IDENTIFICATION AND RANKING OF DANGEROUS VIOLATION TYPES: ABU DHABI CASE STUDY

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ABSTRACT

While motorized travel provides many benefits, it can also do serious harm in the form of road-related accidents. The problem affects millions of human lives and costs billions of dollars in economic and social impacts every year. The problem could be addressed thorough several approaches with engineering and enforcement initiatives being usually recognized as sustainable and cost effective. The success of any initiative in reducing accident occurrences hinges upon the existence of reliable methods that provide accurate estimates of road safety. This paper focuses on the enforcement side of safety improvement programs where the aim to identify and rank hazardous traffic violation types. From our perspective, a dangerous/hazardous violation type is the one which may lead to more severe accident occurrences. Identifying violation types that are considered more "hazardous" is essential for refining the traffic law penalties so that a violation type that would be considered more hazardous should be more rigorously penalized. An extensive empirical investigation was carried out using drivers' violations and accidents databases of Abu Dhabi Emirate, the capital of the UAE for a period of 8 years (2008-2015). Different methods to identify and rank hazardous violation types were applied and compared; the confidence interval (CI) method, the rate quality control (RQC) method, and the percentage of drivers involved in severe road accidents. A survey was also undertaken to solicit experts and drivers' opinions on how they perceive the hazardousness of each violation type. The results of the survey were also used to rank the violation types according to their hazardousness. In terms of identification, the CI and RCQ methods showed different outcomes. Nonetheless, for the same two methods, the results were identical for the ranking. Ranking violation types by the percentage of drivers involved in severe road accidents was very similar to the ranking using the CI and RCQ. Nevertheless, experts and drivers' opinions were shown to be significantly different from the results of CI and RQC methods. Legislation and enforcement efforts focusing on "more hazardous" violation types, if properly designed and implemented, are believed to be effective in reducing the overall number of severe accidents.

KEY WORDS

Dangerous violations, traffic enforcement, traffic legislation.

INTRODUCTION

Traffic safety has been a serious concern since the start of the automobile age, approximately eleven decades ago. In spite of this concern, traffic safety problems have prevailed over the past century causing enormous economic and social costs. It is commonly accepted that there are many costs associated with vehicular mobility such as air pollution, noise, visual intrusion, and accidents. However, the economic and social costs associated with road accidents greatly exceed other mobility costs due to the pain, loss of property, injury, and deaths attributed to road accidents.

At the highest level of abstraction, the road system is usually characterized by three main components: the driver, the vehicle, and the road (Haddon May 20, 1983, Sayed, Abdelwahab and Navin, Identifying Accident-Prone Locations Using Fuzzy Pattern Recognition 1995) .The dynamic and complex nature of the road system can be interpreted through the interactions and relationships that exist among the road system components. Road accidents and other system negative impacts (i.e. noise, congestion, pollution, etc.) are usually regarded as the "byproducts" of the road system and they result from the failure in any of the three components of the road system (Sayed and Abdelwahab, Using Accident Correctability to Identify Accident Prone Locations 1997, Karacasu and Er 2011).

Several studies (Sayed, Abdelwahab and Navin, Identifying Accident-Prone Locations Using Fuzzy Pattern Recognition 1995, Karacasu and Er 2011) have shown that driver error contributes to approximately 75-90% of all accidents on the road. Thus, safety initiatives focusing on the driver should often lead to significant reductions in accident occurrence. Nevertheless, it has never been easy to understand the complex human driving behavior which is not only governed by individual's knowledge and skills but also by the surrounding environment. Indirect influences, such as the design and layout of the road, the type and nature of the vehicle, and traffic laws and their enforcement – or lack thereof – also affect the driving behavior.

A better understanding of the drivers' behavior is likely to support the development of better traffic laws and legislation. This is particularly important for a country like the UAE where more than two hundred different nationalities with different education levels, cultural backgrounds, languages, and driving skill sets live in the country. Such diversity of road network users creates a considerable challenge for different authorities responsible for road safety. In the Emirate of Abu Dhabi (AD), the capital of the UAE, tangible efforts have been recently undertaken to improve road safety by focusing on strategies targeting enhancements in the engineering, education and enforcement sides. As a result, the number of accident fatalities in the emirate has dropped significantly from 376 in 2010 to 245 in 2015 (i.e. about 35% reduction). Noteworthy is that the number of registered vehicles increased by 46% and the number of licensed drivers increased by 45% during the same period in AD.

Currently, the traffic law in AD includes 147 types of violations along with their penalties. Out of the 147 violation types, 73 violation types are penalized by deductions of driving points while 33 violation types are penalized by car impounding. In all cases, all violation types are penalized by traffic fines in addition to any other penalty.

A question of interest is whether the penalties listed in the traffic law are actually consistent with the dangerousness level of the traffic violation type. A more authentic question is how to identify and rank dangerous violation types. These two questions were the main motive behind undertaking this research where the focus of this paper is only on the second question. The authors try to shed some lights on the issue of violation types' hazardousness.

PREVIOUS WORK: VIOLATIONS AND SAFETY

In general, research on traffic violations is usually rare and sporadic. This is mainly attributed to the confidentiality of the violations data which is owned and managed by police departments. To overcome such data shortage, some researchers use video data collected mostly at intersections for a short period to automatically detect violations. In most cases, the data is used for before-and-after safety evaluations where violations are used as a surrogate safety measure (Zaki, et al. 2012, Shaaban and Anurag 2016). One of two different data types are usually employed: historical records of violations and accidents, and a self-report survey for a sample of drivers.

