Methods of multicriteria decision analysis within the road projects like an element of the sustainability

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Abstract

The present communication is based on the research undertaken by the author and whose principal results are detailed in its thesis entitled « Choice of alternatives of road infrastructures : multicriteria methods » like on the prospects offered by this one.

The problems of the choice between various alternatives are permanent and crucial in the projects of systems of transport and road infrastructures. The designer who works out a technical solution must have objective and global methods in order to propose to the decision makers, who are generally a political entity, an optimal alternative. The complexity of the many fields affected by the transport infrastructure as well as the diversity of the various intervening actors directly or indirectly in the study process are as much elements to integrate in this choice.

Only methods of multicriteria decision analysis, associated with a dialogue integrated into all the stages of the study process, make it possible to the designer as well as possible to take account of this complexity. The use of such methods also makes it possible to bind the objective aspects of the choices, based in particular on technical evaluation of the performance indicators of the alternatives for each criterion, with its subjective aspects which are the relative consideration of importance of each criterion, also called weighting.

These methods of multicriteria decision analysis used in parallel with dialogue methods are clearly at the basis of a study process ensuring the realization of a sustainability road. They indeed make it possible to bind social, by the dialogue of the various actors, economic and environmental dimensions by the consideration of adequate criteria. Moreover, the consideration of the needs for the future generations, by the taking into account of the cycle of life of the infrastructure, is easy to realize.

The author carried out an actualization of methodology of the road project process while basing him on the integration of these principles in the procedure. An evaluation of the various methods of multicriteria decision analysis was carried out and tested on a real case in Switzerland.

It results the following main clauses from them :

- ✓ The use of the method of partial aggregation Electre III makes it possible to better moderate the judgments and use easy indicators
- ✓ The honest separation in the stages of the process of the phase of weighting, which is to be realized before the alternatives generation, this one preceding the phase of the evaluation of the criteria
- ✓ The objective judgment is to be realized by the designer and subjective weighting by the decision makers

Keywords

Road project – Road design – Actualized methodology - Multicriteria decision analysis – Partial aggregation – Criteria – Weighting - Electre III – 3rd Swiss Transport Research Conference – STRC 03 – Monte Verità

1. Introduction

The present communication is based on the research undertaken by the author and whose principal results are detailed in its thesis entitled « *Choix de variantes d'infrastructures routières : méthodes multicritères* » (Tille M., 2001) like on the prospects offered by this one.

1.1 Typology of the problematic

The most recurrent problems that one can meet in road infrastructures project in Switzerland and in the Occidental Countries are the follows :

- Lengthening of the study duration : the study of a road project is a long work but when the duration is express in decades either in years, it appears increasingly difficult to carry out an infrastructure as well as possible holding account context
- Splitting of the study : the longer projects are not necessarily better projects because additional time is devoted to the resolution of conflicts in particular elements
- Importance of the particular interests : the concept of public interest is called more and more into question in aid of the particular interests
- Conflict relationship between the actors of the project : the climate reigning between the various protagonists is often not serene and the study can finish in a court
- Increasing of the costs : the tendency is to have an increasing of the unit costs of the current road achievements compared to those carried out there are two or three decades. (CGCN, 1997) This difference can be charged too many parameters but the lack of dialogue is a significant factor and the consensus necessary to the approval of the road projects is often "*acheté à coups de milliards*" (Miéville D. S., 1997)
- Uncertainty for the end of the projects : when the project is blocked in very long legal procedures, it happens sometimes that its initiators stop it, when well even their project met a proven public need
- Unsatisfactory solution : when a solution is found, it is always the result of a compromise. The compromise is not the "*ideal solution*" because it reflects only the ratio of the force between the different actors and not the optimum. Moreover, often the solution is viable at short-term but the long-term assessment is not considered

1.2 Factors of the problematic

One can put the question to know if a road project must by generating being definition of conflicts. Undoubtedly, the answer is negative, but force is to note that there isn't inevitably the case. One can then put the following question: "*Which are the principal factors which generally return like source of the problem, knowing that each project has finally its own characteristics?"*. One can raise the following causes of this problematic :

- Many affected fields : the road projects of share their direct and especially indirect influences on the natural and human environment assign many fields to the divergent objectives. It is impossible to design a project which is optimum for each one and we need for having a multicriteria and global vision
- Multiple actors: one understands by the term of "*actor of the project*" or "*main participant*", (Knoepfel P., 1997) all the people, companies or associations who take part in the design of the project or who revolve around this one and which have a real or potential influence on sour its unfolding
- Evolution of the society : actually, the community is in a full metamorphosis and the values and the social waiting of the individuals are changing (Besnaïnou R., 1999). The hierarchical report of the citizen, who is emancipated and becomes more changeable, compared to the authority is not also extremely. The will of transparency of the decisions and the need of information became significant for the acceptability of any major project
- New paradigms : the environmental awakening of ethical model of the society, which of the sustainability associated a standard of living of quality. The participation of the citizens in the infrastructures projects, by the means of the dialogue, is clearly one of the elements of this new paradigm. The setting out of balance of the contradictory interests, based on a multicriteria examination of the problems, is also an integral part of the sustainability
- Ill-adapted methodology : the methodology of study used by the designer in the road projects has not followed the wishes of the actors
- Rigorous procedure : the designers must evolve within a framework of very rigorous legislative procedure (Cabioch F., 1997) which has little flexibility and which corresponds less to waiting of the actors. There is a source of multiple incomprehension

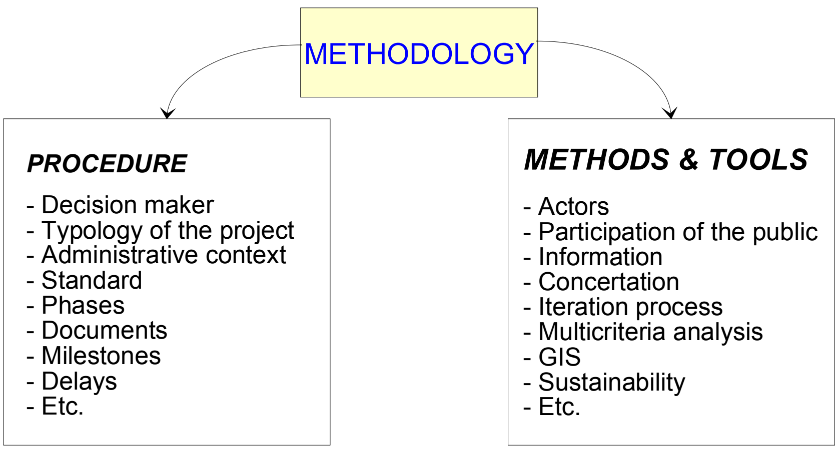
As one can notice it, the sources of the problematic are multiple and varied. This richness of the potential conflicts which does finally all the interest for the road projects for a designer : to be able to !

2. The road project

The road project is the study of dimensions, costs, effects and location of the road infrastructure. The methodology of the road project is an aggregation of two notions : the procedure (*What to do ?*) and the methods and tools (*How to do it ?*) :

- Procedure : check-list to follow and all the rules to respect during the project (laws, norms, etc.)
- Methods and tools : there is the material which the designer used to do his work

Figure 1 The methodology : aggregation of two different notions

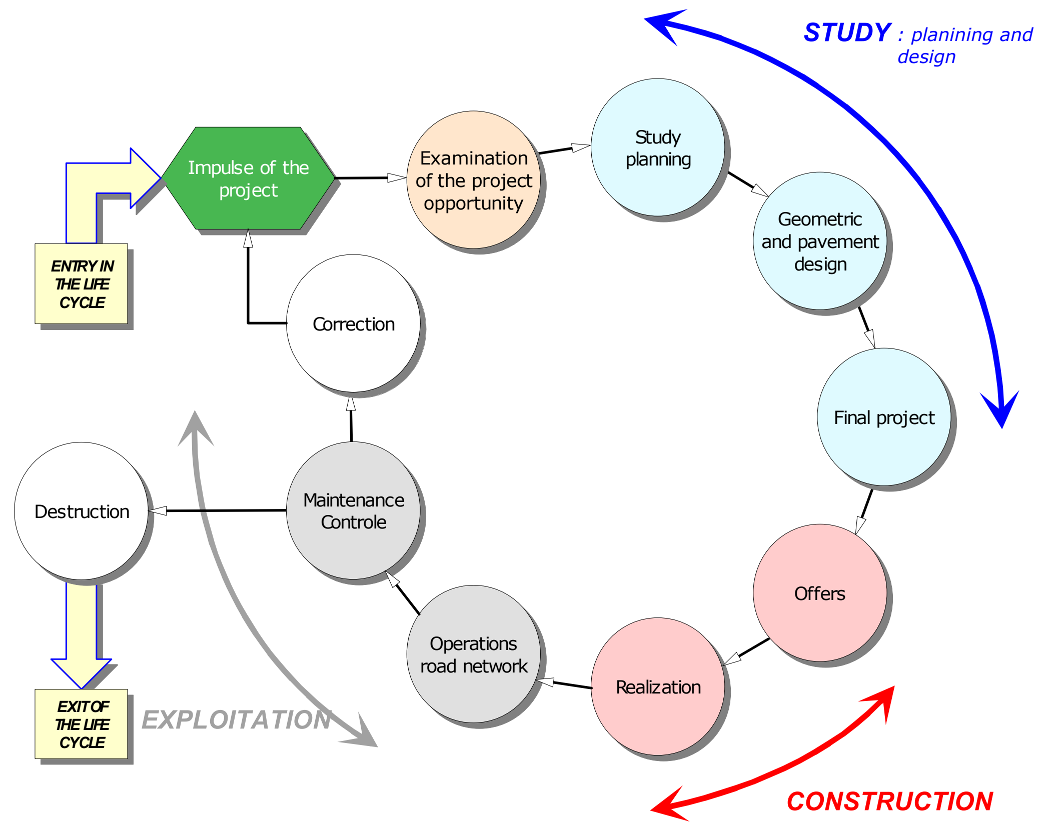


The goal of this study was only to propose a new methodology for the designer. The procedure is a frame which can be changed only by the way of the law.

2.1 Life cycle of a road infrastructure

The study process of a road project proposed by the Swiss standards postulates clearly that a road infrastructure is subjected to a cycle of life. (Article 3, VSS, SN 640 026) A road is planned, designed, built, used and exploited, maintained and possibly demolished. The planning and the design of the road project comprise only some elements of this cycle of life. The volume of work which the project requires is significant but its duration is weak compared to all the cycle. It is nevertheless a significant gearwheel of this one because it dictates its operation.

Figure 2 The Road Life Cycle



2.2 Critical analysis of the existing methodology

The study showed the following problems in the projects of road in Switzerland :

- Examination of the project opportunity: he is often lacking in Switzerland. For the nationals roads this explain by the fact that the needs are not directly to prove considering the master line was approved by the Federal Swiss Councils (LRN, 1960)
- Complexity : the procedure is sometimes very complex, which can disconcert the public. For the Swiss nationals roads, the procedure is " *trop lourde, trop lente et manque totalement de transparence* " (CGCN, 1997)
- Political approach : the complexity of the procedure tends to multiply its technicality (expertise, complementary studies). (Veuve L., 1994) This causes that to evacuate the subjective aspects and to reduce the political dimension related to the project
- Liberty of the designer : the procedures are often very strict what can be prejudicial because the socio-economic context evolves sometimes more quickly than the law

- Linear approach : the approach is strongly linear and each step conditions the results of the following even though the definition of the problem and the search for solutions are concomitant and no successive actions (Veuve L., 1994)
- Participation : the intervention of the actors come only at the end of the process and sometimes doesn't exist (Bassand M., Veuve L. et al., 1986)

2.3 Actors of the road project

2.3.1 Categories

One can classify the actors intervening in the road project in the following categories :

- the **decision-maker** who finances the realization of the infrastructure and who will be the future owner. There is the actor for whom the project is intended. The decision maker is a political actor of the executive field, responsible for road administration
- the **study group** includes the technical actors who work out the road project and prepare the elements of analyze for the decision maker. Its principal actor is the road designer, who is generally a civil engineer. This one work with various specialists, when some problems that he cannot solve appears
- the **administrative actors** who come from various services of public administration. The purpose of they are to check the conformity of road project with the law
- the **public** understands :
  - actors **affected** by the future road infrastructure (borders). Those can meet in spontaneous groups when they estimate that some their concerns are not sufficiently taken into account by the traditional relays of the citizen wishes. Generally, these regroupings are transitory
  - the **users** which are the directly or indirectly beneficiaries of the future road
- the **no-governmental organization**s (NGO) which are perennial structured groups which intervene to defend environmental values, social or economic themes
- the **politicians actors** are the members of the executive or legislative power which are not in the same role as that of the decision maker

One little also to announce the **legal actor** who strongly influences the road project while intervening in the conflicts between the actors which haven't been able to be regulated within the procedure.

