Ranking Projects Using the ELECTRE Method

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Abstract

Ranking and selecting projects is a relatively common, yet often difficult task. It is complicated because there is usually more than one dimension for measuring the impact of each project and more than one decision maker. This paper considers a real application of project selection for ECNZ, Northern Generation, using an approach called ELECTRE. The ELECTRE method has several unique features not found in other solution methods; these are the concepts of outranking and indifference and preference thresholds. The ELECTRE method is explained and applied to the project selection problem using a Visual Basic application within Microsoft Excel. Results show that ELECTRE was well received by the decision makers and, importantly, provided sensible and straightforward rankings.

1 Introduction

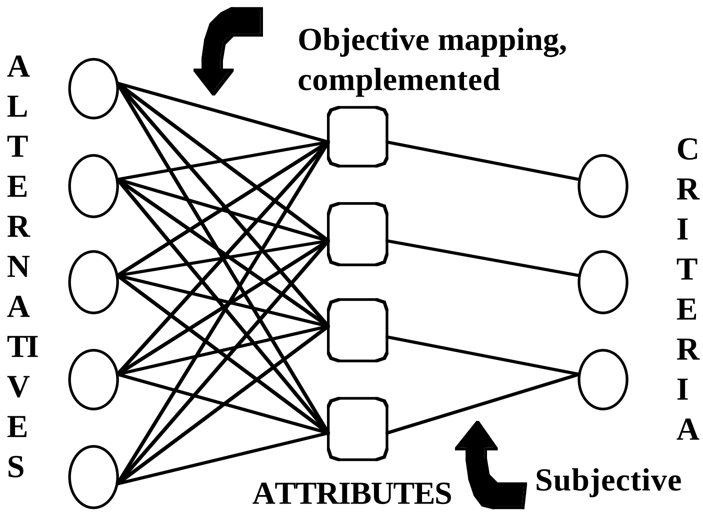
Each year ECNZ Northern Generation plan capital and maintenance programmes to enhance and maintain generating plant. Since the "wish list" of proposed projects invariably exceeds financial targets, the task of cutting the list to a reasonable size is an annual challenge. There are two rationalisation processes, one for minor projects (less than $250,000) and one for major projects. The economics of each major project is evaluated using a standard cost benefit spreadsheet and the results of this form the basis of discussion as to whether the project should be accepted or rejected. The process for minor projects is quite different. Generally the total funding requirements of these projects considerably exceeds the target and a large cut is required. Historically, the process of fund allocation for minor projects consists of the Group Accountant coordinating a meeting of about thirty sponsors and stakeholders, where each project is presented by it's sponsor. Arguments for and against projects are generally subjective with little reference to quantitative analysis. A goal of Northern Generation this year was to introduce a more objective methodology for the allocation of minor project funds.

This paper discusses the introduction and use of a methodology for project ranking in ECNZ Northern Generation and, in particular, illustrates the use of a particular solution method called ELECTRE.

2 The project ranking decision problem

The project ranking problem is, like many decision problems, challenging for at least two reasons. First, there is no single criterion which adequately captures the effect or impact of each project; in other words, it is a multiple criteria problem. Second, there is no single decision maker; instead the project ranking requires a consensus from a group of decision makers.

Henig and Buchanan [3] and Buchanan *et al*. [1] have argued that good decisions come from good decision process and suggest that where possible the subjective and objective parts of the decision process should be separated. This separation enables the decision making process to move away from being unnecessarily subjective and toward a more objective orientation. A decision problem can be conceived as comprising two components; a set of objectively defined alternatives and a set of subjectively defined criteria. The relationship between the alternatives and the criteria is described using attributes, which are the objective and measurable features of alternatives. Attributes form the bridge between the alternatives and the criteria. In Figure 1 the alternative-attribute-criteria mappings are illustrated.



