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Comparison of Accident Severity and Frequency Index Method in Identifying Hotspot Segments of Intercity Road Network

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Abstract

This study presents an integrated method for identifying an important segment of traffic accidents in an intercity road network. The spatial analysis method is known as network Kernel Density Estimation (KDE). The importance of critical accident rate is that it takes into account several factors including exposure rates, type of road section, variance of accident data, etc. Also, in this study, we compared the results of the road severity index with the Kernel Density Estimation method. The results of the study were obtained for two almost identical models. We found that the key points determined by the Kernel Density Estimation method reflect the severely problematic component segments, and filter out components that are not vulnerable. This approach can help transportation officials and safety professionals prioritize locations that need more safety attention.

Keywords*:* Crash, Kernel Density Estimation (KDE), Intercity Network, Severity Index

1. Introduction

Today, with the development of cities and the expansion of urbanization, road transport is an integral part of human life. In this regard, facilities are added day by day to increase speed and convenience in the road transport system. But speed and convenience as well as safety and security are desirable and important. It is the man who values transportation with his being, and the preservation of human life is the most important goal of any system. Hence, the most important factor in road management is its safety; the transportation network accounts for the majority of accidents.

According to the World Health Organization (WHO), 1.2 million people are killed and more than 50 million are injured in road accidents each year. In the statistics provided, more than 90% of deaths occur in middle- and low-income countries, which have only 48% of registered vehicles. Therefore, if

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the current trend continues and no preventive measures are taken, according to the World Health Organization, by 2030, traffic accidents will become the fifth leading cause of death. The average global growth in traffic casualties will reach more than 68% from 2000 to 2020, which is much higher for developing countries. In 2002, traffic accidents were the ninth leading cause of death in the world. Many accidents have paralyzed people and left them paralyzed for the rest of their lives, while also putting financial pressure on families and communities. Road accidents in the Asia-Pacific region have resulted in more casualties than common dangerous diseases, which are often a major problem in developing countries. While the situation of road accidents in the industrialized and rich countries of the region, such as Australia, Japan, and New Zealand, is gradually improving, but most developing countries in the region are facing a dire situation. Although infectious diseases are gradually being brought under control, the high rate of deaths and injuries caused by road traffic accidents has become more important in recent years. For example, in Thailand, most people's potential lives are lost mainly through road accidents rather than tuberculosis and malaria. In many developing countries, road accidents are the second leading cause of premature death for the majority of the population (5 to 46 years of age). What is even more worrying is that there is evidence that many of the existing accidents are not reported, and so the official statistics used here are less than true. Therefore, paying attention to safety in urban management and adopting appropriate policies and strategies to increase safety and reduce deaths in an accident is the most important issue. It should be pointed out that it is necessary to comprehensively examine the traffic safety issues in metropolitan areas; because the intercity transportation system in metropolises is a complex set of influencing factors. In metropolitan areas, a variety of modes of transportation, supply and demand management schemes, a wide range of users at different levels, as well as all road transport infrastructure facilities have created a complex system. Each of these categories must be considered comprehensively. On the other hand, road safety is a comprehensive issue that must be thoroughly studied and planned.

Accident prevention policies, assistance during traffic accidents, and post-accident relief are some of the safety aspects. Obviously, the traffic safety of a metropolis must have a extensive plan in order to achieve the desired goals and objectives in city management. Accidents and human casualties are among the unpleasant consequences of the uneven development of transportation technology, and unfortunately the number of accidents and deaths due to it in Iran is so high that in 2001 more than 340 thousand accidents occurred. As a result, 19727 people were killed and more than 117,000 were injured. This means that an average of 950 accidents occur in the country every day, and 54 people are killed as a result of accidents. This trend increased by about 10% per year before 2005, and there has been no significant increase since then with planned measures. The number of deaths due to accidents in the country is still very high that in 1397, about 17,183 people lost their lives in traffic accidents. Among them, 12,887 fatal accidents occurred on suburban roads, and 4,286 fatal accidents occurred on urban roads. On the other hand, the increase in traffic accidents is considered an important concern for road and transportation engineers. The analysis of safety data requires long-term collection of necessary and sufficient information. Understanding Space-Time accident patterns can help road safety professionals identify sections of the road that have more accidents than other similar locations as hazardous sections. Exploring such high-risk locations plays a key role in road safety management because any mistake in identifying high-risk locations may lead to the identification of really dangerous locations as safe areas or, conversely, the introduction of safe sites as hazardous locations (Shariat Mohaymany et al., 2013). The use of geographic data, such as traffic accidents, requires special attention because spatial data exhibits different characteristics (Haining et al., 2003). The most important problem is that there is a spatial effect between adjacent data within a time period. This problem can be fully solved by using point pattern analysis (Yamada and Rogerson, 2003). Note that most crash reports in developing countries are still based on traditional pen and paper methods. Errors are inevitable when recording such discrete data without accurate spatial information.

Density estimation by extracting continuous surfaces is likely not only to depict the spatial impact of the collision mode but also to create a more realistic picture of hazardous areas. Such locations can then be examined for possible environmental factors that may help identify crash sites that are close to the actual crash site.

