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RESEARCH PAPER

Evaluation of Level Crossing Accident Factors by Logistic Regression Method: A Case Study

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Abstract
The sections where risk of accidents is the highest in railway transport are the level crossings. In many countries, accidents that occur on the level crossings lead to loss of goods and lives. Therefore, governments have adapted some regulations to prevent accidents that occur at level crossings. In this study, we have examined the data of level crossings belonging to particular years in Turkey. The effects of physical and traffic characteristics of the level crossings, which are determined in the framework of the related regulation, are interpreted by logistic regression modeling method. As a result, it was determined "the width" and "the type" of level crossings are independent determinants of accidents, while "traffic moment" is not. Since the traffic moment parameter is not an independent determinant, the sub-parameters forming the traffic moment are used as inputs for the new model. In the new model, which sub-parameters of traffic moment, the type and width of the level crossing parameters are used as input, "the number of annual average traffic value of vehicles" and "the type of level crossing" parameters are found as independent determinants of accidents while the number of annual average traffic value of trains and the width are not.

Keywords Level crossing · Logistic regression · Traffic moment

1 Introduction

Literature definition of level crossing is the point where rail and road cut at the same level. These level crossings are located in conventional railway lines. Traffic accidents happening in developing and especially in undeveloped countries around the world are leading to loss of property and life. In these accidents, train accidents, land vehicles and human traffic, which are the nodes of the intersection, cannot be denied. For this reason, both academics and administrators are involved in many regulations related to the subject.

The ability to conduct academic work on level crossing accidents is directly related to the detailed and proper record of accidents in the regarding country. This is the case in the USA, Canada, etc., that academic studies are examined very comprehensively. For this reason, the number of academic studies about the accidents that is provided in Turkey is limited compared to the USA and European countries. Therefore, Turkey is going beyond academic studies and working on preparing legislative framework (Yılmaz 2013).

In this regard, a risk analysis was carried out for the accidents that took place in the Turkish railways recently, and a number of suggestions were made to reduce the accidents (Tabak 2014).

Accident factors of the accidents that occur in the level crossings can be put forward as a cause factor in reason of the accident. The result factors derived by cause factors are severity, frequency, type, etc., of the related accident.

In this context, a study conducted in Taiwan recently about accidents occurred at level crossings was investigated to determine the most effective accident factors with logistic regression method. The daily number of trains, the lane divided highways, the number of daily heavy vehicles, detection system of obstacles on the railway system together with signs and markings are determined with logistic regression method to be the most affecting factors of accidents risks (Hua et al. 2010).

In a study conducted in the USA about the accident severity and accident frequency of accidents occurring in level

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crossings, it is determined that the train speed, car driver's age, car driver's gender and the passing type through the level crossing are the most effecting factors. For the relationship with each other, the logistics regression model is applied (Russo and Savolainen 2013).

In the study of passenger traffic accidents in the USA between 2005 and 2015, accident analysis of factors such as the age factor of the road users, the weather factor, the visibility of the heavy vehicle and the road vehicle were analyzed by logistic regression method. As a result, the risk of accidents increases to the age of 65 and decreases from the age of 21 years and below and also decreases if the weather is unfavorable and the sky is dark, while driver attention increases in those cases. It has been found that situations such as insufficient visibility do not play a decisive role in the accident (Dabbour 2017).

The Ministry of Transport, the Ministry of Railways reported in 2016 detailed studies on these factors, which are stated to be effective in road vehicle drivers' characteristics, seasonal factors and time-based factors in level crossing accidents between 2005 and 2014. For example, the average age of the drivers who crashed was 42.24, while the average age of the drivers who crashed on Friday and Saturday dropped to 35.37. In addition, it was stated that the months of the most accidents occurred were January and February, and in order to investigate the seasonal accident effect of daylight, accidents occurred in June and December were compared in hourly basis. As a result, the same accidents occurred between 17:00 and 21:00 in December 25–30% more than the accidents that took place in June (Kidda and Allahyar 2016).

Another study is applied for 46 states in the USA for level crossing accidents between the years 1996–2002. The statistical analysis resulted in a positive direction that the educational activities on prevention of level crossing accidents have been revealed to be effective. However, there is no definite judgment on the accidental deaths (Savage 2006).

