# A NEW MODEL TO IDENTIFY HIGH-RISK CORRIDORS FOR SAFETY MEASURES WITHIN IRANIAN ROADS NETWORK

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## ABSTRACT

From the managerial perspective, it is inevitable to devise an operational plan based on top priorities due to limited resources, diversity of measures and high costs needed to improve safety in infrastructure. From the perspective of safety management, top priority is given to measures leaving maximum effects, at macro-level, on reducing mortality and casualties caused by traffic accidents.

Dealing with the high-risk corridors across Iran, this study prioritized the corridors according to statistical data on accidents involving fatalities, injury or damage over three consecutive years. In collaboration with the Iranian Police Department, data were collected and modified. Then, the prioritization criteria were specified based on the expertise opinions and international standards. In this study, the prioritization criteria included accident severity and accident density. Finally, the criteria were standardized and weighted (equal weights) to score each high-risk corridor. The prioritization phase involved the scoring and weighting procedure. The high-risk corridors were divided into twelve groups out of 50. The results of data analysis for a three-year span suggested that the first three groups (150 corridors) along with a quarter of Iranian road network length (excluding rural areas) account for nearly 60% of traffic accidents.

## KEYWORDS

high-risk corridors (HRCs), road safety rating, scoring

## 1. INTRODUCTION

Transportation safety is a multi-modal concept affected by the intervention of various factors in various areas, including driving behaviors, general and professional training and skills, road and environment safety, vehicle safety, quality of rescue and hospitals, etc. For that reason, numerous organizations are involved in relevant legislation, policy-making, control, supervision, training, behavioral improvement, complying with rules, pre-hospital and hospital services etc. The achievement of road safety, resulting in reduction of road causalities are certainly bound to sense of responsibility and collective effort in all agencies as well as joint practical determination of designers and operators of the Iranian transportation system. Thereafter, the United Nations has called the time span of 2011-2020 the decade of measures for road safety in member nations for an effort to grab global attention and find solutions to overcome the increasingly growing concerns around the world. This action served to raise awareness about the role of accidents in public health and promote government intervention to curtail traffic accidents by 50% until 2020, targeting on five pillars regarding the role of trustees (1).

Given the roles of each agency, the Islamic Republic of Iran has been pursuing the recommendation of international authorities by taking extensive measures every year. The recent plans have tremendously cut down on the road accidents. An overview of road accident mortality rates during 2010-2015 reveals that the number of fatalities decreased averagely by 6.4% annually (2). Moreover, the figure was announced as 5.8% in suburban and rural areas. Given the diving trend of traffic accidents (breaking through the tough casualty reduction threshold), the current status can be improved by a great focus on building new capacities in the organizational and operational structure of safety management, while devising integrated and more efficient measures. In line with the UN decade of Action, the World Bank established the Global Road Safety Facility (GRSF- Global Road Safety Facility) in 2006, the key mission of which was to deeply concentrate on the critical roots of road vulnerabilities in low- and middle-income countries roads, later extended to so called Safe System Approach (3). One of the essential components of this system involves a macroscopic approach to the road network for safety measures. In other words, the World Bank envisages a world free of high-risk road accidents (3). Following the recommendations of major international authorities, it is crucial to prioritize and rate roads for several reasons (4):

- There are insufficiently accurate and reliable spatial data on road accidents in most developing countries
- Certain risk factors can be extracted and resolved in the corridor and network safety management, e.g. vehicle overturn, passing pedestrians, motorcycle accidents, head-on clashes, high mortality, such as passenger casualties in the public transportation system
- The network management needs to focus on non-physical factors involved in safety, e.g. surrounding land uses, traffic composition, human factors and driver behavior, enforcement of laws and regulations, intelligent transportation systems (ITS)' rescue and relief services, trauma, etc.
- The roads can be prioritized and rated based on their types, topographic status, geographical condition etc.
- The systemic approach to this technique can well identify the role of interventions and extent of investment made by other agencies to promote safety and resolve the safety loopholes.

Hence, this study attempted to analytically explore and identify the high-risk corridors for taking safety measures. In this procedure, the international experience was employed, while examining the main and arterial corridors across the Iranian road network, where a major portion of travel demand and accidents take place. Furthermore, the traffic accident data were collected in collaboration with the Traffic Police Department. At the latter stage, conventional scientific methods were adopted to prioritize each high-risk corridor. The results were analyzed and evaluated, finally.

