

1 **METHODOLOGY FOR DETERMINING**
2 **TRAFFIC ACCIDENT RISK ZONES**

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5 By

6 Roy Barrantes

7 Road Evaluation Unit Coordinator

8 National Laboratory of Materials and Structural Models (LanammeUCR)
9 University of Costa Rica, P.O.Box 11501-2060, UCR, San José, Costa Rica

10 Phone: + (506) 2511-2507

11 Fax: + (506) 207-4442

12 E-mail: roy.barrantes@ucr.ac.cr
13

14 Jairo Sanabria

15 Road Evaluation Engineer

16 National Laboratory of Materials and Structural Models (LanammeUCR)
17 University of Costa Rica, P.O.Box 11501-2060, UCR, San José, Costa Rica

18 Phone: + (506) 2511-4011

19 Fax: + (506) 207-4442

20 E-mail: jairo.sanabria@ucr.ac.cr
21

22 José P. Aguiar-Moya, Ph.D.

23 Research Program Coordinator

24 National Laboratory of Materials and Structural Models (LanammeUCR)
25 University of Costa Rica, P.O.Box 11501-2060, UCR, San José, Costa Rica

26 Phone: + (506) 2511-2529

27 Fax: + (506) 207-4442

28 E-mail: jose.aguiar@ucr.ac.cr
29

30 Luis Loría, Ph.D.

31 Pavement Infrastructure Program Director

32 National Laboratory of Materials and Structural Models (LanammeUCR)
33 University of Costa Rica, P.O.Box 11501-2060, UCR, San José, Costa Rica

34 Phone: + (506) 2511-4122

35 Fax: + (506) 207-4442

36 E-mail: luis.loriasalazar@ucr.ac.cr
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1 ABSTRACT

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3 In Costa Rica, the traffic accident database is still under development. Due to the limited quantity of
4 information it is very difficult for the DOT to accurately locate the road sections with significant
5 concentration of accidents, also known as “blackspots”.

6 The National Laboratory of Materials and Structural Models of the University of Costa Rica
7 (LanammeUCR) has developed a methodology that initially assesses the potential risk of accidents
8 associated with a combination of four different parameters related to road infrastructure and the
9 environment. The study was performed in four of the Country’s main highways, for a study length of over
10 1,000 km of road. The parameters considered in the methodology were: pavement friction, retro-
11 reflectivity of the road marking, geometrical and topographical alignment of the roadway and climatic
12 factors. The experimental parameters associated with each category were measured directly based on
13 NDT testing. The climatic factors were based on current and historical weather station information.

14 The proposed methodology consists of a combination of values for each individual parameter,
15 which finally result in a susceptibility profile for the road, which is related to the risk that an accident will
16 occur. Finally, the results were correlated with accident data to check for the sensitivity of the method.

1 INTRODUCTION

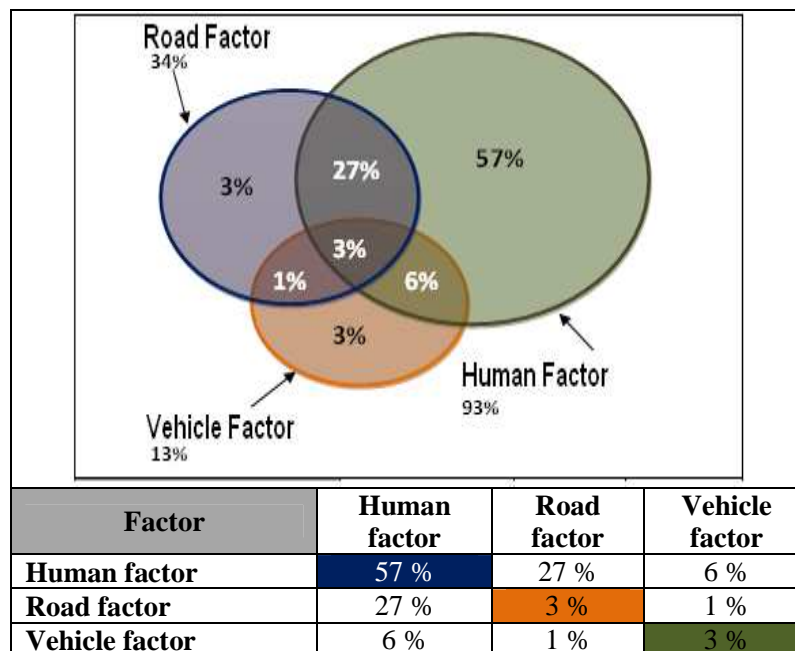
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3 Most of the road accidents cannot be related to a unique factor, since they are the result of the
4 convergence of a series of events that are influenced by a combination of contributing factors (time of
5 day, human factors, speed, vehicle condition, road design, etc.). These factors influence the sequence of
6 events that occur prior, during and after an accident. In general terms three contributing intervals can be
7 associated with an accident:

- 8
9 1. Prior to the accident: factors that contributed to the risk and how the collision may have happened.
10 2. During the accident: factors that contributed to the severity of the accident and how these factors may
11 be addressed with engineered solutions or technological changes that can reduce the severity of the
12 event.
13 3. After the accident: factors that influence the final outcome of the accident and how the damage and
14 the risks may be reduced by improvements the emergency response and medical treatment.

