EIS PROCESS AND DECISION MAKING

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FOREWORD

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Michel Gariepy, associate professor at the University of Montreal's Institut d'urbanisme was project director and Olivier Soubeyran, also an associate professor at the Institut d'urbanisme, was assistant project director.

This research report presents the methodological role that could be payed by a decision aid model, manelly the ELECTRE model, in envirionmental impact studies. The ELECTRE model was developed at the Laboratoire d'analyse et modélisation du système d'aide à la decision (LAMSADE, or from LAMSADE documents (cited in the bibliography).

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1. INTRODUCTION

Any scientific study involves selection of the methods of analysis. This selection is determined, on the one hand, by the problem involved in the study and, on the other, by the objectives of the study. Scientific examination of the problems caused by man within his environment, or, more specifically, impact studies, involve this same problem of the selection of research methods.

An impact study consists essentially of using acquired information to anticipate possible changes and their consequences on the environment as a result of the implementation of a project. This is its primary objective. Because the content of impact studies may vary considerably depending on the project under study, and because the environment is a dynamic system made up of a multitude of factors, all of which must be taken into consideration, a project's impact on the environment will inevitably affect a number of aspects of the area in which it is implemented. For these reasons, choices must be made, either among a number of potential impacts of a project, or among a number of possible sites for the project, or even between proceeding and not proceeding with the project under study, etc. In order to permit these choices, the impacts identified by the impact studies must be assessed. Impact studies are produced to assist in making this choice.

In short, impact studies thus involve a dual problem: determining the impacts which a project will have on its environment and assessing the project on the basis of these impacts and of economic and social considerations, etc.

The task of synthesis and analysis arising out of a problem of this nature reveals the extreme complexity of the problem. This complexity is related, on the one hand, to the large number of factors involved, many of which may be contradictory or, at least, difficult to quantify (for example, it is frequently difficult to quantify adequately the social impact of a project), and frequently, on the other, to the large number of parties affected or concerned by the potential impact of a project (each with its own view and its own values to defend in relation to the project under study). Yet a decision will be made as to the desirability of proceeding or not proceeding with the project under study. Since this decision will be made on the basis of the scientific analysis performed, we believe that it is important that this effort at synthesis and assessment be performed with the assistance of instruments (or methods) which make it possible to structure, stimulate and guide reflection on the choices to be made.

From this perspective, we shall attempt to test the potential contribution to the process of assessing environmental impact offered by a methodology (the ELECTRE method) which permits and regulates the type of constraints affecting the selection of an action which may modify one or more elements of the environment. The question which we will attempt to answer is thus a dual one:

- how is a choice to be made between a number of possible actions or options? and
- how are options to be selected when they are judged on the basis of criteria which in many cases are not comparable?

Choosing involves making a decision which indicates the preference assigned to one object, person or idea over others. Indicating one or more preferences implies the expression of a *judgment* or feeling that one object, idea or person is considered superior, better or more important than the rest. It is like expressing an order of magnitude or a scale of value with respect to a number of *objects.* These definitions also imply acceptance of the need for comparisons on the part of the individual or individuals making the choice. Choice is impossible for those who refuse to establish relations of relative importance among the various *objects* in competition.

The four generations of the ELECTRE model, developed by Bernard Roy[1], have been prepared on the basis of this concept of preference (implied in any choice) to guide the decision-making process. The ELECTRE models represent preferences in a formal manner (mathematical modeling), defined as *outranking relations* by a multicriteria problem.

We thus propose to use a project which has been the subject of an environmental impact assessment to:

1. define more specifically the type of content and the conditions for application of the ELECTRE model;
2. identify one stage in the impact study which clearly reflects the problem involved in the process;
3. perform a detailed application of the ELECTRE model;
4. analyse, in conclusion, the contributions and suitability of the ELECTRE method to the EIS process in relation to the example of application.

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[1] In the past fifteen years, four generations of models (ELECTRE I, II, III AND IV) have been developed by B. Roy's School: The Laboratoire d'analyse et modélisation du système pour l'aide à la décision (LAMSADE, Université de Paris-Dauphine).

2. THE ELECTRE METHOD[2]

In preparing a mathematical representation of preferences, the modeler uses *descriptors* and *evaluators.* We use the term evaluators for the projection of the set of options on a set of descriptors. The descriptors may be mathematically very different. They may be:

- measurements;
- totally ordered sets;
- elements of a set;
- something in between.

The concept of **a** descriptor does not include the idea of preference. That of *criterion* does. We will use the term criterion for a descriptor involving a preference structure. In fact, a measurement (for example, temperature expressed in degrees Celsius) does not represent a value judgment, but rather the collection and systematic classification of data on one or more objects. The results of measurements may be subsequently assessed. We then interpret the results of the measurement by assigning it a significance, and making a value judgment. Thus, a single descriptor may have a number of different **significances** on the same assessments; hence the idea of a number of possible viewpoints on a single problem. We shall see later how the ELECTRE III model makes in-depth use of this concept of a preference structure on a criterion.

An assessment table is thus developed on the basis of the matrix of data on each of the actions.

Actions \ Criteria	1	2	3
a			
b			
c			

In short, in order for a descriptor to be a criterion, it must first have some involvement in the decision problem under study. Similarly, since the structure associated with the descriptor does not necessarily coincide with its preference structure, this preference structure must be defined.

In addition, the ELECTRE method makes it possible to express other value judgments on the basis of the relative importance of the criteria, by assigning a (numerical) weight to each of the criteria. The assessment table thus takes the following form:

Actions \ Criteria	1	2	3
a			
b			
c			
weights	**x**	**y**	**z**

In relation to the specific problem in question, modeling thus involves the following steps:

1. Definition of the set of possible alternatives for the problem under study.
2. Identification of the descriptors to be taken into consideration in selecting the preferred option and definition of the preference structure of these descriptors (that is, definition of the criteria).
3. Preparation of a double-entry table: the criteria are listed along the side, the possible alternatives across the top. At each of the intersections, we place the assessment of alternative (a) on criterion **(e).** This table is called: ***multicriteria** assessment table.*
4. Determination of the weights assigned to each of the criteria.

This formulation of the case under study is one of the most important and most delicate steps in any decision-making study. It is essential:

- to select the proper set of possible actions or alternatives, that is, the set which contains all the actions to be taken into consideration;
- to canvass all the relevant viewpoints (or preferences);
- to identify the descriptors and criteria expressing these viewpoints;
- to identify evaluators which are at once reliable and functional.

Finally, before beginning the actual modeling process, it is necessary as well to determine the type of multicriteria problem to be dealt with, that is:

- finding one option which is preferred to all the rest;
- finding a subset of the set of options containing the preferred option;

[2] Our presentation on the ELECTRE method is essentially drawn from the description provided by **Alain Schärlig** in: ***Décider sur plusieurs critères,*** *Panorama* ***de l'aide à*** la ***décision multicritère,*** Presses **Polytechniques Romandes, Lausanne,** 1985.

- visualizing the preferences of a number of the parties to the process with respect to the preferred option;
- assigning the set of options an overall order or preorder structure, that is, ranking the options from best to least good on the basis of the preferences expressed.

The ELECTRE model uses the data from the multicriteria assessment table to “calculate” *outranking relations* among the various options.

The manner of establishing an outranking of one option by another is based on **a** concept expressed by Condorcet in 1785, in connection with democracy: one action outranks another if it is at least as good as the other in respect of a majority of criteria, without being too markedly inferior to the other in respect of the other **criteria**[3]. Outranking is thus subject to a condition of *concordance,* a condition requiring that a certain majority of the criteria favour the outranking option; at the same time, it is subject to a condition of ***non-discordance,*** a condition requiring that there be no overly strong pressure in any one of the criteria in favour of the inverse outranking. It is possible, for example, to have a single divergent criterion, of little weight in the set, yet have the divergence on this criterion so significant that it makes the outranking implausible. This is Condorcet’s concern. Outranking relates to only two options at a time. Since pair ah is different in this case from pair b/a, all the options must be reviewed, one at a time, and compared to all the others, in order to determine in each case whether or not the first outranks the second. In this way, we can establish a **double-**entry table, in which the entries consist of the list of options, expressing the outrankings of one option over another.

Table of outrankings

Option	Option 1	2	3	4
1				
2				
3				
4				

ELECTRE **I and II**

ELECTRE I (1968) is the oldest and simplest of this family of models. It is concerned with the problem of choice, or *alpha* problem. The choice problem consists of identifying a subset in the set of options considered which contains the “best” options or, failing that, the “most satisfactory” options.

The index of concordance is obtained by considering the criteria for which the first option is at least as good as the second (hence **≥).** The weights of these **criteria** are summed, and this sum **is** divided by all the weights. This final operation serves to norm, that is, to obtain an index between 0 and 1.

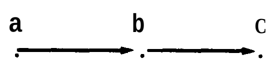
The index of discordance seeks to identify the criteria in which the divergence is strongest, that is, the criterion in which the difference in the assessments of the two options compared shows the greatest discordance on outranking. This difference is then divided by the length of the largest scale of numerical values assigned to the criteria, again in order to obtain an index between 0 and 1. Thus, the larger the **scale** of values, the larger the potential index of discordance for this criterion. In contrast, the length of the scales plays no role in calculating the index of concordance: instead, it is the weights which influence the results obtained for this index.

When these calculations have been performed for all possible ordered pairs, they can be summarized in two matrices: a matrix of the indices of concordance and a matrix of the indices of discordance. Applying Condorcet’s rule, one option outranks another only if the concordance with the data is good and the discordance is not too high on any of the criteria. Selection of these “reference” values is the responsibility of the user of the model.

ELECTRE I does not make decisions. The method allows the user to make the final separation, a trait characteristic of the multicriteria approach, on the basis of the viewpoints expressed by those responsible or by other interested parties. These viewpoints, as formulated by ELECTRE I, are reflected in the outranking graph. It is by analysing this graph that a subset of the **"best"** options is identified.

The subset is defined by the authors of ELECTRE on the basis of graph theory: it is the node of the outranking graph. The definition of node, as the term is used in graph theory, corresponds closely to the goal of the ELECTRE method: a node is obtained in a given graph by selecting a subset such that each of the vertices eliminated is outranked by at least one of the vertices retained, and such that none of the vertices retained is outranked by any of the others retained as well.

Determination of the subset is based on intransitivity. For example, the node of the following examples consists of options **a** and c:



If the relation were transitive, then option **a would** be the only element of the node’. However, since we are dealing with **a multicriteria** problem, in order for **a to** outrank c, there must be an arrow running directly from **a** to **c.** We can

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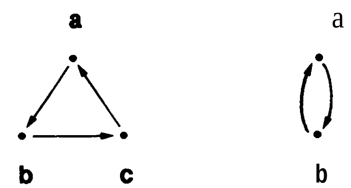
[3] At least as good means that the criteria rating the action equal are considered equivalent to those rating it better.

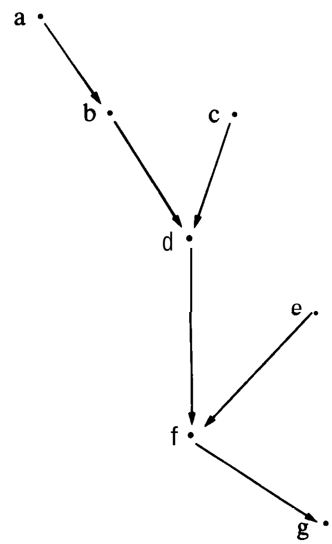
[4] By definition, a relation **R** is transitive if: **aRb** and **bRc => aRc.** This is the case in particular with relations such as “equal to’ or ‘less than’ where: $a < b$ and $b < c \Rightarrow a < c$
But a relation may not necessarily have this property. The relation ‘is equal to twice’ is not transitive. This is true for a number of other relations, which are therefore described as intransitive.

sure in the preceding example that the criteria on the basis of which **a** outranks **b are** different from those on the basis of which b outranks c. If these criteria were the same, then **a** would obviously have outranked c as well.

Once we accept intransitivity, we also accept the presence of circuits in the graph. Circuits are cases in which pairs of options mutually outrank one another. Initially they are considered equivalents. The vertices connected by a circuit are then combined into a single equivalence class in the **graph.**

Example of circuits:





ELECTRE II and III, produced a few years after ELECTRE I, again under the direction of Bernard Roy, fit the same pattern.

ELECTRE II (1971-72) was produced to create a method for use in the problem of ranking, in which options are to be classified from the “best” to the “least good”. In addition, a number of new features were included.

In order to eliminate, as far as possible, the circuits produced by overlapping of the criteria “considered” equivalent, the sum of the weights of the criteria which are better in relation to the weights of the discordant criteria for an outranking of one option over another must be greater than 1.

For the remainder, the index of concordance does not change, but it is assigned three levels. Similarly, the definition of the index of discordance does not change, but it is calculated for each discordant criterion and is assigned two levels in each discordant criterion. The levels of discordance are selected on the basis of the length of the scale of assessments associated with each criterion.

All these levels provide the basis for another new feature, the distinction between weak and strong outrankings. The outranking graph will thus consist of these two types of outrankings.

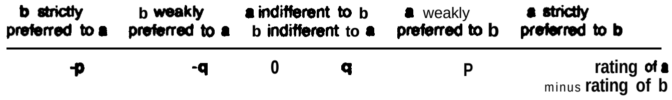
In order to deal with the ranking problem, ELECTRE II then attempts to perform two rankings of the options on the basis of the outranking graph, that is, one “direct” classification and another “inverse” classification. For the direct classification, we **look** at the strong outrankings in order to rank the options by classes, on the basis of the length of the paths. In graph theory, the length of a path is the number of arcs (arrows) of which it consists.

Thus, the first class consists of non-outranked options, that is, those options at which a path of zero length terminates (options **a, c** and e in the example above). The second class consists of those options at which a path of length 1 terminates (these are the options which would be **non-**outranked. if the first class were eliminated from the graph), etc. Tied options in the same class are distinguished, wherever possible, on the basis of the weak outrankings.

For the second, or inverse, ranking, the options are ranked on the basis of the length of the paths, again using the strong outrankings, but this time with the paths emanating from them. Thus, the first class now consists of those options from which a path of maximum length emanates; the last class now consists of those options which are not outranked by any others. Once again, tied options are distinguished within the classes on the basis of the weak outrankings.

The two classifications are then compared. If they are relatively similar, we can assume that the results of the procedure are solid. If the results differ too widely, it is because no classification of all the options presented, on the basis of the criteria and levels used, can be given with any guarantee of solidity. We can then consider the options showing wide variations in the two rankings as impossible to classify on the basis of the information available. These options are then considered noncomparable actions. The ELECTRE methods recognize this situation, which is described as “option incomparability”. Incomparability is a situation in which the effort to clarify a decision is hampered by the imperfection of the information available (a relatively common situation). These two concepts, intransitivity and incomparability, are based on human considerations. This is one of the principal qualities of the ELECTRE methods.

ELECTRE III[5]



Like ELECTRE II, ELECTRE III deals with the problem of ranking. However, ELECTRE Ill does not attempt to identify only two types of outranking, strong and weak, but considers an entire family, ranging from the totally strong (rated **1)** to the totally weak or nonexistent (rated **0),** and including all possible levels on the continuous **scale** between these two extremes. In addition, ELECTRE III considers outrankings in relation to their degree of credibility. The degree of credibility is rated 1 for an outranking completely justified by human judgment, and 0 for an outranking which cannot possibly be justified. As in the preceding **ELECTREs,** the outranking relation makes use of concordance and discordance, albeit in a different manner. This time, the calculation of concordance includes a number of different levels. This permits the introduction of the concept of a preference structure for the assessment criteria.

