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AN ANALYSIS OF INFLUENTIAL FACTORS ASSOCIATED WITH RURAL CRASHES IN A DEVELOPING COUNTRY: A CASE STUDY OF IRAN

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Abstract:

Road traffic deaths continue to rise, reaching 1.35 million in recent years. Road traffic injuries are the eighth leading cause of death for people of all ages. Note that there is a wide difference in the crash rate between developed and developing countries and that developed countries report much lower crash rates than developing and underdeveloped countries. World Health Organization reports that over 80% of fatal road crashes occur in developing countries, while developed countries account for about 7% of the total. The rate of road crashes in developing countries is higher than the global average, despite some measures reducing deaths over the last decade. Numerous studies have been carried out on the safety of urban roads. However, comprehensive research evaluating influential factors associated with rural crashes in developing countries is still neglected. Therefore, it is crucial to understand how factors influence the severity of rural road crashes. In the present study, rural roads in Mazandaran province were considered a case study. The Crash data collected from the Iranian Legal Medicine Organization covers 2018 to 2021, including 2047 rural crashes. Dependent variables were classified as damage crashes and injury-fatal crashes. Besides, independent variables such as driver specifications, crash specifications, environment specifications, traffic specifications, and geometrical road specifications were considered parameters. The logit model data indicate that factors associated with driver and crash specifications influence rural crashes. The type of crashes is the most critical factor influencing the severity of crashes, on which the fatal rate depends. The findings suggested that implementing solutions that minimize the effect of the factors associated with injury and death on rural roads can reduce the severity of crashes on rural roads that share the same safety issues as the case study. Further studies can also be conducted on the safety and mechanics of the vehicle by focusing the research on the types of vehicles and the sources of the damage.

Keywords: *rural roads, severity of crashes, damage crashes, injury-fatal crashes, binary logit model*

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1. Introduction

The number of traffic causalities across the world is unacceptably high. Despite various measures taken to reduce road crashes, based on the latest report by W.H.O, the results have been too far away from the primary goal of these measures to reduce crashes by 50% by 2020 (WHO, 2018). According to the latest published report annual road traffic deaths have come to 1.35 million, making crashes the 8th underlying cause of fatalities throughout human societies (OECD, 2017; WHO, 2018). Besides, road traffic injuries are currently the main reason for deaths of children and young adults in the age range of 5-29 years. It is noteworthy that crashes are not the same worldwide, and developed countries report much lower crash rates than developing and underdeveloped countries. Although there are about 1.5 times more registered cars in developing than developed countries, the rate of causalities is more than 11 times in these countries (OECD, 2017; WHO, 2018). As reported by W.H.O, more than 80% of global road traffic deaths occur in developing societies, while developed countries account for about 7% of the total global crashes (WHO, 2018). As a developing country, Iran is not in good road safety, with a death rate of 20.5 per 100000 population. Although some measures have reduced the death toll from 32 to 20.5 per 100000 population over the last decade, it is still higher than the global average (18.2). Accordingly, Iran ranks 113th out of 175 countries surveyed in the World Health Report, indicating its critical road safety conditions.

On the other hand, the average death toll per 100000 population is less than a quarter of the global average in developed countries. For example, the Netherlands ranks 11th in the world with a death toll of 3.8 per 100000 population, making it one of the countries with the highest road safety globally (WHO, 2018). Although road safety, which may eventually lead to crashes, is associated with several factors (Abounoas et al., 2020; Ersan et al., 2019; Ghasemlou et al., 2015; He and Lin, 2018; Rolison et al., 2018; Sheykhfard and Haghighi, 2018, 2019), the human factor has been obviously among the significant factors that contribute to road traffic crashes. Various studies have reported the role of this factor in more than 90% of road crashes (Ambros et al., 2020; Dingus et al., 2016; Leonardi et al., 2020; Mekonnen et al., 2019; NHTSA, n.d.; Thakur and Biswas, 2019), necessitating the evaluation of driving behaviors more than before. The remarkable point about road crashes is that many crashes occur in particular areas, such as outskirt areas (Sheykhfard and Haghighi, 2020; WHO, 2018). The excessive growth in the global population and geographical and environmental factors have contributed to the saturation of urban populations in some cities. Therefore, people are forced to live in outskirt areas. Living a significant number of people in outskirt areas, which is standard worldwide, is highly common in various regions of Iran, especially in northern parts. Approximately 24% of fatal crashes crashes in Iran happen in transitional zones between rural and urban areas.