A review of past studies shows that the typical kernel density (KDE) function has been used in several safety studies to identify crash risk areas based on crash observation data (Anderson, 2009; Pulugurtha et al. 2007). Spatial models, as a local model, have a fundamental meaning in common with the first law of geography, which states: "Everything is related to everything else, but near things are more related than distant things."(Soroori et al., 2020). Although road safety is one of the most important aspects of transportation systems, safety is not yet well within the framework of its planning strategies (Gomes, Cunto and Silva, 2017). Among the main reasons for the lack of a comprehensive approach to road safety is the lack of a comprehensive, integrated data set for accidents and other related features of traffic accidents and to a limited extent of the tools available to conduct a detailed study. Comprehensive safety analysis, at the managerial level, builds more confidence in rational approaches to adopting strategies or safety assessments in different transportation scenarios.

In the international classification of types of accidents, it can be said that a fatal accident is an accident in which at least one side of it is a moving vehicle and someone has been killed as a result of that accident. An injury is an accident in which at least one side of it is a moving vehicle and someone is injured as a result of the accident. Accidental damage is an accident in which at least one side of the vehicle is moving and no one is killed or injured as a result of the accident and the result of the accident is only damage (Chatterjee et al. 2001; Dumbaugh et al., 2004; Tarko, 2006). As mentioned, to identify the most accident-prone parts of the road, based on the observed and predicted accident data, two methods have been adopted (1) frequency-based methods and (2) models based on accident severity. The first method measures the density of point events based on the density of an area. These methods include Kernel Density Estimation (KDE). The second group measures the spatial dependence of point events based on the intensity and distance of points from each other. This group includes methods such as the nearest neighbor, K functions, and Moran's index (Xie and Yan, 2010).

2. Data Collection Method

The science of traffic engineering deals with three aspects of human, road, and vehicle. In accidents, three categories of human, environmental, and vehicle factors are examined. Human factors include driving violations, lack of driving skills, unconsciousness, etc. Environmental factors are referred to as geometric design of the road (especially in arches and stairs), insufficient lighting, weather conditions, road surface condition, etc. Vehicle-related factors are included vehicle technical system defects (brakes, steering, and other cases). In analyzing the causes of accidents at one point (which is done to root out accidents and provide safety solutions), it is necessary to first prepare statistics and information about all accidents that have occurred within 3 to 5 years. This statistic should include the following information items for each accident:

- Exact location of the accident
- Date and time of the accident
- Cause and mode of accident (in terms of angle of impact, such as front to back)
- Type of accident (including death, injury, and damage)
- Damage rate
- Climate and environmental conditions at the time of the accident
- Pavement condition and road surface
- Driver status (in terms of age, gender, drowsiness, unconsciousness, etc.)

Usually, after each accident, a special form is filled out by the police officer that contains the above information. But sometimes it is seen that for the "accident location" only the name of the passage is mentioned, and its exact location is not recorded. In the past, for severe traffic accidents, a written report in the form of a description of the accident, and not in the form of coded and codified, prepared by the police; and this report is considered by the judicial authorities. In this type of information form, the information is descriptive without any special rules or forms that somehow enter the theories and conclusions of the police in the report. Since the early 1960s, accidents have been reported on special forms prepared by traffic police at the scene. Accidents that are referred to the judiciary or referred to insurance for compensation need to be reported to the police.

In this study, police reporting forms have been used. But since the accident situation report was not recorded in the form, with the cooperation of the responsible organizations, the exact location of all accidents was identified and recorded.

3. Method

Road safety engineering approaches based on accident analysis are divided into three main parts, which are:

- Management of accident hotspots and subsequent actions
- Assess and inspect road safety in order to take preventive measures
- Road safety operational plan

The first is the management of accident hotspots and their appropriate actions, which include a series of specific measures to correct specific points and parts along the way. These parts are the parts in which many accidents are observed and are known as high-accident points. In this analysis, the statistics and information of accidents can be used because the management of accident-prone points is done based on the recorded information of accidents. In this analysis, the statistics and information of accidents can be used because the management of accident-prone points is done based on the recorded information of accidents. In Iran, although approaches and criteria for defining high-accident points, such as at least 10 accidents in three years or determining the severity of accidents in high-accident points, have been defined. But none of these criteria are based on comprehensive and accurate scientific studies and current conditions. It has been external sources or people's experiences. Correction of accident hotspots is often considered as a profitable and quick-return measure, so in the first years of safety promotion programs, it is used as one of the important priorities to increase road safety.

The second case, road safety assessment, and inspection are process that is performed by a team on behalf of the employer regularly at the network level.

Finally, the operational and executive plan is road safety. This executive plan includes all activities and executive measures to improve the safety that are predicted in advance and the appropriate budget is considered to achieve their main goal, which is to achieve the safety of infrastructure.

3.1. Network KDE

As mentioned earlier, many recent studies have used the kernel density network method developed by Okabe and Sugihara (2012) to examine the spatial correlation of point events in a road network. In this study, the KDE network method for estimating component density Road has been used in the road network of Hamedan province. This method is based on the study (Okabe and Sugihara, 2012). An unbiased kernel function should be used to prevent inaccuracies. Hence, the formulation of the "kernel density function" method is used. Using this approach, the performance of the network kernel is defined for two things: (1). The center of the q-core does not match a node, and (2). The center of the q-core coincides with a node. In the first case, the following function by (Figure 1) is defined. The kernel density function shows Equation 1.

