models for supplier selection.

Of fundamental importance in any discussion on decision models is the necessarily differentiated approach to the area in which the development or use of decision models is considered. Trivial as this may sound, it is often overlooked: decision models are criticized as being inappropriate for dealing with problems or situations they were not developed for dealing with in the first place.

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0969-7012/98/$19.00
PII: S0969-7012(97)00034-8

Therefore, before describing in detail the outranking models for supplier selection in Section 3 and Section 4, we present a review of existing traditional decision models for supplier selection. The models are evaluated with respect to the extent to which they seem useful and appropriate in different supplier selection cases. In this way, we can position both the traditional models and the outranking models and show that the outranking models should not be seen as a replacement of existing models but rather as a very useful supplement, considering the ongoing developments in purchasing.

2. Review of existing models

The point of departure when reviewing the existing models is that a specific purchasing situation, e.g. supplier selection, provides a specification of the desired properties of such a decision model. The purchasing situation thus is the starting point for giving concrete form to the decision-making process and determining the relevance and appropriateness of possible means of decision support therein. From the vast amount of literature on supplier selection (see for an overview De Boer, 1996) we conclude that when evaluating and reviewing decision models for supplier selection the following properties are worth considering.

1. The number of criteria and their nature. Vendor selection decisions are complicated by the fact that various criteria must be considered in the decision-making process (Weber et al., 1991). The criteria may have quantitative as well as qualitative dimensions and may also be conflicting. A strategic approach towards purchasing may further emphasize the need to consider multiple criteria. In the case of strategic supplier selection, Ellram (1990), for example, stresses the need to not only consider traditional criteria such as price and quality but also more longer term and qualitative criteria such as 'strategic fit' and 'assessment of future manufacturing capabilities'.

2. The interrelatedness of decisions. Interrelated decisions are likely to be present in purchasing. A single buying decision cannot be isolated and evaluated alone (Kingsman, 1985). Once the decision to buy has been made, often a number of decision stages follow (see, for example, Van Weele, 1994). Typically, a first decision is made in order to create a set of acceptable suppliers. In the stages that follow, this set is further reduced until a final supplier is eventually selected. The question how many suppliers should be selected, raises the interrelated question how the purchase order quantity could be allocated best to the (potential) suppliers if two or more suppliers have been or are to be selected.

In addition to initial purchasing decisions being interrelated with operational purchasing decisions, these initial purchasing decisions may also be interrelated with decisions in other functional areas, especially in view of purchasing's increasing strategic importance. Lee (1972) describes three examples in which initial purchasing decisions clearly interrelate with decisions in other areas such as production planning, capacity planning and financial planning.

3. The type of decision rule used. Basically, two decision rules can be used: compensatory decision rules leading to an optimal solution or non-compensatory rules in which a bad score of an alternative on a particular criterion can be compensated by high scores on other criteria. From the literature it can be concluded that in purchasing the classic concept of 'optimality' may not always be the most appropriate model. For example in Kingsman (1985): "The (purchasing, auth.) problems are often complex and it is difficult to define a precise optimality criterion". Following the literature on organizational buying behavior it seems more appropriate to assume that in initial purchasing decision making several types of decision rules are being used. Chambers (1983) states: " … the individual will in all likelihood employ some type of choice model, e.g. compensatory or non-compensatory, to select a vendor or vendors". Brand (1992) reports on empirical research which suggests that in purchasing both compensatory as well as non-compensatory rules are used. Factors that influence the type of rules are for example: time pressure, the extent to which the situation is perceived as new, the number of criteria and the number of suppliers to choose from. The combination of compensatory and non-compensatory decision rules in vendor selection processes is also reported by Naudé (1994).

4. The number of decision makers. The overall conclusion that can be drawn from the literature is that many purchasing decisions are taken or at least influenced by several actors (see, for example, Van Weele, 1994; Choffray and Lilien, 1978). Webster and Wind (1972) describe organizational buying as a complex process of problem solving in which many individuals with varying backgrounds are involved. Since every decision maker may bring in his own "view of reality", multiple views on the same reality may add to the complexity of the decision situation.

5. The various types of uncertainty. In practice, decision making is often hampered by uncertainty. However, uncertainty may manifest itself in many different ways. Following Roy (1986) we in distinguish between the following types of uncertainty. With *imprecision* we refer to the difficulty of determining the score of an alternative on a criterion or the importance of some criterion with a high degree of precision, irrespective of possible random fluctuations, due to the inability of a decision maker to express his preferences in a completely consistent way or the absence of relevant information. In the sequel of this paper the term *stochastic uncertainty* represents the classic stochastic type of uncertainty on which probability theory is founded. Finally, we speak of *indetermination*, if the actual definition of a criterion is the result of a rather arbitrary choice. For example, in practice, several attributes could be measured in order to assess the R & D capabilities of a supplier, but the interpretation of the term R & D capability just as many other criteria is far from univocal.

