Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 111 (2014) 624 – 633

Procedia
Social and Behavioral Sciences

EWGT2013 – 16th Meeting of the EURO Working Group on Transportation

Road safety performance assessment: a new road network Risk Index for info mobility

Vaiana Rosolino[a], Iuele Teresa[a,*], Astarita Vittorio[a], Festa D. Carmine[a], Tassitani Antonio[a], Rogano Daniele[a], Zaffino Claudio[a]

[a]*Department of Civil Engineering, University of Calabria, Arcavacata Campus, Cosenza, 87036 Italy*

Abstract

The development of communication systems for road traffic safety improvement has become one of the most important aims of information technology for road users. Detecting risk factors and informing drivers about them can contribute to make the transportation system more safe and comfortable. This assumption is the base of the Research Project "M2M – Mobile to Mobility" carried out at the University of Calabria, Italy. This research presents first applications of a methodology for developing a road safety performance index, Risk Index (RI), related to the risk deriving from infrastructure's features. In detail six different classes of events are identified: number of occurred accidents; density of intersections/accesses on the road section; road surface anomalies; problems related to both horizontal and vertical road signs and deficiencies of roadside and safety barriers. The research is focused on the possibility of giving real time information to road users about the risks associated to the specific travelled road segment, using a multiplatform mobile application and GPS system. The information is given to drivers considering driver's speeds (operating and average speeds) that are registered continuously by the application. In order to reach this aim, the road network is discretized with a squared grid: each node derived from the intersection of the grid with the infrastructure's network is considered as an informative node which contains the information related to an area, centered on the same node (RI_j). This step represents just the initialization of the road network, which will be enriched with new points generated by users trips uploaded through an automatic server-side. According to this procedure, the road network will be more "information-rich" as many users will use the platform, according to a *user-generated schema*. When the single driver is approaching to the i-th node, he may be informed on the Risk Index associated to the relative area and he simultaneously provides its speed at server.

Keywords: Risk Index; road safety; accident rate; user-generated contents; SOA.

* Corresponding author. Tel.: +390984496771; fax: +390984496771.
E-mail address: teresa.iuele@unical.it

1877-0428 © 2013 The Authors. Published by Elsevier Ltd.
Selection and/or peer-review under responsibility of Scientific Committee
doi:10.1016/j.sbspro.2014.01.096

1. Introduction

The use of information technology has become a key factor for road traffic safety improvement. In fact, detecting risk factors and informing drivers about them can contribute to make the transportation system more efficient, safe and comfortable. In the last few years, traffic safety has been one of the most important issue in road infrastructure management and many efforts have been made by both construction and management operators in order to contribute to a consistent reduction of accident risks. As it is well known, a road traffic crash results from a combination of several factors that include many components of the transportation system and the way they interact among them; in particular, recent studies have demonstrated that the accident risk, in terms of repeatability, localization and severity, is related to three main factors: i) vehicle type, depending on both passive and active provided safety systems; ii) road, in terms of design consistency and pavement surface performance (friction, texture), especially in wet conditions; iii) driver, who is the main factor for the occurrence of an accident (Elvik et al, 2009). Previous studies showed that many elements contribute to determine an unsafe and a distracted driving behavior related to driver's psycho-physical conditions, his mental workload, the reduction of the attention threshold and the increase of the perception-reaction time, PRT (Page, 2001).

Vehicles features determine about 10% of the overall accidents; about 30% of the accidents is related to road characteristics, such as the pavement (in a percentage of 10%), geometry (10%) and other factors (signal, guardrails, safety barriers, etc.). Accordingly, the most significant factor in an accident is the human behavior (60%) (PIARC, 2005; Mohan et al, 2006; Muhlras and Lassarre, 2005). A more recent study, based on a dataset of 100 vehicles for a year, showed that distractions and inattention (e.g., fatigue) contribute to approximately 80% of crashes and that distraction contribute to around 65% of rear-end crashes (Lee, 2008). The age of the driver also contributes to the attention failure due to a change in visual motion detection (Henderson, 2007). The development of new technologies for mobile devices allows a continuous monitoring of drivers behavior by means of position, speed and acceleration data collection (Astarita et al., 2012); on the other hand, with the widespread use of mobile application for driving assistance and navigation, it is possible to give road users some information about infrastructures features, in order to warn drivers during their trip and help them to correct their driving style in relation to the travelled road (Lee, 2008).