With over 9.6 percent of total deaths on rural roads in Iran, Mazandaran is the 3rd province regarding the casualties caused by a crash (WHO, 2018). According to the death statistics from 2018 to 2021, which the Mazandaran Legal Medicine Organization provides, more than 60 percent of crash causalities in the Mazandaran province occurred on rural roads (Iranian Legal Medicine Organization, 2018). The statistics show that this province is one of the high-risk Iranian provinces regarding the number of fatal crashes on rural roads. Therefore, it is necessary to investigate the causes and factors that affect the severity of crashes on rural roads. This study includes Modeling and evaluating factors affecting the severity of rural road vehicle crashes in Mazandaran province.

A total of five sections are included in the study. The data collection method and data analysis are discussed in the second and third sections. In section four, the research results are presented and compared with previous studies. The fifth section will summarize the research findings and suggest future research topics.

2. Literature review

Crash rates are not the same worldwide, and developed countries report much lower rates than developing countries. Also, the consequences of these crashes are more severe: although developing countries have 1.5 times as many registered cars as developed countries, the number of fatalities is more than 11 times higher in developing countries than in developed countries (WHO, 2018). Furthermore, in Iran, a developing country, road crashs constitute a major public health concern, with a fatality rate of

20.5 per 100,000 people. Although the generalization of results of limited research in one country to other countries is quite a challenging issue, the role of vehicles in the severity of crashes in developing countries suggests that low-quality vehicle designs are highly effective in increasing the severity of crashes. Research on crashes, especially when considering the vehicle-side perspective, may, therefore, influence policymakers' decisions regarding the current situation, particularly regarding improvements to the design of vehicles. To our best knowledge, there are no studies examining the role of various factors related to human, road, environment, and vehicle severity in rural routes in Iran. Due to the high injury-fatal crashes occurring in rural areas of Iran, the present study aims to examine most of the primary causes of these crashs. By examining a range of parameters, including driver, crash, environment, traffic, and geometrical road characteristics, we seek to identify factors increasing the risk of crashes on rural roads. It may be possible to establish a program that proposes instructions and conducts traffic control operations to reduce rural traffic crashes by identifying the factors contributing to their occurrence.

Many studies have examined the causes of crashs and their severity according to human factors, the environment, and the road. Some of these studies are listed below.

In 2004, (K.W.Yau) examined the risk factors affecting the severity of single-vehicle traffic crashes in Hong Kong for personal vehicles, transport vehicles and motorcycles. Among the factors affecting the severity of injuries and damages for private vehicles, gender, age, time of the crash, and road light condition are the most important. Safety belts and days of the week were both critical factors concerning the severity of damage to transport vehicles. Motorcycle crashes were affected by age, day of the week, and time of the crash. In China, Zhang, K.W.Yau, and Chen (2013) used logistic regression to study risk factors related to driving offenses and crashes severity. Such factors contributed to the severity increase in the study. Several studies have identified factors that increase crashes probabilities, including a male driver, vehicles transporting goods, poor safety conditions, extra loaded vehicles, roads without lighting at night, poor vision, and holidays (Agbelie, 2016; Theofilatos et al., 2017; Wang et al., 2021). According to Ranja and Mitra (2013), crash severity is influenced by several factors. In this case, a logit model, multiple probit model, and sequential probit model are used in conjunction with parameters such as crash time, vehicles involved, crashes type, driver gender, victim gender, road surface friction, road geometry (intersections, etc.) and roadside use. Crash severity was classified into three categories: minor injuries, significant injuries, and fatal injuries. (Bandyopadhyaya and Mitra, 2013) showed that vulnerable road users are subject to more crashes because of road geometry (intersections). Using an ordered logit model, Chris and Xuancheng (2014) studied single-vehicle crashes. A model was used to identify the relationship between injury severity and non-homoscedasticity. Several variables are to consider, including driver profiles, traffic profiles, time and type of crashes, and vehicle profiles. Crash types were classified by Lee and Li (2014) as damage, major injuries, and fatalities. In a mixed logit model, Kirolos and Albert (2013) evaluated the impact of road geometry, traffic, demographic data, and driver details on the severity of the damage. Road geometry was the most significant variable related to a crash.