An increasing number of purchasing decisions can be characterized as dynamic and unstructured. Situations are changing rapidly or are uncertain and decision variables are difficult or impossible to quantify (Cook, 1992). Apart from uncertainty in a stochastic sense, imperfect information also demonstrates itself as imprecision. For many purchases it is highly unlikely that point estimates of expected values can be made with a high degree of accuracy (Thompson, 1990). The general conclusion from the literature is that all possible forms of uncertainty may be present in initial purchasing decision making.

From the foregoing we can conclude that supplier selection may involve several and different types of criteria, interrelated decision structures, combinations of different decision rules, group decision making and various forms of uncertainty. The existing formal decision models for supporting supplier selection decision can thus be evaluated with respect to the degree to which these properties are taken into account. However, the presence of each of these properties or the necessity to take them into account in a decision model will vary from one situation to another and is also dependent on how the decision makers perceive the situation. This is reflected in several typologies of purchasing situations that have been developed, for example the taxonomy suggested by Bunn (1993) in which six different buying decision approaches are derived on the basis of an extensive empirical study among manufacturing, service and public administration organizations. This taxonomy clearly shows that purchasing decisions situations differ in terms of both perceived importance and complexity.

It will be clear that especially in situations of high importance and high complexity, decision makers employ a moderate to high level of search for information and use of sophisticated analytical techniques, whereas in the more straightforward cases of minor importance decision models are not used at all. By means of an extensive literature search, an overview of existing decision models for supplier selection has been developed. The various models were evaluated in terms of the properties described before. Furthermore, the existing models were grouped according to the underlying (Management Science) technique. The results of the literature search are presented in Table 1. For a more detailed description see De Boer (1996).

From the results of the literature search on existing models from Management Science for supplier selection several conclusions can be drawn. Put together, the models capture some of the properties identified earlier on in this section. Especially the need to incorporate several multidimensional criteria is well recognized, be it to various degrees: many models only use quantitative criteria. Other properties, such as imprecision are barely present. Most models assume that precise and accurate data and preferences are available. None of the models found incorporates all of the properties that may be present in supplier selection cases. As was already pointed out not all supplier selection decisions will be perceived equally complex by different decision makers and not all of the properties described previously will necessarily manifest themselves simultaneously. The majority of the articles dedicated to decision models for purchasing, essentially deal with operational purchasing decisions, e.g the determination of quantities that should be ordered from a given set of suppliers. In terms of Kraljic's portfolio approach (Kraljic, 1985) these problems especially relate to the procurement of routine items and to a lesser extent, leverage items. The degree of uncertainty, the number of decision makers and the nature of the criteria that have to be taken into account in these situations are of course different from situations where more strategic decisions have to be made, for example supplier selection decisions for strategic and bottleneck items. Considering the increasing importance as well as the increasing complexity of many contemporary supplier selection decisions, it is somewhat surprising that the following properties have gained very little attention:

- non-compensatory decision rules aimed at selecting acceptable alternatives;
- uncertainty, indetermination and imprecision resulting from for example incomplete data, vaguely and/or arbitrarily defined criteria and imprecise appraisal of criteria.

Outranking techniques may provide the basis for developing supplier selection models that can effectively deal with these properties. In Section 3.3, we present an example of a supplier selection problem in which qualitative as well as quantitative criteria are aggregated in a non-compensatory way taking into account imprecision and indetermination. Before we show how this can be done, we give an outline of the basic concepts of outranking in Sections 3.1 and 3.2.

3. Outranking methods

3.1. Introduction

In this section outranking techniques as well as some other methods are discussed that are often used as tools

Table 1
Overview of existing models for supplier selection

Category	Criteria	Decision structure	Decision rule	Concept of uncertainty
Cost ratio (Stevens, 1978)	One dimensional (Only costs)	Isolated	Optimizing	Deterministic
Categorical model (Zenz, 1981)	Multi-dimensional	Isolated	Choice not formalized	Deterministic
Linear weighting (Baily and Farmer, 1990)	multi-dimensional	Isolated	Compensatory	Deterministic, stochastic (Williams, 1984), imprecision (Thompson, 1990; Narasimhan, 1983)
Weighted product method (Yoon and Naadimuthu, 1983)	Multi-dimensional	Isolated	Compensatory	Imprecision
Mathematical programming (Buffa and Jackson, 1983; Narasimhan and Stoynoff, 1986; Pan, 1989; Turner, 1988; Chaudry et al., 1993; Sharma et al., 1989; Weber and Current, 1993; Bender et al., 1985; Gaballa, 1974)	Multi-dimensional (quantitative)	Selection interrelated with order allocation	Optimizing and non-compensatory	Deterministic
Multi Attribute Utility Theory (Min, 1993)	Multi-dimensional	Isolated	Compensatory	Deterministic, stochastic
Data Envelopment Analysis (Papagapiou et al., 1997)	Multi-dimensional (quantitative)	Isolated	Compensatory	Deterministic
Decision tree (Soukup, 1987; England and, Leenders, 1975)	One-dimensional (expected costs)	Isolated	Optimizing	Stochastic

in multiple criteria decision making. One specific outranking model, ELECTRE I, is discussed in some detail.