## 2. INTERNATIONAL BENCHMARKING PRACTISES

The road safety ratings was initially commenced in Europe, inspiring and the procedures of vehicles safety rating in 1997, since 2001, based on three sources of information and statistics Netherlands, Sweden and Britain and also in Catalonia Province of Spain was set to practice as trial The during 2001 and 2002. The reason for this selection was that these countries relatively owned comprehensive statistical data about road safety and traffic accidents and on the other hand, the information access to that content in these countries was possible. Other states including Germany, Spain and Ireland, consider the implementation of the program until over 30 countries acceding this program (5).

## 2.1. Euro RAP (European Road Assessment Program)

The assessing program for road safety in Europe includes three protocols, including follows(5):

### *2.1.1 Providing Map for Road Safety Risk*

This step is based on the accident data and relevant background, recorded in certain period. This task includes mapping coded by color, indicating the risk of death or serious injury to the user that face along the way. Road administrators also use this map. The road safety risk map is prepared based on measurements of accidents frequency, casualties, and fatalities of a road. Two types of risks are defined in practice. The first one is the road risk, which is expressed based on the number of accidents occurring along a road. This parameter is only focused on the nature of road safety regardless of traffic volume and the other is the road user risk that is calculated based on the number of accidents occurred along a road, regarding due traffic volume, and declares that every driver or vehicle travelling the road the possible risks for that particular person following the recorded history of registered accidents.

### *2.1.2 Performance Tracking*

It refers to assessment of actions taken for increasing road safety to improve road performance in certain periods and would consider changes of recorded accidents. The assessment results determine whether the actions reduced casualties and losses during a specific period. It also determines the amount of decrease and its effect on the risk level. As a result of this assessment, properly effective and efficient actions are identified.

### *2.1.3 Road Performance Scoring (Star Rating)*

It is based on a road's potential for protecting the passengers in a vehicle at time of possible accidents, and refers on the utility and precision of design of a road, while one to four stars are given to each road, accordingly. A four star road is a road designed to minimize casualties of passengers at time of accident or minimizes likelihood of mortality of passengers during severe accidents.

## 2.2. United States' Road Performance Scoring Plan

In general, road performance is scored in the United States using the European method by making modifications and changes to comply with the United States' circumstances. This plan is composed of the same three parts forming the European one. However, the first part, resulting in the roads safety risk map would proposes other risk maps. Regarding the score, it seems that the American method reduces the effect of intervention and different interests by further stressing quantitative and numerical statistics derived from the road specification.

## 3. RESEARCH METHOD (PRIORITIZING AND SCORING METHODS)

Iran’s suburban and rural roads network, with a length of approximately 215,000 km consists of 86000 km of suburban roads and 129000 km of rural roads is suffering from 101,000 accidents and 12,048 fatalities in 2015, in approximate. The Assessment of accidents in this widespread network calls for a budget, time, and many other facilities, as well as thus prioritization of roads for analyzing accidents and safety actions as the goal of this research, evidently. After examining rate of accident in Iran’s roads network, the country’s main arterial roads (with a length of 40,000 km, in approximate) were chosen as the research area for covering over 80% of accidents. One of the important stages of developing a model in this research was defining the variables or roads ranking indices. After examining the existing accident data and reliable impressive information and summarizing technical and international viewpoints on this topic, the accident severity (the composite index of fatal (coefficient: 9), injury (coefficient: 3), and damage (coefficient: 0.5) accidents and accident density (total accidents in each road divided by the road length) indices were selected. To calculate the mentioned indices, the following variables were taken into account “The number of accidents classified as fatal, injury, and damage accidents and the length of road, studied.”

There have been various methods for classifying different indices and eventually prioritizing the roads. Examples of these methods include the simple analytical Hierarchy process (AHP), numerical taxonomy, clustering, and scoring and weighting methods.

The weighting and scoring method is one of the methods commonly used for prioritization. It is known as the multi-objective programming method in industrial engineering and as the scoring and weighting method in transportation engineering. In other words, if the figures and indices defined for a prioritization process are known, this method will be effective in prioritization. In this method, since the range of variations of factors in different roads varies considerably by factor, the differences between roads in terms of each assessment factor and criterion are not the same. Hence, it is not rational to score roads based on their order of placement. To resolve, different numbers in plenty columns of the related matrix must be standardized. These stages are described in the following:

- Forming the $n \times m$ matrix (n different roads with m indices for each);
- Forming the standard matrix;
- Translating the data to obtain a zero and positive database.