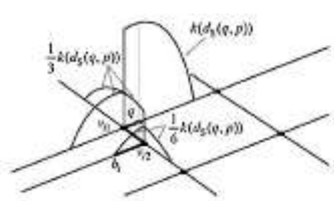

Figure 1. Simplified example of an equal split discontinuous kernel function (modified from Okabe and Sugihara 2012).

$$k_q(p) = \begin{cases} 0 & d_s(q,p) \geq h \\ \dfrac{k(d_s(q,p))}{(n_{i1}-1)(n_{i2}-1)\ldots(n_{ik}-1)} & d_s(q,v_{ik}-1) \leq d_s(q,p) < d_s(q,v_{ik}) \end{cases} \quad (1)$$

In this Equation k (x) is a function of the base kernel; y is the center of the kernel; d is the distance between the path y and x. H is the bandwidth and destroys the degree of the node.

In this case, as shown in the Figure 1, the value of the kernel performance is the same as the performance of the base kernel as long as the kernel is in the shortest path and does not recognize a node ds(q,vik) > ds(p,q) > 0

3.2. Accident Severity Index

Accidents are divided into three components: damage, injury, and death. In this method, a coefficient is considered for each of these types of accidents. The use of weighting coefficients is a kind of emphasis on severe accidents as opposed to minor accidents. There are several methods for determining these coefficients, and one option is to consider the weighting coefficients obtained from socio-economic costs. In situations where accident statistics and information are accurate and reliable, coefficients of 300, 20, and 1 can be used for fatal, traumatic, and damaging accidents. But for the city of Hamedan, considering that the system of collecting and processing information about accidents has not been very accurate and principled, it is better to use a series of logical coefficients suggested by a person named Agent, which is equal to 9.5, 3.5 and 1 are for fatal accidents, injuries, and damages, respectively. The relationships used in this method are as follows:

$$S_i = \frac{\sum_j W_j \cdot f_{ij}}{f_i} \quad (2)$$

$$\overline{S}_i = \frac{S_i}{L_i} \quad (3)$$

$$\overline{S}_{ave} = \frac{\sum_i S_i}{\sum_i L_i} \quad (4)$$

Si: Number of accidents equivalent to damage in the segment i

Wj: Weight coefficient of type j

fij : The number of accidents of type j in the i-th segment

fi : Total number of accidents in the i-th segment (excluding weighting coefficients)

Li : The length of the i-th segment

$\overline{S}_i$: The number of accidents is equivalent to the damage per unit length of the i segment

$\overline{S}_{ave}$: The average number of accidents is equivalent to the damage of all roads

The frequency-severity method of the accident is the simplest, easiest, and most explicit method for identifying the points of the crash. In this method, the points and sections that have the highest number of accidents are known as accident-prone points based on the conversion factor of the accident intensity. The location and time of all accidents should be recorded and using a point map is the best way to preserve information.

It should be noted that today, using GPS, the exact location of points can be determined and recorded. This method is easy to use due to the lack of other information such as traffic volume, and considering that most of the required information, such as traffic volume statistics, to calculate and determine the rates and indicators of accidents in our country is not acceptable accuracy. This method is usually recommended for small towns, areas in a large city, and low-traffic intercity roads. One of the disadvantages of this method is that it has no sensitivity to the volume of traffic and is useful for areas where the volume of traffic in the whole network has an acceptable homogeneity. The simplicity of this method can be justified by the low volume of traffic on the road network. In this method, using the identified points, good information will be obtained to carefully examine and determine whether the lack of road facilities has caused such an occurrence.

$$I = (9*T_f + 4*T_{ia} + 3*T_{ib} + 2*T_{ic} + T_d) \tag{5}$$

Tf = Fatal accident
Tia = Injury accident type A
Tib = Injury accident type B
Tic = Injury accident type C
Td = Damage accident

Locations, where the crash index is more than twice the average of all situations, are known as high-risk crash points. The advantage of this method compared to method number three is that in addition to the number of accidents, their severity is also considered.

In this study, to zone the risk of an accident based on the factors affecting the accident, first, the data cleansing operation was performed. According to international standards, the three main factors influencing the occurrence of accidents include road factor-vehicle factor-human factor, which has been studied separately in many studies. In this study, the relationship between accident time and road section length is based on the geographical location of the accident has been assessed to identify the parts of the road and take the necessary measures to improve the parts of the road that are suitable for the specific lighting conditions by the relevant authorities. It should be noted that in the study conducted by the authors of this article, the identification of accident components of roads in Hamadan province was done based on the criteria of human factors and the geometric design of the road. Since the time of the accident in your day requires special arrangements to improve the roads the present study seems necessary. In this study, in addition to zoning road sections based on the location of the accident and the time of the accident, the relationship between severity index and frequency index has also been measured. According to international standards, the accident severity index is more important than the accident frequency index. Therefore, identifying accident-prone sections with high frequency and severity of accidents is of great importance in improving and securing roads. In cases where access to GPS is restricted for road safety agents, accurate naming of axes and coding of road sections will be of great importance, so in this study, all road sections are coded. To accurately determine the risk situation.