As mentioned earlier many purchasing decisions include quantitative as well as qualitative aspects. Linear weighting models like the Analytic Hierarchy Process (AHP) (see Saaty 1980 and Narasimhan 1983) and the Simple Multi-Attribute Rating Technique (SMART) (see Goodwin and Wright, 1991) are capable of dealing with this kind of decision problems. Both methods start with the construction of a so-called value tree, a graphical representation of the criteria and their subcriteria worked out to such an extent that the scores for the different alternatives on the attributes on the bottom level can be evaluated. In AHP pairwise comparisons are used for obtaining the scores of the alternatives as well as the importance weights of the attributes. In SMART, the so-called value functions and direct rating methods are used for the evaluation of the alternatives and swing weights for obtaining the weights of the criteria. AHP and SMART can both deal with imprecision caused by the decision maker's inability to translate his preferences for some alternative to another into a totally consistent preference structure. In AHP, the so-called consistency ratios are used in order to measure the consistency of the decision-making process. This consistency is calculated in every step of the procedure. In case pairwise comparisons in some step appear to be inconsistent, the pairwise comparisons can be repeated. Afterwards the consistency ratio for the whole process can be calculated and, if necessary, some of the pairwise comparisons may be reconsidered. In SMART sensitivity analysis is used then to measure the influence of changes in the weights of some of the criteria.

A characteristic property of AHP and SMART (and other linear weighting methods) is that they are fully compensatory. In practice, this might not always be very realistic. Consider, e.g. the situation where one supplier scores much better than a second one on all attributes except the attribute "quality". Suppose, this second supplier offers a much higher quality. It is not necessarily true that the decision maker accepts that good scores on almost all criteria are worth the difference with respect to quality. An important underlying assumption of all linear weighting models is that any two alternatives can be compared to each other. In many real-world situations the assumption of comparability is not valid due to lack of information and/or the unwillingness to compare two alternatives with respect to some criterion. The former refers, e.g. to the situation in which it is costly to obtain the necessary information and one is not willing to spend a large amount of money or time for checking alternatives that might appear to be less attractive than others.

Outranking methods are only partially compensatory and are capable of dealing with situations in which imprecision is present. From this point of view incomparability can be seen as an expresssion of imprecision.

The first paper on outranking was published in the late 1960s (Roy,1968). Since then, a lot of attention has been paid to outranking models, primarily in Europe. However, so far, in the purchasing literature there is no evidence of applications of outranking models in purchasing decisions. Nowadays, there exist three classes of outranking methods: ELECTRE, PROMETHEE and ORESTE methods. The main purpose of this paper is to show the general ideas behind outranking and how these methods may be used as a decision tool for supplier selection problems. The details and technicalities of specific variants of the methods are less important at this stage and will therefore not be discussed here. Only one of the outranking methods that were developed, is introduced here in detail. ELECTRE I is the first outranking method and it gives a good notion of the ideas behind outranking. Other outranking methods are more advanced as they accept differences in the strength of the decision maker's preferences as well as the possibility of the decision maker being indifferent with respect to two alternatives. Compared to ELECTRE I, e.g. ELECTRE III models the decision maker's preferences in a more subtle fashion. Put into mathematical terms, ELECTRE I is based on constructing crisp, binary outranking relations whereas ELECTRE III results in the construction of fuzzy outranking relations between alternatives.

In Section 3.2, ELECTRE I is discussed in some detail, illustrated by a supplier selection problem in Section 3.3. In Section 3.4 some aspects of a more general outranking method like ELECTRE III are discussed.

3.2. The basic ideas behind outranking

In this subsection the basic ideas behind outranking are covered following the ELECTRE I method. A numerical example of the concepts described here is given in Section 3.3.

Assume that a set A of alternatives and a set G of n criteria are given. In the sequel, alternatives will be denoted by the symbols a, b, c, … and the criteria by g_j, $j = 1, \dots, n$. So, $g_j(a)$ denotes the score of alternative a on the jth criterion.

