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A decision support system for assessing alternative projects for the design of a new road network

(Methodology and application of a case study)

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A DECISION SUPPORT SYSTEM FOR ASSESSING ALTERNATIVE PROJECTS FOR THE DESIGN OF A NEW ROAD NETWORK

Methodology and application of a case study

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Abstract

This study aims to offer an applicable evaluation framework for assessing project alternatives by employing different Multicriteria Evaluation Methods as a tool to reduce conflicts in a decision making process.

The first part of the paper consists of a brief survey of the great diversity of modem assessment methods that have been developed over the last ten years. This helps to provide a perspective for procedural types of decisions in which various qualitative and quantitative aspects are incorporated. This paper initially focuses on three recently developed techniques, viz. Regime analysis, the Analytical Hierarchic Process (AHP) methods and the Flag model.

In the second part of the paper, the above mentioned multicriteria methods are applied to a 'real-world' case concerning the design of a new road network in the area of the Cilento National Park in Italy.

Key words: evaluation, participation, multidimensional, conflicting objectives.

1. Modern Decision Support

In modern policy analysis we witness an increasing emphasis on analytical Decision Support methods. After the popularity of cost-benefit analysis and related financial-economic evaluation methods (such as cost-effectiveness, compensatory methods, survey methods) we have seen an increasing and widespread use of multicriteria methods. Such methods are capable of dealing with the multiple dimensions of evaluation problems (e.g. social, cultural, ecological, technological, institutional, etc.) and give due attention to interest conflicts among various stakeholders in a planning process. They aim to combine assessment techniques with judgement methods and offer a solid analytical basis for modern decision analysis. Their popularity is reflected in the great many multicriteria methods that have developed over the past decades.

The paper aims at highlighting the potential of a merger of three recently developed techniques, viz. Regime analysis, the Analytical Hierarchic Process (AHP) methods and the Flag model. Based on these joint methods, it presents an empirical application for sustainable road planning in Italy.

2. Multicriteria Analysis as a Decision Support System in a Complex Decision-Making Process.

2.1. General

In the framework of discrete choice analysis with conflicting judgement criteria, a wide variety of evaluation methods have been developed in the past decade. These methods serve to make a complex multidimensional choice problem more transparent. They are usually called multiple criteria methods, and they pay particular attention to major constituents of choice problems, including:

- the identification of relevant choice options
- the definition of appropriate evaluation criteria (emanating from conflicting objectives)
- assessment of the numerical value of each evaluation criterion for each choice option
- the collection of measurable prior information about each of the relevant decision criteria (e.g. by means of weights or interactive computer methods)
- the identification of the relevant decision level or of the proper institutional decision procedure (in case of a multi-actor choice situation)
- ***and*** the specification of a suitable measurement scale for the available information (e.g. ratio, ordinal or fuzzy information).

In the field of multiple criteria analysis, a whole series of different quantitative and qualitative evaluation methods has been developed. It includes:

- the eigenvalue (or prioritisation) method (see Saaty, 1977; Lootsma, 1980)
- the extreme expected value method (see Kmietowicz and Pearman, 1981; Rietveld, 1980)
- the permutation method (see Mastenbroek and Paelinck, 1977)
- the frequency method (see Van Delft and Nijkamp 1977)
- the multidimensional scaling method (see Nijkamp and Voogd, 1981)
- *and* the mixed data method (see Voogd, 1983).

We will focus our attention on three particular multicriteria methods based on both ordinal and mixed ordinal-cardinal data: the Regime method, the Saaty method and the Flag model They all will be concisely discussed in Sections 2.2- 2.4.

2.2. Regime analysis

The Regime analysis is a discrete multi-criteria method (Nijkamp et al., 1990). The fundamental framework of this multi-criteria method is based upon two standard kinds of input data: an evaluation matrix and a set of political weights. The evaluation matrix is composed of elements that measure the effect of each alternative considered in relation to each relevant criterion. The set of weights provides information about the relative importance of criteria to be considered.

Regime analysis in its qualitative version is an ordinal generalisation of pair-wise comparison methods that can examine quantitative as well as qualitative data. In Regime analysis, as in concordance analysis, we compare all alternatives of all criteria in order to define and calculate the concordance index. Let us consider, for example, the comparison between alternatives i and j for all criteria. The concordance index will be the sum of the weights related to the criteria for which alternative i is better than j. We will call this sum c_{ij}. Then we may calculate the concordance index for the same two alternatives by considering the criteria for which j is better than i, i.e. c_{ji}. After having calculated this sum, we subtract the two values to obtain the index $\mu_{ij} = c_{ij} - c_{ji}$. When we have only ordinal information about the weights, our interest is in the sign of the index μ_{ij}.

If the sign is positive, this will indicate that alternative i is more attractive than alternative j; if negative, it will imply the reverse. We will, therefore, be able to make a ranking of our alternatives. This ranking is possible due to the ordinal nature of the information. In the indicator μ_{ij} no attention is given to the numerical size of the difference between the alternatives.

We may encounter another complication in this framework in that we may not manage to determine an unambiguous result, i.e. a unique rank order of alternatives. This is because we may face the problem of ambiguity in the sign of the index μ_{ij}. In order to solve such a problem, we introduce a certain probability p_{ij} for the dominance of criterion i with respect to criterion j.

Here we assume a specific probability distribution for the set of feasible weights. This assumption is based on the criterion of Laplace in the case of decision making under uncertainty. In the case of a probability distribution of qualitative information, it is sufficient to mention that in principle the use of stochastic analysis, which is consistent with an originally ordinal data set, may help to overcome the methodological problem we encounter by conducting a numerical operation on qualitative data.