The level crossing accident factors are categorized in three groups in the USA for level crossing accidents between 2002 and 2011: property damage, injuries and fatalities, protected and unprotected level crossings to detect the most effecting one. Sequential probit model and the likelihood ratio test applied for those factors under these indicators: accident time (whether traffic is in peak hour), vehicle speed, vehicle type, the sky brightness conditions, the weather, train speed, driver's age, gender, level crossings coating type and the effect of the number of annual vehicle accident data analysis of average daily effects. As a result, all of these factors have effects on accidents and each effect's percentages were calculated (Hao and Daniel 2014).

In the state of Texas, vehicle crossing violations in barrier level crossings were examined and statistics were analyzed using traffic volume at 19 level crossings, number of road lanes across the level crossing (level crossing width), visibility distances and past accident statistics. Especially, most effecting factor was found as passage alert time length. By the additional research, it was recommended to regulate this time to reduce violations. It also highlights the importance of public education and awareness-treated, and propose a reasonable penalty can be applied to reduce the violations (Fitzpatrick et al. 1997).

The Bangladesh Railways Accident Report deals with the travel moment values, physical characteristics and protection types obtained by multiplying the number of trains passing through four-level crossings with high risk of accidents. In all countries where this movement momentum was high like Iran, Thailand and India, it was written in their regulation to build an overpass or underpass if the limit momentum was exceeded. In addition, it is mentioned that the warning signs of the level crossings and qualification of guards were inadequate. Car driver was unconscious and it was also noted that they very often made passage violations in those countries. As a suggestion, by considering the high momentum values it is much safer to construct overpass or underpass in these places and the level crossings and protection systems should be maintained regularly. Penalties must be imposed for the drivers who are in violation and other legal measures may be taken to prevent from level crossing accidents was additionally emphasized (Haque 2011).

For more than 30,000 accidents happened between 1997 and 2006, a research is conducted that dealt with those factors as triggers for accidents such as age of the driver involved in the accident, gender information, vehicle types, level crossing traffic density, level crossings types of protection, the environment and the effects of time and the role of the cars in the accident. Although there is no final judgement at the end of the statistical research, according to the analysis results it is claimed that the accidents occurring in harsh weather conditions at night and with driver's age of 40 or below is building a group, where another group is categorized for when the weather temperature was 0 °C and below and in daytime with driver age of 40 and above (Eluru et al. 2011).

It is clear that current studies abroad are more effective in identifying problem areas and proposing solutions due to the data kept regularly by the administration departments. Some of the studies related to the subject in Turkey are as below.

The factors effecting level crossing accidents are listed under four headings such as: traffic conditions, environmental conditions, technical factors and human caused factors. The case study covered 10 level crossings between Torbalı-Ödemiş and Çatal-Tire line. The physical, environmental and traffic attributes are considered under the risk measurement model to study on determining the level crossing risk coefficient (Erdoğdu et al. 2015).

In the study of the traffic patterns, components and crash statistics on the railway network in Turkey, taking into consideration the studies carried out to prevent accidents abroad, suggestions have been made about measures to reduce the accidents that occurred in the passengers in Turkey (Yılmaz 2013).

In another study conducted on five-level crossings in the Turkish State Railways (TCDD) line, scoring was made according to the physical, environmental, traffic and technical characteristics of the level crossings using the analytical hierarchy process (AHP) scoring method and by examining the costs of the improvements priority interpretation has been made. It has been emphasized that the improvements to be made in the level crossings during the study should take into consideration not only the traffic moment criterion but also the other criteria specified in the regulation (Bozalioğlu et al. 2017).

In a study in which various parameters were determined for a risk model that can be developed for accidents occurred in level crossings by examining their current situations, similar studies were mentioned in it and it has indicated that no public data can be reached for detailed studies about accidents occurred in level crossings, and it was stated that this kind of work may be possible with permission to be taken from TCDD (Güncan et al. 2011).

Various analyses and statistical studies have been carried out using human and technical data belonging to this accident, which are the level crossings where the accidents have occurred and the events that took place in the field, as seen in the studies in the literature. It is obvious that our country is inadequate to work in this direction.

In this context, data about accidents in level crossings and situation of them in Turkey's railway lines in 2008–2009 and 2013–2014 years were received with the permission of General Directorate of Turkish State Railways "TCDD." The importance of this study is to evaluate the risk factors and the factors affecting the accidents within the framework of the regulation on the measures to be taken at railway level crossings and the implementation principles with the obtained logistic regression modeling method.