4. Results

Accidental information on roads and intersections is needed to determine accident hotspots. For this purpose, accident information has been used separately for the number of accidents leading to injuries, the number of accidents resulting fatal and the number of damaging accidents at segments of roads with a length of 300 meters. Note that the length of road segment can be reduced or increased depending on the conditions. For this purpose, it is necessary to equip traffic police accident experts with GPS global positioning device and prepare a database of accidents in GIS environment in order to analyse accidents more accurately. Also, the final information of the accidents should be published by the traffic police and should be easily available to the users. To determine the selected method of identifying and prioritizing accident hotspots for urban roads in the country, the following criteria have been considered:

1. Consider the severity of accidents and the cost-benefit ratio if accident hotspots are corrected.
2. Easy access: Existence of required data and information or the ability to prepare and collect the required data according to the information of the traffic police accident forms.
3. Applicable to country conditions
4. Reliability of data until the exact location of the accidents is determined every 300 meters of the road, the average number of accidents per 1000 meters of road length is used.

According to the conditions and method of recording information in Iran, this instruction has been developed in two parts: determining and prioritizing accident hotspots.

In the first part, using general indicators that have been accepted in other countries of the world, accident hotspots within the city are identified and in the second part, the priority of these accident hotspots is done. To prioritize accident hotspots, two methods of severity - rate and frequency - the severity of accidents have been proposed, which further discussion and study of these methods and points that should be considered are explained.

In general, determining and prioritizing accident hotspots can be divided into the following three stages:

- Determining accident hotspots in the road network
- Prioritize accident hotspots
- Before and after studies to investigate the effects of road safety methods

In this section, according to the statistics and information of accidents, intersections and special lengths of axes whose number of accidents is more than the desired criteria, are identified as accident hotspots.

Therefore, according to the statistics and information of accidents, intersections and certain lengths of road axes whose number of accidents is more than the desired criteria, are identified as accident hotspots. Roads that have been newly constructed or the level of road facilities have changed or the number of accidents during the 3 years is not known, the road safety audit method for inner-city roads can be used to identify areas with potential for accidents.

This study has carried out a study with an accuracy of 1 square kilometer in the entire road safety network of Hamadan province (Iran). For the term, three different databases from different sources are used. First, a basic road network map was obtained from "Hamadan Province". The map is prepared in the form of a GIS file, which includes road specifications such as length, road type, and speed limit. During the study period, 2995 accidents were recorded on the roads of Hamadan province. The accident database is provided in Excel format and includes significant parameters of the accident, such as the date of the accident, place of accident, age, sex, type of vehicle, weather conditions, etc. These accidents are then converted into GIS files. And are positioned using latitude and longitude using the ArcGIS map (Figure 2). This study only considers that vehicle crashes by safety analysis vehicles and other types of accidents such as pedestrian cycling accidents are outside the scope of this study. Third, in this study, we have used traffic volume data provided by the Ministry of Transport of Iran Average annual traffic (AADT) and average daily traffic (ADT). To improve road safety and create a safe environment, it is important to identify segments of the road that have relatively high accident densities compared to other segments of the network. These places are known as important points that are characterized by the high prevalence of accidents, due to the lack of division of traffic areas in the entire study area (for example, state, state, urban area, or city center) (Chainey and Ratcliffe, 2013). Kernel density estimation (KDE) can be classified into two categories: surface and network classification. The first method uses the Euclidean distance to indicate the density of events. A review of previous studies shows that estimation of kernel density at the network level Traffic area analysis has been used (Fotheringham, Brunsdon, and Charlton, 2002; Vemulapalli, 2015; Erdogan et al., 2008; Oris, 2011). The KDE method at the grid level estimates the crash density in a moving cell in a homogeneous two-dimensional space. Accidents based on the Euclidean distance, in which accidents close to the center produce a higher degree, recently, several studies have used the KDE method to estimate important locations Crash, However, and one of the major problems with the kernel density network is that there is no specific statistical method for testing critical points (Nie et al., 2015; Yao et al., 2015). Examining the spatial relationships between accidents from different Accident severity index (DASI) is necessary to achieve a better understanding of the DASI and factors affecting the collision. However, relatively few researchers have focused on analyzing this type of data. Therefore, in this study, we used DASI for different segments of the road to measure the spatial relationships in accidents (Okabe and Sugihara, 2012). However, many of these studies neglect two main factors in their accident analysis. First, they used long-term cumulative crash data (for example, three or more years of protection) at each site, regardless of whether the crashes occurred continuously in a particular location. They did not take into account the high crash density at a particular site because of a problem or problem that does not exist at a regular time (such as a geometry design problem in a given location). Therefore, in this study, we have tried to have a more acceptable estimate of the accident segment by comparing the accident severity index and KDE.