Relationship between Violations History and Risk of Accidents

An early study by Peck et al. (Peck, McBride and Coppin 1971) suggested that it is difficult to accurately predict drivers who will or will not be involved in accidents in the future. One year later, Stewart and Campdell (Stewart and Campbell 1972) made use of a four-year history of accident and traffic violation records of North Carolina drivers to predict the future accidents of drivers. Later, Lui and Marchbanks (Lui and Marchbanks 1990) analyzed the relationship between previous traffic violations and fatal accidents and they suggested that the involvement in a fatal accident is not a random event.

Since that date, many researchers investigated the inherent relationship between driver's historical records of traffic violations and his/her involvement in traffic accidents (Hauer, et al. 1991, Gebers and Peck, The identification of high-risk older drivers through age-mediated point systems 1992, Chen, Cooper and Pinili 1995, A. M. Gebers 1999, Gebers and Peck, Using Traffic Conviction Correlates to Identify High Accident-Risk Drivers 2003, Blascoa, Prietob and Cornejoa 2003, Chandraratna, Stamatiadis and Stromberg 2006, Tseng 2013, Zhang, Yaub and Chena 2013, Alver, Demirel and Mutlu 2014) (af Wåhlberg, Barraclough and Freeman 2015, Nishida 2015, Kim, Ramjan and Mak 2016, Machado-León, et al. 2016). Almost all of these studies showed a statistically significant relationship between the future frequency of accident involvements and the previous violation record of the drivers. An issue that has also been explored in previous research is whether the past accident history of an individual is more correlated to future accidents than past violation history. Through an examination of the impact of driver's age, previous violation records, and previous accident data, Daigneault et al. (Daigneault, Joly and Frigon 2002) concluded that prior accidents would be a better predictor for future accident risk than past violations. On the contrary, Gebers and Peck (Gebers and Peck, Using Traffic Conviction Correlates to Identify High Accident-Risk Drivers 2003) found that the driver's violation records are better than accident history records to predict dangerous drivers.

Some studies showed that certain violation types such as speeding and driving under alcohol or drugs lead to higher probability of future accident occurrences (Winter and Dodou 2010, Watson, et al. 2015, Das, et al. 2015, Kim, Ramjan and Mak 2016).

Self-report survey techniques have been intensively used by many researchers to identify the interaction between drivers' history of violations/behavior and his/her accident involvements (Winter and Dodou 2010, Constantinou, et al. 2011, Illiescu and Sarbescu 2013, Pearson, Murphy and Doane 2013, Sümer 2003, Stanojevic, Jovanovi´c and Lajunen 2013, Xu, Li and Jiang 2014, Oña, et al. 2014). These studies proved the tendency of drives who frequently take traffic violation tickets to be involved in traffic accidents. In a recent study, Machado-Leon et al. (Machado-León, et al. 2016) used a Stated Preference (SP) ranking survey to explore the accident risk perception among a sample of 492 drivers on an inter-city, two-way road. The study showed that risky driving behaviors led to a significant increase in accident risk perceptions. A regression-based model was developed using the survey data where the model results were used to differentiate between significant versus less significant unsafe driving behaviors. Furthermore, the study analyzed the potential differences in risk perception of these traffic violations among drivers of different characteristics.

DATA DESCRIPTION

The current study made use of three different datasets obtained from the traffic engineering department of Abu Dhabi Police (ADP). These datasets included: 1) traffic violations, 2) severe accidents, and 3) licensed drivers' database. An accident is considered to be severe if it leads to at least one major injury or a fatality. Eight years of data, from 2008 to 2015, were queried from each dataset and saved separately. The three queried subsets were integrated into one comprehensive database. Records of each subset were matched using the unique driver's traffic code, which is typically assigned to each licensed driver upon receiving his/her driver's license. The total number of registered drivers was found to almost double between 2008 and 2015 (i.e. 636,907 in 2008 and 1,234,009 in 2015). A sequence of processes was carried out for data filtration and selection of the final data sample. First, records of drivers with private driver's licenses were only selected (i.e. excluding driver's licenses of companies, government, diplomats, institutions, etc.). Second, drivers with zero records of both violations and accidents during the eight years were omitted. Most probably, this category of individuals represents "inactive drivers" who are either persons not using their driver's licenses, or, persons who left the country soon after issuing their licenses. Despite the fact that some drivers might still have not committed any violation or have not been involved in an accident, their percentage will be negligible. Traffic violations, especially speeding, in AD are very common so that even conservative drivers could have at least one violation in eight years. Finally, drivers who issued their driver's licenses after 2008 were also removed from the database to ensure that all drivers in the final sample have been practicing driving during the eight years.

The final sample included 624,568 drivers who had committed a total 4,116,149 traffic violations and were involved in 7,676 severe accidents between 2008 and 2015. The database was structured to show the detailed historical records of each driver including types of violations, at-fault accident involvements, and demographic characteristics.

Insights from the Data

The integration of the violations, severe accidents, and drivers' license databases enabled defining the driving history/profile of each driver during the study period. Table 1 gives an example of the final structure of the database after the integration of the three datasets.

