THE MULTICRITERIA DECISION MAKING METHODS : A PRACTICAL TOOL FOR DESIGN A SUSTAINABILITY ROAD INFRASTRUCTURE

M. TILLE & A.-G. DUMONT
Laboratoire des voies de circulation, Ecole Polytechnique Fédérale de Lausanne, Suisse
micael.tille@epfl.ch & andre-gilles.dumont@epfl.ch

ABSTRACT

The problematic of the choice between various alternatives is permanent and crucial in the projects of road infrastructures. The designer must use objective and global methods for proposing to the decision maker, who is generally a political entity, an optimal alternative. The complexity of the many fields affected by the road infrastructure and the diversity of the various participants of the study process are different elements to integrate in this choice. Only multicriteria decision making methods (MCDM), associated with a dialogue integrated into all the stages of the study process, can be used by the designer as well as possible to considerate this complexity. The use of such methods also makes it possible to bind the objective aspects of the choice, based in particular on technical evaluation of the performance indicators describing the alternatives for each criteria, with its subjective aspects, which are the relative consideration of importance of each criteria, also called weighting. These multicriteria decision making methods used simultaneously with dialogue integrated into all the steps of the procedure are clearly at the basis of a study process ensuring the design and the realization of a sustainability road infrastructure. They indeed make it possible to consider social, by the dialogue of the various actors, economic and environmental dimensions by the using of adequate criteria. Moreover, the consideration of the needs for the future generations, by the taking into account of the life cycle of the road infrastructure, is easy to realize. The author proposes an actualized methodology for the road design project process, which is based on the integration of these principles in the procedure. An evaluation of the various multicriteria decision making methods was carried out in a real case in Switzerland. It results the following main remarks for a good use of these methods for the designer and the decision maker : to use a partial aggregation method like Electre III, using in particular the notion of the fuzzy criteria, permits to better moderate the judgments and to use easily various indicators ; a strong separation during the design process between the weighting, which is realized before the alternatives generation, and the evaluation of the criterias is necessary ; the objective judgment is realized by the designer and the subjective weighting is done by the decision maker.

KEYWORDS

SUSTAINABILITY / DESIGN PROJECT / ACTUALIZED METHODOLOGY / MULTICRITERIA DECISION MAKING METHODS / PARTIAL AGGREGATION / ELECTRE III

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, 2001)

1. CHARACTERISTICS OF THE ROAD PROJECT

1.1 Factors of the problematic

The recurrent problems that one can meet actually in road project in Switzerland and in Occidental Countries are the follows :
- Lengthening of the study duration : the modifications of the context are faster than those of projects lasting many years
- Fractionation of the studies : partial studies are not inevitably guarantors of a global optimum
- Prevalence of the particular interests : the public interest is strongly contested by the particular interests
- Conflict relationship between the actors of the project : the working conditions are often degraded
- Increasing of the costs : the requirements relating to installations are increasing
- Uncertainty for the end of the projects : some projects can be blocked even if they are necessary
- Unsatisfactory solution : the result is sometimes a compromise, which is not the "ideal solution" because it reflects only the ratio of force between the different actors

One can 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 ?"* The major causes are .
- Many affected fields : the road projects have direct and indirect influences on many environmental fields assign with divergent objectives. It's impossible to design a project which is optimum for each one and one needs to have a multicriteria and global vision
- Multiple actors : the term of "actor of the project" designates all the people, companies or associations who take part in the road design project or who revolve around this one and which have a real or potential influence on its development
- Evolution of the society : the society is in a full metamorphosis and the values and social waiting of the individuals are changing. 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 become significant for the acceptability of any major project (Besnaïnou, 1999)
- New paradigms : the environmental awakening in the society changes the attempts for the road standards, which must be henceforth established in the respect of the sustainability. The public participation in the project and the setting out of balance of the contradictory interests are clearly elements of these news paradigms
- Rigorous procedure : the designers must evolve within a framework of very rigorous legislative procedure which has little flexibility (Cabioch, 1997)