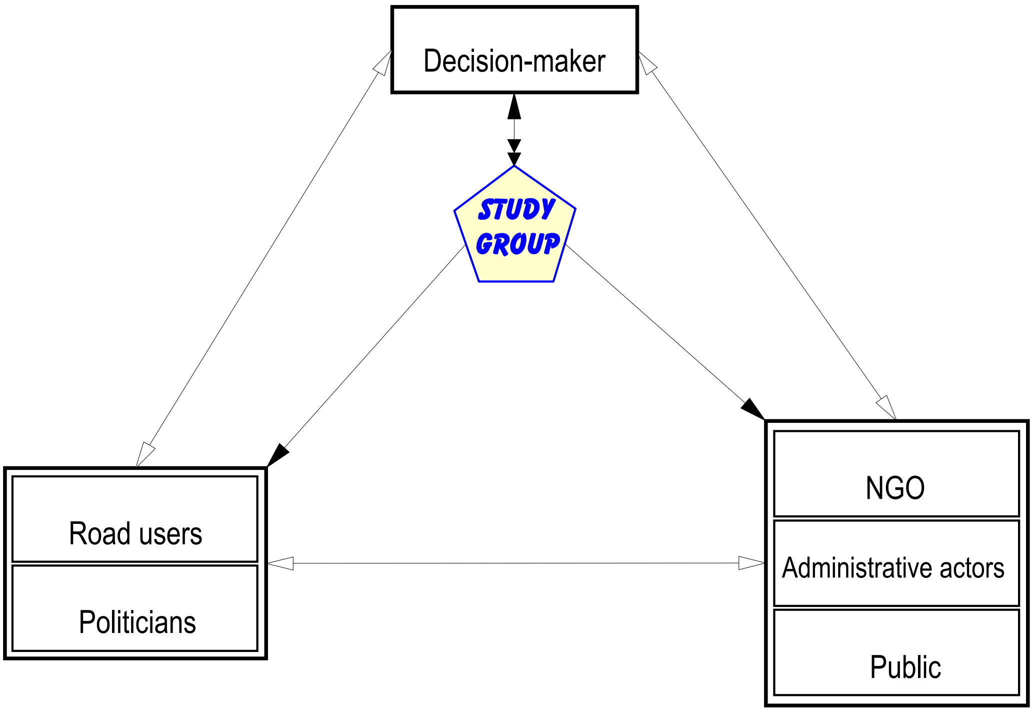
2.3.2 Relations between the actors

In any environmental problems, one can summarize the existing ratios of forces between the actors by using the notion of the **iron triangle** defined by (Knoepfel P., 1997). The tops of the triangle represent the actors and the sides, the reports of force between those. According to the cases, this diagram can burst into 4-5 even 6 actors

The relations between the categories of actors can be of two types :

- **conflict**, when the interests are opponent
- **coalition** when the interests are convergent or when it is necessary to have an alliance to make fold a third actor

Figure 3 Example of a iron triangle with two coalitions



To be most objective possible, the composition of the study group must be a mini-system similar to the general system of the actors. It thus contains in its center of a significant potential of conflicts.

3. Multicriteria decision analysis methods

The definition that B Roy proposes for the decision analysis is the follows :

> " *L'aide à la décision est l'activité de celui qui, prenant appui sur des modèles clairement explicités mais non nécessairement complètement formalisés, aide à obtenir des éléments de réponses aux questions que se pose un intervenant dans un processus de décision, éléments concourant à éclairer la décision et normalement à prescrire, ou simplement à favoriser, un comportement de nature à accroître la cohérence entre l'évolution d'un processus d'une part, les objectifs et le système de valeurs au service desquels cet intervenant se trouve placé d'autre part* " (Roy B., 1985)

3.1 The process of the decision

3.1.1 Actors of the decision

The two principal actors of the decision analysis are the decision maker and the designer :

- the **decision maker** is the person with whom the decision analysis is referred. He occupies a central place in the study process whose characteristics depend on its waitings. Sometimes, there is a little fuzzy entity, but its identification is of primary importance. Sometimes, the decision-maker is not and individual people but a group of different actors (case of the Swiss national roads where some levels are concerned)
- the **designer** is an individual or a group of people who has as a role to establish a system of preferences, to define the model of the decision analysis, to use it, to have answers and to make some recommendations to advise the decision maker on the possible solutions. (Maystre L. Y., Pictet J. et al., 1994) The designer is to be distinguished from the negotiator, who are elected by the decision maker in order to put forward his position in research of a consensual alternative, and from the mediator, who is a referee helping the decision makers to lead to a compromise

In a preoccupation with a perfect independence, it is necessary that the **decision maker** is distinct from the **designer**. Indeed, the tasks which must carry out each one of these actors are different and they must not to have an influence between them.

3.1.2 Subjectivity and objectivity

The decision is of subjective nature what can be sometimes difficult to admit by an engineer. From its technical training and its scientific and rational way of thinking, this one is indeed more inclined to prefer judgments based on approved models which bring the demonstration than the solution suggested is indisputable. One can note however that this tendency to want to minimize the share of subjectivity in any decision relates to other people that the scientists.

The subjectivity is not to be regarded as being a defect or an inaccuracy of the decision, but rather as being the reflection of her human aspect. A. Schärlig speaks even about the "comedy of the decision" which is finally an anarchistic process and very seldom a rational process. He quotes an evocative sentence of R. Howard "*decision making is what you do when you don't know what to do*". (Schärlig A., 1985)

The subjectivity reflects the systems of values of the decision maker and the actors who condition the decision. The subjective and objective aspects are closely dependent in all the decision-making process. It is thus significant to clearly distinguish them and to identify them throughout the study.

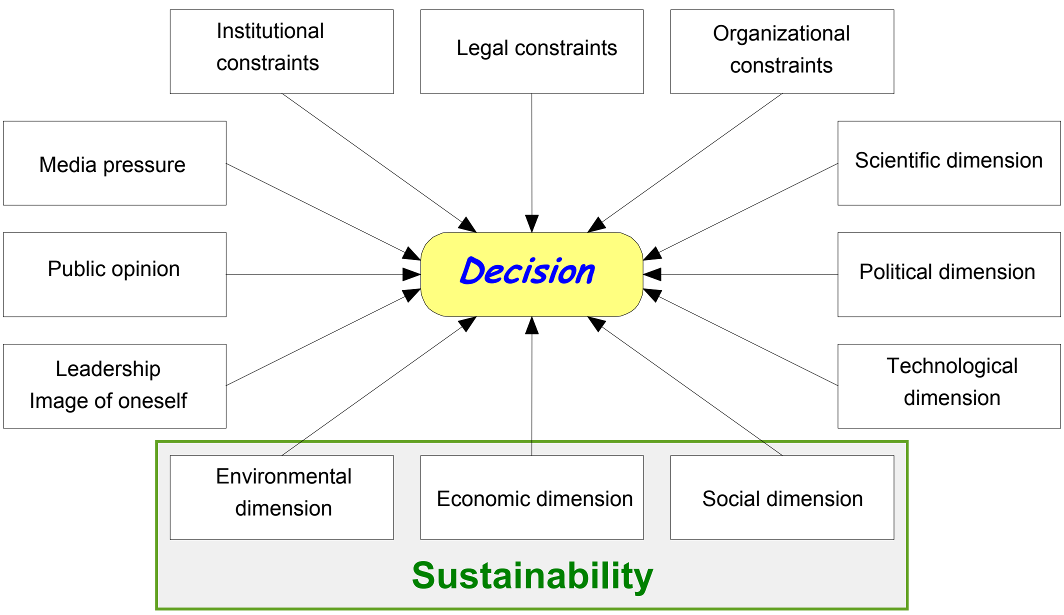
3.1.3 Influential factors of the decision

The subjectivity of the decisions is the faithful reflection of the system of proper values of the decision maker. However this grid of evaluation on which the decision is based, in a conscious way or not, doesn't depend intrinsically on the characteristics of him. He is being indeed strongly conditioned by many external factors : (André P., Delisle C E. et al., 1999)

- Institutional constraints (lawful frame of the political institutions, structure of distribution of the power, traditions) which create a model of behaviour conditioning the decision maker
- Legal constraints : the legislative texts must be respected by the decision maker, what can appear very constraining as for its independence of action
- Organisational constraints : distribution of competences and relations between the various services of the administration
- Scientific dimension : the experts can have contradictory opinions what can involve the decision maker to delay his decision to have more elements for make his analysis

- Political dimension : various special interest groups can influence directly or indirectly the decision. The ideological values (conservative, progress, etc.) defended by the decision maker influence also his decision
- Technological dimension: trust or reserve in the effects of technology
- Social dimension : effects on the population, accessibility with a mobility of quality, principles of equity as well as the values and beliefs of the decision maker
- Economic dimension : public financial statement and direct and indirect effects of a road on the economic activities of a territory
- Environmental dimension
- Public opinion : the democracy consists in delegating to the decision maker a power which can be significant but which is limited in time. The public satisfaction of the public opinion, by extension of the voters, is essential for a political actor (election !)
- Media pressure: certain projects have a significant media cover
- Image of oneself and leadership : to make a decision is in oneself an act of being able. To decide in a complicated context or to affirm a position prone to the dispute shows decision clearly works an image of leadership of the decision maker. One can notice that in contrary to a political actor "go-ahead type", a political actor trying to find a consensus permanently can also have a strong image

Figure 4 Influential factors of the decision



3.2 Searching of the optimum

Within the framework of the road projects, the decision maker often waits of the designer that he provides him an answer which is clearly defined and justified. However, the research of an optimum is sometimes stripped of sense because it supposes that three constraints are filled simultaneously : (Roy B., 1985; Schärlig A., 1985)

- Stability : the whole of the studied actions is stable throughout the study
- Uniqueness : it exists only one action among the whole of the studied actions which is the optimal solution
- Transitivity : by comparing two different actions, only two transitive relations are possible, namely strict preference of one compared to the other or indifference

In the major part of the decision-making problems, these conditions are rarely met in a concomitant way. The most constraining condition of the optimization relates to the transitivity of the indifference which is not to be confused with the equality. This indifference is in fact an intransitive relation. There is completely plausible that in the case of three alternatives *a*, *b* and *c*, the fact that *a* is indifferent opposite to *b* and that *b* is indifferent opposite to *c* doesn't mean that *a* is indifferent to *c*. The relation of preference is also intransitive : a decision maker can indeed prefer *a* to *b*, *b* to *c* but not to prefer *a* to *c*.

To seek an optimum appears thus sometimes stripped of direction or too reducer and it are thus necessary, like says it A. Schärlig, "*to dare the incomparability !*" and to admit that sometimes there exist not inevitably a single solution for a given problem.

A justification of the optimization is that she simplifies the complexity of reality, this by bringing significant a loss of information however. If there is easier to give an opinion on a simple model, but sometimes detached of the context of the problems, it is sometimes trying to then want to impose like the only possibility of appreciation. This frequently practiced operation is with the source of many misunderstandings and lead often to confusion. As well as A. Schärlig says "*la réalité est à critères multiples - elle est donc impossible à optimiser - et la voie à suivre est celle des méthodes multicritères*". (Schärlig A., 1985)

As a decision maker cannot integrate simultaneously a number limited of informations to carry his judgement, the designer will organize and synthesize information by the means of the multicriteria decision-making methods. It will not however seek to obtain only one information, the optimal solution, who is an operation too reducing and far away from reality.

3.3 Process of study

The study process of a multicriteria decision analysis method proceed in five successive and independent steps : (Schärlig A., 1985)

- **Inventory** of the **alternatives**: the list of the alternatives to assess isn't exhaustive and final. It can evolve throughout the study (suppression or addition of alternatives)
- **List** of the **criterias** to take in consideration
- **Weighting** of the **criterias** : a criteria can be more significant that another. This relative importance is expressed by a number called weight, term which has more one picturesque smell that physical
- **Judgment** of the **actions** : every alternative is judged for each criteria. The criterias are not always directly measurable and in this case an indicator is associated at the criteria. The whole of the evaluations is presented in a two-dimensional board, called "*table of the performances*", in which each line represents an alternative and each column a criteria
- **Aggregation** of the **judgments** : at the end, the judgments are aggregated to define which alternative enjoys the best evaluations overall

The first four stages are practically common to all the multicriteria decision analysis methods. On the other hand, the fifth stage, which is a technical stage, is specific to each method. (Molines N., 1997)

3.4 Typology of multicriteria decision analysis methods

3 types of aggregation of the judgments are to be distinguished in the multicriteria decision analysis methods : complete aggregation, partial aggregation or iterative local aggregation.

3.4.1 Complete aggregation

These methods are developed by the "*North-American school*". They consist in allotting a function of utility to each criteria. Then, for each alternative, a mathematical function incorporates the various specific partial utilities to each criterion. One thus obtains a synthetic answer which is single (single criteria of synthesis). These methods authorize the compensation of the judgments, which are transitive, between the various criteria. Another defect comes owing to the fact that the determination of the function of utility is sometimes very complex.

3.4.2 Partial aggregation

These methods are developed by the "*European school*". The partial aggregation consists in first to compare the alternatives two by two, criteria by criteria. This makes it possible to establish the relations of outclassing which exist between them (strong or weak preference, indifference or incomparableness). Then, a synthesis of these relations between the various alternatives is made, in form generally of a graph of the relations, in order to carry out a sorting, to carry out an arrangement or to make leave the best alternative the batch.

