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Tool to manage Road Safety Deficiencies and risk of highway crashes

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Abstract

In order to facilitate the management of the results obtained in the project "Analysis of the relationship between Road Safety Deficiencies, crashes and hazardous sections" financed by Public Works Agency of the Regional Government of Andalusia (AOPJA) and led by the research group TRYSE from University of Granada, a safety management tool has been developed. This application allows safety managers to consult some factors affecting crashes on two-lane rural highways.

The main aim of that project was to analyze the influence of some road deficiencies on crashes and hazardous sections in the Complementary Road Network of Andalusia. These deficiencies were defined in a checklist and were identified by a road inspection. Decision Trees (DTs), that are a data mining technique that allows the extraction of Decision Rules (DRs), were used. DRs revealed the relationship between road deficiencies and crashes.

The application allows two different analyses. A specific analysis of the Complementary Road Network of Andalusia, in which, particular safety problems can be identified, and the location of roads with those problems can be obtained. A more general analysis in which some characteristics related to road safety can be selected in order to know the combination of factors contributing to traffic crashes. Safety problems are based on data from Complementary Road Network of Andalusia but results can be extrapolated to other rural highways in Spain.

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Keywords: Traffic crashes; road safety inspections; safety management tool

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1. Introduction

Reducing highway crashes is one of the main aims of the Administrations, particularly of Andalusia Regional Government. In order to generate knowledge and scientific evidence which support the implementation of road safety measures, occasionally, research funds are granted by Administrations. Nevertheless, although innovative techniques are applied in investigations and obtained results are very interesting, a problem arises when a better exploitation of results by Administration is required.

For this reason, a computer application has been developed by complementing the outcomes of a research project financed by Andalusia Regional Government. The software allows queries about factors affecting to road safety in Andalusia roads. It has been developed in the framework of the project "Analysis of the relationship between Road Safety Deficiencies, Crashes and Hazardous Sections", financed by Andalusia Regional Government. This research project has been led by Transport and Safety research group (TRYSE) from University of Granada and with the assistance of INECO.

The main objective of the computer application is to allow two types of analysis to be made. The first one is an analysis of Andalusian Roads (two-lane rural highways from Complementary Road Network of Andalusia with Annual average daily traffic [AADT] above 500 vehicles per day). This analysis makes it possible to identify safety problems in two-lane rural highways and locate road segments where these problems arise. The information is related to crashes and hazardous sections. A more general analysis also may be made in order to detect safety problems in rural highways. This analysis is focused on road safety managers and enable to identification of particular problems involving crashes. It is worth noting that although road deficiencies were identified for a certain road network in Andalusia, results can be extrapolated to other rural highways in Spain.

2. Data and methodology

The starting point of the project was to find relationships between Road Safety Deficiencies (RSD), crashes and hazardous sections in two-lane rural highways for a 3-years period, from 2006 to 2008.

2.1. Data

The study data came from two different sources: the Andalucía Regional Government provided Road Inventory databases, whereas the Spanish Road Crashes database came from to the Spanish General Directorate of Traffic (DGT). The first source provided two databases. The first one contained a list of two-lane rural highways in Andalusia, particularly, in the Complementary Road Network, with their geometrics and equipment characteristics. These roads were selected by the high number of fatal crashes in them. In Europe approximately 60% of road accident fatalities occur on two-lane rural roads (Cafiso et al., 2010). The second one contained information about a road safety inspection developed on these roads. In that inspection a checklist with some risks associated with road safety deficiencies were identified. These risks were defined as Road Safety Deficiencies (RSD). Urban segments, junctions and segments with road work places were removed from the study. The total length of the investigated road network was 1,635 km.

The DGT provided the accidents occurred in the studied roads. The period of study was 3-years (2006 to 2008). The total number of accidents on these segments was 1,454.

Using these three datasets, a global dataset with the crashes, information about road and roads safety deficiencies was built. Taking into account the variables available in the original dataset a total of 8 variables related to geometric and environmental road characteristics and 20 road deficiencies (D1-D20) (see table 1) were selected for the analysis.