We can look at the difference by taking the rating of option **a** minus the rating of option **b.** This difference *-* whether positive or negative **- may** be considered too-weak to be of any significance; in this case, we have a situation of indifference. In applying ELECTRE Ill, this involves defining a value q, known as the indifference level, and deciding that indifference exists when the difference is less than q. If, however, the difference is very strong, greater than a quantity **p,** known as the preference level, the more highly rated option is considered to be preferred. In this case, we have a situation of strict preference. Between the two, that is, between **q** and **p,** is the zone of weak preference for the more highly rated option. This situation thus reflects a transition between indifference and strict preference.

These levels are selected by the user or users of the model. A preference structure is then defined in relation to each of the criteria, which then become, in Bernard Roy's terminology, *pseudo-criteria.* A pseudo-criterion is a criterion into which the two functions (or constants) **p** and **q** have been introduced. This formulation of the problem is based on human considerations which frequently conflict with mathematical logic, but are well adapted to the constraints of environmental problems. Definition of these levels thus makes it possible to assign each of the criteria its own preference structure.

As in ELECTRE I and II, the outranking relation is constructed through the application of the techniques of concordance and discordance to each of the criteria, before synthesis is attempted.

ELECTRE III thus attempts to rank actions by expressing the relative positions of the options in some detail and attempting to divide them into equivalence classes.

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[5] Our description of ELECTRE III is derived from the research report prepared by Bernard Roy, author of the method (see bibliography).

3. THE PROJECT UNDER STUDY

The project which will be used as the basis for this study involves the construction of a 735 kV electrical power line and the construction of a 735230 kV station in the Eastern Townships region of Quebec. Since this type of facility is subject to Quebec's Environment Quality Act (RSQ, c Q-21, the promoter of the project, Hydro-Quebec, performed impact studies which were made public in 1983 and reported on by the Bureau d'Audiences Publiques sur l'Environnement (BAPE). Analysis of this research will therefore be based on the impact studies performed in connection with the project, entitled "Poste Des Cantons à 735-230 kV et lignes 735 kV Nicolet-Des Cantons" [735-230 kV Townships station and 735 kV Nicolet-Townships lines].

Briefly, the intention to construct these new facilities is based on historical analyses of the increase in peak demand for electricity over a 15-year period (1966-l 981) and on economic and demographic projections for a 17-year period (1981-1998) for Quebec as a whole.

Working from these data, the promoter produced projections of the demand for electricity for the period 1981 to 1998. The promoter then demonstrates that, by 1986, the demand for electricity in the Sherbrooke region will exceed the capacity of the existing network. The promoter thus justifies the construction of a new power line to serve the Sherbrooke region.

Study of the context

Two solutions involving voltages of 230 and 735 kV were examined. Both voltage levels are available at the Nicolet station, the only station considered close enough to Sherbrooke to offer a possible starting point for a new line. The Hertel and Boucherville stations were not considered for reasons of a technical nature' (Figure 1).

[6] These stations offer the possibility of a 315 kV option; but the distance of approximately 125 km separating these stations from the region to be supplied made this option technically unacceptable. Source: Hydro-Quebec, Rapport sur les etudes d'avant-projet [Report on preliminary studies], April 1993, p 12.

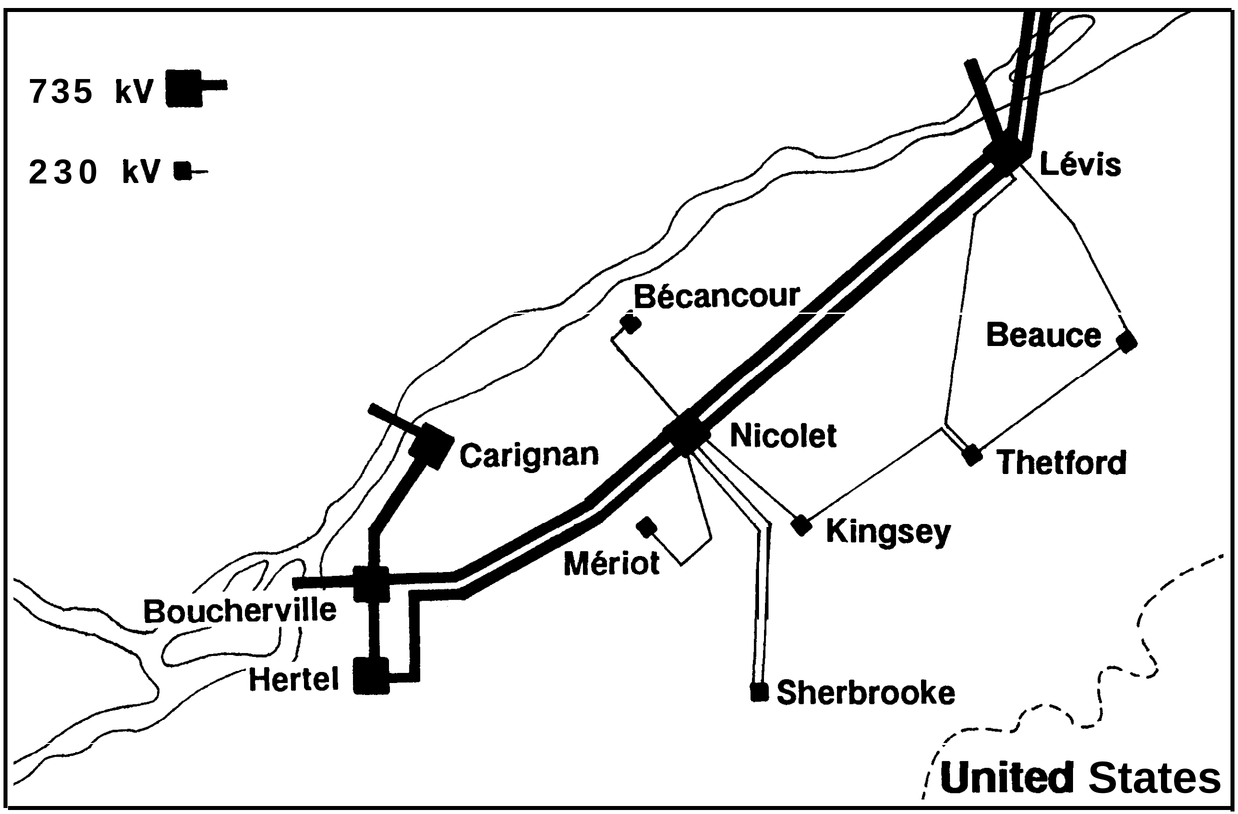


Figure 1: 735 - 230 kV network

Source: Hydro-Québec, Rapport sur les etudes d'avant-projet [Report on preliminary studies], April 1993, p. 15.

In addition, the two solutions visualized must form part of a network designed to meet the long-term needs not only of the Eastern Townships region but also of the entire region bounded by the St Lawrence River, the American border, the town of Montmagny **(east** of Quebec City) and the Ontario border. The assessment thus considers three closely related projects within this area:

- the construction of the 735 kV Delorme station to meet anticipated demand in the Saint-Hyacinthe-Granby region. It is expected that this station will be required by about 1989;
- the construction of new facilities to meet anticipated long-term demand in the Beauce-Thetford region, about the year 2000;
- the construction, about 1995, of a new 735 kV line across the St Lawrence between Quebec City and Trois-Rivières.

All these projects are associated with the establishment of a 735 kV network in this area.

An initial 230 kV solution was therefore considered. This project involves retaining the same supply voltage. In the short term, this means constructing a 230 kV sectioning station by 1986 in the Sherbrooke region and a new 230 kV double-circuit line approximately 70 km long to connect this station to the Nicolet station. Given anticipated demand, this solution would make it possible to meet the Sherbrooke region's needs adequately over the long term, that is, for approximately 20 years.

Another solution, involving 735 kV voltage, was also studied. This would involve constructing **a** 735-230 kV station and connecting it by means of three 230 kV lines to the existing Nicolet-Sherbrooke lines. This future station would be connected to the existing network at the Nicolet station by a 735 kV line.

Given anticipated demand, these new facilities would be used, initially at least, at a voltage of 230 kV. According to the promoter, by 1996 it will no longer be possible to meet demand in the event of a breakdown on one of the four 230 kV circuits of the Nicolet-Sherbrooke network. The Sherbrooke station (known as the Des Cantons [Townships] station) will thus require a second 735 kV line.

Economically, the two solutions considered are comparable. The cost of **a** 735 kV solution is estimated at $107 million and that of the 230 kV alternative at $105 million.

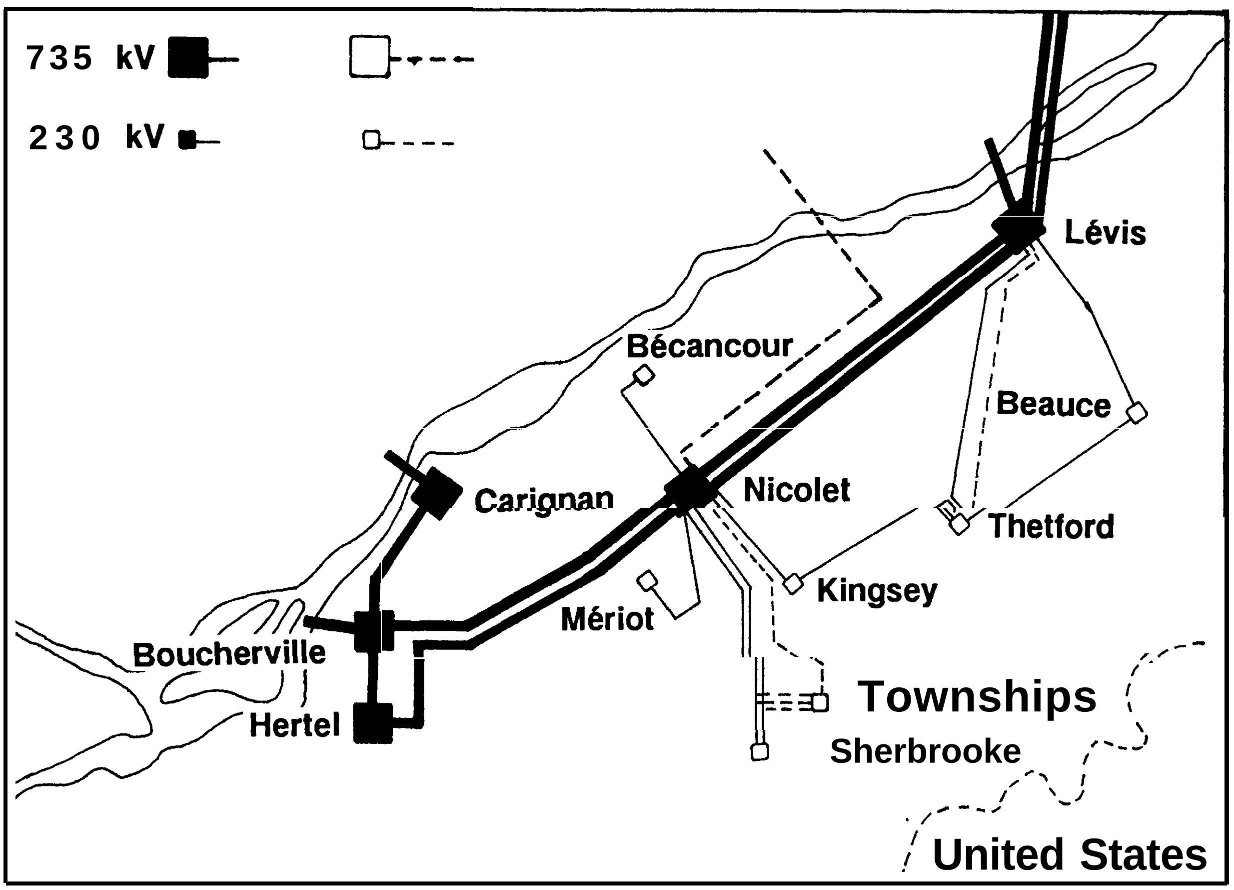


Figure 2: 230 kV solution

Source: Hydro-Québec, Rapport sur les études d'avant-projet [Report on preliminary studies], April 1983, p. 15.

Technically, the **735 kV** solution is considered preferable:

- better adaptation to demand;
- better because 230 kV lines permit considerable loss of electricity over long distances and hence underutilization of the power lines;
- the 735 kV solution would permit the eventual establishment of an additional 735 kV link between the Quebec City region and Drummondville and a shorter line to the new river crossing.

Environmentally, the 735 kV solution would provide power for a longer period than 230 kV circuits, and thus minimize the additional facilities required in the area: in the long term, the 230 kV solution would involve the installation of another line along this axis (given the anticipated demand for electricity).

In addition, the 735 kV solution would make it possible to link all the proposed facilities for a 735 kV network in the region of the South Shore of the St Lawrence, as defined above.

This initial stage of the impact study thus made it possible, on the one hand, to opt for the establishment of a 735 kV line and, on the other, to define the study zone for the subsequent stages of the impact study. This study zone is defined on the basis of the existing electrical network supplying the Sherbrooke region and on the basis of the selected starting point (the Nicolet station) for the new power line.

Information on the study zone and on the installation corridors and areas

A systematic initial inventory of the human and natural areas involved was performed on a scale of **1:125,000,** taking into account existing, potential and foreseeable factors. The study zone was thus divided into ecological regions and districts, using Jourdant's methodology.

Eight ecological regions and 74 ecological districts were defined by Hydro-Quebec. The promoter then proceeded to assess the relative importance of the elements of the human and natural areas, in order to identify the environmental assets at stake for each ecological district and to determine their degree of resistance to implementation of the project.

By environmental assets, the promoter means everything that can be lost or affected, from the environmental standpoint, by the establishment of a line or station within the given area.