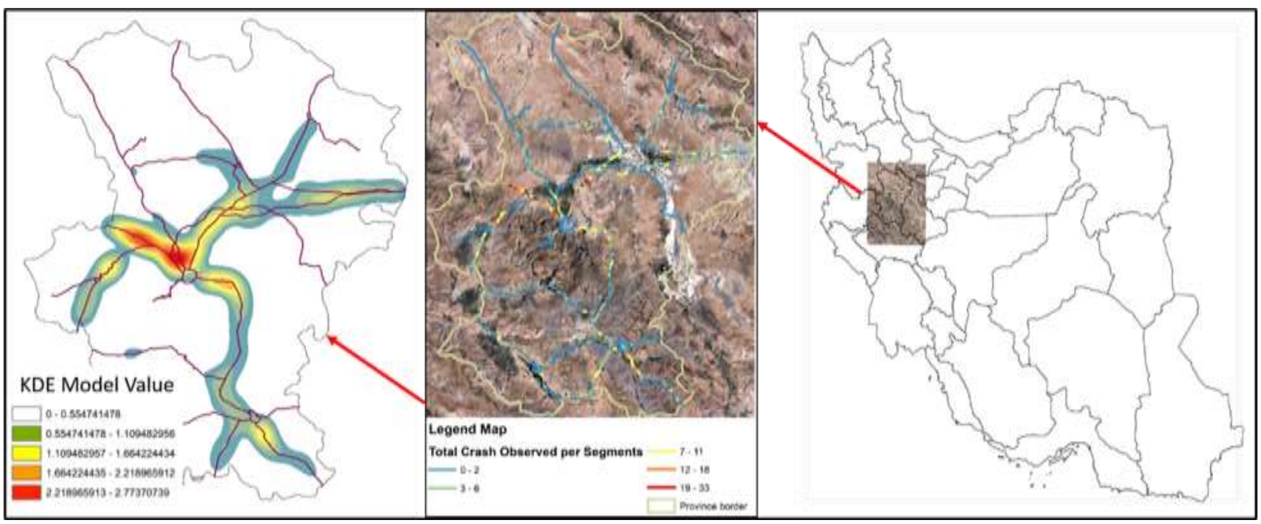

Figure 2. Total location of accidents in intercity axes of Hamadan province

In this study, two methods of accident severity index (EPDO) and the frequency of accidents were used to perform a safety analysis of 26 axes (52 reciprocating axes). Each suburban axis of Hamedan province was analyzed based on a 1000-meter section, so the province's total suburban axes were divided into 1295 1000-meter sections, and the province's accident data on suburban roads covered about 1300 km.

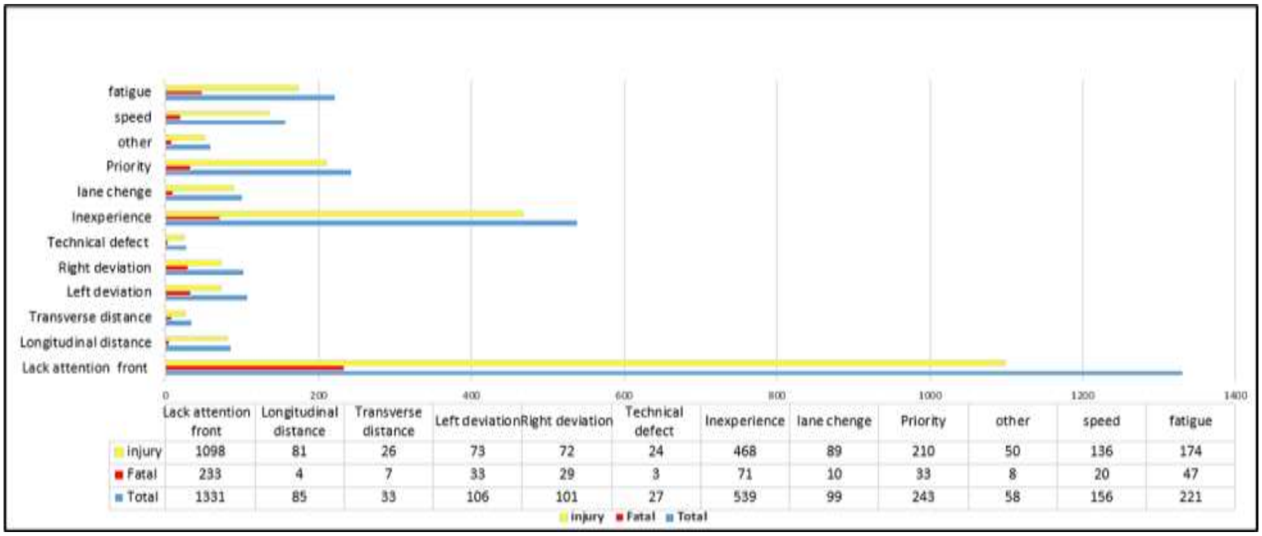

Figure 3. Accident frequency graph based on the accident caused

Equation No. 1 and 4 were used for calculating the accident intensity index for all 1000 meter sections of Hamadan province using GIS software.

Based on Equation No. 4, the segments whose intensity index was less than the average of the axis intensity index were zero (white status).

Parts with an intensity index between one and 1.2 times the average of the part index (code 1 (optimal condition)).

Parts with an intensity index between 1.2 and 1.4 times the average of the axis intensity index were assigned code 2 (relatively desirable).

Parts with an intensity index between 1.4 and 1.6 times the average intensity index received code 3 (relatively unfavorable).

Parts whose intensity index was obtained between 1.6 to 1.8 times the average intensity index axis code 4 (unfavorable condition).

Parts with an intensity index between 1.8 Code 5 (critical condition) was obtained up to 2 times the average of the axis index.

Code 6 (red status) was considered for the parts whose intensity index was more than 2 times the average of the axis intensity index.

Also, to evaluate the safety status of the province's roads based on the accident frequency index, equation (3) has been used. In addition, the desirability of the section has been calculated based on the accident severity index method.