1.2 Life cycle of a road infrastructure

A road is planned, designed, built, exploited, maintained, and sometimes demolished. It is clearly a cycle of life, which must be considered by the road designer.
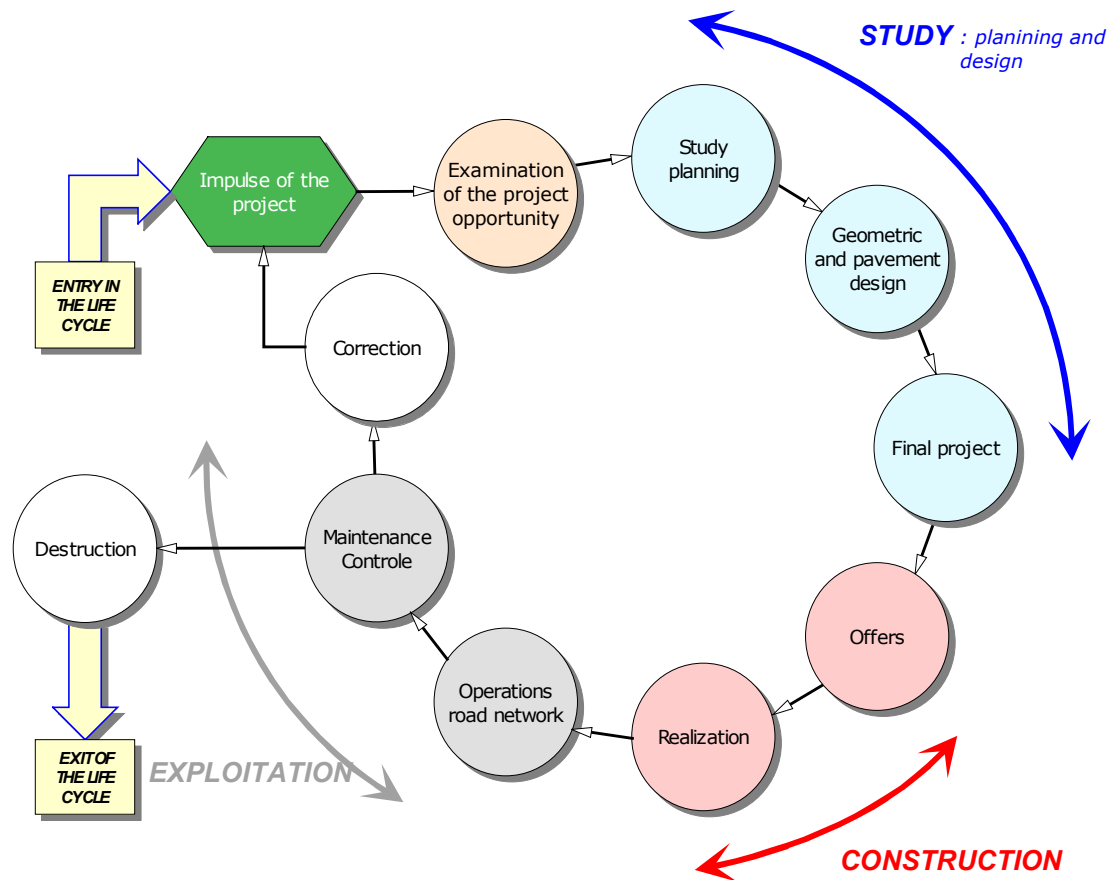

Figure 1 - The Road Life Cycle

1.3 Actors of the road project

One can classify the actors intervening in the road design project in different categories :
- Decision maker who finances the realization of the infrastructure and who will be the future owner. He is a political actor of the executive field, responsible for road administration
- Study group including the technical actors who work out the road design project and prepare the elements of analyze for the decision maker. Its principal actor is the road designer, who works with various specialists when some problems that he can't solve appears
- Administrative actors who come from various services of public administration. Their role is to check the conformity of the road project with the law
- Public made up of the actors affected by the future road (borders) and the users beneficiaries of the future road
- Non-governmental organizations (NGO) which are perennial structured groups and which defend environmental, social or economic values
- Politicians actors are the members of the executive or legislative power which are not in the same role like the decision maker

It is significant for the road designer to clearly identifying the different actors at the beginning of the project.

2. THE PROCESS OF THE DECISION

2.1 Actors of the decision

The two principal actors of the decision making process are the followings : (Maystre, Pictet & al., 1994)

- The decision maker is the person with whom the decision making process is intended. He occupies a central place in the study process whose characteristics depend on its waiting
- The designer is an individual or a group of people who has as the role to make some recommendations to advise the decision maker on the possible solutions.

In a preoccupation of a perfect independence, it is necessary that the decision maker is clearly distinct from the designer. Indeed, the tasks of each one are strictly different and this both actors mustn't to have an influence between them.

2.2 Subjectivity and objectivity

By nature, the decision is a subjective activity. This can be sometimes difficult to admit by our occidental scientific and rational way of thinking because one is more inclined to prefer judgments based on approved models.

The subjectivity isn't to be regarded as being 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. He quotes an evocative sentence of R. Howard *"The decision making is what you do when you don't know what to do"*. (Schärlig, 1985)

The subjectivity reflects the systems of values of the decision maker and other actors who condition the decision The objectivity concerns the values of the descriptive indicators which are calculated without major contestation by the designer. The subjective and objective aspects are combined in all the decision making process and there is a strong necessity to clearly distinguish and identify them throughout the study.