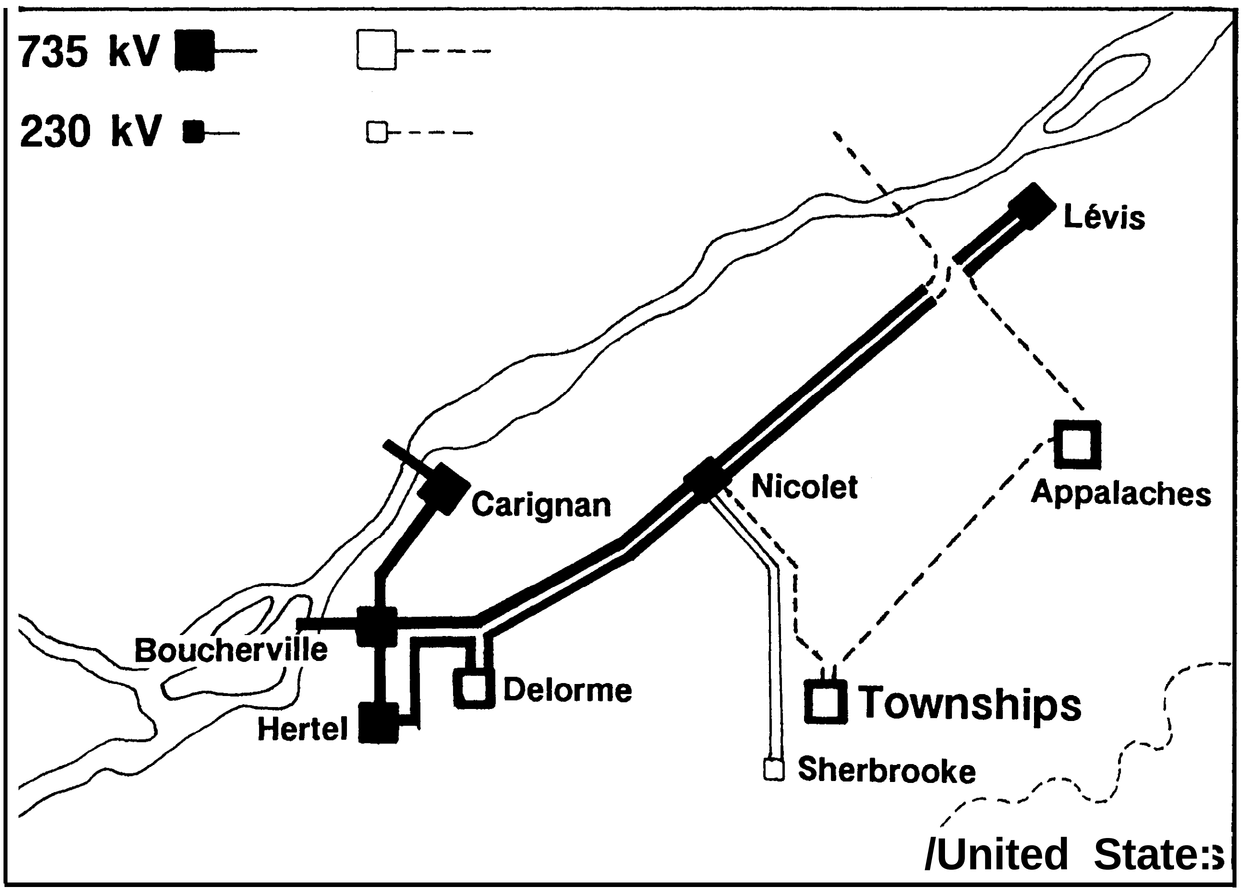
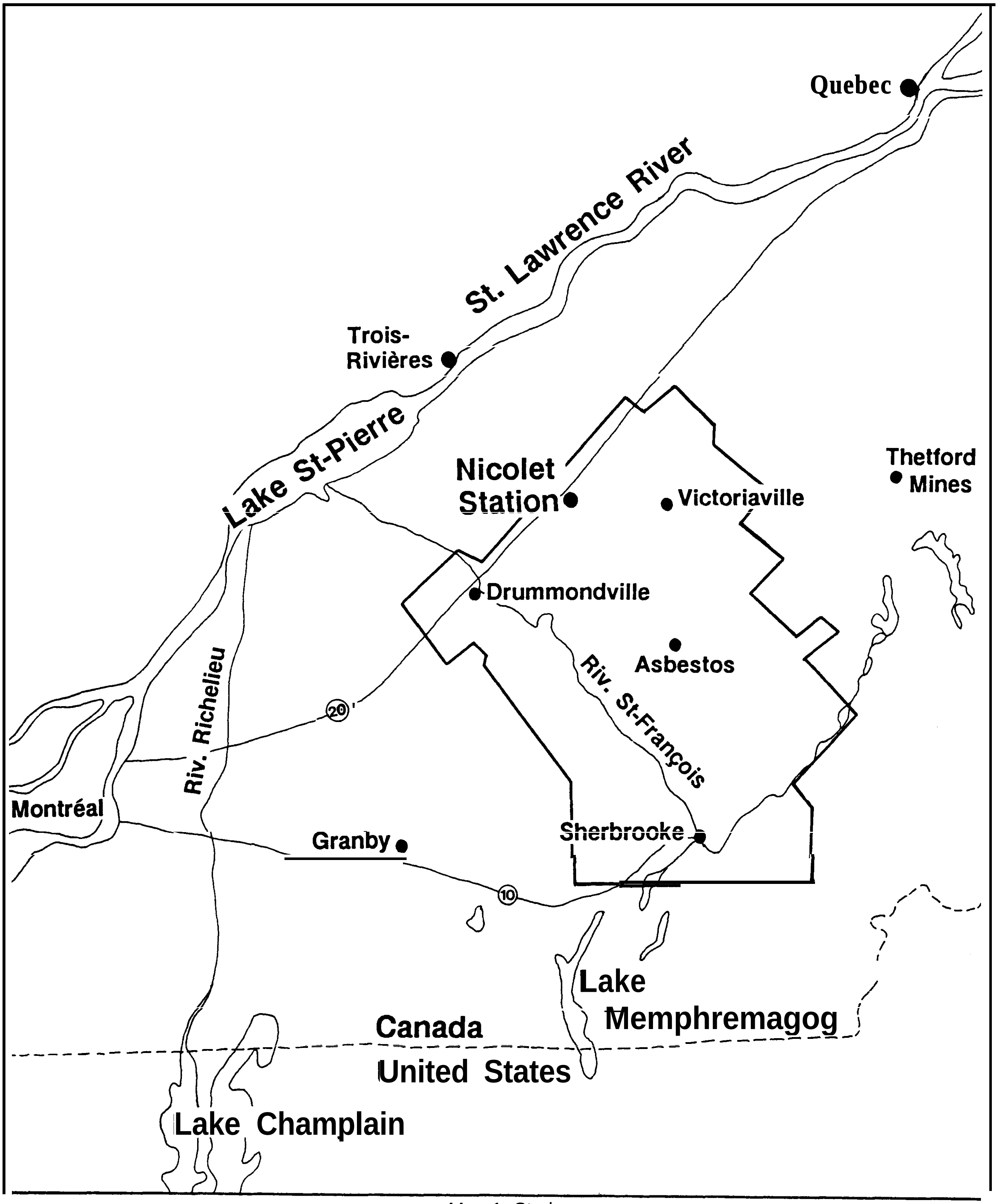


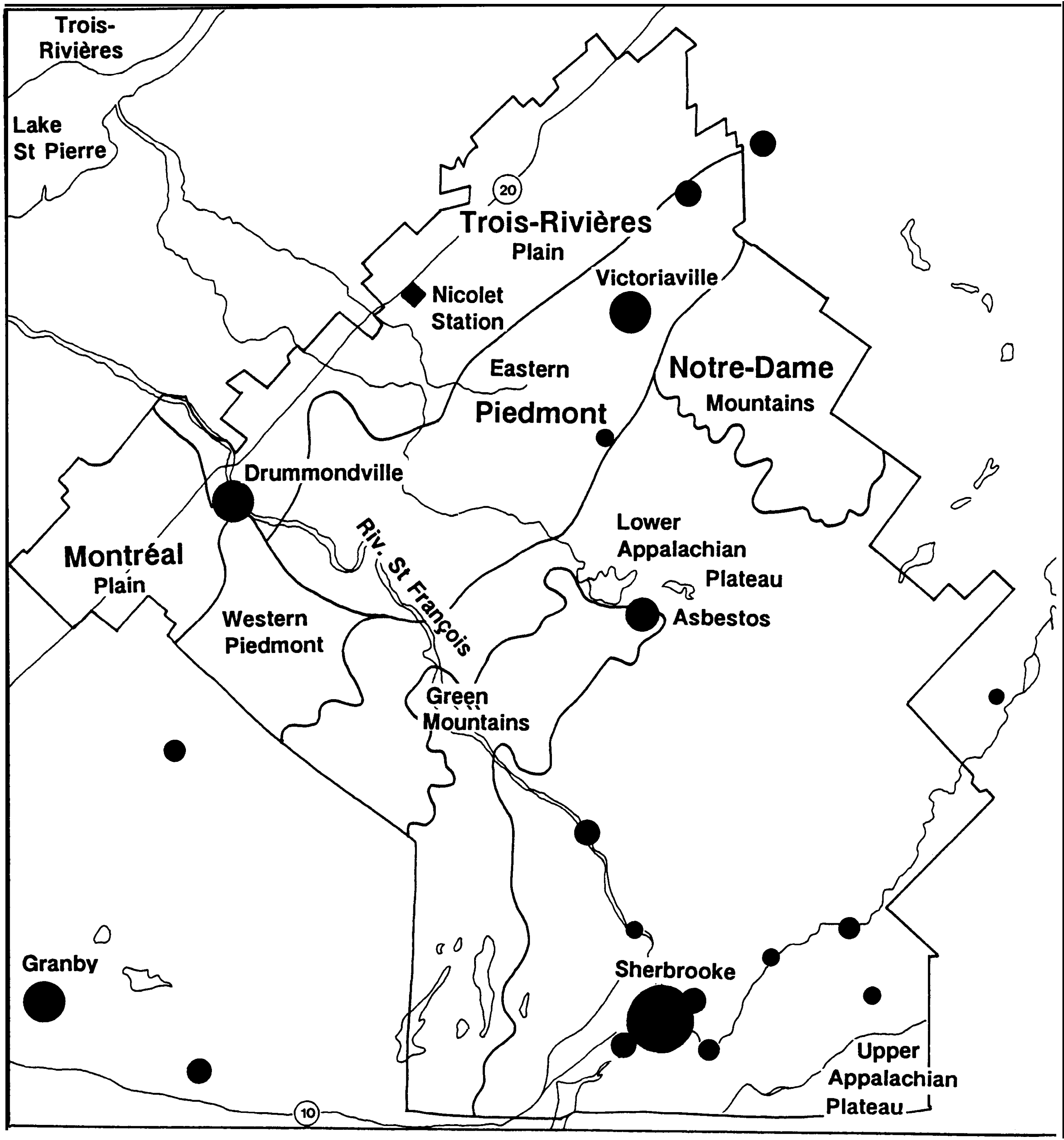
Figure 3: 735 kV solution

Source: Hydro-Quebec. Rapport sur **les études d'avant-projet** [Report on preliminary studies], April 1983, p. 23.



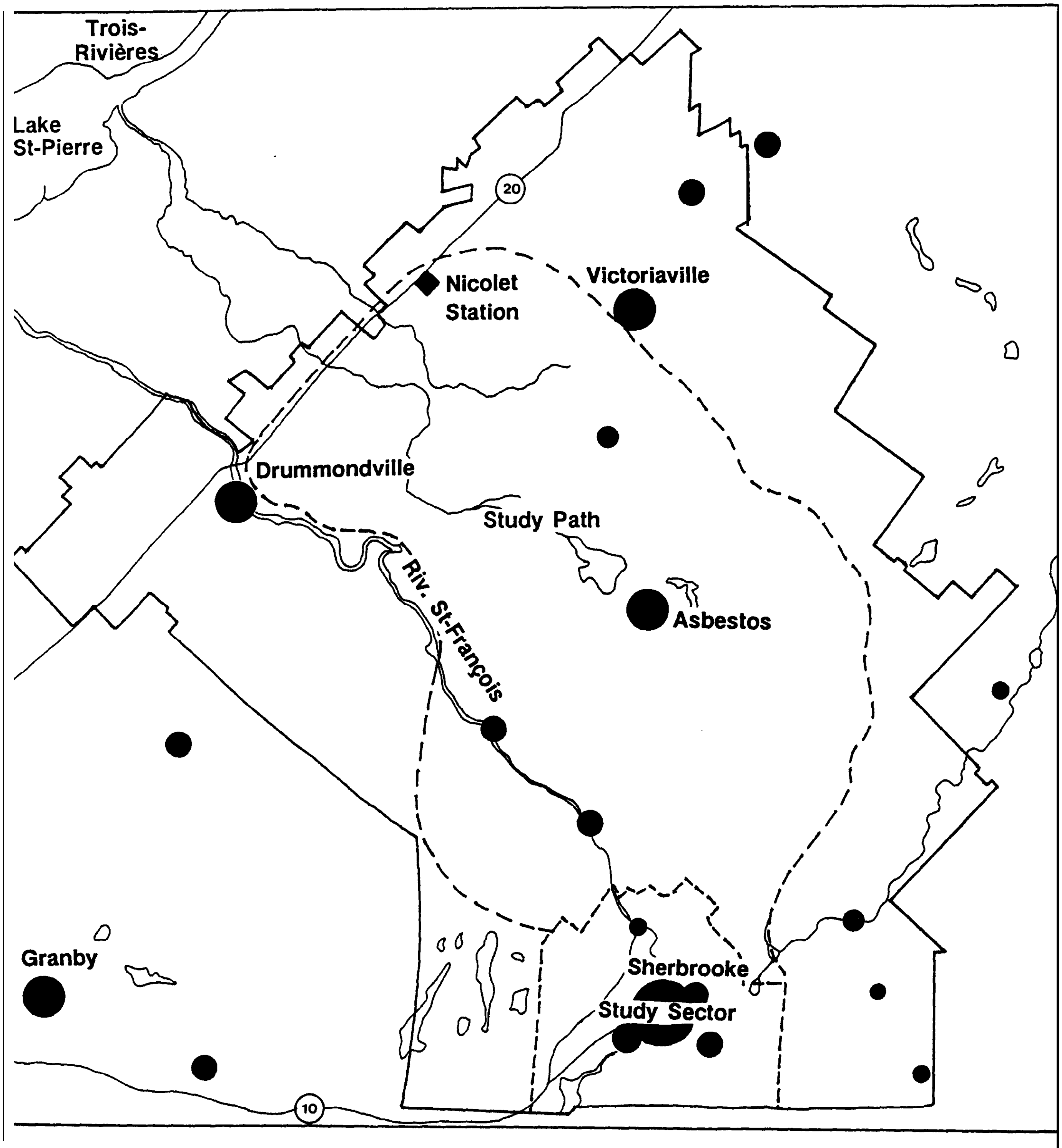
Map 1: Study zone

Source: **Hydro-Québec,** Rapport sur **les études** d'avant-projet: Dossier cartographique [Report on preliminary studies: Cartographic file], April **1983.**