The Regime method can identify the feasible area into which values of feasible weights must fall in order to be compatible with the condition implied by the probability value. By means of a random generator, numerous values of weights can be calculated. In the end, this allows us to calculate the probability score (or success score) p for each alternative i. We can then determine an unambiguous solution and rank order of alternatives.

2.3. Saaty method

The Saaty method (Analytic Hierarchy Process-AHP) was developed by Thomas Lorie Saaty in the '970s (Saaty, 1980; Saaty and Vargas, 1982; Saaty, 1994). This method is based on three important components:

1. The hierarchy articulation of the elements of the decision problem
2. The identification of the priority
3. Checking the logic consistency of the priority.

The procedure is articulated in different steps. The first step consists of the definition of the problem and of the identification of the criteria in a hierarchy of five levels (see also section 3.3, Table 2):

1. Level: general objective of sustainability
2. Level: criteria
3. Level: sub-criteria
4. Level: indicators
5. Level : index

After defining the hierarchy articulation of the elements, the second step consists of assessing the value of the weights related to each criterion through the pair-wise comparison between the elements.

The Saaty method employs a semantic 9-point scale (Table 1) for the assignment of priority values. This scale relates numbers to judgements, which express the possible results of the comparison in qualitative terms. In this way, different elements can be weighted with a homogeneous measurement scale.

Through this method, the weight assigned to each single criterion reflects the importance that every party /agent /group involved in the project, attaches to the objectives. In addition to this, the method verifies the fit between the components of the weight vector and the original judgements. From the pair-wise comparison a 'comparison matrix' is derived from which, through the eigenvector approach, it is possible to calculate the weight vector under investigation. Finally, the method is able to check the consistency of the matrix through the calculation of the eigenvalue.

Value	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate value

Table 1 Semantic scale of Saaty

2.4. Flag Model

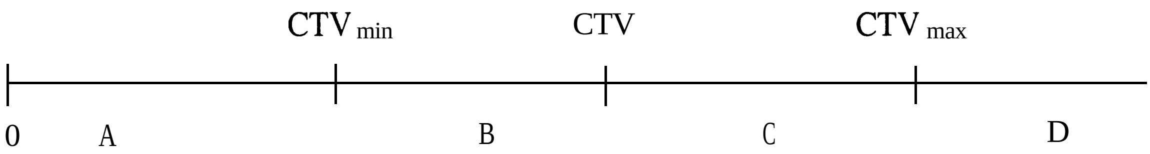
The Flag Model has been developed in order to assess the degree of sustainability of values of policy alternatives (Nijkamp, 1995; Nijkamp and Ouwersloot, 1997). The model develops an operational description and definition of the concept of sustainable development based on critical threshold values.

There are three important components to the model:

1. Identifying a set of sustainability indicators
2. Establishing a set of normative reference values
3. Developing a practical methodology for assessing future development.

The inputs in the program are an impact matrix and a set of critical threshold values defined for each relevant sustainability indicator. The sustainability indicators have two formal attributes: class and type. There are usually three classes of indicators, which correspond to the main dimensions of the sustainability analysis: (1) biophysical, (2) social, (3) economic. The two types are defined as benefit indicators and cost indicators.

The critical threshold value represents the reference system for judging actual states or future outcomes of policies or scenario experiments. Since in certain areas and under certain circumstances experts and decision makers may have conflicting views on the precise level of acceptable threshold values, we estimate a bandwidth of values of the thresholds ranging from a maximum value (CTV_{max}) to a minimum value (CTV_{min}).This can be represented as follows:



Section **A**	**Green flag**	no reason for specific concern
Section **B**	**Orange flag**	be very alert
Section C	**Red flag**	reverse trend
Section **D**	**Black flag**	Stop further growth

The third component of the model, the impact assessment, provides a number of instruments for the analysis of the sustainability problem. This analysis can be carried out in two ways. The first is an inspection of a single strategy or scenario. The second is the comparison of two strategies or scenarios. In the former procedure, we decide whether the scenario is sustainable or not. In the latter case, by comparing the scenarios, we can identify which policy or scenario scores best fits the perspective of the sustainability issue.

The working set of indicators is evaluated in a separate module of the program.

There are essentially three approaches to this evaluation: a qualitative, a quantitative and a hybrid approach.

The qualitative approach only takes into account the colour of the flag (i.e. nominal or ordinal information). This method then needs flag counts and a cross tabulation (when two policies or scenarios are compared). Pie charts or stack bars may also be used to visualise the number of coloured flags. These summary statistics are also available for the subset of indicators for the three classes. Obviously, these various qualitative methods do not give different results, but merely represent various ways of displaying the same information.

For the quantitative and hybrid form, a transformation of the underlying outcome of the indicators is required (except for the simple tabular of the data). This transformation is necessary, since the indicators are measured on very different scales. To present the information in a compact way, standardisation is useful.

2.5. Retrospective and prospective.

Plan and project evaluations have become an important component of modern public planning and administration. Especially in the socio-economic and physical planning process (such as transportation planning), nowadays much attention is paid to the assessment and appraisal of alternative policy options. In this perspective, decision making is not considered to be a "one shot" activity but a part of a process in which choice possibilities, relevant criteria and urgency of choice, gradually become clearer. (See Nijkamp, Rietveld and Voogd 1990.)

The complexity of reality and the conflicting objectives in policy games do not often allow us to analyse the problem from an unambiguous point of view. Therefore, we are faced with the need for an evaluation tool to support decision makers and to help all stakeholders involved in reaching the most plausible and accountable choice when taking economic, social and ecological aspects into account.

