A NOVEL APPROACH TO THE ROAD MAINTENANCE PLANNING, BASED ON THE POSSIBILITY THEORY

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1. INTRODUCTION

The roads existence is due to the mobility need of people that, after the infrastructure construction, become its users. From this point of view, the road user should play an important role in roads planning, building and maintaining processes. In particular, the roads maintenance should be planned taking into account also the satisfaction of travellers: the more important is the road they are going along, the higher is expectation of “road quality” and “maintenance quality”.

The concepts of service quality and users’ satisfaction have been deeply investigated during the past decade; however, the exact nature of users’ judgements and relationship between quality and satisfaction are not well-defined yet: sometimes quality and satisfaction are considered like synonyms (see for example Zeithaml et al., 1993), other times considerable attempts have been made to integrate them in one conceptual model (de Ruyter et al., 1997). In this paper we propose a novel approach to the concepts of quality and satisfaction in road maintenance, based on the Possibility Theory. The aim of the paper is to find a break-even point between users’ satisfaction in regard to maintenance works (conditions of road surface, signs, safety, etc.) and costs of maintenance, that are often unbearable by public administrations.

2. THE METHODOLOGY

The more prevalent conceptualisations of satisfaction are process-oriented. For example, Tse and Wilton (1988) define satisfaction as “the customer’s response to the evaluation of the perceived discrepancy between prior expectations (or some other norm of performance) and the actual performance of the product as perceived after its consumption”. In other words, satisfaction is the measure of how much the perception of quality of the product or service meets customer’s expectations (fig. 1).

In this kind of models, how to handle the uncertainties associated with customer’s perception and the analyst’s (modeler’s) lack of knowledge about the mind of the user is the major
problem. Traditionally, in the field of transportation systems the stochastic modelling framework is used to deal with uncertainty, and probability is used to express the most likely values in a particular situation. When a choice process is involved, the users’ satisfaction level is defined as the Expected Maximum of Perceived Utility (EMPU) (Cascetta, 2001), that is:

\[ s^i = E[\max_j(U^j)] \quad j \in I^i \]  

where:
- \( s^i \) is the satisfaction degree for the i-th user;
- \( I^i \) is the choice set for the i-th user;
- \( U^i \) is the vector of utilities perceived by the i-th user.

Different measures of uncertainty were developed in the 1980's, and in this decade treatment of uncertainty has been systematized. These new paradigms are developed in the context of the evidence–proposition connection. While the field is not yet fully matured in terms of real world applications, new theories of uncertainty have provided a better insight into the understanding of uncertainty and redefined the place of probability theory when dealing with uncertainty.

Among the new theories, Possibility Theory is said to be amenable to the framework for representation of human perceptive uncertainty. This point has been suggested by prominent systems scientists such as Shackle (1969, 1979) and Cohen (1970). They argue that the traditional approaches using Probability Theory do not completely represent the true level of uncertainty in people’s perception. Possibility Theory deals with uncertainty when the evidence points to a nested set of propositions; and hence, it can deal with propositions that refer to a range as well as a single value.

In our case, uncertainty related to both users’ expectation and quality perception can be easily
represented in terms of a range or in linguistic expressions; therefore, in the proposed approach also users’ satisfaction is treated as a fuzzy concept, not as a random variable, which is the case in the classical stochastic choice approach.

In particular, quality $Q$ is assumed made up through a set of attributes $A_i$, valued in terms of linguistic variables such as, for example, “excellent”, “good”, “fair”, “poor”. The comparison of these attributes with users’ expectation determines the satisfaction, through a set of rules like in fig. 2. The process starts by taking the crisp inputs and determining the degree to which they belong to each of the appropriate fuzzy sets via the membership functions of linguistic variables. Then, all rules are evaluated in parallel using fuzzy reasoning; each rule results in one satisfaction level (fig. 3). The final result is obtained combining the different satisfaction levels and defuzzifying the result of combination.

Since the aim of this paper is to find a break-even point between users’ satisfaction and costs of
maintenance, the problem is then to minimize the costs of maintenance $c(A_i)$, reaching at least a given level of satisfaction $Q_{\text{min}}$:

$$\min c(A_i) \quad (2)$$

subject to:

$$Q(A_i) \geq Q_{\text{min}}$$

$$A_i \geq A_{i,\text{min}}$$

where $A_{i,\text{min}}$ is the minimum value of i-th attribute, required for safety purposes. The program (2) is to be solved by fuzzy optimisation techniques.

3. CONCLUSIONS

Random utility theory can take into account the uncertainty due to analyst’s errors and/or imprecision of the model. But the stimulus – response process in a human being mind adds another different dimension of uncertainty, due to the users’ imprecise reasoning. The Possibility Theory and Fuzzy Sets Theory allow handling these situations, and we applied them in calculation of the perceived quality level in road maintenance. After that, the calculated quality level has been used in optimisation of road maintenance costs for a case study. Since outcomes are encouraging, future developments of the model will deal with a deeper analysis of the human perception mechanism.

REFERENCES


