A PRIORI EVALUATION OF TRANSPORTATION PROJECTS

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ABSTRACT

This paper proposes one approach for evaluation of efficiency of an urban transportation service in a multi actors and multi criteria framework. A priori analysis is intended for clarifying options, by reducing uncertainty and, more generally, by providing information about the alternatives in their specific context. Firstly, a diagnosis phase based on hierarchical ascending classification is performed for grouping actors in agreement with pertinent criteria that they have selected. The evaluation of the main impacts is based on the aggregate probability to use the service by users of transportation network. For it, stated preferences are collected from a representative sample size and an algorithm based on Fuzzy Logic allows us to obtain the probability to use a new transportation service. The robustness analysis for evaluating behavioural changes in agreement with external criteria is studied with Taguchi's method. The search of an optimum solution is done with Doehlert's framework and consists in defining a combination levels of criteria for the best satisfaction of the requirements and constraints of the ones (urban planners, traffic engineers) and the exigencies of the others (users, residents).

Keywords: a priori evaluation, transportation service, use rate, stakeholders, stated preferences

1. INTRODUCTION

Urban society faces an unrestrained growth of mobility and, more specifically, of the car use. Public authorities try as much as they can to limit their negative environmental impacts. But the public transportation planning is a highly complex task. First, the process involves a host of very different criteria (economic, environmental, social, etc.) and, second, there is more than one stakeholder with different points of view or perceptions of these criteria (see Georgopoulou et al., 1998; Roy 1999).

In past years it was accepted that even a 'perfect' project could be socially unacceptable (Dente and Fareri, 1998) because it is increasingly exposed to resistance or dissatisfaction from the people they affect. In this somewhat controversial statement, the term 'perfect project' refers to a project which is thought out, studied and designed extremely well in all its aspects by a group of competent experts, but which is also designed in a vacuum, without a communication strategy or a mechanism to ensure the participation of all stakeholders.
We consider that a successful implementation of a transportation project includes one preliminary analysis of the problems that occur in the urban area. During this step the perception of phenomena and the preferences of all stakeholders are taken into account for the selection of a set of pertinent criteria. The participation and "concertation[1]" between stakeholders reduce conflicts because no one point of view is neglected.
For solving problems in an urban area several strategies (alternatives) can be pointed out. The selection of one alternative needs the development of a method for a priori evaluation of the potential impacts. At short or medium time level (< 5 years), we consider that all impacts are dependent on the use rate of the service. Because the evaluation is done ex-ante, the consequences of transportation, their environmental impacts must be computed (by traffic simulation or models) in order to evaluate the expected efficiency of each alternative.
But even at short time, the use rate of a service can change in agreement with external criteria (such as price of gasoline, accessibility conditions). A robustness analysis of impacts must be done in a dynamic environment. When a selected alternative is technically feasible a compromise solution can be searched in order to better satisfy the preferences of stakeholders.
The main steps of our approach are presented in Figure 1 and they illustrate the structure of our paper.

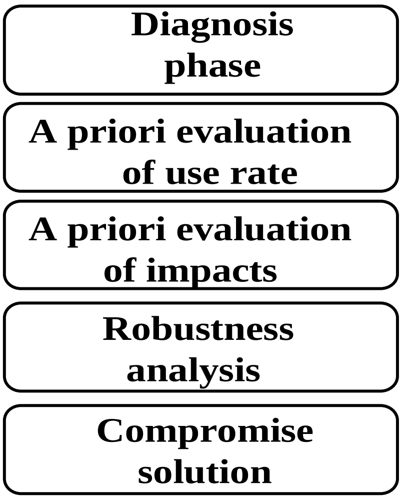


Figure 1- Main steps of our approach

Section 2 presents the principle of our evaluation approach and fixes the temporal framework for *a priori* evaluation. Section 3 describes how the diagnosis of an urban area is performed for grouping actors in agreement with the similarities of their perception of phenomena and for classifying pertinent criteria. Section 4 shows how the probability to use a new service

1 The French word ''Concertation'' does not have any real equivalent in English. It designates a participative decision process where the various stakeholders are able to express their point of view and have it taken into account in the decision- making process

can be estimated in despite with the vagueness perception of its future quality. In the section 5, we propose the robustness analysis to capture behavioural changes of the users. Section 6 describes a method for searching a compromise solution satisfying all stakeholders. Discussion elements are described in the section 7. The section 8 is dedicated to conclusions and perspectives. To better illustrate our approach, we propose a case study for the implementation of a transportation project (Park and Ride) with the aim to underline the role of the a priori evaluation in the improving of project's efficiency.

2. PRINCIPLE OF A PRIORI ANALYSIS

2. 1. Method for *a priori* evaluation

Different methods are used nowadays for projects evaluation:

- Cost Benefit Analysis (CBA): The effects are represented in a monetary value, and included in an overall economic appraisal of the total value of the project in monetary terms.

- Multi-Criteria Analysis (MCA): The effects are not necessary represented into monetary value, but are included in an overall project appraisal by assigning non-monetary weights to the individual effects.

- Quantitative Measurements (QM): The effects are estimated in physical units or numbers (cardinal scale), but in contrast to the multi-criteria analysis (MCA) no specific weights are assigned to allow an aggregation of the effects to a single criterion.

- Qualitative Assessment (QA): The effects are classified into one of several ranked categories (ordinal scale) based on well-defined standard criteria for each of the categories, which are invariant from project to project

All impacts can not be evaluated with CBA since Multi criteria tools explicitly take into account several criteria, even those that are very different in nature and not necessary quantitative. Many techniques exist for attributing weights of criteria and interactions such as AHP or Macbeth (Figueira and all, 2005). But the assignment of weight remains a particular problem, especially for interactions between criteria. In the multi actors' context, the classification of alternatives could generate conflicts between the stakeholders because of different views for the same criteria. Roy (1985) pointed out that "the aim of multiple criteria decision aid is not to discover a solution, but to construct or create a set of relations amongst actions and better inform the actors taking part in a decision process".
For these reasons, the solution retained is the Quantitative Measurements (QM) where each evolution of criteria is computed and actors are faced with these results. Because the alternatives have not been implemented yet, only an *a priori* analysis can be done in order to evaluate the expected efficiency of each one.