TABLE 1 Structure of the Final Database Used in the Analysis

TCN (Unique Driver's Code)	No. of Violations	Severe Accidents	PDO Accidents	Total Accidents	Black Points Violations	Black Points	Hazardous Violations
1980199378	27	4	8	12	5	26	3

In fact, the case presented in Table 1 is one of many cases where the numbers indicate that the driver is definitely reckless and dangerous. The first severe accident of the driver took place in 2010 and led to the death of a pedestrian. The fourth and last severe accident of the driver led to his personal death in 2014. A controversial question rises with the availability of such information; could this driver and many others of the same behavior have been saved if they were identified earlier as dangerous drivers so that an action could have taken place? Similar other cases were found in the database where drivers were involved in three severe accidents and many violations while they are still driving normally causing a threat to public safety.

ANALYSIS METHODOLOGY

As mentioned earlier, the main objective of this research is to present a method(s) to identify and rank the most dangerous violation types. The methodology followed in this paper can be described by the following steps:

1. Selection of Potential Dangerous Violation Types
2. Calculation of Severe Accident Rate by Violation Type
3. Identification and Ranking of the Most Dangerous Violation Types

The following paragraphs briefly describe each of these steps.

Selection of Potential Dangerous Violation Types

Intuitively, not all types of traffic violations may be indicative of risky behavior or may lead to an involvement in a severe traffic accident. In other words, some traffic violations, by definition, are not considered hazardous or dangerous. For example, traffic violations such as illegal parking, driving with expired license, dark tinting of windows, etc., might not be as dangerous as driving under alcohol or red light crossing. Accordingly, and as a step to refine the initial pool of selection of dangerous violations, an initial list of potentially dangerous violations needed to be identified based on engineering judgment and intuition. This list can be later on used to identify and rank the most dangerous violation types.

Calculation of Severe Accident Rate by Violation Type

For each of the initially-defined dangerous violation types, the total number of individuals who committed at least one traffic offence of that type needed to be calculated along with the total number of severe accidents made by drivers committing each violation type. If a driver had committed more than one type of violations, he/she would be counted in each violation type group. For each violation type, the rate of severe accidents per 1,000 drivers needed to be computed along with the percentage of drivers in a violation group who are involved in severe accidents.

The following notations will be used for better understanding of the procedure:

n_i = the total number of dangerous violation types,
i = index for the violation type,
M_i = the total number of drivers committing a violation of type i,
m_i = the number of drivers involved in severe accidents and committing a violation of type i,
y_i = the total number of observed severe accidents for drivers committing a violation of type i,
λ_i = the severe accident rate per 1000 drivers for each violation type i,
r_i = the ratio of drivers involved in severe accidents and committing a violation of type i to the total number of drivers committing a violation of type i.

A severe accident rate per 1000 drivers for each violation type i can be calculated as:

$$\lambda_i = \frac{1000\ y_i}{M_i}$$

And the ratio of drivers involved in severe accidents while committing a violation of type *i* to the total number of drivers committing a violation of type *i* is calculated as:

$$r_i = \frac{m_i}{M_i}$$

Identification and Ranking of the Most Dangerous Violation Types

In this section, we propose using three simple methods to identify and rank dangerous violation types. These methods are quantitative in nature and they have been applied long ago to identify and rank accident prone locations (APLs).

Severe Accident Rate Method

In this method, ranking of the hazardousness of the violation types is made according to the calculated severe accident rate of each violation type (i.e. violation types of higher rates are considered more hazardous). The advantage of using accident rates is that it allows comparisons to be made between violation types that are considered similar but with different levels of exposure (expressed here by the number of individuals committing this violation type). The main disadvantage of the method is that it does only allow for the ranking but not the identification of the hazardous violation types.

Confidence Interval Technique (CI)

A simple statistical technique to identify hazardous violation types is the confidence interval technique, which is based on the assumption that the observed severe accident rates are normally distributed. The assumption was checked and it turned out that the severe accident rate follows a lognormal distribution (p= 0.236) as in Figure 1.

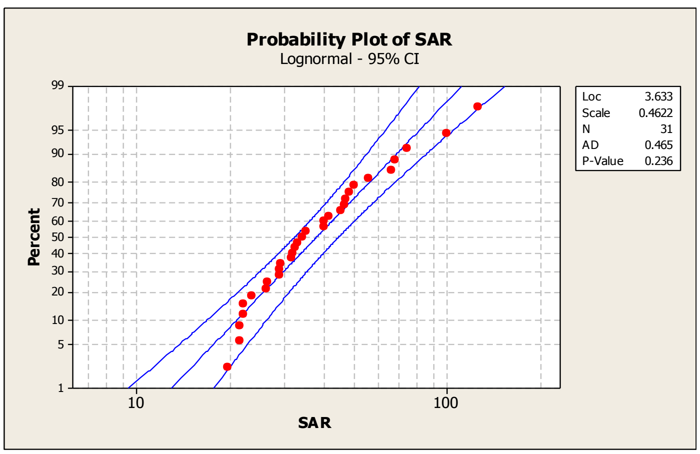

FIGURE 1 Lognormal Probability Plot of Severe Accident Rates of Different Violation Types

The technique involves calculating a critical threshold, which is equal to the sample mean frequency or rate plus a multiple of the sample standard deviation. The multiple coefficient depends on the degree of confidence desired. This can be expressed mathematically as:

$$\lambda_{critical} = \bar{\lambda} + k \cdot \sigma$$

A violation type is considered hazardous (i.e. accident prone) if the estimated safety measure exceeds the defined critical threshold.

$$\lambda_i > \lambda_{critical}$$

Where:

- $\bar{\lambda}$ = the mean severe accident rate of the population of similar violation types, $\bar{\lambda} = \frac{\sum_{i=1}^{n} \lambda_i}{n}$
- λ_i = the estimated severe accident rate of violation type *i*,
- k = a constant related to confidence level obtained from the normal distribution function (k = 1.645 for 90% confidence level), and
- σ = standard deviation of accident rate of the population of violation types.