In the light of the abovementioned facts, this research focuses on the development of a multiplatform mobile application that advises drivers on the risk associated to the specific travelled road segment, in relation to the value of driver current speed. The risk evaluation is based on the calculation of a synthetic and composite indicator, named Risk Index (RI), that takes into account a set of significant factors related to the main three parameters influencing driving safety, as listed above. The paper is organized as follows. In section 2, the main risk factors are briefly described, together with their influence on traffic safety; the next section (Section 3) gives some details on the proposed index and the methodology used for its calculation is also discussed. The analysis of the road network management and the design of the system architecture are proposed in Section 4. The main results of a pilot study are summarized in Section 5. Finally, in Section 6, some conclusions and future perspectives are drawn. It is noted that this research is part of the wider Research Project "M2M – Mobile to Mobility: Information and communication technology systems for road traffic safety", which has been carried out by the Department of Civil Engineering at the University of Calabria, Italy.

2. Risk factors for road traffic accidents

A safe road traffic system can be defined as the one that accommodates and compensate for human vulnerability and fallibility (Muhlrad and Lassarre, 2005). During the last decades, many resources have been spent by automotive industry for the improvement of road user's protection (both drivers and pedestrian). Several activities also led to the enhancement of the safety level that a vehicle may offer by means of numerous new technologies: airbags, active safety systems like advanced brake systems, the ESC (Electronic Stability Control) are just some examples. However, these efforts seem to be not enough for a consistent reduction of traffic fatalities and crashes if they are conducted independent of an improvement of road infrastructure safety at all the stages of its lifetime: planning, design, construction and operation. By introducing different tools such as Road Impact Assessment, Road Safety Audits and Inspections and Black Spots Management, an integrated concept of safety, also within the road infrastructure field, was promoted and developed (Perandones and Ramos, 2008). All these efforts may not completely eliminate the transportation risk but they can contribute to a consistent reduction of risk exposure and to a minimization of crashes intensity and consequences.

Each transportation system is characterized by a high complexity and can be risky for human health. In order to make this system less hazardous it is necessary to evaluate the interactions among its potential dangerous elements by means of a comprehensive approach that may be helpful also for an adequate identification of interventions. Furthermore, the need to evaluate road safety by means of performance indicators is rapidly increasing, also because many influential factors have to be taken into account. Each of this factor determines different impacts on traffic safety, being more or less significant in relation to crashes severity.

The possibility of informing drivers about the risk associated to the road segment they are travelling is aimed at preventing future road accidents, especially where road infrastructure must be improved and previous fatalities occurred (ETSC, 2001; Perandones & Ramos, 2008). A risk factor is any factor that, all else being equal, increases the probability of sustaining an accident or worsens the severity of injuries (ETSC, 2001)**.** Previous studies have identified a number of risk factors influencing the possibility of being involved in a crash. Many of these parameters are summarized in Table 1 (Elvik et al, 2009; ETSC, 2001; Perandones and Ramos, 2008).

Table 1. Main factors affecting road safety

FACTORS	*Descriptions*
ROAD USER BEHAVIOUR	Speed; Fatigue; Overtaking manoeuvres; Alcohol; Travelling in darkness; Age of drivers; Use of seat belts;
ROAD CONDITIONS	Road surface; Inadequate visibility; Road Alignment; Defects in road design; Road junctions; Superelevation; Defects in road maintenance; Private accesses; Consistency;
VEHICLE FACTORS	Vehicle defects; Vehicle size; Technical conditions;
TRAFFIC FACILITY	Perfect rate of traffic sign; Serviceability rate of traffic marking; Traffic accident emergency rescue;
SOCIO-ECONOMIC FACTORS	Gross National Product; Unemployment; Urban population; Illiteracy.