2.2. Temporal framework

We suppose a set of criteria X= {X_1, X_2…X_i…X_n}. The evolution of each criterion can be computed as follows:

$$e_i(\%) = \frac{X_{i\,in} - X_{i\ \exp}}{X_{i\,in}} \tag{1}$$

$X_{i\ in}$ – Initial value of the indicator $X\,i$

$X_{i\ \exp}$ – Expected value of indicator Xi

The indicators can be presented in quantitative manner (e.g. traffic flow level) or in monetary terms. If the evaluation is done for a long horizon (5-20 years) the reference scenario (initial values of criteria) is done by business-of-usual scenario (conceptual baseline scenario which projects what would happen in transportation area if there were no changes).
When the evaluation is done for a short or medium period (1-5 years) the initial state corresponds to the moment that precedes the implementation of the project because economic and urban context will not fundamentally change. We have been placed in the context of a short period (< 5 years), when only contextual changes are expected (such as the price of the carburant). In this case, the values of indicators for the initial and final state can be evaluated by experimental measurements (e.g. traffic level) or formulas (emissions).

3. DIAGNOSIS OF URBAN AREA

Diagnosis is the process of identifying the strong and weak points of an urban area. In our case, the interest of diagnosis step is to define the groups of stakeholders and the main important criteria for different groups. For Keeney (1993), the stakeholders should be involved as soon as possible in the decision-making process because this increases their willingness to cooperate. “Concertation” entails the participation of multiple actors and supposes that their varied views are somehow taken into account (Damart and Roy, 2009). The concertation is a solution to better understanding of transport problems and helps generate innovative solutions and can be a key factor of acceptability for transport strategy.

3.1 Individual perception of phenomena

Because the decision is the result of interactions among the actors, it is crucial to understand who the actors are, what role each one plays and what they expect from the decision-making process. An actor or stakeholder is any participant in this process, such as the decision-maker, the analyst and any individual or group interested in or affected by the decision.
The stakeholders for a medium size project can usually be grouped into the following categories (figure 2): the key decision-makers are directly linked to the project manager; the project manager, together with the city officers and the external experts, constitute the ‘core planning group’; media and the general public; the representatives of interest groups participate through a ‘project group’ and express their points of view, and bring in new ideas.

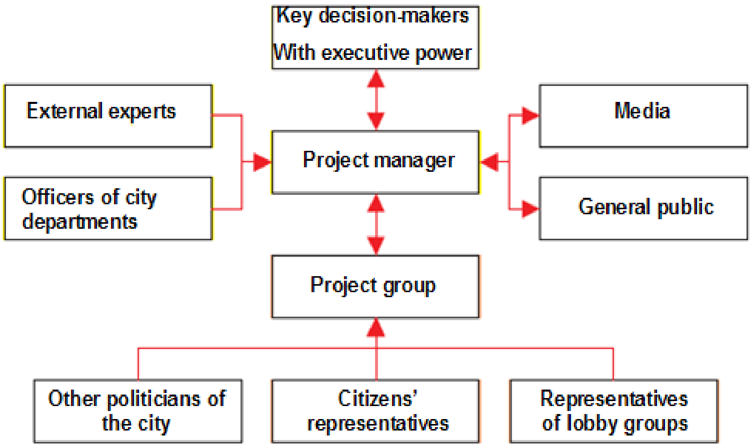


Figure 2-Actors for a medium size project. (*Source: Kelly, 2004)*

We can remark that generally the stakeholders are grouped according their socio-professional characteristics. Our proposal is to represent the group of stakeholders based on their perception of urban reality, their sense of the preference for the criteria evolution: the criteria should be minimized or maximized.
For it, the selection of pertinent criteria is a fundamental step. Nothing serves to implement techniques of evaluation if the way that the criteria were constructed was proved inconclusive. The participatory nature is evident in this situation. Today, it is no predefined and systematic method of criteria construction.
We'll define the criteria according to the preferences of stakeholders of decision process. A questionnaire is submitted to the actors in order to capture the individual representation of the mobility system and its consequences in the urban area. The collection of responses is done in several steps:
1) Firstly we present to the stockholders a set of phenomena and criteria corresponding to 4 categories: economy, energy, environment, transport (example Table I).

Table I: Impacts and Criteria of evaluation

CATEGORY	PHENOMENON	CRITERIA
ECONOMY	Balance costs/benefits	Operating revenues
		Costs
ENERGY	Fuel Consumption	Gasoline consumption
		Diesel Consumption
ENVIRONMENT	Emissions	CO2
		NOX
		PM
	Noise	Level (dB)
TRANSPORT	Service reliability	Accuracy of timekeeping
	Transport Safety	Number of accidents
	Traffic levels	Number of vehicles/hour
	Congestion level	Number of vehicles/km

Each representative stakeholder describes the perception of the phenomena. We propose this type of question: "What do you think about the traffic level in this urban area? It is high, weak, moderate?" The people interviewed can answer only to questions that they are concerning.

2) In this step, the people propose the improvements desired for the criteria: For example: "If the traffic level is high, what kind of evolution you expect: to maximise or to minimise?"
3) To highlight the interaction between the criteria we use this type of question: "If the traffic level is minimised, what about the rest of criteria? Are they minimised, maximised or not changed?"

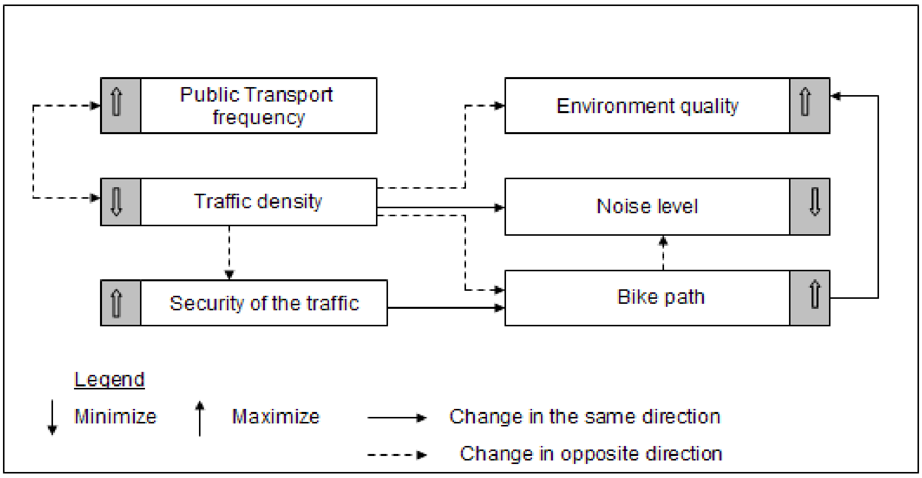


Figure 3: Causal representation of transport phenomena

The modelling of the mobility image of the city with all socials, economics and politics interactions gives a form of causal model of the actors. The interpretation of this model permits to highlight critical phenomena through considering the preferred causal axes in order to output the stakeholder's goals.

