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Prioritizing Roads Safety Based on the Quasi-Induced Exposure Method and Utilization of the Analytical Hierarchy Process

Behbahani, H.[1], Rezaei, S.[2*] and Nafar, H.[3]

[1] Professor, Faculty of Civil Engineering, Iran University of Science and Technology, Tehran, Iran.
[2] MSc., Faculty of Civil Engineering, Iran University of Science and Technology, Tehran, Iran.
[3] MSc., Faculty of Civil Engineering, University Putra, Malaysia.

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ABSTRACT: Safety analysis of the roads through the accident rates which is one of the widely used tools has been resulted from the direct exposure method which is based on the ratio of the vehicle-kilometers traveled and vehicle-travel time. However, due to some fundamental flaws in its theories and difficulties in gaining access to the data required such as traffic volume, distance and duration of the trip, and various problems in determining the exposure in a specific time, place, and individual categories, there is a need for an algorithm for prioritizing the road safety so that with a new exposure method, the problems of the previous approaches would be resolved. In this way, an efficient application may lead to have more realistic comparisons and the new method would be applicable to a wider range of time, place, and individual categories. Therefore, an algorithm was introduced to prioritize the safety of roads using the quasi-induced exposure method and utilizing the analytical hierarchy process. For this research, 11 provinces of Iran were chosen as case study locations. A rural accidents database was created for these provinces, the validity of quasi-induced exposure method for Iran's accidents database was explored, and the involvement ratio for different characteristics of the drivers and the vehicles was measured. Results showed that the quasi-induced exposure method was valid in determining the real exposure in the provinces under study. Results also showed a significant difference in the prioritization based on the new and traditional approaches. This difference mostly would stem from the perspective of the quasi-induced exposure method in determining the exposure, opinion of experts, and the quantity of accidents data. Overall, the results for this research showed that prioritization based on the new approach is more comprehensive and reliable compared to the prioritization in the traditional approach which is dependent on various parameters including the driver-vehicle characteristics.

Keywords: Analytical Hierarchy Process, Prioritizing, Quasi-Induced Exposure, Road Safety.

* Corresponding author E-mail: eng.rezaei@ymail.com

INTRODUCTION

Evaluation of the road safety level must be based on a process so that by combining the involvement ratios (number of accidents divided by the exposure) tangible values could be obtained. By doing that it would be then possible to compare and prioritize the safety problems of various roads. As the number of accidents is provided by the police or the related organizations based on certain forms, this determination of this parameter is not associated with any concern. In contrast, the parameter of exposure and the way by which the involvement ratios are combined are of significant impertinence and may be associated with some concerns.

The important point in relation to the exposure is that the measurement of exposure should be in a way to be applicable for the sub-branches of the driver-vehicle characteristics. In this way, the unsafe characteristics can be identified and determined and then efforts can be made to improve the unsafe elements. Although the vehicle-kilometers traveled and vehicle-travel time are used extensively as the exposure measurement tools in analyzing the traffic safety, these tools are not able to measure the exposure of the specific groups (such as the exposure of women drivers with a license of less than 5 years in highways). In addition, the basic assumptions of these tools have been criticized and questioned by different researchers (e.g. Lighthizer, 1989; Lyles et al., 1991). Given the problems associated with these tolls, there is, therefore, a need for a new method which includes specific sub-branches of exposure with simple calculations for determining the exposure and involvement ratio, exploring the road safety problems, and combining the involvement ratios logically. On the other hand, influential factors in the accidents are hierarchical in nature because an accident is any collision due to the impact of adverse interaction between triplet components of the traffic (people, vehicles, and environments) or the incidence of deficiencies in one or more of the components. Note that each of these factors also depends on other factors that this dependency creates status of hierarchy. It seems that the use of quasi-induced method along with using the Analytical Hierarchy Process is a promising way to solve the errors. As a result, one of the objectives of this study is to provide a new method for the prioritization of the roads based on the new approach of quasi-induced exposure along with using the Analytical Hierarchy Process. Also this study compares the new approach to the old approach in order to explain the advantages and disadvantages of the new method. The novelty of this study is that it determines the safety level of the roads based on the new approach through using the Analytical Hierarchy Process, and also it evaluates this method.

Another important issue associated with the exposure, particularly the quasi-induced exposure, is how the validity of the induced-exposure method can be confirmed. It should be noted that so far little researches have been conducted on the validity of the quasi-induced method and the only research that has been done is Jiang (2010). That is why validating the quasi-induced method is the main objective of this study which is based on the provincial accidents data bases of Iran. The other purpose of this study is to determine the involvement ratio of some driver-vehicle characteristics that affect the accident occurrences and express their safety problems.

The assumption of this study is that the data that was collected by the police are accurate and the police judgments on determining the culpable and non-culpable drivers in accidents are correct. The null hypothesis of the study is "quasi-induced

exposure method in estimating the real exposure is valid".

LITERATURE REVIEW

Surprisingly reviewing the previous research shows that few studies have considered the verification of the quasi-induced method and the rest have gone through the calculation of the involvement ratio with this method without considering the method validity. Many researchers have proposed simple assumptions and then analyzed them without considering the validity of this method. Studies such as: (Carr, 1969; Hall, 1970; Carlson, 1970; Joksch, 1973; Cerrelli, 1973; Lyles, 1991; David and De Yong, 1997; Stamatiadis, 1998; Aldridge et al., 1999; Chandraratnaet al., 2003; Hinget al., 2003; Chandraratna and Stamatiadis, 2009;) can be cited for using this method to estimate the exposure, however, without considering the validation of this method. The research by (Lighthizer, 1989; Lyles et al., 1994; Stamatiadis and Deacon, 1997; Kirk and Stamatiadis, 2001; Huang and Chor, 2009) were conducted to validate this method, however, these studies are too qualitative and also imprecise due to the lack of quantitative data. Few studies (such as: Jiang, 2005; Jiang and Lyles, 2007; and Jiang and Lyles, 2010) can be mentioned that had appropriate research quality invalidating the quasi-induced exposure method; however, they encountered limitations in their research and eventually declared the validity of quasi-induced exposure at the state (provincial) level. In other words, Jiang studies showed that the quasi-induced exposure method is a good way to measure the exposure of specific groups of drivers-vehicle with an extensive amount of accidents data.