Multicriteria evaluation methods in public planning and administration can cope with the limitation of conventional monetary approaches such as cost-benefit analysis, characterised by an attempt to measure all effects in monetary units, including intangible and incommensurable effects which reflect the complexity of the reality under analysis.

This paper proposes the integration of the multicriteria methods described above (Regime method, Saaty method, Flag model) with the aim to develop a tool to reduce conflicts in a decision making process. As previously indicated, such an approach simultaneously can investigate the impact of a policy strategy on relevant criteria, partly monetary, partly non-monetary (including qualitative facets).

In the next section, this methodology is tested in an empirical case study based on the choice of project alternatives for the improvement of the road network in the area of the Cilento National Park. The Regime analysis is used as a tool to initiate a dialogue or communicative process between policy makers and experts in the choice of alternative projects, and to pinpoint conflicting goals.

The integration of the Saaty method with the Regime analysis can handle the problem of subjectivity of policy makers and experts in the weight choice procedure. Moreover, the Flag model is used as a tool to verify the sustainability of each alternative, by using a blend of critical threshold values.

3. A Case Study on the Cilento National Park

In this section, we illustrate the application of the preceding multicriteria methods on the basis of a real-world case regarding the design of a new road network in the Cilento National Park in Italy

First, we describe the main characteristics of the area (physical, environmental and social-economic aspects) to illustrate its complexity and to identify the "soft" and "hard" information that plays a role in the choice of alternative projects. Secondly, we illustrate the methodology followed by a specification of the input dates: the impact matrix and the set of political weights. Finally, we apply the above-mentioned method to the choice problem by using the Saaty method to calculate the weights, the Regime analysis to obtain a rank order of alternatives, and the Flag model to check the sustainability of the alternatives in relation to a set of threshold values.

3.1. The territorial context and its major features

The National Park of "Cilento and Vallo of Diano" located in the south of Italy (Campania region) was established in 1991 with Law Order 394

The Park, also classified in the Mediterranean Ecosystem, was included in 1997 in the "Reserve of Biosphere" (MAB program) network because of its mixed historical, socio-economic, artistic and spiritual features.

The landscape is characterised by a mountainous area, flatland zones and coasts rich in caves and inlets. It is considered to be one of the most important territories for the preservation "in situ" of biological diversity and the survival of extinguishing species.

Moreover, the preserved cultural heritage expresses the history of rural civilisations and their traditions.

Our study is mostly focused on the area of the "mountain community of Alburni", which includes 12 communes (Aquara, Bellosguardo, Castelcivita, Controne, Corleto Monforte, Ottati, Petina, Postiglione, Roscigno, Sant`Angelo a Fasanella, Serre, Sicignano degli Alburni). This community area covers about 50.355 ha, situated in the northern part of the Cilento National Park. 55% of this area is mountainous, 3 1% is hilly with extensive agriculture, and the remaining 14% is flatland with intensive agriculture.

The productive structure is weak - despite the amazing natural beauty of this area (we can mention the Castelcivita cave, the S.Michele cave, the "Smoke" cave in Sant' Angelo a Fasanella, the old centre of Roscigno, the archaeological excavations of the mountain Pruno, the castle and the rural settlement of S.Elia and Postiglione). It relies on external economies, which means that unemployment is high and productivity is low.

The Social Economic Development plan for the region shows that the communes are basically mountainous. The principal production sectors are agriculture, construction, and manufacturing (mostly handicrafts).

Only 40% of the total population (22.349 inhabitants estimated in 1991) is likely to find work. 75% of this active population consists of employees of which 30% are resident. Moreover, apart from the lack of a strong local economy, the scarcity of services and the inadequacy of transport networks prevent the development of this area.

Having said that, all the communes are equipped with the main services (elementary school, secondary school, medical services, etc.), and the community of Roccadaspide, located in the vicinity, has a hospital and a high school.

The road network consists of an ancient Roman route that hampers the internal connection between the communes as well as the connection with principal economic (Salerno/Battipaglia) and tourist (Pestum/Eboli) points of attraction. So, the major problems in the area are represented by:

- a large decrease in population (the population census of 1991 indicates a decrease of 10% compared to the past census), mostly due to the difficulty of reaching a workplace in a short period of time
- poverty essentially due to the lack of a flourishing local economy and the geographic marginality related to the main point of economic attraction
- loss of local traditions and values as a consequence of the two first mentioned problems.

Nowadays, one of the most serious reasons for this social-economic and cultural backwardness, is the poor accessibility of the area.

3.2. Goals and project alternatives

With regard to the above-mentioned problems, the general objective of the infrastructure project in the area is to improve the accessibility of the communes. In fact, it can be statistically proven that there is a close correlation between the economic social and cultural development and the level of mobility of people and goods.

From this perspective, it is possible to identify the specific goals of the project:

- integration of the communes inside the Park, in the main valley (valley of Sele)
- reduction in emigration

- preservation and increase in value of natural and cultural heritage
- protection of the environment.

Considering the complexity of the area under analysis, these objectives - in the logic of sustainable development - address the chosen problem from different points of view, looking into functional aspects (budget limit, travel costs, time of travel) as well as environmental and social features (pollution, fitting into the landscape, etc.). The project seeks to achieve these goals by improving the road network, which serves the western part of the communes of the Mountain Community of Alburni.

The need for feasible solutions in natural, geological and hydrological constraints has led to the identification and design of three project-alternatives (A, B, C), as Figures l-2-3 show.