3.2 Collective perception of phenomena

The individual representations can be integrated into a collective representation using analytical tools (classification, aggregation). The collective representation of the mobility is described by a matrix of dissimilarity between individual models. The groups of actors are created according the converging and diverging elements of actor's preferences about the urban mobility. The criterion of the classification of the groups is the minimum dissimilarity between the members of each group. This method is largely described in works about SIG (Desthieux, 2005) and has been adapted for our approach in transportation context.
The method described creates an advantageous framework for the interaction between these stakeholders around the representation of urban reality. There are several interests of the diagnosis step:
-The stakeholders are grouped in agreement with the perception of phenomena and their preferences (and not according their socio-professional characteristics) (Figure4).

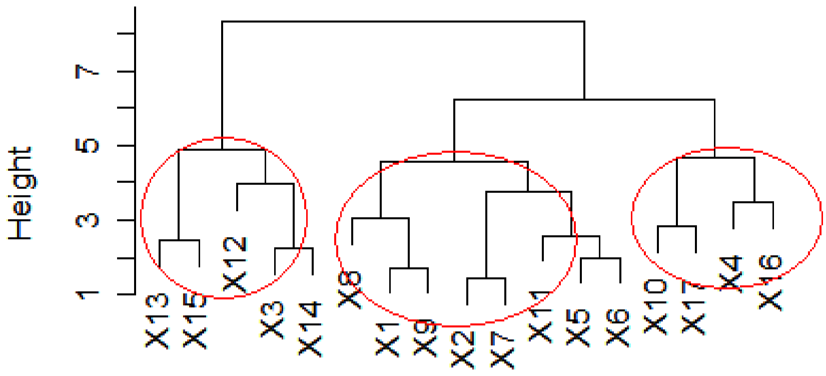


Figure 4: classification of stakeholders

According this representation, we choose the evaluation group among 200 persons. The 17 stakeholders are grouped in three classes. In the fist class, five people are represented. The method of classification is the hierarchical ascending classification with Ward principle (S+ software). This principle regroups the people with the minimum of the distance between the preferences of criteria.

A set of pertinent criteria corresponding to expected changes can be selected for each group (without searching to associate weights for criteria).

This framework for the interaction between the stakeholders generates innovative solutions (alternatives) to solve problems. For example, if the diagnosis shows a strong traffic level in an urban area, several alternatives could be proposed (such as the implementation of a bus lane, a bike path or a car-pooling service).

In order to better illustrate this step of our approach a study case is presented below.

3.3 Study case: implementation of a Park and Ride

<u>One unsuccessful transportation project</u>

A Park-and-Ride has been built at the northern entrance of La Rochelle, France (a medium sized city) and links the city centre to an important residential area comprising five towns of the Urban Community. A park and ride is a public transport station that allows commuters and other people wishing to do a travel into city centres to leave their personal vehicles in a park station and make the rest of the trip with a bus, rail system (rapid transit, light rail or commuter rail), or carpool.

In despite on security conditions, promotion activities, particular efforts done by the Transportation Service to implement an innovative project, the number of park-and-riders (subscribers) has never exceeded 10 (for 100 available parking places). After analysis, the main barriers explaining this unsuccessful project are:

- Lack of diagnosis phase: the presence of a large free car park very close to the city centre (a few hundred meters only from the city centre). Commuters working in the city centre can quite easily reach this car park and find free spaces. They do not really yet need to find an alternative solution.

- Lack of analysis of preferences and expectations of potential users: without the presence of quick transportation mode for arriving in the city centre (dedicated bus lane, or path bike, or dedicated shuttle service for example) they can not see the interest to park.

- Lack of "concertation" between actors: discussions have occurred between the Urban Community and the Council of the City for considering an entrance fee to access this free parking, which would enhance attractiveness of the Park-and-Ride for commuters but no political decision has been taken so far. In fact, two local elections took place, i.e. in June 2007 and March 2008. The political risk of suppressing several hundred free car parks has been considered too high.

- Lack of "concertation" with the residents: La Rochelle Urban Community negotiated with the owners of the three houses located on the targeted area (of the Park&Ride site). Two of three houses were demolished; for one house, the owner refused to sell it (the result was only 100 parking places for 120 planned).

<u>Alternatives to improve the efficiency of the park&ride</u>
What is possible to do now, in order to ameliorate the efficiency of Park&Ride, is to analyse the behaviour of potential users. For it, the main actors must be selected and corresponding criteria must be identified.
<u>Main impacts and corresponding criteria</u>
Table II presents the main criteria selected and the sources used for estimating initial and expected values.
Only traffic and environmental criteria will be discussed in this paper. It is clear that impacts such as use rate, traffic flow and average speed are pertinent for traffic engineers, and emissions, acoustic level, average speed are interesting for the residents of the city centre, network users and ecologists.

Table II: Impacts, criteria, sources

Impact	**Criteria**	**Source**	
		Initial state	**Expected state**
Use rate of Park&Ride	number of users/peak period	counting	model
Traffic level	number of light vehicles/peak	counting	model
Average speed	average of instantaneous speed/hour	measurements	simulation
Traffic density	number of vehicles/ road space	counting	simulation
Emissions	CO2, CO, Nox, PM	model	model
Acoustic level	Noise level (monetary)	measurements	model

For initial state : Traffic measurement stations located at strategic points of the studied area collected data such as average value/hour of the number of vehicles (distinction between cars and trucks/buses) and average value/hour for speed of vehicles. COPERT III methodology (Ntziachristos, 2000) is used for computing fuel consumption and traffic emissions.