The ranking of hazardous violation types is made according to the critical ratio (CR_i), which is defined as the ratio between the observed severe accident rate and the critical rate. A higher critical ratio indicates that the violation type is more hazardous.

$$CR_i = \frac{\lambda_i}{\lambda_{critical}}$$

Rate Quality Control Technique (RQC)

The rate quality control technique was proposed by Norden et al. (1956), and it has been widely used by highway agencies to identify hazardous locations. Again, we will borrow the same concept and apply it to violation types. The technique defines a violation type as hazardous if the observed severe accident rate (λ_i) exceeds a critical rate. The main assumption of the technique is that the number of accidents occurring within a given violation type during a given time period can be approximated by the Poisson distribution. In this case, the upper control limit (i.e. the critical limit) can be calculated using a table of Poisson distribution. Norden et al. (Norden, Orlansky and Jacobs 1956) developed satisfactory approximations to determine the critical rate such that:

$$\lambda_{critical} = \bar{\lambda} + k\sqrt{\frac{\bar{\lambda}}{M_i}} + \frac{1}{2 \cdot M_i}$$

Where:

- $\bar{\lambda}$: The mean accident rate of the population of similar violation types,
- k : A constant related to the Level of Significance.

A violation type that has a higher accident rate than $\lambda_{critical}$ is considered hazardous since its deviation from the expected mean cannot be reasonably attributed to the random fluctuation in accident occurrence. Similar to the confidence interval method, ranking of hazardous violation types can be made using the critical ratio index.

Experts' and Drivers' Opinions

A survey was designed and implemented to solicit the options of the traffic experts and local drivers on the most dangerous violation types from their points of view. The survey sample included individuals with local experience and extensive knowledge of the driving environment and potential safety hazards. The sample was composed of 10 experts from the Traffic Engineering Department of the ADP who were mainly traffic engineers or officers or legal advisors, and 35 experienced drivers. The survey was subjective in nature where the list initial violation types was introduced to the survey subjects and each subject was asked to provide a rating on a scale from 1-10 on how he/she perceives the risk or hazardousness of each violation type, with 1 being the least hazardous and 10 being the most hazardous.

RESULTS

Identification of Dangerous Violation Types

The initial list of candidate dangerous violation types included 30 violation types, which were defined according to our engineering judgment and intuition. For each violation type, the rate of severe accidents per 1000 drivers was calculated along with the percentage of drivers involved in severe accidents. As for the identification of the hazardous violation types, both the confidence interval and the rate quality control methods were applied as described earlier. The critical rate of the CI method was 82.29 severe accident/1000 drivers. The method identified only two violation types as hazardous: driving under alcohol/drugs and unsafe loading of trucks. On the other hand, the critical rate varied for each violation type in the RQC method according to the exposure measure (i.e. M_i) as shown in Figure 2. Points above the curve indicate identified hazardous violation types and vice versa.

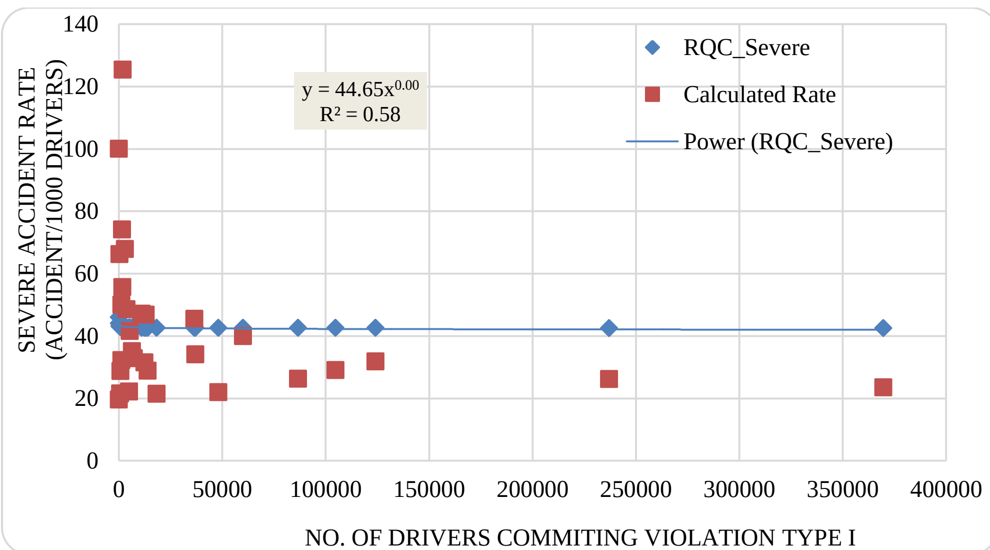

FIGURE 2 Critical Rate Curve of Severe Accidents for Different Violation Types

The RQC method defined 11 different violation types to be hazardous including the two types defined in the CI method. Table 2 shows a summary of all the calculations and final results.