3. Risk Index: objective and methodology

First stages of this research attempt to find a sub-set of variables, among the most important factors related to road safety (see Table 1),for the calculation of the Risk Index. This measurable parameter can be used for assessing and monitoring the risk level of a road segment. The possibility of giving this information to road users is addressed to the improvement of the active safety (accident mitigation), with the final purpose of solving road safety problems before they may become traffic accidents. The proposed integrated approach is based on the identification ofthe following six classes of factors, which can contribute to an accident occurrence:

- Number of previous occurred accidents. The safety level of a road infrastructure can be evaluated by means of the number and the severity of accidents that occurred during time. The analysis of historical data is a useful tool that allows road management operators to define the priority of maintenance intervention where the accident rate is high (Hautzinger et al, 2007). Historical accident data are an important indicator of roads safety performance for the identification of high-accident locations. A high-accident location is a road section (or intersection)characterized by a number of accidents greater than a specified fixed threshold during a recent period (typically 1 to 3 years). However, if no accident occurred in a road section in the past several years, it is not correct to think that it will never experience an accident; for this reason it seems to be necessary to investigate on other hazardous factors that can determine the risk level of a road segment. (Harwood et al., 2000).

- Density of intersections/lateral accesses on the road section. Direct access to roads can significantly increase accidents: previous studies show that a roadway segment with 10 driveways per kilometer can experience 75% more accidents than a segment with 4 driveways per kilometer (Cafiso et al., 2005). In particular, two issues are related with this topic: i) the excessive number of consecutive accesses on the road; ii) the position of accesses in both sides of the road one in front of the other; in this last case the effect on crash rate is higher because of the increase in the number of potential conflicts. Furthermore, the joint effect of roadway access and geometry, such as the combination of private access and horizontal curvature, intensifies the effect of access on the accident rate.
- Road surface anomalies and irregularities. Many bituminous roads are characterized by serious damages and distresses especially as regards surface performance. Several previous studies identified a correlation between the crash rate and road surface properties (friction, texture). Surface friction, developed at the tire-pavement contact, largely depends on pavement surface properties. Friction is an essential component of traffic safety because it provides the grip that a tire needs to maintain vehicle control and for stopping in emergency situations (especially in wet conditions). It is related to pavement texture and, consequently, accident ratio depends both on texture and friction (Vaiana et al., 2012). The presence of anomalies, such as potholes, on the road surface causes discomfort and pose safety risks to drivers (Steyen, 2011; Wilkie and Fergus, 2003; Shen et al., 2004). Moreover, pavement rutting could lead to vehicle hydroplaning and loss of skid resistance, especially in wet weather conditions. Previous studies showed that increasing road unevenness and rut depth determines an increase in accident by 2.3% after 10 years and by 4.8% after 20 years (Tiong et al., 2012; Elvik et al., 2009).
- Problems related to horizontal road signs. Generally, deficiencies in horizontal signs are referred to edge lines missing or inadequate, centreline missing or inadequate, and no-overtaking line missing, especially where passing sight distance is not provided. The accident risk is primarily affected by no-overtaking line missing: in this case the number of crashes can increase of 50% (Wilkie and Fergus, 2003). Moreover, an increase in injury accidents risk of about 8% was registered for edge lines missing, the rate of increase was of 13% for centerline missing (Wilkie and Fergus, 2003).
- Problems related to vertical road signs. A traffic signal can be defined as an object placed along the roadway in an attempt to aid or control the driver, transmitting an unambiguous, quick and clear message to road users (Ramos et al., 2008). Road signs that have the greatest effect on traffic safety are warning signs, since they call attention to hazardous situations (Montella, 2005). In a previous work, the relative risk factor for missing or ineffective curve warning signs on severe curves was fixed to10% (Wilkie and Fergus, 2003).
- Deficiency of the roadside and safety barriers. Designing a “forgiving” roadside is one of the most common best practices for road safety improvement. In fact, a roadside should be designed to minimize the consequences of a runoff-road event. The roadside configurations that are commonly associated with fixed-object crashes include many conditions such as the presence of obstacles in close lateral proximity to the curb face or lane edge, the presence of objects placed near lane merge points, etc. Furthermore, when an accident occurs, crash barriers along the roadway allow the kinetic