For final (expected) state: Traffic characteristics can be simulated by a object-based micro simulator that we have been adapted by our team in our previous works (Teng, 2008). Traffic characteristics, fuel consumption and pollutants concentration are the outputs of this simulation according the use rate of park and ride (Figure 5).

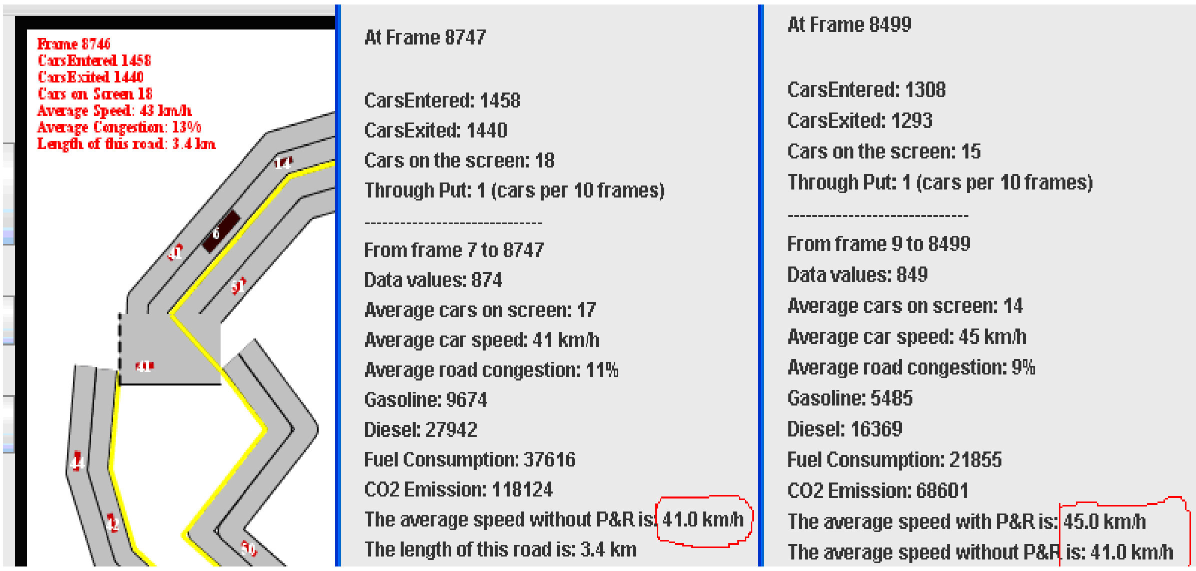


Figure 5 -The output of the road without and with P&R

It is easy to see that the average speed increased with 5 km/h when the occupation rate of the Park and Ride is about 44%.
Next paragraph shows how the number of users and the impacts of the modal changes could be estimated in a probabilistic manner.

4. EVALUATION OF ALTERNATIVES

4.1. Probability to use a public service

At short time (<5 years) all criteria (see table I) are depending on the probability of the network users to use the service: bus, bike, car-pooling, etc. Because of a priori analyse, only probabilistic discrete choice models based on the vagueness perception of the new alternative can be used for evaluating the main impacts. The expected number of people Ni using a certain travel option equals the sum over each individual of the probabilities of choosing an alternative:

$$N_i = \sum_n P_{in} \qquad (2)$$

Discrete choice model can be represented in general by

$$P_{jq} = f_j(x_q) \qquad (3)$$

Where P_{jq} is the probability that individual q selects opinion Aj. x_q is the set of variables influencing her decision and fj is the choice function for Aj (see some examples in (Juan Dios, 2002)). While a disaggregate model allows us to estimate individual choice probabilities, we are normally more interested in the prediction of aggregate travel behaviour.

For a population of Q individuals the aggregate proportion choosing a travel mode Aj is the expected value of the probabilities of each individual.

$$P_{jQ} = \frac{1}{Q}\sum_{q} f_j(x_q) \qquad (4)$$

In agreement with the studied problem, there are several means to establish representative sample sized of the population: the artificial sample can replicate the population of each zone concerned by the new project. Another practical method is known as the classification approach which consists in approximating (3) by a finite number of relatively homogeneous classes, as in:

$$P_{jQ} = \sum_{q} f_j(X_c)\frac{Q_c}{Q} \qquad (5)$$

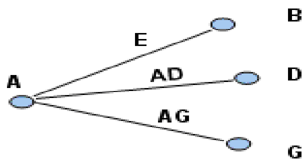
Where X_c is the mean of the variable set vector for subgroup c and Q_c / Q is the proportion of individuals in the subgroup.
When this probability is known, expected number of users is known (formula (2) and the evolution of each indicator Xi selected for illustrating the evolution of one impact Ij (e;g. NOx emissions for air quality) can be computed by using formula (1).

4.2. Individual preferences

The evaluation of the probability to use a service is based on stated preferences of network users. Criteria affecting the perception of the quality of the service can be tested (such as price, distance to a service, etc.). Many techniques were employed in specialized applications (Ben-Akiva, 1999).
The difficulty of those methods is to establish the decision rules IF-THEN for building the behavioural model. In theory it is possible to consider all combinations of variables, but it leads to an explosion of the number of rules (a questionnaire to examine the effects of the variation of 6 input variables, at 2 levels, needs $2^6 = 64$ questions). For our analysis it would be strongly exhaustive. For collecting the preferences of the potential users of a new service, a method generally employed for the optimisation of industrial process has been used to reduce the number of scenarios to test (questions).
An orthogonal factorial design is a subset of a complete plan (Taguchi, 1987). For studying jointly the effects of the criteria and the interactions, the questionnaire must contain particular combinations: each level of each criterion must be present an equal number of times as well as each combination between the levels of two distinct criteria. In each scenario, the simultaneous variation of input several criteria can exert interactive effects on the studied answer. Each scenario (question) is penalised by a score Sin in a given range (1-6, for example). Table III presents one example and a linear graph for the assignment of the columns (the nodes correspond to the criteria; the arcs correspond to possible interactions)

Table III- Orthogonal array

	Actions ou interaction					
Question	**A**	**B**	**D**	**E**	**G**	**Score**
1	1	1	1	1	1	
2	1	1	2	2	2	
3	1	2	1	2	2	
4	1	2	2	1	1	
5	2	1	1	1	2	
6	2	1	2	2	1	
7	2	2	1	2	1	
8	2	2	2	1	2	