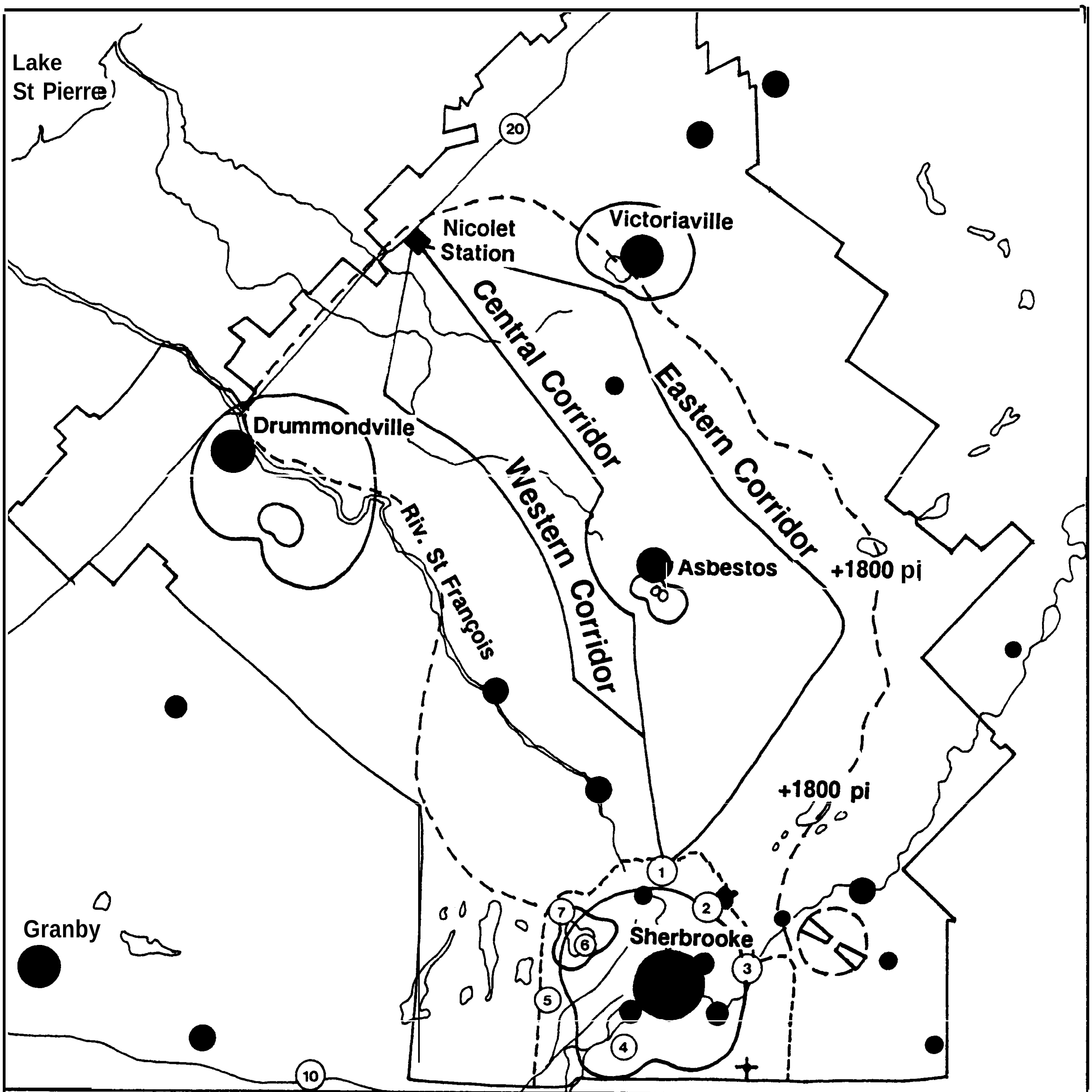
Map 2: Ecological regions

Source: **Hydro-Québec,** Rapport sur **les études** d'avant-projet: Dossier cartographique [Report on preliminary studies: Cartographic file], April 1983.



Map 3: Study path and sector

Source: **Hydro-Québec,** Rapport **sur les études** d'avant-projet: Dossier **cartographique** [Report on preliminary studies: Cartographic **file],** April 1983.



Map 4: installation corridors and areas

1 Brompton Township installation area
. Constraints **and** resistance:
. Air spaces
. Radiation diagram, **(0)1000** and **(0)1200** **mV/mNA**
. Clearance (airport)
. **Horizontal area (airport)**
. **Other communication tower**
. Land spaces
. 1800 Altitude over 1800 feet

Source: **Hydro-Québec.** Rapport sur **les études** d'avant-projet: Dossier **cartographique** [Report on preliminary studies: Cartographic file], April 1983.

A weighting is then assigned to each of the indicators selected, in order to define three levels of environmental assets:

- major assets include spaces protected by law or spaces highly valued by the population;
- important assets are wellastablished agricultural production spaces and spaces valued by the population for vacation and recreational activities;
- weak assets are spaces with no major or important assets.

This stage was used to exclude a number of districts considered spaces with major assets, in order to reduce the study zone to a study path and a study sector.

Within the study path, three possible corridors for the installation of a power line were defined on the basis of the constraints and resistance of the land and air spaces involved. Similarly, seven potential areas for the installation of the future 735230 **kV** station were defined within the study sector.

Hydro-Quebec then prepared a second analysis of the inventories, at a scale of **1:20,000,** to define the homogeneous elements of the area in terms of environmental units. These environmental units (441 units were identified) were then ranked on the basis of their resistance to the establishment of a station or passage of a line. This weighting defined fiie levels of resistance:

- first, special areas protected by law or valued by the population;
- second, urban and vacation areas;
- third, agricultural and agro-forestry areas;
- fourth, forest areas;
- fifth, para-urban areas.

Comparative analysis on the basis of the types of areas traversed showed the Central corridor to be less favourable than the other two. However, one element militates in favour of the Central corridor: the fact that it already contains 230 and 120 **kV** lines between the Nicolet station and the Brompton Township installation area. The other two options would involve establishing new lines through the area. **Hydro-**Quebec is considering the possibility of dismantling certain lines within the Central corridor: the possibility has been confirmed for one 230 **kV** line (within the existing **right-of-**way of the Central corridor) and for two 120 **kV** lines in another portion of the Central corridor. As a result of this dismantling, the **additional** right-of-way required for a new 735 **kV** line would vary considerably: from 15 to 80 m (80 m is the standard right-of-way for a 735 **kV** line) the length of this corridor.

The variations in length and width of the additional **rights-**of-way modify the initial unfavourable judgment on the Central corridor. The right-of-way of the Central corridor would affect **half** the area of the Western corridor and **one-**third that of the Eastern corridor. The removal of approximately 500 towers will reduce the farm area taken up by the electrical power corridor. Scenic quality should therefore benefit.

Hydro-Quebec thus favours the Central corridor. The opportunity to group electrical power lines within a single power corridor is the primary factor behind this decision. The justification for this choice is dependent on the proposed dismantling.

As regards the selection of the installation area, the preferred option is Brompton Township, for the following reasons:

- permits connection outside existing and future urban centre, in a wooded area, with little impact on **agriculture;**
- the possibilities for integration with the 230 **kV** Nicolet-Sherbrooke network are excellent;
- it is the best option for connection with the future Appalachian station;
- it is the best in terms of the length of the lines to be constructed and, consequently, the most economical solution.

In view of the fact that these comparative analyses conclude that the 735 **kV** line should be constructed largely in the place of existing lines, the promoter stipulates that the **1:20,000** inventory was not used to reduce the space or to select a route for the line. The inventory served this purpose solely in selecting a site for the station within the Brompton Township installation area. Moreover, the width of the corridors, which were set at 1 to 3 km, "implies that it is impossible, in Hydro-Quebec's view, to locate routes which differ substantially in terms of the areas traversed".[7] The inventory will thus serve to rank the components of the area so that it is better defined when the time comes to determine the impacts and to propose measures for implementation.

Selection of the example of application

In the report on the preliminary studies, an initial assessment of the possible areas to be traversed by the power line is performed by ranking the ecological districts. A second assessment of the same kind is then performed, on a smaller scale, by ranking the environmental units. Thirdly, an assessment of the three proposed corridors is performed. The same approach is used for selection of the installation area. The potential impacts associated with installation of the power line are considered only at the very end of the report, in connection with proposed measures for implementation of the project.

All these stages could be performed by the **ELECTRE** model. However, since selection of the final route was performed essentially on the basis of a location methodology, involving the inventory of the components of the human and natural areas (defined in terms of environmental resistance and assets) likely to be affected by implementation of a project, we fett that it would be more useful to perform our example

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[7] BAPE, Rapport **d'enquête** et **d'audience** publique, **Poste des** Cantons **Lignes** Nicolet-Des Cantons et Des **Cantons-Nouvelle-Angleterre** [Survey and public hearing report, Townships station, **Nicolet-Townships** and **Townships-New England** lines],' 1983, **pp.** 4-13 **[TRANSLATION].**

of application on the ranking of the ecological districts. Other factors justify this choice. First, it seemed clear, on reading the report of the Environmental Commission which reviewed this project, that the method used to rank the ecological districts was not understood by the public. In fact, it is often difficult to identify, in the reports on the preliminary studies, the factors used to distinguish major environmental assets from important assets. Yet it is clearly indicated in the reference file (Annex Ill, page 6) that the indicators permit concrete differentiation between districts with major, important and weak environmental assets.

These criticisms, from the public and from the Environmental Commission, thus cast doubt on the true consistency of the system of comparison used by the promoter in ranking the ecological districts. Yet this was an important stage in the development of the impact study, since it served to exclude a number of districts with major assets and thus to define a new spatial framework within which variants of potential power line corridors were developed. Here, then, we have a specific case in which the use of a formal method, in this case the ELECTRE III method, could prove useful. The type of multicriteria problem with which we are concerned is the establishment of a ranking (or, in other words, a hierarchization) of a set of "objects", the objects in this case being the ecological districts. The set selected will be one of the eight ecological regions (we shall explain in the following pages the reason for this simplification).

Thus, working with the same parameters and specifications applied in the impact study, we shall attempt to reproduce the same ranking as that developed by Hydro-Quebec, but this time through the use of the ELECTRE method. We do so in order:

- to test the flexibility with which the method can be adapted; and
- to determine whether all the parameters of the ranking process were in fact defined in the impact study.

4. EXAMPLE OF APPLICATION OF THE ELECTRE III MODEL

The following diagram illustrates the various stages in the ELECTRE III method. For the purposes of this study, a computer program was developed (in FORTRAN) to permit rapid processing of the data. The algorithms for this program follow the stages used by the method, as defined below.

Stage	Content
Multicriteria assessment table	• determination of the set of potential actions • determination of the assessment criteria • preference level • indifference level • veto level • index of importance
Calculation of indices of concordance for each criterion: **cj(a, b)** Calculation of indices of discordance for each criterion: **Dj(a,b)**	Assessment of the actions for each pair of actions on each criterion
Calculation of the concordance relation: **C(a,b)** ↓ Calculation of the indefinite outranking relation: **d(a,b)**	Assessment of the actions for each pair of actions on the set of criteria
2 total preorders: P and <u>P</u> ↓ 1 partial preorder: P	Ranking algorithm • determination of the degrees of separation

Similarly, formulation of the problem of ranking the ecological districts will follow the stages illustrated by the diagram.

Multicriteria assessment table: Determination of the set of potential actions

In accordance with the preferences expressed by the promoter of the project, each ecological region forms a distinct set. This preference is based primarily on the fact that, in the agricultural context, the size of the percentage of area under cultivation and of class 1, 2 and 3 soils' is compared to the mean for the ecological region and not to the study zone as a whole. No other reference of this nature is made in connection with the other assessment criteria.

Since the ecological regions do not all have the same characteristics, the ranking will thus not be based on a comparison of the 74 ecological districts among themselves. Instead, the ranking will be by ecological region, and thus there will be eight potential rankings based on different considerations. For the ELECTRE III method, set A of the potential actions will thus consist of the ecological districts of one of the eight ecological regions. For this study, the example of application of the ELECTRE method will use the data from the Lower Appalachian Plateau ecological region

[8] Soil class established on the basis of the Canada Land Inventory (CLI) and the Quebec Land Inventory.

(Table 14 of the impact study)'. (See table 1 and map 5 on pages 40, 41 and 42).

Multicriteria assessment table: Determination of the assessment criteria

In its impact study, Hydro-Quebec essentially selected five elements of the natural and human areas on which to base its ranking of the ecological districts:

- the percentage of area under cultivation;
- the percentage of area of category 1, 2 and 3 soils;
- the percentage of wooded area;
- the number of cottages; and
- the scenic value, defined in relation to three levels:
  - recognized scenic value
  - quality scenic value
  - nil.

There are thus four quantitative criteria and one qualitative criterion.

Among these descriptors the promoter included, in the table of raw data, the assessments justifying the assignment of major or important assets to the ecological districts. We shall therefore work from these values to determine the assessments which will have a real influence on the ranking of the ecological districts. If we refer to table 1, which reproduces the table of data from the impact study, we note that:

- for areas under cultivation, only percentages greater than 46 are included;
- for areas of category 1, 2 and 3 soils, only percentages greater than 26 are included;
- only numbers of cottages greater than 162 are included;
- only areas of recognized or quality scenic value are included; and
- no values are included for wooded area.

These considerations will have a number of consequences with respect to the definition of parameters for the ELECTRE III method. First of all, wooded area will have no influence on the ranking of the ecological districts. This descriptor could therefore be eliminated from the set of assessment criteria; however, it will be retained. We shall explain later how we can use the indices of importance to reflect this preference on the part of the promoter. Secondly, as regards the other descriptors, only those assessments which were included will influence the ranking. In the example of application of the ELECTRE III method, the table of data from the impact study will thus be modified to respect these requirements. Thus, all values below those included will be reduced to zero, while all assessments included will be retained at the same levels, with the exception of the assessments of percentage of wooded area, which will be retained at the same levels. If we refer to table 2 on page 43, we observe immediately that the ranking is, in fact, based on a very limited number of assessments, given the fact that the assessments of wooded area will be given no weight in the problem of ranking the ecological districts.

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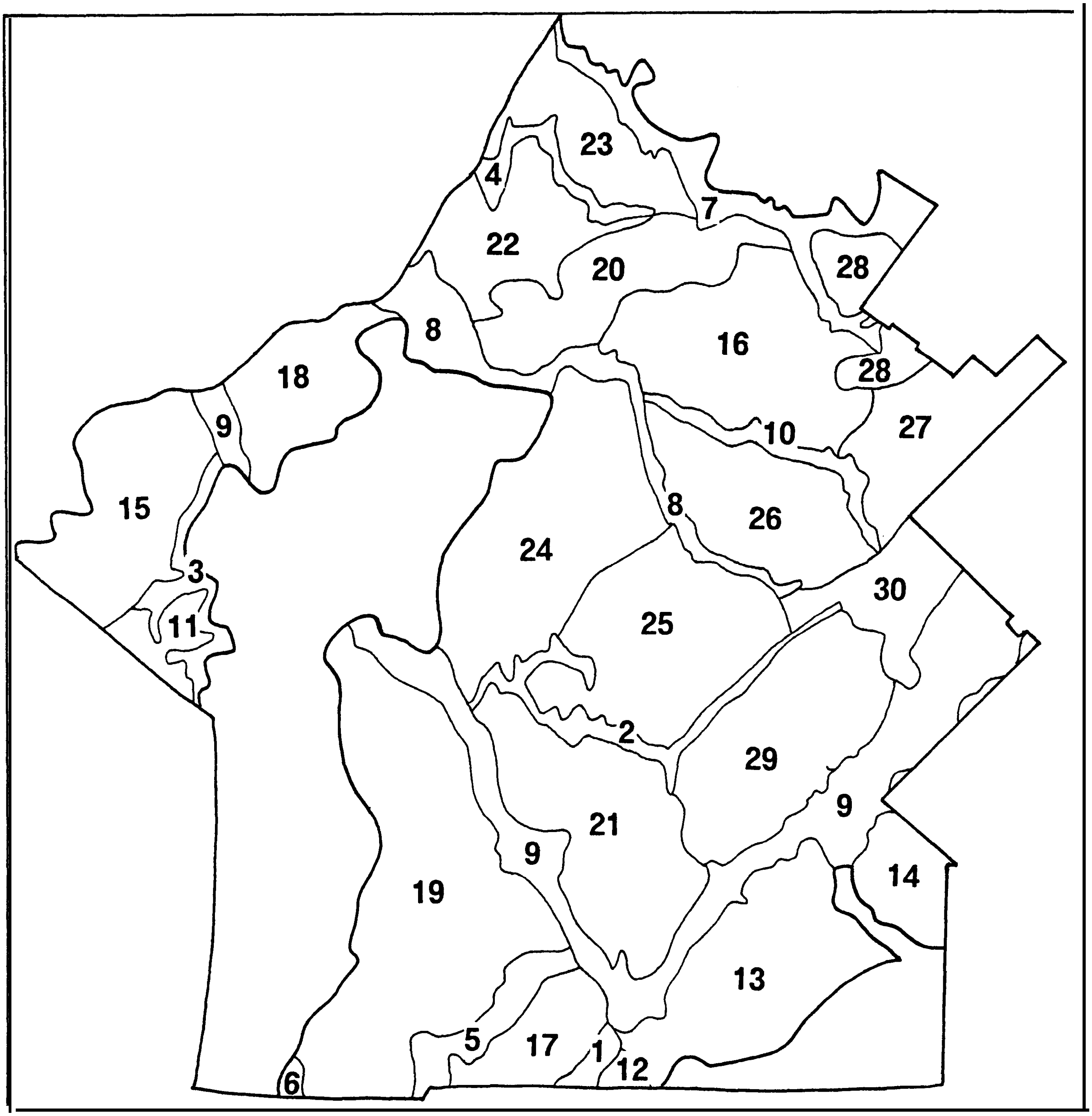
[9] Hydro-Québec, Rapport sur les études d'avant-projet [Report on preliminary studies], April 1983, p. 73.