15
16 In terms of contributing factors, accidents can be classified in the following three categories:

- 17
18 • Human – includes age, driver ability, concentration, fatigue, experience, use of medications or other
19 substances;
20 • Vehicle – includes design and maintenance;
21 • Road/environment – includes geometrical alignment, cross-section, traffic control devices, IRI, slope,
22 road marking, weather, visibility;
23

24 Understanding these factors and how they can influence the sequence of events, the frequency of
25 the accidents and their severity may allow for a decrease in risk by implementing specific actions to
26 address each of these factors. The relative contribution of these factors in the accident may help determine
27 how to assign funds to reduce collisions. A summary of previous research quantifying the contributing
28 weight of the factors is summarized in **Figure 1**.



30
31 **FIGURE 1** Combination of contributing factors to vehicular accidents (1).

1 A framework to relate the series of events in an accident with the categories of contributing
2 factors to collisions is the Haddon matrix (1). The Haddon matrix helps order the different factors to
3 determine which ones have the higher influence an accident and at what time.

4 Some of the strategies that can be applied to reduce collisions and their severity are:
5

- 6 • Design, planning and maintenance: may reduce accidents by improving and maintaining the
7 transportation system (e.g. adjusting traffic light phases). The severity of the accidents may also be
8 reduced by selecting appropriate treatments (e.g. crash barriers to prevent frontal collisions).
- 9 • Policy: may reduce collisions by influencing the human response and the design of roads and vehicles
10 (e.g. ban cellphone use while driving, minimum design requirements, required use of helmets and
11 seatbelts).
- 12 • Demand management/traffic reduction: may reduce accidents by reducing the demand on a given
13 section of the system.

14
15 It is imperative that the different agencies responsible for road management have the most
16 effective methodology/mechanisms to improve the decision making process, in order to reduce the risks
17 on the road user and to improve the investment plan, from a road safety perspective.
18

19 **OBJECTIVE**

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21 The objective of this study is to provide a practical methodology that can be used to identify road sections
22 with high susceptibility to accidents. The methodology is based on GIS databases for a combination of the
23 four main road factors that are involved in a collision incident: pavement friction, retro-reflectivity of the
24 road markings, geometrical alignment, and climatic factors.
25

26 **METHODOLOGY**

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28 This study focuses on identifying the road factors that contribute to generate adverse conditions for road
29 users that may eventually lead to an accident. A methodology adapted from the vulnerability analysis
30 performed in LanammeUCR since 2000 was used. The methodology is based on individually weighting
31 factors according to group categories, which are later combined to complete the vulnerability analysis of a
32 road section. This type of analysis has been implemented in Costa Rica on several sections of the of the
33 road network since 2009.

34 Several methods and case studies were analyzed prior to development of the methodology: i)
35 Practices to Manage Traffic Sign Retro-reflectivity (2), ii) PennDOT's Retroreflectivity Database Study
36 (3), iii) Retro-reflectivity Research to Enhance Driver Safety (4), iv) Computer-based Modeling to
37 determine the Visibility and Minimum Retro-reflectivity of Pavement Markings (5), v) Multicriteria
38 Dynamic Segmentation (6), vi) Sensitivity Analysis on Dry and Wet Retro-reflectivity of Pavement
39 Markings (7), vii) Effects of Road Geometry and Cross-Section Variables on Traffic Accidents (8), and
40 viii) Development of Simplified Approach for Assessing Level of Safety of Highway Network Associated
41 with Pavement Friction (9).

42 However, a general methodology that combines pavement friction, retro-reflectivity of the road
43 markings, geometrical alignment, and climatic factors in a single procedure in order to build a profile of
44 susceptibility of the road was not identified. Consequently, this methodology allows to identify critical
45 sections of roads and to perform a full road safety assessment by means of high resolution images and
46 field assessments.
47

48 **ROADWAY SUSCEPTIBILITY PROFILE**

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1 To determine the susceptibility profile of a road, the principle of superposition was used. Relative values
 2 (weights) to correlate the measurements in a given section with the risk level were assigned. The assigned
 3 weights depend on categories that are defined in the following sections of the paper.

4 The analysis sections were defined as 100 meters long. After characterizing the sections, the
 5 scaled factors were summed: the higher the number, the higher the quantity of critical factors within a
 6 given section. Then, based on summed scaled factors for the sections of a given road, a frequency
 7 distribution is constructed to serve as a tool to analyze the distribution of data with respect to the road
 8 average, and to quantify the variability within the given road. The data can also be used to develop a road-
 9 specific susceptibility model. A cumulative frequency distribution is then developed to analyze changes in
 10 data behavior and to define road-specific susceptibility ranges. The results are finally plotted in a map that
 11 shows the different susceptibility ranges. **Figure 2** illustrates the process.