In order to establish the scores for all the scenarios not-tested, we used the principle of the models of discrete choices (Ben-Akiva, 1999). An individual n, facing discrete alternatives $i \in I$, chooses the alternative that maximises utility (6):

$$U_{in} = S_{in} + \varepsilon_{in} \qquad (6)$$

Where S_{in} (in our case called score), is a determinist part, related to the characteristics of the alternative i, ε_{in} is a random variable of unknown value, is an unobservable component of utility which captures the dispersion of choices, particular of each person. Its score function can be represented by an additive model as follows:

$$S_{in} = M + (a_1 a_2)A + (b_1 b_2)B + (c_1 c_2)C + ... + \begin{pmatrix} a_1 b_1 & a_1 b_2 \\ a_2 b_1 & a_2 b_2 \end{pmatrix} AB + ... \qquad (7)$$

Where $a_i = S_{av}(A_i) - M$ is the effect of an input variable, for example A, at the level *i* and $a_i b_j = S_{av}(A_i B_j) - M - a_i - b_j$ represent the effect of interaction between two variables AB when A is on level i and B on the level j; M-average of all the results; S_{av} (A_i) - average of all the results with A on level i; Sav(AiBj) - average of all the results with A on level i and B on the level j. The remarkable propriety is that the sum of matrix elements is always zero.

Where $\sum_i a_i = 0; \quad \sum_i \sum_j a_{ij} = 0$

The model allows us to estimate the score that each respondent would put for untested scenarios. For example, the model being additive, the deterministic part of the utility (score) corresponding to a scenario n for an individu i for A on level 2 and B on level 1, is calculated in the following way:

$$S(A_2 B_1, ...) = M + a_2 + b_1 + a_2 b_1 + ... \qquad (8)$$

Finally, the scores (evaluated by questionnaire or obtained by model) are fuzzified on two modalities ("very interested" and "not interested").
A fuzzy subset A of a set X is characterized by assigning to each element x of the set X of the degree of membership of x in A (Zadeh, 1965)

For representing vague information, one defines a trapezoidal function of membership; the value indicates the "degree" of membership of an output variable to a unit. As example, Figure 6 shows the fuzzification of final score.

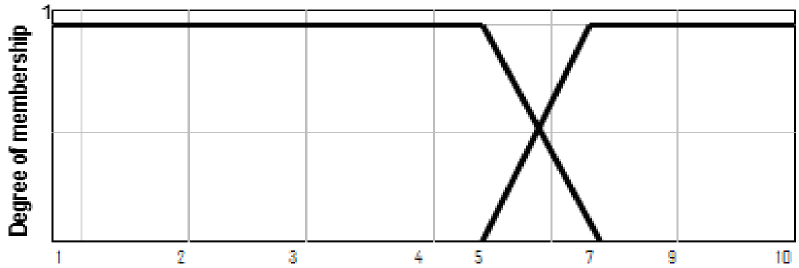


Figure 6- Score fuzzification

If the score S_{in} is:

- $S_{in} < 5$ the person is not interested for the project;
- $5 \leq S_{in} < 7$ the person is undecided
- $7 \leq S_{in} \leq 10$ the person is interested for the project

4.3. Aggregated preferences

After the application of the fuzzy logic algorithm, for each respondent, we can have 2 situations: person is decided (the membership degree is 1 for one of two output modalities: "very interested" or "not interested") or person is undecided (the output variable is distributed on both modalities).

The belief theory is a framework to represent quantified uncertainties (Shafer, 1976). Let θ be a finite set of hypotheses mutually exclusive and exhaustive called the frame of discernment. In our case θ is θ = {Not interested, Very interested}. Generally the mass assignment is the most critical stage and it depends on the application domain. In our case, the mass assignment is based on the frequentist analysis. For a given scenario we can obtain, for the tested scenario: n% persons « very interested »; p % for « not interested »; and q% for «undecided».

The mass (m) assignment is m (very interested) = n; m (not interested) =p; m (undecided) = q. For each scenario, the mass of the subsets which are not singletons is redistributed by the pignistic transformation (Smets, 1990):

$$\forall H_i \in \Theta, \quad P_\Theta(H_i) = \sum_{\substack{A \in 2^\Theta \\ H_i \subset A}} \frac{1}{|A|} m_\Theta(A) \tag{9}$$

where P (Hi) is the pignistic probability for Hi; |A| is the cardinality of A (for our example with only 2 singletons, P is redistributed in a Bayesian manner).

The pignistic probability will be used for computing the evolution of the main impacts of the service according to the number of potential users for each representative social category (formula 4).

4.4. Study case: use rate of the Park and Ride

A questionnaire based on orthogonal arrays has been submitted in 2009 in order to analyse the preferences of travellers (workers) for different modes linking the Park and Ride and the hyper-centre (bike, bus, car-sharing and car-pooling). 3024 answers from workers have been collected during 5 months. The sample sized has been considered statistically significant for representing the category of the workers.
Parameters tested are: type of connexion between park and Ride and the city centre, distance on foot from service, price of the travel, type of activity, distance of the travel (table IV). Each scenario is analysing by a score in the range 1-6. The mean score is the average value of all scores for the corresponding scenario.
Figure 7 shows the effects of criteria (average model corresponding to the sample size) in agreement with their levels for Park&Ride + bus and Park&Ride + bike. Main results are:
-The price and the distance on foot from service are the most significant criteria. After analysis of variance, the distance of the travel (from Park and Ride to Centre) is not significant.
- Most important satisfaction level is obtained for both modes for the scenario: price= “low”, distance on foot is“<100 m”, activity =“work”.