The literature review shows that no study has been done on the prioritization of the safety level of the roads based on the quasi-induced exposure method. However, many researchers like (Carr, 1969; Hall, 1970; Carlson, 1970; Joksch, 1973; Cerrelli, 1973; Lighthizer, 1989; Lyles, 1991, 1994; Jiang, 2010) have conducted studies on the quasi-induced exposure method without providing an answer as to how to use the quasi-induced exposure method for applying the involvement ratio in prioritizing the road safety, while there are too many specific sub-branches of exposure and abundance of influential characteristics on the accidents. Therefore, there are certain concerns about prioritizing the road safety based on this method for which the prioritization of the safety level was explored through the aid of analytical hierarchy process and applying the knowledge and experience of the safety experts and researchers. This was done in order to find the most efficient and logical method of combination and to compare its results with that of the traditional method so as to explore its credibility.

METHODOLOGY

As it is clear from its name, prioritizing the road safety based on the quasi-induced exposure method with the aid of analytical hierarchy process consists of two separate general parts. The first part includes the quasi-induced exposure method for obtaining the involvement ratio of the influential characteristics on accidents, while the second part deals with analytical hierarchy process for applying the knowledge and experience of the road safety experts in weighing the influential factors on the accidents. Finally, by combining these two parts, the safety level of different roads are prioritized.

Regarding the first part, the rural accidents data of 2009-2010 of the following provinces in Iran was used: Gilan, Kerman, Golestan, Isfahan, Fars, West Azerbaijan, Semnan, Lorestan, Sistanand Baluchistan,

Mazandaran, and Tehran. As suggested by Jiang (2010), in order to determine the exposure, the accidents data in which only two vehicles were involved and one party was the at-fault driver was used. This data was obtained from the revised database which was based on revising the accidents data process and the method of designation of the at-fault driver in the accidents.

The validity of the quasi-induced exposure method in Iran was explored through: A) comparing the distributions of a not-at-fault driver in two car accidents (D_2) and three and more car accidents (D_2). B) Comparing the distributions of the first not-at-fault driver (D'_{2s}) and other distributions of the not-at-fault driver (D_{3s}) in three or more car accidents. C) Comparing the results of the quasi-induced exposure method with the exposure results of the vehicle-kilometer traveled.

The null hypothesis of the study is that "the quasi-induced exposure is valid in estimating the actual exposure" and the alternative hypothesis is that "the quasi-induced exposure is not valid in estimating the actual exposure." To test the hypothesis, U-Mann Whitney test which is a comparative test was used to compare two independent groups, for instanceD_2andD'_2 in method A, D'_{2s} and D_{3s} in method B, and the results of quasi-induced exposure method and exposure of the vehicle-kilometer travelled in method C. In order to runthis test, SPSS software version 19 was used. According to the test, when the significance value of testing is obtained (Asymp, Sig 2-tailed; P-value less than 0.05), the difference between the two groups is significant. As a result, the first assumption will be rejected. On the other hand if the significance value is equal or greater than 0.05, the difference between the two groups is not significant and the null hypothesis is confirmed.

After the validation based on Eq. (1) of the revised database, the involvement ratio (IR) was measured for the combinations of the drivers' age, gender, education, license background, type of vehicle, and pickup and passenger car's system. All the models of involvement ratio include the combinations of the driver-vehicle because the quasi-induced exposure method is based on the combination of the driver-vehicle and the environmental conditions are not taken into account in this method.

$$\text{IR} = \frac{\text{characteristic of at} - \text{fault drivers}}{\text{characteristic of not} - \text{at} - \text{fault drivers}} \quad (1)$$

With regard to the second section, by using the Expert Choice software and the opinions of the traffic safety experts, the mentioned provinces were prioritized from the safest to the least safe. Thus, the hierarchy of less safe provinces was formed as given in Figure 1. In this hierarchy, based on their role, the influential systems and components on accidents were broken down to their composing parts. The highest level (choosing the least safe province) shows the general goal of the hierarchy and is synthesized to two criteria of driver's and vehicle characteristics. Each of these criteria is divided to sub-criteria to form the hierarchy tree.

In order to obtain the weight of the third, second, and first level criteria, the experts opinions in the traffic safety department of Road Maintenance and Transportation Organization of Ministry of Roads and Urban Development of Iran, Transportation Institute of Iran's Ministry of Roads and Urban Development, and the traffic safety experts of Planning and Budget Department of Islamic Republic of Iran police force were used. Analytical hierarchy process (AHP) is not related to the number of experts, in other words, this method can be applied with the

opinions of one traffic safety expert (Saaty, 2012; Xu, 2000). However, in this study, opinions of 22 experts were used.

In order to blend the opinions of the experts and get to the final weight of the provinces, the geometrical average of the experts' opinions called "Criteria", and the weight of the provinces resulting from the involvement ratio called "Alternative" were given to the Expert Choice software. This software is a program for prioritization based on the analytical hierarchy process whose validation had been approved by Saaty (2012).