Using this information an aggregate preference model can be built. This model can be seen as an interpretation of the outranking concept defined by Roy (1974):

> "an outranking relation is a binary relation S defined on A such that aSb ("a outranks b") if, given what is known about the decision maker's preferences and given the quality of the valuations of the actions and the nature of the problem, there are enough arguments to decide that a is at least as good as b, while there is no essential reason to refute that statement".

Note that this definition takes explicitly into account that the consequences of the alternatives are not completely known, that the problem definition might not be exact and that the preferences of the decision maker are not fully known and inconsistent to a certain extent.

The question now is how to aggregate the scores of an alternative on the different criteria to an overall score for that alternative. In order to aggregate these scores the decision maker needs inter-criteria information with respect to the relative importance of the various criteria. Therefore, for every criterion j a "weight" k_j is determined. These weights of the criteria may be found in several ways, see e.g. Saaty (1980), Goodwin and Wright (1991) and Roy et al. (1986). Furthermore, as we indicated in the previous subsection, a relatively bad score of an alternative on a particular criterion may be unacceptable for a decision maker regardless of possible superior performance on other criteria. This implies that the decision maker has to decide for which combinations of alternatives outranking of alternative b by alternative a is refused on the basis of a very bad score of a on a certain attribute relative to the score of b and irrespective of the scores of both alternatives on other criteria. (If desired, these combinations can be modelled formally as so-called discordance sets.[1])

After the weights and discordance sets have been determined, the aggregation procedure proceeds as follows. First, the concordance index conc(a,b) for any two alternatives a and b is calculated. This index conc(a,b) represents the strength of preference of the decision maker for the first alternative above the second, i.e. the strength of the arguments in favor of the assertion "a outranks b". As a matter of fact, this strength of preference is measured by the sum of the weights of the criteria on which alternative a scores at least as good as alternative b. Secondly, a concordance threshold is determined by the decision maker in such a way that he feels that in case the concordance index for two alternatives exceeds this threshold, there are considerable supporting arguments for the assertion that "a outranks b". Now, the assertion "a outranks b" holds if two conditions are met. First, conc(a,b) has to exceed the threshold value. Secondly, a should not have a very bad score relative to b on a certain criterion which prohibits outranking of b by a.

[1] At the moment, the authors are involved in a number of case studies to check the applicability of a number of decision making models in different problem contexts in purchasing. In one of these cases (evaluation of tenders for a cleaning contract for a university) discordance appeared to be present. In case the costs of the contract offered by supplier a were more than 10% less than the costs of the contract offered by supplier b, then outranking of a by b was refused.

Note that the ELECTRE I method just works out what is said in Roy's definition. First, the arguments in favor of outranking of *b* by *a* (i.e. conc(*a*,*b*)) are calculated. In case these arguments are strong enough and there are no arguments against outranking of *b* by *a*, then the proposition '*a* outranks *b*' is accepted. Elaboration of the ideas in the definition of Roy in a different way may lead to other outranking methods.

In the next subsection a supplier selection example is presented to illustrate how ELECTRE I can be used in practice.

3.3. Example

In this section we will illustrate how the outranking approach may support supplier selection processes. The numerical data and the qualitative evaluations in the following example are fictive. However, the criteria which are considered as well as the decision context are based on the outcomes of an extensive joined study by the first author (Van Stekelenborg, 1997). This study resulted in detailed descriptions of over 30 different cases of supplier selection within a Dutch manufacturer of professional equipment.

3.3.1. Problem statement

Suppose that an industrial company is looking for a back-up supplier in order to ensure the supply of a range of high quality and rather dedicated components. Management has appointed a special taskforce responsible for recommending one or two suitable suppliers. The taskforce consists of several officers from various functional departments within the company, such as purchasing, engineering, marketing, R & D and production. First, the members of the taskforce organize several meetings in order to agree on a profile of the desired supplier. After several sessions and discussions with management, the following profile emerges:

- The supplier should be a major player in its markets with a high yearly turnover. On the other hand, the supplier should not be too big in order to maintain sufficient commitment on the long term. Preferably, the supplier's turnover approximates $9.5 million.
- Because of the JIT-driven production system, the supplier should not be located too far away.
- Obviously, a low general cost level is imperative as this range of components significantly impacts the total costs of end products.
- The quality image of the supplier is of significant importance, especially because of its contribution to the overall quality appeal of the end- products in which the supplier's components will be used.

Based on previous market research and suggestions of several members within the taskforce, an initial set of 5 candidate suppliers is constructed. Next, the taskforce evaluates these 5 suppliers with respect to the ideal profile. The results of this evaluation are presented in Table 2.