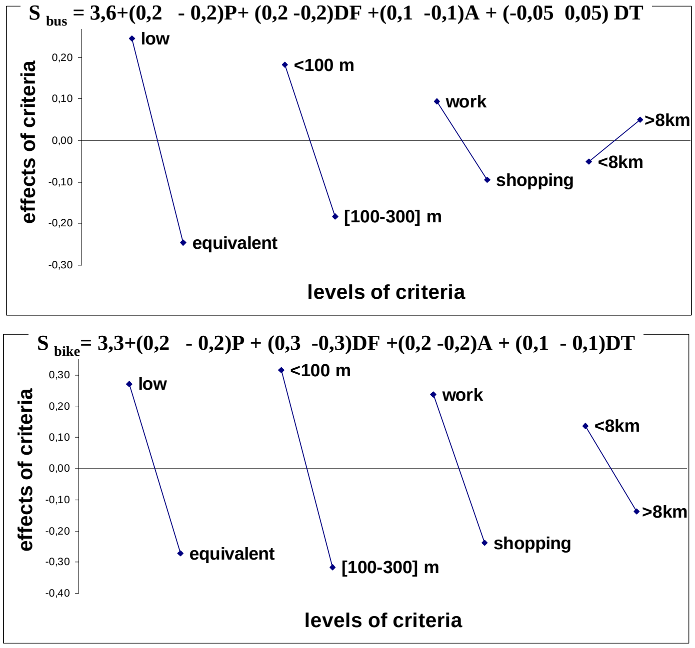


Figure 7: Effects of criteria for the perception of the quality of the service by using bus and bike (P- price; DF- distance on foot; A – activity; DT - distance travel)

After fuzzy logic application and pignistic transformation, the probability to use a service was computed for each scenario.

Table IV: one example of tested scenarios

	Price	Distance to walk	Type of activity	Distance of travel	Mean of score	Pignistic probability
BUS	As the private car	[100-300]	Work	<8 km	3,33	0,52
BIKE	less than the private car	[100-300]	Work	<8km	3,28	0,42

The pignistic probability in last column of the table IV will be used for computing the evolution of the main impacts of the service according to the number of potential users for each representative social category (formula 4). We can see that for two scenarios technically possible the pignistic values are not significantly different. It means that a part of the expected impacts (congestion level, pollution, fuel economy) should be similar. In this case and generally for a most rigorous evaluation of impacts at medium term (about 5 years), a robustness analysis of the users' behaviours must be done.

5. ROBUSTNESS OF USERS' BEHAVIOUR

5.1. Principle of robustness analysis

The term "robustness" is generally associated with that of "risk" and "decision making" (Kleijnen and Gaury 2003, Durieux and Pierreval 2003). The underlying idea of system robustness is generally that the measured functions do not diverge significantly from a given value. The most common approach when studying robustness of a system in production is the well known Taguchi's method (Taguchi, 1987). Taguchi's methodology is based on the use of crossed designs of experiments and a quadratic loss function or a signal to noise ratio (S/N). This S/N ratio takes into account both the variability in the response data and the closeness of the average response to a target value (Mezgar et al. 1997). Table V shows one example with crossed arrays. Higher is this indicator, better the compromise is.

Table V: Crossed arrays for robustness analysis

Outer array

Exp. n° j	1	2	3	4
E	1	1	2	2
F	1	2	1	2
G	1	2	2	1

Inner array

Exp. n° i	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

Y11	Y12	Y13	Y14
Y21	Y22	Y23	Y24
Y31	Y32	Y33	Y34
Y41	Y42	Y43	Y44

responses

Y	σ	s/n
Y1	σ_{1X1}	s_1/n_1
Y2	σ_{2X1}	s_2/n_2
Y3	σ_{3X1}	s_3/n_3
Y4	σ_{4X1}	s_4/n_4

5.2 Robustness analysis in transportation

In spite of attempts that the choices are stationary, it was allowed (Ben-Akiva,1999) that the individuals are not always faithful to an initial behaviour. External conditions (such as the petrol price or characteristics of the travel or of the service) could affect strongly the use of the service and so the results of the initial evaluation. In this case, the analysis of the robustness of the user's preferences must be discussed. Several definitions exist for "robustness" of tactical plan that could by applied in transportation domain. Zäpfel (Zäpfel, 1998) and Roy (Roy, 1998) considered a tactical plan as robust if an operational plan can be calculated for all the possible sets of demand.

Our proposal is that a jointly study of effects of input criteria (known before the implementation of the project, e.g. distance, price ...) and external criteria (such as the carburant price, future characteristics of the service) could test the faithfulness of the users (the evolution of the behaviours in agreement with external criteria). Our proposal is to use a double array, one (inner array) for input criteria (such as price of service, distance, etc) and another (outer array) for external criteria (such as price of petroleum, information system, etc). This study will have several interests:

1. Firstly, the possibility to compute the results of the scenarios not-tested. The score function including the effects of the inner array and outer array is :

$$S = M + \underbrace{(a_1 a_2)A + (b_1 b_2)B}_{\text{Effects of input criteria}} + \underbrace{\ldots + (e_1 e_2)E}_{\text{Effects of external criteria}} + \ldots \qquad (10)$$

The effects of the criteria of the inner and outer array are computed in agreement with formula (7). Analysis of variance can inform about the importance degree of each parameter.

2. Secondly, if several projects are studied in parallel and the probabilities to use the service are equivalent, the decision makers could choose the project according to S/N- signal-to-noise ratio because it is the illustration of the most robust solution. “The strategy of making a product or process robust against noises by selecting the proper level for the appropriate parameters is the lowest-cost way of intentionally designing quality into a system” (Ross, 1988).

3. Several S/N ratios are available depending on the objective of the experimentation; higher is better (HB), lower is better (LB), or nominal is best (NB) (Madu and Madu, 1999). In our study, if the different scenarii have the near probability to use the service, the robustness of the scenario will be analysed according to the nominal ratio.

Nominal is best: $$\left(\frac{S}{n}\right) = 20\log\left(\frac{P_{ij}}{\sigma_{ij}}\right) \qquad (11)$$

P_{ij} is the probability to use a service in the scenario j of the inner array and in the scenario i of the outer array and σ_{ij} is the standard deviation (Table V).

4. Last, imagine that changes of the characteristics of the service (such as the price) are imagined several months after the implementation of the service. In this case, the probability to use the service will change, as well as the corresponding impacts. The final evaluation of the impacts must take into account this evolution.

5.3. Study case: robustness of decision-making

Two possibilities have been considered technical possible:
- bike: price low, distance [100-300] m or < 100 m, activity : work, distance < 8 km
-bus: price equivalent to a car, [100-300] m or < 100 m, activity: work, distance < 8 km

How presented in table III, the probability for using the bus and the bike are not quite different (42 % for bus and 52 % for bike). It is evident that this probability can modify even at short temporal horizon with external criteria such as the accessibility in city centre, the price of petrol, the security of the park&ride.