energy of the vehicle to be absorbed as they are deformed over a distance. In this way, human errors do not necessarily end in death or serious injury (European Commission, 2003; Karen et al, 2008). Risk increase for inadequate safety barriers was estimated to be equal to 60%. This rate was calculated by taking into account analytical relationships between a barrier's containment capacity and impact conditions that allow evaluating the number of vehicles successfully redirected in relation to the safety barriers containment level (Montella, 2001).

In order to consider the influence of each variable on the global level of risk, the following expression was used for the Risk Index calculation:

$$\sum_{i=1}^{n} x_i \cdot \alpha_i \tag{1}$$

where α_i represents the weight to be assigned to the each class of event (n=6), where x_i is a quantitative estimation obtained by the numerousness of each event occurred in an area of interest. x_i may change according to the number of occurrences of the single type of event and it can assume the following values:

- 0.25 (first level);
- 0. 50 (second level);
- 1.0 (third level).

In particular, the last four classes of events (Road surface anomalies and irregularities, Problems related to horizontal and vertical signals, Deficiency of the roadside and safety barriers) were collected using two sources of data: i) information obtained from a Road Safety Inspection on the Test site; ii) information generated from the contributions of professional users by means of another application developed for mobile devices. This application allows road management operators to send some warning messages about road deficiencies to a central server by means of geo-referenced photos. According to the selected analytical formulation, the Risk Index (RI) has a range between 0 and 1.Three levels of risk have been defined. Each level is determined on the basis of the RI value obtained by equation (1), as reported in Table 2.

Table 2. Level of risk associated to RI values

	0 < RI≤0.3	0.3 <RI≤ 0.6	0.6 <RI≤ 1
RISK INDEX	Low	Medium	High

The index is equal to zero if there are no occurrences related to the factors listed previously.

4. Road network management and platform design

The system architecture design has been carried out considering the *user generated content* paradigm and the geographical extension of data. User generated content is the information generated from the numerous contributions from users, enriched in this case study by certified information produced by professionals.

A Geographical Information System can be used to manage geographical information, in addition to a spatial object-oriented database to manage the big amount of information linked to the entire road infrastructure (Miller and Song, 2011). As shown in figure 1, the architecture illustrates the components of the platform: the web server (1), the spatial object-oriented databases (2), and the front-end user interface (3). The last component can be further classified by use cases:

- Information regarding road safety can be viewed through the use of a web browser, in this case referring to a web GIS;
- Real-time messages can be received by driving users on board, through the use of a dedicated smartphone mobile application.

The entire dataset is processed and published as REST services via the internet by the web server. The concept of REST service is supported by an architecture style of networked systems based on the use of REST, a common implementation of Service-Oriented Architecture (SOA). REST is the acronym of Representational State Transfer and it defines a set of principles by which it is possible to design Web services focusing on system's resources, including the way how resources are addressed and transferred by a wide range of clients over the internet through HTTP protocol (Giaglis et al., 2004).

