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A decision support system for road safety analysis

Gianfranco Fancello [a,] *, Michele Carta [a] and Paolo Fadda [a]

[a]D.I.C.A.AR, Department of Civil and Environmental Engineering and Architecture, University of Cagliari,09123 Cagliari, Italy

Abstract

The aim of this paper is to develop a procedure for supporting public administrations in planning safety interventions on the road network. Road safety conditions depend on several factors, represented by a variety of quantitative and qualitative data, including: number of traffic accidents, traffic flow, lane width, shoulder width, road curvature and grade, access-point density, road markings and road signs (Mooren et al. 2012; OECD, 2002). By analysing a set of given roads or different sections of the same road, each with specific safety conditions, this methodology allows to determine which sections require interventions to improve safe driving conditions. Specifically, the multicriteria analysis technique is used in decision-making processes to support the choice among different alternatives in complex problems (Fadda, 2002). Among the different multicriteria techniques available, the Concordance Analysis will be used here. This paper proposes a unique modelling tool that incorporates the different indicators to calculate safety conditions. The methodology has been applied to a real case study for evaluating road safety on sections of a motorway infrastructure.

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Keywords: multicriteria; concordance analysis; road safety conditions

1. Introduction

The management of funds to be allocated in safety interventions is one of the most important aspects of public administration. It is not only a question of the financial resources required but also the consequences of inadequate road maintenance, in terms of road accidents and/or above all damage to persons and property. However, it often (indeed almost always) happens that resources are insufficient to keep roads in good condition and up to required standards. Thus when planning safety interventions on the road network, public authorities are faced with the need

* Corresponding author.
E-mail address: fancello@unica.it

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to decide on which portions of the road network to intervene as a function of available resources. Clearly, when road segments exist with a high frequency of accidents involving casualties, the choice is obvious. In many cases, however, the selection process in not simple in so far as achieving road safety involves different variables concerning the infrastructure itself, traffic flows, surrounding environment, etc.

To ensure that this choice is as objective as possible and to actually reduce accident risk, a decision support system is required to assist public authorities in identifying those sections of road (and hence allocation of funds) where safety interventions should be carried out. This procedure should be able not only to account for all those variables that contribute to making the road dangerous, but also to establish intervention priority among different road sections.

In the scientific literature there are numerous papers focused on road safety and planning interventions but there is not a unique methodology to support the administrator of the road when it is necessary to optimize resources allocated to safety. Saaty (1995) applies the Analytic Hierarchy Process (AHP) to transportation planning with multiple criteria, Dell'Acqua (2011) presents a classification model of black spots in road networks using a decision support system (DSS) based on cluster analysis techniques. Coll et al. (2013), present a contribute to the ongoing research effort on the estimation of road safety composite index for identification and ranking of hotspots.

This paper presents a methodology for ranking the different alternatives by comparing them on the basis of different variables. In the specific case, a multicriteria technique called Concordance Analysis (Giuliano, 1985) is adopted. This technique is usually applied applied to choice problems but is used here for the first time for ranking purposes. In strictly analytic terms, the level of safety of a road infrastructure is a function of the characteristics of the users (c_u), of road geometry (c_g) and of traffic flow (c_f).

$$l_s = f(\mathrm{c_u}, \mathrm{c_g}, \mathrm{c_f}) \tag{1}$$

Analysis of the component (c_u) is beyond the scope of this work. Of the traffic flow characteristics reported in the literature as having a major bearing on safety are the presence of heavy vehicles, traffic intensity and vehicle density (Martin J. L., 2002), while for road geometry, lane width, the presence of shoulders, road curvature and surface regularity (Karlaftis et. al., 2002) are the most significant.

$$\mathrm{g_k} = f(c_u, \mathrm{c_g}, c_f) \tag{2}$$

These conditions are expressed by objective functions that define the overall safety performance of a road infrastructure. When the road does not comply with adequate performance standards, then it becomes necessary to intervene to to ensure good safety conditions. The work to be carried out to achieve this is however subject to budget constraints. When available funds are not sufficient to cover all the safety interventions required, then the most critical road sections need to be identified. Here we propose a decision support model that defines a set A', a subset of all the elements comprised in the network A = (a_1, a_2, a_3,…, a_n), containing those elements with the lowest level of safety l_s. The authorities of the road can use this analysis to identify the road segments with the worst safety conditions. Therefore available funds may be used to improve safety conditions of these elements.

2. Methodology

In this paper we use the multicriteria method called "Concordance Analysis", as described by Giuliano, G. (1985); this analysis is derived from Electre I method and uses the outranking relations based on both concordance and discordance analysis. This techniques addresses the "α " problematique whose objective is to identify the best alternative from among a finite number of competing alternatives. Roy (1996) provides a comprehensive discussion of the different types of decision "problematiques"', i.e., choice, ranking, sorting. Thus it does not rank the alternatives, as typically happens in multicriteria techniques characterized by "γ" problematique, where the competing alternatives are ranked from best to worst. The shortcoming of techniques with the "γ" problematique, lies in the very high level of analyst/decision maker subjectivity. In fact, besides introducing (as in "α "problematique) a set of weights for each criterion, in this case the analyst/decision maker introduces another six subjective parameters, in order to determine the strict preference, indifference and veto thresholds.