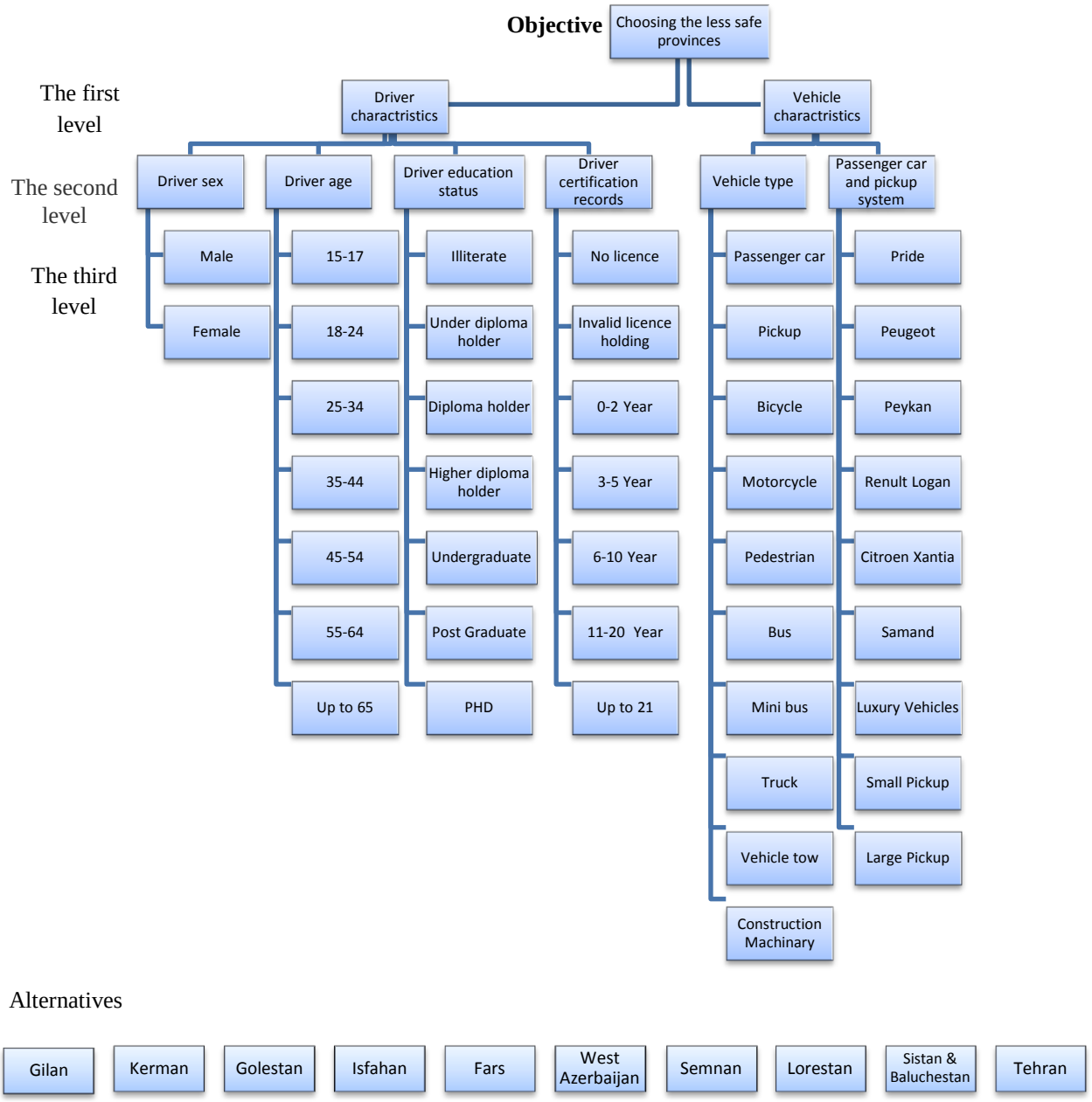

Fig. 1. Hierarchical structure of the less safe provinces, the goal, the first to third level of criteria with alternatives.

One of the objectives of this study is to compare the prioritizations based on the new and the traditional method. For this purpose, based on the traditional method, accident rate was considered as "the number of accidents divided by direct exposure". To determine the direct exposure, the common method of vehicle-kilometers traveled based on Eq. (2), announced by the American agency of transportation engineers, was used. In order to determine the exposure of the vehicle-kilometers traveled, the detector database of 2009 and 2010 of the same provinces was used. Based on the detector database taken from the Maintenance and Transportation Organization, the vehicles being studied to determine the exposure were classified as what follows:

1. Vehicles with a length less than 5 meters (various pickups and passenger cars)
2. Vehicles with a length more than 5 meters and less than 7.5 meters (various kinds of minibuses and two-axle trucks)
3. Vehicles with a length of more than 7.5 meters and less than 10 meters (two and three-axle heavy trucks)
4. Vehicles with a length of more than 10 meters and less than 12 meters (various kinds of buses)
5. Vehicles with a length of more than 12 meters (various kinds of trailers)

$$\overline{VKT} = \sum_{h}^{H} \overline{VKT_h}$$
$$\overline{VKT_h} = K_h * \overline{VOL_h} \quad (2)$$
$$\overline{VOL_h} = \left(\frac{1}{N_h}\right) * \sum_{i}^{N_h} VOL_{h_i}$$

H: Number of classifications
K_h: The number of driven kilometer trips of "h_i" classification
N_h: The number of implemented detector database
$\overline{VKT}$: Estimation of the average area's *VKT* during the desired time
$\overline{VOL_h}$: Average estimated traffic volumes of the "h" classification
VOL_{h_i}: The measured traffic volumes of "i" detector for "h" Classification
$\overline{VKT_h}$: The average estimated VKT for "h" classification during the desired time.

For prioritization based on the traditional method, the hierarchy of the less safe provinces was formed as shown in Figure 2. In this hierarchy, the influential parts and systems on accidents were divided to their composing components based on their roles. The highest level (choosing the least safe province) shows the general goal of the hierarchy and is classified into five groups: pickups and passenger cars, minibuses and two-axle trucks, two and three-axle heavy trucks, buses, and trailers.

Finally, like what was mentioned in the new method, by using the Expert Choice software, the opinions of the traffic safety experts, and the accident rates, the prioritization of the provinces (alternatives) was conducted from the least safe province to the safest province.

The common types of pickup and passenger car's system including Peykan, Pride, Peugeot, Samand, small pickup (pickup with carrying capacity 0.5-0.75 tons) and big pickup (pickup with carrying capacity 1-2 tons), have considered in the current study in both new and traditional methods as the third level criterion and as the criterion, respectively. They are shown in Table 1.