Therefore, n roads with m indices are defined (n vectors). In this research, each road is introduced based on the number of indicators (2 criteria). The n vectors can be written in the form of a matrix. Therefore, the Y matrix is defined as follows: (in this matrix, the attribute is the j-th index of the i-th road.)

$$Y = \begin{bmatrix} Y_{11} & y_{12} & y_{13} & \cdots & y_{1m} \\ Y_{21} & y_{22} & y_{23} & \cdots & y_{2m} \\ Y_{31} & y_{32} & y_{33} & \cdots & y_{3m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ Y_{n1} & y_{n2} & y_{n3} & \cdots & y_{mm} \end{bmatrix} j = 1,2,3,...,m \quad i = 1,2,3,...,n$$

The above expression suggests that in the Y matrix, severity of an accident is placed next to the density of accidents, which is not a rational thing to do. To eliminate the different scales and different units of indices and to select the required scale, the Y matrix must be standardized. A variable is standardized when the mean value is subtracted from its value and is divided by its standard deviation. To standardize the Y matrix, first the mean value of each column of the Y matrix is calculated as follows:

$$\overline{Y}_j = \frac{1}{n}\sum_{i=1}^{n} Y_{ij}$$

Afterwards, the standard deviation of each column of the Y matrix is calculated.

$$Sd_j = \sqrt{\frac{\sum\left(Y_{ij} - \overline{Y}_j\right)^2}{n}} = \sqrt{\frac{\sum_{i=1}^{n} X_{ij}^2}{n}}$$

Using the calculated mean and standard deviation of each column of the Y matrix, the ( $m \times n$) Z matrix is formed as follows.

$$Z_{ij} = \frac{Y_{ij} - \overline{Y}_i}{Sd_j}$$

Where, Zij denotes the standardized j index of the i road. By applying the aforesaid standardization method to all numerical indices, the value of each numerical index will be expressed in the same scale and unit to sort the roads. In this method, after obtaining the score of each road, the rank of each road is calculated based on its sorted score.

Another major problem is the unequal effects of different factors, and thus the significance or weight of each factor must be determined, using questionnaire information and expert opinions. In this research, both factors have the same weights according to the expert opinions, and thus a coefficient of one is determined for both.

## 4. STUDY DATA AND ROADS

Information on the number of fatal, injury and damage accidents was obtained from traffic police stations in Iran provinces via the Road Maintenance & Transportation Organization (RMTO) provincial agencies. To this end, after defining the problem and the research goal, the variables were identified as explained in the previous section and the resulting information was collected from provincial administrations.

An important note to consider in completing the information form is inclusion of statistics of accidents in main arterial roads. Moreover, the information provided by roadside traffic police stations or minor/access roads is revised and edited and separated from the data on the main roads. Table 1 presents an example of information provided by the Qom Province. This information confirmed, later sent by the provincial administration and traffic police stations.

**TABLE 1 Information on Accidents in Arteries Roads of Qom Province in 2015**

| No. | Road | Length (km) | The accidents for 2015 | | | Total |
|---|---|---|---|---|---|---|
| | | | Fatal | Injury | Damage | |
| 1 | Qom-Tehran expressway | 65 | 15 | 85 | 443 | 543 |
| 2 | Qom-Kashan expressway | 35 | 6 | 31 | 121 | 158 |
| 3 | Saveh expressway | 36 | 6 | 16 | 63 | 85 |
| 4 | Garmsar | 50 | 3 | 16 | 57 | 76 |
| 5 | Qom-Arak ring road | 12 | 5 | 38 | 175 | 218 |
| 6 | Qom-Kashan ring road | 9 | 2 | 38 | 75 | 115 |
| 7 | Delijan | 37 | 7 | 24 | 68 | 99 |
| 8 | Arak- Salafchegan | 18 | 4 | 15 | 81 | 100 |
| 9 | Qom Salafchegan | 40 | 8 | 44 | 166 | 218 |
| 10 | Old Qom-Tehran road | 63 | 6 | 22 | 79 | 107 |
| 11 | Old Qom-Kashan road | 35 | 2 | 17 | 42 | 61 |
| 12 | Old Saveh road | 40 | 2 | 12 | 62 | 76 |
| 13 | Neyzar | 45 | 3 | 11 | 35 | 49 |
| 14 | Jafarieh | 38 | 5 | 44 | 71 | 120 |
| 15 | Dastjerd | 38 | 1 | 1 | 3 | 5 |
| 16 | Kuh Sefid | 60 | 0 | 10 | 9 | 19 |
| 17 | Kahak | 25 | 5 | 15 | 45 | 65 |