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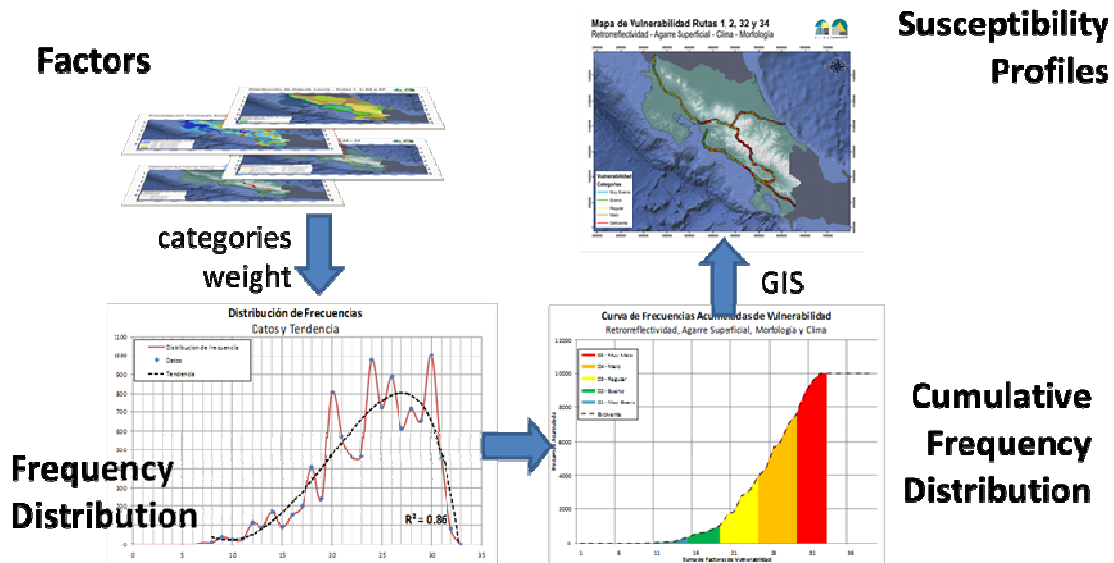


FIGURE 2 Susceptibility profiles development method.

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ROADWAY GEOMETRIC FACTORS

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There are a wide number of geometric components on each road, some are based on the horizontal or vertical alignment, and the presence of cuts and fills, that together with the environment result in a given risk.

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For the present methodology, these factors were evaluated at the network level, which implies that the defined factors are representative of one or more geometric elements, based on the risk that the road user is exposed to. Two variables to generally characterize the vertical and horizontal alignment were chosen. To characterize the vertical elements, the slope of the road was used, and for the horizontal elements, a categorization depending on the number of curves per kilometer was chosen

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Type of Terrain

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The first classification is based on the type of terrain. Costa Rican roadways were classified as per **Figure 3 (a)**. When applying this classification to the roadways under study, it was possible to assign risk factors associated with the area or type of terrain that affects the accident susceptibility of the roadway. Then, based on GIS for the routes under analysis, it is possible to very accurately identify sections with different terrain categories and therefore define the first layer in the susceptibility analysis **Figure 3 (c)**.

Roadway Alignment

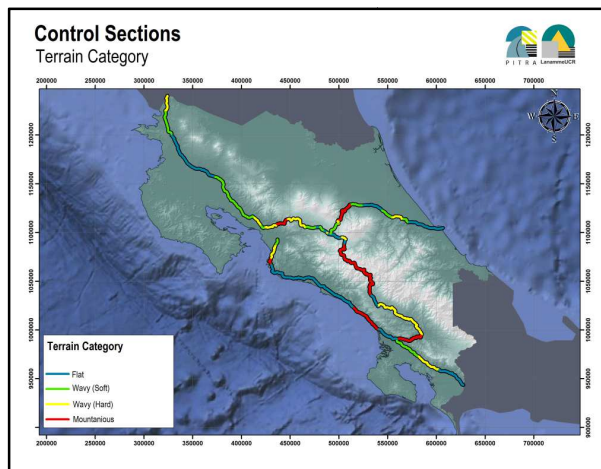
The second parameter included under geometric factors is the roadway alignment. The alignment grouping was established based on a classification derived from the GIS database of LanammeUCR and is based on data from the DOT. The classification is a function of the number of curves present in the alignment along a kilometer of roadway. The classification and corresponding weights are defined on Figure 3 (b). Figure 3 (d) is obtained by applying this classification to the analysis routes.

Classification	Description	Weight
1	Flat	0
2	Wavy (Soft)	1
3	Wavy (Hard)	2
4	Mountain Road	3

(a)

Classification	Description	Curves/km	Weight
1	Very sinuous	15+	3
2	Frequent curves	10 – 15	3
3	Somewhat sinuous	5 – 10	2
4	Some curves	2 – 5	1
5	Straight with smooth curves	0 – 2	0

(b)



(c)



(d)

FIGURE 3 Classification of roadway sections based on geometric factors.

CLIMATIC FACTORS

The effect of the environment on roadways is variable, depending on the type and variability of the climate and seasonal changes. Statistical information to weight its effect and analyze its impact roadway safety is required. Therefore, the analysis is based on two yearly annual statistics: the percentage of days with rainfall, and the average annual (in mm).

The use of these two factors allows the quantification of the amount and distribution of rain, and can be used to define the level of threat on the road user, from a climatic point of view.

Amount of Days with Rainfall

Data provide by the National Weather Institute (10) was used to define the groupings of days with rain per year. The classification is shown on Figure 4 (a) and is based on 5 uniform ranges to describe the amount of rainfall a given section of roadway is subjected to rainfall throughout the year.

Figure 4 (c) shows the resulting distribution of this classification on the map of Costa Rica, which allows for spatially assigning a measure to describe the time distribution of rainfall and its influence on the analyzed routes.

Average Annual Rainfall

The average annual precipitation data is derived from climate maps for Costa Rica (11), and allows for prediction on expected amount of rainfall for the entire Country. Based on the maps the classification indicated on Figure 4 (b) was proposed.