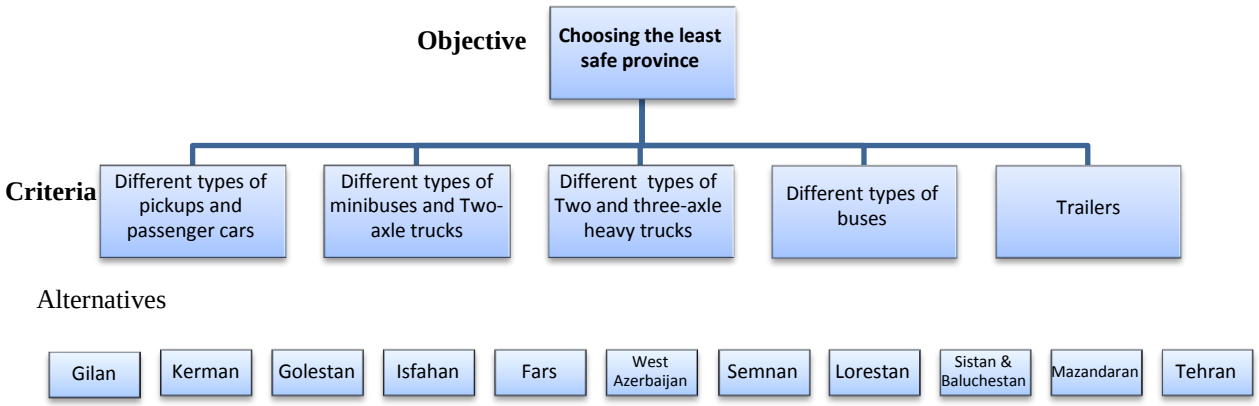

Fig. 2. Hierarchical structure of the less safe provinces, the goal, criteria with alternatives.

Table 1. The common types of pickup and passenger car's system in Iran.

Peykan	Deluxe	Kar	1600i		
Pride	Saba	hatchback	111	141	132
Peugeot	405 GLX	206	Persia	1600RD	Roa
Samand	Normal	LX	Soren	Sarir	
Small Pickup	Peykan	Mazda 1000			
Big Pickup	Nissan Zamyad	Mazda 2000	Toyota Land Cruiser		

RESULTS

As it was mentioned, in order to determine the prioritization of the road safety level based on the quasi-induced exposure method, first it was necessary to validate the quasi-induced exposure method according to Iran's accidents database. For this, the following three steps were taken:

First Step

The distributions of the vehicles Pride, Peugeot, and Pickups (the most common vehicles) in not-at-fault drivers of two car accidents and not-at-fault drivers of three and more cars accidents were compared.

As it can be seen in Table 2, values of 8.37 and 8.59 in the column of Pride in the order of two car accidents and three and more car accidents in West Azerbaijan mean that 8.37% of all not-at-fault drivers' vehicles involved in two car accidents and 8.59% of all not-at-fault drivers' vehicles involved in three or more car accidents were Pride. As it can be seen in Table 2, P-Value of U-Mann Whitney test (Asymp Sig; 2-tailed) in the three categories of Pride, Peugeot, and pick up is more than 0.05 which means that the difference between the two groups of "two-car accidents" and "three or more-car accidents" is not significant. As a result, in the first step the validity of the quasi-induced exposure is approved at the provincial level.

Table 2. Real distribution of a not-at-fault driver in two car accidents and three or more car accidents for Pride, Peugeot and Pickups separated by the province.

Provinces	Type of accident	Pride (%)	Peugeot (%)	Pickups (%)
West Azerbaijan	Two car accidents	8.37	8.16	9.77
	Three and more cars accidents	8.59	11.85	9.51
Isfahan	Two car accidents	9.15	8.23	7.93
	Three and more cars accidents	8.01	7.73	6.21
Tehran	Two car accidents	11.50	10.28	7.28
	Three and more cars accidents	12.59	9.28	5.30
Sistan & Baluchestan	Two car accidents	12.61	9.37	15.00
	Three and more cars accidents	9.32	7.07	14.14
Semnan	Two car accidents	10.39	8.87	5.82
	Three and more cars accidents	8.21	9.70	5.60
Fars	Two car accidents	11.14	10.69	9.66
	Three and more cars accidents	8.61	8.51	8.72
Kerman	Two car accidents	11.30	8.74	10.90
	three and more cars accidents	8.33	7.86	6.45
Golestan	Two car accidents	15.91	5.85	7.01
	Three and more cars accidents	12.01	6.38	6.93
Gilan	Two car accidents	13.03	5.14	5.21
	Three and more cars accidents	10.77	6.17	5.51
Lorestan	Two car accidents	11.15	7.34	7.57
	Three and more cars accidents	6.80	5.22	5.22
Mazandaran	Two car accidents	10.89	8.05	7.53
	Three and more cars accidents	12.05	7.57	6.77
Asymp. Sig. 2-tailed		0.056	0.519	0.116

Second Step

The distribution of Pride, Peugeot, and Pickups (the most common vehicles) in the first not-at-fault driver (D'_{2s}) and the rest of not-at-fault drivers (D_{3s}), in three and more car accidents, was compared.

As it can be seen in Table 3, values of 14.58 and 16.10 in the column of Pride in the order of the first not-at-fault driver and the rest of not-at-fault drivers in three and more car accidents in West Azerbaijan mean that 14.58% of all the first not-at-fault drivers' vehicles involved in three and more cars accidents, and 16.10% of all the second or more (in case there are) not-at-fault drivers' vehicles involved in three and more car accidents was Pride. As it can be seen in Table 3, P-Value of U-Mann Whitney test (Asymp Sig. 2-tailed) in the three categories of Pride, Peugeot, and pick-up is more than 0.05 which means that there is no significant difference between the two groups of "not at-fault driver" and "the rest of the not at-fault drivers". As a result, in the second step the validity of the quasi-induced exposure is approved at the provincial level. For the final confirmation of the quasi-induced exposure method validation, the results of this method are compared with the vehicle-kilometer travelled exposure.

Table 3. Real distribution of the first not at-fault driver and the rest of not at-fault drivers in three and more car accidents for Pride, Peugeot and Pickups separated by the province.