1. Alternative-Attribute-Criteria Mapping

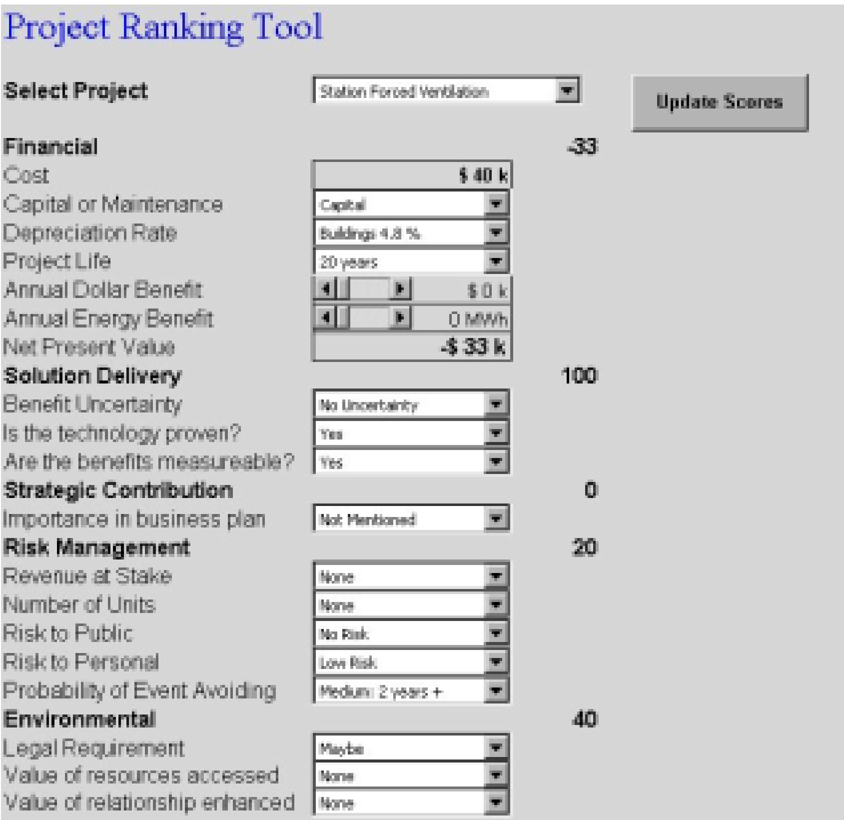
In the context of the project ranking problem for Northern Generation, the alternatives tend to be clearly defined. They are the projects, such as:

- Maraetai 2 Penstock and Power Station Area Rock Stabilisation,
- Automatic Generator Control,
- Lower Station Electrical Upgrade,
- Station Forced Ventilation, and so on.

For each project, there are a number of criteria that measure the impact of each alternative or project. The choice of appropriate criteria can be quite an art and is typically far more difficult than identifying alternatives. The five criteria eventually used to evaluate the projects were:

- *financial* (including: cost and financial return) F
- *solution delivery* (including: consequences of poor implementation and "proven-ness" of the technology) SD
- *strategic contribution* (including: contribution to the business plan and to the core business) SC
- *risk management* (including: risk of plant failure and damage following natural disaster), and RM
- *environmental* (including: effect on relationship with resource partners and on access to resources). E

The inputs are captured using a menu-driven screen; an example is shown Figure 2.



2. Input screen for capturing project impact on criteria

Most criteria have been decomposed into simpler, well-defined attribute measures. These are then combined to produce a score for each project for each criterion. The scores for the last four criteria use a 0-100 scale. The financial criterion uses net present value (NPV). This input, where each alternative is assessed using each criterion, produces a matrix of impacts - referred to as performances. Table 3 provides an example of such a performance matrix, using a subset of five projects.

Using the conception of Figure 1, the "objective" part of the decision problem is that part which does not include the preferences of the decision makers; that is, the performance matrix. This does not mean that these performances are known with certainty - clearly they are estimates - but rather that they are independent of the preferences (the subjective inputs) of the decision makers. In terms of process, then, we first endeavoured to derive a matrix of performances which was accepted by all involved.

	F	SD	SC	RM	E
Project 1	-14	90	0	40	100
Project 2	129	100	0	0	0
Project 3	-10	50	0	10	100
Project 4	44	90	0	5	0
Project 5	-14	100	0	20	40

3. Performance Matrix

The subjective inputs are provided by the decision makers and relate specifically to the criteria and their relative importance. These will be discussed in the following section, once some of the initial concepts of ELECTRE have been introduced.