2.3 Influential factors of the decision

The decision maker making a decision is conditioned by his own system of values but also by many external factors (André, Delisle & al., 1999)
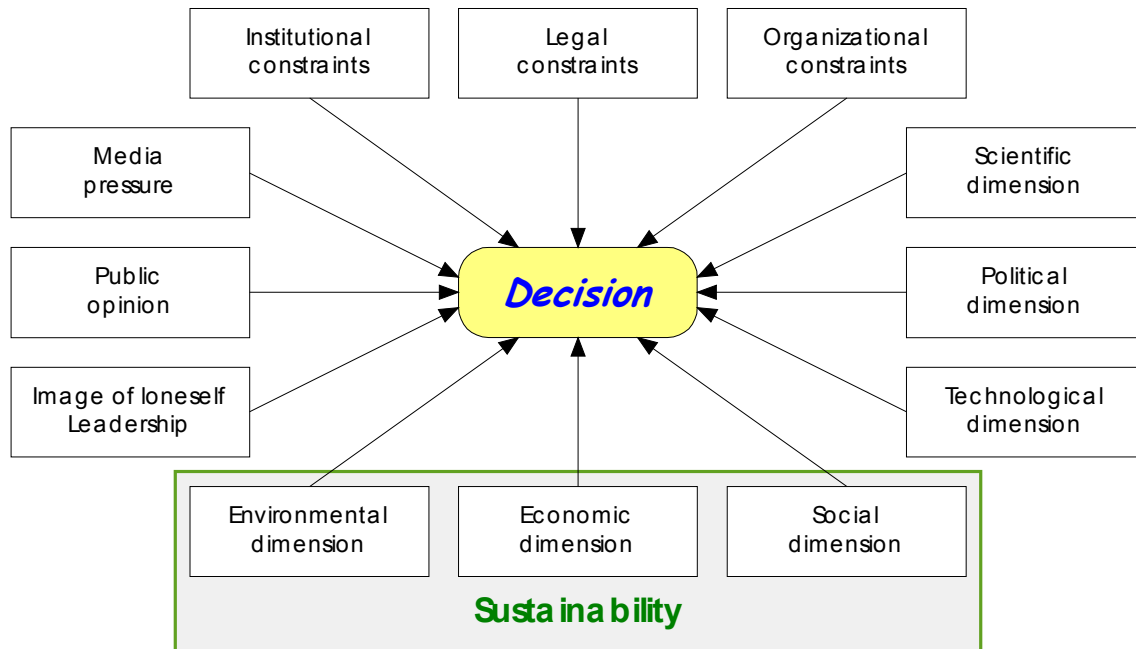

Figure 2 - Influential factors of the decision

3. MULTICRITERIA DECISION MAKING METHODS

3.1 Study process

The study process of a multicriteria decision making method (MCDM) is broken down into five successive steps : (Schärlig, 1985)
- Inventory of the alternatives
- List of the criterias considered
- Weighting of the criterias : relative importance between those
- Judgment of the actions
- Aggregation of the judgments : combination of the weighting and the judgments

The first four stages are common to all the methods, which are only characterized by the mode of aggregation of the judgments. (Molines, 1997)

3.2 Typology

Two major modes of aggregation of the judgments exist in the multicriteria decision making methods : complete and partial aggregation.

The complete aggregation 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 criteria. One thus obtains a synthetic answer. The major inconvenients are the compensation of the judgments and the fact that the determination of the function of utility is sometimes very complex.

The partial aggregation methods are developed by the "*European school*". They consist 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. These methods admit the postulates of the incomparability and of the intransitivity and authorize a greater richness in the relations between the alternatives. The results are sometimes complicated to understand and the weakening on the clearness of the result can perturb the decision maker who wants to receive a comprehensible and definitive answer. (Schärlig, 1985)

It exits three type of partial aggregation methods :
- α problematic : choice or selection   Electre I, Electre IS
- β problematic : sorting or segmentation   Electre Tri
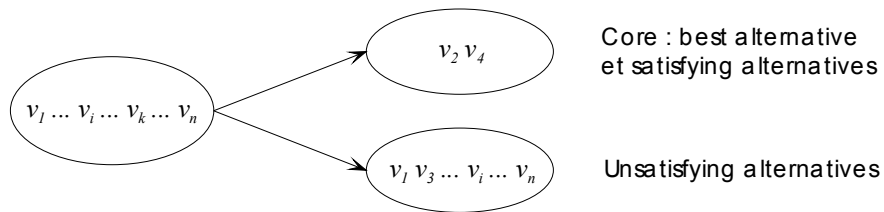- γ problematic : classification or ranking   Electre II, Electre III, Electre IV

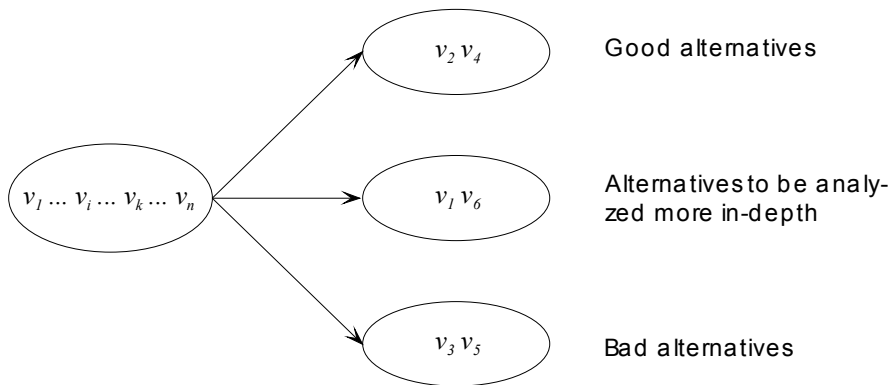Core : best alternative et satisfying alternatives