The aforementioned process was continuously repeated in three consecutive years (2013 to 2015 of accident statistics) for 32 provincial agencies on the main arteries and roads. Table 2 presents overall results of collecting and modifying the information include the status, number, and length of roads, and number of accidents in three consecutive years.

**TABLE 2 Overall Status of Study Roads from 2013 to 2015**

| Year | Number of roads | Length (km) | Number of accidents |
|---|---|---|---|
| 2015 | 591 | 40390 | 81177 |
| 2014 | 529 | 36807 | 80150 |
| 2013 | 439 | 31112 | 83670 |

## 5. METHOD APPLICATION

After realizing a databank for the accidents number on the studied roads, the selected indicative variables were calculated and the indices were combined using the previously explained method. Combination of indices is important because while prioritizing based on accident severity only, roads with higher accident severity are ranked higher regardless of the road length. However, while prioritizing based on accident density only, the index of severity coefficient is not taken into account and thus shorter roads with higher accidents are ranked higher. Since the nature and unit of each index differs from those of others, it is impossible to combine them using an algebraic approach. Hence, these indices must be standardized using a statistical method to provide for the algebraic sum. In this method, the score of each road is obtained in terms of frequency of accidents, and thus the roads are ranked based on the accident information of each year. To reduce and omit the information error and increase precision of roads prioritization, a three-year period is used for the survey, and each year is analyzed and prioritized separately. On the other hand, due to multiplicity of errors in the accident data, the roads are prioritized in groups to allow for prioritization of roads, three-year comparisons, and final summarization of results. In other words, the roads are prioritized in 50-road groups for each year, and then corresponding groups are compared in three consecutive years. Finally, the similarities between the groups are depicted in the road safety Map no. 1 in the form of three 50-road groups as the most high risk roads for safety purposes.

It must be noted that major portion of the roads in the three first groups were repeated in the initial three years of the study. For instance, results of the 2015 grouping carried out to compare the shares of road length and accidents of groups are presented in tables 3 and 4 and figures 1 and 2.

**TABLE 3 Grouping of Studied Roads in Length and Number of Accidents in 2015**

| Group | Length (km) | Accident (No.) |
|---|---|---|
| 1 | 3149 | 26103 |
| 2 | 3206 | 13573 |
| 3 | 3393 | 10135 |
| 4 | 4266 | 8265 |
| 5 | 3860 | 6186 |
| 6 | 3869 | 4612 |
| 7 | 3279 | 3687 |
| 8 | 3477 | 2783 |
| 9 | 3849 | 2353 |
| 10 | 2966 | 1774 |
| 11 | 3216 | 1249 |
| 12 | 1860 | 457 |
| Sum | 40390 | 81117 |

**TABLE 4 Grouping of Studied Areas in Terms Shares of Length and Accidents in 2015**

| Group | Length (%) | Accident (%) |
|---|---|---|
| 1 | 7.8 | 32 |
| 2 | 7.9 | 17 |
| 3 | 8.4 | 12 |
| 4 | 10.6 | 10 |
| 5 | 9.6 | 8 |
| 6 | 9.6 | 6 |
| 7 | 8.1 | 5 |
| 8 | 8.6 | 3 |
| 9 | 9.5 | 3 |
| 10 | 7.3 | 2 |
| 11 | 8.0 | 2 |
| 12 | 4.6 | 1 |
| Sum | 100 | 100 |

In 2015, 591 roads are grouped into 12 groups. As seen in Figure 1, groups 1, 2, and 3 (150 roads) account for app. 60% of the accidents, and the other 9 groups (441 roads) account for 40% of the accidents. Based on Figure 2, the share of accidents involves app. 24% of the length of the reported roads. On the other hand, the bar diagram in Figure 2 properly reflects the lack of compliance between the number of accidents (in red) and the road length (blue) in the first three groups. From the fourth group onward the share of accidents decreases in relation to road length. In fact, the lengths of roads in the 12 groups are approximately homogenous; however, the number of accidents is decreased drastically.