Furthermore, traffic volume and truck percentage were significant variables related to crashes (Haleem and Gan, 2013). Based on research conducted by Chen, Zhang, Huang, Wang, and Tarefder (2016), wet road surfaces, safety belt use, and crashes with animals reduce the level of injuries in rural non-interstate road crashes. However, factors such as single-vehicle crashes, multiple-vehicle crashes, severe vehicle damage, and a driver under the influence of alcohol or drugs increase the probability of injuries and death. Wu, Zhang, Zhu, Cathy Liu, and Tarefder (2016) found that rollovers, crashes with fixed objects, snowy weather, alcohol consumption, female drivers, and drivers over 65 influence the severity of injuries in single-vehicle crashes. Michaelalaki, A.Quddus, Pitfield, and Huetson (2015) investigated factors influencing the severity of hard-shoulder (HS) and main carriageway (MC) crashes on English highways. Driver fatigue was the most common cause of hard-shoulder crashes in this study. The severity of primary carriage-type crashes was increased by the high volume of traffic during off-peak hours and dry-surface conditions on the roadway. Factors such as "no construction during the crash time" and "good visibility while driving" had a positive impact and reduced the severity of the damages. A study conducted by Shrestha and Shrestha in 2017 examined the factors associated with the severity of crashes along Nevada's rural highways. According to the results, variables such as the day of the week, month, and type of vehicle as well as the driver of the vehicle play a significant role in the outcome of crashes resulting in injuries. In their study, Ditcharoen, et al. (2018) concluded that factors such as speed, human characteristics, vehicle type, weather, alcohol consumption, and driver fatigue influence the severity of traffic crashes. A study by Kaiser, Furian, and Schlembach (2016) demonstrated that most casualties occurred as a result of aggressive driving behaviors, and there is a strong correlation between the risky behavior of divers and their involvement in driving crashes. Ratanavaraha and Suangka (2014) found that speed is the only factor that influences the severity of highway crashes using a multivariate regression model. Fatal crashes are more likely at high speeds. Using the crash severity index, we can identify the factors that are effective in increasing the severity of an crash. The study of (Zhou and Chor Chin, 2019) on the impact of effective factors on the severity of injuries in Singapore revealed that such factors as age (more than 65), driving under the influence of alcohol, lack of control, left-turn and right-turn maneuvers, and driving after midnight are all associated with more severe injuries. Conversely, wet, oily, or gravelly roads cause less damage and injuries. It was determined that the dependent variable (Ayazi, Khorsand, and Sheikholeslami, 2020) was financial damage, while the independent variables were crashes type, crashes cause, road type, road surface, road light condition, engine power, and driver gender. Financial damage is least likely to be caused by side crashes. Unauthorized speeds are most likely to result in injuries and financial damage. Moreover, an offensive vehicle's engine power increases the probability of property damage. In urban roadways, male drivers have more severe crashes than female drivers. By using a mixed logit model, Qiong et al. (2014) analyzed the injury severity of drivers in single-vehicle crashes and rural two-lane roads. Single-vehicle crashes caused by overtaking have significant driver damage. In crashes, dark lighting conditions and dusty weather conditions significantly increase injury severity (Wu et al., 2014). A mixed logit model was used by Pahukul et al. (2015) to assess the effects of truck crashes on urban roads. Due to the dark lighting conditions in the evening, the severity of the damage increased, resulting in serious injury and damage (Pahukula et al., 2015). According to a study by (Oikawa and Matsui, 2017), injuries are common in passenger cars and at low speeds, but at high speeds, there are more bone fractures and head injuries. It has been reported that speeding on different routes, overtaking lanes, and failing to obey traffic regulations, such as passing a red light, are among the high-risk behaviors that can lead to crashes (Mohamed and Bromfield, 2017). (Wang and Cheng, 2019) found that human damage and case fatality rate variables increased crash severity in China. In addition, a study by (Thomas et al., 2020) reported that Alcohol and drugs are the most influential factors in error driving involved in a crash.