Unsatisfying alternatives

Figure 3 - Choice problematic α

Good alternatives

Alternatives to be analyzed more in-depth

Bad alternatives

Figure 4 - Sorting problematic β

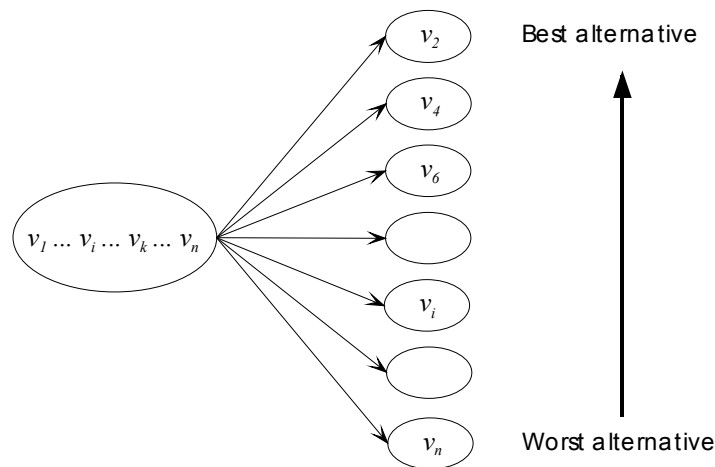Best alternative

Worst alternative

Figure 5 - Classification problematic γ

For this study, the partial aggregation method Electre III developed by the Laboratory for Analysing and Modelling Decision-Aid Systems was chosen. (LAMSADE, 1994)

3.3 Terminology

The alternatives are the elements that make the object of the multicriteria study. One uses n alternatives v_1 to v_n.

A criteria is a qualitative or quantitative expression permit to judge, by the way of an indicator, the performance of an alternative for objectives or constraints relatives of the considered project. One uses m criterias c_1 to c_m. The performance of the alternative v_i for a criteria c_j is defined by the term $g_j(v_i)$.

The weight P_j qualifies the relative importance of a criteria c_j compared to the others.

3.4 Relations between the alternatives in the Electre III method

Electre III analyzes the difference $g_j(v_i)$ - $g_j(v_k)$, noted $\delta_j(v_i,v_k)$, between the performances of two alternatives v_i and v_k, this for each criteria c_j.

It exists three relative situations :
- $\delta_j(v_i,v_k) > 0$ v_i is preferred to v_k for the criteria c_j, noted v_iPv_k
- $\delta_j(v_i,v_k) = 0$ v_i is equivalent or indifferent to v_k for the criteria c_j, noted v_iIv_k
- $\delta_j(v_i,v_k) < 0$ v_k is preferred to v_i for the criteria c_j, noted v_kPv_i

For a criteria c_j, one determines two index qualifying the relations between v_i and v_k :
- a concordance index, noted $c_j(v_i,v_k)$, which is qualifying the degree of the credibility of the relation "v_i is outclassing v_k", noted v_iSv_k
- a discordance index, noted $d_j(v_i,v_k)$, which indicates for the criterias where v_iPv_k isn't verified, if the no-respect of the hypothesis of outclassing v_iSv_k isn't to important

Electre III is based on the notion of the fuzzy criteria which is consists of a progressive transition between the indifference and the preference. To carry out this, three thresholds are introduced for each criteria c_j :
- Indifference threshold Si_j which is the smallest significant difference. Below this threshold, it's impossible to decide between two alternatives
- Preference threshold Sp_j which is the value where the difference between two alternatives is perceptible and makes prefer one to the other
- Veto threshold Sv_j which means that if at least for one criteria c_j, it exists one $\delta_j(v_i,v_k)$ negative with $|\delta_j(v_i,v_k)|$ less than Sv_j, then the hypothesis v_iSv_k isn't verified. The no-respect of the outclassing hypothesis is then too important. This threshold is a limit at the compensation between the criterias.