These methods admit the postulates of the incomparability and of the intransitivity. They authorize a greater richness in the relations between the alternatives. The results are sometimes not very clear because they are based on an analysis of the graph of the relations which is difficult and complex. The fact "*of weakening*" on the clearness of the result can be perturbing for the decision maker who want to receive a clear and final answer. (Schärlig A., 1985)

Three type of partial aggregation methods are used :

- α **problematic** ⇨ choice (selection procedure) : Electre I, Electre IS
- β **problematic** ⇨ sort (affect procedure) : Electre Tri
- γ **problematic** ⇨ classification (ranking procedure) : Electre II, Electre III, Electre IV

Figure 5 Choice problematic α

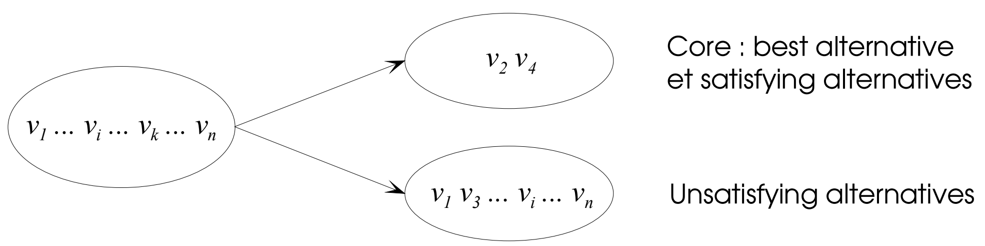


Figure 6 Sorting problematic β

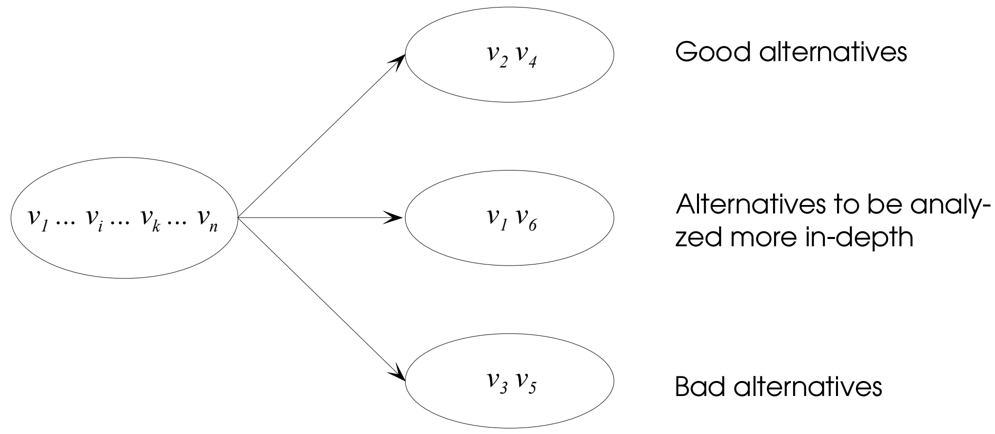
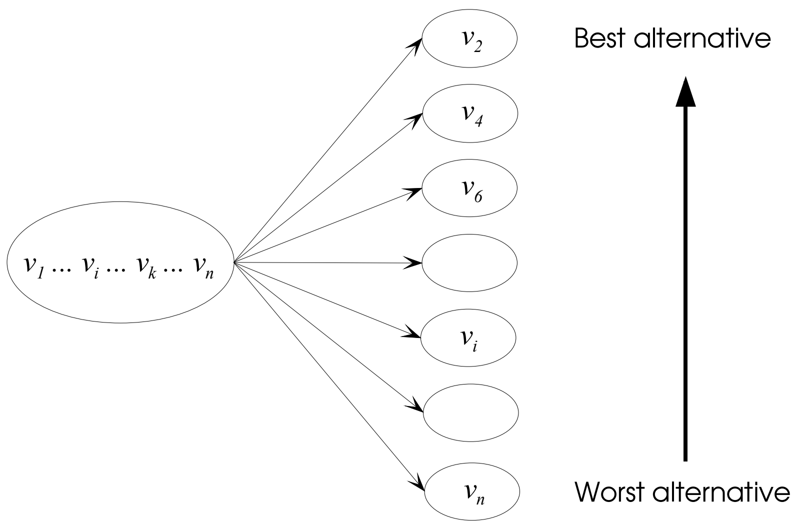


Figure 7 Classification problematic γ



3.4.3 Iterative local aggregation

The two preceding methods can prove heavy to use when we have a great number of alternatives or a quasi infinite number of alternatives. In this case, one makes a local exploration by fixing in first a starting solution corresponding to an initial alternative which is as good as possible. Then, one looks in the alternatives close to the initial alternative if there exists an alternative which is better to make a new analysis. One proceeds thus by iterations.

3.5 Terminology

3.5.1 Alternatives

There are the elements which make the object of the multicriteria study. The whole of alternatives V [1] understands n alternatives (v_1 to v_n). When we speak about two particular alternatives of this whole, the terms of alternatives v_i and v_k are used.

3.5.2 Criteria

A criteria is a qualitative or quantitative expression permit to judge the consequence or the performance of an alternative for an objective or a constraint of the considered project. The whole of the criteria C understands m criterias (c_1 to c_m). The performance of the alternative v_i for a criteria c_j is defined by the term $g_j(v_i)$.

A criteria must be useful and reliable. It is associated an ordinal or cardinal scale with a direction preferably. For the road projects, the criteria can be numerous and it is necessary to gather them in families of criteria in order to in particular facilitate the appreciation of their relative importance by the decision maker.

The choice of the criteria must be coherent, which is checked if 3 conditions are observed :

- Exhaustively
- Coherence enters the local preferences of each criteria and the total preference
- Independence : there should not be redundancy between the criteria. Their number must be such as the suppression of one of the criteria does not make it possible more to satisfy the two preceding conditions (Maystre L. Y., Pictet J. et al., 1994)

The criteria are not always directly measurable. One uses sometimes an **indicator** which is a measurable variable being used to quantify a situation or the tendency of this criteria.

[1] In this paper, one take the abbreviation from the French term of alternatives (V for Variantes)

3.5.3 Relation of outclassing

One alternative v_i is outclassing an alternative v_k, noted $v_i\boldsymbol{S}v_k$, if she is at least as good as v_k comparatively at one majority of criterias, without to be too much bad as v_k comparatively at the other criterias. (Schärlig A., 1985) It is thus necessary to check criteria after criteria the whole ordered pairs, or couples, of possible alternatives. The partial aggregation methods check the degree of credibility of this assumption of outclassing $v_i\boldsymbol{S}v_k$ while basing itself on a concept of concordance (*Is there sufficiently arguments to admit this assumption ?*) and a concept of discordance (*Is there a significant reason to refuse this assumption ?*).

3.5.4 Relations between the alternatives

The partial aggregation methods compare the alternatives two to two for each criteria or overall for the whole of the criteria. This comparison for a criteria c_j between the performances of two alternatives v_i and v_k is based on the difference $g_j(v_i)$ - $g_j(v_k)$, which is noted $\delta_j(v_i, v_k)$. While proceeding to a comparison between two alternatives v_i and v_k for the criteria c_j, it exists three relative situations which are given from the difference between the both performances :

- $\delta_j(v_i, v_k) > 0$ the alternative v_i is preferred to the alternative v_k for the criteria c_j, noted $v_i\boldsymbol{P}v_k$
- $\delta_j(v_i, v_k) = 0$ the alternative v_i is equivalent to the alternative v_k for the criteria c_j, noted $v_i\boldsymbol{I}v_k$
- $\delta_j(v_i, v_k) < 0$ the alternative v_k is preferred to the alternative v_i for the criteria c_j, noted $v_k\boldsymbol{P}v_i$

For a criteria c_j, one determine two indices qualifying the relations between v_i and v_k :

- a **concordance indice**, which is qualifying the degree of the credibility that the relation "v_i *is outclassing* v_k ». This index is designed by the term $c_j(v_i, v_k)$
- a **discordance indice**, which is qualifying for the criterias where $v_i\boldsymbol{P}v_k$ isn't verify verified, if the no-respect of the hypothesis of outclassing $v_i\boldsymbol{S}v_k$ isn't to important. This index is designed by the term $d_j(v_i, v_k)$

While proceeding to a total comparison on the whole C of the criteria, one seeks to check the agreement of the hypothesis of outclassing « v_i *is outclassing* v_k», noted $v_i\boldsymbol{S}v_k$.

Four relative's situations are possible :

- $v_i\boldsymbol{S}v_k$ the alternative v_i is outclassing the alternative v_k : there are sufficient criteria checking the outclassing hypothesis $v_i\boldsymbol{S}v_k$
- $v_i\boldsymbol{I}v_k$ the alternatives v_i and v_k are indifferent : one cannot decide between them because there is as much arguments in favor of $v_i\boldsymbol{S}v_k$ than in favor of $v_k\boldsymbol{S}v_i$
- $v_k\boldsymbol{S}v_i$ the alternative v_k is outclassing the alternative v_i : there are sufficient criteria checking the outclassing hypothesis $v_k\boldsymbol{S}v_i$
- $v_i\boldsymbol{R}v_k$ the alternatives v_i and v_k are incomparable : the two hypothesis of outclassing $v_i\boldsymbol{S}v_k$ and $v_k\boldsymbol{S}v_i$ are not checked

All these relations are intransitive: $v_i\boldsymbol{S}v_k$ and $v_k\boldsymbol{S}v_i$ are totally compatible.

The global relations analyzed for all the criterias between the two alternatives v_i and v_k are qualified by two synthetic indices :

- a **global concordance indice**, determined with the concordance indcies $c_j(v_i, v_k)$ of each criteria. Designed C_{ik}, it qualify the degree of credibility of the relation of outclassing $v_i\boldsymbol{S}v_k$
- a **global disconcordance indice**, désigned D_{ik}. It is determined with the discordance indices $d_j(v_i, v_k)$ and it qualify the no-respect of the outclassing hypothesis $v_i\boldsymbol{S}v_k$

These two indices can be compared with a political system where for that one object is accepted in voting, it is necessary to obtain the majority of the voters (global concordance indice) and that the minority which is opposed to it is not seriously opposed (global disconcordance indice). (Schärlig A., 1985)

3.5.5 Use of the fuzzy criteria

The **fuzzy criteria** consist of a progressive transition between the indifference and the preference. Two additional thresholds, related to a c_j criteria given, are introduced :

- Indifference threshold $\boldsymbol{Si_j}$: there is the smallest difference which is significant. Below this threshold, it's impossible to decide between the two alternatives
- Preference threshold $\boldsymbol{Sp_j}$: there is the threshold from which the difference between the two alternatives is perceptible and makes prefer one to the other

A veto threshold $\boldsymbol{Sv_j}$ specific for a criteria c_j can be defined.[2] It means that if at least for one criteria c_j, it exists one $\delta_j(v_i, v_k) < 0$ like that $\delta_j(v_i, v_k) + Sv_j \leq 0$, then the hypothesis $v_i\boldsymbol{S}v_k$ isn't verified (the no-respect of the outclassing hypothesis is too important). This threshold veto is a limit at the compensation between the criterias.

One has : $\boldsymbol{Sv_j} \geq \boldsymbol{Sp_j} \geq \boldsymbol{Si_j}$. It's possible to have $Sp_j = Si_j$

The values of the specific concordance indice $c_j(v_i, v_k)$ are continued between 0 and 1 if $\delta_j(v_i, v_k)$ is between Si_j and Sp_j. It means that the answer at the outclassing hypothesis is more or less respected (fuzzy preference). In this case, one speaks about **light preference** noted $v_i\boldsymbol{Q}v_k$. In this case, the relation $v_i\boldsymbol{P}v_k$ is designed by the term of **strict preference**.

One can identify five relatives situations between the alternatives, presented with the values of the specific concordance indices $c_j(v_i, v_k)$ et $c_j(v_k, v_i)$:

- $\delta j(vi, vk) \geq Spj$ — $viPvk$ — $cj(vi, vk) = 1$ — $cj(vk, vi) = 0$
- $Spj \geq \delta j(vi, vk) \geq Sij$ — $viQvk$ — $cj(vi, vk) = 1$ — $cj(vk, vi) = 0$ *to* 1
- $Sij \geq \delta j(vi, vk) \geq - Sij$ — $viIvk$ — $cj(vi, vk) = 1$ — $cj(vk, vi) = 1$
- $- Sij \geq \delta j(vi, vk) \geq - Spj$ — $vkQvi$ — $cj(vi, vk) = 1$ *to* 0 — $cj(vk, vi) = 1$
- $- Spj \geq \delta j(vi, vk)$ — $vkPvi$ — $cj(vi, vk) = 0$ — $cj(vk, vi) = 1$

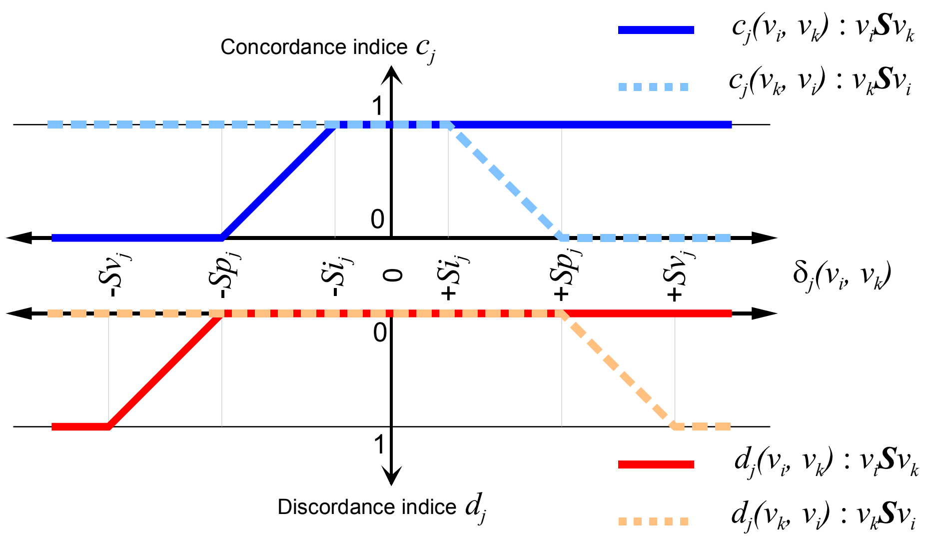
The fuzzy discordance is the follow, presented with the values of the discordance indices $d_j(v_i, v_k)$ et $d_j(v_k, v_i)$:

- $\delta j(vi, vk) \geq Svj$ — $dj(vi, vk) = 0$ — $dj(vk, vi) = 1$
- $Svj \geq \delta j(vi, vk) \geq Sij$ — $dj(vi, vk) = 0$ — $dj(vk, vi) = 1$ *to* 0
- $Sij \geq \delta j(vi, vk) \geq - Sij$ — $dj(vi, vk) = 0$ — $dj(vk, vi) = 0$
- $- Sij \geq \delta j(vi, vk) \geq - Svj$ — $dj(vi, vk) = 0$ *to* 1 — $dj(vk, vi) = 0$
- $- Svj \geq \delta j(vi, vk)$ — $dj(vi, vk) = 1$ — $dj(vk, vi) = 0$

[2] One will see by after the interst to don't systematically using this veto within the framework of road projects, because it can be sometimes too restrictive

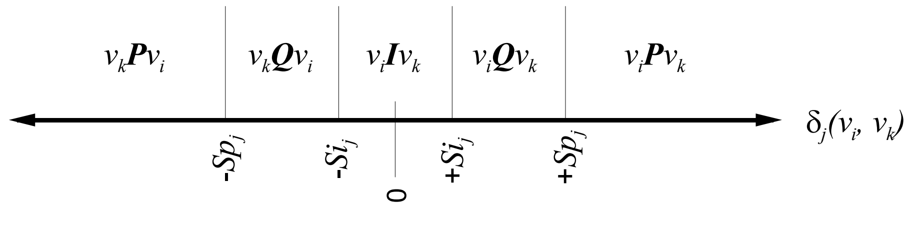
This figure presents the differents situations for the verification of the both hypothesis of out-classing between two alternatives v_i and v_k.

