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Gender Influence on the Severity of Vehicle Driver Injury in Highway-Railway Grade Crossings

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A B S T R A C T

The involvement of more severe Highway-Railway Grade Crossing (HRGC) crashes between male and female drivers is controversial. The aim of this paper is to identify the differences in contributory factors to injury severity between male and female in these locations. The current research was implemented based on HRGC crash data in the United States from 2004 to 2013. Three separated prediction models were established through the Ordered Probit approach. Results showed that the driver gender considerably affected the injury severity of HRGC crashes; in particular, the female drivers had a higher probability of involving in a more severe crash than the male drivers. Besides the driver gender, it was determined that a number of causal factors such as train speed, vehicle speed and driver age could be influenced the crash severity. The presences of audio warning systems and crossbucks were contributed to the crash severity of the male and female drivers, respectively. Such results were an indication of the driver training and education improvement, so, the maintained safety performance at the HRGC.

1. Introduction

It is essential to identify the contributory factors to the severity of HRGC crashes and the difference between them. It would be helpful for improving the safety of HRGC and also control features, which are related to the high crash and injury risk at the HRGCs.

HRGCs crash could become a catastrophe. For instance, two HRGC crashes happened in the United States in February 2015. At the first one, six and twelve people were killed and injured, respectively. The eyewitnesses described that the fire flared from the crash location led to the complete burning of the first wagon of the train and car [1]. In the other HRGC crash in June 2016, five-car passengers, including three children, were killed, and the involved vehicle was pulled by the train for a long distance in the direction of the track until the train could be completely stopped [2].

There were more than 212,000 HRGC crashes in the United States during a 10-year period from 2004 to 2013. It was the equivalence to the three HRGC crashes per hour regardless of the numerous mitigation measures imposed to improve the design and control of HRGCs. It should be mentioned that not only the frequency of HRGC crashes but also the crash severity has been of concern. The HRGC crashes have been recognized as the second most significant cause contributing to the fatality of the railway system

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[3]. According to the statistics of the Federal Railroad Administration (FRA) and National Highway Traffic Safety Administration (NHTSA), the probability of the HRGC crashes fatality was 20 times higher than that of the other road crashes. For instance, in the HRGC crashes that occurred in the period between 2009 and 2014 in the United States, 1490 and 5471 people were killed and injured, correspondingly [3]. The HRGC crash severity can be quantified in terms of some monetary cost issues like the reduced life expectancy of car passengers, pedestrians, and the train passengers involved in the HRGC crashes [4, 5].

Many types of research have been conducted to determine the influential factors on higher crash frequency in the HRGC [4, 6, 7]. Therefore, more effective control measures of the train and highway could be developed to improve the safety performance of HRGC [8, 9, 10]. Some studies [11, 12] showed that the presence of advanced safety control measures is connected to the higher probability of more severe injury for female drivers.

From the viewpoint of the analysis method, ordered probit, multinomial logit, and random parameter models have been established to model the crash severity [13]. Moreover, data mining approaches, including association rules and Classification and Regression Tree (CART), have been used due to the relaxing hypothesis of parameter distribution. Another study showed that daytime, vehicle speed, train speed, and driver age could interfere with the association between crash prevalence and driver gender [14].

Numerous research works [6, 11, 9] have been emphasized the effect of gender on the crash severity in the HRGCs. However, there is no exact information about the more probability of severe crashes for female drivers [4, 12, 13]. Furthermore, it would be worth exploring the effects of interaction by driver gender on the association between crash severity in the HRGC and possible risk factors.

As mentioned, some researchers have stipulated the gender factor is effective in the severity of crashes in HRGCs [6, 11, 15], while others have not considered this factor influencing [16, 17]. Among the researchers considering the influence of gender, some believe that the futurities of the crash in these spots will be more severe for females [6, 12, 13], whereas some others indicate more severity for males [11, 15]. In addition, none of these studies have specifically addressed this issue - of vehicle drivers' gender effect- on the severity of crashes in HRGCs. The most important reasons expressed in studies about the relationship between the severity of the crash and gender included physical differences between males and females, low power of timely response, and higher venturing for females and males, respectively. It seems that further discussions on the role of gender in the severity of crashes may help to resolve the problem.