Alternative A seeks to achieve a new road in the valley of the river Calore to obtain a straight connection between the two main streets, SS166 and SS19. This solution favours the access to the main traffic direction (Motorway A3 and the coastal road towards Salerno). Moreover, a motorway link connecting the principal axle of the road with the SP12 contributes to a further improvement in local mobility.

The alternative plan B aims to cover part of the new road of alternative A, in particular the stretch between the SS19 and the commune of Castelcivita, and to renew part of the ancient route along the SS12 which serves the communes in the southern part of the Park. In contrast to alternative A, this solution improves local accessibility, but presents a major problem of design to be developed inside the Park.

Alternative C is a combination of the first two alternatives (A, B). It aims to achieve all the aspects of alternative A and part of alternative B. It will produce a road improvement of, in particular, the stretches that pass through the communes of Ottati, S.Angelo a Fasanella and Corleto Monforte.

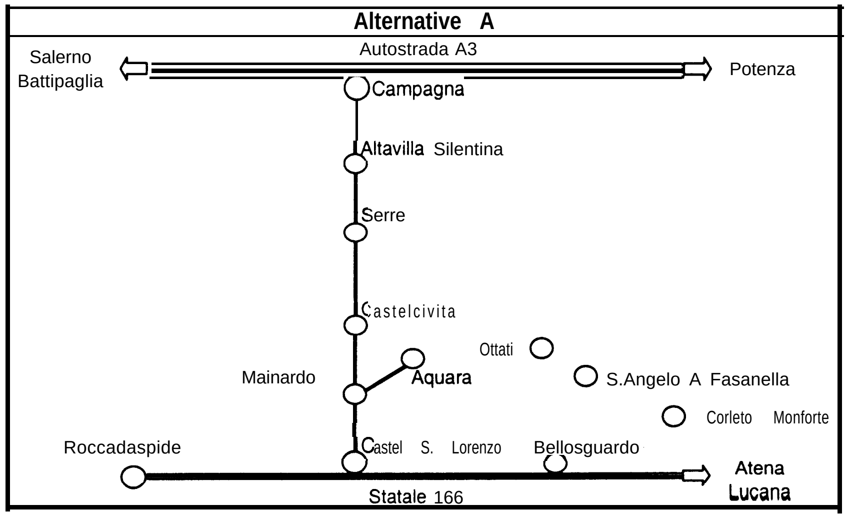


Figure 1 Alternative A

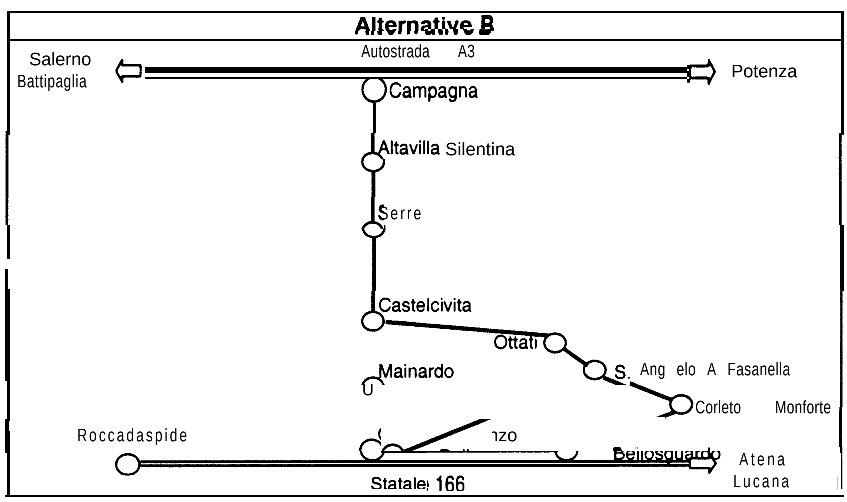


Figure 2 Alternative B

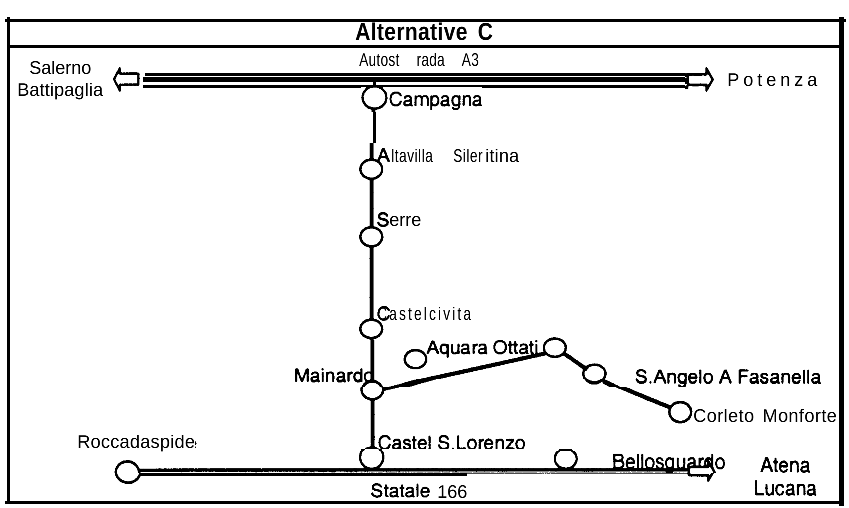


Figure 3 Alternative C

3.3. Hierarchical definition of criteria and evaluation of impact matrix

The choice of a transport infrastructure, which respects the concept of sustainability, must be based on a set of criteria that allows for the simultaneous consideration of a project impact from an economic, social and environmental viewpoint. The presupposition of this adopted view is that an optimisation of the functionality will not result in excessive costs for the environment nor for society, i.e. a burden greater than the system's carrying capacity. Such a carrying capacity is not solely related to the physical capacity infrastructure, expressed in terms of road network congestion linked to traffic flows, but also to the environment's carrying capacity. The latter concept is defined by factors like pollution (of water, air and soil, in visual and acoustic forms etc.); the territory's capability to facilitate new infrastructures; and by the society's carrying capacity, in terms of safety levels. (see Hinamen, Nijkamp, Padjen, 1992)