Table 2
Evaluation of suppliers

	Supplier *a*	Supplier *b*	Supplier *c*	Supplier *d*	Supplier *e*
Turnover (million $)	7.5	8	11	9	8
Distance (km)	50	500	900	200	550
Costlevel ($)	20	15	18	25	11
Quality image	moderate	excellent	good	good	bad

The evaluation of the cost level is based on various sources of information, e.g. listprices of comparable components, historical data, supplier estimates etc. Referring to the contemplation in Section 2 on the various forms of uncertainty we see that in this supplier selection case stochastic uncertainty, imprecision as well as indetermination are bound to be present. For example, the supplier's cost level may be subject to fluctuations. And even if it were not, a precise assessment of the actual cost level would still be difficult to obtain. In addition, the criterion 'quality image' does clearly not allow for a crisp, precise evaluation either. Finally, indetermination might play a role, e.g. the geographical distance might not necessarily be the only relevant factor indicating a supplier's expected ability to deliver according to the JIT requirements.

The set of alternatives clearly consists of Suppliers *a* to *e*. As mentioned earlier the ideal yearly turnover of a supplier is around $9.5 million. For actual turnovers differing from this value there is a priori no reason to prefer a turnover that is larger than the ideal to one that is as much smaller. So, the decision makers are indifferent to suppliers having turnovers of $7.5 million and $11.5 million, respectively. It is straightforward now to define a criterion g_1 in the following way: given a Supplier *a*, $g_1(a) = |\text{turnover}(a) - 9.5|$, where $|\,|$ denotes the absolute value. Clearly, the smaller $g_1(a)$ the better. For criteria 2 and 3 it is obvious that $g_2(a)$ equals the distance from Supplier *a* to the company and $g_3(a)$ denotes the general cost level of Supplier *a*. The scores on the qualitative criterion g_4 are included in the set {bad, moderate, good, excellent}. Assume that management has agreed on the following weights k_j for the criteria (Table 3).

Apparently, the quality image of the supplier is regarded most important, closely followed by the cost level. In this particular case, distance and turnover are considered to be of less importance. Even with all these data it is not immediately clear which supplier(s) should be recommended to management: a common problem in practice.

3.3.2. Application of ELECTRE I

The first step in the application of ELECTRE I is the definition of discordance sets.

Table 3
Weights for the criteria

Criterion	g_1	g_2	g_3	g_4
Weight	0.20	0.15	0.30	0.35

Table 4
Calculation of concordance indices

	Supplier *a*	Supplier *b*	Supplier *c*	Supplier *d*	Supplier *e*
Supplier *a*	—	0.15	0.15	0.45	0.50
Supplier *b*	0.85	—	1.0	0.65	0.70
Supplier *c*	0.85	0.20	—	0.65	0.55
Supplier *d*	0.55	0.35	0.70	—	0.70
Supplier *e*	0.50	0.50	0.65	0.30	—

Assume that the taskforce has agreed to refuse the outranking of Supplier *b* by Supplier *a* in the following two cases:

- The general cost level of Supplier *a* is at least twice as high as the cost level of Supplier *b* (*).
- The quality image of Supplier *a* is bad, while the quality image of Supplier *b* is excellent (**).

Although it is not difficult to translate these statements into mathematically correctly defined discordance sets, we will not do so here. Refusal of outranking of *b* by *a* can easily be checked from the statements (*) and (**) every time the concordance indices are compared to the concordance threshold. Note that for criteria 1 and 2 the differences between all possible pairs of suppliers are acceptable, in other words, the discordance sets for criteria 1 and 2 are empty.

The following step is the calculation of the concordance indices. As stated in Section 3.2, the index conc(*a*,*b*) denotes the strength of the arguments that are in concordance with the proposition "*a* outranks *b*". This index equals the sum of the weights of the criteria on which Supplier *a* scores at least as good as Supplier *b*. Note that since the sum of the weights is equal to 1, this index can take values ranging from 0 to 1.

For example, Supplier *c* performs as good as Supplier *e* with respect to criterion g_1 (the absolute values of the differences between 11 and 9.5 and between 8 and 9.5 are equal), while Supplier *c* performs better than Supplier *e* with respect to criterion g_4, hence:

$$\text{conc}(c,e) = k_1 + k_4 = 0.20 + 0.35 = 0.55$$

Analogously, Supplier *e* performs at least as good as Supplier *c* on the criteria g_1, g_2 and g_3, so

$$\text{conc}(e,c) = k_1 + k_2 + k_3 = 0.65.$$

The results of the calculation of the indices for the 5 suppliers are presented in Table 4.

Note that $\text{conc}(c,e) + \text{conc}(e,c) = 1.2$. This is caused by the fact that the scores of both alternatives on the first criterion are equal. It is obvious from Roy's definition that equality of scores speaks in favor of the proposition '*c* outranks *e*' as well as for '*e* outranks *c*'.

Now, Supplier *a* outranks Supplier *b* if the concordance index $\text{conc}(a,b)$ exceeds a certain threshold, while at the same time outranking is not refused on the basis of (*) or (**).