This research using comprehensive information about geometric design, traffic control, vehicle and train characteristics, and driver attributes of 5,345 HRGC crashes in the United States, attempts to diagnose the possible contributing factors in the HRGC crash severity. More importantly, the intervention effects were evaluated by the driver gender on the association. In the following parts of the current paper, the data collection method is described in Section 2. The analysis method and results are presented in Sections 3 and 4, respectively. Finally, Section 5 and 6 demonstrate conclusions by providing the implications to the effective safety strategies and measures and also recommendations for future research, correspondingly.

2. DATA

In the U.S., there are more than 250 thousand HRGCs, the high number of crossings and HRGC accident consequences (1889 accidents with 217 fatalities and 679 injuries in 2020) in this country motivated the authors to use the U.S. FRA HRGCs accident database [18, 3].

According to the US Federal Railroad Administration (FRA), the database for the period of 2004-2013 accounts for over 24 thousand HRGC accidents in the US. After cleaning the database, 5345 have remained. As a result, 577 drivers were killed, and 1860 drivers were seriously injured.

The U.S. FRA contains two databases related to HRGC: (1) inventory database and (2) accident records. The inventory database contains detailed information on HRGC location, geometry, pavement type, etc., corresponding to all the crossings in the U.S. The accident database contains information such as crash time, collision circumstances, and injury severity; the data sets contain a unique identifier to merge the crossing infrastructure information with the actual accident record. The inventory database was merged with appropriate crossing information using this unique identifier [18].

According to the previous investigations, initially, 17 variables have been considered as follows for further investigations: road type, type of warning system, intersecting angle between railway and roadway, pavement type, illumination, number of passing train and Annual Average Daily Traffic (AADT) of road vehicle, train speed, vehicle speed, time of crash, visibility, weather condition, temperature, position of the vehicle at the time of crash (position), driver age and driver gender. Also, in this study, the driver injury severity (dependent variable) is as follows: property damage, injury, and fatal.

The cleaning database is required to achieve more accurate analysis. After cleaning the database, developing a correlation matrix is necessary. As a result, ten factors remained. Table 1 represents the summary statistics of considered factors. It should be mentioned that a two-step clustering approach was applied to stratify the data.

3. Method

This study identifies the factors contributing to the HRGC crash severity and the effects of intervention through the vehicle driver gender on the association, for instance, an ordered probit regression model was established in order to provide the ordinal nature of the dependent variables called crash severity, i.e., mortality, injury, and property damage [19].

The maximum probability method will be applied to estimate the parameter of the proposed ordered probit model [20]. The specification of the expression is given through Equation (1) to (7).

Table 1. Description of HRGCs Crashes Characteristics for Analysis

Dependent Variable		**Severity**	**Description**	**Frequency**	**Percentage (%)**
			0 (uninjured)	2908	54
			1 (injured)	1860	35
			2 (killed)	577	11
Category	**Factor**	**Attribute**	**Description**	**Frequency**	**Percentage (%)**
Environmental Factors	Visibility	Night	0 (no)	3671	69
			1 (yes)	1674	31
		Day	0 (no)	2094	39
			1 (yes)	3251	61
	Weather	Snow	0 (no)	5188	97
			1 (yes)	157	3
	Illumination	Illuminated	0 (no)	3515	66
			1 (yes)	1830	34
	Warning system	Audible warning	0 (there is not)	3148	60
			1 (there is)	2197	40
		Cross bucks	0 (there is not)	1457	27
			1 (there is)	3888	73
HRGC Characteristics	Angle	HRGC angle <30	1 (yes)	142	2
		30≤ HRGC angle≤59	1 (yes)	782	15
		60≤ HRGC angle≤90	1 (yes)	4421	83
	Pavement	Asphalt	0 (no)	4063	76
Driver demographics	Gender	Male	0 (no)	2260	42
			1 (yes)	3085	58
	Age	Driver age<52	1 (yes)	3802	71
		52≤ Driver age≤71	1 (yes)	945	17
		Driver age≥72	1 (yes)	598	11
Vehicle & Train Characteristics	Vehicle speed	Vehicle speed≥15mph	0 (no)	3967	74
			1 (yes)	1378	26
	Train speed	1≤ Train speed<14	1 (yes)	1650	31
		14≤ Train speed<29	1 (yes)	1236	23
		29≤ Train speed<43	1 (yes)	1253	23
		43≤ Train speed<61	1 (yes)	1025	19
		61≤ Train speed<95	1 (yes)	181	3