However, before we consider the ELECTRE method in detail, there remains at least one important question, "How should these projects be ranked?" There are a variety of solution methods available. Two well-known methods are a simple decision analysis technique - SMART [2] and the analytic hierarchy process - AHP [7]. The choice of solution method is, in itself, a multiple criteria decision problem. The ELECTRE method was selected over the other two due to its ability to incorporate the fuzzy nature of decision making (by using thresholds of indifference and preference) and because the number of pairwise comparisons required by AHP when comparing 80 projects was overwhelming - approximately 16,000. The choice of ELECTRE was also based on successful applications of the method, including ranking Paris Metro stations for renovations [6].

3 The ELECTRE method

ELECTRE was conceived by Bernard Roy [5] in response to deficiencies of existing decision making solution methods. ELECTRE is more than just a solution method; it is a philosophy of decision aid - the philosophy is discussed at length by Roy [5]. However, for this paper we shall concentrate on the method and specifically on what is referred to as ELECTRE III. ELECTRE has evolved through a number of versions (I through IV); all are based on the same fundamental concepts but are operationally somewhat different. It is important to note that ELECTRE is not being presented as the "best" decision aid. It is one proven approach. Simpson [8] has compared both SMART and ELECTRE and she concludes that, "*There are obvious differences between the methods, but it is not obvious that one method is stronger than the other*." (p. 928)

Two important concepts underscore the ELECTRE approach; thresholds and outranking. These will now be discussed. Assume that there exist defined criteria, g_j, j=1,2,…,r and a set of alternatives, A. Traditional preference modelling assumes the following three relations hold for two alternatives (a, b) ∈ A:

a**P**b (a is preferred to b) | g(a) > g(b)
a**I**b (a is indifferent to b) | g(a) = g(b)
a**J**b (a cannot be compared to b).

However, consider Project1 and Project3 for criterion F with values of -14 and -10 respectively (using Table 3 data). Does this mean that Project1 is preferred to Project3? Is the small difference of 4 sufficient reason to make one more preferred than the other? If, for example, you have two cups of tea - one has 10 mg of sugar and the other has 11 mg of sugar - could you tell the difference? Traditional preference modelling says that because the amount of sugar is not equal, then one will be preferred over the other.

In contrast to the traditional approach, ELECTRE introduces the concept of an indifference threshold, q, and the preference relationships are redefined as follows:

a**P**b (a is preferred to b) ⇔ $g(a) > g(b) + q$
a**I**b (a is indifferent to b) ⇔ $|g(a) - g(b)| \leq q$, and
a**J**b (a cannot be compared to b) remains.

The indifference threshold is specified by the decision maker. While the introduction of this threshold goes some way toward incorporating how a decision maker actually does feel about realistic comparisons, a problem remains. There is a point at which the decision maker changes from indifference to strict preference. Conceptually, there is good reason to introduce a buffer zone between indifference and strict preference; an intermediary zone where the decision maker hesitates between preference and indifference. This zone of hesitation is referred to as weak preference; it is also a binary relation like **P** and **I** above, and is modelled by introducing a preference threshold, p. Thus we have a double threshold model, with the additional binary relation **Q** which measures weak preference. That is:

a**P**b (a is strongly preferred to b) ⇔ $g(a)-g(b) > p$
a**Q**b (a is weakly preferred to b) ⇔ $q < g(a)- g(b) \leq p$
a**I**b (a is indifferent to b; and b to a) ⇔ $|g(a) - g(b)| \leq q$

The choice of thresholds intimately affects whether a particular binary relationship holds. While the choice of appropriate thresholds is not easy, in most realistic decision making situations there are good reasons for choosing non-zero values for p and q.

Using thresholds, the ELECTRE method seeks to build an outranking relation **S**. To say a**S**b means that "a is at least as good as b" OR "a is not worse than b." It should be noted that these binary relationships are applied to each of the *r* criteria; that is,

a$\mathbf{S}_j$b means that "a is at least as good as b with respect to the j^{th} criterion."

In order to develop this outranking relationship, two further definitions are required - that of concordance and discordance.

The j^{th} criterion is in <u>concordance</u> with the assertion a**S**b if and only if a$\mathbf{S}_j$b. That is, if $g_j(a) \geq g_j(b) - q_j$. Thus, even if $g_j(a)$ is less than $g_j(b)$ by an amount up to q_j, it does not contravene the assertion aS_jb and therefore is in concordance.