The case under analysis is characterised by limited traffic flows (as shown by the results of the studies performed on the existing road conditions) and remarkable environmental value. Hence, attention has to be drawn to the best possible solution, i.e. one that is functionally effective and at the same time compatible with the natural resources. The evaluation criteria for the different alternatives have been defined, as previously stated, with a view to sustainability, notably through the identification of three main classes of judgement: economy, accessibility and environment.

For each of these classes, a list of indicators has been specified. The latter have been derived from site-specific problems and allow for the measurement of the fit of each alternative with the pre-defined objectives.

The structure of the classes of criteria and their relative sub-criteria have been designed in accordance with a tree-diagram, as shown in Table 2.

The main economic, accessibility and environment criteria reflect the fundamental objectives of sustainable development, formulated by, for example, the R&D program DRIVE launched by the Commission of the EU, DG XIII. Unfortunately, due to the absence of relevant data, the safety criteria included in the list of the above-mentioned program have to be eliminated in this study.

The data referring to the sub-criteria have been expressed through the use of different scales, which are to be ascribed to the inaccuracy of the available data.

The economic criteria have been estimated in quantitative terms, and more specifically, the sub-criteria related to the costs have been quantified as a monetary scale.

Accessibility criteria are also measured on a quantitative scale, through the consideration of the average time of access, while the environmental criteria have been expressed as an ordinal scale in which the values (1,2,3) are assigned to the different alternatives, where the highest value represents the best.

CRITERIA	SUBCRITERIA	INDICATOR	INDEX
ECONOMIC	Financial costs	Investment costs	Billion of lira
		Maintenance costs	Billion of lira per year
	Transport costs	(C)/(L)	Billion of lira per year
	Users costs	Travel costs + time cost	Billion of lira per year
ACCESSIBILITY	External accessibility	Time needed from C and L on entire network	Minute
		Time for C to access from the communes to N.W point	Average time
		Time for L to access from the communes to N.W point	Average time
		Time for C to access from the communes to N.E point	Average time
		Time for L to access from the communes to N.E point	Average time
		Time for C to access from the communes to Roccadaspide	Average time
		Time for L to access from the communes to Roccadaspide	Average time
ENVIRONMENT	Acoustic pollution	Vicinity of population centres	Qualitative value
	Alteration of landscape	Fitting in the landscape	Qualitative value
	Soil pollution	Possibility of accidental fall of dangerous material	Qualitative value
	Landslide risk	Stability of sides	Qualitative value
	Hydrology risck	Flooding areas	Qualitative value
	Alteration of biological components	Loss of vegetation	Qualitative value
		Alteration of fauna' s habitat	Qualitative value
	Violation of regulation on natural environment	Park/oasis	Qualitative value

Table 2 Tree of criteria

So, looking into the economic criteria, the investment and maintenance costs have been calculated on the basis of a (metric) assessment method. The prices were obtained from the price list of the ANAS (National Motorway Company).

The accessibility of the area has been measured by considering the average time it takes to access from the communes to the principal point of economic (point N.W.) and tourist attraction (point N.E), as well as to the commune of Roccadaspide where the main services are located.

As mentioned above, the environmental criteria have been expressed as an ordinal scale (1,2,3) where the highest value represents the best.

- For acoustic pollution (vicinity of population centres) due to the noise of the vehicles, the alternative with the highest score is the one that is more distant from the communes.
- For soil pollution (possibility of accidental fall material dangerous for the environment), the alternative with the highest score is the one that is of less interest for a small number of lorries.
- The alternative with the highest score for the landslide risk is the one that is of less interest for the areas with a probability of landslide and steep soil pinpointed by geological studies.
- For hydrological risk, the alternative with the highest score is the one that is of less interest for the flooding areas (return period 50-100-200 years).
- For the loss of vegetation, the alternative with the highest score is the one that causes the lowest loss of vegetation due to the construction of a new stretch of road.
- The alternative with the highest score for the alteration of fauna's habitat is of less interest to the usual route of local fauna identified in the environmental studies.
- For the violation of regulation on natural environment, the alternative with the highest score is the one that does not interfere with the following environmental regulations:
  - boundary of National park of "Cilento and Vallo di Diano" (DL 394/1991)
  - landscape regulation (law 431/1985 and law 1497/1939)
  - Persano Oasis founded in 1977.
- Finally, for 'fitting in the landscape' (change in the landscape morphology), the alternative with the highest score is the one that creates the least change to the morphology of the places as result of the design of the road.

Starting with the above-mentioned criteria, linked to the previously defined alternatives, it is now possible to build up the impact matrix Table 3.