$$y_i^* = \beta X_i + \varepsilon_i \quad (1)$$

Where y_i^* is the response variable of the crash severity, X_i is the independent variables vector of crash i, β is the coefficients vector of independent variables, and ε_i is a normally distributed random error component with zero mean and variance one. Additionally, the random error component is supposed to be independent across the alternate outcomes. The response variable Y has the values 1, 2,… J, which is defined in Equations (2), (3), and (4):

$$Y = 1 \;\; if \;\; -\infty \leq y_i^* < \tau_1 \quad (2)$$

$$Y = j \;\; if \;\; \tau_{j-1} \leq y_i^* < \tau_j \quad (3)$$

$$Y = J \;\; if \;\; \tau_{J-1} \leq y_i^* < +\infty \quad (4)$$

Where J is the number of possible alternatives that is to say crash severity and τ_j indicates its threshold limit. The probability of each crash severity is determined by Equations (5), (6), and (7). In these equations, Φ is the cumulative probability of the normal distribution [11].

$$P(y_i = 1) = \Phi(\tau_1 - \beta X_i) \quad (5)$$

$$P(y_i = j) = \Phi(\tau_j - \beta X_i) - \Phi(\tau_{j-1} - \beta X_i) \quad (6)$$

$$P(y_i = J) = \Phi(\tau_{J-1} - \beta X_i) \quad (7)$$

To examine the intervention effect by the driver gender on the association measure between the HGRC crash severity and possible factors, separated prediction models for the male and female drivers have been implemented [21, 22].

4. Results

Table 2 presents the parameters estimate results for the overall model. As shown in Table 2, the factors including the driver gender, lighting, weather and pavement conditions, railway and highway intersecting angle, driver age, vehicle, and train speeds affect the HRGC crash severity by the 5% level of significance.

It is worthy to note that the male drivers had a lower probability of severe injury in the HRGC crash (coefficient=-0.138) than the female drivers based on the difference in physiological conditions between them, which is in agreement with the previous researches [4, 11, 12].

According to Table 2, the HRGC crash had a higher probability of being severe (0.112) under the dark condition than that of dawn, day, or dusk times. This is in agreement with the findings of the preceding literature [7, 13]. It could be attributed to the unclear visibility during the dark times leading to the insufficient response time during emergency conditions.

Table 2. The results of Ordered Probit Regression for Overall

Attribute	Coeff.	Std. Err	Sig.
Male	-0.138	0.034	0.000
Dark	0.112	0.037	0.003
Snow	-0.265	0.106	0.012
30≤HRGC angle≤59	0.330	0.121	0.006
60≤HRGC angle≤90	0.346	0.114	0.002
Asphalt	-0.125	0.034	0.000
52≤Driver age≤71	0.153	0.044	0.001
Driver age≥72	0.363	0.053	0.000
Vehicle speed≥15 mph	0.318	0.038	0.000
14 ≤Train speed≤29 mph	0.442	0.049	0.000
29 ≤Train speed≤43 mph	0.974	0.048	0.000
43 ≤Train speed<61 mph	1.354	0.05	0.000
61 ≤Train speed<95 mph	1.711	0.092	0.000
τ_1	1.142	0.240	0.000
τ_2	2.467	0.236	0.000

Snow conditions also had a lower possibility of being severe (-0.265) than the other weather conditions because of the more cautiousness of vehicle drivers [12, 15].