Figure 8 Values of the specifics indices of concordance and discordance for a fuzzy criteria



One can observe five relatives situations between two alternatives v_i et v_k.

Figure 9 Relatives relations between two alternatives v_i and v_k for a fuzzy criteria



3.5.6 Weight

A weight P_j qualify the relative importance of a criteria c_j comparatively the others criterias.

3.6 A multicriteria decision analysis methods adapted to the road project

3.6.1 Proposition of the author

On the basis of reflexion carried out in his study, the author proposes to use the multicriteria decision analysis method Electre III[3] in concertative methodology of the road project.

The shade brought by this method (fuzzy criteria, partial aggregation) make it possible to better approach the complexity of the environment of a road infrastructure project than an complete aggregation method like an method of utility or a benefice-cost method. The use of this method requires however the use of a software such ELECTRE III-IV. With this tool, which is of a relatively modest size and cost, Electre III becomes thus a method easy to use by the road designer and is consequently easily considerate in the study process.

A restriction is to be brought for the use of Electre III about the veto thresholds for certain criteria. Indeed, if one considers in the analyze of the alternatives the alternative "*current state*", within the framework of a criteria concerning the cost of realization, the application of a veto threshold can mean that all the alternatives cannot outclass the current state, the no-realization of a road infrastructure being by definition definitely less expensive than its realization. These thresholds of veto are thus to use with caution.

3.6.2 Performances of the alternatives

The determination of the performances of the alternatives for a given criteria is based on an **indicator** which is a measurable variable being used to quantify a situation or the tendency of the criteria.

[3] This paper doesn't present the principles of Electre III method. The lector can find in annexe (Appendix A) an extract of this explanation like was done by the author in his thesis (the appendix is write in French)

If several indicators are used to qualify the criteria, one proceeds to a technical weighting between these partial indicators for have a single aggregate indicator for the criteria. This technical weighting is a complete aggregation carried out between these various partial indicators.

For r partial indicators IP_p relating to the criteria c_j, one can qualify the state of a alternative v_i for the criteria c_j with an aggregate indicator $I_j(v_i)$ while proceeding in the following way :

$$\boldsymbol{I}_j(v_i) = \sum_{p=1}^{p=r} IP_p(v_i) \cdot PT_p$$

One has :

- $I_j(v_i)$ aggregate indicator qualifying the state of the criteria c_j for the alternative v_i
- $IP_p(v_i)$ partial indicator qualifying for the domain p the state of the criteria c_j for the alternative v_i
- PT_p technical weighting for the partial indicator $IP_p(v_i)$

The sum of the technical weighting PT_p for a criteria c_j make 100 % :

$$\sum_{p=1}^{p=r} PT_p = 100\ \%$$

The technical weighting of the different partial indicators is realized only by the designer or the study group. It must however be clearly defined and supported in the report.

3.6.3 Family of criteria

As the road projects necessitate many criterias, due to the multiples domains affected by a road, it are necessary to carry out an aggregation of the criteria in **family of criteria**. The weighting is made thus in two levels on a number of criteria which ideally should not exceed seven per category. However, one does not proceed to two levels of use of a multicriteria decision analysis method but only at one by using a cross weighting to each criteria. This cross weighting is obtained by multiplying the weight of the criteria within its family by the weight of her family.

Thus, the whole of the criteria C understands m criterias divided into f families of criteria F_i. The weight P_j of a criteria is determined thus in the following way :

$$\boldsymbol{P_j} = P_{j,i} \cdot P_i$$

One has :

- P_j weight of the criteria c_j relative with the other criteria of the whole C
- $P_{j,i}$ weight of the criteria c_j relative with the other criteria of his family F_i
- P_i weight of the family of criteria F_i of the criteria c_j r relative with the other families of criterias

One can see that for t criterias c_j [4] of a family of criteria F_i, one has :

$$\sum_{j=1}^{j=t} P_{j,i} = 100\ \%$$

In the same way, the whole weights P_i of f families of criterias make :

$$\sum_{i=1}^{i=f} P_i = 100\ \%$$

3.6.4 WEIGHTING

The weighting must be organized with the most independence for the actors of the project. Some rules are nevertheless necessary for the weighting of the objectives[5] :

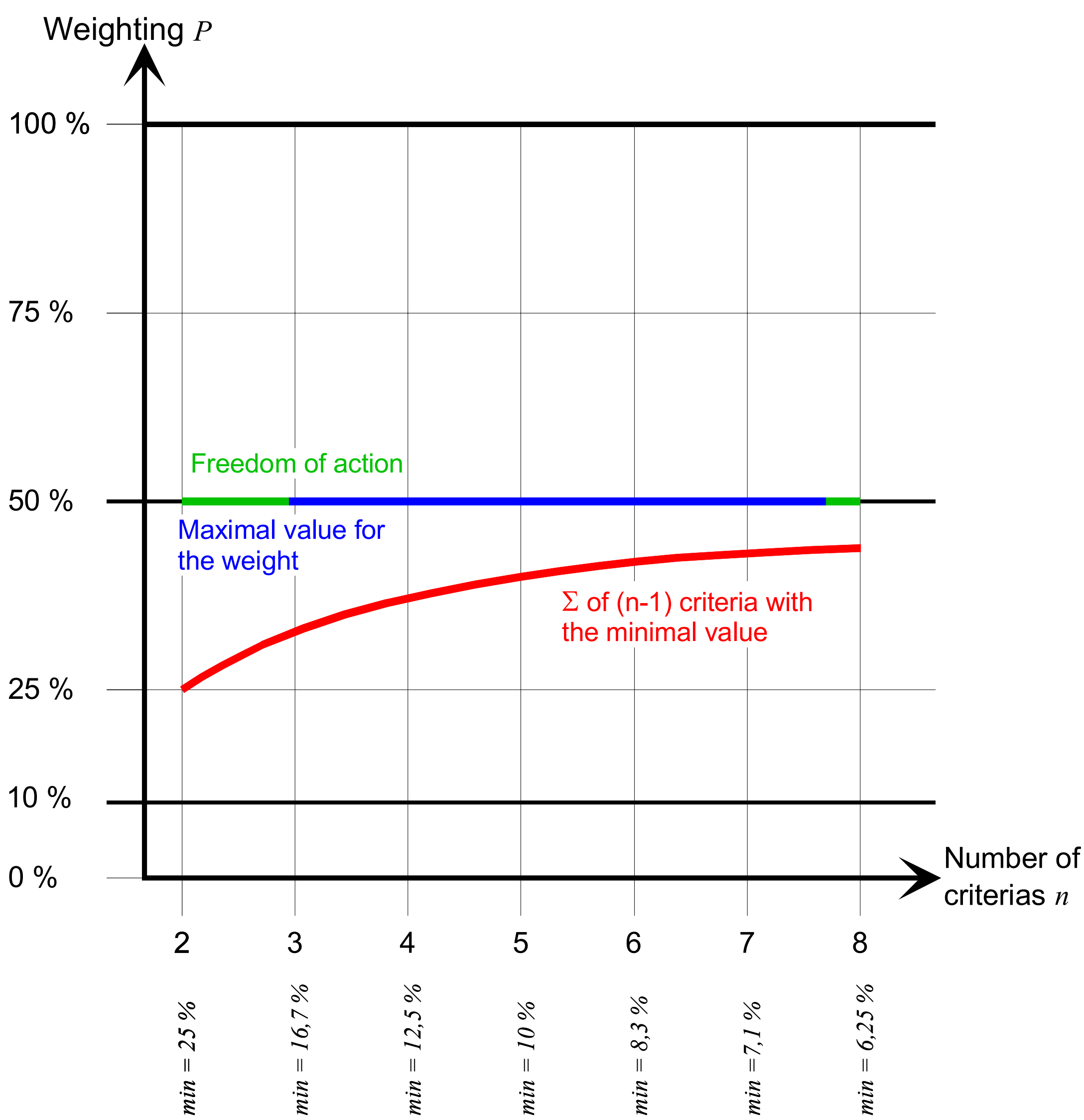
- the weight are attributed in %
- the sum of various weightings within a category is worth 100 %

[4] One can say that $t << j$ and that $t \leq 7$ and $f \leq 7$

[5] An objective is a criteria or a family of criteria

- in the presence of more than two objectives in a given category, the maximum weight for an objective is fixed at 50 %
- the minimal weight attributed to an objective is fixed thus : $\boldsymbol{P_{min}} = \frac{\sum P_i}{2 \cdot n} = \frac{100}{2 \cdot n}$
  - P_{min} → minimal weight attributed to an objective
  - $\sum P_i = 100\%$ → sum of the weighting of the different objectives in a category
  - n → number of objectives in a category

Figure 10 Weighting if one considerates the number of objectives for the minimal weighting



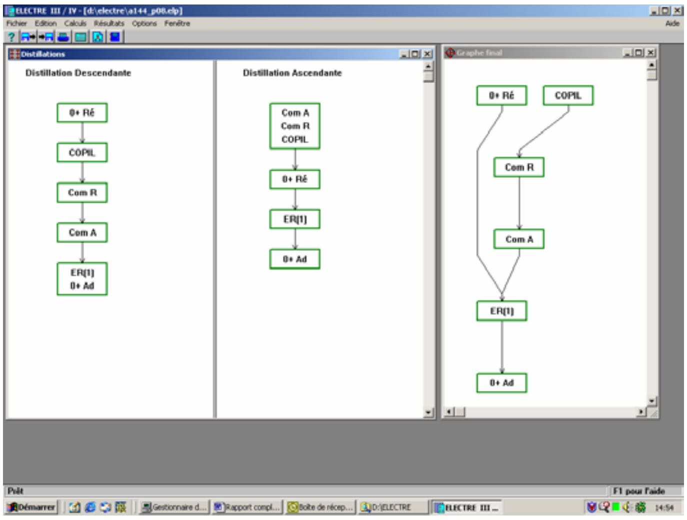
With these principles, the freedom of action at disposal of the designer remains always fixed at 50 %. One can however postulate that the number of objectives within a category should not in general be higher than seven. This facilitates the attribution of the weighting on behalf of the decision maker. Indeed, beyond this value, the distinctions between the criteria (their relative importance) is going thin and contribute to make weighting homogeneous (obtain of the same criteria weight or with weak relative difference).

The weighting is realized by the study group.

3.6.5 Presentation of the results

The ELECTRE III-IV software developed by the LAMSADE proposes the results of the two distillations like we can see in the la figure. (LAMSADE, 1994)

Figure 11 Print screen of the results of the distillations and final graph with ELECTRE III-IV

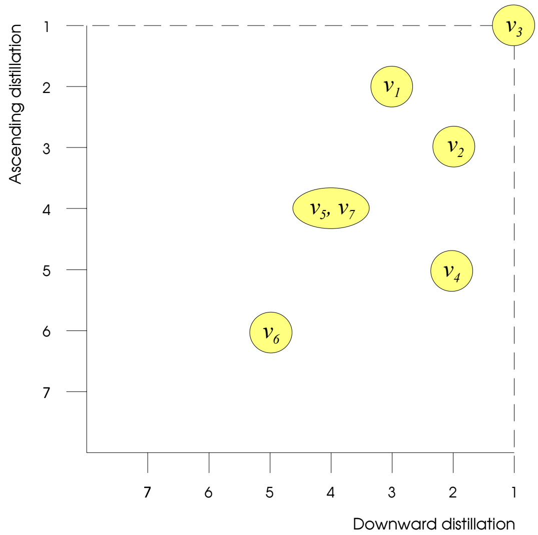


This way of proceeding can complicate the analyze, especially one is in the presence of alternatives presenting of great variations of row between the two distillations. If the number of alternatives is significant, the analyze is also more difficult to establish. Simos and Maystre propose to have the results of the two distillations carried out in Electra III (row of the alternatives) in the form of a graphic very simple to realize and to understand. (Maystre L Y., Pictet J and Al, 1994) The horizontal is consisted with the ranks in opposite direction of downward distillation. The vertical is consisted with the ranks in opposite direction of ascending distillation.[6]

There is an example of this type of graph :

Figure 12 Example of representation of the results obtained with Electre III adapted from Simos and Maystre

Ascending distillation		Downward distillation	
Variantes	Rang	Variantes	Rang
v_3	1	v_3	1
v_2 v_4	2	v_1	2
v_1	3	v_2	3
v_5 v_7	4	v_5 v_7	4
v_6	5	v_4	5
		v_6	6



This mode of representation of the results is based on the hypothesis that the variations of ranks are regarded as equal, which can be a little formal because nothing justifies the reality of this postulate. Its interest also lies in the fact that the final or median classification, which involves a loss of information, isn't to be realized.

The best alternatives are close to the left higher corner. The alternative located along the diagonal connecting the corners left inferior and higher right can make the object of a stable judgement because their row is constant in two distillations. The alternatives being towards the corners left superior and lower right are incomparable, more "*wandering*". (Schärlig A., 1996)

6 The rank is defined as being the class in which the alternative is placed. Two equal alternatives are of the same rank.

4. Actualized methodology of the road project

4.1 A new methodology : major result of the research

The research leads to the proposal a new methodology for the study of a road infrastructure project which is iterative and which takes account of the new societal paradigms like the sustainability or the public participation. This methodology process will be indicated by the term of "*actualized methodology of the road project*".

The attention made by the author with the development of the study process of road project isn't without reason. Veuve underlines the importance well process of the project when he writes that "*when the problem arises in term of value, the process by which the project is defined is as significant as the him project even*". (Veuve L., 1994)

The purpose of this methodology is to integrate in its heart all the actors affected by the road project. She consists in adopting a dynamic attitude of prevention of the problems, by quickly incorporating these actors in the study process so as to carry out a sustainable project and accepted by all the parts. This is an attitude which is preferable with a defensive and static step trying to attenuate the impacts related to any road infrastructure. It's like an extent of "*to prevent rather than to cure*". The actualized methodology of the road project is based on a process which takes again the circular structure of the road life cycle.