As shown in Table 1, the condition of Hamedan's suburban axes is based on the frequency of accidents, which are divided into 1295 segments of 1000 meters. Due to the high volume of information, several road sections are shown in Table 1.

Table 2 and Equation 4 provide the frequency of accidents based on the number of accidents occurring on the axis, and the severity of the accident based on Equation 3, where 9.5 is the coefficient for each fatal accident and 3.5 is the coefficient for each injury accident. And the damage accident is considered equal to 1.

Also, in the index column, the intensity of the values obtained is calculated based on Eq.3. According to Table 2, the higher the number related to the intensity index, the more critical the axis position.

Thus, the red position axes are shown in red, the critical position axes are shown in gray, and the unfavorable position axes are shown in yellow. The information recorded by the traffic police between

2017 and 2019 didn't have UTM coordinates, and it was reported with a moderate level of accuracy based on address. Based on the results, one cannot know with certainty which axis is in critical condition, but by identifying critical points, making field visits, and verifying the accuracy of the information, better results can be achieved. Consulting engineers of road designers recommend that the parts identified as being a priority for improvement and safety be visited before field improvements can be made, confirm or calibrate study results by recording field information.

Table 1. Condition segments of suburban axes of Hamadan province based on accident frequency index.

Name Axis	Segment length	Segment Name	Type of accident		Accident time			Total accidents	Frequency index code
			Injured	Death	00:00-8:00	8:00-16:00	16:00-24:00		
Asad Abad Axis	1000	AS1516	1	1	2	0	0	2	2
Asad Abad Axis	1000	AS1617	0	1	0	1	0	1	1
Asad Abad Axis	1000	AS1718	2	6	1	3	4	8	5
Asad Abad Axis	1000	AS1819	2	4	1	1	4	6	4
Asad Abad Axis	1000	AS1920	2	9	5	0	6	11	6
Asad Abad Axis	1000	AS2021	1	9	6	2	2	10	6
Asad Abad Axis	1000	AS2122	1	14	7	3	5	15	6
Asad Abad Axis	1000	AS2223	0	3	1	1	1	3	2
Asad Abad Axis	1000	AS2324	1	1	2	0	0	2	2
Asad Abad Axis	1000	AS2425	2	9	5	3	3	11	6
Asad Abad Axis	1000	AS2526	0	7	3	3	1	7	5
Asad Abad Axis	1000	AS2627	1	13	4	3	7	14	6
Asad Abad Axis	1000	AS2728	0	5	2	0	3	5	4
Asad Abad Axis	1000	AS2930	1	4	1	0	4	5	2
Asad Abad Axis	1000	AS3031	4	9	7	2	4	13	6
Asad Abad Axis	1000	AS3132	0	3	2	0	1	3	2
Freeway	1000	FR6768	0	1	1	0	0	1	1
Freeway	1000	FR6869	2	2	2	1	1	4	2
Freeway	1000	FR6970	0	2	1	1	0	2	2
Freeway	1000	FR7071	1	3	2	1	1	4	2
Hamedan-Bijar	1000	HB118119	0	0	0	0	0	0	1
Hamedan-Malayer	1000	HM4142	1	9	5	1	4	10	6
Hamedan-Razan	1000	HR2425	0	3	1	0	2	3	3
Hamedan-Razan	1000	HR2526	4	13	7	3	7	17	6
Hamedan-Razan	1000	HR2627	1	4	0	2	3	5	4
Hamedan-Razan	1000	HR2728	0	5	1	1	3	5	4
Hamedan-Razan	1000	HR2829	3	6	5	3	1	9	5
Hamedan-Sanandaj	1000	HS2324	4	13	6	3	8	17	6
Hamedan-Sanandaj	1000	HS2425	0	8	3	0	5	8	5
Hamedan-	1000	HS2526	1	10	6	2	3	11	6

Name Axis	Segment length	Segment Name	Type of accident		Accident time			Total accidents	Frequency index code
			Injured	Death	00:00-8:00	8:00-16:00	16:00-24:00		
Sanandaj									
Hamedan-Sanandaj	1000	HS2627	2	11	3	4	6	13	6
Hamedan-Sanandaj	1000	HS2728	1	22	10	5	8	23	6
Hamedan-Sanandaj	1000	HS2829	0	11	8	1	2	11	6
Hamedan-Sanandaj	1000	HS2930	1	4	2	0	3	5	4
Hamedan-Sanandaj	1000	HS3031	5	16	6	6	9	21	6
Hamedan-Sanandaj	1000	HS3132	0	2	0	1	1	2	2
Hamedan-Sanandaj	1000	HS3233	2	11	7	1	5	13	6
Hamedan-Sanandaj	1000	HS3334	2	5	2	1	4	7	5
Hamedan-Sanandaj	1000	HS3435	0	3	1	1	1	3	2
Malayer-Brojerd	1000	MB0102	0	0	0	0	0	0	2
Malayer-Brojerd	1000	MB0203	0	8	5	1	2	8	5
Malayer-Brojerd	1000	MB0304	1	1	1	1	0	2	2
Malayer-Brojerd	1000	MB0405	1	4	3	0	2	5	4

Table 2. Relationship between frequency and severity of accidents based on severity index