3. Method and material

3.1. Logit model

The Bernoulli test is a random sample space test that is only made of the two events as defeat or victory. Y, Bernoulli random variable is defined as follows:

$$\begin{cases} \text{Y (Victory)} = 1 \\ \text{Y (Failure)} = 0 \end{cases} \tag{1}$$

The present study divided the dependent variable severity property damage into damage crashes and fatal-injury crashes. The set of options is based on the following equation:

$$F = \{\text{ PDA (Fatal)}, \text{FIA (financial losses)}\} \tag{2}$$

So the potential logit model for damage crashes and injury-fatal crashes, respectively, based on the relationships (3) and (4) will be:

$$\mathbf{P_{PDA}} = \frac{\mathbf{e^{U_{PDA}}}}{\mathbf{e^{U_{FIA}} + e^{U_{PDA}}}} \tag{3}$$

$$\mathbf{P_{FIA}} = \frac{\mathbf{e^{U_{FIA}}}}{\mathbf{e^{U_{FIA}} + e^{U_{PDA}}}} \tag{4}$$

Equation (3) can be expressed as follows

$$\mathbf{P_{PDA}} = \frac{\mathbf{1}}{\mathbf{1 + e^{U_{FIA} - U_{PDA}}}} \tag{5}$$

On the other hand:

$$\mathbf{P_{FIA}} = \mathbf{1} - \mathbf{P_{PDA}} \quad (6)$$

where: P_{PDA} – probability of crashes resulting in injury-fatal; P_{FIA} – probability that the crash results in financial damage; U_{PDA} – utility function for the random injury-fatal; U_{FIA} – utility function is compensation for financial damage crashes.
Utility function for damage crashes or injury-fatal crashes and financial function of the factors contributing to the crash (environmental, geometric designs, human, vehicle, and traffic) can be considered as follows (7):

$$\mathbf{U_I} = \beta_0 + \sum_{i=1}^{k} \beta_i X_i \quad (7)$$

The U_I: utility option i (i = F), β_0: constant coefficient of model, β_i: coefficient of estimated parameters, and X_i: is the vector of variables. In the present study, SPSS software, a valuable application in statistics, was used to analyze statistical data and Modeling

3.2. Case study

According to the Iranian Legal Medicine Organization report, Mazandaran province (Fig 1) in northern Iran (area of about 24,000 km2 and a population of over 3 million) is one of the three provinces with the highest number of road crashes in Iran (Iranian Legal Medicine Organization, 2018). Furthermore, about 700 people are killed on different roads in Mazandaran province annually, of which more than half of them occur on rural roads. The data on major rural roads (11 roads) in Mazandaran province were collected between 2018 and 2021. The variables were gathered from the Iranian Legal Medicine Organization, including a sample size of 2047 cases.

3.3. Variables

This study examines the Severity of crashes by dividing them into two categories: crashes resulting in property damage and crashes resulting in injury-fatality. The dependent variables in Table 1 and the independent variables used in the model are shown in Table 2. Figure 2 shows the coding part of the vehicle involved in a crash.

Table 1. Dependent variables

Dependent variable	Factor (Encoding)
The Severity of crashes	Lead to financial damage (0), Lead to injury or death (1)