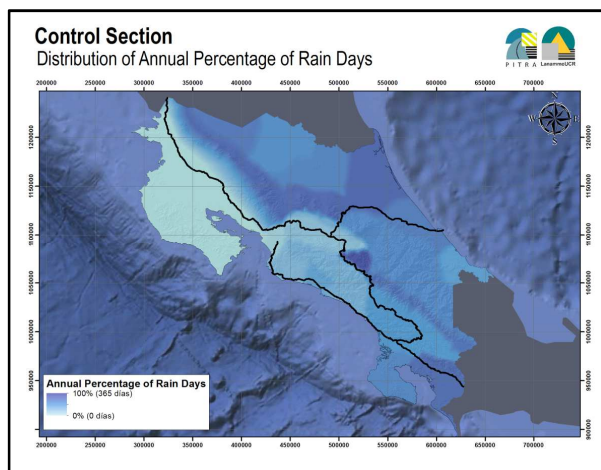
Figure 4 (d) shows classification of the roadways sections based on the proposed categories of average annual rainfall on the map of Costa Rica. This allows for the spatial distribution of rainfall per year along the study routes.

Classification	Condition	Description (days with rainfall/year)	Weight
1	Very low	0 – 20 %	0
2	Low	20 – 40 %	1
3	Regular	40 – 60 %	2
4	High	60 – 80 %	3
5	Very high	80 – 100 %	3

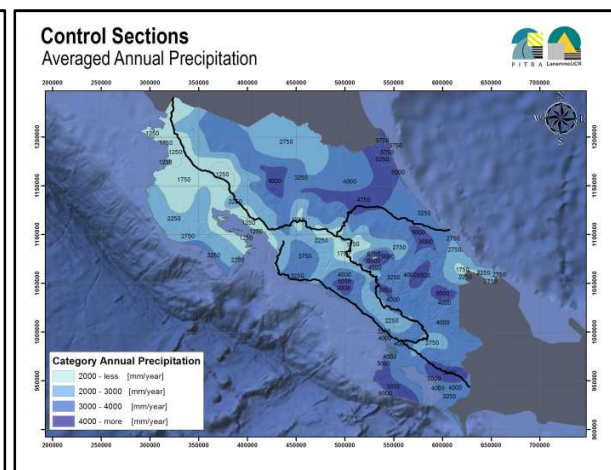
(a)

Classification	Description (mm/year)	Weight
1	2000-	0
2	2000 – 3000	1
3	3000 – 4000	2
4	4000+	3

(b)



(c)



(d)

FIGURE 4 Classification of roadway sections based on climatic factors.

1 INFRASTRUCTURE RELATED FACTORS

2
3 The following elements of the analysis consist of specific parameters associated the roadway: the retro-reflectivity of the horizontal paint (white for edge lines, yellow for the center line) and the skid resistance (coefficient of friction for the pavement surface).

7 Skid Resistance (Grip Number)

8
9 A very important aspect of road safety is the skid resistance experienced between the tire of the vehicle and the road surface. The higher the level of friction, the greater the force that minimizes vehicle skid, which is of extreme importance when stopping or making turns at moderate speeds. However, pavements with low friction levels result in unsafe conditions for users: skidding or loss of vehicle control.

10
11 Maintaining a minimum value of surface friction is vital to maintaining the service and safety conditions of a route. This is based on the high correlation between low levels of friction of a road segment and higher rates of accidents, which suggests that the level of friction should be improved to reduce the number of accidents and the costs associated with them.

12
13 The level of friction of the surface depends on several factors, being the main factors the macro and micro texture of the roadway surface. The macro texture is directly related to the type of exposed aggregate in the surface mixture, and directly affects the water drainage capacity at the surface of the road. If the macro texture is higher, it improves drainage, but at the expense of tire wear on vehicles. The lower the macro texture, the lower the drainage capacity of the road. This can result hydroplaning: the tire is not in direct contact with the surface (there us a thin film of water between the two), resulting in loss of vehicle control when maneuvering the vehicle. Table 1 shows the International Classification of Pavement according to the Grip Number (GN) (12), and has been selected as the classification criteria for the methodology.

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27 **TABLE 1 International Classification of pavement by the GN.**

GN	Condition	Level			Category	Weight
		Slippery	Hazardness	Average risk of accident (*)		
< 0,50	Bad	Very slippery	Very dangerous	Greater than 20	4	8
0,50 – 0,60	Regular	Slippery	Dangerous	16 to 20	3	6
0,60 – 0,78	Good	Little slippery	Moderate	10 to 16	2	4
> 0,78	Very good	Non slippery	Safe	Less than 10	1	2

28
29 (*) Number of accidents per million vehicles/km.

30
31 The equipment used to measure the coefficient of friction in this study uses a partially fixed tire in the direction of movement (GripTester). The advantages of this device are its ease of operation and its small size which does not require a dedicated vehicle. It allows continuous measurements of friction along the roadway.

36 Retro-Reflectivity

37
38 One of the key aspects in the design and operation of a road are the horizontal markings, which are based on the geometric properties of the road and should be able to inform the users about traffic behavior, roadway characteristics, number of lanes, safety zones (islands), permitted driving maneuvers (overtaking and restricted areas). All of these factors are vital for the safety of the user and the functionality of the road.

1 During daytime, or in the presence of proper lighting conditions, the chromatic scale and the
 2 contrast of the pavement markings define if the visibility is adequate or not. However, the safety factor is
 3 incomplete if the items cannot be seen at night or in the absence of light (e.g. heavy fog). The parameter
 4 that is required under these conditions is known as retro-reflectivity and can be measured using
 5 equipment to ensure that the markings along the road meet the needs of the user.