4.2 Study process

This process is described on the next page. There is in five major steps with some majors aspects like :

- Strictly separation between weighing of criteria and evaluation of indicators. The first is made by the decision-makers before the study of alternatives, the second is made after this study by the study group
- Iterative process (see figure 14)
- Total integration of the actors in the process

Figure 13 Study process of the road project

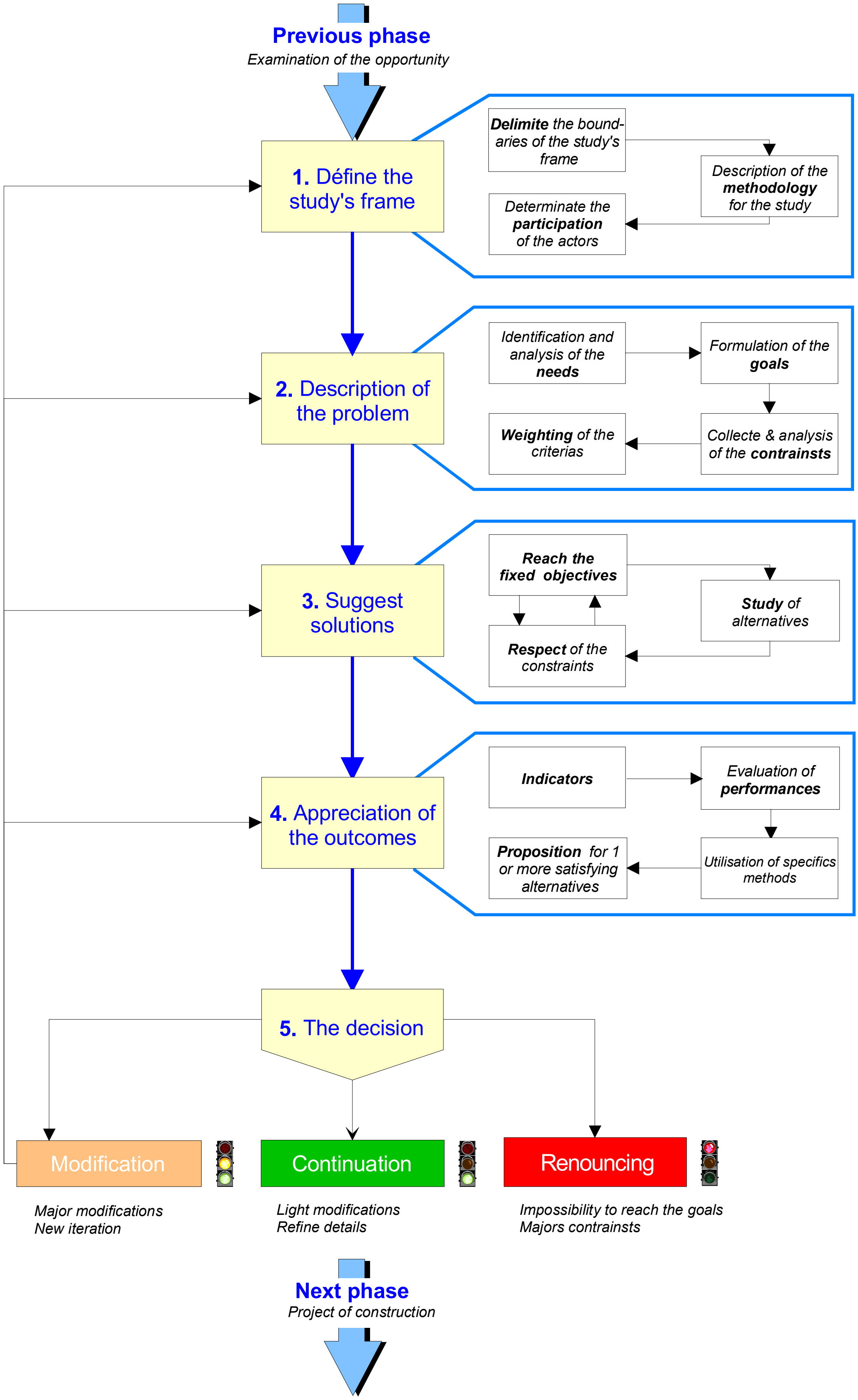
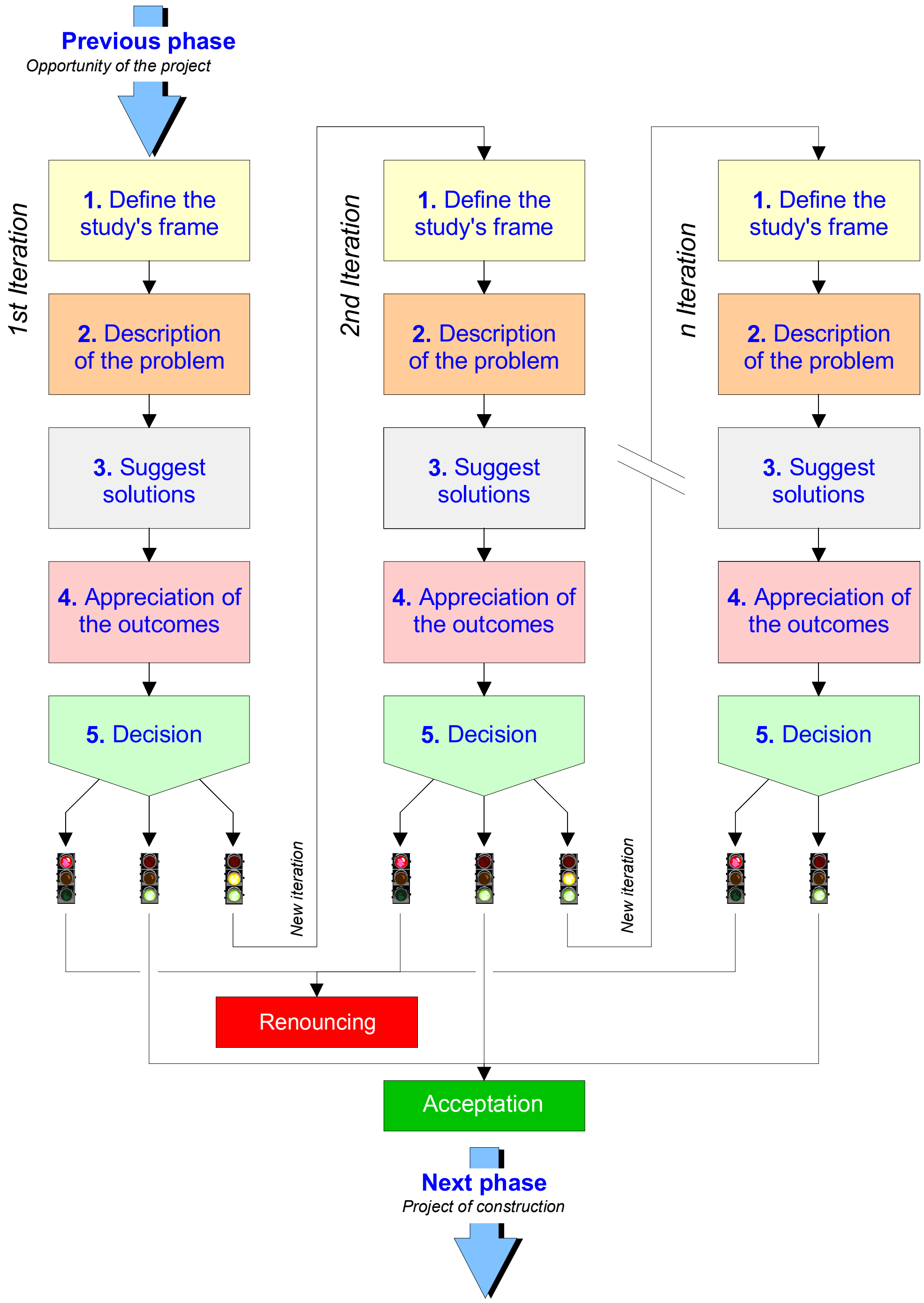

Previous phase
Examination of the opportunity
1. Défine the study's frame
Delimite the boundaries of the study's frame
Description of the methodology for the study
Determinate the participation of the actors
2. Description of the problem
Identification and analysis of the needs
Formulation of the goals
Weighting of the criterias
Collecte & analysis of the contrainsts
3. Suggest solutions
Reach the fixed objectives
Study of alternatives
Respect of the constraints
4. Appreciation of the outcomes
Indicators
Evaluation of performances
Proposition for 1 or more satisfying alternatives
Utilisation of specifics methods
5. The decision
Modification
Continuation
Renouncing
Major modifications
New iteration
Light modifications
Refine details
Impossibility to reach the goals
Majors contrainsts
Next phase
Project of construction

Figure 14 An iterative process

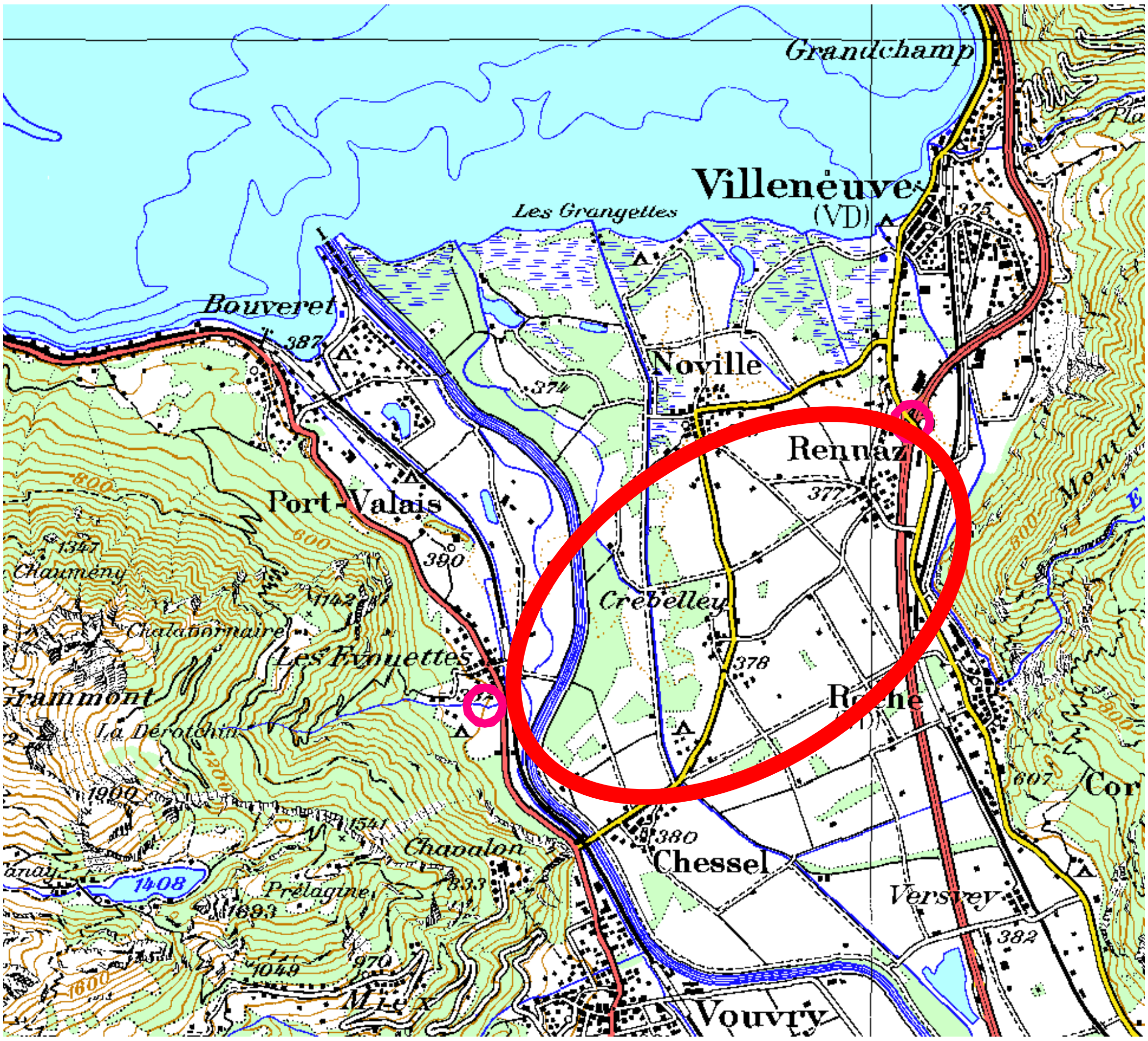


5. Study case : the road H144 Villeneuve – Le Bouveret

5.1 Context

The swiss main road H 144 is located in Chablais which is on the cantons of Vaud and of Wallis. This road link crosses the plain of the Rhone East to West, this in the south of the natural reserve of Grangettes (Ramsar convention area → International importance), in order to connect the national highway A9 to the acesse road at the border post of Saint-Gingolph. (Infraconsult, 2000)

Figure 15 Study domain of the H 144



5.2 Problematic

The actual road between Villeneuve and le Bouveret has a very insuffisant standard for a modern road infrastructure :

- insecurity and the harmful effects for the population of the villages of the plain
- crossing of the localities, sinuosities of the layout and geometric profile of the road fulfill any more the requirements of the motorized traffic
- the bridge on the Rhone at the Posrtes du Scex is a bottleneck for the motorized traffic and obliges the heavy lorries to carry out a significant turning