2 Materials and Methods

2.1 Data Definition

Database required for level crossing accidents factors which are the subject of our study was received with the official correspondence between Gazi University Faculty of Technology, Civil Engineering and TCDD.

Obtained data, TCDD accident records and accidents in level crossings were compared. Those who recorded accident records at unregistered kilometers were not subjected to analysis. Parameters such as railroad slope, skew angle and curve information did not show any change from year to year, whereas parameters such as traffic moment, type of level crossing, visibility distance and clearance are changed due to the reasons such as socioeconomic status of the country and city planning. For this reason, the data of the level crossing accidents occurred in 2008, 2009, 2013 and 2014 were used by eliminating the data.

After the usable data arrangement is done, the data are grouped as level crossings in which accidents occurred ($ACCIDENT_{group}$) and not occurred ($CONTROL_{group}$). These clusters were sampled for 398 control groups in comparison with the 199 passenger accident casualties within the scale of years aforementioned. Here, the control group was selected so that the number of data would be twice as large as the accident group (Hennessy et al. 1999).

Control group dataset has been formed according to the number of accidents occurred in each region and each route. The number of samples generated ($ACCIDENT_{group}$) and ($CONTROL_{group}$) are given in Table 1.

Table 1 Sample distribution

Regional directorates	$ACCIDENT_{group}$ (Number of level crossings in which accident occurred)		$CONTROL_{group}$ (Number of level crossings in which no accident occurred)	
	2008–2009	2013–2014	2008–2009	2013–2014
TCDD 1. Region	15	3	30	6
TCDD 2. Region	18	13	36	26
TCDD 3. Region	12	34	24	68
TCDD 4. Region	6	17	12	34
TCDD 5. Region	14	19	28	38
TCDD 6. Region	15	8	30	16
TCDD 7. Region	12	13	24	26
Total	92	107	184	214
General Total	199		398	

2.2 Statistical Methods

Independent variables of accident group and control group in sample group are as follows:

- Traffic moment ($= \mathrm{YOGT}_{\mathrm{railroad}} \times \mathrm{YOGT}_{\mathrm{road}}$)
  - $\mathrm{YOGT}_{\mathrm{Railroad}}$: Average daily value of number of trains passing through level crossing
  - $\mathrm{YOGT}_{\mathrm{Road}}$: Average daily value of number of road vehicles passing through level crossing
- Type of level crossing
- Sight distance of train
- Sight distance of road vehicle
- Clearance
- Skew angle
- Rail slope
- Curve information

The control sample group data were generated with the data of level crossings in which no accident occurred. Logistic regression modeling has also been used to determine which of the independent variables independent determinant is. The reason for selecting logistic modeling method is that it can measure the relationship between independent and independent variables.

Before this decision was made, the normality hypothesis was tested by performing the most commonly used tests (Kolmogorov–Smirnov and Shapiro–Wilk) in hypothesis tests to decide whether to perform parametric and/or non-parametric tests on the data (Demir et al. 2016).

Kolmogorov–Simirnov test is an alternative to conformity tests. It was proposed by Kolmogorov in 1933. Kolmogorov recommended the goodness of fit test for a single sample. In 1939 Simirnov, a Russian mathematician, developed a goodness of fit test for two independent samples. Because of the similarity of the Kolmogorov and Simirnov test, in practice, Kolmogorov–Simirnov is known as goodness of fit tests. In order to perform the chi-square test, the expected frequencies are required to be greater than 5. Kolmogorov–Simirnov test is not based on such a condition and can be easily applied.

As a result of the normality hypothesis, the independent variables were determined which are not normally distributed, and therefore the non-parametric (Mann–Whitney *U*) test was used to determine the effect on accidents. The determined independent variables were used as inputs to the logistic regression model (Sullivan et al. 2018).

Mann–Whitney *U* test is a non-parametric method used to compare the mean of two independent groups in a non-normal distribution.

In the choice of logistic regression model, two categorical (binary) logistic regression models were chosen because of the dependent variables such as the level crossings in which accident occurred (ACCID = 1) and those in which no accident occurred (Control = 0). In the binary logistic regression model, how much of the change in dependent variables was explained by independent variables (Cox-Snell R^2 and Nagelkerke R^2) was tried to be determined by explanatory coefficients (Urgancı 2012).