In case the concordance threshold equals 0.8 the following conclusions can be drawn from Table 4 and the discordance sets:

- Supplier *b* outranks Suppliers *a* and *c*,
- Supplier *c* outranks Supplier *a*.

Note that for none of the concordance indices larger than 0.8 outranking of one supplier by another supplier is refused on the basis of (*) or (**). It is clear now that Supplier *b* is preferred to Suppliers *a* and *c*, but that a comparison between Suppliers *d* and *e* and the other suppliers cannot be made. This implies that Suppliers *b*, *d* and *e* are incomparable. In order to be able to choose between these alternatives, a more precise evaluation of the given criteria and/or other criteria has to be carried out.

The choice 0.8 for the concordance threshold is rather arbitrary. To analyze the influence of this threshold on the final decision other values of this threshold have to be considered. The conclusions in case the concordance threshold equals 0.7 are:

- Supplier *b* outranks Suppliers *a*, *c* and *e*,
- Supplier *c* outranks Supplier *a*,
- Supplier *d* outranks Supplier *c*.

Although the value of conc(*d*,*e*) equals 0.7, outranking of *e* by *d* is refused on the basis of (*), because the cost level of Supplier *d* (25) is more than twice the cost level of Supplier *e* (11). Now, Suppliers *b* and *d* are the most attractive ones. Outranking of Supplier *e* by Supplier *b* is present now because the strength of arguments for validating outranking of Supplier *b* by Supplier *a* has decreased.

The main insight resulting from using the ELECTRE I method in this case is that from now on, the taskforce can focus its attention on the Suppliers *b*, *d* and *e*. Since the exclusion of Supplier *e* depends on whether the value of the concordance threshold is 0.7 or 0.8, the taskforce may decide to conduct a further investigation concerning the supposed preference for Supplier *b* over Supplier *e*. Besides, the example here clearly shows the importance of conducting sensitivity analysis before implementing results that follow from any kind of formal decision support tool. However, it seems obvious to recommend to management Supplier *b* and Supplier *d*. An ultimate decision on which supplier to choose should then be based on additional information and/or criteria.

3.3.3. Inclusion of qualitative criteria that capture future performance

Every decision-making problem has its own context. In the problem description described above dynamic aspects, for instance, were not taken into account. In other cases these aspects might play a crucial role. For instance, assume that a company of electronic equipment that has adopted the JIT-philosophy is considering outsourcing the making of some vital components to a supplier. In the longer term the company strives to a comakership relation with the supplier. Aspects that might play a role in the weighing out of possible suppliers include criteria like price, delivery time, delivery reliabity and quality. Obviously, these criteria are direct indicators of the actual or short-term performance of the supplier with respect to realizing the desired physical supply of goods or services However, other aspects like the R & D potential of the supplier and its innovativeness may be also important. In fact, such criteria serve as predictors of future supplier performance rather than indicators of actual or short-term performance. The uncertainty in the criteria indicating actual supply is often smaller compared to the uncertainty in the 'predictive' criteria. Nevertheless, by benchmarking, company visits and discussions with the suppliers management it is possible to obtain qualitative insight in the performance of the candidate suppliers. As we have shown in the previous section, such qualitative criteria can be easily included in an outranking model.

3.4. Extensions

From the preceding subsections it is clear that ELECTRE I is a quantitative decision-making tool that is able to handle qualitative as well as quantitative criteria. The method is only partially compensatory due to the fact that a relatively bad score on some criterion cannot be compensated for by excellent scores on other criteria.

ELECTRE I also takes into account imprecision and indetermination, at least in the sense of allowing qualitative criteria and facilitating the elicitation of preferences through the formulation of criteria and discordance relations between criteria. Other outranking methods have been developed to handle these aspects with even more care, e.g. the ELECTRE III method (see e.g. De Boer and Van der Wegen, 1996). Note that in the supplier selection example the score of alternative *a* on the criterion distance is better than the score of alternative *b* in case *a* is located closer to the industrial company under consideration and equal in case the distances are exactly equal. One might argue that it is difficult to distinguish between distances of, for instance, 500 and 525 km, respectively. Especially, since geographical distance is not the only aspect influencing a good deliverance performance. A way to overcome this problem is to extend the outranking method in such a way that this indifference could be taken into account. For instance, the decision maker is indifferent between two alternatives with respect to the criterion distance as long as the difference is less than (for instance) 5% of the nearest alternative under consideration, while the decision maker strictly prefers the nearest alternative in case the other one is 20% further away from the company site. In case the distance to the company for the second alternative relative to the nearest alternative is growing (between 5 and 20%) the preference for the nearest alternative becomes larger. Working out this method is more elaborate than working out Electre I. For instance, several additional thresholds (like the 5 and 20% values) have to be determined and the influence of their values on the final decision has to be analyzed. An important advantage of these thresholds is that the weighing out is more subtle. A disadvantage of the use of these thresholds is that scores on qualitative criteria have to be quantified (see De Boer and Van der Wegen, 1996; Roy, 1986). Moreover, the sensitivity analysis used to find out whether the solution is very sensitive to changes in the values of certain parameters is more involved. Therefore, the more advanced and elaborate models such as ELECTRE III seem particularly appropriate for important and crucial supplier selections involving a high degree of imprecision and indetermination, e.g. in case of strategic new task purchases. Furthermore, we also point out that the ELECTRE model as such does not perse require additional information gathering or extensive, complicated calculations. The model merely serves as a means for structuring data that are collected anyway and making the uncertainties and vague preferences surrounding these data more explicit.