The j^{th} criterion is in <u>discordance</u> with the assertion a**S**b if and only if b$\mathbf{P}_j$a. That is, if $g_j(b) \geq g_j(a) + p_j$. That is, if b is strictly preferred to a for criterion j, then it is clearly not in concordance with the assertion that a**S**b.

These two concepts of concordance and discordance can be thought of as "harmony" and "disharmony." For each criterion j we are looking to see whether, for every pair of alternatives (a,b), there is harmony or disharmony with the assertion a**S**b; that is, a is at least as good as b.

With these concepts it is now possible to obtain a measure of the strength of the assertion a**S**b. This measure is called the concordance index **C**(a,b), for a given pair of alternatives (a,b) ∈ A. Let k_j be the importance coefficient or weight for criterion j. We define a valued outranking relation as follows:

$$C(a,b) = \frac{1}{k}\sum_{j=1}^{r} k_j c_j(a,b), \text{ where } k = \sum_{j=1}^{r} k_j$$

where

$$C(a,b) = \begin{cases} 1, \text{ if } g_j(a) + q_j \ ? \ g_j(b) \\ 0, \text{if } g_j(a) + p_j \leq g_j(b) \\ \theta, \text{if in between} \end{cases} \qquad \text{and } \theta = \frac{p_j + g_j(a) - g_j(b)}{p_j - q_j}$$

We shall provide a simple example using the data from Table 3 and calculate the concordance index for the pair of projects P2 and P5. First, we must define the thresholds and weights, as in Table 4.

	F	**SD**	**SC**	**RM**	**E**
Indifference threshold (q)	25	16	0	12	10
Preference threshold (p)	50	24	1	24	20
Weights	1	1	1	1	1

4. Thresholds and Weights

Then

C_1(P2,P5) = 1, since 129 + 25 ≥ -14

C_2(P2,P5) = 1, since 100 + 16 ≥ 100

C_3(P2,P5) = 1, since 0 + 0 ≥ 0

C_4(P2,P5) = 0.333, since 0 + 12 $\ngeq$ 20 and 0 + 20 $\nleq$ 40, then $\frac{24 + 0 - 20}{24 - 12} = 0.333$

C_5(P2,P5) = 0, since 0 + 20 ≤ 40.

Therefore **C**(P2,P5) = $\frac{(1)(1) + (1)(1) + (1)(1) + (1)(0.333) + (1)(0)}{1+1+1+1+1} = 0.667.$

This value of 0.667 measures the strength of the assertion that P2 is at least as good as P5. Table 5 presents the complete concordance matrix.

	P1	**P2**	**P3**	**P4**	**P5**
Project 1	1.00	0.80	1.00	0.80	1.00
Project 2	0.60	1.00	0.80	1.00	0.67
Project 3	0.60	0.60	1.00	0.60	0.80
Project 4	0.60	0.80	0.80	1.00	0.75
Project 5	0.67	0.80	0.80	0.80	1.00

5. Concordance Matrix

The concordance values are easily interpreted. For example, a value of 0.80 for **C**(P1,P2) means that for four out of five criteria, P1 was at least as good as P2. Only for the financial criterion **F** was P2 strictly preferred to P1; that is, the difference exceeded the preference threshold of 50. As thresholds are made smaller, the concordance matrix becomes more symmetric. In the limiting case of no thresholds,

$$\mathbf{C}(P_i,P_j) + \mathbf{C}(P_j,P_i) = 1, \ \forall i, j;\ i ? j.$$

Here, the concordance value is simply a count of the number of criteria where one alternative is preferred to the other.

At this point, two issues remain unresolved. The first is the explicit inclusion of discordance into the method and the second concerns how to produce a final project ranking from the pairwise outranking information. While it is beyond the scope of this paper to go into detail of these issues, a brief discussion follows.