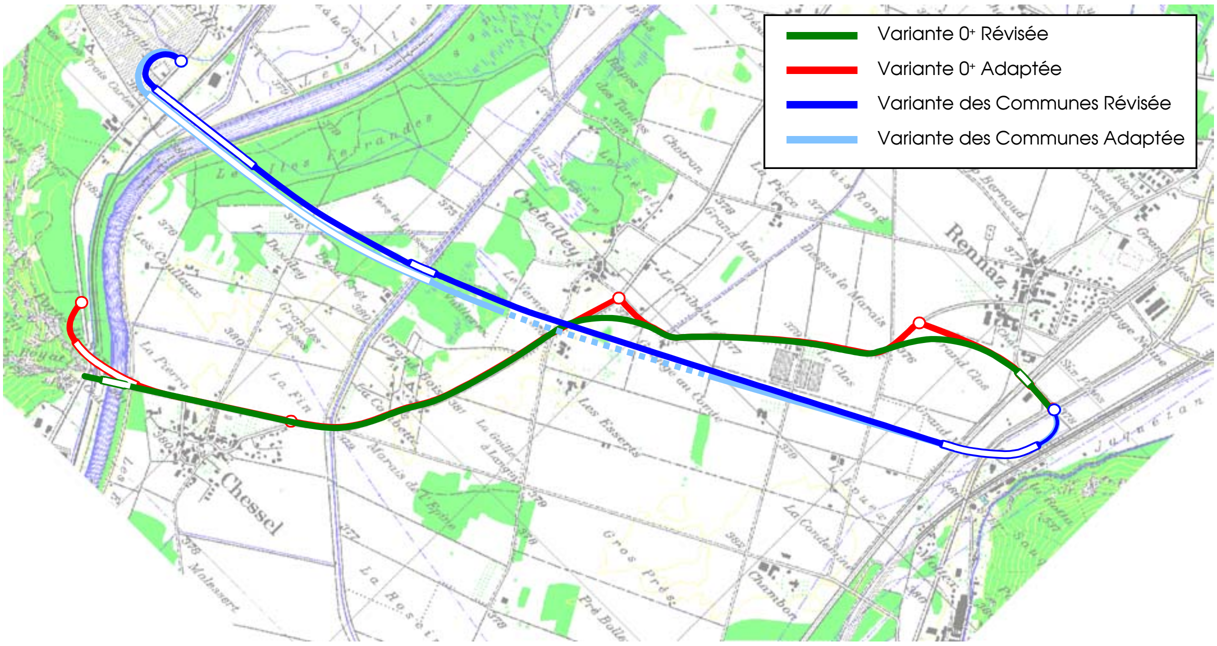
For all these reasons, the realization of a road link of quality between Villeneuve and Bouveret is necessary.

5.3 A new project : "Comparaison de variantes 1999"

Since nearly forty years, of many projects studied without a solution is obtained. The reltaiosn between the diferentes actors was unpleasant. Because of the impossibility to obtain a consensual choice, the OFROU proposed in November 1998 to form a working group in order to carry out a comparative multicriteria analysis. The four alternatives wich were kept for the "*Comparaison de variantes 1999*" were :

- Variante 0^+ Revised → studied in 1998
- Variante 0^+ Adapted → first proposition, simplificated in beginning 1999
- Variante des Communes Revised → studied in 1997
- Variante des Communes Adapted → first proposition of 1992

Figure 16 Alternatives studied in the "*Comparaison de variantes 1999*"



The study was finished after 10 months in September 1999 and the solution obtained at the end of the "*Comparaison de variantes 1999*" was the alternative named "*Solution COPIL*". There is a second adaptation of the alternative "*Variantes des Communes Revised*". [7]

The multicriteria decision analysis method used in the "*Comparaison de variantes 1999*" was a complete aggregation method (analyze method of the utility values) with a separation of weighting, done by all the members of the Steering committee, and the evaluation, done by the Technical group.

For the author, it was a very interesting study case and a laboratory of ideas to obtain major informations for his thesis.

[7] For more informations to the process of the study, the interested lector can read the thesis of the author where the "*Comparaison de variantes 1999*" is describe in details

5.4 Actors

An organization comprising three working groups was installation for the "*Comparaison de variantes 1999*", namely: steering committee (Comité de Pilotage - COPIL), technical group and external agent. (DINF, 1998) and (Infraconsult, 2000) Put aside the external agent, the representative of the OFROU chairing the steering committee and a listener, the steering committee and the technical group are made up distinct of actors. This is with the fact that the objectives and the working methods of these two working groups are different and they also need to have a total independence between them.

There were 30 actors in the Steering committee which can distributed in 6 groups of actors :[8]

- Group 1 : Politicians of the Wallis – 5 actors
- Group 2 : Politicians of Vaud – 7 actors
- Group 3 : Economic associations – 4 actors
- Group 4 : Environmental associations – 5 actors
- Group 5 : Public administration – environment and territory – 5 actors
- Group 6 : Road administration – 4 actors

5.5 Analysis of weighting : profile of representative actor

The author has studied the weighting of each actors of the Steering committee. The principal result was that a profile of weighting for a "*middle actor*" or a "*representative actor*" has not sense in the case of the "*Comparaison de variantes 1999*". One must use some different representative profiles for the weighting.This exercise carried out on the "*Comparaison de variantes 1999*" can prove to be interesting for the road designer. Indeed, if this one studies a project of low scale or a very summary preliminary draft, it can at the time of the use of the multicriteria decision analysis method use some profiles of representative actors of the various points of sights. These representative profiles can for also be useful him to categorize the actors.

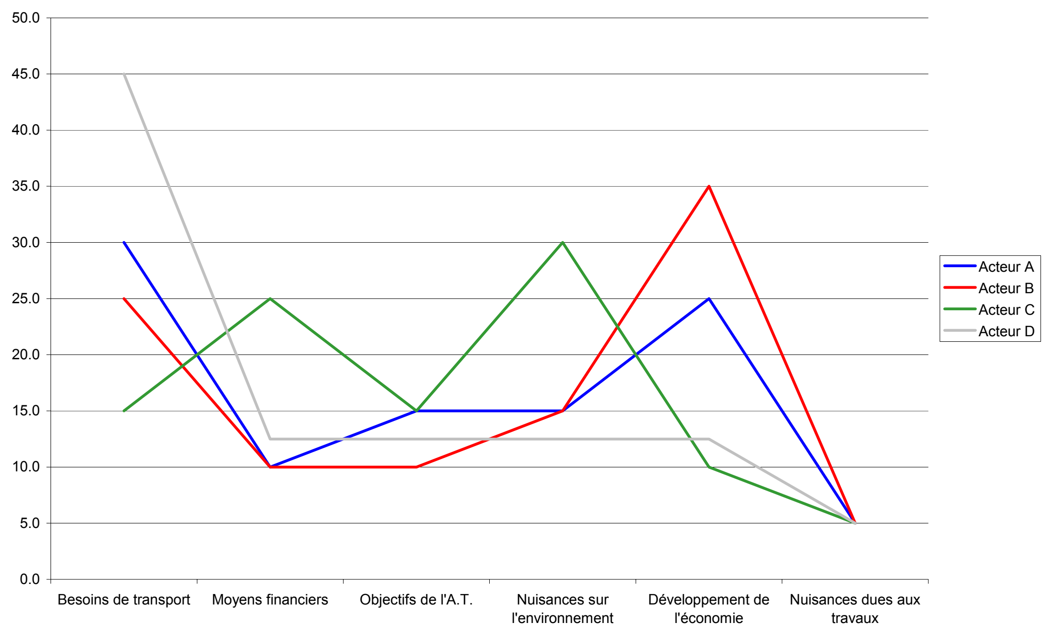
[8] This distribution in six groups of actors was carried out by the author to analyze the weighting. Each group represents more or less identical points of sights

Four profiles of representative actors was found.

Table 1 Weighting of the representative actors of the "*Comparaison de variantes 1999*"

Family criteria	***Acteur A*** *Transport + Economy*	***Acteur B*** *Economy + Transport*	***Acteur C*** *Environment + Finance*	***Acteur D*** *Transport*
Besoins de transport	30	25	15	45
Moyens financiers	10	10	25	12.5
Objectifs de l'A.T.	15	10	15	12.5
Nuisances sur l'environnement	15	15	30	12.5
Développement de l'économie	25	35	10	12.5
Nuisances dues aux travaux	5	5	5	5

Figure 17 Profiles of weighting for the four representative actors identified



5.6 Application of Electre III

The author has taken the results of the evaluation made by the Technical group and the weighting made by 28 actors of the Steering committee in an application of Electre III. The objective was to compare the results and the potential of this method with the method used in the "*Comparaison de variants 1999*".

The method Electre III was used 28 times, one time for each weighting of each actor. The ranks of the alternatives in the 56 ascending and downward distillations obtained are then analyzed. As the differences in performances are sometimes very significant between the alternatives, it was postulated that the method Electre III will be used in this application without threshold of veto, this for all the criterias.

These analyses haven't for goal to show if the "*Comparaison de variantes 1999*" has credible results or not. They constitute rather in an application of the methodological principles described before. Certain choices were arbitrarily carried out by the author in order to carry out this analysis which is not the claim to be "*the solution*" which would have being used for this study. As one will note it by after, the results are very similar to those obtained in practice

The software ELECTRE III-IV (LAMSADE, 1994) was used to do this application. It was used 28 times with the news evaluations and for six alternatives (ER(1) ; Communes adapted ; Communes revised ; 0+ adapted ; 0+ revised ; Solution COPIL).

The results of ascending and downward distillations obtained by the application of Electre III to the 28 profiles of weightings are presented at the following pages in the shape of graphs as defined by Simos and Maystre.