The Road Safety Deficiencies D1 to D7 were related to delineation deficiencies found in studied roads; D8 to D13 were related to signaling; D14 referred to containment systems; D15 and D16 concerned accesses; D17 to D20 were associated with other circumstances.

Table 1 – Description, values and codes of geometric and environmental road characteristics and Road Safety Deficiencies

Num	Type	Description	Values	Code
1	Variable	TER: Terrain	Flat or Rolling terrain	FR
			Mountainous terrain	MT
2	Variable	AADT: Annual average daily traffic(veh./day)	≤1.000	[1]
			(1.000-5.000]	[2]
			>5.000	[3]
3	Variable	RW: Roadway width (m)	≤5 m	NAR
			(5 m-6.5 m]	MED
			>6.5 m	WID
4	Variable	LW: Lane width (m)	≤2.5 m	NAR
			(2.5 m-3 m]	MED
			>3 m	WID
5	Variable	PW: Paved width (m)	≤6 m	NAR
			(6 m-7 m]	MED
			>7 m	WID
6	Variable	CLANE: Climbing lane	Yes	Y
			No	N
7	Variable	SHT: Shoulder type	Yes	Y
			No	N
8	Variable	ALIG: Alignment	Tangent	TAN
			Curve	CUR
1	RSD	D 1: Insufficient operating speed	Yes/No	Y/N
2	RSD	D 2: Minimum tangent length	Yes/No	Y/N
3	RSD	D 3: Inadequate speed limit	Yes/No	Y/N
4	RSD	D 4: Development of horizontal curves	Yes/No	Y/N
5	RSD	D 5: Excessive speed reduction between successive tangents and curves	Yes/No	Y/N
6	RSD	D 6: Insufficient cross section	Yes/No	Y/N
7	RSD	D 7: Punctual road narrowing	Yes/No	Y/N
8	RSD	D 8: No regulatory sign or in incorrect position	Yes/No	Y/N
9	RSD	D 9: No warning sign or in incorrect position	Yes/No	Y/N
10	RSD	D 10: No guide sign or in incorrect position	Yes/No	Y/N
11	RSD	D 11: The road markings does not exist or were deleted	Yes/No	Y/N
12	RSD	D 12: Lack of correspondence between vertical signs and road markings	Yes/No	Y/N
13	RSD	D 13: Incomplete removal of road works markings	Yes/No	Y/N
14	RSD	D 14: Culvert-end in ditches on the roadside	Yes/No	Y/N
15	RSD	D 15: Potentially dangerous left turn from a point access	Yes/No	Y/N
16	RSD	D 16: Disordered point accesses on roadside	Yes/No	Y/N
17	RSD	D 17: Pavement defects	Yes/No	Y/N
18	RSD	D 18: Signalized pedestrian crossing in interurban area	Yes/No	Y/N
19	RSD	D 19: Usual vehicle parking on the pavement	Yes/No	Y/N
20	RSD	D 20: Existence of speed reducers in unsuitable areas	Yes/No	Y/N

2.2. Methodology

2.2.1. Data sets and subsets

Due to the fact that some RSD might only be checked in certain road segments, it is not possible to analyze at the same time the 20 RSD from Table 1. For example, road deficiency D2 "Minimum tangent length" is not appropriate to check it on curve segments. Furthermore, road deficiency D4 "Development of horizontal curves" can be checked only on curve segments.

Thus, the total length of the investigated road network was divided into different segment typologies regarding to some variables: alignment type (curve; tangent); AADT (<5,000 veh/day; ≥5,000 veh/day); terrain (flat or rolling; mountainous); roadway width (<7 m; ≥7 m); and speed reduction between two successive alignments higher than 15 km/h. Thus, 36 different subsets were obtained. For each subset, all 8 variables and some road safety deficiencies from Table 1 were analyzed according to suitability of application.

Table 2 shows 36 subsets characteristics created from 8 considered variables. For example, the subset 1 is composed by all the curve segments on studied roads, while subset 1.1 is composed by curve segments with roadway width of 7 meters.