The values of the specific concordance index $c_j(v_i,v_k)$ are continued between 0 and 1 if one has $Si_j \leq \delta_j(v_i,v_k) \leq Sp_j$. 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_iQv_k. The relation v_iPv_k is then designed by the term of strict preference.
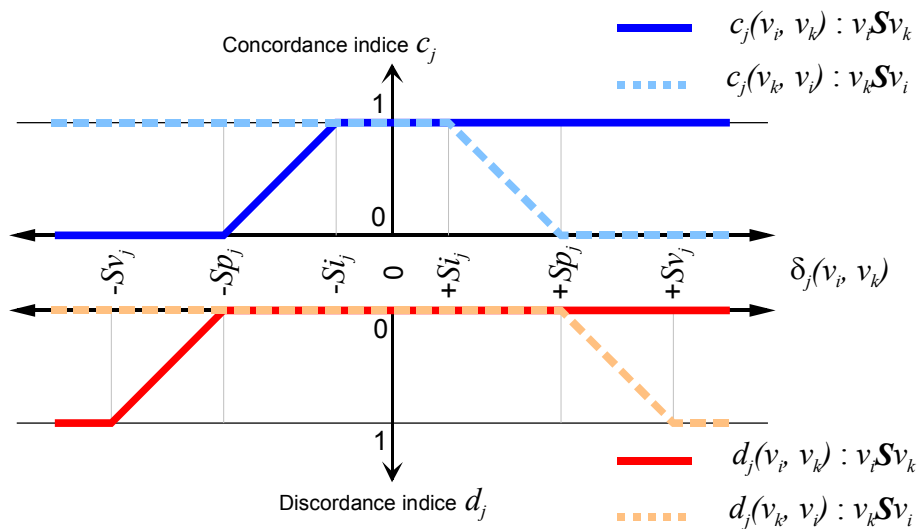
Figure 6 - Specifics index of concordance and discordance for a fuzzy criteria

With the method Electre III, one obtains five relatives relations between two alternatives :
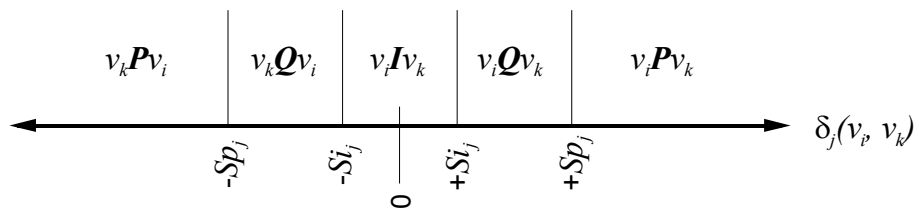

Figure 7 - Relatives relations between two alternatives v_i and v_k for a fuzzy criteria

4. ACTUALIZED METHODOLOGY OF THE ROAD PROJECT

This research leads to the proposal a new methodology for the road infrastructure design project which is iterative and which takes account of the new societal paradigms like the sustainability or the public participation. This methodology process is designed by the term of "Actualized methodology of the road project".

The purpose of this methodology is to integrate in its heart all the participants of the road design project. She consists in adopting a dynamic attitude of prevention of the problems, by quickly incorporating these actors in the study process to carry out a sustainable project and accepted by all the parts. This is an attitude that is preferable with a defensive and static behavior trying to attenuate the impacts related to any road infrastructure. This approach is like the concept of *"to prevent rather than to cure"*. This methodology is based on a process which takes into account the circular structure of the road life cycle.

This actualized study process is described on the next page.

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
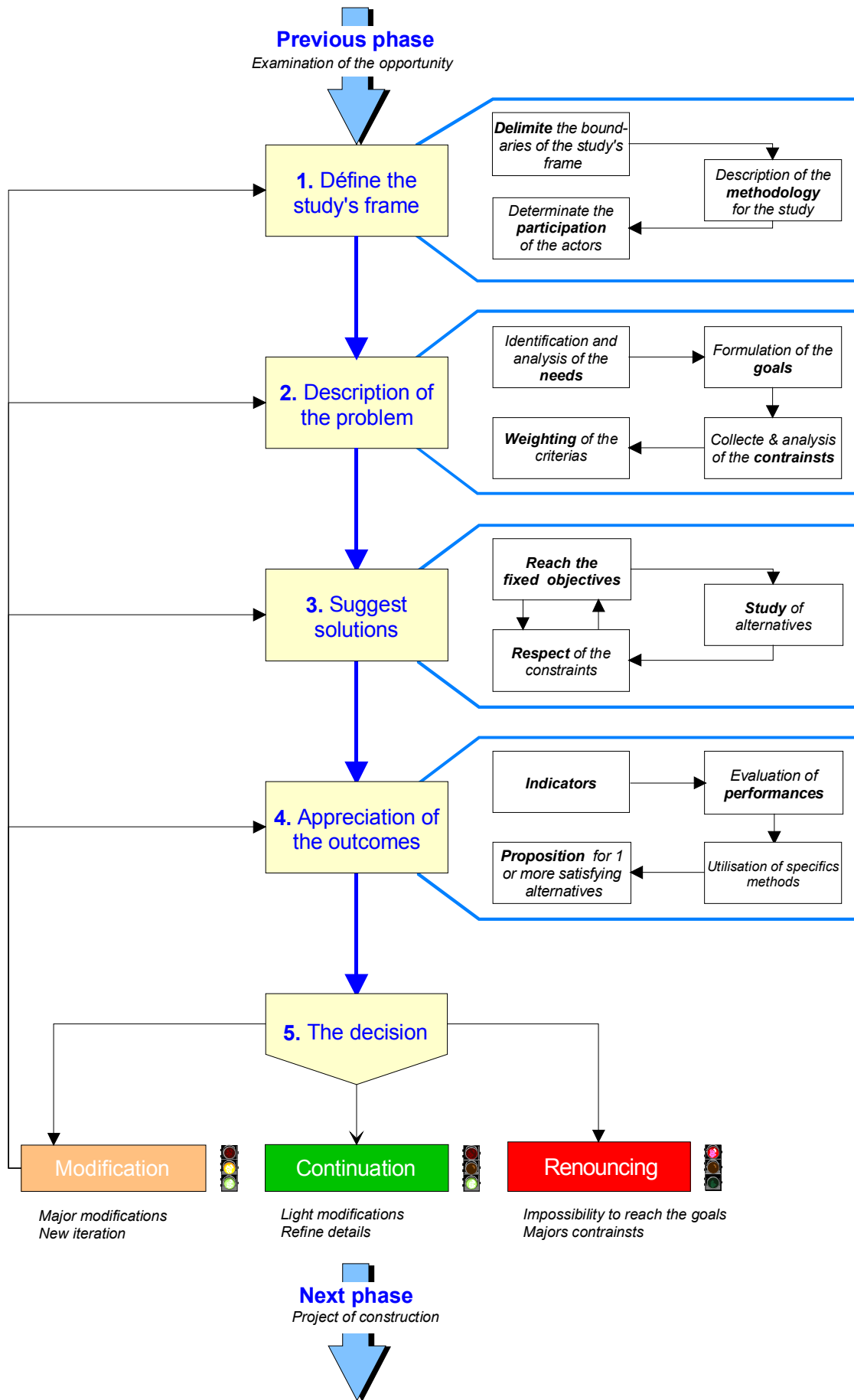*Project of construction*