	CRITERION	INDEX	A	B	C
Econ	Investment costs (-)	Mld	107	143	127
	Transport Maintenance costs costs by C (-) and L (-)	Mld/Year	36 1	39 1.3	35.4 1.3
	Transport costs by C and L+ time costs (-)	Mld/Year	64	71	63
Accessibility	Time needed from C and L on entire network (-)	Minute	32.2	37	32
	Time for C to access from the communes to N.W point (-)	Average minute	30	34	29.7
	Time for L to access from the communes to N.W point (-)	Average minute	32.5	38	32.2
	Time for C to access from the communes to N.E point (-)	Average minute	38.7	42	38.4
	Time for L to access from the communes to N.E point (-)	Average minute	43.8	48	43.5
	Time for C to access from the communes to Roccadaspide (-)	Average minute	24.3	29.4	24.1
	Time for L to access from the communes to Roccadaspide (-)	Average minute	26.8	32.7	26.5
Environment	Vicinity of population centres (+)	Qualitative	3	1	2
	Possibility of accidental fall of dangerous material (+)	Qualitative	2	3	3
	Landslide risk (+)	Qualitative	3	1	2
	Hydrology risk (+)	Qualitative	2	3	3
	Loss of vegetation (+)	Qualitative	2	1	2
	Alteration of fauna's habitat (+)	Qualitative	2	1	2
	Violation of regulation on natural environment (+)	Qualitative	3	1	1
	Fitting in the landscape (+)	Qualitative	2	3	1
	Change in the landscape morphology (+)	Qualitative	2	3	2

Table 3 Impact matrix

Legend:

- C = private car
- L=lorry
- (-) = cost indicator
- (+) = benefit indicator

3.4. **The weight vector**

The definition of the system of weights, or in other words, the identification of the priority rankings between the different criteria included in the impact matrix, fundamentally is a political problem. In the present analysis the assignment of weights has been performed on the basis of the hierarchical logic described in Section 3.3.

Two weight systems have been specified. The first one refers to the main classes of judgement (economic, accessibility, environment) and the second one to the sub-criteria. The latter set of weights strongly reflects the preferences of the political class and of the technical experts involved in the project.

The vectors have been calculated with the aid of the Saaty Method software contained in the program for multicriteria evaluations (SamiSoft program). This program, which reproduces the logic described in Section 2.3, allows us to derive a priority ranking through a paired comparison between the criteria based on a scale of 9 point (from 1 = equal important to 9 = extremely important). Moreover, the program allows us to verify the coherence of collected information through the specification of the principal eigenvalue. The first step of the methodology in this study consists of interviewing the political class and the technical experts by means of a questionnaire based on Saaty's fundamental scale in order to identify subjects' preferences among the listed criteria.

The results of the interviews are then used for the calculus of the two weight vectors employed in the evaluation. One expresses the views of the political class, the other the views of the technical experts.

The analysis also considers a vector of uniform weights, in which for each criterion, the priority is assumed to be irrelevant. In other words, all the combinations of weights are equally probable.

Table 4 shows the results of the calculations for the three sets of weights.

		Uniform weight vector		Experts		Public Administration	
		W1	w2	Wl	w2	Wl	W2
E comic	Investment costs	0.25	0.33	0.749	0.089.	0.584	0.056
	Maintenance costs	0.25		0.142		0.133	
	Transport costs by C and L	0.25		0.044		0.036	
	Transport costs by C and L+ time costs	0.25		0.315		0.247	
Access ibi	Time needed from C and L on entire network	0.143	0.33	0.396	0.735	0.384	0.702
	Time for C to access from the communes to N.W point	0.143		0.208		0.147	
	Time for L to access from the communes to N.W point	0.143		0.044		0.036	
	Time for C to access from the communes to N.E point	0.143		0.094		0.107	
	Time for L to access from the communes to N.E point	0.143		0.033		0.039	
	Time for C to access from the communes to Roccadaspide	0.143		0.303		0.269	
	Time for L to access from the communes to Roccadaspide	0.143		0.065		0.024	
Envir onent	Vicinity of population centres	0.111	0.33	0.28	0.676	0.41	0.242
	Possibility of accidental fall of dangerous material	0.111		0.059		0.024	
	Landslide risk	0.111		0.338		0.293	
	Hydrology risk	0.111		0.215		0.198	
	Loss of vegetation	0.111		0.082		0.026	
	Alteration of fauna's habitat	0.111		0.077		0.095	
	Violation of regulation on natural environment	0.111		0.199		0.233	
	Fitting in the landscape	0.111		0.068		0.038	
	Change in the landscape morphology	0.111		0.06		0.05 1	

Table 4 Table of alternatives weight systems

Analysing the preferences expressed by the public administration and the group of experts for each criterion, we find:

the importance of the "Investment cost" in regard to the Economic criterion,

the importance of "time needed from car and lorry on entire network" in regard to the Accessibility criterion,

the importance of "landslide risk" and "Hydrology" risk for the experts while the public administration attached a high importance to the pollution problem in regard to the Environment criterion.

In general, the weights linked to the main evaluating classes reflect the preferences for the criterion of accessibility. Particularly the interviewed group of experts appears to assign a value quite similar to the accessibility and environment criteria, while the public administration assigns a higher value to the accessibility criterion.

3.5. Rank order of alternatives using the Regime analysis

The previously defined impact matrix, linked to the weight vectors calculated in the last section has been further analysed by the Regime method. The Regime method, as described in Section 2.2, allows us to analyse a matrix with mixed data linked with a weight vector and to define a ranking of the alternatives.

The results obtained (Table 6-7-8) using a new software for multicriteria analysis (SamiSoft program) are expressed by an index of success for each alternative. This index emphasises how much a project is preferable, compared to others.