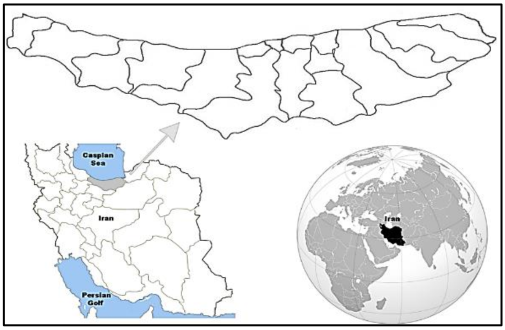

Fig. 1. The geographical location of Babol in Mazandaran Province, Iran

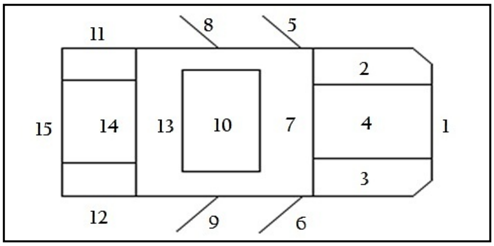

Fig. 2. The coding part of damaged vehicles

3.4. Data coding and analysis

A frequency test was carried out for all independent variables. Defining the causes and variables of the side to side and side to forward motion with rear gear, which were rare, and separating them were then set aside. Then correlation analysis was performed between the parameters, and independent variables associated with each other in models were not used. To achieve this aim, the statistical software used the Pearson method for nominal variables by Chi-Square, for ranked variables Kendall's tau-b and for quantitative variables. The study results showed that the variable, vehicle type, variable, and median type of the road were related. The absolute value of the correlation coefficient linked was more than 0.7, which showed the dependence of these two factors (Ma et al., 2010). By taking these two factors in the model for estimating the effect of each parameter, part of the coefficients of these two factors are replaced. So for calculating the impact of variables obtained, based on their coefficients in the model, the type of road, which was significantly less meaningful than the Median, was removed from the model. As for quantitative variables, many unauthorized distance violations were related to variables such as the hourly traffic volume and cargo volume and thus was removed from the Modeling of variables. The modeling process was performed using the remaining independent variables. A significant correlation between the independent variables and the response variable was examined according to the test mentioned. Then the relationship between independent and dependent variables was analyzed separately and independent of other factors, and the role of each factor alone was shown. Since the effect of the factors together is observed. Thus, a significant variable can be meaningful independently, but not significant in the final model or vice versa. This phenomenon is due to significant collinearity or conjunction between a variable with other variables in the model. For Modeling, to control the variables entering or exiting their logit equation, Statistical Package for Social Science (SPSS) provides several methods used by backward elimination in this study. In this method, at the beginning, all of the independent variables are included in the model. Then, a variable that causes the least amount of change in the R2 is removed at every step. The value of R2 should be enough to reject the assumption that the actual value of R2 is zero (with a predetermined default value of 0.1 or greater). Excluding model, variables can be stopped by removing any residual variables of the model that make significant changes in R2 (Ma et al., 2010). According to the above description and selection method with backward elimination, the model is calibrated after it was repeated for 28 stages. Given the significant factor (P-Value) of 0.05, some of the independent variables are excluded. Then the model has repeated; finally, after three times, removing the variables that have a significant coefficient (P-Value) of 0.05 (sig> 0.05), the final model was calibrated after the second iteration.

Table 2. Independent variables and coding

Independent variable	**Factor (Encoding)**
The definite cause of the crash	Overtaking (1) Violation of the speed (2) Redirect (3) Lack of attention to the front (4) Failure to Yield Right of Way (5) Lack of tailgating (6) Non-compliance with a cross (7) The reverse gear (8) Other (9)
Time of crash	0 - 4 (1), 4 - 8 (2), 8 -12 (3), 12 - 16 (4), 16 - 20 (5), 20 -24 (6)
Day of crash	Saturday (1), Sunday (2), Monday (3), Tuesday (4), Wednesday (5), Thursday (6), Friday (7)
Type of crashes	Reversal (1) A fixed object (2) Pedestrian (3) Single-vehicle (4) Multi-vehicle (5)
Type of fault vehicle	Pride (1) Peugeot (2) Heavy vehicles (3) Motorcycles (4) Pickup and Nissan (5) Peykan (7) Other (6)
Non-fault vehicle	Samand (0) Pride (1) Peugeot (2) - Heavy vehicles (3) - Motorcycles (4) Pickup and Nissan (5) Peykan (7) Other (6)
Sex	Man (1) Women (2)
Type of road	Separated (1) Not separated (2)
How crashes happened	Front to Front (1) Front to the side (2) Back to side (3) Front to Back (4) Side to Side (5) Side to front (6) Other (7)
Median type	Kerb (1) Guard rail (2) Concrete New Jersey (3) Without Median (4)
Track Type	Direct (1) With arch (2) Cut (3) Three-way or four-way (4)
Driving record	0- 5 years (1) 5- 10 years (2) -> 10 years (3)
Lighting condition	Night with lighting (1) Night without lighting (2) Day (3)
Weather	Clear (1) Rainy (2)
Traffic situation	Average speed, Traffic volume, The number of violations in anticipation, The number of violations unauthorized distance, The number of violations speeding, The number of heavy vehicles per hour (and without all the factors are code)
Age of at-fault driver	From the age of 0- 30 (1) From the age of 30- 40 (2) From the age of 40 - 50 (3) From the age of 50- 60 (4) Older than the age of 60 (5)
Type Certificates	Basic license 1 (1) Basic Certification 2 (2) Basic Certification 3 (3)
Land use	Residential (1) Farm (2) Business or workshop (3) Other (4)
Road shoulder	Asphalt (1) Sandy or without shoulder (2)
Place of the damage to the fault person's vehicle	Part 1 (1) Part 2 (2) Part 3 (3) Part 4 (4) Part 5 (5) Part 6 (6) Part 7 (7) Part 8 (8) Part 9 (9) Part 10 (10) Part 11 (11) Part 12 (12) Part 13 (13) Part 14 (14) Part 15 (15)
Place of the damage to the non-fault person vehicle	Part 1 (1) Part 2 (2) Part 3 (3) Part 4 (4) Part 5 (5) Part 6 (6) Part 7 (7) Part 8 (8) Part 9 (9) Part 10 (10) Part 11 (11) Part 12 (12) Part 13 (13) Part 14 (14) Part 15 (15)