Figure 8 - Actualized methodology for the road project

This methodology is divided in five principal steps including the following majors aspects :

- Strictly separation between the weighting of the criterias and the evaluation of the indicators. The first is made by the decision maker before the generation of the alternatives, the second is made at the end of the project by the study group
- Weighting is done by all the actors assuring so a great variability of the results
- Iterative process
- Total integration of the actors during all the process
- Use of a partial aggregation multicriteria decision making method : Electre III

5. STUDY CASE : SWISS MAIN ROAD VILLENEUVE - LE BOUVERET

5.1 Problematic

The Swiss main road H 144 is located in the Alps at the outlet of the valley of the Rhone on southern bank of the Lake Léman (Lake of Geneva) and close to the international natural reserve of Grangettes which is a Ramsar Convention area. She connects the Swiss national highway A9 to the French border and has 5 km length. (Infraconsult, 2000)

This road has an insufficient standard for a modern infrastructure : crossing of the localities, sinuosity and geometric profile unsatisfactory for the motorized traffic, bridge on the river Rhone that is a bottleneck (one lane and limited load of 15 tons), etc. For these reasons, the realization of a road link of quality is a imperious necessity.

5.2 A new project : "Comparaison de variantes 1999"

Since nearly forty years, many projects were studied without obtaining a solution and the relations between the different actors are execrable. Due to the impossibility to obtain a consensual result and in order to solve this problem, the Swiss Federal Roads Authority has proposed in November 1998 to form a working group in order to carry out a comparative multicriteria analysis.

The six alternatives which were analyzed in the "Comparaison de variantes 1999" are :
- Actual road (E1)
- 2 alternatives based on the actual road with some modifications : 0^+ revised (0R) and 0^+ adapted (0A)
- 2 alternatives proposed by the local authorities: Communes revised (CR) and Communes adapted (CA)
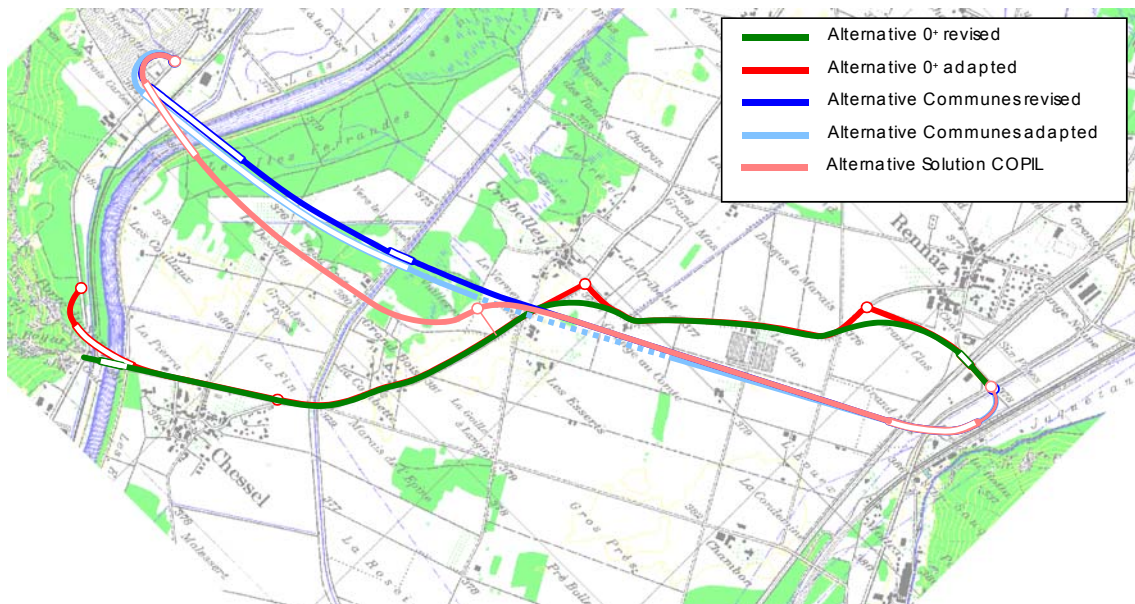- A solution developed during the study : Solution COPIL (SC)