Figure 18 Results for the profile of weighting P1 to P12

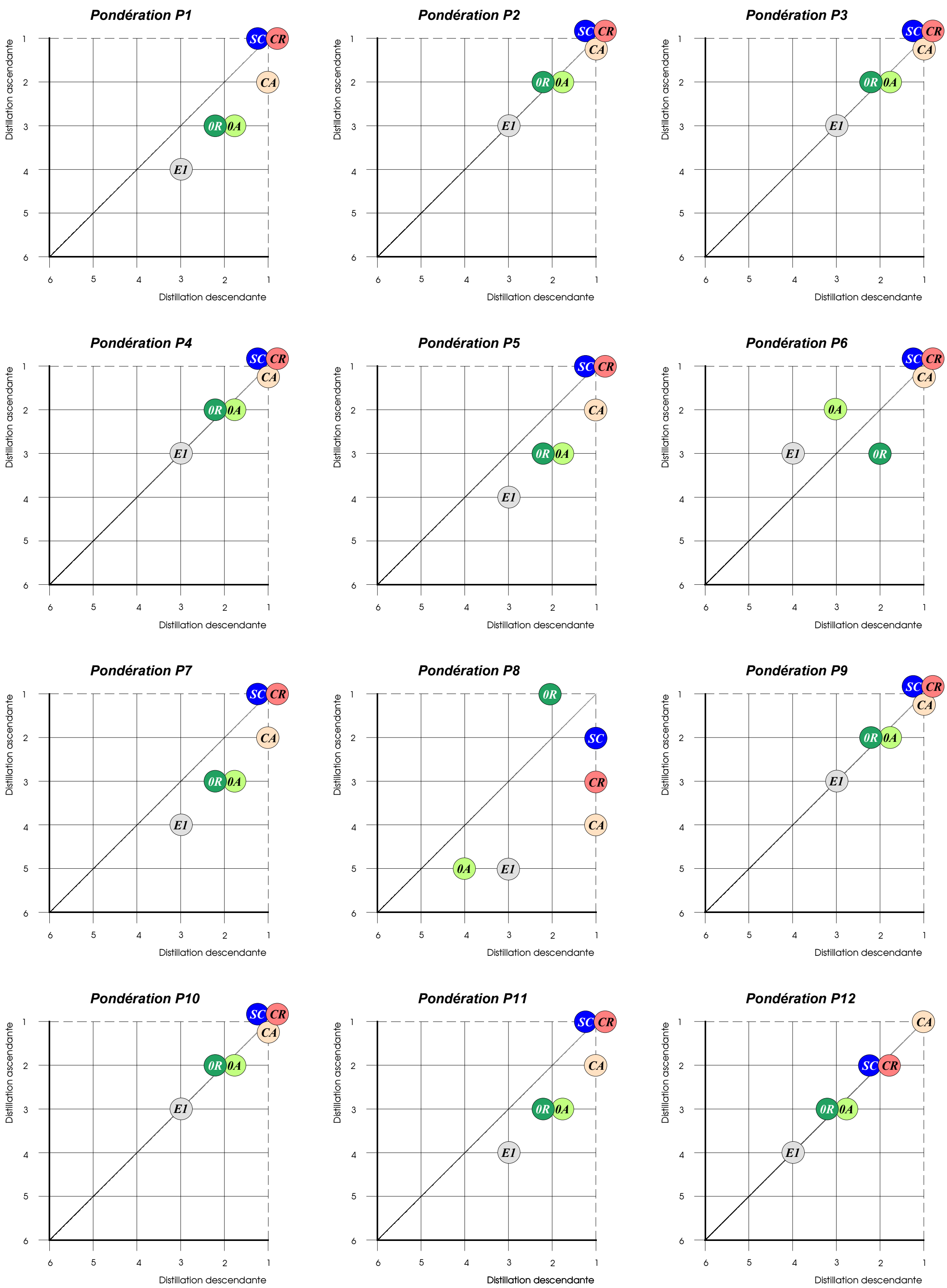


Figure 19 Results for the profile of weighting P13 to P24

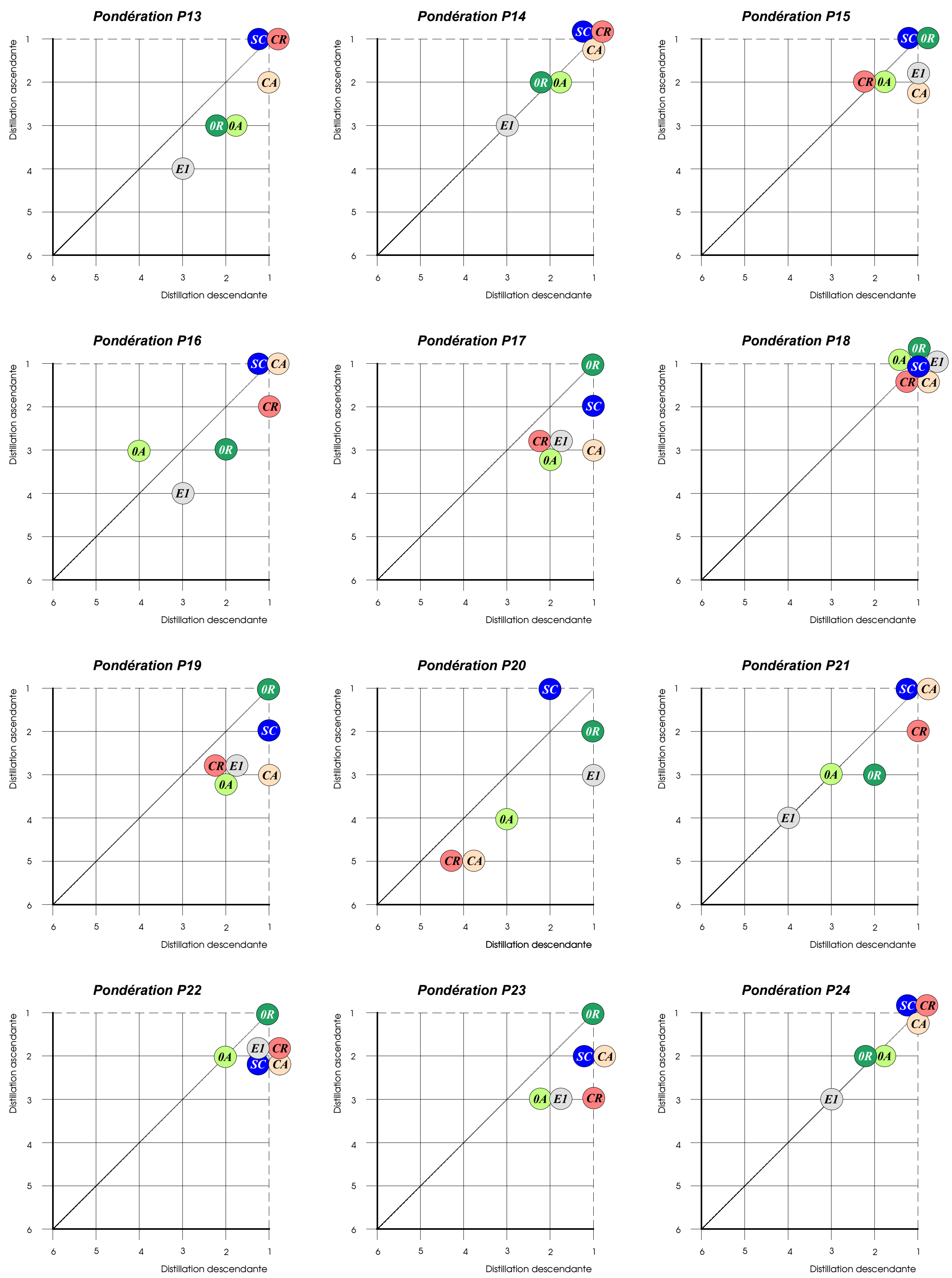
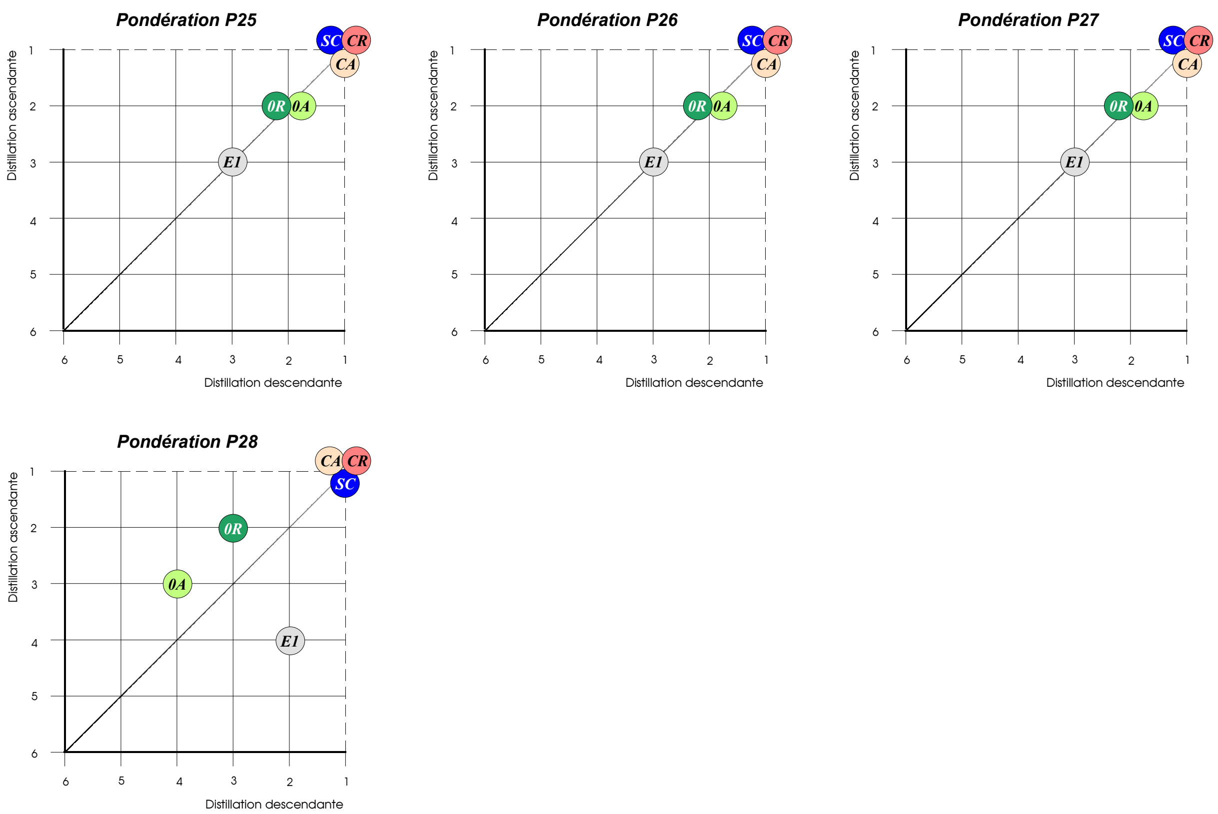


Figure 20 Results for the profile of weighting P25 to P28



The results of the 56 distillations made with the software ELECTRE III-IV are resumed in this table :[9]

Table 2 Ranks obtained with the use of Electre III for 28 profiles of weighting

Alternatives	***Rank of the alternative***[10]					
	1	2	3	4	5	6
ER (1)	5	6	***32***	12	1	
Communes adaptée	***43***	8	2	2	1	
Communes révisée	***41***	9	4	1	1	
0+ adaptée	2	***33***	16	4	1	
O+ révisée	14	***31***	11			
Solution COPIL	***48***	8				

The exam of this table shows that there is any distillation where the classification makes it possible completely to decide between the alternatives, the maximum row obtained being indeed a fifth rank for six analyzed alternatives. Moreover, all the alternatives appear in the forefront. There are thus particular profiles of weighting which make it possible to emphasize in the first rank each of the six analyzed alternatives. It is noticed however that these appearances in the first rank are unequally distributed :

- the Solution COPIL is 48 time at the first rank (85 %) and his worst rank is second
- the alternatives of the Communes appear 43 and 41 time at the first rank (75 %)
- the alternatives 0+ appear only 2 and 14 time at the first rank (25 %) and at 60 %, they are after the second rank
- the alternative ER(1) is 5 time at the first rank (10 %) and at 60 %, she is at the third rank

[9] The rank most frequently met by the alternative is highlighted in the table

[10] The rank of an alternative in a classification carried out by Electre III is a concept which should not be confused with the position in the classification

This table resume the comparison between the ranks of each alternative for the 56 distillations which was made :

Table 3 Comparaison between the ranks of each alternative for the 56 distillations

Alternatives	ER(1)	0+ adapted	O+ révised	Communes révised	Communes adapted
0+ adapted	0A > ER(1) : ***38*** 0A = ER(1) : 11 0A < ER(1) : 7				
O+ révised	0R > ER(1) : ***49*** 0R = ER(1) : 6 0R < ER(1) : 1	0R > 0A : 19 0R = 0A : ***36*** 0R < 0A : 1			
Communes révised	CR > ER(1) : ***43*** CR = ER(1) : 10 CR < ER(1) : 3	CR > 0A : ***44*** CR = 0A : 10 CR < 0A : 2	CR > 0R : ***41*** CR = 0R : 4 CR < 0R : 11		
Communes adapted	CA > ER(1) : ***46*** CA = ER(1) : 8 CA < ER(1) : 2	CA > 0A : ***48*** CA = 0A : 6 CA < 0A : 2	CA > 0R : ***41*** CA = 0R : 7 CA < 0R : 8	CA > CR : 8 CA = CR : ***42*** CA < CR : 6	
Solution COPIL	SC > ER(1) : ***50*** SC = ER(1) : 5 SC < ER(1) : 1	SC > 0A : 11 SC = 0A : ***43*** SC < 0A : 2	SC > 0R : ***42*** SC = 0R : - SC < 0R : 6	SC > CR : 11 SC = CR : ***43*** SC < CR : 2	SC > CA : 12 SC = CA : ***44*** SC < CA : -

By considering the preceding table, one can preferably analyze the relations existing between the various alternatives. Three possibilities then are distinguished :

- Strict preference, noted **P** : in this case, there is a good concordance of the hypothesis of outclassing of an alternative compared to another. This means that the number of times where, in the preceding table, this alternative is in a better row than the other is significant. There is the checking of the concordance. [11] Moreover, the number of times where it is in a worse row must be weak. There is the checking of the discordance [12]
- Light preference, noted **Q** : there is the case where the concordance of the hypothesis of outclassing of an alternative compared to another is less clear than in the preceding case. That is to say the equality between the two alternatives win, with however a majority of case where the hypothesis of outclassing is checked. The discordance must also remain weak. That is to say then the discordance is strong when the hypothesis of outclassing is checked.
- indifference, noted **I** : when we cannot separate the alternatives between them

[11] This number is admitted at 28 here (50 % of the classification realized)

[12] This number is admitted at 6 here (10 % of the classification realized)

In resume, one makes some successive checking as follows :

- N_1= number of times when $v_i > v_k$ 2 cases are possible
  - Case 1 : $N_1 \geq 28 \Rightarrow v_i\boldsymbol{P}v_k$ or $v_i\boldsymbol{Q}v_k$
  - Case 2 : $N_1 < 28 \Rightarrow v_i\boldsymbol{Q}v_k$ or $v_i\boldsymbol{I}v_k$
- N_3= number of times when $v_i < v_k$ 4 cases are possible
  - Case 3 : case 1 and $N_3 < 6 \Rightarrow v_i\boldsymbol{P}v_k$
  - Case 4 : case 1 and $N_3 \geq 6 \Rightarrow v_i\boldsymbol{Q}v_k$
  - Case 5 : case 2 and $N_3 < 6 \Rightarrow v_i\boldsymbol{Q}v_k$[13]
  - Case 6 : case 2 and $N_3 \geq 6 \Rightarrow v_i\boldsymbol{I}v_k$

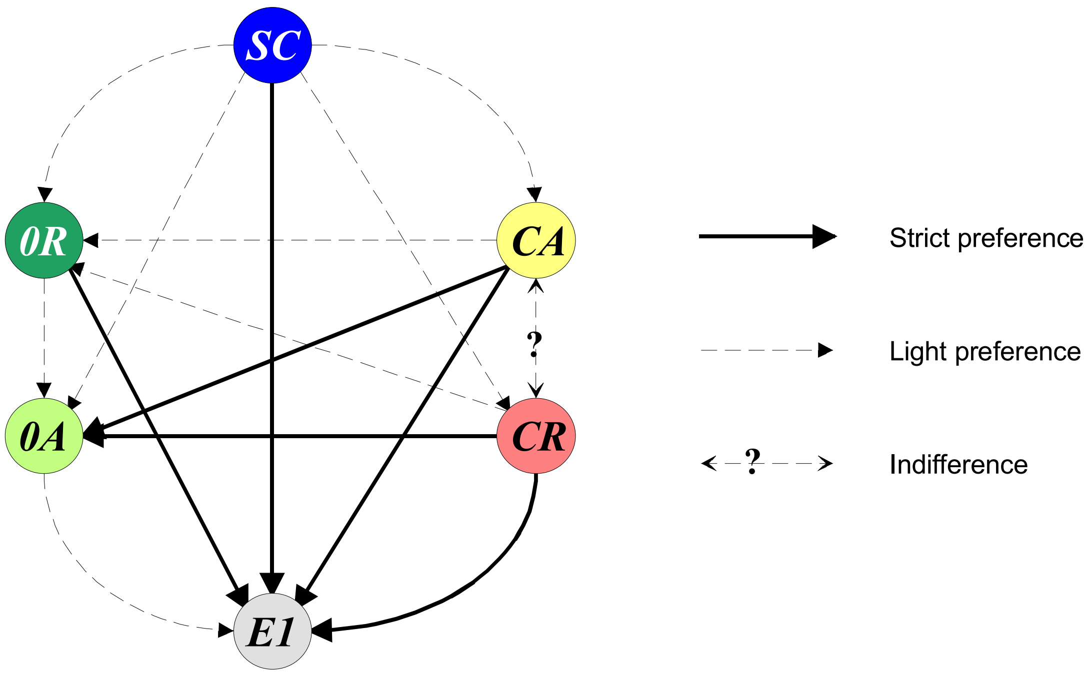
One obtains these relations between the six alternatives analyzed :

Table 4 Relations between the alternatives of the "*Comparaison de variantes 1999*"

Alternatives	ER(1)	0+ adapted	O+ révised	Communes révised	Communes adapted
0+ adapted	*Q*				
O+ révised	***P***	*Q*			
Communes révised	***P***	***P***	*Q*		
Communes adapted	***P***	***P***	*Q*	*I*	
Solution COPIL	***P***	*Q*	*Q*	*Q*	*Q*

[13] Here, N_2, wich is the number of times when $v_i = v_k$, has the minimal value 22 (56 – $N_{1,max}$ (case 2) – $N_{2,max}$ (case 5) = 56 – 27 – 7 = 22)

Figure 21 Relations of preference between the alternatives of the "*Comparaison de variantes 1999*"



One can raise the following facts :

- all the alternatives outclass the alternative ER(1),
- except the alternative ER(1), the alternative 0+ adapted is outclassed by all the other alternatives
- except the alternatives ER(1) and 0+ adapted, the alternative 0+ revised is outclassed by all the other alternatives

Thus the three last alternatives of the classification are 0+ revised which outclasses 0+ adapted, which it even outclasses ER(1).