4. Results and discussion

Table 3 shows the coefficients of influential factor associated with severity of crashes. The coefficients are obtained from the probability of injury-fatal damage function in which variables with negative coefficients decrease the Severity of the crash (crash injury-fatal damage possibility function) and variables with positive coefficients increase it. The relations below show the final version of the model shaped based on coefficients:

$$\mathbf{P_{PDA}} = \frac{\mathbf{1}}{\mathbf{1 + e^{U_{FIA} - U_{PDA}}}} = \frac{\mathbf{1}}{\mathbf{1 + e^{\Delta U}}} \quad (8)$$

$$\begin{aligned} \Delta U = {} & 1.76 + 3.123\, X_1 - 0.918\, X_2 + \\ & + 0.644\, X_3 + 2.129\, X_4 - 0.544\, X_5 - \\ & - 0.733\, X_6 - 0.824\, X_7 + 3.149\, X_8 - \\ & - 0.525\, X_9 - 0.726\, X_{10} - 1.179\, X_{11} - \\ & - 1.148\, X_{12} - 1.099\, X_{13} + 0.556\, X_{14} + \\ & + 0.975\, X_{15} + 0.412\, X_{16} + 0.571\, X_{17} + \\ & + 0.340\, X_{18} - 0.398\, X_{19} + 0.460\, X_{20} - \\ & - 0.741\, X_{21} - 0.01\, X_{22} \end{aligned} \quad (9)$$

Regression model power was tested by Naglekerke test R2 model in which the amount of $0 < R2 < 1$ and as the value of R2 is closer to one, model is more powerful. As shown in Table 4, the value of R2 for the final model is equivalent to 0.615, representing a good model for estimating the severity of crashes. Table 5 shows the results of the observed and predicted data based on the parameters defined in Table 3. The results shows that the presented models can correctly predict severity of crashes with high precision.