The reliability of the CI method has always been questionable since it is very sensitive to the sample mean and standard deviation of the population accident rates. Another problem with this technique is the normal distribution assumption which does not account for the special nature of collisions as rare and random events. The RQC method is more robust and has a solid theoretical basis. Hence, we herein, suggest the use of the RQC for the identification and raking of dangerous violation types.

TABLE 2 Summary of the Data and Results for the 30 Violation Types

Violation ID	Violation Type	Drivers involved in severe accidents (m_i)	No. of drivers (M_i)	No. of severe accidents (y_i)	Severe accident rate per 1000 driver (λ_i)	Ranking using r_i	Confidence Interval Technique			RQC Technique		
							$\lambda_{critical}$	Hazardousness	CR_i	$\lambda_{critical}$	Hazardousness	CR_i
1	Dangerous loading of a heavy vehicle	1	10	1	100.0	2	82.29	Hazardous	1.22	45.97	Hazardous	2.18
2	Dangerous overtaking of a heavy vehicle	1	51	1	19.6	30	82.29	Not Hazardous	0.24	44.04	Not Hazardous	0.45
3	Non Lane-discipline heavy vehicle	13	650	14	21.5	28	82.29	Not Hazardous	0.26	42.95	Not Hazardous	0.50
4	Stopping a vehicle at a dangerous location or blocking traffic	16	765	22	28.8	22	82.29	Not Hazardous	0.35	42.92	Not Hazardous	0.67
5	Not wearing helmet while driving a motorbike	17	302	20	66.2	5	82.29	Not Hazardous	0.80	43.15	Hazardous	1.53
6	Overtaking in a wrong way	34	1,301	42	32.3	17	82.29	Not Hazardous	0.39	42.83	Not Hazardous	0.75
7	Overtaking at a prohibited location	53	1,279	64	50.0	7	82.29	Not Hazardous	0.61	42.83	Hazardous	1.17
8	Racing on the road	84	1,670	93	55.7	6	82.29	Not Hazardous	0.68	42.80	Hazardous	1.30
9	Turning at undesignated points	98	4,922	109	22.1	26	82.29	Not Hazardous	0.27	42.69	Not Hazardous	0.52
10	Running away from a traffic policeman	108	1,578	117	74.1	3	82.29	Not Hazardous	0.90	42.80	Hazardous	1.73
11	Failure to follow the directions of the policeman	140	3,729	181	48.5	8	82.29	Not Hazardous	0.59	42.71	Hazardous	1.14
12	Overtaking from the right	188	5,359	223	41.6	12	82.29	Not Hazardous	0.51	42.68	Not Hazardous	0.98
13	Reckless driving	190	2,977	202	67.9	4	82.29	Not Hazardous	0.82	42.73	Hazardous	1.59
14	Driving under the influence of alcohol or drugs	206	1,859	233	125.3	1	82.29	Hazardous	1.52	42.78	Hazardous	2.93
15	Sudden entering a road	213	7,370	242	32.8	16	82.29	Not Hazardous	0.40	42.66	Not Hazardous	0.77
16	Driving dangerously	214	6,343	223	35.2	14	82.29	Not Hazardous	0.43	42.67	Not Hazardous	0.82
17	Not using indicators when changing direction or turning	333	12,415	391	31.5	19	82.29	Not Hazardous	0.38	42.63	Not Hazardous	0.74
18	Not giving pedestrians priority	342	18,239	391	21.4	29	82.29	Not Hazardous	0.26	42.61	Not Hazardous	0.50
19	Driving on the wrong direction	345	13,986	404	28.9	21	82.29	Not Hazardous	0.35	42.62	Not Hazardous	0.68
20	Sudden swerve	467	10,959	516	47.1	9	82.29	Not Hazardous	0.57	42.63	Hazardous	1.10
21	Tailgating	565	13,048	611	46.8	10	82.29	Not Hazardous	0.57	42.63	Hazardous	1.10
22	Using hand-held mobile phone while driving	931	48,237	1060	22.0	27	82.29	Not Hazardous	0.27	42.58	Not Hazardous	0.52
23	Red light crossing	1161	36,959	1261	34.1	15	82.29	Not Hazardous	0.41	42.59	Not Hazardous	0.80
24	Exceeding speed over 60kph	1514	36,485	1661	45.5	11	82.29	Not Hazardous	0.55	42.59	Hazardous	1.07
25	Light vehicle lane discipline	1914	86,625	2279	26.3	23	82.29	Not Hazardous	0.32	42.57	Not Hazardous	0.62
26	Exceeding speed between 50-60kph	2206	60,136	2404	40.0	13	82.29	Not Hazardous	0.49	42.58	Not Hazardous	0.94
27	Not use seat belt while driving	2584	104,787	3048	29.1	20	82.29	Not Hazardous	0.35	42.57	Not Hazardous	0.68
28	Exceeding speed between 40-50kph	3629	124,138	3951	31.8	18	82.29	Not Hazardous	0.39	42.56	Not Hazardous	0.75
29	Exceeding speed between 30-40kph	5577	237,170	6205	26.2	24	82.29	Not Hazardous	0.32	42.55	Not Hazardous	0.61
30	Exceeding speed up to 30kph	7413	369,770	8689	23.5	25	82.29	Not Hazardous	0.29	42.55	Not Hazardous	0.55

Ranking of Dangerous Violation Types

The results of the experts' and drivers' opinions survey are presented followed by the ranking results. The average score of violation type hazardousness was calculated using the experts' and drivers' survey data as in Table 3.