With relation to the angle between the railway and highway, results showed that the HRGC crashes with less acute intersecting angles (30° to 59° and 60° to 90°) had a higher possibility of being severe than that of less than 30°. It is attributed to the more cautiousness of drivers when they encounter poor visibility. There is another reason which relates to the higher dissipated energy when the collision angle is close to 90 degrees.

The pavement condition results specified that the asphalt roadway had a higher possibility of being severe, which is in agreement with prior literature [7, 20].

Based on the driver age, elderly drivers (aged between 52 and 71 and aged 71 or above) had a higher probability of severe injury in the HRGC crash, which shows the inability of elderly drivers to adequately control the vehicles during emergency conditions and also their vulnerability [12].

Furthermore, higher vehicle speeds were accompanied by a higher chance of a more severe crash in the HRGCs, closely associated with the collision impact and the dissipated energy [11, 13]. It is anticipated that increasing train speed creates an undesirable situation.

To sum up, the overall model pointed out that the driver gender meaningfully helps to cause the HGRC crash severity. Via succeeding analyses, the effects of intervention by gender on the association measure are evaluated using a separated prediction model for the male and female drivers.

Table 3 shows the sensitivity analysis results of the factors contributing to the HRGC crash severity. According to the data of Table 3, the probabilities of being killed and injured for the male drivers were reported 2% and 3.5% lower than that of the female drivers, respectively. For example, the probability of fatal crashes increases 51.6 % for a speed higher than 61 mph compared to that less than 61 mph.

To examine the effect of intervention through the driver gender on the association measure between crash severity and possible factors, separated Ordered Probit models for the male and female drivers were developed.

Table 3. The sensitivity of the Overall Crash Severity Model

Factor Attribute	Sensitivity Estimates		
	Damage Only	**Injured**	**Killed**
Male	**5.5**	**-3.5**	**-2.0**
Dark	**-4.4**	**2.8**	**1.6**
Snow	**10.2**	**-7.1**	**-3.1**
30≤HRGC angle<60	**-13.1**	**7.6**	**5.5**
60≤HRGC angle≤90	**-13.4**	**9.2**	**4.1**
Asphalt	**4.9**	**-3.2**	**-1.7**
52≤Driver age<72	**-6.1**	**3.8**	**2.3**
Driver age≥72	**-14.4**	**8.2**	**6.2**
Vehicle speed≥15 mph	**-12.6**	**7.6**	**5.0**
14≤Train speed<29 mph	**-17.5**	**10.1**	**7.4**
29≤Train speed<43 mph	**-37.0**	**17.5**	**19.5**
43≤Train speed<61 mph	**-48.3**	**16.4**	**31.9**
61≤Train speed<95 mph	**-50.8**	**-0.9**	**51.6**

4.1. Crash Severity Model for the Male Drivers

Table 4 exhibits the results of the ordered probit model for the male drivers. The dark attribute coefficient is equal to 0.167, which means that the crashes happening in the dark are highly severe than the others at dawn or dusk. It may be because of the lack of clear visibility at night, resulting in a lack of timely response by drivers to the crash [7, 10].

The calculated coefficient for the Snow attribute in the model is equal to -0.341, indicating the lower severity of crashes than those that happen in clear weather conditions. Cautious actions of drivers in snowy weather conditions seem to be the reason for reducing the crash severity [4, 15].

The coefficient of the illuminated attribute has also been calculated negative equal to -0.104, which can be concluded that the existing lighting system in the HRGC reduces the crash severity. The lighting system can improve the driver's visibility that results in a timely reaction to the crashes.