In the case study under analysis, the software used for multicriteria analysis considers all the input scores as benefit criteria, where the highest value is the best. In our impact matrix we have both cost and benefit criteria, so we have to transform the cost criteria into benefit values using a standardisation function (A_{min}/A) that is able to obtain values between 0 and 1 where the highest score is the best (Table 5)

	CRITERION	INDEX	A	B	C
Economic	Investment costs (+)	Mld	1	0.75	0.84
	Maintenance costs (+)	Mld/Year	1	0.77	0.77
	Transport costs by C and L (+)	Mld/Year	0.98	0.91	1
	Transport costs by C and L+ time costs (+)	Mld/Year	0.98	0.89	1
Accessibility	Time needed from C and L on entire network (+)	Minute	0.994	0.864	1
	Time for C to access from the communes to N.W point (+)	Average minute	0.99	0.873	1
	Time for L to access from the communes to N.W point (+)	Average minute	0.991	0.847	1
	Time for C to access from the communes to N.E point (+)	Average minute	0.992	0.914	1
	Time for L to access from the communes to N.E point (+)	Average minute	0.993	0.906	1
	Time for C to access from the communes to Roccadaspide (+)	Average minute	0.992	0.82	1
	Time for L to access from the communes to Roccadaspide (+)	Average minute	0.99	0.81	1
Environment	Vicinity of population centres (+)	Qualitative	3	1	2
	Possibility of accidental fall of dangerous material (+)	Qualitative	2	3	3
	Landslide risk (+)	Qualitative	3	1	2
	Hydrology risk (+)	Qualitative	2	3	3
	Loss of vegetation (+)	Qualitative	2	1	2
	Alteration of fauna's habitat (+)	Qualitative	2	1	2
	Violation of regulation on natural environment (+)	Qualitative	3	1	1
	Fitting in the landscape (+)	Qualitative	2	3	1
	Change in the landscape morphology (+)	Qualitative	2	3	2

Table 5 Standardised impact table

Our investigation of Table 6 shows that the ranking of alternatives obtained when using a uniform weight vector in the final results, leads to a supremacy of alternative A.
Actually, the intermediate results show that alternative A is the winner for both economic and environmental criteria, while alternative C wins only for the Accessibility criteria.
Alternative B is always the loser.

Criteria	Intermediate results			Final results		
	A	B	C	A	B	C
Economic	1	0	0,5			
Accessibility	0,5	0	1	0,88	0	0,662
Environment	0,82	0,18	0,5			

Table 6 Rank order of alternatives using the uniform weight vector

However, considering the results of Table 7 and 8 obtained when using the weight vector (previously calculated with the Saaty method), from the point of view of the experts and the public administration, alternative C turns out to be the best in the final results. This is the case, even if the intermediate results show once more that alternative A wins on both economic and environmental criteria. Also under these circumstances, alternative B is always the loser.
The supremacy of alternative C depends on the higher value of the weight assigned to the criteria of accessibility.

Criteria	Intermediate results			Final results		
	A	B	C	A	B	C
Economic	0,97	0.04	0,5			
Accessibility	0,5	0	1	0,65	0	0,79
Environment	-1	0	0,5			

*Table 7 Rank order of alternatives using the weight vector from the point of view **of** experts*

Criteria	Intermediate results			Final results		
	A	B	C	A	B	C
Economic	0,97	0.04	0,5			
Accessibility	0,5	0	1	0,65	0	0,79
Environment	1	0	0,5			

Table 8 Ranks the order of alternatives, using the weight vector from the point of view of public administration

In conclusion, alternative C appears to be a good compromise between the necessity to improve the mobility of people and goods among the Communes and the external point of economic and tourist attractions, as well as in the necessity to preserve the natural heritage.

3.6. Sustainability of alternatives using the Flag Model

In this paragraph, we will illustrate the application of the Flag Model on the case study under analysis to check the sustainability of the alternatives in relation to a set of threshold values.

This analysis is carried out using software (the Flag Model) that includes a program for multicriteria analysis (SamiSoft program), which essentially reproduces the logic previously described in section 2.4.

The program has two inputs: an impact matrix and a set of critical threshold values.

Therefore, it is necessary to establish a critical threshold value for each of the relevant criteria in the impact matrix previously described in section 3.3. The concept of critical threshold value is related to the normative concept of sustainability (see Nijkamp and Ouwershoot, 1997) - where wider attention is focused on how sustainability can be identified as a normative orientation for policy.

In other words, the question is whether it is possible to define a set of reference values or threshold values (limits, standards norm) on resource use and environmental degradation (pollution) to verify the impact of policy strategy and projects on the environment and society.

In this context, the notion of carrying capacity is of great importance, as it indicates the maximum environmental resource that is still compatible with an ecologically sustainable economic development. This means that this concept refers to a threshold value that cannot be exceeded without causing unacceptably high damage and risk to the environment.

Clearly for each of the sustainable indicators, whether environmental or socio-economic, a CTV as to be specified so that an entire set of CTV' s may act as a reference system for judging actual states or future results.

A major problem is the fact that the CTV level is not always unambiguous. In certain areas and under certain circumstances, different expert and decision-makers may have different views on the precise level of an acceptable CTV.

A relatively simple and manageable approach to the above problem is the introduction of a bandwidth for the corresponding sustainability indicator (min-max condition). On the other hand, CTV max refers to the maximum allowable value of sustainability indicators, beyond which there an alarming development will take place (max-max condition) (Nijkamp and Ouwersloot, 1997).

In this specific case the bandwidth of critical threshold values, due to the lack of normative references values, has been defined on the basis of the judgement expressed by the group of experts involved in the project. It has also been based on the average values typical of the area under analysis.