3 Results and discussion

In this section, frequency analysis, chi-square analysis and logistic regression analysis results are given with the factors which have an effect on the accident formation on the official data of the level crossings in seven regional directorates. The type and curve radius obtained from raw data and present in the categorical group are given numerically and as a percentage in "Appendix 1". Curve radius is the curved part of the path that connects the correct paths in different directions. The frequency distributions of the criteria except for the categorical group such as "Navigation Moment, Clearance, Average Number of Vehicles Passing 24 h ($\mathrm{YOGT}_{\mathrm{road}}$), Average Number of Trains Passing 24 h ($\mathrm{YOGT}_{\mathrm{railroad}}$), Railway Vehicle Sight Distance, Road Vehicle Sight Distance, Railroad Slope and Skew Angle" are given in "Appendix 2". When "Appendix 2" is examined, it is seen that the data are not normally distributed.

As shown in Sects. 2 and 3, the statistical analyses on the data groups were first applied to two independent methods with two different methods such as normality test "Kolmogorov–Smirnov and Shapiro–Wilk," and the results are given in Table 2.

Table 2 Normality test of independent variables)

Non-categorical Independent Variables	Accident control ($n = 597$)	
	Kolmogorov–Smirnov (p)	Shapiro–Wilk (p)
Clearance (m)	0.000	0.000
Traffic moment	0.000	0.000
$\mathrm{YOGT}_{\mathrm{Road}}$	0.000	0.000
$\mathrm{YOGT}_{\mathrm{Railroad}}$	0.000	0.000
Railroad vehicle sight distance (m)	0.000	0.000
Road vehicle sight distance (m)	0.000	0.000
Railroad slope (per thousand, ‰)	0.000	0.000
Skew angle (°)	0.000	0.000

Hypothesis assumption and its results: H0: Data with normal distribution ($p > 0.05$)

H1: Data with abnormal distribution ($p < 0.05$)

Table 3 Results of non-parametric "Mann–Whitney U" Test

Non-categorical independent variables	Accident control ($n=597$) Mann–Whitney U (p)
Clearance (m)	0.000
Traffic moment	0.000
$YOGT_{Road}$	0.000
$YOGT_{Railroad}$	0.416
Railroad vehicle sight distance (m)	0.360
Road vehicle sight distance (m)	0.936
Railroad slope (per thousand, ‰)	0.902
Skew angle (°)	0.807

Hypothesis assumption and its results: H_0: Independent variable has no significant effect on occurrence of accident ($p>0.05$); H_1: Independent variable has significant effect on occurrence of accident ($p<0.05$)

Table 4 Chi-square test for categorical independent variables

Categorical independent variables	Accident control ($n=597$) (p)
Type of level crossing	0.000
Curve radius	0.992

Hypothesis assumption and its results: H_0: Categorical independent variable has no significant effect on occurrence of accident ($p>0.05$); H_1: Categorical independent variable has significant effect on occurrence of accident ($p<0.05$)

H_0 hypothesis was rejected according to the normality test results on independent variable data, and it was determined that independent variable data did not have normal distribution. For this reason, the non-parametric "Mann–Whitney U" test was applied to the data with abnormal distribution. It was determined whether the independent variable had a meaningful effect on the occurrence of accidents at the significance level of $p=0.05$ (Table 3).

When the "Mann–Whitney U" test data on the independent variable data were examined, it was observed that there was a significant effect of independent variables such as clearance, traffic moment and $YOGT_{Road}$ on accidents occurred in level crossings on the basis of their hypothetical setup and on the level of significance, $p=0.05$, it was observed that independent variables such as $YOGT_{Railroad}$, road vehicle sight, railroad slope and skew angle have not been found to have any significant effect on accidents occurring in level crossings.

The chi-square test was used to determine the effect of our categorical independent variables on accidents that occurred in level crossings. Hypothetical setup and results were tested at $p=0.05$ significance level (Table 4).

It was observed that the type of level crossing, as one of our categorical independent variables, had a significant effect on the accidents that occurred in the level crossings, but the curve radius was found to have no significant effect on the accidents that occurred in the level crossings.

