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# Influence of deficiencies in traffic control devices in crashes on two-lane rural roads

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ABSTRACT

One of the main objectives of all public administrations is reducing traffic crashes. To this end, Road Safety Inspections (RSI) stand out as a key measure. Signaling roads is one of the foremost tasks of RSI. A road that is improperly or poorly signaled can lead to incorrect placement or maneuvers of vehicles and ambiguous situations that can increase the risk of crashes. This paper analyses the relationship between road crashes in two-lane rural highways and certain deficiencies in signaling. The results show that deficiencies such as "incomplete removal of road works markings" or "no guide sign or in incorrect position" are the ones associated with a higher probability of crashes in two-lane rural highways. In view of these results, governmental agencies should verify that the original conditions of a highway are re-established after any construction work is completed. They should also continuously follow up on the signaling of this type of highway in order to maintain optimal conditions.



## 1. Introduction

Traffic accidents are complex events involving the interaction of different contributory factors, including road, driver, and vehicle. While it is well known that the human factor is the main cause of traffic crashes, present in nearly 90% of them (Siskind et al., 2011), previous studies have shown that the infrastructure also plays a significant role. Nearly 28% of crashes are due to infrastructure and, in most cases a combination of human and road factors is a major contribution in road crashes (Ogden, 1996).

In the literature, the crash contribution from human factors is usually analyzed in the context of driver errors. The human error most often identified in crashes is related to the perception and processing of information presented by the road or traffic environment. Situations that cause problems with road user perception, interpretation or judgment stages may lead to driver error or loss of control (Croft and Schnerring, 2009). An estimated 30% of driver-distracted crashes derive from diverse sources outside the vehicle (Regan et al., 2009). Hence, it is crucial to maintain the road features in optimal conditions so that they have the least possible impact on the driverís performance.

Reducing highway crashes is a priority of the Administrations in Europe and elsewhere. One means of reducing them is to detect and correct roadway deficiencies. Road Safety Inspections (RSI), established for this purpose, have proven to be an effective tool for the management of safety on existing roads. The European Directive on Road Infrastructure Safety Management (EC, 2008) defines RSI as "an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety". Following the principle "Prevention is better than cure", the RSI are used to evaluate existing road traffic facilities and to improve road safety performance (Laurinavičius et al., 2012). While some RSI treatments will have a greater impact than others, as underlined by Elvik (SETRA, 2008), significant reductions in crashes can be expected as a result of RSI and associated interventions.

After some years of experience with RSI, it is broadly recognized as one of the most important and effective engineering tools available to improve road safety (Antov, 2011). This is why the European Union makes RSI mandatory for trans-European Road Networks and they are recommended for the rest of the transport infrastructures (EC, 2008). These inspections should be undertaken after establishing a series of criteria to be articulated by means of checklists. The checklists are ordered lists used to cover the most important issues that should be inspected during the RSI. The detected hazards will be identified as Road Safety Deficiencies (RSD).

Some aspects of an RSD that can be analyzed include those related with signaling. They are easier to correct and involve a lower

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cost than other measures, such as the design of the road itself. It is important for the highway to be properly signaled, and that the information provided is clear and concise.

Several authors stress the importance of correct signaling: Miller (1992) reported that existing longitudinal pavement markings reduce crashes by 21%, and edge lines on rural two-lane highways reduce crashes by 8%; and Cho et al. (2012) suggested that pavement markings provide guidance to road travelers. An alteration of pavement color and/or texture or incomplete removal of pavement markings during construction projects could confuse individuals driving through the construction work zones. To make matters worse, under certain lighting and weather conditions the supposedly removed markings may become more visible than the new ones. Antov (2011) highlighted as common problems missing, contradictory or incomprehensible signs/marking. Croft and Schnerring (2009) pointed out that incorrect or poorly maintained pavement marking can lead to undue placement or maneuvers of vehicles, thus increasing the risk of crashes. They also demonstrated the influence of delineation devices in road safety—poorly placed or missing delineation devices can transmit a false picture of the way ahead, contributing to driver error (Croft and Schnerring, 2009). The methodological approach for safety evaluation of two-lane rural highways segments put forth by Cafiso et al. (2007) served to establish that daytime delineation of a road can be effectively accomplished with pavement markings, whereas nighttime and rainy conditions may require a different approach to provide long-range delineation of the roadway alignment. Supplementary delineation is an important safety factor in any condition; but it may prove critical on horizontal curves, especially on isolated curves with a short radius. Croft and Schnerring (2009) also indicated that signs poorly located/incorrectly situated can cause confusion, increasing crash risk, just as excessive signing can increase potential risk for road users. Montella (2005) described a systematic process to determine which road features should be investigated and how each should be evaluated during RSI. Accordingly, a safety improvement index was calculated and compared with the expected collision frequency, and this procedure was carried out in 406 km of rural two-lane rolling highways in Italy. The study revealed that for missing or ineffective curve warning signs on severe curves, the relative risk factor could be assumed equal to 10% (Montella, 2005).