Provinces	Type of fault	Pride (%)	Peugeot (%)	Pickups (%)
West Azerbaijan	The first not-at-fault driver	14.58	21.88	17.19
	The rest of not-at-fault drivers	16.10	20.76	16.95
Isfahan	The first not-at-fault driver	13.26	14.36	13.26
	The rest of not-at-fault drivers	15.11	13.33	9.33
Tehran	The first not-at-fault driver	23.86	11.36	10.61
	The rest of not-at-fault drivers	19.77	19.21	7.91
Sistan & Baluchestan	The first not-at-fault driver	15.15	14.14	30.30
	The rest of not-at-fault drivers	12.50	12.50	23.21
Semnan	The first not-at-fault driver	16.42	22.39	8.96
	The rest of not-at-fault drivers	12.22	12.22	9.99
Fars	The first not-at-fault driver	18.49	15.13	17.65
	The rest of not-at-fault drivers	18.18	13.64	18.18
Kerman	The first not-at-fault driver	15.09	13.84	10.69
	The rest of not-at-fault drivers	16.47	14.20	13.64
Golestan	The first not-at-fault driver	21.21	10.39	10.39
	The rest of not-at-fault drivers	22.79	12.87	14.70
Gilan	The first not-at-fault driver	19.17	13.21	11.14
	The rest of not-at-fault drivers	20.08	9.61	9.17
Lorestan	The first not-at-fault driver	17.09	10.13	10.76
	The rest of not-at-fault drivers	9.04	9.60	9.04
Mazandaran	The first not-at-fault driver	25.50	11.16	11.55
	The rest of not-at-fault drivers	18.21	15.33	12.46
Asymp. Sig. 2-tailed		0.478	0.797	0.748

Third Step

The results of the quasi-induced exposure method were compared to those of the Vehicle–Kilometer Traveled exposure in the 5 classifications of vehicles.

As it can be seen in Table 4, values of 85.25 and 77.47 in the column of pickups and passenger cars in the West Azerbaijan row indicate that 85.25% and 77.47% of all the passing vehicles on the roads of West Azerbaijan is pickups and passenger cars, respectively, based on the exposure of vehicle-kilometers traveled and quasi-induced exposure, is of pickups and passenger cars. As it can be seen in Table 4, P-Value of U-Mann Whitney test (Asymp Sig; 2-tailed) for the two groups of "quasi-induced exposures" and "vehicle-kilometers traveled exposures" was much more than 0.05which means that there is no significant difference between these two methods of exposure. Consequently, this study proves with high reliability that the quasi-induced exposure is similar to the exposure in the vehicle-kilometer travelled method.

As it was stated, to determine the prioritization of the road safety, the quasi-induced exposure should obtain the involvement ratio of the influential characteristics on accidents. On the other hand, one of the purposes of this article is to diagnose the safety problems of the influential characteristics on accidents in order to resolve them. Thus, Tables 5 to 8 were obtained.

As it can be seen in Table 5, the age groups of 25-34 and 35-44 are not in a good situation from the aspect of safety. The gray cells on Table 5 indicate that values of involvement ratio are greater than 1.05 which suggests the poor conditions of that element in the roads.

As it can be seen from Table 6, among the different levels of education diploma,

post diploma, and bachelors were improperly involved in accidents. Meanwhile, the drivers who had a license background of 0-5 years were improperly involved in the accidents who also should try to reduce their proportion from the accidents. The gray cells on Table 6 indicate that values of involvement ratio are greater than 1.05 which suggests the poor conditions of those elements in the roads.

Table 4. A comparison of the two exposure methods.

	Comparison of the two exposure methods (The gray columns are VKT and the white columns are Quasi-induced exposure)									
	Pickup & Passenger car	Pickup & Passenger car	Minibus & Lorry	Minibus & Lorry	Truck	Truck	Bus	Bus	Trailers	Trailers
West Azerbaijan	85.25	77.47	8.72	3.20	2.53	13.82	1.87	1.60	1.63	3.91
Isfahan	65.14	61.55	9.74	2.54	8.15	20.64	6.03	1.82	10.94	13.45
Tehran	80.83	68.60	8.73	1.77	3.28	19.00	2.84	3.37	6.31	7.26
Sistan & Baluchestan	71.79	78.56	6.32	1.71	5.08	10.91	7.37	2.21	9.44	6.61
Semnan	67.01	56.07	8.57	1.73	9.31	23.49	5.59	2.15	9.52	16.56
Fars	80.48	67.23	7.86	1.10	4.44	20.99	2.98	1.57	4.25	9.11
Kerman	72.06	73.25	6.09	0.74	6.00	14.30	3.82	1.62	12.02	10.09
Golestan	85.74	82.28	7.84	3.04	3.11	11.13	1.40	1.18	1.91	2.37
Gilan	83.89	84.66	6.69	1.57	3.45	10.33	2.26	1.07	3.70	2.37
Lorestan	63.62	64.84	11.64	3.67	9.80	20.37	5.55	1.09	9.38	10.03
Mazandaran	85.82	77.42	6.88	1.86	3.59	15.78	1.65	1.86	2.06	3.08
Asymp. Sig. 2-tailed					0.464					

Table 5. Determining the involvement ratio of age groups and gender groups based on the classification of provinces.