Table 5 Omnibus test for signicancy of logistic regression model 1

Accident control ($n=597$)
Model 1
Omnibus significance value (p)
0.000

Hypothesis assumption and its results: H_0: Logistic regression model is not significant ($p>0.05$); H_1: Logistic regression model is significant ($p<0.05$)

Table 6 Nagelkerke goodness of fit test

Accident control ($n=597$)
Model
Nagelkerke R^2
0.216

As a result of the statistical analyses made above, it was determined that the type of level crossing, clearance and traffic moment parameters had significant effects on the level crossings. However, it is not known whether these parameters are independent determinants of accidents that occur on the level crossings. A logistic regression modeling method was used to search for the answer to this question.

The significance of the model (Model 1) was assessed by the "Omnibus coefficient test" before the logistic regression model was set (Table 5). It is clear that the model is significant.

The significance of the logistic regression model is not considered sufficient, but the dependent variables of the model are determined by the independent variables in percentages. For this reason, the value of "Nagelkerke R^2" is calculated (Table 6) (Urgancı 2012).

"Nagelkerke R^2" value indicates that dependent variable can be explained by independent variables with a percentage of 21.6%.

In light of these evaluations, parameters such as clearance, traffic moment and type of level crossing, which have significant effects on accidents occurring at level crossings, were used as inputs in the logistic regression model. In the model, the traffic moment parameter considered in the Regulation is used firstly and $YOGT_{Road}$ and $YOGT_{Railroad}$ which are the sub-parameters of traffic moment are not involved. The type of level crossing as a categorical independent variable was evaluated separately according to the model of level crossing (Table 7).

In the table of logistic regression model, (β) is read as the risk assessment, whereas (p) implies whether the

Table 7 Logistic regression model

Independent variables	Accident control ($n=597$)				
	β	p	Exp(β)	Exp(β) Confidence interval	
				Bottom	Top
Clearance (m)	0.053931	0.018	1.055	1.009	1.104
Traffic moment	0.000001	0.327	1.000	1.000	1.000
Type of level crossing	–	–	–	–	–
With manned mechanical gate	–	0.000	–	–	–
With automatic barrier	1.074354	0.016	2.928	1.217	7.046
With Flasher-Bell without barrier	3.460401	0.000	31.830	12.533	80.834
Free (with cross)	1.914399	0.000	6.783	3.004	15.316
With Flasher-Bell with automatic barrier	1.057664	0.002	2.880	1.466	5.658

Table 8 Omnibus test for significance of logistic regression model 2

Accident control ($n=597$)
Model 2
Omnibus significance value (p)
0.000

Table 9 Nagelkerke goodness of fit test

Accident control ($n=597$)
Model
Nagelkerke R^2 value
0.244

independent variables are independent determinants for accidents. Moreover, in sub-groups of types of level crossing, the comparison was made with taking the level crossing with manned mechanical gate as a reference. Exp(β) value implies the risk ratio in other categories in comparison with reference category in categorical will be between the bottom and top limits given with a probability of 95% (Kul et al. 2014).

According to logistic regression model, it is observed that the type of level crossing and clearance are independent determinants for accidents occurred in level crossings, whereas traffic moment is not independent determinant. In response to an increase of 1 m in clearance value, accident risk increases with a percentage of 5.39%. In the comparison of level crossing with manned mechanical gate, risk ratio Exp(β) is 292.8% in level crossing with automatic barrier, 3183.0% in level crossing with flasher-bell without barrier, 678.3% in free level crossing and 288.0% in level crossing with flasher-bell with automatic barrier.

Regulations on measures that will be taken in level crossings and their code of practice also mention that level crossings whose traffic moments are over 30,000 should be transformed into overpass or subways after closure (Turkey 2013). In fact, according to logistic regression model, traffic moment is not independent determinant for level crossings. This situation indicates that theory does not conform to the application. So a separate logistic regression model was established for components of traffic and it was searched whether those components were independent determinants.

Before modeling with the components of traffic moment ($YOGT_{Road}$, $YOGT_{Railroad}$), the significance of new model (Model 2) was tested and it was determined whether it was significant or not (Table 8).

The dependent variable of the model to be established by the components of the traffic moments is defined as 24.4% by the independent variables (Table 9). This is also a sign that the dependent variable of the new model is better explained by the independent variables.