The D3 and D8 to D20 RSD's could be analyzed in all of 36 subsets in Table 2. The remaining RSD were analyzed only in the some subsets indicated in Table 2.

Then, for each subset, models based on Decision Trees (Dts) were developed and Decision Rules (DRs) were extracted from them. These Decision Rules support the developed software. Definition and extraction process of Decision Rules can be found in Montella et al. (2012), De Oña et al. (2013) and López et al. (2014).

2.2.2. Application development

Once DTs models were obtained and DRs were validated for each subset, a total of 936 crashes rules were collected.

Using as inputs all DRs, a Road Deficiencies queries application is developed. This application allows analyze road deficiencies causing crash probability in two-lane rural highways. Moreover, segments in studied roads where road deficiencies exist can be located from selected decision rules.

Developing this application aims at achieving the following objectives: allow the identification of issues related to crashes in Complementary Road Network of Andalusia and allow the identification of road segments according to some characteristics previously selected; provide some specific parameters in order to state the main factors affecting road safety in Complementary Road Network of Andalusia.

Achieving these objectives, the following results could be reached: provide aid to safety managers in identifying measures to improve road safety in Complementary Road Network of Andalusia; establish prior measures to reduce crash probability related to geometrical and environmental factors, as well as RSD.

3. Results

Results of consultations in the application are displayed in the form of logic rules with a structure like this "IF → THEN", where the part "IF" is the antecedent of rule. The antecedent is composed by a set of statuses of several attribute variables and the part "THEN" is the consequent, which indicates the status of the class variable that is accident occurrence (Abellán et al., 2013). Moreover, for the Andalusian Highways analysis, segments in studied roads where road deficiencies exist can be located through the decision rule selected.

Using this application, safety managers can solve some questions like these: "Which is the factors combination that generates a higher crash probability? How is a specific RSD (for example D11: "The road markings does not exist or were deleted") influencing the crash probability in a flat road segment?

Below the operation application and all features are shown via screenshots.

First, before choosing any type of analysis, the user must have clear the main objective and expected results. Screen 1 allows choose the type of analysis, according the main objective. An "Analysis of Problems in Roads" or "Analysis of Problems in Conventional Roads" can be performed. Moreover this screen includes a button called report legend that explains all rule parameters and variables used in the application, and a button to exit the application.

Table 2 – Road characteristics and Road Deficiencies analyzed (D1-D7) for each subset