The decision makers have 2 possibilities:

- compute advantages of each alternative taking into account the evolution of the probabilities if external criteria change.
- select the most robust solution (the solution for what the potential users are insensible to external changes). The results can be submitted to all actors for the next step.

Table VI shows two crossed arrays for studying the robustness of the decision of potential users:

- Inner array contains criteria linked to the alternative (mode, distance on foot, price);
- Outer array contains combinations of external criteria –such as the petrol price, the accessibility from city centre, the presence of a security system of Park&Ride.

For untested scenarios such as three last scenarios of the outer array, data collection and statistical treatment have been done (see section 4).

Table VI: Robustness analysis

		OUTER ARRAY	**security**	no	yes	yes	no	
			accessibility	easy	difficult	easy	difficult	
INNER ARRAY			**petrol price**	present	present	superior	superior	
Mode	**Distance on foot (m)**	**Price of a travel**		**Probabilities Pij**				**20log(Pij/σ)**
bus	<100	lower		0,64	0,65	0,67	0,68	31,2
bus	[100-300]	equivalent		0,52	0,55	0,54	0,53	32,3
bike	[100-300]	lower		0,42	0,54	0,56	0,57	27,9
bike	<100	equivalent		0,47	0,5	0,52	0,52	26,6

If only scenarios 2 and 3 of the inner array are technically possible, the choice corresponds to the second scenario because the S/N is greater, who means a greater faithfulness for the service bus.

<u>Evaluation of impacts of the use of a dedicated bus</u>

In order to simplify the presentation we considered that only a social category is representative of potential users of the service Park&Ride and bus. A survey in 2007 (from 200 respondents) showed that 85% of respondents would be interested to use this service. In this case, the probability to use the Park&Ride and the dedicated bus is the multiplication of probabilities:

$$P = P_{p\,\&\,r} * P_{bus} \tag{12}$$

In this case the number of potential users is 88 (computation takes into account the number of potential users living in North of La Rochelle). For the scenario considered the most robust (dedicated lane bus), the evolution of selected criteria (table II) are presented in table VII.

Table VII: Expected impacts of Park and Ride project (8-10 o'clock)

Criteria	Initial	Expected	Evolution (%)	Evolution
Use rate of Park&Ride +bus	0	88	44%	increase
Traffic flow (veh /hour)	750	678	10%	decrease
Average speed (km/h)	38	42	11%	increase
Emissions CO2(tons/hour)	597	575	4%	decrease
Acoustic level (euros/km)	0,18	0,18	0%	constant

The results correspond to the immediate changes expected. By using the model obtained with formula (10), the results can be extended for 5 years. Actors compare their main objectives (criteria) with expected values. When actors are not satisfied, they can search a compromise solution by using the method proposed in next section. Only the principle is presented because this part has not been done yet for our study case.

6. WORKS IN PROGRESS: COMPROMISE SOLUTION

The search of an optimum solution consists in defining a combination of levels of variables for the best satisfaction of the requirements and constraints of the ones (urban planners, traffic engineers) and the exigencies of the others (users, residents). The main steps of our approach are described below.

1) Identify variables to test: Partners and actors of a new project will establish a set with variables (characteristics) to test. Each variable V varies in a range [Vmin; Vmax] (for example, the frequency of a bus could be defined in the range [1 bus/hour; 6 buses/hour]). Several levels can be defined for each variable in agreement with partners' demand. The idea is to collect information beside all partners about the quality of each combination obtained using corresponding levels of each variable. For instant, only quantitative variables are taken into account (semantic variables, like the comfort perception, can not be included in our model).

2) Questionnaire: testing by questionnaire n variables at m levels means to use a very great number of questions (this kind of questionnaire becomes prohibitive if 4 variables at 5 levels must be tested because 4^5 questions are necessary!). In order to reduce the number of scenarios to be tested, we propose to adapt an approach used in optimization of industrial processes and called Doehlert's network. The principle of this method is to design one non-orthogonal array which uniformly covers the experimental framework. The design of the questionnaire (array of scenarios to be tested) is based on the definition of an initial simplex. If several variables are tested, the reduction of the number of scenarios is drastic (for example, for 4 variables we will obtain 21 questions for 315 possible combinations). Each partner gives a value (score S_{ij}) in the range 1-10 for each scenario which is included in this array. It is possible to imagine a study of users' preferences of a service in agreement with their age, profession (socio-demographic categories).

One example is presented in table VIII:

Table VIII: Part of questionnaire

Non-orthogonal array					Scores					
question	VARIABLES TO TEST				Engineers	Urban planning	Managerrs	...	Category X	Category Y
	Price	Distance	Number of cars	Frequency of a bus						
1	3	300	150	2	1	2	1,45	...	2,15	
...	...	...	...	...	...	...	...	...	...	
3	0,8	200	100	6	2	2	2,6	...	1,8	
...	...	...	...	...	...	...	...	...	...	
21	2,8	100	120	5	4	1	3,85	...	2,13	

3) <u>Modelling scores for each actor:</u> Untested scenarios will be estimated with a designed model from results obtained for tested scenarios. For it, each variable is coded. The operation of coding consists in transforming the value v_i corresponding to the variable V into a coded value x_i:

$$x_i = \frac{v_i - \left(\frac{v_{max} + v_{min}}{2}\right)}{\left(\frac{v_{max} - v_{min}}{2}\right)} \qquad (13)$$

It is the relationship of centring and reduction of variable V. It is easy to see that $x_i \in [-1,+1]$.