Table 1. Ecological region: Lower Appalachian Plateau

OPTIONS	REGION/ DISTRICTS/ PRINCIPAL MUNICIPALITIES (1)	FACTUAL CRITERIA				QUALITATIVE CRITERIA	Orientation of the ecological district	Environmental assets of the ecological district
		Agricultural areas		Forest areas	Recreation			
		Area under cultivation (%)	Area of 1,2,3 soils (%)	wooded area (%)	Number of cottages	Recognized, quality scenic value		
	LOWER APPALACHIAN PLATEAU	31	14	53	3504			
	1. MASSAWIPPI VALLEY . Hatley . Ascot	7	26	30	473	Recognized scenic value	Vacation and recreation	Major
	2. STOKE VALLEY . Stoke . Windsor	18	23	72	98	Nil	Forestry	Weak
	3. ULVERTON VALLEY . Durham South	28	3	59	14	Nil	Agro-forestry	Weak
	4. UPPER DES PINS VALLEY . Chénier . Warwick	33	13	53	10	Nil	Agro-forestry	Weak
	5. MAGOG VALLEY . Sherbrooke . Magog	8	3	31	640	Recognized scenic value	Vacation and recreation	Major

6. MEMPHREMAGOG VALLEY NORTH . Orford	23	0	32	84	Recognized scenic value	Vacation and recreation	Important
7. UPPER NICOLET VALLEY Ham North	42	3	38	167	Quality scenic value	Vacation and recreation	Important
8. UPPER NICOLET VALLEY SW . Asbestos	24	19	66	542	Nil	Vacation and recreation	Important
9. UPPER ST-FRANCOIS VALLEY . Sherbrooke . East Angus	21	13	56	302	Quality scenic value	Vacation and recreation	Important
10. NICOLET VALLEY CENTRE	43	0	45	0	Nil	Agro-forestry	Weak
11. ALTON DURHAM PLATEAU	30	0	56	8	Nil	Agm-forestry	Weak
12. ASCOT-COMPTON PLATEAU	40	51	51	2	Nil	Agro-forestry	Important
13. ASCOT EATON PLATEAU . Ascot	34	16	51	55	Nil	Agro-forestry	Weak
14. BERRY WESTBURY PLATEAU . Bury	23	16	71	33	Nil	Forestry	Weak
15. DURHAM PLATEAU . Durham South . L'Avenir	52	26	32	67	Nil	Agricultural	Important
16. HAM PLATEAU . Saint-Adrien . Wotton	21	2	65	56	Nil		Weak
17. HATLEY-ASCOT PLATEAU . Sherbrooke . Ascot	25	17	55	162	Quality scenic value	Agro-forestry and vacation	Important
18. KINGSEY PLATEAU . Kingsey	59	28	32	27	Nil	Agricultural	Important
19. RICHMOND-SHERBROOKE PLATEAU . Sherbrooke . Magog	26	17	51	354	Quality scenic value	Vacation	Important
20. SAINT-REMI DE TINGWICK PLATEAU . Saint-Rémi de Tingwick	30	6	48	23	Nil	Agro-forestry	Weak
21. STOKE-ASCOT PLATEAU . Sherbrooke . Stoke . Bromont	31	14	54	30	Nil	Agro-forestry	Weak
22. TINGWICK PLATEAU . Chénier	58	18	37	24	Nil	Agricultural	Important
23. TINGWICK/ARTHABASKA PLATEAU . Chénier . Warwick	60	3	30	20	Nil	Agricultural	Important
24. WINDSOR PLATEAU . Asbestos . Windsor	50	28	41	230	Nil	Agricultural	Important
25. WINDSOR/STOKE PLATEAU . Stoke . Windsor	19	25	86	50	Nil	Forestry	Weak
26. WOTTON-SAINT-CAMILLE PLATEAU . Wottonville . Saint-Camille	56	17	36	2	Nil	Agricultural	Important
27. WEEDON GARTHBY PLATEAU Saint-Joseph de Garthby	10	0	82	0	Nil	Forestry	Weak
28. WOLFESTOWN GARTHBY PLATEAU . Ham North	6	0	84	-	Nil	Forestry	Weak
29. STOKE MOUNTAINS . Ascot Corner . Stoke	8	3	96	25	Recognized scenic value	Recreation	Major
30. STOKE MOUNTAINS WEEDON DUDSWELL SECTION . Malbestos . Dudswell	22	3	69	-	Nil	Forestry	Weak

Provided to assist the reader in locating the ecological district.
Source: Hydro-Quebec, Rapport sur les études d'avant-projet [Report on preliminary studies], April 1983, p. 73.



Map 5: Ecological districts of the Lower Appalachian Plateau

Source: Hydro-Québec, Rapport sur les études d'avant-projet: Dossier cartographique [Report on preliminary studies: Cartographic file], April 1983.

Table 2. Matrices of modified data

ECOLOGICAL DISTRICTS	ASSESSMENT CRITERIA				
Options (number)	Area under cultivation (%)	Area of 1, 2, 3 soils (%)	Wooded area (%)	Number of cottages	Scenic value
1.	.0	26.0	30.0	473.0	4.0
2.	.0	.0	72.0	.0	.0
3.	.0	.0	59.0	.0	.0
4.	.0	.0	53.0	.0	.0
5.	.0	.0	31 .0	640.0	4.0
6.	.0	.0	32.0	.0	4.0
7.	42.0	.0	38.0	167.0	2.0
8.	.0	.0	66.0	542.0	.0
9.	.0	.0	56.0	302.0	2.0
10.	43.0	.0	45.0	.0	.0
11.	.0	.0	56.0	.0	.0
12.	40.0	51 .0	51 .0	.0	.0
13.	.0	.0	51.0	.0	.0
14.	.0	.0	71 .0	.0	.0
15.	52.0	26.0	32.0	.0	.0
16.	.0	.0	65.0	.0	.0
17.	.0	.0	55.0	162.0	2.0
18.	59.0	28.0	32.0	.0	.0
19.	.0	.0	51 .0	354.0	2.0
20.	.0	.0	48.0	.0	.0
21.	.0	.0	54.0	.0	.0
22.	58.0	.0	37.0	.0	.0
23.	60.0	.0	30.0	.0	.0
24.	50.0	28.0	41 .0	230.0	.0
25.	.0	.0	80.0	.0	.0
26.	56.0	.0	36.0	.0	.0
27.	.0	.0	82.0	.0	.0
28.	.0	.0	84.0	.0	.0
29.	.0	.0	90.0	.0	4.0
30.	.0	.0	69.0	.0	.0

Multicriteria assessment table: Determination of the indices of importance

The indices of importance will reflect the weighting on the assessment criteria expressed in the impact study. This weighting distinguishes three types of assets:

- “major assets corresponding to spaces protected by law or to spaces highly valued by the local or regional population;
- important assets corresponding:
- agriculturally, to spaces in which the area under cultivation or in which the percentage of class 1, 2 and 3 land clearly exceeds the mean for the ecological region;
- to spaces highly valued by the population for vacation and recreational uses (confirmed by the number of cottages); and
- to spaces the scenic value of which is considered to be of good quality.
- weak assets are spaces not meeting any of the criteria for major or important assets.“”

In fact, in this example of application of the ELECTRE III method, the indices of importance will play a major role in ranking the ecological districts: since the formulation of the problem of ranking reflects the concerns of Hydro-Quebec, these scales of value must therefore be included in the **algorithms** of the ELECTRE III method.

In short, only the “scenic value” criterion will be considered in identifying major assets; major assets will thus correspond to ecological districts of recognized scenic value. For important assets, four criteria may be taken into account:

- area under cultivation;
- area of class **1,** 2 and 3 soils:
- number of cottages; and
- areas of quality scenic value.

These four criteria are considered equivalent in importance. Wooded area is not taken into consideration. The ranking will thus be based on the four remaining criteria. Since the total of the indices of importance must equal 1, the distribution of the weights on the criteria will be as follows:

Criteria	**Indices of importance**		
Scenic value recognized scenic value = 4 quality scenic value = **2** nil = **0**	**If a or b = 4** weight = 0.57	If a and b < 4 and a or b = 2 weight = 0.14	If a and b = 0 weight = 0.0
Area under cultivation	**If a or b > 0** weight = 0.14	If **a** and b = 0 weight = 0.0	
Area of class **1,2,3** soils	" = 0.14	" = **0.0**	
Number of cottages	" = 0.14	" = 0.0	
Wooded area	always equal to 0.01		

In short, the wooded area criterion will always have **a** weight equal to 0.01. The scenic value criterion will have three indices of importance, depending on the values of the two ecological districts being compared on this criterion, etc. The general principle of the indices of importance is thus as follows: a weight equal to or greater than 0.57 will correspond to **a** major asset” and a weight less than 0.57 and greater than or equal to 0.14 will correspond to an important asset. Weights less than 0.14 are considered weak assets.

[10] **Hydro-Québec,** Rapport sur **les études d'avant-projet** [Report on preliminary studie**], , April** 1963, pp. 61-62.

[11] In fact, even if an **ecological** district has 4 criteria corresponding **to** important assets, it will have a weight equal to 0.56. However, if the weight of the **wooded** area criterion is added, the district will then have a weight equal **to** 0.57, corresponding **to** a **major** asset. Thus, even with **a** weight of 0.01, the wooded area criterion can play **a** major role. This possibility was intentionally included by the modeler to demonstrate the possibilities of the indices of importance in the ranking problem. However, this case does not occur in this example of application of the ELECTRE III method to the ecological region of the Lower Appalachian Plateau.

Multicriteria assessment table: Determination of the levels on each of the criteria

There is no reference in the impact study to anything resembling the concepts of strict preference, indifference or veto **as** visualized by the ELECTRE method. However, in view of the considerations already formulated, it is fairly safe to conclude that, on each of the criteria, all of the assessments which have been included will be strictly preferred to those which are not. We should point out here that the modification of the data explained above will enable us to establish a strict preference between those assessments which **have been** included and those which have not. Similarly, very high values have been given to the veto levels, to ensure that they have no influence on the calculations of the degrees of credibility assigned to the outrankings. Thus, for the first three criteria, that is, the percentages of area under cultivation, area of 1, 2 and 3 soils and wooded area:

- the veto levels equal 10,000;
- the strict preference levels equal 10.0; and
- the indifference levels equal 5.0.

For the number of cottages:

- the veto level equals 30,000;
- the strict preference **level equals 100.0; and**
- **the indifference level equals 50.0.**

For areas of scenic value:

- the veto level equals 100.0;
- the strict preference level equals 2.0; and
- the indifference level equals 1.0.

In this way, the preferences expressed in the impact study will be respected but, in addition, the various strict preference and indifference levels will permit more detailed ranking of districts belonging to the same class in terms of environmental assets. It will be recalled that the formulation of the multicriteria assessment table is designed to reproduce, as far as possible, the preferences expressed in the impact study in order to test the parameters of application of the ELECTRE III model.

Calculation of the indices of concordance: cj(a,b)

If we examine the case of pair **"a to b"**, the index of concordance on criterion **j** will equal:

$$cj\,(a,b) = \frac{pj\,(a) - \mathrm{Min}\,[bj - aj,\ pj\,(a)]}{pj\,(a) - \mathrm{Min}\,[bj - aj,\ qj\,(a)]}$$[12]

In order to calculate the concordance of pair **"b to a", we** replace the values of option **a** with those of **b and vice versa.** Consider, for example, the case of the "upper Nicolet valley" ecological district (option 7) to the "upper Nicolet valley SW" ecological district (option 8). The assessments of these two ecological districts on the 5 criteria are reproduced here:

Criteria	1	**2**	**3**	4	5
Options					
7	42.0	.0	38.0	167.0	2.0
8	.0	.0	66.0	**542.0**	**.0**

The concordance of 7 to 8 on the first criterion will equal:

$$c_1(7,8) = \frac{10 - \mathrm{Min}\,(0-42,\ 10)}{10 - \mathrm{Min}\,(0-42,\ 5)} = \frac{10 - (-42)}{10 - (-42)} = 1.0$$

The concordance of 7 to 8 **on the other criteria will equal:**

$$c_2(7,8) = \frac{10 - \mathrm{Min}\,(0-0,\ 10)}{10 - \mathrm{Min}\,(0-0,\ 10)} = \frac{10 - 0}{10 - 0} = 1.0$$

$$c_3(7,8) = \frac{10 - \mathrm{Min}\,(66-38,\ 10)}{10 - \mathrm{Min}\,(66-38,\ 10)} = \frac{10 - 10}{10 - 5} = 0.0$$

$$c_4(7,8) = \frac{100 - \mathrm{Min}\,(542-167,\ 100)}{100 - \mathrm{Min}\,(542-167,\ 50)} = \frac{100 - 100}{100 - 50} = 0.0$$

$$c_5(7,8) = \frac{2 - \mathrm{Min}\,(0-2,\ 2)}{2 - \mathrm{Min}\,(0-2,\ 1)} = \frac{2 - (-2)}{2 - (-2)} = 1.0$$

For the concordance of 8 to 7, we take the same data and perform the same calculations, but inversely. Thus:

$$c_1(8,7) = \frac{10 - \mathrm{Min}\,(42-0,\ 10)}{10 - \mathrm{Min}\,(42-0,\ 5)} = \frac{10 - 10}{10 - 5} = 0.0$$

$$c_2(8,7) = \frac{10 - \mathrm{Min}\,(0-0,\ 10)}{10 - \mathrm{Min}\,(0-0,\ 5)} = \frac{10 - 0}{10 - 0} = 1.0$$

$$c_3(8,7) = \frac{10 - \mathrm{Min}\,(38-66,\ 10)}{10 - \mathrm{Min}\,(38-66,\ 10)} = \frac{10 - (-28)}{10 - (-28)} = 1.0$$

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[12] aj **equals the assessment of option a on criterion** j
pj (a) is the strict preference level **associated with option a on criterion** j
qj (a) is the indifference level associated with option a on criterion **j**
The same observations apply to b.

$$c_4(8,7) = \frac{100 - \text{Min}(167\text{-}542, 100)}{100 - \text{Min}(167\text{-}541, 50)} = \frac{100 - (-375)}{100 - (-375)} = 0.0$$

$$c_5(8,7) = \frac{2 - \text{Min}(2\text{-}0, 2)}{2 - \text{Min}(2\text{-}0, 1)} = \frac{2-2}{2-1} = 0.0$$

In short:

$c_1(7,8) = 1.0$ and $c_1(8,7) = 0.0$
$c_2(7,8) = 1.0$ and $c_2(8,7) = 1.0$
$c_3(7,8) = 0.0$ and $c_3(8,7) = 1.0$
$c_4(7,8) = 0.0$ and $c_4(8,7) = 1.0$
$c_5(7,8) = 1.0$ and $c_5(8,7) = 0.0$

When cj(7-8) = 1.0 and cj(8,7) = 0.0, we have a situation of strict preference of option 7 to option 8. When cj(7-8) and cj(8,7) = 1.0, we have a situation of indifference on the criterion. There is one other possibility which has not been noted: that of weak preference. To illustrate this situation, let us consider the case of option 1 to option 8 on criterion 4 (number of cottages):

$$c_4(1,8) = \frac{100 - \text{Min}(542\text{-}473, 100)}{100 - \text{Min}(542\text{-}473, 50)} = \frac{100 - 69}{100 - 50} = 0.62$$

$$c_4(8,1) = \frac{100 - \text{Min}(473\text{-}542, 100)}{100 - \text{Min}(473\text{-}542, 50)} = \frac{100 - (-69)}{100 - (-69)} = 1.0$$

Since $c_4(1,8) = 0.62$ and $c_4(8,1) = 1.0$, option 8 is thus strictly preferred to option 1, while option 1 is weakly preferred to option 8 on criterion 4.