TABLE 3 Hazardousness Score of the 30 Violation Types

ID	Violation Type	Score
1	Dangerous loading of a heavy vehicle	7.0
2	Dangerous overtaking of a heavy vehicle	9.0
3	Non Lane-discipline heavy vehicle	7.2
4	Stopping a vehicle at a dangerous location or blocking traffic	6.5
5	Not wearing helmet while driving a motorbike	7.7
6	Overtaking in a wrong way	7.1
7	Overtaking at a prohibited location	7.4
8	Racing on the road	9.1
9	Turning at undesignated points	6.9
10	Running away from a traffic policeman	8.8
11	Failure to follow the directions of the policeman	6.9
12	Overtaking from the right	6.4
13	Reckless driving	8.9
14	Driving under the influence of alcohol or drugs	9.5
15	Sudden entering a road	8.4
16	Driving dangerously	9.1
17	Not using indicators when changing direction or turning	6.6
18	Not giving pedestrians priority	7.5
19	Driving on the wrong direction	9.0
20	Sudden swerve	8.8
21	Tailgating	8.0
22	Using hand-held mobile phone while driving	9.2
23	Red light crossing	9.6
24	Exceeding speed over 60kph	9.0
25	Light vehicle lane discipline	6.3
26	Exceeding speed between 50-60kph	7.9
27	Not use seat belt while driving	7.3
28	Exceeding speed between 40-50kph	6.8
29	Exceeding speed between 30-40kph	6.0
30	Exceeding speed up to 30kph	5.2

Subsequently, the ranking of the most dangerous violation types was made using four measures: the critical ratio of the CI method, the critical ratio of the RQC method, the ratio of drivers involved in severe accidents, defined earlier as r_i, and the average hazardousness score as obtained from the survey results. The final rankings using the three quantitative methods and the survey results are presented in Table 4. The shaded cells represent the most dangerous 20 violation types.

TABLE 4 Final Ranking of the 30 Violation Types using Different Methods

Violation Type ID	Violation Group	Ranking			
		C. I Technique	RQC Technique	% of Drivers Involved In Severe Accidents	Experts' Opinion
14	Driving under the influence of alcohol or drugs	1	1	1	2
1	Dangerous loading of a heavy vehicle	2	2	2	21
10	Running away from a traffic policeman	3	3	3	10

Violation Type ID	Violation Group	Ranking			
		C. I Technique	RQC Technique	% of Drivers Involved In Severe Accidents	Experts' Opinion
13	Reckless driving	4	4	4	9
5	Not wearing helmet while driving a motorbike	5	5	5	15
8	Racing on the road	6	6	6	4
7	Overtaking at a prohibited location	7	7	10	17
11	Failure to follow the directions of the policeman	8	8	11	23
20	Sudden swerve	9	9	8	11
21	Tailgating	10	10	7	13
24	Exceeding speed over 60kph	11	11	9	8
12	Overtaking from the right	12	12	13	27
26	Exceeding speed between 50-60kph	13	13	12	14
16	Driving dangerously	14	14	14	5
23	Red light crossing	15	15	15	1
15	Sudden entering a road	16	16	17	12
6	Overtaking in a wrong way	17	17	19	20
28	Exceeding speed between 40-50kph	18	18	16	24
17	Not using indicators when changing direction or turning	19	19	18	25
27	Not use seat belt while driving	20	20	21	18
19	Driving on the wrong direction	21	21	20	7
4	Stopping a vehicle at a dangerous location or blocking traffic	22	22	24	26
25	Light vehicle lane discipline	23	23	23	28
29	Exceeding speed between 30-40kph	24	24	22	29
30	Exceeding speed up to 30kph	25	25	25	30
9	Turning at undesignated points	26	26	27	22
22	Using hand-held mobile phone while driving	27	27	29	3
3	Non Lane-discipline heavy vehicle	28	29	26	19
18	Not giving pedestrians priority	29	28	30	16
2	Dangerous overtaking of a heavy vehicle	30	30	28	6

Interestingly, the ranking was almost identical when using the CI and the RQC methods showing very strong agreement in the ranking. The ranking using the ratio of drivers involved in severe accidents showed some differences as shown in Table 4. Nevertheless, the six most dangerous violation types were still the same. On the other hand, the ranking using the survey results was very different showing high discrepancy between what experts and drivers perceive as "hazardous" violation types versus the empirical findings from accident data. For a more quantitative assessment of the agreement between the four rankings schemes, Spearman rank correlation coefficient (ρ_s) was computed for each pair of ranking types (Sayed and De Leur 2002) where:

$$\rho_s = 1 - \frac{6\sum_{1}^{n} d_i^2}{n(n^2-1)}$$

n = number of violation types, and

d = difference in rank for each violation type in the two rankings.

Table 5 shows the Spearman rank correlation matrix of the four methods.