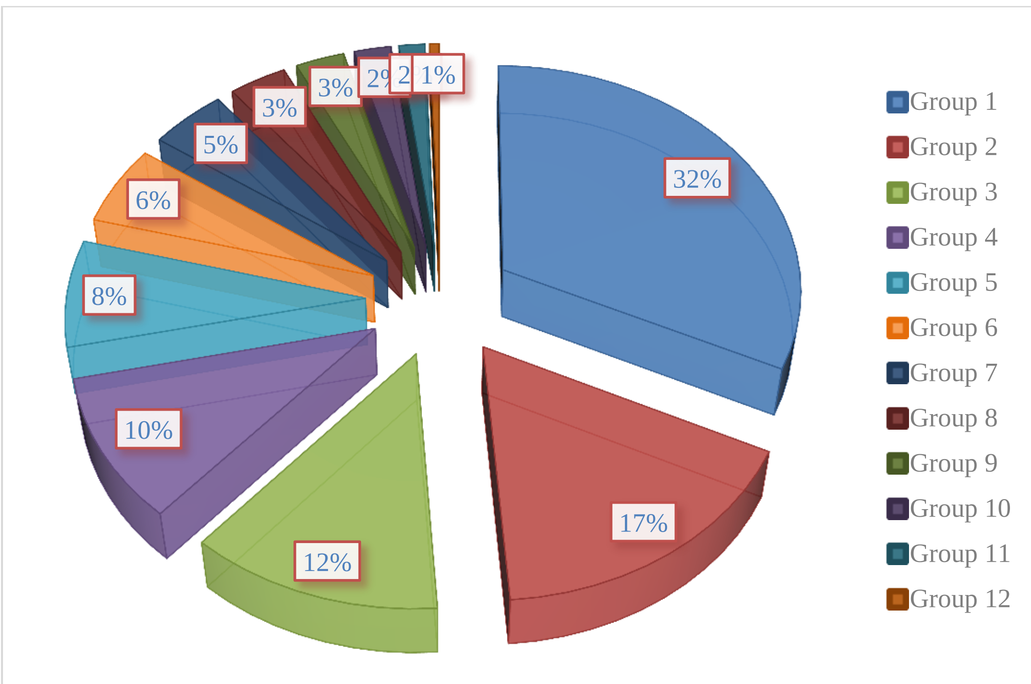


**FIGURE 1 Accident Shares (%) of Roads in the 12 Groups Under Study**

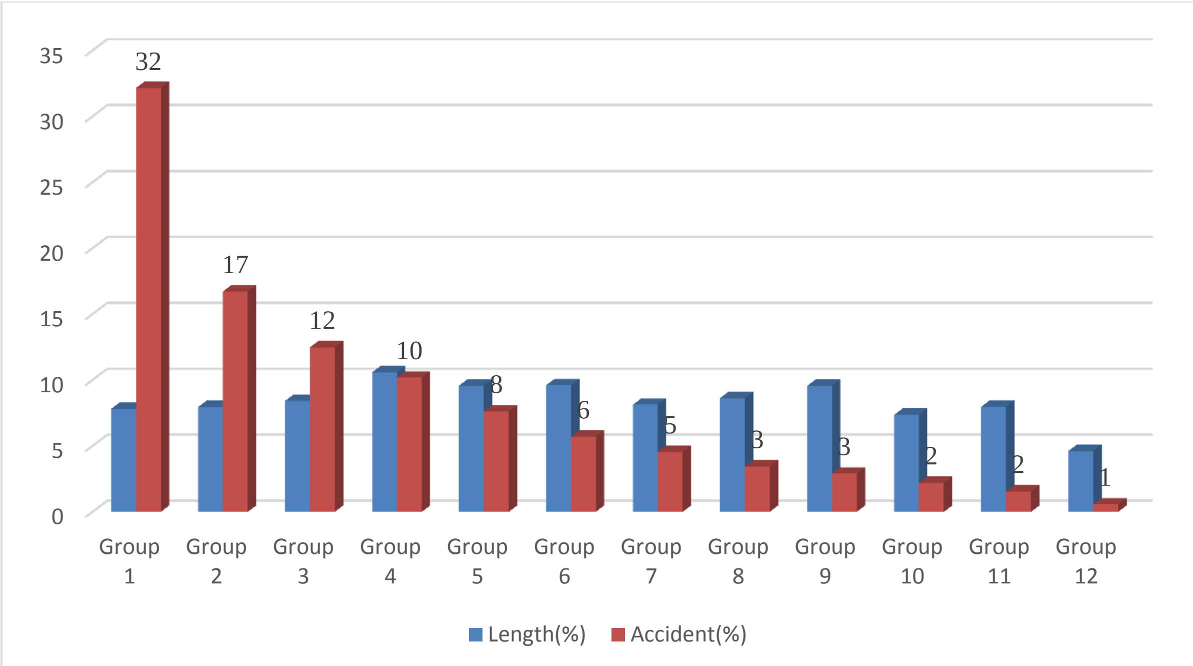


**FIGURE 2 Accident Shares & Length of Roads in the 12 Groups Under Study**

Figure 3 depicts the cumulative percentage of accidents on these roads in relation to their length. This figure confirms the above discussion. In other words, there is a steep slope on the diagram considering the number of accidents-road length ratios in the first three groups; however, it is decreased in the subsequent groups.