Model established with data of components of traffic moment instead of data of traffic moment is shown in Table 10.

According to the results of logistic regression modeling based on the components of the traffic moment, while $YOGT_{Road}$ and type of level crossing are independent determinants, $YOGT_{Railroad}$ has no independent determining role. In addition to this, the hearing threshold is also an independent determinant.

In addition, an increase in 1 m in the clearance of level crossing increases the possibility of accident in level crossing by 3.53%, whereas an increase in the number of vehicles using the level crossing could increase the risk of accidents that may occur by 0.02%.

In logistic regression model established by taking the components of traffic moment as the basis, risk assessment was made in terms of types: in level crossing with automatic barrier, it is 329.9%; in level crossings with flasher-bell without barrier, 3362.3%; in free level crossings, 739.1%; in level crossings with flasher-bell with automatic barrier, 302.1%.

Table 10 Logistic regression model based on traffic moment components: average daily traffic counts of trains and vehicles

Independent variables	Accident control ($n=597$)				
	β	p	Exp(β)	Exp(β) confidence interval	
				Bottom	Top
Clearance (m)	0.035360	0.125	1.036	0.990	1.084
$YOGT_{Road}$ (number)	0.000214	0.006	1.000	1.000	1.000
$YOGT_{Railroad}$ (number)	−0.016203	0.051	0.984	0.968	1.000
Type of level crossing	–	–	–	–	–
With manned mechanical gate	–	0.000	–	–	–
With automatic barrier	1.193736	0.010	3.299	1.322	8.232
With Flasher-Bell without barrier	3.515225	0.000	33.623	13.067	86.516
Free (with Cross)	2.000323	0.000	7.391	3.156	17.312
With Flasher-Bell with barrier	1.105531	0.002	3.021	1.487	6.139

4 Conclusion and suggestions

Accidents in today's world have become the main theme of many disciplines such as social sciences, engineering sciences and health sciences. This issue has not only become a problem of administrations but also one of the main subjects of the world of science at the same time. Because of this reason, accidents in level crossing as the subject of our study have taken the lead in railway accidents. The statistical data acquired from the relevant units reveal the situation clearly.

Based on the fact that related situation should be evaluated in an academic manner, following conclusions were reached as a result of analyses made according to the data on level crossing accidents located in the territories of seven regional directorates affiliated with Turkish State Railways.

- There is no linear correlation between independent and dependent variables. According to the result of logistic regression analysis in which the probability of event occurrence is measured, type of level crossing, width (clearance) of road on the rail line and number of vehicles passing through the level crossing ($YOGT_{Road}$) are independent determinants.
- The most reliable type of level crossing is the one with manned mechanical gate.
- While the value of traffic moment is not an independent determinant, since annual average daily road vehicle number as a component that constitutes the traffic moment is an independent determinant, it is required to take this criterion into consideration in the arrangements that will be made in level crossings.

Regulations on measures that will be taken in level crossings and their code of practice that is still in force have considerably decreased the number of accidents in level crossings. But the statistical data indicate that accidents still occur in level crossings to which the criteria of regulations are applied.

It has been determined that the level crossings which are closed within the framework of the regulations and transformed into subways or overpasses have a ratio of 10% in total level crossings. But even though this situation is aimed at reducing accidents in level crossings, it also puts a heavy burden on the economy of the country. However, the number of types of level crossings is reduced to three: one with manned mechanical gate, one with automatic barrier and free type.

It was seen that one of the decision criteria in the closing of level crossings within the framework of regulations is the traffic moment. It can be said that this is not a solely true approach within the scope of the study. The traffic moment should be taken as the closure criterion and number of vehicle as a component that constitutes the traffic moment is an independent determinant, so it is required to take this criterion for transformation of level crossings into subways and overpasses.

Regarding the parameter of clearance, which seems to be an independent determinant on accidents in our first model, the fact that the barriers cannot close the path completely in the level crossings which have a lot of clearance suggests that it causes an accident because it makes illegal transitions possible.

It is a fact that the accidents are inevitable despite the physical precautions taken by the relevant public institutions. Because there are many physical parameters that have to be solved psychologically and educationally as well as physical parameters of the accidents that occur in the level crossings. There are also a number of academic degrees related to the subject. It is considered that an important step will be taken in preventing accidents by applying psychotecnical trainings during the training process and applying the tests on the result of the education of the driver from the relevant primary school age.

