MODELING CRASH RISK AT RAIL-HIGHWAY
GRADE CROSSINGS

by

Soumya Sharma

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Approved by:

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Dr. Srinivas S. Pulugurtha

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Dr. Martin Kane

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Mr. David Naylor

ABSTRACT

SOUMYA SHARMA. Modeling crash risk at rail-highway grade crossings (Under the direction of DR. SRINIVAS S. PULUGURTHA)

The Federal Railroad Administration (FRA)'s Web Based Accident Prediction System (WBAPS) is used by federal, state and local agencies to get a preliminary idea on safety at a rail-highway grade crossing. It is an interactive and user friendly tool used to make funding decisions. WBAPS is almost three decades old and involves a three-step approach making it difficult to interpret the contribution of the variables included in the model. It also does not account for regional / local developments and technological advancements pertaining to signals and signs implemented at rail-highway grade crossings. Further, characteristics of rail-highway grade crossing vary by track class which is not implicitly considered by WBAPS. This research, therefore, examines and develops a method and models to estimate crashes at rail-highway grade crossing by track class using regional / local level data. The methodology and models developed for each track class as well as considering all track classes together are based on data for the state of North Carolina. Linear as well as count models based on Poisson and Negative Binomial (NB) distributions were tested for applicability. Negative binomial models were found to be the best fit for the data used in this research. Models for each track class have better goodness of fit statistics compared to model considering data for all track classes together. This is primarily because traffic, design, and operational characteristics at rail-highway grade crossings are different for each track class. The findings from statistical models in this research are well supported by model validation.

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DEDICATION

I dedicate this work to my Grandfathers, Late Mr. R. P. Sharma and Late Mr. B. P. Sharma.

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CHAPTER 1: INTRODUCTION

A rail-highway grade crossing works as an at-grade junction to allow for traffic movement between railroads and highways. These are one of the most vulnerable spatial locations in a rail transportation system. The United States has about 129,644 public crossings *(Railroad Safety Statistics, 2010)*. Data for the year 2010 show that there were 11,555 incidents at public rail-highway grade crossings in the United States. These incidents resulted in 746 deaths and 8,307 injuries *(Miller et al., 1991).* The estimated cost of a rail-highway crash is about $2.6 million *(Railroad Crossing Facts, 2013).* The Federal Rail Administration (FRA) has undertaken many measures to improve the safety at rail-highway grade crossings. The installation and maintenance of these measures is expensive. As an example, the cost of a warning device installation at each rail-highway grade crossing is about $446,000(As per dollar value of 2013 using GDP deflator and wage/earning index) (*Farr, 1987).* It is therefore crucial for the agencies to make intelligent engineering decisions and effectively prioritize implementation plans to improve safety at such conflicting locations. Successful implementation of such engineering decisions depends on current techniques to model and assess risk at rail-highway grade crossing.

1.1. Web Based Accident Prediction System (WBAPS)

The FRA provides users with an analytical tool called the Web Based Accident Prediction System (WBAPS). The intent of the tool is to help the individual states, railroads, and local highway authorities with fund allocation processes for safety improvement. WBAPS does not rank rail-highway grade crossings in the order of more dangerous to less dangerous rail-highway grade crossings. It only informs that a rail-highway grade crossingis more hazardous than other rail-highway grade crossings. The WBAPS is based on the United States Department of Transportation (USDOT) FRA accident (referred to as "crash" hereafter) prediction formula. This formula was developed in April 1968 and revised in June 1987 to address the shortcomings of previous models - Peabody Dimmick Formula, New Hampshire Index, and National Cooperative Highway Research Program (NCHRP) Hazard Index *(Farr, 1987)*. Table 1 summarizes the formulas / indices that were developed in the past.

The FRA crash prediction formula uses two broad categories of data. They are (a) basic data about a rail-highway grade crossing's physical and operating characteristics, and, (b) five years of crash history data at the rail-highway grade crossing. The basic formula was first developed using non-linear regression methods. This formula is based on the physical characteristics of the rail-highway grade crossing and is represented as follows *(Farr, 1987)*.

Table 1: Previous crash prediction formulas

Crash prediction formula	Expression	Constants	Remarks
Peabody Dimmick	$A_5 = 1.28(\frac{v^{0.17} * T^{0.151}}{p^{0.0171} + k})$	A_5 = number of expected crashes in 5 years; v = average annual daily traffic (AADT); T = average daily train traffic; P = protection coefficient indicative of warning devices present; K = additional parameter.	Developed in 1941. It is also known as the Bureau of public road formula. The formula was used for resource allocation on rail-highway crossings through the 1950s. Protection coefficients represent conditions in 1941 and are now obsolete.
New Hampshire	$HI = (V)(T)(P_f)$	HI=hazard index; V=average annual daily traffic (AADT); T=average daily train traffic; P_f=protection factor indicative of warning devices present.	Many states have significantly modified the formula that includes other factors influencing crashes.
NCHRP Hazard Index	$EA = (A)(B)(CTD)$	where EA=expected crash frequency; A=vehicles per day factor (provided in tabular format as a function of vehicles per day); B=protection factor indicative of warning devices present (crossbucks, stop signs, wigwags, flashing lights and gates); CTD=current trains per day	Developed in 1964. Two values of protection factor (B) for crossbucks, flashing lights and gates based on urban/rural environments. However urban and rural areas not defined but left to discretion of user.