6 To quantify this parameter LanammeUCR uses a high performance retro-reflectometer
 7 (LaserLUX CEN 30), which can continuously measure the retro-reflectivity values of the horizontal
 8 markings based on ASTM E1710 (13). The equipment uses scanning laser to measure the values of the
 9 retro-reflectivity of the paint. At operating speeds of 100 km/hr it generates over 720 measurements per
 10 kilometer, and averages the values for 100 m sections. The obtained values are then compared with a set
 11 of categories derived from minimum recommended values of retro-reflectivity (14) as per Table 2.

12
 13 **TABLE 2 Recommended minimum values of retro-reflectivity.**

14

Type of Pavement Marker	Color of paint	Rural Roads < 40 mph	Secondary roads 45 - 55 mph	Principal road > 60 mph
With raised pavement marker	White	30 mcd/lx/m ²	35 mcd/lx/m ²	70 mcd/lx/m ²
	Yellow	30 mcd/lx/m ²	35 mcd/lx/m ²	70 mcd/lx/m ²
Without raised pavement marker	White	85 mcd/lx/m ²	100 mcd/lx/m ²	150 mcd/lx/m ²
	Yellow	55 mcd/lx/m ²	65 mcd/lx/m ²	100 mcd/lx/m ²

15
 16 **ANALYSIS OF ROADWAY SECTIONS WITH HIGH ACCIDENT SUSCEPTIBILITY**

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 18 The next part of the methodology consists of defining “analysis sections” where the susceptibility of
 19 accidents, by the combination of previous parameters, qualifies as a high. The definition of these roadway
 20 sections is required to calibrate the results and to define the needs of the sections rated as critical.

21 After the definition of the sections a road safety audit checklist adapted from (15) was used to
 22 examine with more detail all the remaining elements of the infrastructure than can have some influence in
 23 the occurrence and severity of accidents. The road segments to be analyzed were selected by combining
 24 the results of susceptibility described previously and the sections that have reported higher concentration
 25 of accidents according with the accidents database available in Costa Rica. The length of the analysis
 26 sections was defined as 500 m.

27 Table 3 shows the general categories that come into this analysis and the values assigned to
 28 weight its importance among the elements to evaluate. Each category is subdivided into several items to
 29 quantify. The values are defined according to expert judgment and can be calibrated and validated for
 30 each particular roadway based to its importance.

31 For each case a condition score is assigned depending on the applicability of the items, for a
 32 maximum of 100% (e.g. if there are no intersections on the segment, category C is not considered and the
 33 remaining categories are adjusted to sum up to 100%). The points are assigned as follows: condition is
 34 not applicable or in bad condition (0), regular condition (50% assignable points), and good condition
 35 (100% assignable points).

36 The final result for the sections under analysis corresponds to a rating based on the total scored
 37 susceptibility points for the route and the percentage level associated with sections of high susceptibility.
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1 **TABLE 3 General roadway safety categories and associated weights.**
2

Category	Item	Assignable Points
A	Alignment and Cross Section	2
B	Acceleration or deceleration lanes	4
C	Intersections	8
D	Vertical Signage and Lighting	15
E	Demarcation and delineation	15
F	Containment barriers and lateral clearance zones	7
G	Traffic lights	7
H	Pedestrians and cyclists	9
I	Bridges and culverts	8
J	Pavements	8
K	Provision for heavy vehicles	4
L	Watercourses and flood	8
M	Others	5
N	Alignment and Cross Section	2

3
4 **Visual Inspection**

5
6 The analysis of the sections with high concentration of accidents was performed based on a visual
7 monitoring system configured for LanammeUCR (Trimble GEO 3D). This mobile system has 6 high-
8 definition cameras that are positioned with respect to a local coordinate system based on the vehicle in
9 order to apply the principle of photogrammetry. The system integrates detailed global positioning
10 information with distance measurement instruments (DMI) and inertial measurement units (IMU) to
11 ensure the desired level of detail on the required information.
12

13 **CASE STUDY**

14
15 The previously described methodology was applied in four routes of Costa Rica's highway network (RN
16 1, RN 2, RN 32, and RN 34), for a total of over 1000 kilometers of evaluated highway.
17

18 **Retro-Reflectivity Measurement Results**

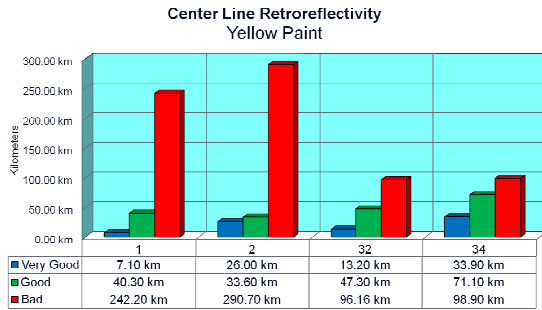
19
20 The measurement of retro-reflectivity is carried out for two types of road markings: the center line
21 (yellow), and the edge line (white). The markings are expected to provide different types of information
22 on lane use and directions and allow the users to gain critical information of the safety of the route (e.g.
23 the white line on the edge of the road informs the road users about the width available to users and the
24 presence of one or more lanes and even the operating speeds). Consequently, retro-reflectivity is one of
25 the most appropriate ways to measure how critical are the conditions for road users.