	Age Group							**Gender Groups**	
	15-17	18-24	25-34	35-44	45-54	55-64	65 and above	Male	Female
West Azerbaijan	0.72	0.88	1.11	1.07	1.00	0.97	0.57	1.00	1.13
Isfahan	0.75	0.87	1.07	1.01	1.03	0.98	0.98	0.99	1.17
Tehran	0.71	1.24	1.09	0.90	0.95	0.85	0.63	1.00	1.01
Sistan & Baluchestan	1.20	0.87	1.06	1.17	0.94	0.74	0.32	0.99	1.28
Semnan	1.18	1.01	1.02	1.04	0.93	0.92	0.96	1.00	0.94
Fars	0.68	0.86	1.18	1.08	0.88	0.80	0.65	0.98	1.24
Kerman	1.10	0.93	1.03	1.03	0.97	0.95	1.13	1.02	0.79
Golestan	1.23	0.98	1.02	0.96	1.04	0.91	0.82	1.00	1.00
Gilan	0.67	0.82	1.06	1.10	1.13	1.05	0.67	0.99	1.26
Lorestan	0.86	0.89	1.11	1.07	0.93	0.73	0.83	1.00	0.90
Mazandaran	0.47	1.07	1.24	0.94	0.93	0.89	0.49	1.00	0.91

Table 6. Determining the involvement ratio of educational level of drivers and driver's license background in percent based on the classification of provinces.

	Educational Level							**Driver's License Background**						
	Illiterate	Lower Diploma Holder	Diploma	Post Diploma Holders	Bachelor	Master degree	PHD	Without Driver's license	invalid driver's license	0-2 years	3-5 years	6-10 years	11-20 years	Up to 21 years
West Azerbaijan	0.46	0.98	1.07	1.61	1.10	1.02	0.85	0.68	1.00	1.02	1.04	0.98	0.76	1.71
Isfahan	0.82	0.67	1.29	1.53	1.07	1.00	0.78	1.05	0.75	1.04	1.03	0.95	0.75	0.96
Tehran	0.66	0.89	1.17	0.70	0.64	0.39	1.00	1.04	1.00	0.98	1.05	1.00	0.75	0.79
Sistan & Baluchestan	0.49	1.10	0.99	1.19	1.02	0.77	0.79	1.25	1.40	0.96	1.04	0.98	0.78	0.78
Semnan	1.05	1.12	0.98	0.78	0.85	0.70	1.04	0.50	1.00	1.09	1.06	0.95	0.71	1.23
Fars	0.77	1.13	0.90	1.16	1.46	1.00	0.91	0.36	0.29	1.02	1.09	1.00	0.84	0.83
Kerman	0.98	0.80	1.13	1.05	1.13	0.88	0.92	0.44	0.25	1.02	1.18	0.97	0.82	0.87
Golestan	0.34	0.88	1.21	1.58	0.53	0.19	0.61	0.75	0.23	1.02	1.07	0.98	0.73	1.43
Gilan	0.74	0.92	1.05	0.82	1.11	0.87	0.80	0.78	1.00	1.07	1.01	0.96	0.91	0.97
Lorestan	0.62	0.85	1.11	1.83	1.10	0.98	0.91	0.46	1.27	1.00	1.05	1.08	0.90	0.60
Mazandaran	0.75	1.01	1.06	0.49	1.16	0.45	0.76	0.47	1.22	1.09	1.06	0.91	0.88	0.64

As it can be seen in Table 7, in all the provinces pickups and passenger cars and in most provinces minibuses, construction machinery (tractor, loader, and grader), and buses had an improper role in the rural accidents. The gray cell son Table 6 indicate that values of involvement ratio are greater than 1.05 which suggests the poor conditions of those elements in the roads.

As it can be seen in Table 8, Citroen Xantia (the common type of Citroen in Iran), small Pickup, and big Pickup (the common type of pickups in Iran as in Table 1) in most provinces had a less profound role in the rural traffic accidents. The gray cell son Table 6 indicate that values of involvement ratio are greater than 1.05 which suggests the poor conditions of those elements in the roads.

Table 7. Determining the involvement ratio of type of vehicle in percent based on the classification of provinces.

	The group of "Type of vehicles"									
	Passenger Car	Pickup	Bicycle	Motorcycle	Pedestrian	Bus	Minibus	Truck	Trailers	Construction Machinery
West Azerbaijan	1.70	2.01	0.76	0.71	0.00	1.20	0.58	0.77	0.77	0.89
Isfahan	1.56	1.67	0.88	0.67	0.01	1.20	1.08	1.03	0.90	1.24
Tehran	1.53	1.29	0.79	1.20	0.27	0.89	1.11	0.86	0.69	0.35
Sistan & Baluchestan	1.31	1.98	0.88	0.71	0.00	1.00	0.86	0.94	0.98	0.78
Semnan	1.52	1.81	0.23	0.79	0.00	1.75	1.17	1.14	0.43	1.56
Fars	1.73	1.72	0.67	0.58	0.00	0.96	1.24	0.74	0.66	1.37
Kerman	1.40	1.58	1.95	0.87	0.00	1.11	1.08	0.90	0.82	0.91
Golestan	1.52	1.92	0.93	0.90	0.00	0.84	0.87	1.15	0.83	1.48
Gilan	1.78	1.93	1.54	0.72	0.00	0.87	1.09	1.06	0.66	1.18
Lorestan	1.63	1.78	0.68	0.74	0.00	1.72	0.98	0.90	0.64	0.76
Mazandaran	1.81	1.56	1.08	0.81	0.00	0.39	0.83	0.93	0.81	0.89

Table 8. Determining the involvement ratio of pickups and passenger cars in percent based on the classification of provinces.

	Groups of pickups and passenger cars								
	Pride	Peugeot	Peykan	Renault Logan	Citroën Xantia	Samand	Cars more expensive than 20000 dollars	Small Pickup	Big Pickup
West Azerbaijan	0.97	1.08	0.90	1.00	1.09	0.68	0.92	1.00	1.19
Isfahan	0.97	0.91	1.12	0.99	1.17	0.92	1.00	0.99	1.09
Tehran	1.10	1.00	1.01	1.33	1.11	0.80	0.93	1.08	0.79
Sistan & Baluchistan	0.81	1.05	0.62	0.64	0.86	0.86	0.51	1.41	1.26
Semnan	0.91	1.03	0.98	0.00	1.88	1.21	0.74	1.21	1.12
Fars	0.98	1.00	1.24	0.36	1.07	1.02	0.70	1.19	0.90
Kerman	0.97	1.02	0.91	0.51	1.54	0.73	1.12	1.17	1.03
Golestan	0.92	0.99	0.91	0.47	0.61	1.11	1.22	1.09	1.24
Gilan	0.94	1.03	0.99	0.85	1.34	1.00	1.35	1.32	0.92
Lorestan	0.79	1.14	1.12	0.19	1.42	1.01	0.90	1.14	1.00
Mazandaran	1.10	1.17	0.87	0.57	1.71	0.90	0.57	1.01	0.84

As it was mentioned, in order to prioritize the safety level of the roads, it is necessary to blend the involvement ratios obtained in Tables 5 to 8 in a way that the less and more safe provinces are identified. Therefore, after obtaining the experts opinions, a geometrical average of their opinions was taken and with the help of Expert Choice software, the prioritization of the provinces was obtained as is presented in Figure 3.