Row	Name Axis	Frequency accidents	Severity accident	Accident severity index	Existing situation	Executive treatment
1	Assadabad	138	184	5.75	Up to one-sided curve - two-sided curve	One-way arching - road widening - warning signs - continuous police presence
2	Asadabad - Ajin	4	4	0.22	two-sided curve	-
3	Assadabad-Kangavar	105	123	2.67	one-sided	Road widening - Safety check - Speed control
4	freeway	274	390	4.7	N/A	Speed control - Video surveillance camera - Continuous police presence - Establishment of a roadside assistance base
5	Gol Tappeh - Ali Sadr	3	7	0.5	two-sided curve	-
6	Hamedan-	149	201	1.36	two-sided curve	Road widening - access

Row	Name Axis	Frequency accidents	Severity accident	Accident severity index	Existing situation	Executive treatment
	Bijar					control - checking warning equipment
7	Hamedan - Kamijan	3	3	0	To enter the desired route (Malayer-Hamedan) one-way, from the entrance of Qahvand route two-way	-
8	Hamedan-Malayer	420	554	7	One-sided - in a two-sided four-lane arch	Double-sided all the way - repairing the road pavement - continuous presence of the police - creating a roadside assistance base - speed control camera
9	Hamedan - Razan	445	582	7.1	one-sided	Roadside access control - Video surveillance camera and vehicle control along the route by establishing a connection between existing speed cameras - Installation of intelligent warning sign (ITS) - Calming the flow - Continuous police presence - Establishment of a resort - Modification of safety equipment - Increase Path signs
10	Hamedan - Sanandaj	442	536	9.5	one-sided	Roadside access control - Video surveillance camera and vehicle control along the route by establishing a connection between existing speed cameras - Installation of intelligent warning sign (ITS) - Calming the flow - Continuous police presence - Establishment of a resort - Modification of safety equipment - Increase Path signs
11	Hamedan - city	17	19	0.7	two-sided curve	-
12	Jokar - Kangavar crossroads	92	116	1.6	From Tuyserkan to Kangavar, approximately 15 km. Initially one-sided and	Road widening - Checking safety equipment at different sections of the route - Increasing the direction signs

Row	Name Axis	Frequency accidents	Severity accident	Accident severity index	Existing situation	Executive treatment
					then two-sided	
13	Kaboudar Ahang-Gol Tappeh	69	91	2	two-sided	Road widening - Checking safety equipment at different sections of the route - Increasing the direction signs
14	Kaboudar Ahang - 2 on the way to Hamedan	2	2	0	one-sided	
15	Kaboudar Ahang - Zarrin Rood	27	33	0.45	-	-

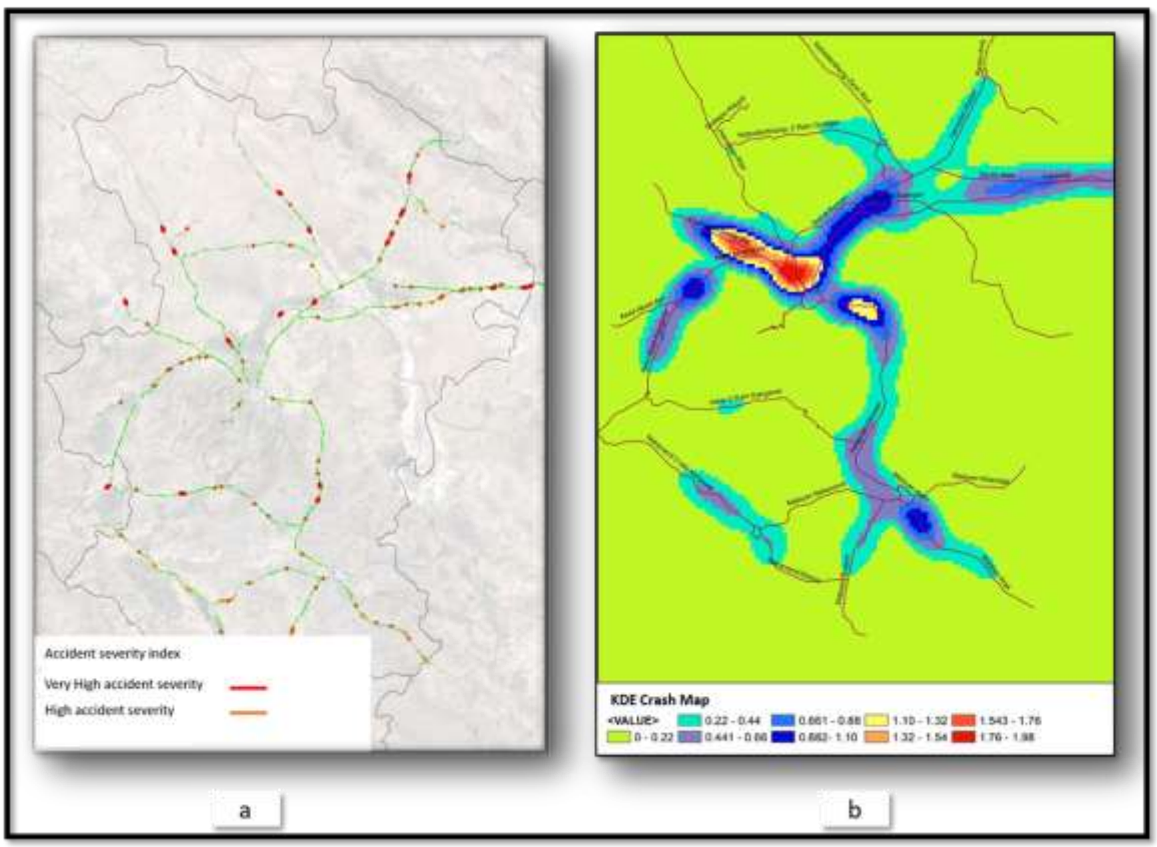

Figure 4. Results of crash density model (a) and crash intensity index model (b)