This study analyses the relationship between crashes and certain deficiencies in signaling identified by a previous RSI. The RSI was performed on two-lane rural highways in Andalusia (Spain). From the Road Safety standpoint, it is vital that two-lane rural highways be studied, as they are the scenario of most crashes. In Spain, 70% of crashes occur on this type of roads (Ministerio del Interior, 2013).

A number of data mining techniques have been used in the road safety field in the recent past, giving satisfactory results (Kuhnert et al., 2000; Sohn and Shin, 2001; Abdelwahab and Abdel-Aty, 2001; Chang and Wang, 2006; De Oña et al., 2011; Kashani and Mohaymany, 2011; Pakgohar et al., 2010; Chang and Chien, 2013; De Oña et al., 2013a,b; López et al., 2014). The main aim of data mining is the extraction of knowledge from large amounts of previously unknown and indistinguishable data. Among the different techniques, artificial neural networks (ANN), bayesian networks (BN) and decision trees (DT) may be highlighted. Each of them, with its advantages and disadvantages, has been widely applied.

ANN have been used to model the relationship between traffic injuriy severity and crash factors in different research efforts (Abdelwahab and Abdel-Aty, 2001; Abdel-Aty and Abdelwahab, 2004; Delen et al., 2006; Moghaddam et al., 2011). ANN can be used to model complex problems. In broad terms, they search for data patterns and allow for potentially non-linear relationships between the injury severity levels and independent variables. The main disadvantage is the "black box effect". Data are uploaded into a "black-box" and predictions are obtained, but the nature of the variablesí relationships are usually not disclosed (Tullis and Jensen, 2003).

BN have been applied in different studies. De Oña et al. (2011) used BNs to model the relationship between traffic accident severity and different variables related to driver, vehicle, roadway, and environmental characteristics. They concluded that BNs could be used for classifying traffic accidents according to their injury severity. Mujalli and De Oña (2011) presented a simplified method based on BNs and variable selection algorithms to predict the injury severity in a traffic crash. Kwon et al. (2015) used BN and Decision Trees to rank risk factors. However, with this methodology it is not possible to derive patterns from rules.

In turn, Decision Trees and association rules extracted from DTs are one of the most popular data mining techniques. This nonparametric method can be adopted for safety analysis. Kuhnert et al. (2000) used classification and regression trees (CART) to analyze motor vehicle injury data. They suggested that CART be used as a precursor to a more detailed logistic regression analysis. Sohn and Shin (2001) compared neural networks, logistic regression, and decision trees using accuracy measures, and found that the three models exhibited a similar level of classification accuracy. Geurts et al. (2005) applied association algorithms to identify and differentiate between crash patters within and outside of hazardous road segments. In Pande and Abdel-Aty (2009), the application of association rules to find simple rules that indicate which crash characteristics are associated with each other was demonstrated and therefore recommended for detecting patterns in crash data. In a study by Pakgohar et al. (2010), the traffic data were also analyzed by data mining techniques such as classification trees. Chang and Wang (2006) and Kashani and Mohaymany (2011) used the CART model to establish the relationship between injury severity and influential factors. Montella et al. (2011a,b) used decision trees and association rules to analyze accidents involving pedestrians and powered two-wheeler vehicles. Das and Sun (2014) used the association rules mining technique to discover hidden patterns in rainy weather crash data. Kwon et al. (2015), in modelling the severity of traffic accidents, applied two classification methods, the Naive Bayes classifier and the decision tree classifier. Subsequent comparison showed that the decision tree's choice of the top five risk factors was superior in terms of allowing Naive Bayes to perform better, and that the ranking of risk factors from the decision tree classifier could contribute to efficient safety countermeasures in limited resources. Jung et al. (2016) reviewed, validated, specified, and prioritized Korea's strategic policies for pedestrian safety enhancement using the classification tree method to model pedestrian injury severities. Weng et al. (2016) employed the AR approach to examine the characteristics and contributory factors of work zone crash casualties. In addition, they investigated relationships among these factors in order to understand the general patterns of work zone crash casualties. In sum, substantial research has relied on association rules and CART because they can deal with data containing a large number of variables, and can interpret their relationships. Association rules moreover provide specific and easy to describe relationships between crash attributes (Montella et al., 2012).

DTs are appropriate for studying crashes because they are non-parametric techniques that do not require prior probabilistic knowledge of the study phenomena. An association rule could reflect the fact that risk factors may exhibit heterogeneous or hidden effects under various circumstances. Further advantages of DTs with respect to other methods having similar aims reside in the extraction of Decision Rules (DRs) (De Oña et al., 2013a). Although each crash is the result of a unique chain of events, some specific factors are common to several crash circumstances, and DRs can be