In particular, the economic criteria were examined:

on the *investment cost* we consider as a limit the budget available to realise the project

CTV_{min} = 85 MLD of lira; CTV = 100 MLD of lira; CTV_{max} = 150 MLD of lira

for the *maintenance cost* we consider the average cost calculated for the Campania region in regard to the actual road condition.

CTV = 1,5 MLD of lira per year

on the *transport cost by* C *and L* we consider the average cost for car and lorry to move estimated for the Campania region.

CTV = 33. MLD of lira per year

on the *transport costs by C and L + time cost* we consider the average cost for car and lorry to move plus the value of the time estimated for the Campania region.

CTV = 66. MLD of lira per year

Looking into the criterion of accessibility, we assume a range of threshold values estimated by the experts, making a distinction between the internal accessibility among the communes and the accessibility as regards the external point of attraction (N.W. point and N.E. point)

For the internal accessibility we consider:

CTV_{min}= 15 Average minute; CTV= 20 Average minute; CTV_{max}= 30 Average minute

For the external accessibility we consider:

CTV_{min}=30 Average minute; CTV= 45 Average minute; CTV_{max}= 60 Average minute.

Looking, instead, into the environment criterion, as the qualitative nature of the scores, we assume that the value 2 in the predefined ordinal scale (1,2,3) represents the minimum allowable value of sustainability indicators, beyond which an alarming development could take place.

Table 9 shows the results of the calculation points up to the frequency of flags in relation to each relevant class of criteria and the total scores for each alternative. Moreover, Figures 4-5-6 show the frequency of flags for each alternative in a qualitative sense in a cluster column chart.

	ALL FLAG				BIOPHISICAL INDICATORS				ECONOMIC INDICATORS				SOCIAL INDICATORS			
	B	R	Y	G	B	R	Y	G	B	R	Y	G	B	R	Y	G
A	2	5	3	10	0	0	0	9	1	3	0	0	1	2	3	1
B	4	4	8	4	0	0	5	4	2	2	0	0	2	2	3	0
C	2	5	5	8	0	0	2	7	1	3	0	0	1	2	3	1

Table 9 Frequencies of flags

B= Black flag: stop further growth

R= Red flag: reverse trend

Y= Yellow flag: be very alert

G= Green flag: no reason for specific concern

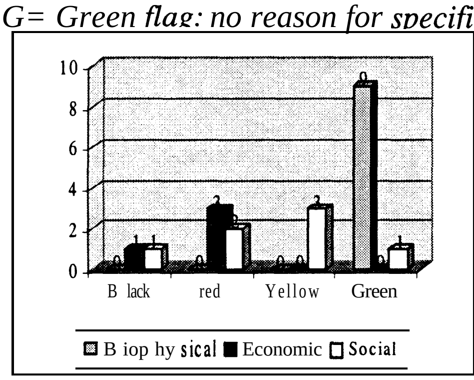


Figure 4 Alternative A

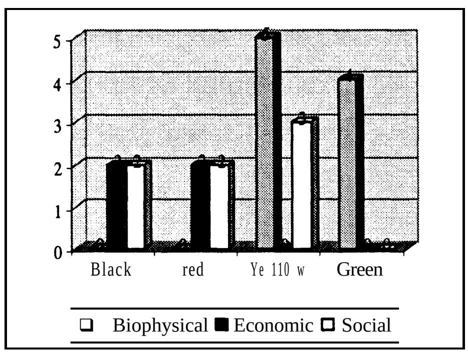


Figure 5 Alternative B

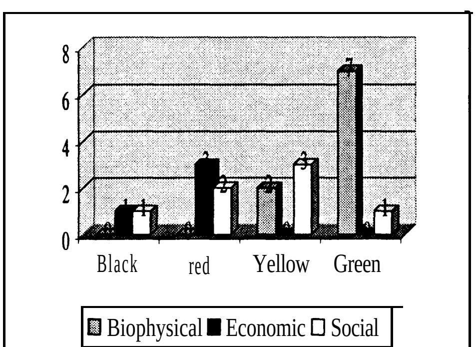


Figure 6 Alternative C

Our investigation of Table 9 shows that alternative A is the most sustainable. In fact, it has 10 green flags in the total scores, determined mainly by the biophysical indicators, as was expected. Upon examining the economic criterion, all alternatives appear to be unsustainable, while for the social criterion (accessibility), alternatives A and C are more sustainable than alternative B.

4. Conclusion

The aim of this study was to analyse the sustainability and the priority of project alternatives in order to achieve a new road network in the area of National Park of Cilento.

The application of the method described in the previous sections has led to the definition of a dominance degree for each alternative, checking in the meantime its sustainability in relation to the pre-defined set of threshold values.

Our investigation of the results shows that alternative C better satisfies the need to improve the accessibility of the area under analysis, not only in regard to the external point of attraction, but also in relation to the internal connection among the communes. The study on sustainability, however, shows that alternative A better meets the environmental issues, as was expected, because it was mainly developed outside the National Park.

Alternative B always gets the lowest scores.

In conclusion, the employment of the previous described multicriteria methods represent a useful tool to reduce conflicts in a decision making process. Three critical points deserve our attention. First, there is the possibility of analysing conflicting objectives, even if a qualitative assessment has to take place. Secondly, we could take into account the subjectivity of policy makers and experts, and check the impact of each relevant choice. And finally, the use of CTV's appears to offer an operational framework for sustainability analysis at regional level, although lack of quantitative and reliable information (as in our case) may force to resort to qualitative assessment.

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