26 Due to the heterogeneity of the routes and the recurring presence of road markers these road
27 elements were included in the measurement of the retro-reflectivity. A reference value of 150 mcd/lx/m²
28 was used to define the minimum conditions for any category.
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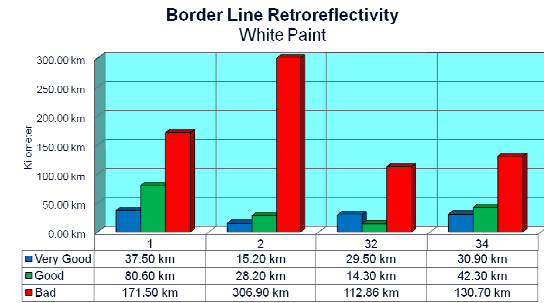
30 *Center Line Condition*

31
32 The retro-reflectivity measurements of the center line indicated that a total of 728 km (72%) did not
33 provide the minimum acceptable levels for road marking, and acceptable values were found on only 192
34 km (19%). Very good values were identified only 80.2 km (8%), mainly along NR 34. The results are
35 shown in **Figure 5 (a)**. The figure provides information as to the needs of the roadways and indicate that

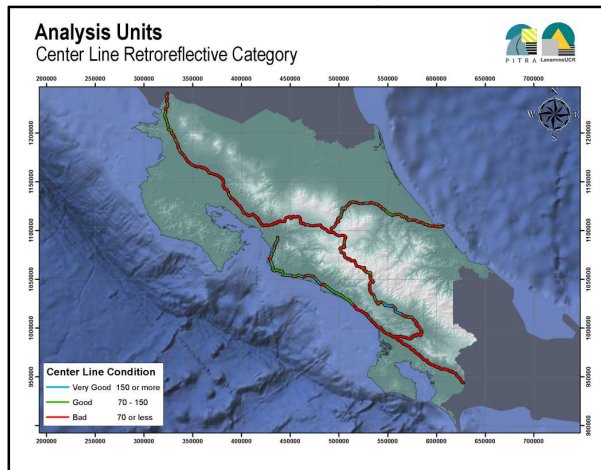
1 RN 1 and RN 2, which have the longer lengths, presented a non-compliance rate of retro-reflectivity of
 2 over 80%.
 3



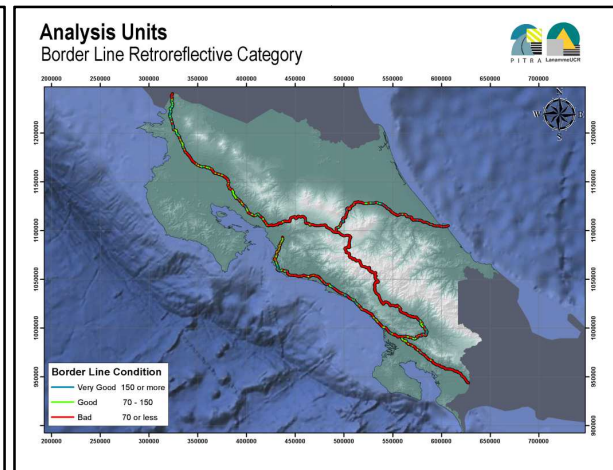
(a)



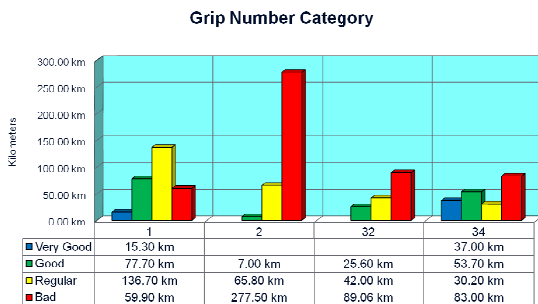
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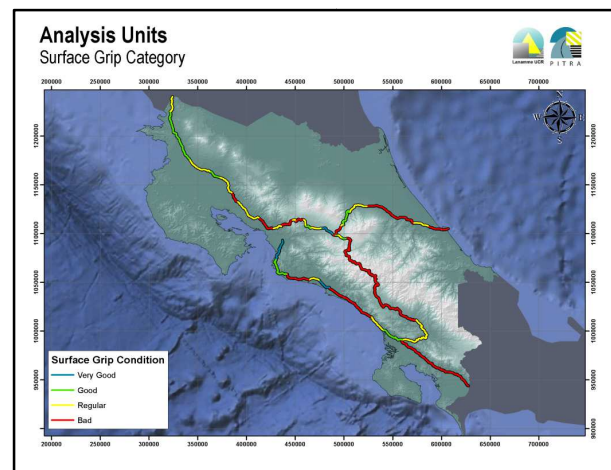
(c)



(d)



(e)



(f)

FIGURE 5 Retro-reflectivity and skid resistance analysis results.

The geographical distribution of the results is shown on Figure 5 (c). The red areas represent the values of retro-reflectivity that do not exceed 70 mcd/lux/m² defined as the minimum recommended

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1 value, the green areas are in the range of 70 to 150 mcd/lux/m² while light blue represents areas where
 2 retro-reflectivity meets all of the minimum retro-reflectivity requirements established in [Table 2](#).

3
 4 *Border Line Condition*

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 6 The measurement of retro-reflectivity for the border lines indicates that of the evaluated 1000 kilometers,
 7 a total of 721 km (72%) did not provide the minimum acceptable levels for road marking and acceptable
 8 values were found only in 165 km (17%). Very good values were only observed on 113 km (11%),
 9 mainly along RN 34. The details are shown in [Figure 5 \(b\)](#).

10 In general, RN 2 exhibits a non-compliance of over 80%, RN 1 is non-compliant by 59%, and RN
 11 32 and RN 34 are in worse condition than the line center retro-reflectivity. The geographical location of
 12 the problem areas is shown in [Figure 5 \(d\)](#). The color scale that is used is consistent with the one used for
 13 center line markings.