Calculation of the indices of discordance for each criterion

The assessment of an option a on a criterion j will be in discordance with the hypothesis "a outranks b" if the concordance of a to b on this same criterion equals 0, that is, if cj(a,b) = 0.0. The discordance will increase in proportion to the difference between the assessments of a and b on the criterion in question, up to a value V (the veto level), beyond which it will seem prudent to assign no credibility to the outranking of b by a.

In practice, index cj(a,b) will equal 0 as soon as the difference obtained by subtracting the assessment of a from the assessment of b on criterion j is greater than or equal to the strict preference level of option a on criterion j. Thus, as soon as one of the indices cj(a,b) equals 0, we will attempt to calculate the extent of the discordance. If the difference between the two assessments is greater than or equal to the veto level, then discordance Dj(a,b) = 1. If this same difference is equal to the strict preference level of a: Dj(a,b) = 0. Between these two values, Bernard Roy suggests that the index be calculated by means of a linear interpolation formula[13]:

$$Dj(a,b) = \text{Min}\left[1, \text{Max}\left(0, \frac{bj - (aj - pj(a))}{vj(a) - pj(a)}\right)\right]^{14}$$

In this way, we can assess the relative importance of the discordance.

The computerized program was developed on the basis of this algorithm and will automatically calculate the index of discordance whenever a cj(a,b) value equals zero. As mentioned earlier, very high assessment values have been defined as veto levels in order to respect the problem of ranking the ecological districts. Thus, since $c_3(7,8)$ equals zero, the program will calculate the magnitude of the discordance:

$$D_3(7,8) = \text{Min}\left[1, \text{Max}\left(0, \frac{66 - (38 - 10)}{10{,}000 - 10}\right)\right]$$

$$D_3(7,8) = 0.0038$$

Thus, the discordance is so weak that it is, for all practical purposes, nil. Consequently, it will have no real influence on the calculation of the' outranking relation.[15]

Calculation of the concordance relation: C(a,b)

Working with the cj(a,b) values of a pair of options on all the criteria, we calculate the concordance relation by summing the cj(a,b) values multiplied by the index of importance of the corresponding criterion:

$$C(a,b) = \sum_{j\,F} pdj \times cj(a,b)^{16}$$

Thus, for the two pairs of options (7,8) and (8,7), the concordance will equal:

C(7,8) = (.14x1.0) + (0x1.0) + (0.1x0) + (.14x0) + (1.4x1) = 0.28

C(8,7) = (.14x0) + (0x1.0) + (0.1x1) + (.14x1) + (.14x0) = 0.15

Pair of options (7,8) thus has stronger concordance on all the criteria than pair (8,7), as a result of the indices of importance.

[13] Some other method of calculation could be used here without affecting the basic principles of ELECTRE III.

[14] Vj (a) is the veto level associated with option a on criterion j.

[15] This example is applicable to all other cases involving this model.

[16] pdj : the weight (or index of importance) associated with criterion j. F : the set F of assessment criteria.

Calculation of the indefinite outranking relation: d(a,b)[17]

According to the algorithms of the ELECTRE III method, if $c(a,b) = 1$, this necessarily implies that all the $c_j(a,b)$ values equal 1 and that all the $D_j(a,b)$ values equal 0. Under these conditions, it is reasonable to assume that the degree of credibility $d(a,b)_2$ equals the concordance $C(a,b)$.

If cases exist in which $c_j(a,b) = 0$ and $D_j(a,b) \neq 0$, then the weight of a criterion of this nature no longer contributes to the sum of $C(a,b)$. In addition, the discordant criterion may affect the index of concordance. If the discordance is weak compared to the concordance, the latter continues to provide an accurate reflection of the credibility of the outranking. We will thus assume that $d(a,b) = C(a,b)$.

However, the ELECTRE III method considers cases in which certain criteria reflect significant discordance in comparison to the concordance: for example, those in which one of the $D_j(a,b)$ values is greater than $C(a,b)$.

Let us assume, first of all, that only one of the criteria is in significant discordance with the outranking. If the $D_j(a,b)$ value on this criterion is equal to 1, the discordance on the criterion is so strong that it cancels out the outranking relation on all the other criteria: thus $d(a,b) = 0$. If $D_j(a,b)$ is less than 1 and greater than the concordance $C(a,b)$, then

$$d(a,b) = C(a,b) \times \left(\frac{1 - D_j(a,b)}{1 - C(a,b)}\right)^{18}$$

When there are a number of criteria on which $D_j(a,b)$ is less than 1 and greater than $C(a,b)$, then the degree of credibility is calculated as follows:

$$d(a,b) = C(a,b) \times \prod_{j \in \bar{D}(a,b)} \frac{1 - D_j(a,b)}{1 - C(a,b)} \quad ^{19}$$

In this example of application of the ELECTRE III model, the degree of **credibility** assigned to the outranking relation will correspond to the concordance relation since there is no discordance strong enough to affect the calculations of outranking credibility. Table 3 gives the results of the degrees of credibility on all the options. The pairs of options **(7,8)** and **(8,7)** already calculated have been included to familiarize the reader with the manner in which this matrix is to be read.

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[17] **Indefinite outranking relation and** degree of credibility may be considered synonyms.

[18] Assuming once again a linear decrease.

[19] $\bar{D}(a,b)$: the set of $D_j(a,b)$ values **in significant discordance for pair (a,b).**

OPTIONS to	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
OPTIONS 1		.01	.01	.01	.72	.58	.15	.15	.01	.15	.01	.29	.01	.01	.29	.01	.01	.29	.01	.01	.01	.15	.15	.29	.01	.15	.01	.01	.58	.01
2	.85		.00	.00	.71	.57	.42	.15	.28	.14	.00	.28	.00	.01	.28	.01	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14	.01	.01	.58	.01
3	.85	.01		.01	.71	.57	.42	.15	.29	.14	.01	.28	.00	.01	.28	.01	.29	.28	.28	.00	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
4	.85	.01	.01		.71	.57	.42	.15	.29	.14	.01	.29	.01	.01	.28	.01	.29	.28	.29	.01	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
5	.72	.01	.01	.01		.58	.15	.02	.01	.15	.01	.29	.01	.01	.29	.01	.01	.29	.01	.01	.01	.15	.15	.29	.01	.15	.01	.01	.58	.01
6	.86	.01	.01	.01	.72		.29	.15	.15	.15	.01	.29	.01	.01	.29	.01	.15	.29	.15	.01	.01	.15	.15	.43	.01	.15	.01	.01	.58	.01
7	.42	.01	.01	.01	.29	.15		.15	.29	.15	.01	.29	.01	.01	.29	.01	.29	.29	.29	.01	.01	.15	.14	.43	.01	.15	.01	.01	.15	.01
8	.80	.01	.01	.00	.71	.57	.28		.14	.14	.00	.28	.00	.01	.28	.01	.14	.28	.14	.00	.00	.14	.14	.28	.01	.14	.01	.01	.58	.01
9	.42	.01	.01	.01	.28	.14	.28	.15		.14	.01	.29	.01	.01	.28	.01	.15	.28	.29	.00	.01	.14	.14	.36	.01	.14	.01	.01	.15	.01
10	.85	.01	.01	.01	.71	.57	.43	.15	.29		.01	.29	.01	.01	.28	.01	.29	.28	.29	.01	.01	.14	.14	.43	.01	.14	.01	.01	.58	.01
11	.85	.01	.01	.01	.71	.57	.42	.15	.29	.14		.29	.01	.01	.28	.01	.29	.28	.29	.00	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
12	.71	.01	.01	.01	.71	.57	.42	.15	.29	.15	.01		.01	.01	.14	.01	.29	.14	.29	.01	.01	.14	.14	.28	.01	.14	.01	.01	.58	.01
13	.85	.01	.01	.01	.71	.57	.42	.15	.29	.15	.01	.29		.01	.28	.01	.29	.28	.29	.01	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
14	.85	.01	.00	.00	.71	.57	.42	.15	.28	.14	.00	.28	.00		.28	.01	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14	.01	.01	.58	.01
15	.86	.01	.01	.01	.72	.58	.29	.15	.29	.04	.01	.15	.01	.01		.01	.29	.29	.29	.01	.01	.15	.15	.43	.01	.15	.01	.01	.58	.01
16	.85	.01	.01	.00	.71	.57	.42	.15	.28	.14	.00	.28	.00	.01	.28		.28	.28	.28	.00	.00	.14	.14	.42	.01	.14	.01	.01	.58	.01
17	.42	.01	.01	.01	.28	.14	.42	.15	.29	.14	.01	.29	.01	.01	.28	.01		.28	.29	.01	.01	.14	.14	.42	.01	.14	.01	.01	.15	.01
18	.86	.01	.01	.01	.72	.58	.29	.15	.29	.01	.01	.15	.01	.01	.23	.01	.29		.29	.01	.01	.15	.15	.32	.01	.15	.01	.01	.58	.01
19	.42	.01	.01	.01	.28	.14	.28	.15	.28	.15	.01	.29	.01	.01	.28	.01	.15	.28		.01	.01	.14	.14	.28	.01	.14	.01	.01	.15	.01
20	.85	.01	.01	.01	.71	.57	.42	.15	.29	.15	.01	.29	.01	.01	.28	.01	.29	.28	.29		.01	.14	.14	.43	.01	.14	.01	.01	.58	.01
21	.85	.01	.01	.01	.71	.57	.42	.15	.29	.14	.01	.29	.01	.01	.28	.01	.29	.28	.29	.01		.14	.14	.42	.01	.14	.01	.01	.58	.01
22	.86	.01	.01	.01	.72	.58	.29	.15	.29	.01	.01	.15	.01	.01	.26	.01	.29	.29	.29	.01	.01		.15	.35	.01	.15	.01	.01	.58	.01
23	.86	.01	.01	.01	.72	.58	.29	.15	.29	.01	.01	.15	.01	.01	.21	.01	.29	.29	.29	.01	.01	.15		.29	.01	.15	.01	.01	.58	.01
24	.85	.01	.01	.01	.71	.57	.31	.15	.29	.09	.01	.15	.01	.01	.28	.01	.24	.28	.29	.01	.01	.15	.14		.01	.15	.01	.01	.58	.01
25	.85	.00	.00	.00	.71	.57	.42	.14	.28	.14	.00	.28	.00	.00	.28	.00	.28	.28	.28	.00	.00	.14	.14	.42		.14	.01	.01	.58	.00
26	.86	.01	.01	.01	.72	.58	.29	.15	.29	.01	.01	.15	.01	.01	.29	.01	.29	.29	.29	.01	.01	.15	.15	.40	.01		.01	.01	.58	.01
27	.85	.00	.00	.00	.71	.57	.42	.14	.28	.14	.00	.28	.00	.00	.28	.00	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14		.01	.58	.00
28	.85	.00	.00	.00	.71	.57	.42	.14	.28	.14	.00	.28	.00	.00	.28	.00	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14	.01		.58	.00
29	.85	.00	.00	.00	.71	.57	.28	.14	.14	.14	.00	.28	.00	.00	.28	.00	.14	.28	.14	.00	.00	.14	.14	.42	.00	.14	.00	.01		.00
30	.85	.01	.00	.00	.71	.57	.42	.15	.28	.14	.00	.28	.00	.01	.28	.01	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14	.01	.01	.58	

Table 3. Matrix of degrees of credibility

The classification algorithms

The next step, to borrow Bernard Roy's terminology, is to make use of the information contained in the assessments available on the options, in such a way as to distribute and arrange in equivalence classes all or some of the elements of set A of the potential actions: the objective being to develop a ranking expressing in some detail the relative positions of these classes. When a ranking of this kind is intended to assist a given person or group of persons, it must reflect the **superiority,** importance and priorities which the decision-maker or -makers would normally attach to the various potential actions, given their own value systems. It is in this context that the modeling of the ecological districts has been developed.

The ranking will thus attempt to assign a classification rank to each of the options of set A of the potential actions. Two options will have the same rank if the data do not permit distinctions to be made between them. Equivalence classes will thus be formed on the basis of the rankings of the options.

There is, however, one danger. By limiting the objective to the development of a complete ranking on set A of the potential actions, we risk producing such a ranking even if the data fail to justify it. In fact, a set of data may often be incomplete or conflicting. In order to identify these non-weightings which may be subtly concealed in a data matrix, the ELECTRE III model (like ELECTRE II) operates in two stages to establish a ranking on the basis of the outrankings and to permit demonstration or, where applicable, refutation of the existence of a ranking on a set of options. These two stages can be summarized as:

- construction of two complete preorders in accordance with the outranking relation, but based on opposite considerations; and
- comparison of the two preorders obtained and development of a final ranking.

The final ranking is developed from the intersection of the two complete preorders. The common points between the two preorders will thus be considered a reliable ranking, based on the data available. In extreme cases, the two complete preorders may be identical.

Principles of the classification algorithm

Let **"a"** represent an ecological district, p(a) the strength of **a** in the set of ecological districts, that is, the number of districts in which a is strictly preferred, and f(a) the weakness of **a** in the set of ecological districts, that is, the number of districts which are strictly preferred to it. The quantity:

$$q(a) = p(a) - f(a)$$

is an indicator the value of which is characteristic of the position of "a" in a preorder. This value, which we shall term the qualification of a, is constant for all the elements of a given class.