As it can be seen in Figure 3, West Azerbaijan, Isfahan, and Gilan are the first three least safe provinces based on all the driver-vehicle characteristics, and Mazandaran, Golestan, and Sistan & Baluchestan are among the first three safest provinces. What is significant is that the difference between the least safe province and the safest province based on the safety weight is small. That is to say that, West Azerbaijan as the first priority of the least safe province and Mazandaran as the eleventh priority of the least safe province had 9.78% and 8.19% of the share of the accidents respectively. It can be concluded that these provinces, at first glance, have a similar situation in breaking the safety parameters (accidents).

In order to prioritize the road safety level based on the old method, Table 9 was obtained. The values in this Table are indicative of the number of the injured drivers on million vehicle-kilometers traveled.

As it can be seen in Table 9, this study showed that the average rate of accidents for the above-mentioned provinces in the five classifications was 0.206. Therefore, the accident rates more than the average indicate an improper situation. Based on this, classifications of trucks, passenger cars and pickups, and trailers do not have the proper conditions from the aspect of drivers' safety.

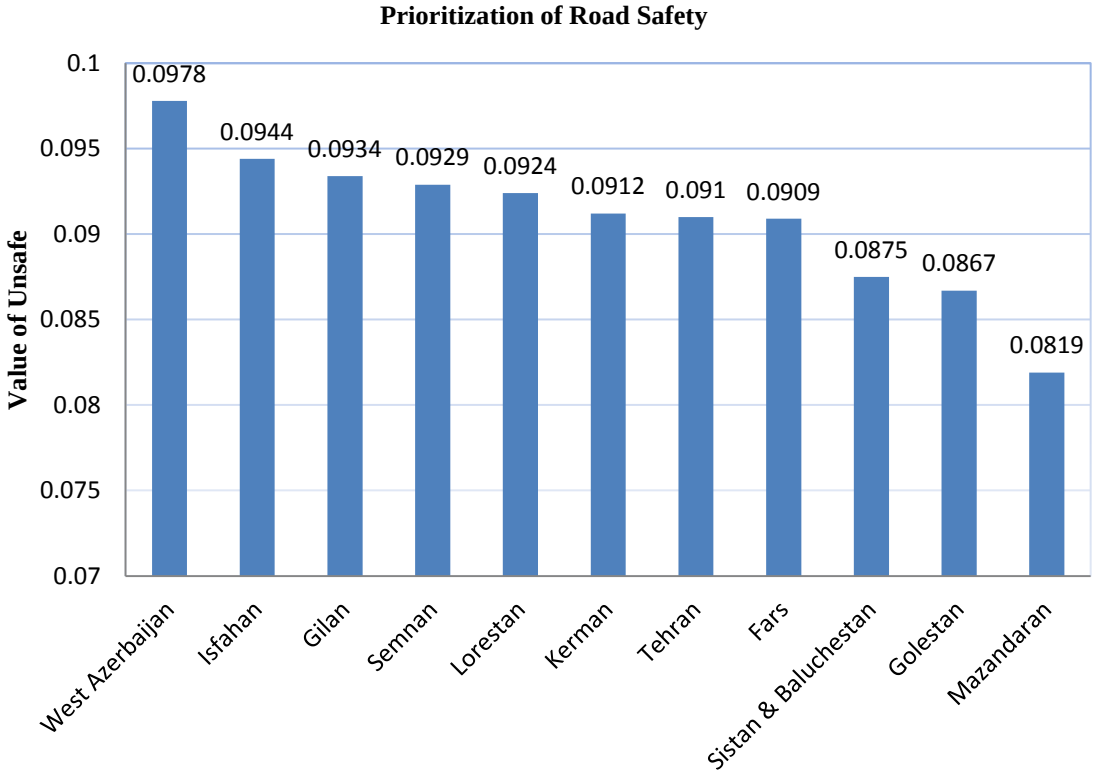

Fig. 3. Final prioritization of provinces from the aspect of the least safe province: Left to right, the less to more safe provinces.

In order to prioritize the safety level of the provinces roads, the accident rates presented in Table 9, which were based on person to million vehicle-kilometers traveled, were de-dimensioned and then the weight for each of the provinces was calculated. Finally, prioritization of the safety level of the roads based on the geometrical average of experts' opinions and with the help of Expert Choice software was determined as in Figure 4.

Table 9. Determining the rate of injured drivers of different car classifications on million vehicle-kilometers traveled.

	Rate of Fatal Drivers of Different Car Classifications on Million Vehicle-Kilometers Traveled				
	Pickup & Passenger Car	Minibus & Lorry	Truck	Bus	Trailers
West Azerbaijan	0.311031	0.026394	0.743938	0.616181	0.259232
Isfahan	0.210523	0.044869	0.315100	0.018114	0.154800
Tehran	0.090945	0.016084	0.209058	0.192230	0.057998
Sistan& Baluchestan	0.666166	0.033645	0.836695	0.086520	0.236381
Semnan	0.605113	0.014798	0.740083	0.158807	0.235385
Fars	0.184650	0.015499	0.384470	0.384479	0.160509
Kerman	0.074787	0.000000	0.128251	0.060438	0.073629
Golestan	0.143750	0.045350	0.610222	0.084408	0.310172
Gilan	0.049594	0.008573	0.041636	0.063446	0.007750
Lorestan	0.298735	0.045199	0.555207	0.189579	0.236882
Mazandaran	0.043391	0.032090	0.176781	0.033334	0.026726