Thanks to a regression model, we can estimate the coefficients of a score function and residue value (corresponding to fluctuations of preferences).

$$S = b_0 + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} c_{ij} x_i x_j + \sum_{i=1}^{n} e_{ii} x_i^2 \qquad (14)$$

<u>4) Search of optimum scenario</u>

Firstly, convert each score (or average of scores given by a group of actors) on a function of individual desirability whose nature depends on the objectives to research (to maximize the score for each partner).

$$d_i = (S_{max} - S_i)/(S_{max} - S_{min}) \qquad (15)$$

Where $S_{max} = 10$, $S_{min} = 1$ and S_i is the score obtained for the scenario i (obtained using the questionnaire or using the model). Secondly, define for each scenario i a global desirability (d_{ig}) by using geometric average of individual desirability.

$$d_{ig} = (d_{i1} d_{i2} d_{i3} \ldots)^{\frac{1}{n}} \qquad (16)$$

Where n is the number of partners. It is also possible to imagine a weighted geometric average (weights w_i of partners are different):

$$d_{ig} = (d_{i1}^{w1} d_{i2}^{w2} d_{i3}^{w3} ...)^{\frac{1}{w1+w2+w3+....}} \quad (17)$$

Where w_i varies in the range [1; 10]. For example, for different socio-demographic categories, a criterion to attribute weights could be the number of people for each category susceptible to use the service or could be the demographic level of each urban area concerned by the project. Finally, the model of desirability makes it possible to identify the levels of the variables which make it possible to research the maximum value of global desirability.

7. DISCUSSIONS

Figure 8 resumes the main steps of our approach for a priori evaluation of the efficiency of a service described in sections 2, 3, 4, 5, 6.

A prori evaluation steps	Tools	Actors	output
diagnosis	Systemic analysis	users, expert,politician, media, project group	main criteria group of actors
Collect of users preferences	Questionnaire Orthogonal array	users of the service, ptoject manager	panel of indivudual preferences
Modelling of behavioural Analysis of variance	Vigier's model Statistic tool	project manager	Agregate model Pertinent criteria
Probability to use the alternative	Pignistic probability	project manager users	Use rate
Choice of alternative	Taguchi's methode Abalysis of robustness	users, experts, politician project manager, group	one alternative
Evaluation of impacts	Simulation	project manager, experts	Evolution of criteria
Compromise solution	Doehlert's framework	users, experts, politician project manager, group	Solution for all actors

Figure 8: Steps of a priori evaluation approach

The main interests of a priori evaluation of a transportation project at short and medium term:

1) Multi actors' framework: This approach is not a decision tool but a decision aid tool for better understanding of transport problems and for the generation of innovative solutions and relations amongst actors taking part in a decision process.
For it, each step is the illustration of the "concertation" process and our approach is globally based on mechanisms ensuring the participation of all actors (stakeholders) ; firstly the design of a set of pertinent criteria and of stakeholders groups are done in agreement with

the perception of phenomena and expected changes for a given urban area. The alternatives are pre-selected by taking into account the preferences of potential users. Finally, a compromise solution consists in defining a combination of levels of criteria for the best satisfaction of the requirements and constraints of the ones (urban planners, traffic engineers) and the exigencies of the others (users, residents).

2) Multicriteria aspects: Quantitative impacts (energy consumption, congestion level, atmospheric pollution, acoustic level and economic costs and benefits) are estimated according to the use rate of the service in physical units or in monetary terms. But no specific weights are assigned to criteria or interaction between criteria in order to allow an aggregation of the effects to a single criterion. The reason is that, in a multi actors framework, the weights attribution could be only subjective or otherwise a new conflict source. In fact, in contrast to the MCA and CBA methods, the proposed approach don't search to classify the alternatives and to impose a solution but to furnish to stakeholders a large panel of consequences of the implementation of each one.

3) Impacts in a dynamic framework: The impacts of a new service can be computed for a short or medium period (1-5 years) when only contextual changes are expected (such as the price of the carburant). The initial state corresponds to the moment that precedes the implementation of the project. In this case, the values of criteria for the initial state can be evaluated by experimental measurements (e.g. traffic level) or formulas (emissions). The criteria associated to the final state (or intermediate state) are computed by simulation or formulas. Via the robustness analysis it is possible to estimate the impacts in agreement with external criteria (sometimes changes premeditated by the decision makers, such as the accessibility, sometimes changes imposed by economic context, such as the petroleum price).

Main weak points and solutions of our a priori evaluation of a transportation project at short and medium term

Probabilistic model : The stated preferences allows us to built a set of probabilities taking into account the fuzzy perception of the quality of a service and the indecision of potential users face to a new service. But it is well-known that the stated preferences of potential users are not always reproduced by the observed preferences. This problem is due because the individual models can not capture the effects all the parameters of the choice model. Each model contains an unobservable component of utility which captures the dispersion of choices, particular of each person.

For this raison one of the solutions is to determine the evolution of the criteria according an interval [min, max].

For a more rigorous evaluation, the consequences of the implementation of a service must be done in a given range according with an interval of probabilities to use the service (min and max)

Interference with other transportation project: If the robustness analysis allow us to capture the consequences of some external criteria at short and medium term, it is not possible to evaluate the impacts of the implementation of another project in the same urban area. For it, a similar analysis of stated preferences should be done in order to estimate the redistribution of preferences. In this case, the impacts should be computed in a disaggregated manner for each project.

8. CONCLUSIONS AND PERSPECTIVES

The methodology described in this paper shows a technical tool in the context of multicriteria analysis for conflict dissolution involving multiple actors. The a priori evaluation of the impacts of transport projects, represent an interesting approach not currently seen in the literature. It provides several steps in order to ensure the participation of all actors. A diagnosis phase based on hierarchical ascending classification is performed for grouping actors in agreement with pertinent criteria that they have selected. The evaluation of the main impacts is based on the evaluation of aggregate probability to use the service that must be done by different social category. For it, stated preferences are collected and an algorithm based on Fuzzy Logic allows us to obtain the probability to use of a transportation service. The robustness analysis based on Taguchi's method can estimate the fidelity of the potential users in agreement with changes of external criteria (price of petrol, accessibility, security, etc). If evaluated impacts can not satisfy all stakeholders, a compromise solution is searched with Doehlert's framework. . A study case coupling the Park and Ride and a dedicated bus shows the main steps of our approach. The study for searching of a compromise solution will be done during next months. The simplification of the application of this approach will be possible with our future software

The advantage of this kind of analysis can be summarized as follows:

- Combine disparate knowledge from experts, politicians and users.
- Take into account quantitative and qualitative information.
- Make an evaluation of the impacts in the dynamic context
- Useful to preliminarily calibrate transport projects in order to ensure a successful implementation.
- It could be used for all kind of projects where antagonist preferences and constraints of partners could affect the efficiency of a project.

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