14
 15 **Skid Resistance Measurement Results**

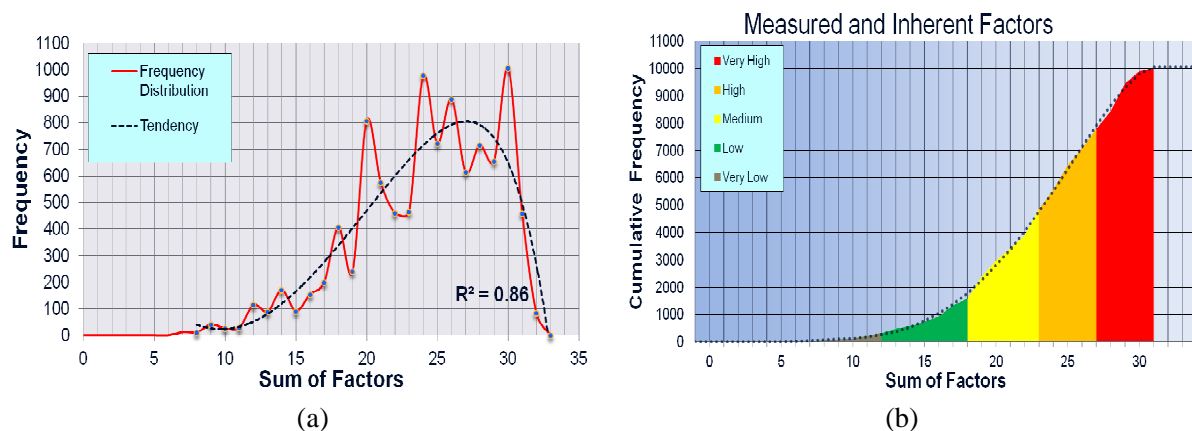
16
 17 The values used for this section of the analysis are based on the National Road Network Evaluation
 18 performed between 2010-2011. The data assessments are made based on [Table 2](#) and field observations.
 19 The results are shown in [Figure 5 \(e\)](#). Of the total number of assessed kilometers, nearly 509 km are in
 20 poor condition (51%), 274 km are in fair condition (28%), 164 km are in good condition (16%). The
 21 remaining 52.3 km are in very good condition (5%).

22 By plotting the results separately for each route, it can be observed that of the total 509 km in
 23 poor condition, a total of 277.5 km correspond to the RN 2 (more than half the kilometers rated in this
 24 condition). The results for all the routes are shown in [Figure 5 \(f\)](#).

25
 26 **Susceptibility Profile**

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 28 The susceptibility profile was performed in 100 meter roadway section (analysis sections). The analysis
 29 sections meet all the requirements defined in the study, and were ranked based on all of the previously
 30 defined categories.

31 The frequency distribution obtained after summing all the category weights is shown in [Figure 6](#)
 32 [\(a\)](#). The average sum of critical factors adds to 27, and is an indicator of the average condition of the
 33 analyzed corridors. Based on the results from the frequency distribution it was possible to establish a
 34 cumulative frequency distribution from the data. The final profile of susceptibility is based on the S-curve
 35 analysis of the cumulative frequency distribution, [Figure 6 \(b\)](#), which is helpful in characterizing the
 36 overall susceptibility of all the routes under the case study and eventually for the entire road network.



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 42 **FIGURE 6 (a) Frequency distribution and (b) cumulative distribution for all analysis sections.**

The next step consists on assigning a category to each unit of analysis (based on Figure 6) and generating a matrix that compares the performance obtained by each route based on defined categories of susceptibility. The summary of these results is shown in Figure 7 (a) which defines the number of kilometers in each condition of susceptibility (percentage of each route).

RN 2 has the largest number of kilometers with high susceptibility to accidents: 220.1 km (25% of the route exhibits poor geometrical alignment, dangerous climatic factors, poor retro-reflectivity and surface friction. RN 1 presents the lower values of accident susceptibility (76% of the data regular accident susceptibility or lower), which is largely attributable to more favorable climatic and alignment conditions. However, this does not imply that the individual assessments of retro-reflectivity are acceptable RN 32 ranges in accident susceptibility from the regular to very high (94% of the routes length). RN 34 has on average a regular susceptibility rating (36%). However the accident susceptibility distribution for this route is skewed to the very high susceptibility tail.

Figure 7 (b) shows the distribution of the vulnerability conditions, with the red representing the conditions of very high susceptibility, the orange areas are equivalent to a high susceptibility, yellow corresponds to regular susceptibility, low susceptibility sections are green, and blue is used for very low susceptibility areas.