ELECTRE III is based on a generalization of this **concept** of qualification. The qualification of the options is based on the outranking relations. In order to determine, on the basis of a given model of preference, the number of options strictly preferred to a, the classification algorithm uses a level λ such that only those outrankings for which the degree of credibility is greater than this level are used in the calculation. The level A may be a constant. However, it may also be defined not a priori (once and for all), but in relation to successive thresholds determined by the. stage reached in the procedure. This threshold is known as the separation level.

Thus, the strength of a is the number of elements which, within the set of ecological districts, are outranked by **a** significantly more strongly than they outrank **a,** with a credibility strictly superior to $S(\lambda)$.[20] The weakness of **a** is the number of elements which, within the set of ecological districts, outrank a significantly more strongly than they are outranked by a, with a credibility strictly superior to $S(\lambda)$. Hence:

- the greater the strength of an element, the closer it must come to the top of the classification, and
- the greater the weakness of an element, the closer it must come to the bottom of the classification.

The classification algorithm, as defined above, proceeds in this manner, by progressively reducing a separation level which defines the thresholds. The determination of the separation level is dependent on the values of the degrees of credibility.

The interactive process which consists of attempting to identify an increasingly reduced subset of actions having a maximum qualification for ever lower **thresholds** will be described as the downward distillation (or $\bar{P}$). Similarly, it is equally reasonable to proceed by attempting to identify the last class of actions not yet classified on the basis of the actions assigned the minimum qualification. This approach leads to the definition of an upward distillation and the linking of these upward distillations to **form** the second preorder $\underline{P}$.

The partial preorder **established** by the intersection of the two complete preorders $\bar{P}$ and $\underline{P}$ will produce a ranking which can be considered well founded on the basis of the data available.

In the example of application, there will be, for the upward distillation, four possible levels of separation, depending on the degrees of credibility, that is:

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[20] $S(\lambda)$ is the discrimination level. This level may be a constant or a function. It is used to establish, on the basis of the two outrankings being compared, the degree of significance required in order for one option to be considered better than another. In this example of application, $S(\lambda)$ has been established on the basis of the problem of the indices of importance, which plays a predominant role in the ranking of the ecological districts.

- 0.57, which will classify the districts with major assets; and
- 0.42, 0.24 and 0.14, which will establish a ranking among the ecological districts with important assets.

On completion of the downward distillation, those ecological districts not classified will be the ecological districts with weak assets.

For the upward distillation, there will be only one level of separation, 0.14.

Similarly, the level of discrimination will be constant at 0.13 for both distillations. In order for **a** to be considered better than **b, a** will thus have to outrank **b more** strongly than **b** outranks a **with a** degree of credibility strictly greater than 0.13 (the weight of an important asset).

Determination of the levels of separation and of the level of discrimination is based on the considerations defined earlier on the indices of importance of the criteria.

Let us look in detail at how the ranking of the downward distillation produced by the ranking algorithm thus defined is performed.

LEVEL OF SEPARATION ASSOCIATED WITH THE **1ST DISTILLATE = .57**
QUALIFICATION OF OPTIONS

-24
-4
-4
-4
24
20
0
-4
0
-4
-4
-4
-4
-4
-4
-4
0
-4
0
-4
-4
-4
-4
-4
-4
-4
-4
-4
20
-4

OPTION 1 BELONGS TO RANK 1 OF THE DOWNWARD DISTILLATION
OPTION 5 BELONGS TO RANK 1 OF THE DOWNWARD DISTILLATION

As the table of the residual matrix of the degrees of credibility (Table 4) shows, the degrees of credibility of options 1 and 5 are set at zero, so that they no longer affect the qualification of the options. Ranking of the ecological districts will continue in this way until all the options have been classified.

OPTIONS to	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
OPTIONS 1		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	.00		.00	.00	.00	.57	.42	.15	.28	.14	.00	.28	.00	.01	.28	.01	.28	.28	.28	.00	.00	.14	.14	.42	.01	4	.01	.01	.58	.01
3	.00	.01		.01	.00	.57	.42	.15	.29	.14	.01	.28	.00	.01	.28	.01	.29	.28	.28	.00	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
4	.00	.01	.01		.00	.57	.42	.15	.29	.14	.01	.29	.01	.01	.28	.01	.29	.28	.29	.01	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
5	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6	.00	.01	.01	.01	.00		.29	.15	.15	.15	.01	.29	.01	.01	.29	.01	.15	.29	.15	.01	.01	.15	.15	.43	.01	.15	.01	.01	.58	.01
7	.00	.01	.01	.01	.00	.15		.15	.29	.15	.01	.29	.01	.01	.29	.01	.29	.29	.29	.01	.01	.15	.14	.43	.01	.15	.01	.01	.15	.01
8	.00	.01	.01	.00	.00	.57	.28		.14	.14	.00	.28	.00	.01	.28	.01	.14	.28	.14	.00	.00	.14	.14	.28	.01	.14	.01	.01	.58	.01
9	.00	.01	.01	.01	.00	.14	.28	.15		.14	.00	.29	.01	.01	.28	.01	.15	.28	.29	.00	.01	.14	.14	.36	.01	.14	.01	.01	.15	.01
10	.00	.01	.01	.01	.00	.57	.43	.15	.29		.00	.29	.01	.01	.28	.01	.29	.28	.29	.01	.01	.14	.14	.43	.01	.14	.01	.01	.58	.01
11	.00	.01	.01	.01	.00	.57	.42	.15	.29	.14		.29	.01	.01	.28	.01	.29	.28	.29	.00	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
12	.00	.01	.01	.01	.00	.57	.42	.15	.29	.15	.01		.01	.01	.14	.01	.29	.14	.29	.01	.01	14	14	.28	.01	4	.01	.01	.58	.01
13	.00	.01	.01	.01	.00	.57	.42	.15	.29	.15	.01	.29		.01	.28	.01	.29	.28	.29	.01	.01	.14	.14	.42	.01	.14	.01	.01	.58	.01
14	.00	.01	.00	.00	.00	.57	.42	.15	.28	.14	.00	.28	.00		.28	.01	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14	.01	.01	.58	.01
15	.00	.01	.01	.01	.00	.58	.29	.15	.29	.04	.01	.15	.01	.01		.01	.29	.29	.29	.01	.01	.15	.15	.43	.01	5	.01	.01	.58	.01
16	.00	.01	.01	.00	.00	.57	.42	.15	.28	.14	.00	.28	.00	.01	.28		.28	.28	.28	.00	.00	.14	.14	.42	.01	4	.01	.01	.58	.01
17	.00	.01	.01	.01	.00	.14	.42	.15	.29	.14	.01	.29	.01	.01	.28	.01		.28	.29	.01	.01	.14	.14	.42	.01	4	.01	.01	5	.01
18	.00	.01	.01	.01	.00	.58	.29	.15	.29	.01	.01	.15	.01	.01	.23	.01	.29		.29	.01	.01	.15	.15	.32	.01	.15	.01	.01	.58	.01
19	.00	.01	.01	.01	.00	.14	.28	.15	.28	.15	.01	.29	.01	.01	.28	.01	.15	.28		.01	.01	.14	.14	.28	.01	.14	.01	.01	.15	.01
20	.00	.01	.01	.01	.00	.57	.42	.15	.29	.15	.01	.29	.01	.01	.28	.01	.29	.28	.29		.01	.14	.14	.43	.01	.14	.01	.01	.58	.01
21	.00	.01	.01	.01	.00	.57	.42	.15	.29	.14	.01	.29	.01	.01	.28	.01	.29	.28	.29	.01		.14	.14	.42	.01	.14	.01	.01	.58	.01
22	.00	.01	.01	.01	.00	.58	.29	.15	.29	.01	.01	.15	.01	.01	.26	.01	.29	.29	.29	.01	.01		.15	.35	.01	.15	.01	.01	.58	.01
23	.00	.01	.01	.01	.00	.58	.29	.15	.29	.01	.01	.15	.01	.01	.21	.01	.29	.29	.29	.01	.01	.15		.29	.01	.15	.01	.01	.58	.01
24	.00	.01	.01	.01	.00	.57	.31	.15	.29	.09	.01	.15	.01	.01	.28	.01	.24	.28	.29	.01	.01	.15	.14		.01	.15	.01	.01	.58	.01
25	.00	.00	.00	.00	.00	.57	.42	.14	.28	.14	.00	.28	.00	.00	.28	.00	.28	.28	.28	.00	.00	.14	.14	.42		.14	.01	.01	.58	.00
26	.00	.01	.01	.01	.00	.58	.29	.15	.29	.01	.01	.15	.01	.01	.29	.01	.29	.29	.29	.01	.01	.15	.15	.40	.01		.01	.01	.58	.01
27	.00	.00	.00	.00	.00	.57	.42	.14	.28	.14	.00	.28	.00	.00	.28	.00	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14		.01	.58	.00
28	.00	.00	.00	.00	.00	.57	.42	.14	.28	.14	.00	.28	.00	.00	.28	.00	.28	.28	.28	.00	.00	.14	.14	.42	.01	.14	.01		.58	.00
29	.00	.00	.00	.00	.00	.57	.28	.14	.14	.14	.00	.28	.00	.00	.28	.00	.14	.28	.14	.00	.00	.14	.14	.42	.00	.14	.00	.01		.00
30	.00	.01	.00	.00	.00	.57	.42	.15	.28	.14	.00	.28	.00	.01	.28	.01	.28	.28	.28	.00	.00	.14	.14	.00	.01	.14	.01	.01	.00	

Table 4. Residual matrix: degrees of credibility

Distillate (number)	1	2	3	4	5	6	7	8	9	
Level of Separation	0.57	0.57	0.42	0.28	0.28	0.28	0.28	0.14	0.14	
Option	Degree of Qualification of Options									Pre-Order
1	24									1
2	-4	-2	-2	-6	-3	-2	-1	-6	-2	
3	-4	-2	-2	-6	-3	-2	-1	-5	-2	
4	-4	-2	-2	-6	-3	-2	-1	-5	-2	
5	24									1
6	20	22								2
7	0	0	16							3
6	-4	-2	0	-3	-2	-2	-1	13	13	9
9	0	0	0	18						4
10	-4	-2	-2	-6	-3	-2	-1	-10	13	9
11	-4	-2	-2	-6	-3	-2	-1	-5	-2	
12	-4	-2	-1	15	15	15	15			7
13	-4	-2	-2	-6	-3	-2	-1	-5	-2	
14	-4	-2	-2	-6	-3	-2	-1	-5	-2	
15	-4	-2	-1	16	16	16				6
16	-4	-2	-2	-6	-3	-2	-1	-5	-2	
17	0	0	-2	15	17					5
18	-4	-2	0	18						4
19	0	0	0	18						4
20	-4	-2	-2	-6	-3	-2	-1	-5	-2	
21	-4	-2	-2	-6	-3	-2	-1	-5	-2	
22	4	-2	0	4	-1	0	0	14		8
23	4	-2	0	4	-1	0	0	14		8
24	4	-2	16							3
25	4	-2	-2	-6	-3	-2	-1	-5	-2	
26	4	-2	0	-5	-2	-1	0	14		8
27	4	-2	-2	-6	-3	-2	-1	-5	-2	
28	4	-2	-2	-6	-3	-2	-1	-5	-2	
29	20	22								2
30	4	-2	-2	-6	-3	-2	-1	-5	-2	

Table 5. Descending Distillation

OPTIONS to	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
OPTIONS 1		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	.00		00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	.01	.00	.01	
3	.00	.01		.01	.00	.00	.00	.00	.00	.01	.00	.00	.01	.00	.01	.00	.00	.00	.00	.01	00	.00	.00	.01	.00	.01	.01	.00	.01
4	.00	.01	.01		00	.00	.00	.00	.00	.00	.01	.00	.01	.01	.00	.01	.00	.00	.00	.01	.01	00	.00	.00	.01	.00	.01	.01	.00	.01
5	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8	.00	.00	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
9	.00	.00	.00	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
10	.00	.00	.00	.00	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
11	.00	.01	.01	.01	.00	.00	.00	.00	.00	.00		.00	.01	.01	.00	.01	.00	.00	.00	.00	.01	.00	.00	.00	.01	.00	.01	.01	.00	.01
12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	00	.00	.00	.00	.00	00	.00	.00	.00	.00	.00	.00
13	.00	.01	.01	.01	.00	.00	.00	.00	.00	.00	.01	.00		.01	.00	.01	.00	.00	.00	.01	.01	.00	.00	00	.01	.00	.01	.01	.00	.01
14	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	01	.00	.01
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
16	.00	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00		.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	.01	.00	.01
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	00	.00	.00	.00
19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
20	.00	.01	.01	.01	.00	.00	.00	.00	.00	.00	.01	.00	.01	.01	.00	.01	.00	.00	.00		01	.00	.00	.00	.01	.00	.01	.01	.00	.01
21	.00	.01	.01	.01	.00	.00	.00	.00	.00	.00	.01	.00	.01	.01	.00	.01	.00	.00	.00	.01		.00	.00	.00	.01	.00	.01	.01	.00	.01
22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		00	.00	.00	.00	.00	.00	.00	.00
23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	.00
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00
25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	00	00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		00	.01	.01	.00	.00
26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		00	.00	.00	.00
27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00		.01	.00	.00
28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	00	.00	.00	00	.00	.00	.00	.00	.00	.00	.00	.00	.01	00	.01		.00	.00
29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	00	.00	.00	.00	.00	.00	.00	00	.00	.00	.00	.00	.00	.00	.00	.00		00
30	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00	.01	.01	.00	

Table 6. Residual matrix: degrees of credibility

END OF THE DOWNWARD DISTILLATION

On completion of the downward distillation, all the unclassified ecological districts are districts with weak environmental assets. The program then performs the upward distillation. The results of the two distillations and the final ranking (intersection of the two distillations) are presented in Tables 7 and 8.