4. Concluding comments

It appears from the foregoing sections that outranking techniques may be a useful additional tool for the problem of supplier selection. ELECTRE I takes noncompensatoriness, imprecision and indetermination into account, while extensions like, e.g. ELECTRE III allow an even more subtle way of dealing with imprecision and indetermination. These two properties, and especially noncompensatoriness are hardly ever present in the formal models that so far have been developed for supplier selection. More specifically, as far as we know, in the purchasing literature, outranking methods have not yet been suggested for supporting (strategic) purchasing decisions.

When applying outranking to a decision process, a number of considerations must be made in order to elicit the decision maker's preferences, such as (in the simplest case) the definitions of the criteria and their weights, the discordance sets and the concordance threshold.

Being forced to think about these aspects is in our opinion one of the strengths of the outranking approach as it contributes to a better understanding of the decision problem. Purchasing decision models are sometimes critized for not including intangible aspects or ignoring the famous buyer's 'feel'. However, we argue that such criticism misses the point of what decision models (and at least outranking models) are about: experience, feel, subjective estimates should determine the model instead of the model forcing a rigid format upon the decision maker. Outranking models do not dictate which criteria should be used, which weights should be used, the information that should be gathered or which thresholds should be used. It merely serves as a structure for guiding the process of making these elements explicit. For example, the buyer's feel and experience will often be essential drivers for identifying the criteria that should be considered.

Within the whole range of decision models available, we believe that in many purchasing decisions the outranking approach may be particularly useful. First of all because both quantitative as well as qualitative criteria can be accomodated. Again, we emphasize the relevance of this for dealing with intangible aspects and criteria. Second, more than the traditional purchasing decision models, outranking models enable the decision maker to apply (semi-)compensatory decision rules. Third, the outranking approach is very flexible. For example, a rather simple ELECTRE I model may be used to reduce a large initial set of suppliers relatively quickly to a smaller set of 'good' suppliers, based on limited information. Subsequently, this small set of good suppliers might then be subjected to a more sophisticated ELECTRE III model in order to arrive at a final decision.

Finally, we state once again that ELECTRE I and ELECTRE III are only two members of a much larger family of outranking techniques. Other outranking models may also be considered for application in a purchasing context. Furthermore, this purchasing context may also include other important purchasing related decisions e.g. make-or-buy problems. More in general we believe that the still growing field of Multiple Criteria Decision Aid has much to offer to the purchasing profession, especially because of the increasing importance of a professional purchasing decision making practice.

References

Baily, P., Farmer, D., 1990. Purchasing Principles and Management. Pitman Publishing, London.

Bender, P.S., Brown, R.W., Isaac, H., Shapiro, J.F., 1985. Improving purchasing productivity at IBM with a normative Decision Support System, Interfaces 15, 106–115.

Boer, L. de., Wegen, L.L.M. van der, 1996. An outranking approach to supplier selection, Working paper University of Twente UT-T & M.OMST.WP.96.09, Enschede.

Boer, L de Buter, J.I.H. Telgen, J., 1994. Purchasing as a multi-disciplinary science. In: Biemans, W.G., Ghauri, P.N. (Eds.), Meeting the Challenges of New Frontiers. Proceedings of the 10th Annual IMP Conference, September 1994, Groningen, The Netherlands.

Boer, L. de., 1996. On a renewed acquaintance: purchasing meets operations research. In: Weele, A.J. van (Ed.), Heading for new frontiers in purchasing and supply management. Proceedings of the 5th annual IPSERA Conference, April 1996, Eindhoven, The Netherlands.

Brand, M.J., 1992. Rationele en emotionele factoren bij inkoopgedrag. Holland Management Review 32, 95–104.

Buffa, F.P., Jackson, W.M., 1983. A goal programming model for purchase planning. Journal of Purchasing and Materials Management, Fall 27–34.

Bunn, M.D., 1993. 'Taxonomy of buying decision approaches'. Journal of Marketing 57, 38–56.