TABLE 5 Spearman Rank Correlation Matrix for the Four Ranking Methods

	CI Technique	RQC Technique	% of drivers involved in severe accidents	Experts' Opinions
Confidence Interval Technique	1.000	1.000	0.985	0.289
RQC Technique	Sig.	1.000	0.983	0.290
% of drivers involved in severe accidents	Sig.	Sig.	1.000	0.309
Experts' Opinion	Insig.	Insig.	Insig.	1.000

As the rankings of the CI and RQC techniques were almost identical, their ranking correlation was close to 1. Meanwhile, the spearman rank correlation was more than 0.98 when comparing the ranking of the CI/RQC from one side and the ratio of drivers involved in severe accidents (r_i) which shows strong agreement between the two ranking procedures. This correlation was significant at a 95% confidence level where the calculated test statistic z = 5.30 was greater than the critical ratio $z_{critical}$ = 2.33. Insignificant Spearman rank correlation coefficients were found between the CI/RQC ranking and the ratio of drivers involved in severe accidents from one side and the experts' opinions ranking. These results indicate that the violation types that are considered dangerous by experts and drivers are not actually as dangerous as other violation types. This conclusion is noteworthy as it indicates that the list of penalties assigned to different violation types in the traffic law are actually inconsistent with the hazardousness level of these violation types.

According to the results in Table 4, the most dangerous ten violation types are driving under alcohol/drugs, unsafe loading of trucks, running away from a traffic officer, reckless driving, not wearing motorcycle helmet, road racing, illegal overtaking, failure to follow the directions of the police officer, sudden swerves, and tailgating. These violation types seem logically dangerous and deserve special attention in terms of enforcement and traffic legislation.

SUMMARY AND CONCLUSIONS

This paper aimed at identifying and ranking the most dangerous violation types that may lead to accident occurrence. The study made use of an extensive accident and violation dataset that covered a period of eight years in Abu Dhabi, the UAE. The current traffic law of Abu Dhabi includes 147 different violation types where the penalties vary significantly from one violation type to another. An initial selection of the most dangerous 30 violation types was made based on engineering judgement and intuition. For each violation type, different safety metrics were calculated such as the number of at-fault drivers, the number of drivers involved in severe accidents, and the total number of severe accidents. Subsequently, the severe accident rate for each violation type was calculated along with the percentage of drivers involved in severe accidents. These two measures were used for the identification and ranking of dangerous violation types through the application of simple statistical methods; confidence interval and rate quality control. The results showed that the CI method identified only two violation types as hazardous while the RQC identified 11 different violation types. Despite the difference in the identification of hazardous violation types, the ranking of the two methods was identical. The percentage of drivers involved in severe accidents was also used to rank the violation types. It was shown that the ranking was in general agreement with the other two methods. The methods applied in this paper can be used by legislation authorities to adjust/modify the list of penalties according to the hazardousness of each violation type.

FUTURE RESEARCH

An immediate extension of the current research is to explore the application of the widely-used Empirical Bayes (EB) approach for the identification and ranking of hazardous violation types. The method has been traditionally utilized for the screening of the accident prone locations and there could be some benefits of applying the same technique within the context of this research. Taking into account the small sample size of violation categories, it might also be useful to apply a Full Bayesian (FB) model to relate the severe accident rate to the number of drivers involved in severe accidents. Furthermore, it will be interesting to compare the most dangerous violation types defined in this research to the pre-defined list of the most dangerous 25 violation types, developed by the ADP. Other potential areas of future work include an investigation of the suitability of the penalties in the current traffic law of AD to the hazardousness level of different violation types.

REFERENCES

1. af Wåhlberg, A.E., P. Barraclough, and J. Freeman. 2015. "The Driver Behaviour Questionnaire as accident predictor; A Methodological Re-Meta-Analysis." *Journal of Safety Research* 55: 185–212.
2. Alver, Y., M. C. Demirel, and M.M. Mutlu. 2014. "Interaction between Socio-demographic Characteristics: Traffic Violations and Traffic Accident History for Young Drivers." *Accident Analysis and Prevention* 72: 95-104.
3. Blascoa, R.D., J. M. Prietob, and J. M Cornejoa. 2003. "Accident Probability After Accident Occurrence." *Safety Science* 41: 481–501.
4. Chandraratna, S., N. Stamatiadis, and A. Stromberg. 2006. "Accident involvement of drivers with multiple accidents." *Accident Analysis and Prevention* 38: 532–541.
5. Chen, W., P. Cooper, and M. Pinili. 1995. "Driver accident risk in relation to the penalty point system in British Columbia." *Accident Analysis and Prevention* 26 (1): 9–18.
6. Constantinou, E., G. Panayiotou, N. Konstantinou, A. Loutsiou-Ladd, and A. Kapardis. 2011. "Risky and Aggressive Driving in Young Adults: Personality Matters." *Accident Analysis and Prevention* 43: 1323–1331.
7. Daigneault, G., P. Joly, and J.Y. Frigon. 2002. "Previous convictions or accidents and the risk of subsequent accidents of older drivers." *Accident Analysis and Prevention* 34 (2): 257-261.
8. Das, S., X. Sun, F. Wang, and C. Leboeuf. 2015. "Estimating likelihood of future crashes for crash-prone drivers." *Journal of traffic and Transportation Engineering* 2 (3): 145 -157.
9. Gebers, A. Michael. 1999. "Strategy for Estimating Drives Accident Risk in Relation to California\s Negligent-Operation Point System." California Department of Motor Vehicles, Research and Development Section.
10. Gebers, M.A., and R.C. Peck. 1992. "The identification of high-risk older drivers through age-mediated point systems." *Journal of Safety Research* 23: 81–93.
11. Gebers, M.A., and R.C. Peck. 2003. "Using Traffic Conviction Correlates to Identify High Accident-Risk Drivers." *Accident Analysis and Prevention* 35 (6): 903-912.
12. Haddon, W. May 20, 1983. "Approaches to Prevention of Injuries." *Presented at the American Medical Association Conference on Prevention of Disabling Injuries.* Miami, Florida.
13. Hauer, E., B. N. Persaud, A. Smiley, and D. Duncan. 1991. "Estimating The Accident Potential of an Ontario Driver." *Accident Analysis & Prevention* 23 (2): 133-152.