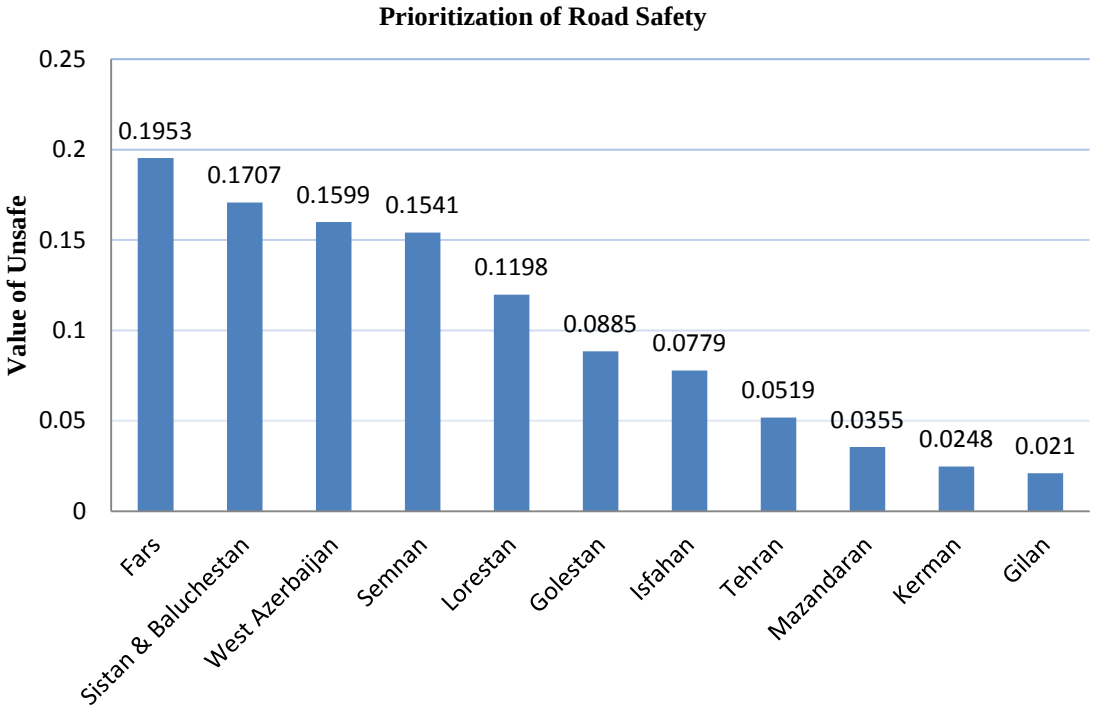

Fig. 4. Final prioritization of provinces from the aspect of the least safe province, based on the old approach: Left to right, left to right, the less to more safe provinces.

As it can be seen in Figure 4, Fars, Sistan & Baluchestan, and West Azerbaijan are the first three least safe provinces based on the old method, and Gilan, Kerman, and Mazandaran are among the first three safest provinces.

CONCLUSIONS

One of the main objectives of this study was to validate the quasi-induced exposure method based on the accidents data base sat the provincial level. According to the results of this study, the significance value (p-value) of the Mann-Whitney test for the whole phase of the quasi-induced exposure validation hypothesis was more than 0.05. Consequently, it could be concluded that the quasi-induced exposure method is valid for estimating the actual exposure at the provincial level.

The other aim of this study was to determine the participation rate of the driver-vehicle influential characteristics in the accidents and to state their safety problems. Hence, the participation rate for age, sex, education, driving license background, type of vehicle systems, and for passenger cars and pick-ups were determined.

One other objective of this study was to provide a new method based on a new approach of the quasi-induced exposure method through using the Analytical Hierarchy Process for the prioritization of the safety level of the roads, then to compare it with the old approach and describe its advantages and disadvantages. Under the new method. What is significant is that the difference between the least safe province and the safest province based on the safety weight is small which is consistent with the actual situation. It can be concluded that at the first glance, these provinces have a

similar situation in breaking the safety parameters (accidents).

One of the other results of this study was the comparison between the traditional method (direct exposure and accident rate) and the new method (indirect exposure and involvement ratio) in determining the prioritization of the safety level of the roads. With regard to determining the prioritization based on the new method, various parameters of driver-vehicle characteristics were included, while in the traditional method only one parameter of the five classifications of the intended vehicle was included. Since there was only one kind of exposure in determining the accident rate, it was necessary to use that type of accident rate. Because the exposure of the vehicle-kilometers traveled was solely based on the classification of the vehicles and not the other driver-vehicle characteristics, it was necessary to mention the number of the accidents merely based on the injured drivers in the five classifications of vehicles so as not to have the bias resulting from not including the related exposure. This shows that with the traditional method, it is impossible or hard to determine the accident rate with the extensiveness of the driver-vehicle characteristics; therefore, the traditional method lacks the variety and extensiveness of the new method. As shown in Figure 3, the standard deviation of the safety weight calculated for the provinces in the new method was 0.004247; while as shown in Figure 4, this value for the traditional method was 0.063231 which shows the variability of the road safety in the traditional method compared to the new one. Meanwhile, in this study, those provinces were included that had the highest number of injured individuals in the traffic accidents of the country and almost the same safety conditions.

Suggestions for further studies in this field are as follows:

- It seems that the number of the accidents data is effective in the prioritization based on the new approach. One study could investigate the number of the required data in order to obtain the required validity in using the approach.
- It seems that different macroscopic and microscopic parameters of the traffic flow have an effect on the validity of the quasi-induced exposure method. Therefore, it is suggested that some research be carried out on the effects of these factors on the validity of the method.
- Due to the hierarchical nature of the factors participating in the accidents, we used the Analytical Hierarchy Process in our research to incorporate the factors that influence the accidents. Therefore, it is suggested that similar studies based on the network analysis be conducted and the results be compared with the findings of this study.

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