Subsets	Road characteristics	Road deficiencies
1	Alignment; curve	D1, D4, D5
1.1	Alignment; curve; Roadway width (m); <7	D1, D4, D5
1.2	Alignment; curve; Roadway width (m); <7; Terrain; Flat or Rolling	D1, D4, D5, D7
1.3	Alignment; curve; Roadway width (m); <7; Terrain; Mountainous	D1, D4, D5, D6, D7
1.4	Alignment; curve; Roadway width (m); <7; AADT (veh/day); ≥ 5,000	D1, D4, D5
1.5	Alignment; curve; Roadway width (m); <7; AADT (veh/day); < 5,000	D1, D4, D5
1.6	Alignment; curve; Roadway width (m); <7; Terrain; Flat or Rolling; AADT (veh/day); < 5,000	D1, D4, D5, D7
1.7	Alignment; curve; Roadway width (m); <7; Terrain; Mountainous; AADT (veh/day); < 5,000	D1, D4, D5
1.8	Alignment; curve; Terrain; Flat or Rolling	D1, D4, D5, D7
1.10	Alignment; curve; Speed reduction (km/h); >15	D1, D4, D5
1.11	Alignment; curve; Roadway width (m); <7; Speed reduction (km/h); >15	D1, D4, D5
1.12	Alignment; curve; Roadway width (m); <7; AADT (veh/day); < 5,000; Speed reduction (km/h); >15	D1, D4, D5
2	Alignment; tangent	D2
2.1	Alignment; tangent; Roadway width (m); <7	D2
2.2	Alignment; tangent; Roadway width (m); <7; Terrain; Flat or Rolling	D2, D7
2.3	Alignment; tangent; Roadway width (m); <7; Terrain; Mountainous	D2
2.4	Alignment; tangent; Roadway width (m); <7; AADT (veh/day); ≥ 5,000	D2, D6, D7
2.5	Alignment; tangent; Roadway width (m); <7; AADT (veh/day); < 5,000	D2
2.6	Alignment; tangent; Roadway width (m); <7; Terrain; Flat or Rolling; AADT (veh/day); < 5,000	D2, D7
2.8	Alignment; tangent; Terrain; Flat or Rolling	D2, D7
3	Roadway width (m); <7	-
3.1	Roadway width (m); <7; AADT (veh/day); ≥ 5,000	D6, D7
3.2	Roadway width (m); <7; AADT (veh/day); < 5,000	-
3.3	Roadway width (m); <7; Terrain; Flat or Rolling; AADT (veh/day); < 5,000	D7
3.4	Roadway width (m); <7; Terrain; Mountainous; AADT (veh/day); < 5,000	-
3.5	Roadway width (m); <7; Terrain; Flat or Rolling; AADT (veh/day); ≥ 5,000	D6, D7
3.6	Roadway width (m); <7; Terrain; Mountainous; AADT (veh/day); ≥ 5,000	D6, D7
4	AADT (veh/day); ≥ 5,000	D6, D7
4.1	Terrain; Flat or Rolling; AADT (veh/day); ≥ 5,000	D6, D7
4.2	Terrain; Mountainous; AADT (veh/day); ≥ 5,000	D6, D7
5	AADT (veh/day); < 5,000	-
5.1	Terrain; Flat or Rolling; AADT (veh/day); < 5,000	D7
5.2	Terrain; Mountainous; AADT (veh/day); < 5,000	-
6	Terrain; Flat or Rolling	D7
7	Terrain; Mountainous	-
8	Roadway width (m); ≥7	-

Figure 1 shows an operation software scheme.

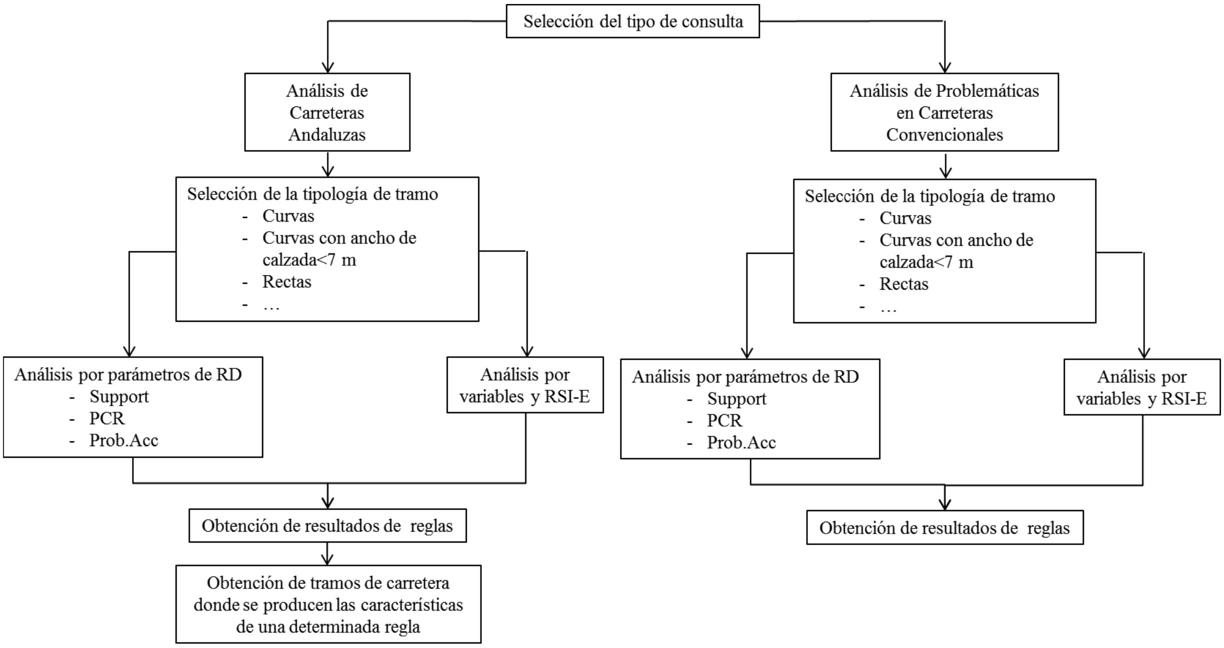


Fig. 1. Operation software scheme

Fig 2. Starting screen (Screen 1)