14. Illiescu, D., and P. Sarbescu. 2013. "The relationship of dangerous driving with traffic offenses: A study on an adapted measure of dangerous driving." *Accident Analysis and Prevention* 51: 33–41.
15. Karacasu, M, and A Er. 2011. "An analysis on Distribution of Traffic Faults in Accidents, Based On Driver's Age and Gender: Eskisehir case." *Procedia Social and Behavioral Science* 20: 776-785.
16. Kim, D.H., L. M. Ramjan, and K. K. Mak. 2016. "Prediction of vehicle accidents by drivers' characteristics and past traffic violations in Korea using a zero-inflated negative binomial model." *Traffic Injury Prevention* 17 (1): 86-90.
17. Lui, K.J., and P.A. Marchbanks. 1990. "A study of the time between previous traffic infractions and fatal automobile accidents." *Journal of Safety Research* 21: 45-51.
18. Machado-León, J. L., Juan de Oña, Rocío de Oña, L. Eboli, and G. Mazzulla. 2016. "Socio-economic and driving experience factors affecting drivers' perceptions of traffic accident risk." *ransportation Research Part F 37* 41–51.
19. Nishida, Y. 2015. "Analyzing Accidents and Developing Elderly Driver-Targeted Measures Based On Accident and Violation Records." *nternational Association of Traffic and safety Science, IATSS Research 39* 26-35.
20. Norden, M., J. Orlansky, and H. Jacobs. 1956. "Application of Statistical Quality Control Techniques to Analysis of Highway Accident Data." *Bulletin 117, HRB, National Research Council.* Washington D.C.
21. Oña, J., R. Oña, L. Ebol, C. Forciniti, and G Mazzulla. 2014. "How to identify the key factors that affect driver perception of accident risk: A comparison between Italian and Spanish driver behavior." *Accident Analysis and Prevention* 73: 225–235.
22. Pearson, M.R., E. M. Murphy, and A. N. Doane. 2013. "Impulsivity-like traits and risky driving behaviors among college students." *Accident Analysis and Prevention* 53: 142– 148.
23. Peck, R.C, R.S McBride, and R.S. Coppin. 1971. "The distribution and prediction of driver accident frequencies ." *Accident Analysis & Prevention* 2: 243-249.
24. Sayed, T, and W Abdelwahab. 1997. "Using Accident Correctability to Identify Accident Prone Locations." *Journal of Transportation Engineering, ASCE* 123 (2).
25. Sayed, T, W Abdelwahab, and F Navin. 1995. "Identifying Accident-Prone Locations Using Fuzzy Pattern Recognition." *Journal of Transportation Engineering* 121 (4): 352-358.
26. Sayed, T., and P. De Leur. 2002. "Development of a Road Safety Index." *Transportation Research Record Journal of the Transportation Research Board* (1): 33-42.
27. Shaaban, K, and P Anurag. 2016. "Analysis of Observational Data on Violation Rates at Intersection Approaches Using Regression Tree." *Proceedings of the Transportation Research Board 95th Annual Meeting.*
28. Stanojevic, P., D. Jovanovi´c, and T. Lajunen. 2013. "Influence of Traffic Enforcement On the Attitudes and Behavior of Drivers." *Accident Analysis and Prevention* 52: 29– 38.
29. Stewart, J.R., and D.J. Campbell. 1972. "The statistical association between past and future accidents and violations." *The University of North Carolina, Chapel Hill.*
30. Sümer, N. 2003. "Personality and behavioral predictors of traffic accidents: Testing a contextual mediated model." *Accident Analysis & Prevention* 35: 949–964.
31. Tseng, C. 2013. "Speeding Violations Related to A Driver's Social-Economic Demographics and The Most Frequent Driving Purpose in Taiwan\S Male Population." *Safety Science* 57: 236-242.
32. Watson, B., A. Watson, V. Siskind, J. Fleiter, and D. Soole. 2015. "Profiling High-Range Speeding Offenders: Investigating Criminal History, Personal Characteristics, Traffic Offences, and Accident History." *Accident Analysis and Prevention* 74: 87–96.
33. Winter, J.C.F., and D. Dodou. 2010. "The Driver Behavior Questionnaire as a predictor of accidents: A meta-analysis." *Journal of Safety Research* 41: 463–470.
34. Xu, Y., L. Li, and L. Jiang. 2014. "The effects of situational factors and impulsiveness on drivers' intentions to violate traffic rules: Difference of driving experience." *Accident Analysis and Prevention* 62: 54– 62.

35. Zaki, M, T Sayed, K Ismail, and F Alrukaibi. 2012. "Use of Computer Vision to Identify Pedestrians' Nonconforming Behavior at Urban Intersections." *Transportation Research Record: Journal of the Transportation Research Board* 2279: 54–64.
36. Zhang, G., K. K.W. Yaub, and G. Chena. 2013. "Risk Factors Associated with Traffic Violations and Accident Severity in China." *Accident Analysis and Prevention* 59: 18–25.