5. Conclusion

One of the most effective cases that can be used as a suitable solution to reduce accidents, violations and increase safety in driving, is the accurate identification of parameters affecting accidents and their effectiveness based on accident hotspots. This identification can be effective when it leads to the presentation of a series of applicable policies. According to the reports of police in Hamedan province, 12 complete causes for suburban accidents have been registered from 2017 to 2019. These complete causes are: not paying attention to the front, not observing the longitudinal distance, not observing the transverse distance, deviation to the left, transgression to the left, technical defect, inability due to speed, change of direction, right of way, speed, fatigue, politicize and others causes (Figure 3). Therefore, examining political variables is vital. Because of the high accident rate on high-density road sections. Table 2 suggests safety measures such as reducing traffic speed, efficient management and monitoring of road safety, behavioral changes to reduce speeding, technical measures, improving signs, evaluating curves, programs, training to oblige drivers to pay attention to the front, change behavior to reduce accidents caused by drowsiness and increase vision distance.

According to international reports, increasing experience is associated with reducing the number of driving due to fatigue and drowsiness. In Hamedan province, fatigue is the most common cause of accidents. Fatigue, which leads to drowsiness and ultimately reduced efficiency, especially in dark conditions, is one of the causes of accidents that occur over long distances and in situations where there is uniformity of paths. Drivers make a variety of mistakes due to physical, sensory, and perceptual limitations. In high traffic volumes, driver error is an important factor in most accidents. For example, drivers may make incorrect judgments about the speed of other vehicles, their distance, archway, and speed. It is also possible for a driver to make an error while processing too much information at the same time. To reduce this amount of information, drivers rely on their previous knowledge and may make errors that they did not expect. In addition to unintentional errors, drivers sometimes suffer from intentional errors that violate the law or traffic control signs, which is described in accidents in Hamadan province as the inability to control the vehicle. If drivers entering a freeway are unable to reach the speed of traffic, incoming drivers converge with the mainline at very low speeds and may take the risk of insufficient distance. If the exit of the next ramp is close to the entrance of the ramp, the incoming drivers will collide with the exiting drivers at a part of the intersection and the number of accidents will increase. The concentration of the driver's senses while driving is necessary for incoming and outgoing vehicles, and it is necessary to simultaneously control the flow of traffic on the main road to enter it, which practically increases the possibility of side-by-side or back-to-front accidents. In Hamedan province, this factor is described as a lack of attention to the front, which includes a large share of accidents. Low mental capacity can cause the driver to become inattentive or drowsy, leading to unintentional diversion to the side of the vehicle. Drowsiness is closely related to driving time. It is also very difficult for drivers to resist drowsiness in the early morning hours (2 am to 6 am) and in the afternoon. Drowsiness may also be due to habits, lack of sleep and work shifts, or the use of alcohol and sleeping pills. Roadside vibrators can be a good example of reducing off-road accidents. In Table 2 and Figure 2, it is clear that axes such as the Tehran freeway, Malayer to Hamedan, and other similar axes have the highest frequency and severity of accidents. Also, the road sections in the middle part of Hamedan province, due to the high density of traffic, the zoning of the severity and frequency of accidents coincide with each other. This indicates that there is a direct relationship between the frequency and severity of the accident in the sections of the road through which more vehicles pass. One of the reasons for this difference could be that in the road sections close to the city of Hamedan, due to the sudden change of speed from the road with a higher degree to a road with a lower degree and also the existence of accesses around the road at the entrance and exit of cities. Pedestrians and other road users such as motorcycles and bicycles are more common, as these users have no protection against collisions with vehicles and are severely injured or killed in a collision. On the other hand, a sudden decrease or increase in speed at the entrances and exits of cities due to changes in the degree of performance of the road increases the frequency of accidents. It is inappropriate that this issue also plays an important role in the frequency of accidents and the increase in the severity of accidents According to the results, the severity of the accident in the last hours of the day at the entrance of Hamedan is higher than other parts of the road, which shows drivers due to fatigue caused by long-term driving and high desire to reach the destination, as well as changing light and reducing brightness. In parts of the road that are farther from the center of the province, the relationship between the frequency and severity of accidents is more to the geometric design of the road and the presence of road signs, as well as restrictive policies such as speed cameras and frequent police presence. Because this study only examines the time of occurrence of the accident and the relationship between the frequency and severity of the accident, it is not worthwhile for the authors to examine in more detail.

Figure 4.a shows the modeling results based on the crash intensity index, Figure 4.b shows the results of KDE-based modeling. Comparison of the two maps shows that the KDE map is also shown in the segments where the accident severity is high. This is because the severity of injuries caused by accidents is high on intercity roads and there is a relationship between the frequency of accidents and the severity of accidents. Therefore, in intercity roads with the increase of accident density, the severity of the accident also increases. Also, the results of our study are consistent with the other results study.

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