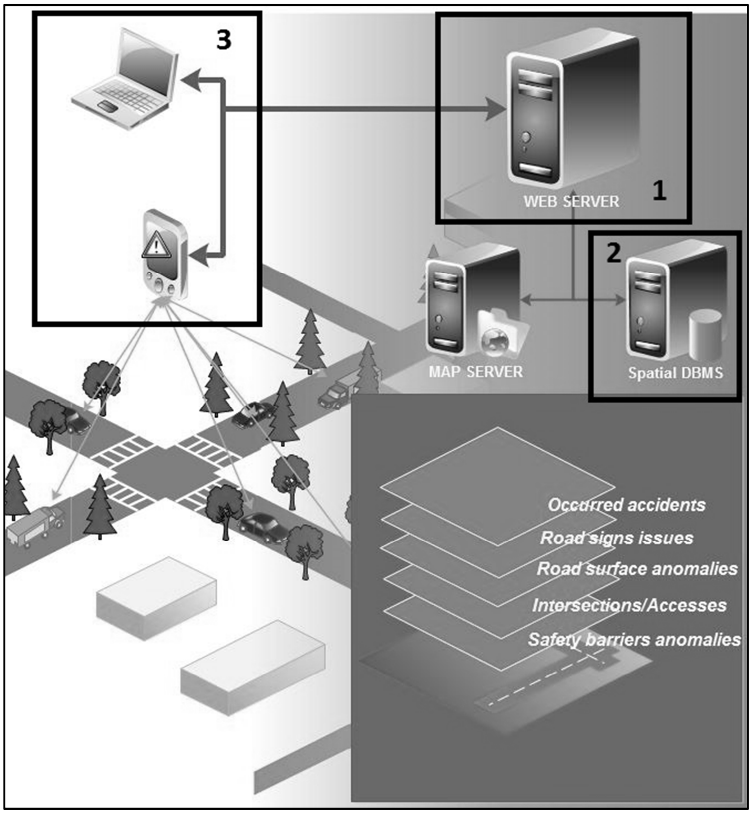

Fig. 1. System architecture

The adoption of REST to implement the architecture ensures scalability of component interaction, generality of interfaces, independent deployment of modules, latency reduction and security enforcement.

The platform as described distributed over the entire road infrastructure, will enable the user to receive real-time information on road safety, with the feature of visualizing the risk of accidents related to the various factors that contribute to the determination of the risk index (Lee et al., 2009). Speed is very often a crucial factor in accident occurrence and it has a great influence on road safety: the higher the speed, the shorter the available time to prevent collisions, and the more severe are the results of a collision. (ETSC, 2001). Starting from this consideration, the system architecture was designed in order to give information to road users on the risk level in relation to their speed. In particular, the road network was discretized with a squared grid: each node, derived from the intersection of the grid with the infrastructure network, is considered as an informative node which contains the information related to an area, centered on the same node. The radius of this area was set to 250 m:

the platform identifies each node, it processes data related to the numerousness of occurrences of each factor in the relative area, and it determines the RI value.

When the single driver is approaching to the i-th node, he may be informed on the Risk Index associated to the relative area; a warning message is given to drivers considering the vehicle speeds that are registered continuously by the application. It is necessary to outline that the warning is given after 30 users travelled on the i-th node according to two conditions: i) the level of risk (low, medium, high); ii) the vehicle current speed (Sc) compared with mean (Sm) and operative speed (So) registered from previous road users. If the number of users is lower than 30, the system assumes as mean and operative speed values the ones estimated by formulas found in literature (IASPIS, 2001) (Praticò and Giunta, 2012). However, the system alerts the driver only in particular conditions, as summarized in Table 3, where the platform logic is explained (0: no warning; 1: warning message).

Table 3. Platform logic for sending a warning message to road users

	RISK INDEX		
	LOW	MEDIUM	HIGH
Sc<Sm	0	0	1
Sm<Sc< So	0	1	1
Sc>So	1	1	1

5. Validation of procedure: a pilot study

A pilot study was carried out for the assessment of the proposed methodology and the analysis of the application feasibility. The test site network is composed of about 60 Km of a two lane road in the district of Crotone (Calabria, Italy). This test site was selected because it is characterized by many problems related to safety: i) the presence of a high number of uncontrolled accesses on the roadway; ii) a high number of occurred previous accidents, especially in particular black points (intersections, roundabouts, etc.); iii) many deficiencies in road pavement (potholes, irregularities) and signs. Data availability and robustness are key factors for ensuring the quality of risk analysis, for this reason, a detailed investigation was carried out on each factor taken into account for the Risk Index calculation. Many official sources of data, including both local governments and national administrations, were consulted. An accident data analysis was carried out by elaborating electronic data for the period 2007-2011. Most frequent accident types are both right and left–angle turning 45%), rear-end (30%) and head-on crashes (16.5%). A set of weights (α_i) and the relative $x_i$were selected by hypothesis as shown in Table 4.