Figure 9 - Alternatives studied in the "Comparaison de variantes 1999"

5.3 Actors

Two working groups was created for this study : a Steering Committee (Comité de pilotage - COPIL) and a Technical Group.

There were thirty actors in the Steering Committee, which can be distinguished in five categories :

- politicians of the regional and local levels - 12 actors
- economic associations - 4 actors
- environmental associations - 5 actors
- public administration - environment and territory - 5 actors
- road administration - 4 actors

5.4 Results

The study was realized in 10 months and has obtained a consensual solution which is the Solution COPIL, an adaptation of the alternative Communes revised.

Table 1 - Results of the utility values (Infraconsult, 2000)

Rank	Alternative	Utility value
1	**Solution COPIL**	0,69
2	Communes revised	0,63
3	Communes adapted	0,55
4	0^+ revised	0,17
5	0^+ adapted	0,13
6	Actual road	0,49

The multicriteria decision making method used was a complete aggregation method (analysis method of the utility values). The interest of this project was that the weighting of each actor of the Steering Committee was considered in the multicriteria decision making method. This operation was carried out individually in an independent and subjective way and with some minimal rules. The technical Group did the evaluation of the indicators separately.

5.5 Application of Electre III

The author has applied the results of the evaluation and the individual weightings of the 28 actors of the Steering committee in Electre III. The objective was to compare the results and the potential of this method with that which was used in the "*Comparaison de variantes 1999*".
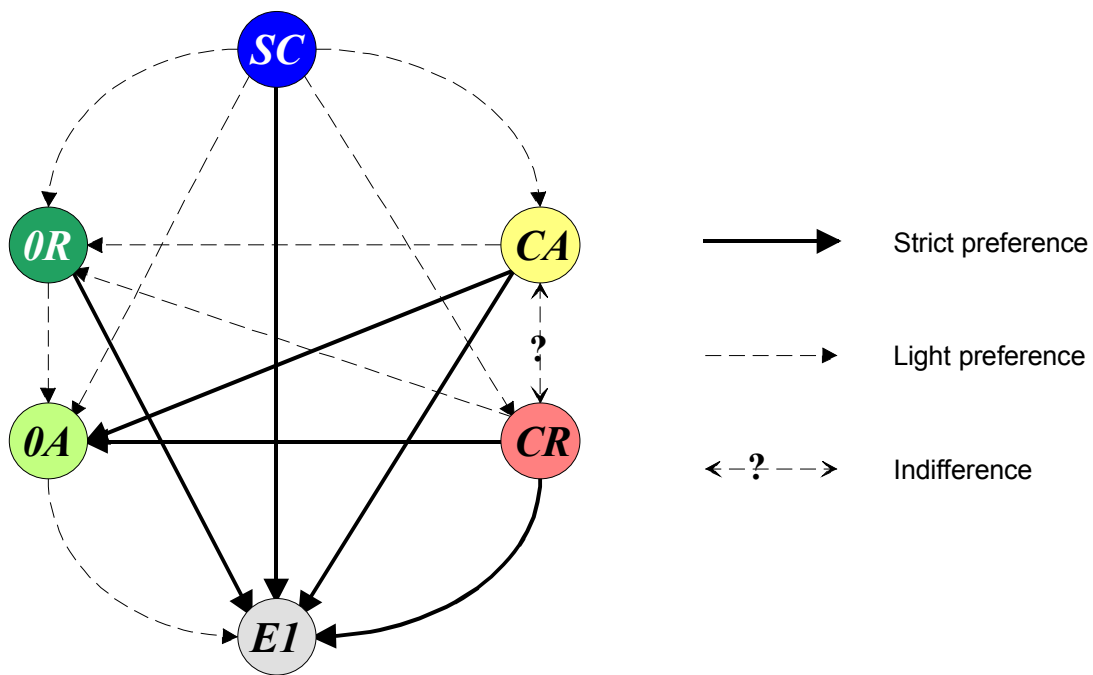

Figure 10 - Relations of preference between the alternatives - Partial aggregation

The results obtained with the method Electre III show that the solution is among the trio made up of Solution COPIL and the alternatives of the Communes. The solution seems to emerge slightly for he Solution COPIL. 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 are between 0,55 and 0,69 for the 28 weightings of the COPIL. By using a complete aggregation method, this fuzzy tinge was eliminated.