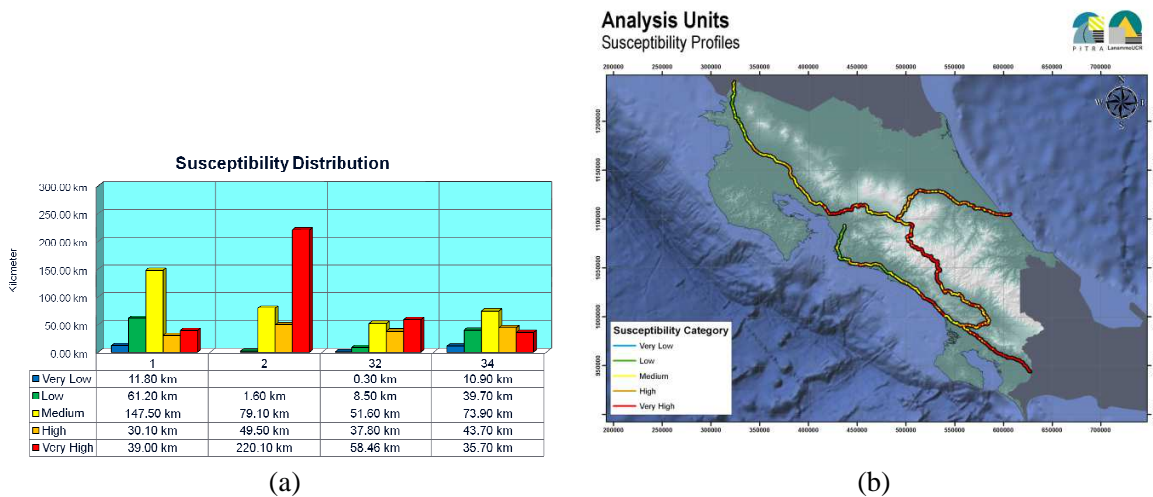


FIGURE 7 Susceptibility conditions per route.

Incorporation of Accident Data in the Susceptibility Analysis

Having identified the sections with different levels of susceptibility in the four major national routes (RN 1, RN 2, RN 32, and RN 34), the available accident data was incorporated into the study. Figure 8 shows the location of accidents along the analysis routes.

However, due to the lack of an official and updated accident database, which represents a mayor limitation of this study, it was necessary to do a geo-referencing of the registered accidents so that they could be incorporated into the GIS database with accuracy. The final database of analysis routes included a total of 550 accidents. The location of the accident records allowed for the establishment of a quantitative relationship between the road sections that are more susceptible to accidents based on the methodology and those with the largest number of recorded accidents.

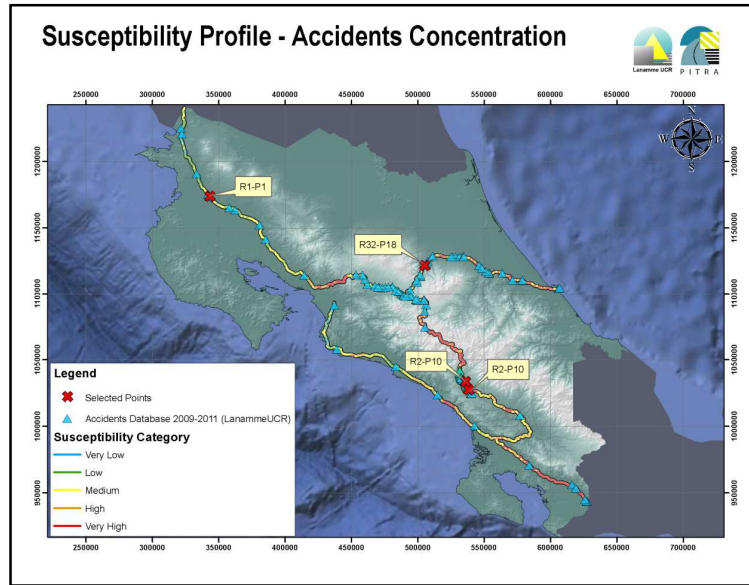


FIGURE 8 Accident that occurred along analysis routes (2009 - 2011).

One critical section of each roadway was used selected for further analysis (based on combined accident information / susceptibility ranking). Each of the sections was evaluated using the automated visual survey equipment mentioned previously and were analyzed using the checklists for conducting road safety audits as per Table 3. The specific location of each of the sections is shown on Figure 8.

These are critical sections, where the susceptibility is high and the concentration of accidents is significant. Analysis by the road safety audit checklists is a detailed diagnosis of route elements that can be corrected by the DOT. The use of the visual inspection device allowed for gathering of information at the level of detail that is required for the analysis using high-resolution geo-referenced images, which allow post evaluation of the data with a high degree of accuracy and efficiency (Figure 9).

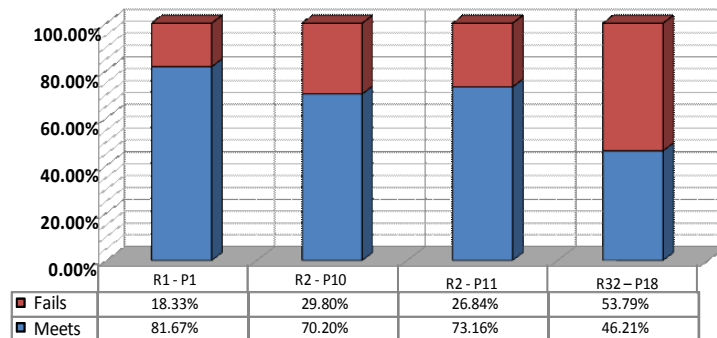


FIGURE 9 Road safety audit results.

CONCLUSIONS

The following are some of the observations resulting from the application of the methodology:

- 1 • The methodology used in this study allows classifying the different sections of a roadway into
2 different levels of vulnerability. The results allow the objective identification road sections, and
3 provide useful information to those in charge of the road safety, in order to program interventions that
4 can result in a significant reduction in the probability of accident occurrence.
- 5 • The performed evaluations using "checklists for road safety audits" demonstrate that in the locations
6 with high vulnerability, it is necessary to implement interventions that improve the road conditions:
7 lane widths, vertical markings and lighting, crash barriers and lateral clearance zones.
- 8 • A total of 61% of the length of the analyzed routes exhibited conditions of high and very high
9 accident vulnerability, when considering the contribution of the different evaluated factors: climate,
10 terrain, retro-reflectivity and friction.

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