The reflexions for the 3 solutions which dominate the alternatives 0+ and ER(1) are :

- one cannot distinguish the Communes alternative adapted from the Communes alternative revised
- the Solution COPIL isn't outclassed by another alternative
- the Solution COPIL has a weak preference compared to the Communes alternatives

The method Electre III thus used shows that the solution is among the trio made up of Solution COPIL and the alternatives of the Communes. With the center this group, the solution seems to emerge slightly for solution COPIL, but very slightly. The blur of the result brought by Electre III shows well that the differences between the notes obtained in the "*Comparaison de variantes 1999"* are very weak : the notes of the three alternatives vary between 0,55 and 0,69 for 28 weightings of the COPIL. By using a complete aggregation method, this blur was eliminated.

6. Conclusions

Using a multicriteria decision analysis method like Electre III which is based on a partial aggregation is very interesting for the road project. The advantages of this method for the comprehension of the phenomena, for taking in consideration the fuzzy of the appreciation are more important of her inconvenient of most difficulty of comprehension for the results and necessity to use of a software.

The integration of Electre III in the road project methodology is possible with some light adaptations:

- Strictly separation of the weighting and the evaluation :
  - in the time : weighting before generation of alternatives, evaluation after it
  - for the actors : decision-maker makes the weighting, study group makes the evaluation

  This double dichotomy is totally absent of many complete aggregation methods
- Adaptation of the notion of veto which can be to strictly for some criterias
- Crossed weighting due to the number of criterias in this type of projects. After a regroup regrouping in criterias family, the weight of each criteria in his family is multiplicated by the weight of the family
- Weighting establishing by each political actors and analyze of the results obtained like this. The use of only one weighting is not relevant
- Total independence for establishing the weighting and for the evaluation : the designer and the decision-maker are note confine in legal frame

The advantages of the use of this actualized methodology with Electre III are :

- The multicriteria is a consideration of multiplicity and complexity, like the three axes of the sustainability
- Participation of all actors is a consideration of the social aspect of the project : transparency, participation
- The liberty of action offer to the decision-maker and the designer assures a total adaptation to the road project context

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Appendix A: Explanation of the Electre III method

Extract of the thesis done by the author (pages 286 – 289, Tille M., 2001) – Text in French

Electre III

Préambule

La méthode Electre III, qui date de 1977, relève aussi de la problématique de rangement ou de classement γ. Elle suit les grands principes déjà énoncé dans la méthode Electre II en constituant sa prolongation naturelle.

Il y a toujours, comme dans les deux précédentes méthodes, une hypothèse de surclassement et des notions de concordance et de discordance.

Le changement le plus important par rapport à Electre II réside dans le fait que Electre III comporte une part de flou dans la relation de surclassement. La réflexion porte désormais sur la crédibilité à accorder à cette hypothèse de surclassement $v_i\boldsymbol{S}v_k$. Ceci est traduit par la mesure du ***degré de crédibilité*** de l'hypothèse de surclassement, qui varie de ***0*** (surclassement certainement inexistant) à ***1*** (surclassement existant). On travaille ainsi avec des valeurs continues et non plus bivalentes.

Electre III utilise la notion de ***critères flous*** qui a été décrite auparavant et qui comporte trois seuils liés à chaque critère : seuil d'indifférence, de préférence stricte pour la concordance et de veto pour mieux exprimer la discordance.[14] Ceci permet de définir une relation supplémentaire entre deux variantes, la ***préférence faible*** notée $v_i\boldsymbol{Q}v_k$.

[14] Le seuil de veto n'est pas obligatoire dans Electre III, ce qui peut se révéler intéressant dans le cadre des projets d'infrastructures routières

Electre III continue sur les traces d'Electre II, mais cette évolution se traduit par deux effets contradictoires : (Maystre L. Y., Pictet J. et al., 1994)

- une information qui est de plus en plus nuancée et qui se rapproche de la complexité de la réalité, ce qui donne un résultat plus net et des conclusions bien fondées
- une complexité croissante du processus, donnant un peu une impression de « boîte noire » et donc une difficulté de compréhension grandissante de la part du décideur

La réalisation des différentes phases d'étude d'Electre III est fastidieuse et complexe. Cependant, le logiciel ELECTRE III-IV développé par le LAMSADE permet de rapidement établir les classements des différentes variantes à partir du tableau des performances et de la définition des différents seuils.[15] Son faible coût, sa facilité d'installation et d'utilisation ainsi que sa convivialité en font un excellent outil d'aide à la décision au service du praticien, épargnant à celui-ci l'examen des procédures complexes de classement. (LAMSADE, 1994)

Comme les descriptions des différentes méthodes d'agrégation partielle sont destinées au praticien,[16] la présentation de la méthode Electre III dans cette thèse de doctorat sera donc volontairement portée sur les éléments principaux de celle-ci. On ne développera pas ici les algorithmes de classement. Le lecteur intéressé peut toujours se référer aux descriptions très complètes situées dans l'ouvrage de L.-Y. Maystre. (Maystre L. Y., Pictet J. et al., 1994)

Démarche d'utilisation

La méthode Electre III se base sur les phases d'études successives suivantes :

- ***Phase 1*** ***Réaliser le tableau des performance***

Il s'agit d'évaluer les performances des variantes auprès de chaque critère en les disposant dans le tableau des performances, tout comme dans Electre II.

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[15] B. Roy et D. Bouyssou affirment que « *le recours à un logiciel est absolument nécessaire* » (Roy B. et Bouyssou D., 1993)

[16] Le praticien intéressé par l'utilisation de la méthode Electre III effectuera son étude à l'aide du logiciel ELECTRE III-IV du LAMSADE. Comme il a été dit précédemment, cette thèse s'intéresse plus à cet aspect d'utilisation qu'à un aspect de développement de la méthode

- ***Phase 2*** ***Indices de concordance***

La détermination d'un indice de concordance globale C_{ik} avec l'hypothèse de surclassement $v_i\boldsymbol{S}v_k$ est identique à Electre I ou II :

$$\boldsymbol{C_{ik}} = \frac{\sum_{j=1}^{j=m} c_j(v_i, v_k) \cdot P_j}{\sum_{j=1}^{j=m} P_j}$$

Dans ce cas, les valeurs de l'indice de concordance $c_j(v_i, v_k)$ sont continues entre 0 et 1 et non plus bivalentes (0 ou 1) comme pour Electre I ou Electre II

Après avoir réalisé des matrices de concordance pour chaque critère (m matrices $n \times n$ comprenant les indices de concordance $c_j(v_i, v_k)$), une matrice de concordance globale est ensuite réalisée (matrice $n \times n$ comprenant les indices de concordance globale C_{ik}).

- ***Phase 3*** ***Indices de discordance***

La discordance avec l'hypothèse de surclassement $v_i\boldsymbol{S}v_k$ se détermine pour chaque critère par le calcul de l'indice de discordance $d_j(v_i, v_k)$.

Des matrices de discordance sont ensuite réalisées pour chaque critère (m matrices $n \times n$ comprenant les indices de discordance $d_j(v_i, v_k)$).

- ***Phase 4*** ***Relation de surclassement floue***

Le ***degré de crédibilité du surclassement*** δ_{ik} est déterminé ainsi :

$$\boldsymbol{\delta_{ik}} = C_{ik} \cdot \prod_{j=1}^{j=m} \frac{1 - d_j(v_i, v_k)}{1 - C_{ik}}$$

Seuls les critères c_j où $d_j(v_i, v_k) > C_{ik}$[17] sont pris en considération dans le calcul du degré de crédibilité (Maystre L. Y., Pictet J. et al., 1994)

[17] Pour calculer le degré de crédibilité, on ne considère que les critères c_j où l'indice de discordance est supérieur à l'indice de concordance globale (Maystre L. Y., Pictet J. et al., 1994)

On peut faire les remarques suivantes en fonction de la valeur du seuil de veto : (Maystre L. Y., Pictet J. et al., 1994)si $-Sv_j \geq \delta_j(v_i, v_k)$ (ou $Sv_j \leq \delta_j(v_k, v_i)$) pour un seul critère, alors $d_j(v_i, v_k)$ = 1, ce qui signifie que le degré de crédibilité du surclassement δ_{ik} vaut alors 0

si il n'y a pas de seuil de veto sur l'ensemble des critères ($Sv_j \rightarrow \propto$ quel que soit le critère c_j considéré), alors $d_j(v_i, v_k) = 0$, ce qui signifie que le degré de crédibilité vaut l'indice de concordance globale : $\delta_{ik} = C_{ik}$

Une matrice des degrés de crédibilité est ensuite réalisée (matrice $n \times n$ comprenant les degré de crédibilité δ_{ik}).

Comparé à Electre II, il n'y a plus deux types de surclassement (fort ou faible) mais une multitude de surclassements caractérisés par leur degré de crédibilité, ce qui permet de mieux saisir la complexité de la problématique étudiée.

- ***Phase 5*** ***Exploitation de la relation de surclassement floue***

Un classement des variantes et établi sur la base des degrés de crédibilité des relations de surclassement entre chaque paire de variantes. La procédure, qui est complexe, et l'algorithme permettant d'arriver à ce classement sont présentés aux pages 93ss de(Maystre L. Y., Pictet J. et al., 1994).

Par analogie avec le classement inverse et le classement direct utilisé dans Electre II, la méthode Electre III procède à deux classements antagonistes, qui sont des préordres complets : une ***distillation ascendante*** et une ***distillation descendante***.

Le ***classement final*** est un préordre partiel, autorisant les ex æquo, qui est tiré de la comparaison des rangs obtenus par les variantes dans ces deux distillations. Il est établi de la même manière que dans Electre II.

La démarche d'utilisation de la méthode Electre III est résumée dans le schéma de la page suivante.

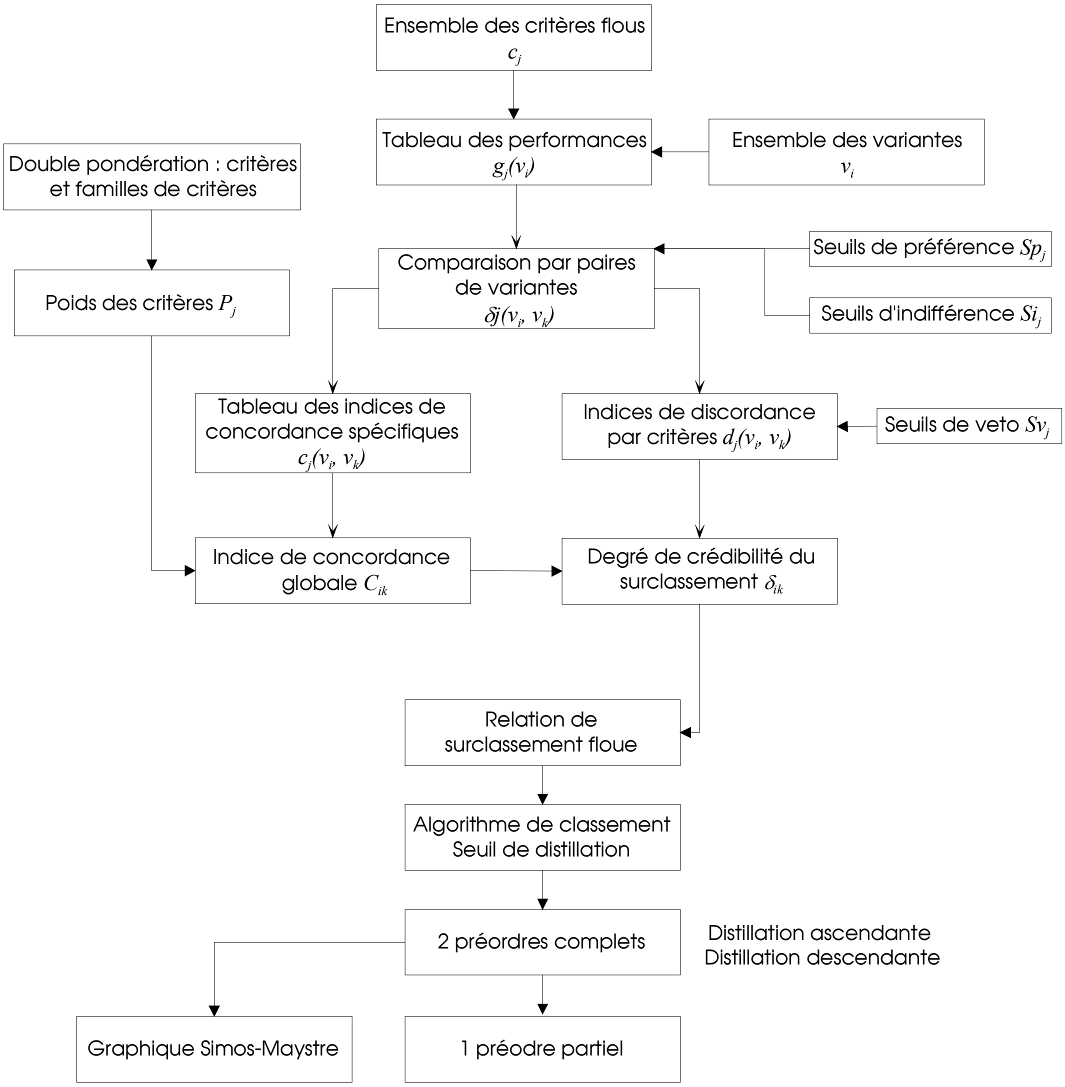

Figure : Démarche d'utilisation de la méthode Electre III (LAMSADE, 1994)