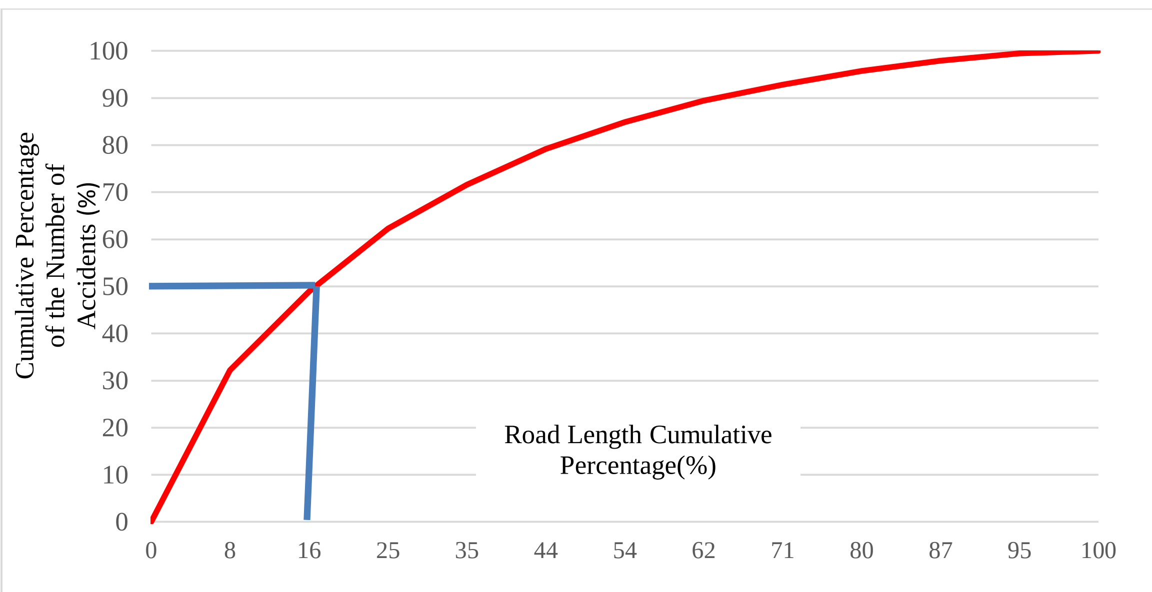


**FIGURE 3 Cumulative Percentage of the Number of Accidents vs. Length Cumulative Percentage of the Roads Under Study**

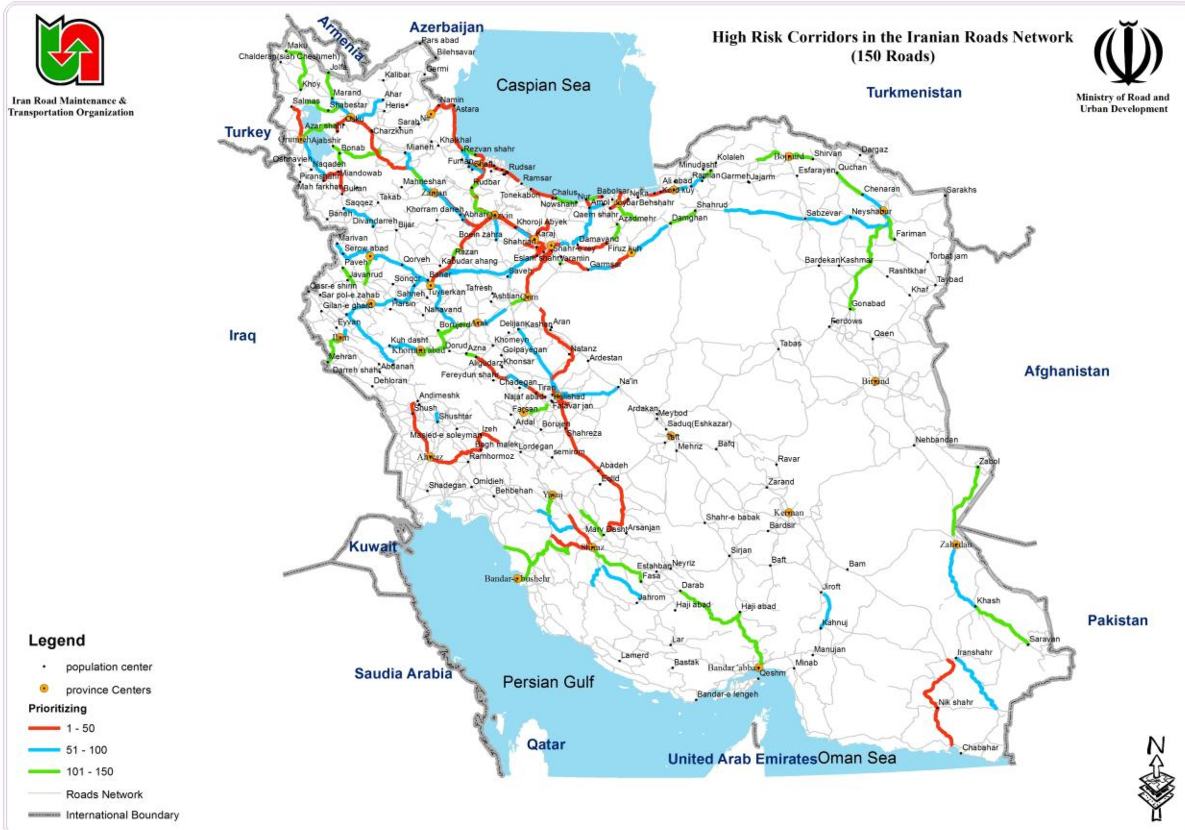


**FIGURE 4 Geographical Position of Three Groups of Iran’s High Risk Roads in GIS**

The summary of the three-year results and analysis results is reflective of the numerous similarities between the three first group roads. In other words, the main roads in the first three groups were repeated in three consecutive years, and the length of these three groups form app. 25% of the reported roads and include over 60% of the accidents. Map no. 1 depicts the positions of these three groups with different colors. As seen in this map of Figure 4, the high risk roads are situated around Tehran and other metropolises, as a pursuant of the population centers in Iran North and West. In the above said map, the high risk roads data have been recorded in GIS layer.

## 6 DISCUSSION AND CONCLUTION

One fourth of Iran’s main arterial roads (app. 10000 km) accounts for 60% of accidents. Hence, planning and concentrating on these roads are of high importance due to the following reasons:

- Allocation of resources including budget and credit resources, facilities, and ITS equipment (such as traffic enforcement cameras for recording speed violations and longitudinal distances, monitoring cameras for recording overtaking, traffic counters, etc.)
- Inspection and examination of safety of roads, especially high risk roads, can be carried out more carefully for the aforementioned roads.
- Road ranking (star rating) can also be considered in future research based on defined indices and international experience.

- In general, the audience of these results includes the following important and major groups:

  - Road users and drivers who can increase their consciousness and precision and can follow traffic rules more carefully by becoming informed of the high risk of accident in high risk roads;
  - Planners, road authorities, and all others in charge of control who can prioritize actions in terms of allocation of credits and increased road safety by becoming aware of weaknesses and status of roads. These agents can also conduct periodic assessments and inspections and use effective solutions and measures to improve road safety;
  - Traffic Police and reinforcement forces that based on road safety priorities can allocate their resources and forces to maximize efficiency and effectiveness and allow for enforcement of regulations and controls matching safety levels.

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