According to the positive value of the audio warning attribute coefficient, it can increase the crash severity due to its presence in the HRGCs. Increasing vehicle speed in order to pass the HRGC spots initiates the influential effect of the audio system on the driver's motivation. Two age ranges of 52 to 71 and more than 71 years have the most influence on the crash severity. It should be noted that the attribute coefficient for the age of more than 71 years is approximately two times higher than the other age range. This demonstrates the vulnerability of the elderly drivers as well as their inabilities to adequately control the vehicles. Both vehicle and train showed that increasing their speed leads to increasing crashes severity based on the calculated coefficients in the proposed model.

4.2. Crash Severity Model for the Female Drivers

During the ten years period from 2004 and 2013, there were 2260 HRGC crashes involving female drivers. Table 5 presents the results of the ordered probit model for the female drivers.

Table 4. The results of the ordered probit model for the male drivers

Attribute	Coeff.	Std. Err.	Sig.	Sensitivity Analysis		
				Uninjured	Injured	Killed
Dark	0.167	0.050	0.001	-0.064	0.040	0.024
Snow	-0.341	0.140	0.015	0.126	-0.088	-0.038
Illuminated	-0.104	0.049	0.034	0.039	-0.025	-0.014
Audible warning	0.077	0.046	0.097	-0.031	0.020	0.011
52≤Driver age<72	0.254	0.060	0.000	-0.102	0.060	0.041
Driver age≥72	0.441	0.070	0.000	-0.176	0.096	0.081
Vehicle speed≥15 mph	0.281	0.050	0.000	-0.110	0.066	0.044
1≤Train speed<14 mph	0.412	0.066	0.000	-0.162	0.093	0.069
14≤Train speed<29 mph	1.014	0.064	0.000	-0.388	0.180	0.208
43≤Train speed<61 mph	1.396	0.067	0.000	-0.504	0.167	0.337
61 ≤Train speed<95 mph	1.557	0.118	0.000	-0.503	0.043	0.460
τ_1	1.067	0.271	0.000	-	-	-
τ_2	2.309	0.267	0.000	-	-	-

The coefficient of day attribute demonstrated that the happening crashes at the day are less severe than the other times like dawn or dusk because of increasing the visibility and also enhancing the female driver's reactions. Two ranges of angles, including 30 to 59 and 60 to 90 degrees, are important for the HRGCs.

According to the base angle (a range of fewer than 30 degrees), two other groups have severe crashes. It should be noted that in this model, unlike the general probit model, the coefficient of the range of 30 to 59 degrees is greater than that of the range of 60 to 90. Given that, the angle factors are not noteworthy for the males in the model. So, the above results firstly denote that the separate investigation of the male and female groups leads to more accurate consequences.

Secondly, in the female model, the crashes for the 30 to 59 degrees range are more severe than those of the 60 to 90 degrees range. Further discussion has been provided in the sensitivity analysis of this study. The coefficient of the crossbucks attribute has been calculated at 0.132 in this model. It means that if the signs exist in the HRGCs, the crashes of female drivers have become severe in these spots. In other words, the presence of crossbucks near these spots should reduce the severity of the crashes related to the female drivers. But increasing the crash severity determines the inefficiency of the crossbucks and their inability to warn the female drivers. This could be due to the high concentration of the female drivers along with no attention to the circumference during driving.

The negative value of the asphalt coefficient calculated in this model results in enhancing the driver's capability to control the vehicle, consequently decreasing the crash severity. Increasing driver age to more than 71 years leads to a growing number of crashes with high severity. Established upon the value of vehicle speed coefficients, the severity of crashes is increased. Similar to the vehicle speed, the train speed has a key effect on the severity of crashes as with more increasing train speed, more severity of crashes is expected.