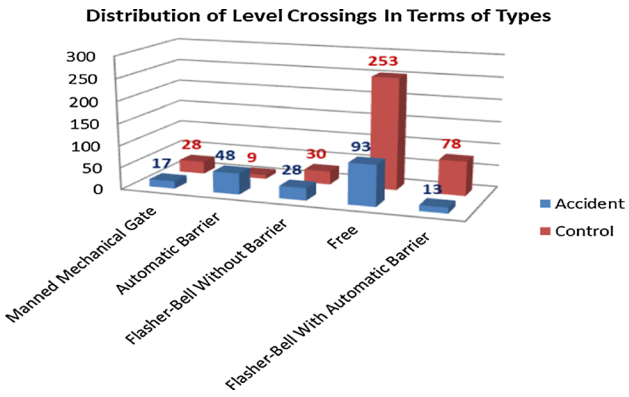
The criteria and regulations to be made in the guidelines on the measures to be taken at railway level crossings and the principles of implementation will allow the crossings to be made safer.

Acknowledgements We owe a debt of gratitude to TCDD General Directorate for sharing the statistics of accidents occurred in level crossings in this study.

Appendix 1: Distribution, percentages and graphics of categorical parameters

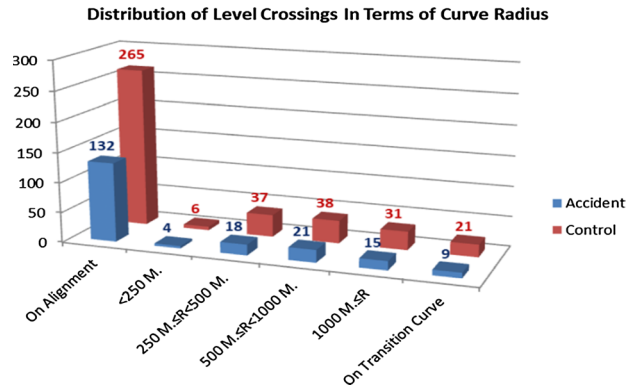
Distribution of level crossings in terms of types

Type of level crossing	Accident (n = 199)	Control (n = 398)
With manned mechanical gate	17 (8.6%)	28 (7.0%)
With automatic barrier	48 (24.1%)	9 (2.3%)
With flasher -bell without barrier	28 (14.1%)	30 (7.5%)
Free	93 (46.7%)	253 (63.6%)
With flasher -bell with automatic barrier	13 (6.5%)	78 (19.6%)

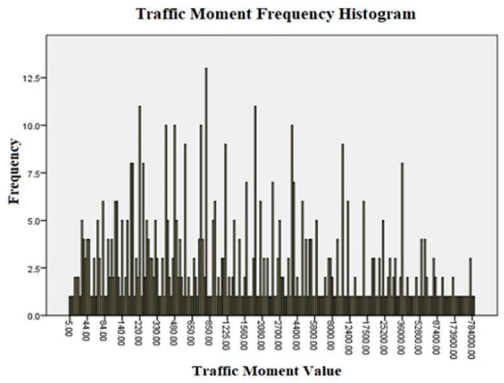


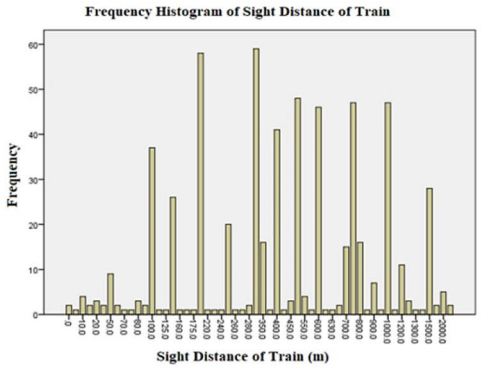
Distribution of level crossing in terms of curve radius