Downward distillation Options	Rank	Upward distillation Options	Rank
1, 5	1	1, 5	1
6, 29	2	7, 9, 19	2
7, 24	3	6, 29	3
18, 9, 19	4	18, 24	4
17	5	15	5
15	6	12, 17	6
12	7	8	7
23, 26, 22 3	8	22, 23	8
8, 10	9	26	9
2, 3, 1:, 13, 14, 16, 20, 21, 25, 27, 28, 30	10	10	10
		2, 3, 4, 11, 13, 14, 16, 20, 21, 25, 27, 28, 30	11

Table 7. Ranking of the ecological districts: ELECTRE III

The ranking of the ecobgical districts performed by ELECTRE Ill is **relatively** similar to the classification by **Hydro-Quebec.** There are, however, certain difference, as the following table shows:

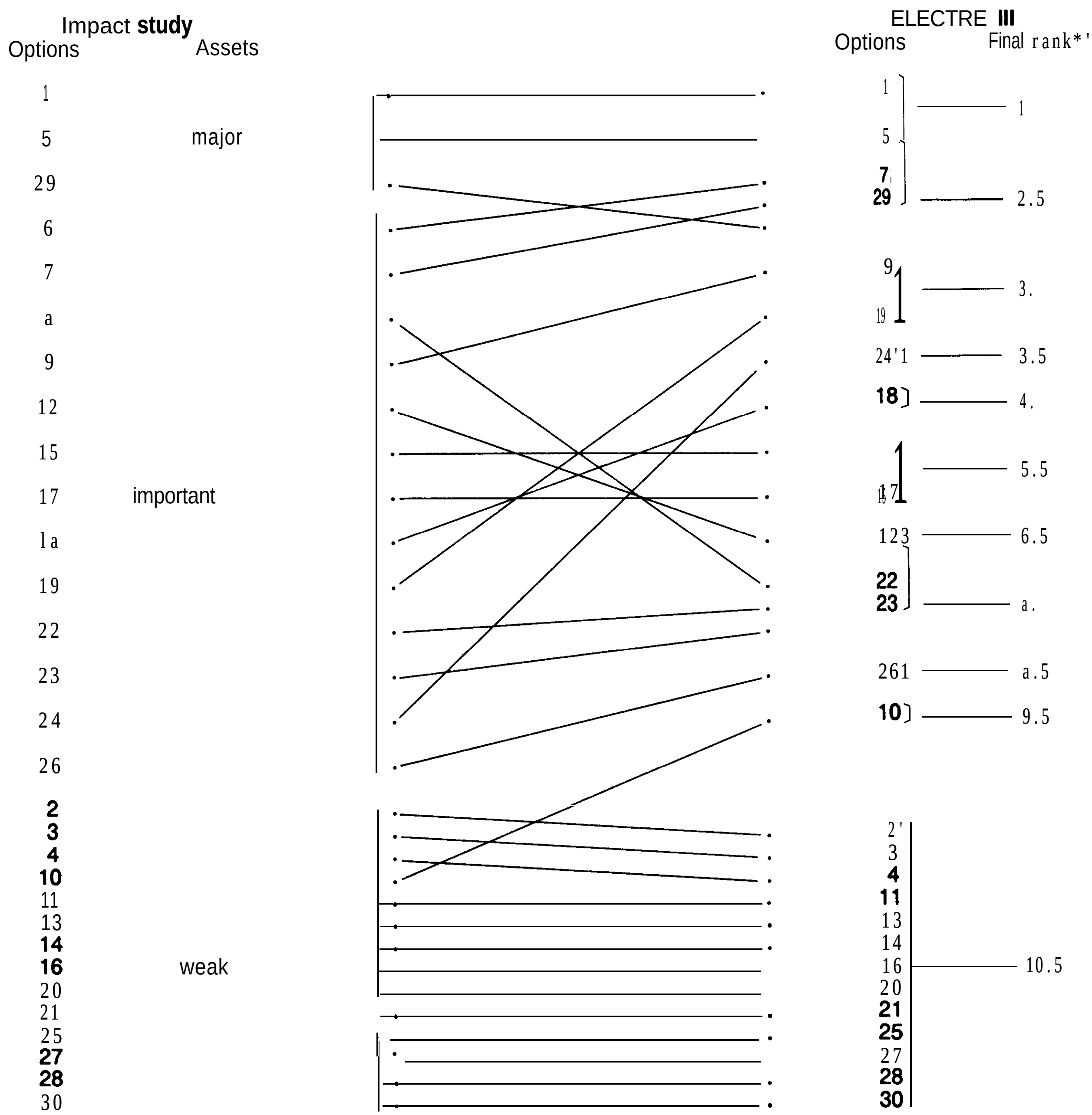

Table 8. Final rankings of the ecological districts

[21] The final ranks are calculated from the intersection of the two distillations.

The ELECTRE III ranking is much more detailed than that of the impact study: there are 11 equivalence classes compared to 3. This is essentially because the ELECTRE Ill model makes certain distinctions between options involving major environmental assets and those involving important assets. For example, according to the impact study, options 24 and 26 are considered equivalent, whereas ELECTRE Ill rates option 24 as “better” than option 26. ELECTRE Ill thus offers more detailed classification of the ecological districts.

The first equivalence class of the ELECTRE Ill ranking represents ecological districts with major assets. The last equivalence class (rank 10.5) represents ecological districts with weak environmental assets. The ranking of these two extreme classes is reliable. Any apparent differences involve the intermediate classes with important environmental assets. The cases showing the largest differences are districts 6, 7 and 29, which belong to the same equivalence class according to ELECTRE Ill, but represent different types of assets according to the impact study. There is also district 10, which is not classified as a weak-asset district by ELECTRE Ill, as it is by the impact study. These apparent contradictions are probably related to the fact that some of the parameters on which the ranking of the ecological districts was based were not clearly identified in the impact study. As noted earlier, it is sometimes difficult to identify the factors used to distinguish major environmental assets from important assets. In fact, the considerations used to rank the ecological districts and translated into the program for the ELECTRE III model are certainly correct, but certain details are probably lacking or not clearly expressed in the impact study.

The following analysis will thus be purely speculative and is designed simply to produce the same ranking as the impact study. Since the ranking performed by ELECTRE III is based solely on the data given in the multicriteria assessment table, we shall therefore use this table in an effort to expand upon the preferences expressed by the promoter of this project.

As stated earlier, the percentage of wooded area appears to play no role. Yet the promoter chose to keep these assessments in the multicriteria assessment table: why? Similarly, we have considered all the ecological districts of recognized scenic value as representing major assets. Yet option 6 is of recognized scenic value but is not considered a major asset in the impact study, while option 29 too is of recognized scenic value and is considered a major asset (these two options have only this one assessment circled). What, then, distinguishes them?

The question arises at this point as to what parameters define or confirm the presence of recognized scenic value. We shall look more specifically at the second aspect of the question, that is, at what confirms recognized scenic value. Still working from the data in the multicriteria assessment table, we shall assume that recognized scenic value will be considered a major asset if this assessment is supported by another criterion. The wooded area of an ecological district could then be used as a supplementary index to the recognized scenic value criterion, either confirming or rejecting the area’s potential for vacation or recreational use. Similarly, the number of cottages could also serve as an index confirming the existence of recognized scenic value. Thus, an ecological district will be considered a major environmental asset if, first, it is characterized by recognized scenic value with, secondly:

- either a large number of cottages;
- or a high percentage of wooded area; or
- both.

These two assessment criteria confirm the potential of the recognized scenic value, while an ecological district with only recognized scenic value will be considered an important asset (for example, option 6).

The distinction between the two rankings on option 10 demonstrates the same type of reasoning, but, in this case, from the agricultural standpoint. Under the ELECTRE Ill model, option 10 was considered an important asset, while the impact study classifies it as a weak asset. This contradiction arises essentially from the fact that, for the “area under cultivation” criterion, all assessments greater than 40% have been considered important assets by ELECTRE Ill. However, in the impact study, the assessment of 43% on option 10 was not included: why? The same applies to the assessment of 42% on option 7. It could thus be assumed that the same reasoning as for recognized scenic value applies here and that an ecological district becomes an important asset from the agricultural standpoint if the assessment of the area under cultivation is very high in relation to the mean for the region, but that in cases where the area under cultivation is only slightly higher than the mean for the ecological region (31%), this agricultural “potential” must be “confirmed” by a relatively high percentage of 1, 2 and 3 soils. This would explain why, in the assessment table from the impact table, the percentages of area under cultivation were not included for option 7 and option 10, while the assessment of option 23 (60%) was included, despite the fact that the area of 1, 2 and 3 soils is very low (3%). The promoter thus appears to have used certain thresholds to determine whether or not to include the assessments for certain ecological districts. However, there is no reference to this practice, which nonetheless now appears evident, in the impact study.

Let us now look very briefly at how these purely speculative observations can be incorporated in the ELECTRE Ill model.

The considerations expressed on the “recognized scenic value” criterion and on the “area under cultivation” criterion are similar to the concept of a veto level but, in this case, not on the basis of two options on the same criterion (as with ELECTRE Ill), but rather on the basis of an assessment of one criterion in relation to the assessment of another criterion on the same option (two criteria in relation to one option). This pseudo veto level can thus reduce or confirm the assessment on a criterion on the basis of the other criteria for assessment of the same option. We must thus include these conditions in the modeling process. These conditions will be expressed in the program in the form of logical expressions permitting modification of the assessments in the matrix of raw data.

Downward distillation

Options	Rank
1, 5	1
29	2
24	3
9, 19	4
17	5 / 6
15	7
123	a
6, a, 22, 23, 26	9
2, 3, 4, 10, 11, 13, 14, 16, 20, 21, 25, 27, 28, 30	10

Upward distillation

Options	Rank
1, 5	1
9, 19, 29	2
1a, 24	3
12, 15	4
17	5
8	6
22, 23	7
26	8
6	9
2, 3, 4, 10, 11, 13, 14, 16, 20, 21, 25, 27, 28, 30	10

Table 8. Ranking of the ecological districts: ELECTRE III

Impact study

Options	Assets
1, 5, 29	major
6, 7, 8, 9, 12, 15, 17, 18, 19, 22, 23, 24, 26	important
2, 3, 4, 10, 11, 13, 14, 16, 20, 21, 25, 27, 28, 30	weak

ELECTRE III

Options	Final rank
1, 5	1
29	1.5
9, 19, 24	3.
18	4.
7, 15, 17	5.5
12	6.
8	7.5
22, 23	8.
26	8.5
6	9.
2, 3, 4, 10, 11, 13, 14, 16, 20, 21, 25, 27, 28, 30	10.

Table 10. Final rankings of the ecological districts

This original addition to the ELECTRE III model is designed to deal with the "contradictions" observed between the initial application of ELECTRE III and the ranking by the impact study.

Thus, all the parameters defined on the initial application of ELECTRE III will remain the same. However, the following elements will be added to this modeling on modification of the matrix of raw data.

- If an ecological district has recognized scenic value and if, in the same ecological district, the percentage of wooded area is greater than or equal to 85" or if the number of cottages is greater than or equal to 162, then the **area** of recognized scenic value will have an assessment corresponding to 4; otherwise, it will have an assessment corresponding to 2.

- If an ecological district has an assessment between 39 and **50**[22] for area under cultivation, then it will retain this assessment on area under cultivation if the area of 1, 2 and 3 soils is greater than **3**[22]; otherwise the assessment on this criterion will equal 0. If the area under **cultivation** is greater than **50**[22], then the assessment will automatically remain the same.

With these few modifications, let us now look at the final ranking of the options.

The results of this second application of the ELECTRE III method are much closer to the ranking by the impact study. In fact, there is no longer any overlap between the three types of assets from the impact study with the ELECTRE III ranking. It could be tentatively concluded that the modifications made to the matrices of raw data reflect the preferences of the promoter. However, according to the conditions governing application of the method, only the ranking of options 1, 5 (class 1), 29 (class 1.5), 24 (class 3), 6 (class 9) and 2, 3, 4, 10, 11, 13, 14, 16, 20, 21, 25, 27, 28 and 30 (class 10) can be considered 100% reliable on the basis of the information used for the model. The final ranking by ELECTRE III on the other options is less certain, since the two inverse rankings (downward and upward distillations) show certain differences (see table 8, page 83). However, we can be certain that these ecological districts, that is, options, 9, 19, 18, 12, 15, 7, 17, 8, 22, 23 and 26, are important assets, since these same options fall **in both distillations** between equivalence classes representing major and weak assets, for which we have reliable rankings.

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[22] These values were selected on the basis of the data matrix since there is no reference in the impact study to this topic.

5. CONCLUSION

The ELECTRE III method emphasizes consistency in decision-making. In addition to reliably reproducing the same classification as that of the impact study, application of the method to the problem of ranking the ecological districts offers more information than the method used in the impact study.

Considering that:

1. The definition of pseudo-criterion, through the introduction of strict preference, weak preference and veto levels on the assessment criteria, permits a better understanding of the assessments which played an effective role in the ranking of the ecological districts;

2. the weighting of the criteria, through the introduction of indices of importance of:
   0.57 on the "recognized scenic value" criterion
   0.14 on the "wooded area" criterion
   0.14 on the "1, 2 and 3 soils" criterion
   0.14 on the "number of cottages" criterion
   0.01 on the "wooded area" criterion
   permits a better grasp of the relative importance assigned to the "recognized scenic value" criterion in relation to the other criteria;

3. the definition of the set of potential actions, that is, the definition of the set of ecological districts to be included in the ranking, has demonstrated that the 74 ecological districts were ranked in relation to each of the 8 ecological regions, or, in other words, that ranking was performed for each ecological region;

it is our opinion that application of the ELECTRE method permits better structuring of the problem of ranking the ecological districts than the method used in the impact study and thus a better understanding of the parameters involved in ranking the ecological districts and the manner in which they operate. For example, the definition of the set of potential actions reveals indirectly that the assessments on the criteria classifying an ecological district as an important asset in the Lower Appalachian Plateau ecological region might well have produced other results in the neighbouring ecological region, since the comparisons do not relate to the same data base. In other words, the promoter of the project under study performed a further reduction of the study zone, on the basis of the ecological regions, before ranking the ecological districts. In addition, the formal structure of the ELECTRE Ill method reveals certain "inconsistencies" in the ranking of the ecological districts of the Lower Appalachian Plateau ecological region by the impact study. For example, how can we explain the fact that ecological districts 6 and 29, with virtually the same assessments, are classified respectively as important and major assets in the impact study (see Table 1)? This questioning, which has led us to a series of speculations on the actual role played by the "wooded area" criterion in ranking the ecological districts, demonstrates the existence of "inconsistencies" very difficult to explain in the application of the method used by the promoter of the project under study. Moreover, these inconsistencies, which were rapidly detected by comparing the results of the initial application of the ELECTRE III model to the results of the impact study, demonstrate the sensitivity of the ELECTRE III model. Finally, the assignment of indices of importance on the criteria used to rank the ecological districts emphasizes the full relative importance assigned to the "recognized scenic value" criterion, and thus to the recreation-tourism orientation of the ecological districts. In fact, this criterion alone assumes as much importance as all the other criteria combined. Since we have been able, on the basis of this weighting, to reproduce the same classification as that of the impact study, we feel that this scale of values, applied to the criteria in the example of application, expresses relatively accurately the preferences of the promoter, in view of the fact (for example, district No 24, see Table 2) that an ecological district with no recognized scenic value but high assessments on all the other criteria will nonetheless be classified as an important asset.

By establishing a formal structure for the process of ranking the ecological districts, the ELECTRE III method also encourages communication of the results of analysis to the public and to those responsible for decision-making. Although this aspect of the EIS process has not been specifically examined in this study, it seems clear, nonetheless, that the participation of a number of parties in a critical examination of the impact studies promotes the use of methods providing information which will permit, for example, a clear understanding of all the stages and parameters involved in the final ranking of the ecological districts. On this latter point, we believe that the ELECTRE III method is an excellent tool. Combined with computer processing capabilities, the method's potential as a tool for communication and for structured decision-making could enable a wide range of individuals to test their viewpoints against those of the promoters. This potential application of the ELECTRE method might even include active participation by the various parties concerned in certain critical phases of the EIS process, for example in the selection of weightings for the criteria, and would permit a rapid response to the incompatibilities between the selections of the various parties and thus, improved orientation, where possible, of the solutions. It would be extremely interesting to test the ELECTRE method against this hypothesis through analyses of model sensitivity and of the possible implications for the EIS process.

The ELECTRE method thus emphasizes consistency in decision-making. Its principal difficulty lies in the fact that, if hypotheses of sufficient strength are not introduced on the criierii selected, the method will not permit distinctions between the options being compared. The key to success in using this method lies in the effort to assign significance to the various levels and parameters used, in order to maintain certain degree of control over the method and thus to permit interpretation of the results obtained. On this point, analyses of model sensitivity are still required, to define even more precisely the limitations of the method.

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