On screen 2, the road segment typology is selected. One or more road segment typologies from Table 2 can be reviewed. To execute the query, the item “EJECUTAR ANÁLISIS” should be selected.

On screen 3 (Figure 3) the type of analysis is selected. On the left-hand side of screen 3 a summary of results is displayed. The number of rules existing on road segment typologies selected on the previous screen and an overview of values range of rule parameters are also shown on screen 3.

Fig 3. Analysis selection according rules parameters (Screen 3)

On screen 3 a parameter analysis related to crash probability can be executed (see Figure 3, OPCIÓN 1). This analysis is focused on identifying crash segments according to three parameters related to crash probability, posterior classification ratio (PCR) and rule support. More information about these parameters can be found in De Oña et al., 2013, Abellán et al., 2012 and López at al., 2014.

On screen 4 (Figure 4) the rule parameters for consulting are shown. For each parameter three options are possible: consult ten rules with the highest crash probability; consult twenty rules with the highest crash probability rules; rank rules from high to low crash probability. Next screen (see Figure 5) shows the results of consultations.

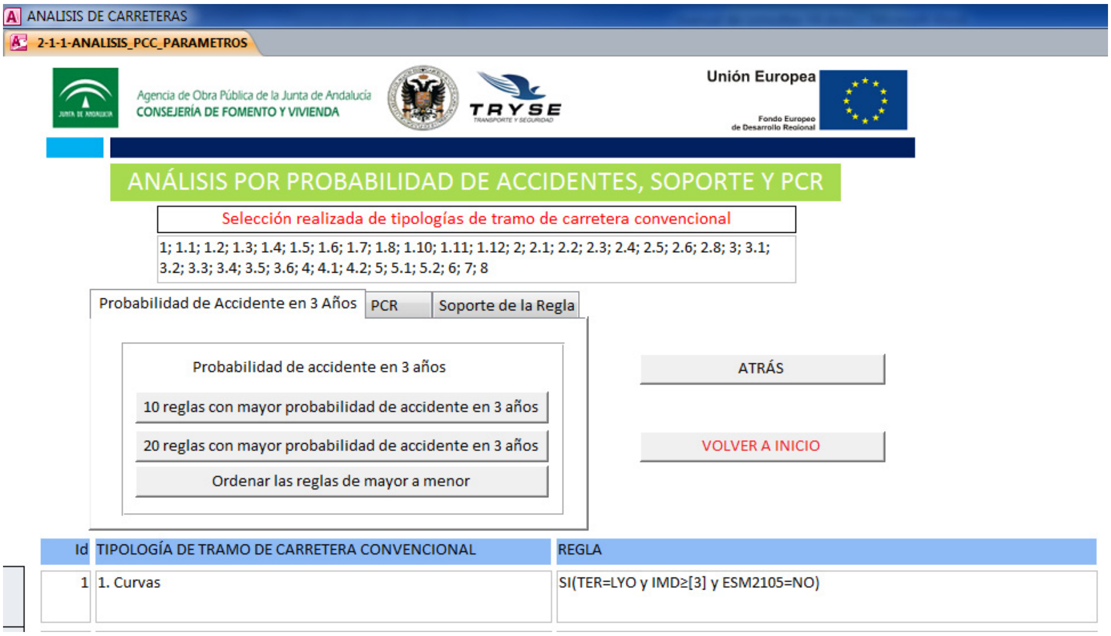
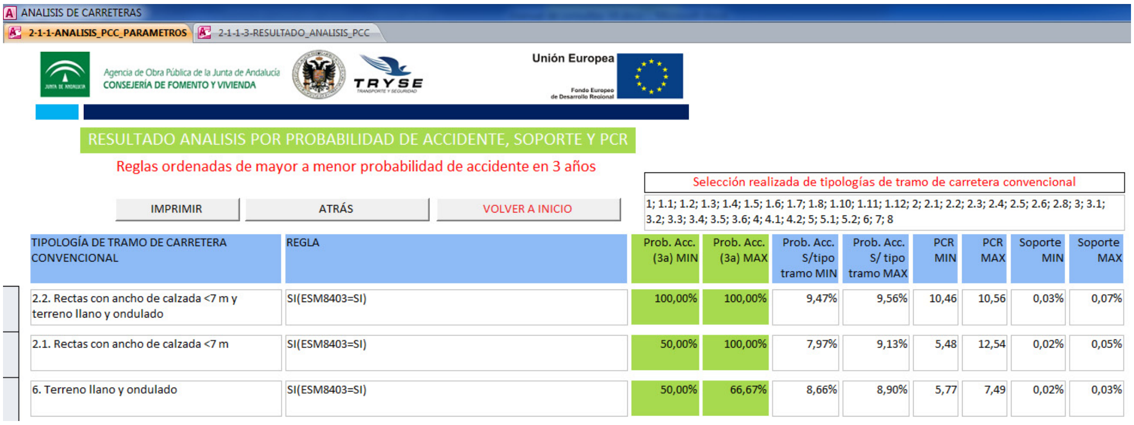