Table 4. Set of weights and levels of occurrence for the pilot study on the selected test site

		LEVELS OF OCCURENCE		
α_i	FACTORS	FIRST	SECOND	THIRD
0.45	Accidents	1 - 3	4 - 7	>7
0.2	Surface anomalies	1 - 3	4 - 5	>5
0.2	Accesses	1 - 3	4 - 5	>5
0.05	Deficiency of vertical signs	1	1 - 3	>3
0.05	Deficiency of horizontal signs	1	1 - 2	>2
0.05	Deficiency of safety barriers	1	1 - 3	>3
	x_i	0.25	0.5	1

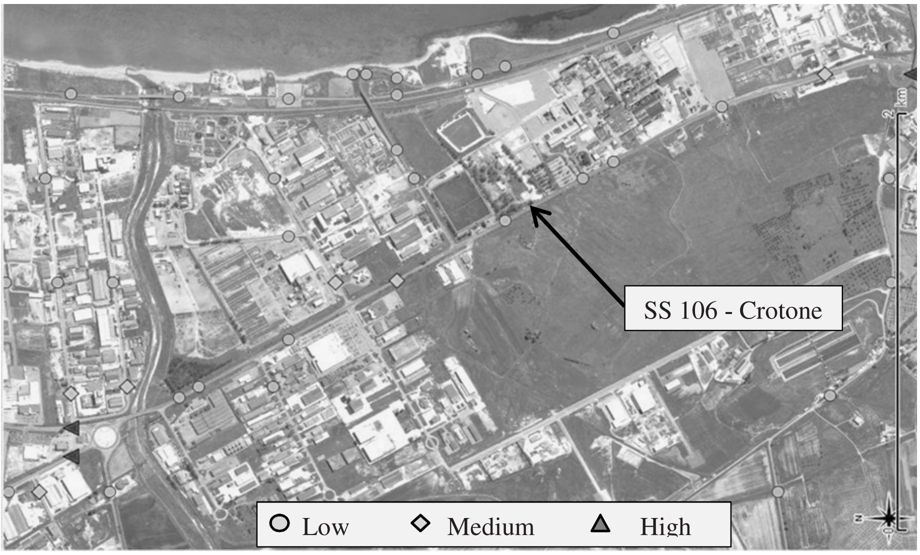

Fig. 2. Risk Index estimation on the test site

The proposed set of weights and levels of occurrence was used for the Risk Index calculation on the nodes of the test site (see Fig. 2). A validation procedure was carried out by a systematic comparison between data obtained from the Road Safety Inspection (RSI) of the test site and the estimated Risk Index in selected road segments. Some results are summarized in Table 5. As it is possible to see a satisfactory matching between the sets of data was reached, confirming the validity of the proposed method.

Table 5. Set of weights and levels of occurrence for the pilot study on the selected test site

ROAD SEGMENT	SAFETY LEVEL (RSI)	ESTIMATED RISK INDEX
SS 106 – "Poggio Pudano" (Straight Section)	FAIR - Few previous accidents; some problems related to pavement surface performance; high density of uncontrolled accesses.	0.36 (MEDIUM)
SS 106 – " Poggio Pudano" (Curve Section)	UNSATISFACTORY - High number of previous accidents; problems related to pavement surface performance; high density of uncontrolled accesses.	0.70 (HIGH)
Roundabout Intersection (SS106-SS107)	POOR - Some previous accidents; problems related to signs and barriers; few uncontrolled accesses	0.58 (MEDIUM)
SS 106 – "Ponte Ponticelli"	GOOD - No significant elements of risk; no previous accidents occurred; good condition of both signs and barriers.	0.10 (LOW)
SS 106 - "Le Spighe" Intersection	UNSATISFACTORY - Very high number of previous accidents; several problems related to the roadside and barriers; presence of surface anomalies; deficiencies in horizontal and vertical signs	0.70 (HIGH)

6. Conclusions

In this study a methodology for evaluating Road safety performance was assessed and a new road network Risk Index for info mobility was proposed.

Many variables affecting accidents occurrence were investigated; in particular six factors were selected for the Risk Index calculation among those proposed by scientific literature: number of previous occurred accidents; density of intersections/lateral accesses on the road section; road surface anomalies and irregularities; problems related to horizontal road signs; problems related to vertical road signs; deficiency of the roadside and safety barriers. A system architecture based on a user generated content paradigm was built for evaluating the Risk Index and informing drivers about the risk associated to the road segment travelled, in order to make the transportation system more safe and comfortable.

The proposed methodology was validated by means of a pilot study on a road test-site in province of Crotone (Calabria, south Italy); a sub-set of input parameters for the Risk Index calculation was selected. The values of the Risk Index estimated for some particular road segments were compared to the qualitative analysis obtained by a Road Safety Inspection of the same test site. Results showed that the methodology allows to reach a satisfactory matching between the two sets of data. Further investigation is needed for a wider application of the proposed method on several road types.

This research is part of the wider Research Project "M2M – Mobile to Mobility: Information and communication technology systems for road traffic safety" (PON National Operational Program for Research and Competitiveness 2007-2013, co-financed by European Regional Development Fund, FESR) carried out at the University of Calabria, Cosenza, Italy .

Acknowledgements

Authors wish to thank the Road Safety Monitoring Centre of the province of Crotone (south Italy) and TMS Consultancy Italy s.r.l., partners of the project M2M-Mobile to Mobility, for the support provided to the project.

References

Astarita, V., Caruso, M.V., Danieli, G., Festa, D.C., Giofrè, V.P., Iuele, T., & Vaiana, R. (2012). A mobile application for road surface quality control: UNIquALroad. *Procedia - Social and Behavioral Science,* 54, 1135-1144, DOI: 10.1016/j.sbspro.2012.09.828.

Cafiso, S., Di Graziano, A., La Cava, G., Leonardi, S., Montella, A., & Pappalardo, G. (2005). *Identificazione e adeguamento delle strade pericolose.* Mid Term Research Report, PROJECT TREN-03-ST-S07.31286, Identification of hazard location and ranking of measures to improve safety on local rural roads.

Elvik, R., Vaa, T., Erke, A., & Sorensen, M. (2009). *The handbook of road safety measures* (2nd ed.). Emerald Group Publishing Limited, ISBN: 978-1-84855-250-0.

European Commission (2003). *Saving 20 000 lives on our roads - A shared responsibility. European Road Safety Action Programme Halving The Number of Road Accident Victims in the European Union By 2010*, Communication from the Commission 311, ISBN 92-894-5893-3

European Transport Safety Council, ETSC (2001). Transport safety performance indicators. *Brussels, ISBN: 90-76024-11-1*

Giaglis, G., Minis, I., Tatarakis, A., & Zeimpekis, V. (2004). Minimizing logistics risk through real Time Vehicle Routing and Mobile Technologies. *International Journal of Physical Distribution & Logistics Management, 34-N°9,* 749-764.

Harwood, D.W., Council, F.M., Hauer, E., Hughes, W.E., & Vogt, A. (2000). *Prediction of the Expected Safety Performance of Rural Two-Lane Highways*. FHWA-RD-99-207, Technical Report.

Hautzinger, H., Pastor, C., Pfeiffer, M., & Schmidt, J. (2007). *Analysis Methods for Accident and Injury Risk Studies.* Project No. 027763 TRACE

Henderson, S. (2007). *Near peripheral motion detection threshold predicts detection failure accident risk in younger and older drivers.* Proceedings of the Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Stevenson, Washington , July 9-12.

IASPIS (2001). *Interazione Ambiente Sicurezza nel Progetto delle Infrastrutture Stradali.* Rapporto Conclusivo del Progetto di Ricerca IASPIS, COFIN 1998, Firenze, (http://roads.dicea.unifi.it/iaspis/Rapporto%20finale.htm).

Karen, K., Dixon, M. L., Zhu, H., Hunter M.P., & Mattox B. (2008). *Safe and Aesthetic Design of Urban Roadside Treatments*. National Cooperative Highway Research Program, NCHRP REPORT 612.