Table 5. The results of the ordered probit model for the female drivers

Attribute	Coeff.	Std. Err.	Sig.	Sensitivity Analysis		
				Uninjured	**Injured**	**Killed**
Day	-0.106	0.055	0.054	0.042	-0.027	-0.015
30≤HRGC angle<60	0.536	0.181	0.003	-0.209	0.114	0.094
60≤HRGC angle≤90	0.527	0.171	0.002	-0.204	0.148	0.056
Cross bucks	0.132	0.059	0.024	-0.053	0.036	0.017
Asphalt	-0.148	0.051	0.004	0.059	-0.039	-0.020
Driver age≥72	0.267	0.080	0.001	-0.106	0.064	0.042
Vehicle speed≥15 mph	0.364	0.059	0.000	-0.144	0.087	0.057
1≤Train speed<14 mph	0.493	0.073	0.000	-0.194	0.113	0.080
14≤Train speed<29 mph	0.941	0.073	0.000	-0.353	0.170	0.182
43≤Train speed<61 mph	1.313	0.077	0.000	-0.458	0.159	0.299
61 ≤Train speed<95 mph	2.004	0.149	0.000	-0.506	-0.112	0.618
τ_1	1.259	0.317	0.000	-	-	-
τ_2	2.709	0.310	0.000	-	-	-

Tables 4 and 5 point out the sensitivity analysis of the attributes incorporated in models B and C. For instance, if the driver age of the vehicle is more than 71 years, the possibility of fatal crashes increases to 8.1% and 4.2% for the male and female drivers, respectively. It means that the possibility of high crash severity when the driver is male at the age of more than 71 years, almost two times more than when the female is as drivers with the same age range.

5. Discussion

The current research specifically determines the driver gender effect on the crash severity of HRGCs. Results indicated that the female drivers have a higher probability of involving in more severe HRGC crashes than the male drivers. Moreover, the other effects of possible contributory factors on the crash severity can be influenced by the driver's gender [21, 22]. This has been approved by the results of separated models of crash severity for the male and female drivers.

According to the acquired results from the male and female drivers, the factors including train speed, driver age, weather, vehicle speed, light condition, and the presence of illuminated and audio warning system was found that contributed to the crash severity of the male drivers, whereas the other factors including train speed, intersecting angle between highway and railway, vehicle speed, driver age, pavement condition, the presence of crossbucks and lighting condition was contributed to the crash severity of the female drivers.

Train speed is one of the most important factors contributing to the crash severity in the HRGC. Increasing the train speed leads to less time for the vehicle driver to properly react during emergency conditions. It should be mentioned that when the train speed increases, due to the braking mechanism of the train wagon, its stop in a short interval is almost impossible. For example, the stopping distance for a train moving at a speed of 55 miles per hour is approximately equal to a mile.

It was anticipated that the sensitivity of coefficient increases with raising the train speed, especially in the possibility of fatal crashes. Nevertheless, no evidence could be established for the high sensitivity of train speed up to 42 mph in the probability of injury crashes. This is in agreement with the findings of previous studies [12, 13]. For the effect of intervention based on the gender on the association between the train speed and the crash severity, the female drivers had a higher probability of involving in more severe crashes when the train speed was below 28 mph and above over 61 mph while when the train speed was intermediate (i.e., 29 to 61 mph), involving in more severe crashes for the female drivers had a lower probability.

The effect of an intervention based on the driver gender on the association between driver age and crash severity was also remarkable [23, 24]. For the male drivers, the involving probability in fatal (4.1%) and injury crashes (6.0%) was higher when the driver age was above 52. In contrast, such an increase could only be revealed when driver age was above 71 for the female drivers.

Another influencing factor on the crash severity in the HRGC is vehicle speed. The probability of more severe crashes was higher when the vehicle speed exceeded 15 mph for both male and female drivers. It was expected that the increase in vehicle speed could increase the dissipated energy during the collision. It could also be attributed to the inability of the vehicle driver to distinguish the train traveling circumstances when the vehicle speed increases [10, 13]. The results of sensitivity analysis also discovered that the effect of vehicle speed on the crash severity has more flexibility for the female drivers.