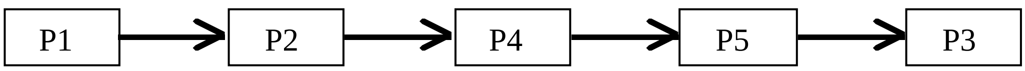
In order to calculate discordance, a further threshold called the veto threshold is defined. This veto threshold, v, allows for the possibility of a**S**b to be refused totally if, for any one criterion j, $g_j(b) > g_j(a) + v_j$. Assume for our example the veto threshold for the financial criterion **F** was 100, and we compare P1 and P2. It is clear that:

$$g_{\mathbf{F}}(P2) > g_{\mathbf{F}}(P1) + v_{\mathbf{F}} \qquad \text{or} \qquad 129 > -14 + 100.$$

Therefore, the discordance index (**D**) for P1 and P2 in this case would be **D**(P1,P2) = 1.00. Thus a discordance matrix is derived which, when combined with the concordance matrix, produces what is called a "credibility" matrix. The credibility matrix provides a quantitative measure of the strength of the assertion a**S**b; that is, a is at least as good as b.

The process for determining a ranking from the credibility matrix is based on graph theory concepts. Essentially two preorders are derived and combined to give a final ranking. An outline of this process can be found in Roy *et al.* [6] and Vincke [9]. Further information is available from the authors. The ranking procedure has been successfully and simply implemented using Visual Basic within Microsoft Excel.

The final ranking of the projects in the example is:



6. Ranking of Example Projects

4 Results and Discussion

Rather than purchase or develop an application to implement the ELECTRE method, we decided to take advantage of the flexibility of Excel and prototype a project ranking tool. The rationale for this was that we considered that the inputs and creation of the performance matrix was very much an iterative process and could change significantly as the project developed. Also, the complete system could be thoroughly tested and proven prior to committing any significant expenditure to application development.

An electronic form to collect the relevant data was made available to staff for submitting minor projects. Approximately 80 minor capital and maintenance projects were submitted and the data for each project consolidated into a single spreadsheet. The Business Analyst and Group Accountant reviewed the input data on each project to ensure consistency and a ranked list of projects was created using ELECTRE. Thresholds and weights were also assigned after consultation with the decision makers. In fact, the AHP method was used to obtain weights for each criterion. The total funds requested against the target were as follows:

	Target	**Funds Requested**
Maintenance	$ 1.25 m	$ 3.07 m
Capital	$ 0.65 m	$ 1.28 m

7. Capital and Maintenance Project Funds

A meeting of project sponsors and stakeholders was called and the ranked list was proposed as a starting point to identify the cut-off line. Each project was then quickly reviewed to ensure that it had been properly represented. Projects “below” the line were more thoroughly reviewed to ensure that an essential project was not being dropped in place of another project with more quantifiable benefits. The inputs to many projects were updated and a revised ranking obtained. This list of projects was then submitted and approved for the 1998/99 financial year.

5 Conclusions

As a pilot project, the use of the ELECTRE method was successful. It passed what came to be referred to as "the common sense test." That is, the ranking process and the outcomes were accepted among decision makers at Northern Generation. One reason for the success is, in our view, the structuring of the project ranking problem. It should be expected that any structuring of a decision problem will improve the process and find favour with the decision makers.

However, an exception to this last statement was taking place at the same time as the ELECTRE approach was being developed. An alternative method for project ranking (referred to by the acronym CCPS) was also being recommended to Northern Generation for their project ranking exercises. CCPS was a structured approach to project ranking, based on a decision analysis approach. It required some 130 questions to be answered for each project; these answers were then aggregated into a small set of criteria from which a ranking was derived. The CCPS method was not well received at Northern Generation because of excessive detail (it was overly structured) and because some of the internal logic appeared to be contradictory. In the end, it was not used.

The simple approach described here first separated the objective components from the subjective components. The performances - the impact of each project on the five criteria - is objective and has nothing to do with decision maker preference. In decision analysis parlance, it is a matter of belief, not of preference. The thresholds and weights, however, are subjective. Once the performances are agreed to by all decision makers, then the subjective inputs of thresholds and weights can be processed. This separation proved helpful, and is common in most structured decision methods.

Sensitivity analysis showed that, in general, the project rankings were considerably more sensitive to changes in the performances than they were to changes in the thresholds or weights. This is helpful and means that within a relatively wide band of preference, the same projects are considered important. Further, it requires the individual project sponsors to make the effort and ensure that the performance data is both accurate and defensible.

This prototype ELECTRE method is now being used to evaluate and rank information technology projects at Northern Generation.

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