Based on the results obtained from the final model, the first factor that has a considerable effect on crash severity is a non-fault motorcycle which increases the possibility of injury-fatal crashes to the damage crashes by 23.302 times. The second influential factor is the type of crashes with a pedestrian, making the possibility of injury-fatal crashes to the damage crashes 22.718 times. The severity of this type of crash may be reduced using pedestrian facilities such as pedestrian bridges and underpasses and pinpointing a pedestrian crossing location. The third factor is the first fault of motorcycle which increases the possibility of injury-fatal crashes to the damage crashes 8.804 times. Motorcycle in both fault and non-fault types has a high risk of injury-fatal. This is major because of not using safety equipment such as helmets for motorcyclists so they should be forced to implement strict rules on the use of safety equipment. The fourth factor affecting the severity of crashes is the vehicle's damage from the right rear door (Part 9). The possibility of injury-fatal crashes to the damage crashes was 2.256. The use of safety seat belts, airbag deployment, and robust construction in vehicles can reduce the Severity of this type of crash. Another factor, the fault vehicles damaged from roof part (Part 10) magnify possibility of injury-fatal crashes to the damage crashes, 1.77 times more. Fault vehicles damaged in the front door of engine part (Part 4), was 6th factor in the Severity of crashes which amplify the possibility of injury-fatal crashes to the damage crashes, 1.743 times. The 7th factor in the Severity of crashes was the non-fault damaged vehicles from the front left door (Part 5), which increases the possibility of injury-fatal crashes to the damage crashes by 1.584 times. The effect is almost equal to that of variable fault vehicles damaged from the rear left door (Part 8), which increase the possibility the possibility of injury-fatal crashes to the damage crashes, 1.510 times. The 9th factor in the Severity of crashes times is non-fault vehicle damaged at the bumper part (Part 1) which may increase the possibility of injury-fatal crashes to the damage crashes to 1.405. Also other factors which increase the Severity of crashes by reducing the possibility of injury-fatal, in order from least effect on decreasing fatal-injury crashes are: traffic volume, the left front fender in non-fault vehicles (Part 2), heavy fault vehicles, the middle of the guard rail, fault Pickup and Nissan vehicles, straight, non-fault vehicles damaged on the vehicle trunk part (Part 14), other fault vehicles, fault Peugeot vehicles, certification base 3, certification base 2 and certificate base 1 that the probability of injury-fatal crashes caused by these factors are respectively: 0.999, 0.672, 0.644 , 0.295, 0.985, 0.484, 0.477, 0.461, 0.439, 0.399, 0.323, 0.317 and 0.308. Or in other words, the probability of damage crash to injury-fatal crashes due to these factors are 1.100, 1.488, 1.552, 1.689, 1.697, 2.660, 2.690, 2.169, 2.772, 2.506, 3.590, 3.154, and 3.246. Having certificates of type 3, 2, and 1 had the most effective for reducing the risk of injury-fatal crashes and reducing the severity rate of the base 3 to base one was more. This fact shows that driving skills and knowledge have a considerable impact on reducing the possibility of injury-fatal crashes. This study was focused on rural roads and, using the double logit model, intends to identify factors affecting the severity of crashes on this type of road. The model presented in the present study makes it possible to investigate the impact of all variables simultaneously on crash severity, so this model can be a valuable model for identifying factors influencing crash severity. Regarding the survey results and factors identified that influence the severity of crashes on rural roads, an effective policies can be created to avoid severe crashes on rural roads in the developing countries with the same conditions.

Table 3.The final coefficients regression model

Variables	**Estimated coefficient**	**Standard deviation**	**Wald**	**P-value**	**The odds ratio**	**95% confidence level for the odds ratio**	
						Down	**Up**
Crashes with pedestrian: X_1	3.123	0.419	55.445	0.000	22.718	9.985	51.690
Peugeot (fault): X_2	-0.918	0.225	16.599	0.000	0.399	0.257	0.621
Heavy vehicles (fault): X_3	0.644	0.320	0.044	0.044	0.644	0.280	0.983
Motorcycles (fault): X_4	2.129	0.475	20.057	0.000	8.408	3.311	21.350
Pickup (fault): X_5	-0.544	0.239	5.159	0.023	0.581	0.363	0.928
Other vehicles (fault): X_6	-0.773	0.306	6.371	0.012	0.462	0.253	0.841
Heavy (non-fault): X_7	-0.824	0.269	9.398	0.002	0.439	0.259	0.743
Motorcycles (non -fault): X_8	3.149	0.396	63.199	0.000	23.302	10.722	50.641
Guard rail (middle type): X_9	-0.525	0.156	11.365	0.001	0.592	0.436	0.803
Direct path (path type): X_{10}	-0.726	0.210	11.910	0.001	0.484	0.320	0.731
Base1 (Type Certification): X_{11}	-1.179	0.320	13.534	0.000	0.308	0.164	0.577
Base2 (Type Certification): X_{12}	-1.148	0.185	38.717	0.000	0.317	0.243	0.457
Base 3 (Type Certification): X_{13}	-1.099	0.161	46.441	0.000	0.333	0.221	0.455
Part 4: X_{14}	0.556	0.145	14.660	0.000	1.743	1.311	2.316
Part 8: X_{15}	0.412	0.201	4.208	0.040	1.510	1.019	2.237
Part 9: X_{16}	0.975	0.232	17.656	0.000	2.652	1.683	4.181
Part 10: X_{17}	0.571	0.188	9.188	0.002	1.770	1.224	2.561
Part 1 (non at-fault damage): X_{18}	0.340	0.159	4.552	0.033	1.405	1.028	1.921
Part 2 (non at-fault damage): X_{19}	-0.398	0.166	5.761	0.016	0.672	0.486	0.930
Part 5 (non at-fault damage): X_{20}	0.460	0.216	4.553	0.033	1.584	1.038	2.418
Part 14 (non at-fault damage): X_{21}	-0.741	0.227	10.616	0.001	0.477	0.305	0.744
Traffic Volume: X_{22}	-0.01	0.000	29.199	0.000	0.999	0.813	1.049
Constant parameter	1.682	0.428	15.478	0.000	5.387	-	-