Fig 4. Parameters selection (Screen 4)

Fig 5. Result of the analysis according to the crash probability (Screen 5)



TIPOLOGÍA DE TRAMO DE CARRETERA CONVENCIONAL	REGLA	Prob. Acc. (3a) MIN	Prob. Acc. (3a) MAX	Prob. Acc. S/tipo tramo MIN	Prob. Acc. S/ tipo tramo MAX	PCR MIN	PCR MAX	Soporte MIN	Soporte MAX
2.2. Rectas con ancho de calzada <7 m y terreno llano y ondulado	SI(ESM8403=SI)	100,00%	100,00%	9,47%	9,56%	10,46	10,56	0,03%	0,07%
2.1. Rectas con ancho de calzada <7 m	SI(ESM8403=SI)	50,00%	100,00%	7,97%	9,13%	5,48	12,54	0,02%	0,05%
6. Terreno llano y ondulado	SI(ESM8403=SI)	50,00%	66,67%	8,66%	8,90%	5,77	7,49	0,02%	0,03%

Turning to screen 3 (Figure 3), there is a second option to choose. A RSD analysis can also be done on screen 3 (see Figure 3, OPCIÓN 2). If this option is chosen, some variables and RSD from Table 1 can be selected on the next screen to study. All rules containing the selected conditions are shown on the next screen. In either of the two options on screen 3, road segments on Complementary Road Network of Andalusia can be consulted.

4. Conclusions

This paper presents a safety management tool in order to facilitate the management of the results obtained in the project "Analysis of the relationship between Road Safety Deficiencies, crashes and hazardous sections".

The computer application allows safety managers to analyze road and environment characteristics affecting to crash probability on two-lane rural highways. Although used datasets come from rural highways in Andalusia, results can be extrapolated to other similar road segments in any area from Spain.

This tool is easy, visual and does not require specialist experience to operate it. Its main objectives are: provide aid to safety managers in identifying preventive measures to improve road safety in Complementary Road Network of Andalusia; allow the identification of issues related to crashes in Complementary Road Network of Andalusia; allow the identification of road segments according to some characteristics previously selected; and provide some specific parameters in order to state the main factors affecting road safety in Complementary Road Network of Andalusia. Using this application, safety managers can solve some questions like these: "Which is the factors combination that generates a higher crash probability? How is a specific RSD (for example D11: "The road markings does not exist or were deleted") influencing the crash probability in a flat road segment?

According to obtained results, safety managers can establish prior measures to reduce crash probability related to geometrical and environmental factors, as well as RSD, investing resources efficiently.

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