5. CONCLUSIONS

The actualized methodology isn't a miraculous solution which correctly applied assures the success for each designer. However, there is a practical tool permitting to cross the difficulties efficaciously and which assures quality, sustainability and acceptance for the project. Using a multicriteria decision making method like Electre III, which is based on a partial aggregation, is very promising for the road design project. The advantages of this method for the comprehension of the phenomena and for taking in consideration the fuzzy of the appreciation are more important of her inconvenient like the difficulty of comprehension for the results.

The integration of Electre III in the road project methodology is possible with some light adaptations :
- Strictly separation of the weighting and the evaluation : this dichotomy is totally absent of many complete aggregation methods
- 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 between establishing the weighting and making the evaluation : the designer and the decision maker work independently

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
- The participation of all actors is a consideration of the social aspect of the project : transparency and dialogue
- The liberty of action offer to the decision maker and the designer assures a total adaptation at the road project context

REFERENCES

André P., Delisle C E., et al. (1999) L'évaluation des impacts sur l'Environnement - Processus, acteurs et pratique. Presses Internationales Polytechnique, Montréal, Canada

Bassand M., Veuve L., et al. (1986) Politiques des routes nationales - Acteurs et mise en oeuvre. Presses Polytechniques Romandes (PPR), Lausanne, Suisse

Besnaïnou R. (1999) Les évolutions des attentes sociales présenté à Aménager pour demain : de l'utilité à l'acceptabilité d'une infrastructure. Journée d'étude ENPC. Ecole Nationale des Ponts et chaussées, Paris, France

Cabioch F. (1997) La concertation des acteurs et du public : une expérience de la DDE du Lot. 5èmes Rencontres de Clermont-Ferrand - La qualité environnementale des projets routiers : de la politique d'aménagement à la réalisation de la route. Semaine des Arts Techniques et Culture de l'Automobile et de la Route (SATCAR), Clermont-Ferrand, France

CGCN (1997) Construction des routes nationales. Rapport de la Commission de gestion du Conseil National. Berne, Switzerland

Infraconsult SA (2000) Routes principales suisses A 144 Villeneuve - les Evouettes - Comparaison de variantes 1999, apport technique du Comité de Pilotage. Rapport pour : Service des routes et autoroutes du canton de Vaud et Service des routes et des cours d'eau du canton du Valais. Berne, Switzerland

Knoepfel P. (1997) Les politiques de l'environnement et la durabilité : du contrôle des émissions vers la gestion des ressources. Support de cours postgrade. Institut de hautes études en administration publique (IDHEAP), Chavannes-près-Renens, Switzerland

LAMSADE (1994) Electre III-IV - Version 3.1b. Logiciel. LAMSADE, Université Paris Dauphine, Paris, France

LRN (1960) Loi fédérale sur les routes nationales. RS 725.11, 8 mars 1960 (état le 21 décembre 1999), entrée en vigueur le 21 juin 1960. Berne, Switzerland

Maystre L. Y., Pictet J. & al. (1994) Méthodes multicritères Electre - Description, conseils pratiques et cas d'application à la gestion environnementale. Presses Polytechniques et Universitaires Romandes (PPUR), Lausanne, Switzerland

Molines N. (1997) - Systèmes d'information Géographique et Méthodes d'analyse multicritère - Perspectives d'utilisation pour la conception d'infrastructures linéaires. Rapport de recherche. CETE, Lyon, France

Norme SN 640 026 (1998) Elaboration des projets - Etapes de projet. Norme. Union Suisse des professionnels de la route (VSS), Zürich, Switzerland

Roy B. (1985) Méthodologie Multicritère d'Aide à la Décision. Collection Gestion, Série "Production et techniques quantitatives appliquées à la gestion". Economica, Paris, France

Schärlig A. (1985) Décider sur plusieurs critères : Panorama de l'aide à la décision multicritère. Collection "Diriger l'entreprise", vol. 1. Presses Polytechniques et Universitaires Romandes (PPUR), Lausanne, Switzerland

Schärlig A. (1996) Pratiquer Electre et Prométhée. Collection "Diriger l'entreprise", vol. 11. Presses Polytechniques et Universitaires Romandes (PPUR), Lausanne, Switzerland

Tille M. (2001) Choix de variantes d'infrastructures routières : méthodes multicritères. Thèse de doctorat, N°2294. Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Tille M. (2002) La méthodologie actualisée du projet routier : un outil au service de l'ingénieur civil et de l'écologue. Revue "Routes et trafic", vol. 03/2002, 13 pages. Union Suisse des professionnels de la route (VSS), Zürich, Switzerland

Tille M. & A.-G. Dumont (2003) Methods of multicriteria decision analysis within the road projects like an element of the sustainability. 3rd Swiss Transport Research Conference, Session Decision support, 52 pages. STRC03, Monte Verità, Switzerland

Veuve L. (1994) Urbanisme et génie-civil. Support de cours. Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland