Perspectives of a web-based software to improve crash data quality and reliability in Italy

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Abstract*—Real-world crash data play a vital part in the development of safer transport since information on crash data is essential as a means of understanding where and why crashes occurred in the past and how the occurrence of similar events may be prevented in the future. Crash databases provide the basic information for effective highway safety management but several existing databases show significant drawbacks which hinder their effective use for safety analysis and improvement. In Italy, the national crash database is maintained by the National Institute of Statistics (ISTAT) and presents major issues related to the crash report form, the crash classification, the crash location, and the crash severity. Moreover, almost all police departments use an out-of-date paper form, not in line with the national and international needs. Modern technologies offer potential for significant improvements of existing methods and procedures for crash data collection, processing and analysis. To address these issues, in this paper we present the development and evaluation of a web-based platform-independent software for crash data collection, processing and analysis named ReGIS (Crash Data Collection, Processing and Analysis). The software is designed for mobile and desktop electronic devices and enables a guided and automated drafting of the crash report, assisting police officers both on-site and in the office. The software development was based both on the detailed critical review of existing Australasian, EU, and U.S. crash databases and software as well as on the continuous consultation with the stakeholders. The evaluation was carried out comparing the completeness, timeliness, and accuracy of crash data before and after the use of the software in the city of Vico Equense, in south of Italy showing significant advantages. The amount of collected information increased from 82 variables to 268 variables, i.e., a 227% increase. The time saving was more than one hour per crash, i.e., a 36% reduction. The on-site data collection did not produce time saving, however this is a temporary weakness that will be annihilated very soon in the future after officers are more acquainted with the software. The phase of evaluation, processing and analysis carried out in the office was dramatically shortened, i.e., a 69% reduction. Another benefit was the standardization which allowed fast and consistent data analysis and evaluation. Even if all these benefits are remarkable, the most valuable benefit of the new procedure was the reduction of the police officers mistakes during the manual operations of survey and data evaluation. Because of these benefits, the satisfaction questionnaires administrated to the police officers after the testing phase showed very good acceptance of the procedure.***

Keywords—highway safety; crash data; web-based software; data collection; data analysis.

I. INTRODUCTION

Real-world crash data play a vital part in the development of safer transport since information on crash data is essential as a means of understanding where and why crashes occurred in the past and how the occurrence of similar events may be prevented in the future. First step of the development of an effective safety management system is to create reliable crash databases since the quality of decision making in road safety depends on the quality of the data on which decisions are based [1]. Improving crash data is a worldwide priority, as highlighted in the Global Plan for the Decade of Action for Road Safety adopted by the United Nations, which recognizes that the overall goal of the plan will be attained improving the quality of data collection at the national, regional and global levels. Actually, modern safety management systems [2] use real-world crash data to: (a) identify sites with the most potential for crash frequency or severity reduction; (b) identify factors contributing to crashes and associated potential countermeasures to address these issues; (c) conduct economic appraisals of improvements and prioritize projects; (d) evaluate the crash reduction benefits of implemented treatments; and (e) estimate the effect of various design alternatives on crash frequency and severity.

Crash databases provide the basic information for effective highway safety efforts at any level of government, but lack of uniformity among countries [3] and among the different states and local jurisdictions in the same country is observed. To bring greater uniformity to crash data collection and to provide guidance to data collectors, guidelines to define a minimum set of standardized data elements which allow for comparable crash data were developed in Australasia [4], in the European Union [5] and in the United States [6].

However, several existing databases show significant drawbacks which hinder their effective use for safety analysis and improvement [7, 8]. Furthermore, modern technologies offer potential for significant improvements of existing methods and procedures for crash data collection, processing and analysis. To address this issue, in this paper we present the development and the evaluation of a web-based software for crash data collection, processing and analysis.

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II. State Of The Art

A. Australasia

In Australia, crash data are collected and validated by the police and transport agencies [1]. Each State has its own database and a crash data analysis system. These databases provide detailed information about crashes reported by the police. Major differences are related to the available tools, the accessibility, and the linkage to the other relevant data. Access to detailed police crash reports is restricted to varying degree in all of the jurisdictions, due to privacy reasons. In Queensland, Western Australia, and Victoria crash data is provided to road safety professionals through the State Governments websites. In other jurisdictions, the crash databases are maintained by the State road controlling authority and access to crash data is strictly monitored. In New Zealand, the Crash Analysis System (CAS) is maintained by the NZ Transport Agency. CAS includes all reported crash data (injury and property damage only crashes) since 1980. CAS is a full GIS based system that provides both database type inputs and outputs and extensive mapping capability. It produces automated collision diagrams and access to the original Police reports, including the diagrams of the crash scene prepared by the police officers. For each crash, over 100 variables are reported. CAS is available through a web-based portal for approved road safety professionals. This has led to a widespread use of crash data in research and road safety investigations.

B. United States

In the United States, State Police collect data on motor vehicle traffic crashes on specific roadways in each of the 50 states. Each state also has local police jurisdictions within counties, cities and towns that collect data on motor vehicle traffic crashes on the roadways not covered by the State Police [9]. Each state has its own safety database designed with content, format, data collection system, and data coding conventions to meet their needs. The Model Minimum Uniform Crash Criteria (MMUCC) represents the directions of improving crash databases on each State [6], but it is necessary to work in two directions: (1) standardization and (2) quality control. The United States has also specialized safety databases at the national level such as the Fatality Analysis Reporting System (includes fatal injuries from all US states) and the Highway Safety Information System (contains crash, roadway inventory, and traffic volume data from seven states).

Several electronic innovative procedures based on the use of software and new technologies are now becoming an emerging tool. Traffic and Criminal Software (TraCS) is an application software that combines with laptop computers, one or more PCs in a central office, and data communications to provide Officers with all of the functionality necessary to record and retrieve incident information wherever and whenever an incident occurs [9]. The software is used in 20 states, such as New York, Iowa, and Florida.

C. European Union

For years, crash data have been collected in the EU countries according to their own national systems. At the European level, disaggregate crash data are available since 1991 in CARE - the Community database on road accidents resulting in death or injury. To improve the uniformity in data collection among the EU states, the recommendation for a Common Accident Data Set (CADaS) consisting of a minimum set of standardized data elements has been developed. The CADaS variables are divided into four basic categories: crash-related, road-related, traffic unit-related, and person-related. Moreover, the EU directive on road safety management defines minimum requirements for fatal crash reports on roads that are part of the trans-European road network [10].

In Italy, the national crash database is maintained by the National Institute of Statistics (ISTAT) and contains only information on injury crashes. The database has strictly restricted access and presents major issues related to the crash report form, the crash classification, the crash location, and the crash severity [11-12]. Nowadays, the Italian Highway Police collects the crash data using a paper form. Most of the urban crashes are collected by Local Police. Almost all departments use an out-of-date paper form, not in line with the national and international needs. The recording and evaluation of the data are manual and there are different paper archives spread through the country.

D. Prospects for improvement

Access procedures to crash data have a significant impact on how widely the data gets applied and differ substantially across countries. The access to crash data to approved road safety professionals through web-based portals may provide the best benefits for road safety improvement. Indeed, qualification is vital for an effective safety management process [13-15].

The most important and troublesome piece of crash data is the crash location [16]. The combined use of GPS devices and GIS overcomes traditional problems associated with the use of GPS devices, such as inaccuracies and collection mistakes.

Crash narrative is a key part of the police report [7]. Including crash narrative in the databases and classifying crashes by the maneuvers and sequence of events of each traffic unit is strongly recommended.

Crash severity is very important since the crash costs greatly varies in relation to the severity. Road deaths represent only the tip of the iceberg out of the total number of road crashes. It would be important to link police data and hospital data [17] as well as to include in the crash databases detailed information on crash severity (and the MAIS score, if available).

To date, the most common road crash data collection methods are manual and paper-based form which involve several problems that may be overcome by the use of an electronic form [18]. To advance real-time decision making, reduce the burden of data collection, improve data quality, facilitate transfer, merging and sharing, and make data available sooner, the use of electronic technologies and methods to collect crash data (E-Crash systems) on a regular basis is strongly recommended in all the countries.

III. Framework of the ReGIS E-Crash System

To improve data quality and reliability, facilitate transfer, merging and sharing, and make data available sooner without increasing the burden of data collection, we developed a web-based software for crash data collection, processing and analysis. The software is named ReGIS (Italian acronym of Crash Data Collection, Processing and Analysis) and has been developed in Italy involving the National Institute of Statistics, the Highway Police Department of Campania and Molise, several Local Police departments, and the road safety offices of the City of Naples and the Metropolitan City of Naples. Since the quality of the collected crash data is undoubtedly related to the collector's skills, we also wrote a User Manual in order to both explain how the system works and to update police officers on main road safety issues.

A. Software architecture

ReGIS is a web application designed as SaaS (Software as a Service) using a cloud infrastructure. This technology enables high flexibility and does not need maintenance activities by the final user. To guarantee redundancy, security and on demand scalability, a cloud based approach has been used. ReGIS uses open source technologies such as frameworks (Bootstrap, JQuery, Google API) and the LAMP (Linux, Apache, MySQL, PHP) platform to host dynamic websites. ReGIS has full compatibility with the standards of the modern mobile devices. This allows to use phone's geolocation sensors and to get GPS coordinates that enable the developing of Geographical Information Systems.

As a web application, ReGIS is Platform Independent and is relying upon real-time services. Further improvements will lead to a system which can work offline and is usable also if the internet connection is unavailable; to date, the missing information in case of unavailability of the connection can be uploaded later. The software is designed for mobile and desktop electronic devices (smartphone, tablet, PC, laptop, etc.). It enables a guided and automated drafting of the crash report on-site, allowing the contemporary access to different users, i.e., different police officers who simultaneously perform different activities in order to speed up the process (Fig. 1).

To run the software, the police officer types the web link to ReGIS in the URL bar of a browser. The login web page is secured by PHP and JavaScript algorithms. After the login, the police officers can start a new crash survey or manage previous reports. ReGIS has three levels of entry: (1) police officer, (2) supervisor, and (3) chief police officer. The police officer cannot use all the functionalities and can only see his reports, the supervisor can use all the functionalities and can see all the crashes but he cannot administrate the users. The chief police officer can also create new accounts, delete accounts and reports, and, in special cases, modify archived crash information.

Each crash has its own management page. This web page gives to the operator the full control of the operations to be performed and the state of progress during the filling of reports, thus facilitating the reporting operations both on site and in the office. The system is user-friendly and easy-to-use, allowing also police officers not familiar with Information and Communication Technologies to easily create a report. When a new survey starts, the software reminds to the police officers all the important actions to be carried out. Entering some basic information, the software automatically creates all the forms needed to input the information in the database. These forms are interactive and the structure of each level changes according to the information entered in the previous one.

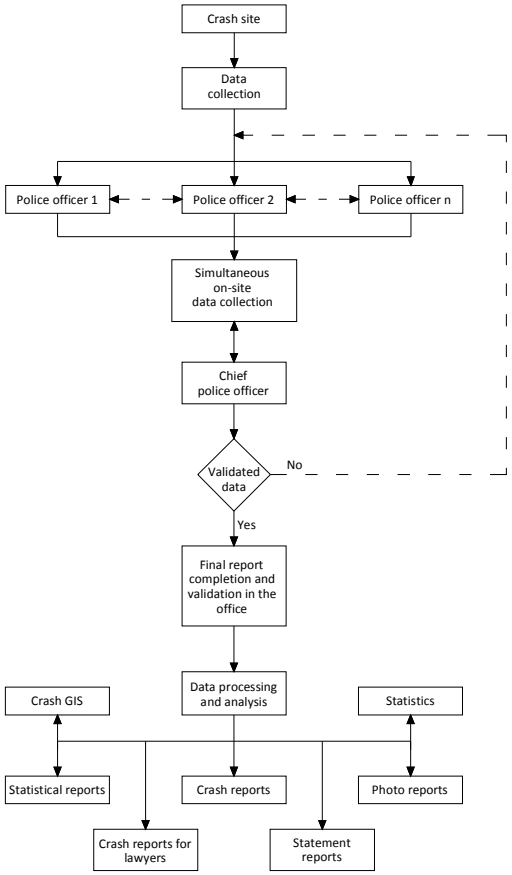

Fig. 1 - Framework of the ReGIS E-crash system.

The crash data are collected using six different standard forms, reflecting the structure of the database. All the variables are divided into six basic categories: (1) Crash, (2) Road and Environment, (3) Vehicle, (4) Driver, (5) Passenger, and (6) Pedestrian. The forms have been designed to meet both the needs of the Police as well as the needs of the road safety agencies which shall use this information to take decisions for the highway safety management. The use of the forms on-site guides the police officer and highly improves data quality and reliability. To help the users to better understand the meaning of some technical and engineering information, there are information buttons that activate pop–ups with a short explanation and a link to the user manual. The forms have also been designed to be easily completed electronically using drop–down lists, check-buttons, and vocal writing.

B. Structure of the database

The database has been developed using MySQL (Relational Database Management System). It is structured in 19 tables, which contain 580 variables. The variables strictly related to the crash analysis are 290. The main feature of the database is the possibility to insert all the needed information by a Relational Database. ReGIS software automatically creates all the input forms needed using an algorithm that allows to insert data of a single crash on more rows, without losing information or slowing the system. To appreciate the differences, it is worth to observe that the Italian National Institute of Statistics (ISTAT) collects 82 variables with not more than 201 fields for each crash (vs. 580 variables of ReGIS). ReGIS software collects more than three times the number of variables now used (Table1).

TABLE I.
DATA COMPARISON BETWEEN REGIS AND THE DATABASE OF THE ITALIAN NATIONAL INSTITUTE OF STATISTICS.

Table	Variables collected by ISTAT	Variables collected by ReGIS	Δ
Crash	17	60	+253%
Road and Environment	13	41	+215%
Vehicle	9	72	+700%
Driver	15	44	+193%
Passenger	13	26	+100%
Pedestrian	15	25	+67%
Total	82	268	+227%

The information is divided into six basic forms: (1) Crash, (2) Road and Environment, (3) Vehicle, (4) Driver, (5) Passenger, and (6) Pedestrian. The other forms contain information about violations, statements, system variables, attached documents, and pictures.

C. Features of the system

Crash data need to be supplemented by other information, including road inventory and survey data of key behaviors, enforcement data, and emergency and medical system quality data. ReGIS software is designed to collect all this information in a user–friendly format.

Crash location is undoubtedly one of the most critical issues. The combined use of GPS devices and GIS overcomes traditional problems associated with the use of GPS devices, such as inaccuracies and collection mistakes. To increase location reliability, the database stores both route name and GPS/GIS information and matches the data. Police officers have also the option to manually correct the crash location.

The crash severity is automatically derived by the ReGIS software from the Injury Status for each person involved in the crash. Crash severity classification has been carried out considering the needs of the different stakeholders and the international definitions of diseases (e.g., MAIS). Information about prognosis and recovery time, the type of injuries and the injury area are collected. This helps to better evaluate the crash consequences. ReGIS detects all the hospital information and has the capabilities to communicate with the hospital databases. Police officers can also store medical reports into the ReGIS archive.

Crash classification needs to take into account that crashes are multi-factor events and that all crashes have a chain of events leading to the collision and to subsequent damages and/or injuries [19-21]. The crash data collection form guides the users to report the crash narrative, to distinguish the different events leading to the collision and to collect them with a standard procedure, reporting for each traffic unit: (a) the controlled maneuver prior to the beginning of the sequence of events, (b) the critical event, (c) the evasive maneuvers, (d) the collision manner, and (e) the events after the collision.

Police officers are not transportation engineers, but a complete collection of the road information is required. To help the crash data collectors to detect technical road information, the software provides a simple collection method. The road information are collected separately. To understand the meaning of the different fields, there are info-buttons which provide fast and simple explanations.

To investigate road users' behavior, the software enables to report in detail the physical and mental condition of the drivers. In the case of professional drivers, a specific section allows to define the number of driving hours and break hours. The pedestrian form allows to report sequence of events before, during and after the crash in order to better understand the contributing factors.

Main specific features of the system are:

a) *Contemporary multi-user compilation.* During the on-site data collection, each police officer can enable one or more colleagues to take part of the collection process. All the involved police officers can simultaneously fill out different forms reducing the time spent on-site.
b) *Input control.* ReGIS uses automated software error controls and logic checks to improve data accuracy. These automated controls generate warning alerts highlighting potential errors but they do not automatically change the input values.
c) *Secure login*. The connection to the platform is carried out through a secure login page protected by PHP and JavaScript algorithms.
d) *Sketch*. The police officer can make a simple and efficient sketch of the scene by a touch screen technology.
e) *Photo gallery*. The photo gallery allows the police officers to update the pictures of the crash scene on the cloud service in order to see and add the pictures from any place and any device.
f) *Geolocation*. Through the use of the GPS and GLONASS sensors of the mobile device, it is possible to collect the correct crash position using the geographic coordinate together with the street name. Officers have also the option to manually correct the position.
g) *Geographical Information System.* The geolocation allows creating a GIS with all the crash locations or with the location of specific crash types.
h) *Automatic statistics.* The web-app elaborates the data and easily produces updated crash statistics. This feature

reduces officer's workload and increases the reliability of the data, eliminating the transmission of incorrect information associated with manual processing.

i) *Digital archive of documents*. It allows to gather into a single space all the documents useful to the reconstruction of the crash dynamics and the identification of responsibilities.

j) *Collection of statements*. It is speeded through the use of the vocal writing. The forms for spontaneous declarations are automatically completed with the personal data of the people involved in the crash (drivers, passengers, and pedestrians).

k) *Crash report*. The software automatically edits a crash report, which can be revised by the police officers, with the aim to offer an effective synthesis of the crash. This document allows to provide a complete summary of the crash information.

l) *ISTAT file.* The system automatically generates a .txt file where the data are reported according to the standards of the Italian National Institute of Statistics. This function enables the electronic transmission of the information to the national database eliminating the mistakes related to the conversion from the paper form. The same function may be easily implemented to convert the data according to the standards of different countries.

IV. Evaluation of the ReGIS E-Crash System

A. Test site

The first experimentation of the system was entrusted to the Vico Equense Police Department by a scientific collaboration agreement with the Department of Civil, Architectural and Environmental Engineering of the University of Naples Federico II signed in October 2015. Vico Equense is a city in the Metropolitan City of Naples in Southern Italy. The average number of crashes per year from 2010 to 2015 was almost one hundred.

The Local Police Department has 28 police officers and until January 1st, 2016 they had never used an electronic system for road crash survey. Indeed, before the experimentation they used only paper forms and manual procedures. The test started by a two-days training course. Initially, the software was delivered to a small number of police officers who carried out the surveys with both the electronic and the manual procedure. At the beginning, the police officers used the software with the assistance of the staff of the University.

This phase allowed evaluating the differences between the old and the new procedures and, at the same time, to monitor the results. Until June 30th, during the first six months of testing, the Police Department collected 47 crashes.

B. Test results

The system effectiveness was evaluated according to three criteria: (1) quantity of information; (2) time spent to collect and process the data; and (3) satisfaction of the police officers.

To compare the data before and after the introduction of ReGIS, the information of the 84 crashes reported in 2015 by the manual procedure have been inserted in ReGIS. Collected data in 2015 and in 2016 were compared (Table 2) and the results show a significant increase in the quantity of collected information after the introduction of ReGIS.

TABLE II.
COMPARISON OF COMPLETED FIELDS BEFORE AND AFTER THE USE OF REGIS.

Table	Completed fields before	Completed fields after	Δ
Crash	28%	32%	+13%
Road and environment	28%	47%	+68%
Vehicle	24%	32%	+32%
Driver	23%	31%	+33%
Passenger	24%	25%	+4%
Pedestrian	34%	51%	+49%
Total	26%	35%	+33%

The amount of collected information increased from 82 variables to 268 variables, i.e., a 227% increase. Road and environmental data showed the most significant increase. This is mainly because the procedure guides the user during the data collection and asks for several information which were not collected before. The presence of multiple choice fields, info-buttons, check-buttons and drop-down lists simplifies the data collection. The use of the digital methodology guides the user in the survey activities, creating all the input forms that shall be filled for each crash providing a validated framework of the data collection process.

To evaluate the time needed to process each crash, six crashes were collected by two different police teams with the traditional and the new procedure. The on-site data collection phase was split into 9 activities and the office evaluation, processing and analysis was split in 7 activities. Average times of each activity have been compared (Table 3). The time saving was more than one hour per crash: 110 minutes per crash with ReGIS vs. 172 minutes per crash with the traditional procedure, i.e., a 36% reduction. The on-site data collection did not produce time saving, however this is a temporary weakness that will be annihilated very soon in the future after officers are more acquainted with the software. The phase of evaluation, processing and analysis carried out in the office was dramatically shortened: 31 minutes per crash with ReGIS vs. 100 minutes per crash with the traditional procedure, i.e., a 69% reduction. Finally, a satisfaction questionnaire was administered to fifteen police officers. The questionnaire was divided in six sections and police officers were asked both to provide a rate on a scale from 1 (very poor) to 5 (excellent) as well as to provide comments about advantages, drawbacks and suggestions for improvement. Average scores were very good: 4.4 for the ReGIS overall satisfaction, 4.9 for the organization of the electronic forms, 4.1 for the quality of the automatic report, 4.8 for the quality of the GIS, 3.4 for the violations, and 4.0 for the photo gallery.

TABLE III.
COMPARISON OF TIME SPENT BEFORE AND AFTER THE USE OF REGIS.

Phase	Action	Before [min]	After [min]	Δ [min]
On-site data collection	Preventive check of the crash site, involved people and vehicles identification and delimitation of the area	6	6	0
	Vehicles data collection	5	7	+2
	Persons data collection	5	7	+2
	Check of the validity of the documentation	4	4	0
	Road and environment data collection	5	6	+1
	Sketch of the crash scene	17	18	+1
	Violations reporting	4	4	0
	Removal of traffic disruptions	17	19	+2
	Photographic surveys	9	10	+1
	Total time on-site	72	79	+7 (+9%)
Office evaluation, processing and analysis	Preparation of the dossier	5	1	-4
	Updating and checking of information	0	15	+15
	Road crash reporting	36	2	-34
	Copy of records and documents	8	4	-4
	Storage	15	1	-14
	Statistical data evaluation	26	3	-23
	Preparation and delivery of the relevant crash information to the lawyers	12	4	-8
	Total time in the office	100	31	-69 (-69%)
	Total time	**172**	**110**	**-62 (-36%)**

V. CONCLUSIONS

ReGIS is a web-based software platform-independent for crash data collection, processing and analysis according to the international best practices that addresses most of the drawbacks of existing procedures. The software is designed for mobile and desktop electronic devices and enables a guided and automated drafting of the crash report, assisting police officers both on-site and in the office.

The evaluation was carried out comparing the completeness, timeliness, and accuracy of crash data before and after the use of the software in the city of Vico Equense, in south of Italy showing significant advantages.

The amount of collected information increased from 82 variables to 268 variables, i.e., a 227% increase, with road and environmental data showing the most significant increase. The time saving was more than one hour per crash: 110 minutes per crash with ReGIS vs. 172 minutes per crash with the traditional procedure, i.e., a 36% reduction. The on-site data collection did not produce time saving, however this is a temporary weakness that will be annihilated very soon in the future after officers are more acquainted with the software. The phase of evaluation, processing and analysis carried out in the office was dramatically shortened: 31 minutes per crash with ReGIS vs. 100 minutes per crash with the traditional procedure, i.e., a 69% reduction. Another benefit was the standardization which allowed fast and consistent data analysis and evaluation. Even if all these benefits are remarkable, the most valuable benefit of the new procedure was the reduction of the police officers mistakes during the manual operations of survey and data evaluation. Because of these benefits, the satisfaction questionnaires administrated to the police officers after the testing phase showed very good acceptance of the procedure.

Finally, in the framework of a safe road system, the ReGIS Software has the potential to create a unique and shared database among the different police offices, the road agencies, the administrative offices, and the hospitals.

REFERENCES

[1] Austroads, 2015. Guide to Road Safety Part 8: Treatment of Crash Locations. Austroads Publication AGRS08/15, Sydney, New South Wales, Australia.

[2] AASHTO, 2010. Highway Safety Manual, 1 st ed. AASHTO, Washington D.C.

[3] WHO, 2010. Data systems: a road safety manual for decision-makers and practitioners. Geneva.

[4] Austroads, 1997. A minimum common dataset for the reporting of crashes on Australian roads. Austroads Report AP-126/97, Sydney, New South Wales, Australia.

[5] De Meester, D., 2011. Recommendation for a Common Accident Data Set. Reference Guide, Version 3.11.

[6] NHTSA, 2012. MMUCC Guideline: Model Minimum Uniform Crash Criteria, 4th ed. Report DOT HS 811 631.

[7] Montella, A., Andreassen, D., Tarko, A., Turner, S., Mauriello, F., Imbriani, L.L., Romero, M., 2013. Crash databases in Australasia, the European Union, and the United States: review and prospects for improvement. Transport. Res. Rec. 2386, 128–136.

[8] Montella, A., Chiaradonna, S. Criscuolo, G., De Martino, S., 2017. Development and evaluation of a web-based software for crash data collection, processing and analysis. Accid. Anal. Prev., http://dx.doi.org/10.1016/j.aap.2017.01.013.

[9] Iowa Department of Public Safety, 2016. Highway Safety Plan.

[10] European Commission, 2008. Directive 2008/96/EC of the European Parliament an of the Council of 19 November 2008 on road infrastructure safety management. Official Journal of the European Union, L. 319/59.

[11] Montella, A., Imbriani, L.L., Marzano, V., Mauriello, F., 2015. Effects on speed and safety of point-to-point speed enforcement systems: evaluation on the urban motorway A56 Tangenziale di Napoli. Accid. Anal. Prev. 75, 164–178.

[12] Montella, A., Persaud, B., D'Apuzzo, M., Imbriani, L.L., 2012a. Safety Evaluation of an Automated Section Speed Enforcement System. Transport. Res. Rec. 2281, 16–25.

[13] Cafiso, S., La Cava, G., Montella, A., 2011. Safety Inspections as a Supporting Tool for Safety Management of Low-Volurne Roads. Transport. Res. Rec. 2203, 116–125.

[14] Montella, A., 2007. Roundabout In-Service Safety Reviews: Safety Assessment Procedure. Transport. Res. Rec. 2019, 40–50.

[15] Montella, A., Mauriello, F., 2012. Procedure for Ranking Unsignalized Rural Intersections for Safety Improvement. Transport. Res. Rec. 2318, 75–82.

[16] Tarko, A.P., Grant, D., Thomaz, J., 2009. Probabilistic Determination of Crash Locations in a Road Network with Imperfect Data. Transport. Res. Rec. 2102, 13–20.

[17] Couto, A., Amorim, M., Ferreira, S., 2016. Reporting road victims: Assessing and correcting data issues through distinct injury scales. Journal of Safety Research 57, pp. 39–45.

[18] Andreassen, D., 1995. The Electronic Accident. Proceedings IPENZ Conference, Vol. 1, 86–91.

[19] Montella, A., 2011. Identifying crash contributory factors at urban roundabouts and using association rules to explore their relationships to different crash types. Accid. Anal. Prev. 43(4), 1451–1463.

[20] Montella, A., Aria, M., D'Ambrosio, A., Mauriello, F., 2012b. Analysis of powered two-wheeler crashes in Italy by classification trees and rules discovery. Acc. Anal. Prev. 49, 58–72.

[21] ROSPA – The Royal Society for Prevention of Accidents, 2002. Road Safety Engineering Manual. Birmingh