Chambers, T.M., 1983. An experimental investigation of a reward/measurement model of organizational buying behavior. Thesis Graduate Faculty of the Virginia Polytechnic Institute and State University.

Chaudry, S.S., Forst, F., Zydiak, J.L., 1993. Vendor selection with price breaks. European Journal of Operational Research 70, 52–66.

Choffray, J.M., Lilien, G.L., 1978. Assessing response to industrial marketing strategy. Journal of Marketing 42, 20–31.

Cook, R.L., 1992. Expert systems in purchasing: applications and development. International Journal of Purchasing and Materials Management, Fall 20–27.

Ellram, L.M., 1990. The supplier selection decision in strategic partnerships. Journal of Purchasing and Materials Management Fall 8–14.

England, W.B., Leenders, M.R., 1975. Purchasing and Materials Management. Irwin, Homewood.

Gaballa, A.A., 1974. Minimum cost allocation of tenders. Operational Research Quarterly 25(3), 389–398.

Goodwin, P., Wright, G., 1991. Decision Analysis for Management Judgment, Wiley, New York.

Gregory, R.E., 1986. Source selection: a matrix approach. Journal of Purchasing and Materials Management, Summer 24–29.

Kingsman, B.G., 1985. Raw Materials Purchasing: an Operational Research Approach. Pergamon Press, Oxford.

Kraljic, P., 1983. Purchasing must become supply management. Harvard Business Review, September/October 109–117.

Lee, W.B., 1972. Corporate simulation models and purchasing decision making. Journal of Purchasing 8, 5–16.

Narasimhan, R., 1983. An analytical approach to supplier selection. Journal of Purchasing and Materials Management, Winter 27–32.

Narasimhan, R., Stoynoff, L.K., 1986. Optimizing aggregate procurement allocation decisions. Journal of Purchasing and Materials Management, Spring 23–30.

Naudé, P., 1994. Changes in attribute salience among DMU members during a decision: some empirical results. In: Biemans, W.G., Ghauri, P.N. (Eds.), Industrial Marketing and Purchasing: Meeting the challenge of New Frontiers, Proceedings of the 10th IMP Annual Conference, September/October, Groningen, The Netherlands, pp. 95–116 (part II).

Pan, A.C., 1989. Allocation of order quantity among suppliers. International Journal of Purchasing and Materials Management, Fall 36–39.

Roy, B., 1968. Classement et choix en présence de points de vue multiples (la méthode ELECTRE) RIRO 8, 57–75.

Roy, B., 1974. Critères multiples et modélisation des préférences: l'apport des relations de surclassement Revue d'Economie Politique.

Roy, B., Présent, M., Silhol, D., 1986. A programming method for determining which Paris metro should be renovated. European Journal of Operational Research **24**, 318–334.

Saaty, T.L., 1980. The Analytic Hierarchy Process. McGraw-Hill, New York.

Sharma, D., Benton, W.C., Srivastava, R., 1989. Competitive strategy and purchasing decisions. In: Proceedings of the 1989 Annual Conference of the Decision Sciences Institute 1088–1090.

Soukup, W.R., 1987. Supplier selection strategies. Journal of Purchasing and Materials Management, Summer 7–12.

Stekelenborg, R.H.A. van, 1997. Information Technology for Purchasing: how to use the power of Information Technology in present-day purchasing. Ph.D Thesis Eindhoven University of Technology.

Stevens, J., 1978. Measuring purchasing performance: with a Special Reference as to how Purchasing Performance is Measured in the United Kingdom. Business Books, London.

Thompson, K.N., 1990. Vendor Profile Analysis. Journal of Purchasing and Materials Management, Winter 11–18.

Turner, I., 1988. An independent system for the evaluation of contract tenders. Journal of the Operations Research Society 39, 551–561.

Weber, C.A., Current, J.R., Benton, W.C., 1991. Vendor selection criteria and methods. European Journal of Operational Research 50, 2–18.

Weber, C.A., Current, J.R., 1993. A multiobjective approach to vendor selection. European Journal of Operational Research 68, 173–184.

Webster, F., Wind, Y., 1972. Organizational Buying Behavior. Prentice-Hall, New York.

Weele, A.J. van, 1994. Purchasing Management: Analysis, Planning and Practice. Chapman & Hall, London.

Williams, R.F., 1984. Purchasing the technological product: selecting and weighting criteria for the inherently complex new product. Ann Arbor, MI, University Microfilms International.

Yoon, K.P., Naadimuthu, G., 1993. Purchasing decisions for public commodities. In: Pawar, K.D. (Ed.), Proceedings of the 2nd International Symposium on Logistics, Nottingham.

Zenz, G., 1981. Purchasing and the Management of Materials. Wiley, New York.