Table 4. The results of the final model for the Severity of crashes\

Parameter	**Value**
The number of observations	2047
Chi- square	906.092
− 2Log Likelihood	1649.106
Degrees of freedom	22
Neglekerke R square	0.615
Cox and Snell R square	0.483

Table 5. The correct percentage for the Severity of crashes

Observation		**Predict**		
		Damage	Injury- Death	Percent correct
Severity of crashes	The damage	639	155	80.5
	Injury- Death	123	508	78.6
Of total %	79.4			

According to the results from this research, colliding with a motorcycle increases the severity of crashes, which is similar to previous research (Nguyen et al., 2021; Phan et al., 2016; Sheykhfard et al., 2020, 2021; Spyropoulou and Sermpis, 2009; Wali et al., 2022) which studied motorcycle crashes on urban roads. Although the present study found that crashes with agricultural vehicles increase the severity of crashes, a study by (Manner and Wünsch-Ziegler, 2013) revealed that all types of heavy vehicles were significantly responsible for the severity of crashes on rural roads. It was shown that overturning crashes increased the severity of fatal crashes, which was similar to the findings of Cho Chang et al. Consistent with the present study, previous that four-way and three-way intersections can lead to more severe crashes on rural roads (Alhomaidat et al., 2022; Jahandideh et al., 2017; Marzoug et al., 2022; Sun et al., 2012). Bandyopadhyaya and his colleagues also found that intersections significantly contributed to the severity of injury crashes (Bandyopadhyaya and Mitra, 2013). In the study by Chris Lee et al., crashes into the left, right, and rear of vehicles increased the severity of crashes (Lee and Li, 2014). However, the roof, the left and right sides increased the severity of crashes in the present study. Also, in the present study, crashes near horizontal curves were almost fatal, which is similar to previous research on crashes near horizontal areas on rural roads (Al-Bdairi and Behnood, 2021, 2021; Echaveguren et al., 2015; Elvik, 2013).

5. Conclusions

The objective of the present study was to investigate the human, road, environmental, traffic, and vehicle-related factors related to crashes on rural roads in Mazandaran province, Iran. Data analysis using logit model identified the most important factors affecting the severity of crashes. Accordingly, factors such as vehicle type, crashes type, pedestrian crashes, and overturning were associated with severity of fatal crashes. In addition, the results showed that road-related factors such as the location of the crashes and human factors such as the type of license a driver holds can have an effect on the likelihood of injury crash.

According to the results, the most important operational and practical solutions aimed at reducing the severity of crashes are:

– strict implementation of the traffic rules related to motorcycles in the subject of using safety equipment;
– managing on the traffic of motorcycles on rural roads through proposing of an exclusive lane;
– installing pedestrian facilities such as overpasses and underpasses or elevators for elderly or the physically disabled pedestrians;
– using traffic calming devices near pedestrian crosswalk to reduce speed of approaching vehicle especially heavy agricultural vehicle;
– enhancing road lighting condition;
– adding parking lane to some segment of the roads to prevent the vehicle especially heavy ones from stopping in the road;
– expanding the width of roads near horizontal curves;
– increase the resistance of vehicles in parts such as roofs and side.

By applying effective solutions concerning the influential factors associated with injury and fatal crashes on rural roads, it is possible to reduce the severity of crashes on rural roads that have similar safety issues to the case study. In addition, by focusing the research on the types of vehicles and the locations of the damage in the vehicles, further studies can be conducted on safety and mechanics of the vehicle.

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