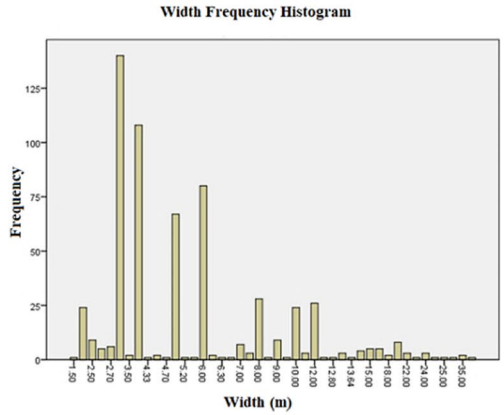
Curve radius	Accident (n = 199)	Control (n = 398)
On alignment	132 (66.3%)	265 (66.6%)
<250 M.	4 (2.0%)	6 (1.5%)
250 M.≤R<500 M.	18 (9.0%)	37 (9.3%)
500 M.≤R<1000 M.	21 (10.6%)	38 (9.5%)
1000 M.≤R	15 (7.6%)	31 (7.8%)
On transition curve	9 (4.5%)	21 (5.3%)

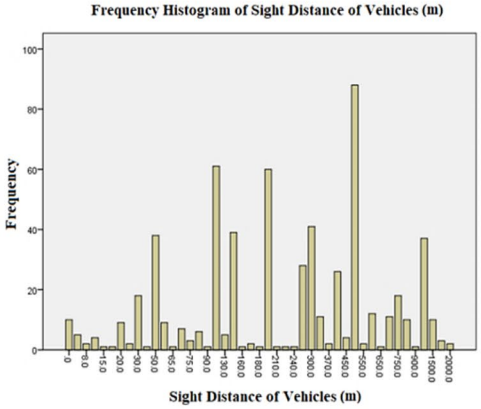


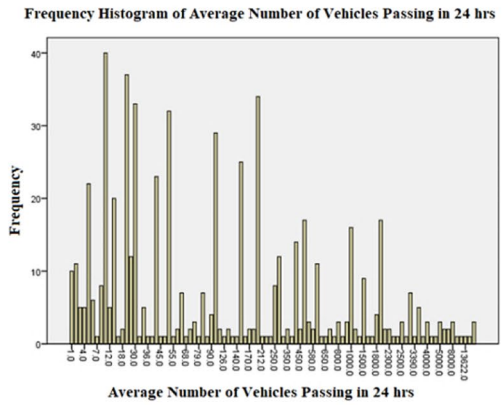
Appendix 2: Data frequency histograms

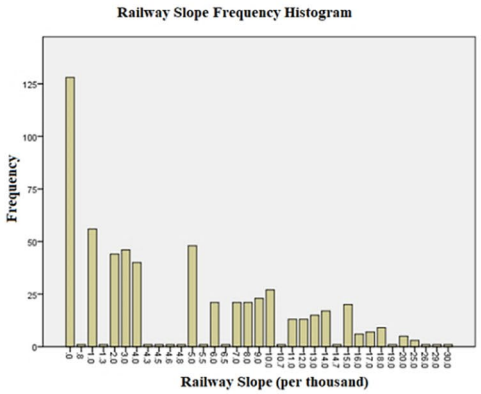


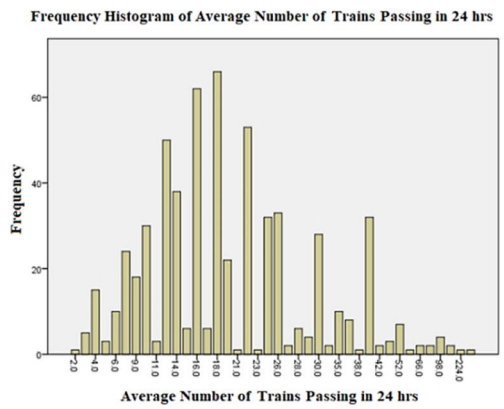


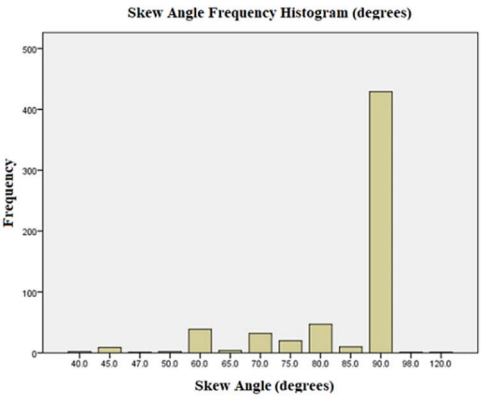












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