Lee, J. D. (2008). Driving Attention: Cognitive Engineering in Designing Attractions and Distractions. *The bridge, Linking Engineering and Society, 38-4*, 32-38.

Lee, W-H., Shieh, W-Y., & Tseng, S. (2009). Collaborative real-time traffic information generation and sharing framework for the intelligent transportation system. *Information Sciences, 180, Issue 1,* 62–70

Miller, H.J., & Song, Y. (2011). *Exploring traffic flow databases using space-time plots and data cubes.* International Conference on Control, Automation and Information Sciences, ICCAIS 2012, IEEE, Hochiminh City, Vietnam.

Mohan, D., Tiwari, G., Khayesi, M., & Nafukho, F. M. (2006). *Road traffic injury prevention training manual- Unit 2: Risk factors for road traffic injuries.* World Health Organization. Indian Institute of Technology Delhi ISBN 92 4 154675 1

Montella, A. (2001). Selection of roadside safety barrier containment level according to European union standards. *In Transportation Research Record: Journal of the Transportation Research Board, No. 1743,TRB, National Research Council, Washington, D.C.,* 104–110.

Montella, A. (2005). Safety Reviews of Existing Roads Quantitative Safety Assessment Methodology. *Journal of the Transportation Research Board*, *1922*, 62–72

Muhlrad, N., & Lassarre, S. (2005). Systems approach to injury control. In: G. Tiwari, D. Mohan, & N. Muhlrad (Eds.) *The way forward: transportation planning and road safety* (pp. 52–73) New Delhi, Macmillan India Ltd.

Page, Y. (2001). A statistical model to compare road mortality in OECD countries. *Accident Analysis & Prevention, 33, 371–385.*

Peden, M. et al. (2004). *World report on road traffic injury prevention*. World Health organization, Geneva.

Perandones, J. M., & Ramos, G. (2008). *Road Safety Index*. Ranking for European road safety, specific targeted research or innovation project, TREN-04-FP6TR-S07.36996/001678- Final Report D4.2.

PIARC, World Road Association (2006). *Interazione strada/veicolo - Monitoraggio delle caratteristiche e delle azioni del traffico veicolare per il progetto e la manutenzione delle pavimentazioni stradali*. XXV National Conference, Naples, Italy, October 4-7.

Praticò, F.G., & Giunta, M. (2012). Quantifying the effect of present, past and oncoming alignment on the operating speeds of a two-lane rural road. *The Baltic Journal of Road and Bridge Engineering, vol. 7(3): 181-190. (DOI: 10.3846/bjrbe.2012.25).*

Ramos, G., Perandones, J. M., Alonso M., Plaza J., & Vega H. (2008). *RANKERS Final Report*. Ranking for European road safety, specific targeted research or innovation project, TREN-04-FP6TR-S07.36996/001678- 2008 Final Report D0.2

Shen, J., Rodriguez, A., & Gan, A. (2004). *Crash Reduction Factors: a state-of-the-practice survey of State Departments of Transportation*. Proceedings of the 83rd Annual Meeting of the Transportation Research Board, January 10-14.

Steyn, W.J. vdM. (2011). *Evaluation of effects of road maintenance actions on applied tyre loads.* 10th Conference on asphalt pavements for Southern Africa, 11- 14 September.

Vaiana R, Capiluppi G.F, Gallelli V, Iuele T, & Minani V. (2012). Pavement surface performance evolution: an experimental application. *Procedia: Social & Behavioral Sciences, 53,* 1150-1161, doi: 10.1016/j.sbspro.2012.09.964.

Wilkie, S., & Tate, F. (2003). *Safety Audit of existing roads: developing a less subjective assessment*. Transfund report OG/0306/24S.

Tiong, P. L. Y., Mustaffar, M., & Rosli Hainin, M. (2012). Road Surface Assessment of Pothole Severity by Close Range Digital Photogrammetry Method - *World Applied Sciences Journal 19 (6,)* 867-873.