One of the factors that were statistically significant only in the prediction model for the female drivers was the intersecting angle of railway and highway. By the curvature degree and also the presence of signal control, the effect of intersecting angle on the crash severity can be moderated [25]. When the intersecting angle increases (from 30-59 degrees to 60-90 degrees), its effect on the crash severity would be less flexible for the female drivers.

In the current research, five different weather conditions, including clear, cloudy, rainy, snowy, and foggy, were investigated. The results showed that the presence of snowy weather could affect the crash severity of the male drivers, while no evidence could be recognized for the association between the weather condition and the crash severity for the female drivers. In particular, in the snowy weather condition, the reduction of the more severe crash probability for the male drivers due to more cautious driving behavior was achieved [4, 15].

Four attributes, including dawn, dark, dusk, and daytimes, were investigated in order to study the visibility effect. Both the dark and day times were associated with the crash severity for the male and female drivers. The effect of dark conditions was more remarkable for the male drivers. Furthermore, the presence of illumination could be significantly reduced the possibility of a more severe injury for them. Therefore, the design, development, and implementation of illumination in the HRGC could improve its safety, especially under adverse weather conditions. The existence of daylight could reduce the probability of severe crashes when the driver is female. It is very helpful because it creates a longer reaction time under poor visibility conditions, which leads to timely responsive action during emergency circumstances [21, 7].

Asphalt pavement was also found to expressively contribute to the reduction of crash severity in the HGRC. Asphalt surface was correlated to a lower probability of more severe crashes related to the female drivers, whereas no evidence could be established between the pavement condition and the crash severity for the male drivers. It could be attributed to the driving performance of the female drivers, which is more sensitive to the pavement condition [20].

The audio warning system systematically contributes to the crash severity of male drivers. In general, it could reduce the crash risk, but based on our investigations, it increased the probability of more severe crashes (2.0% and 1.1% for injury and fatal crashes, respectively). It might be related to the negligence of the male drivers to any advanced warning, while the presence of a warning system is often attributed to the higher crash and injury risk in accordance with the historical crash record [21]. It should be noted that when the advanced warning was active, the male drivers increased the train speed [4].

The presence of crossbucks, similar to the other factors, was correlated to the increase in the possibility of injury and fatal crash by 3.6% and 1.7%, respectively. This implies that the design and management of crossbucks should be improved to enhance the driver responses, especially for the female drivers.

For the effect of intervention by gender on the association between train speed and crash severity, the male drivers had a higher probability of involving in a more severe crash when the train speed was intermediate. However, the possibility of more severe crashes increases when the train speed is low (below 28 mph) and remarkably high (above 60 mph) for the female drivers.

6. Conclusions

The present paper attempted to identify the factors contributing to the crash severity in the HGRC and the possible intervention effect by driver gender on the association using the comprehensive HGRC crash record in the United States. Separated Ordered Probit regression models were developed for the overall crashes involving male and female drivers.

The results showed that the driver's gender could interfere with the association between the crash severity and possible risk factors. In general, the female drivers had a higher probability of involving more severe crashes than the male drivers. Moreover, the effects of weather conditions, train speed, pavement condition, and the presence of a warning system on the crash severity were dependent on the driver's gender. All of these factors could be attributed to the inattention of male drivers and the difference in the maneuvering skills between male and female drivers under different situations.

It was challenging for the wide application of effective traffic control, and management features thus far that could improve the HRGC operation and safety due to the financial constraints. In addition, the cost-effectiveness might be controversial for the HRGCs having low traffic volumes in rural areas. The results of the current research were indicative of effective driving training and education, especially for the appropriate defensive driving behavior while passing the HGRC.

We mentioned the difference in the driver responses between males and females in the HRGC, in particular, the response time to the possible safety features, e.g., audio system and crossbucks, when the comprehensive information on driver reaction is available from the empirical observation survey or driving simulator experiments. Additionally, the effects of protective measures, including airbag and safety belts, and the convicted driving behavior, including drug use and alcohol drinks, can be revealed in the extended study on the simulated collision experiments.

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