$a = k \times EI \times DT \times MS \times MT \times HP \times HL$

where, a = un-normalized initial crash prediction, in crashes per year at a rail-highway grade crossing, and,

k = formula constant.

The constant "k" varies for each of the three device categories. They are:

a) For passive warning devices, k= 0.0006983

b) For flashing lights, k= 0.0003351

c) For gates, k= 0.0005745

Other related factors in the basic formulate are:

EI = Factor for exposure index based on product of highway and train traffic = $(\frac{c*t+0.2}{0.2})^{k_1}$

DT = Factor for the number of through trains per day during daylight = $(\frac{d+0.2}{0.2})^{k_2}$

MS = Factor for maximum speed of train, ms (mph) = e^{k_3*ms}

MT = Factor for the number of tracks = e^{k_4*mt}

HP = Factor for highway paved (hp=1 if yes; 0 otherwise) = $e^{k_5*(hp-1)}$

HL = Factor for the number of highway lanes, hl =$e^{k_6*(hl-1)}$

The basic formula was updated based on the un-normalized crash prediction by incorporating the crash history *(Farr, 1987)*. It is mathematically represented as follows.

$$B = \frac{T_0}{T_0+T} + \frac{T}{T_0+T}(\frac{N}{T})$$

where, T = number of years of crash history considered and $T_0 = \frac{C}{D+a}$.

N = number of accidents in T years.

C and D are constants with values 1 and 0.05, respectively.

These constants for each category of warning device are multiplied with the un-normalized crashes B to obtain the final prediction. These normalization constants are updated on a yearly basis. The normalization is done to adjust for the change in the number of rail-highway grade crossings operational, the crash frequency, and any warning device changes at the rail-highway grade crossings *(Farr, 1987)*. Table 2 summarizes the normalizing constant values for each category of warning device.

Table 2: Normalizing constants by warning device type

Category of Warning Device	Constant
Passive devices	0.8644
Flashing Lights	0.8887
Gates	0.8131

Approximately, two thirds of rail-highway grade crossings have not had a crash in the last 5 years, while 93 percent have had two or less crashes *(McCollister et. al, 2007).* The weighted formula described previously uses the crash history of rare events in order to predict crashes in future. Literature documents little to no research on comparison of FRA rail-highway crash predictions of a year and the actual numbers crashes at a rail-highway grade crossing.

The three step process of the FRA crash prediction formula includes a wide range of 128 explanatory variables but has its own shortcomings. The formula was developed almost three decades ago and has been used since without much improvement (apart from updating coefficients). This formula is used by WBAPS only to give a preliminary idea to the decision makers to allocate resources. The formula is quite complex and difficult to interpret in terms of the most influencing factors of safety at a rail-highway grade crossing. Also, WBAPS is programmed to use only specific data mentioned for generating these results. It does not take into consideration regional / local level geographic and other site-specific data such as sight-distance, highway congestion, local topography, and passenger exposure (train or vehicle) *(Farr, 1987)*.

1.2. Research Objective

The causes of crashes, driver behavior, geometric features, topographical conditions, and presence of safety devices at rail-highway grade crossings vary for one state to another in the United States. As an example, North Carolina has active warning devices at more than 50% of its public rail-highway grade crossings. Thus, the warning device criteria as in the FRA rail-highway grade crossing crash prediction formula may be of little use to identify hazardous rail-highway grade crossings in North Carolina. The formula could also be simplified if an analysis is performed and a method / model developed using state or regional-level data. Further, WBAPS does not explicitly consider track class. Since design and operational characteristics vary by track class, developing models by track class may yield more meaningful results and assist rail practitioners. This research, therefore, focuses on the development of a rail-highway crash prediction model by track class as well as considering data for all track classes. Data for the State of North Carolina is used to illustrate the method and test its validity. In addition to the data used by WBAPS, this study uses data from North Carolina Department of Transportation (NCDOT) that provides information regarding various land use characteristics.

Overall, the research uses data for a five year period for the state of North Carolina. Linear as well as count models are tested for their applicability and goodness of fit. Results and findings are based on statistical parameters and supported by model validation.

1.3. Organization of the Thesis

The remainder of this thesis is comprised of five chapters. The second chapter provides a review of literature on past research on crash prediction models to improve safety at rail-highway grade crossings. The third chapter demonstrates the methodology adopted in this research. The fourth chapter explains elaborately about the source of data, and how it has been coded for analysis. It further describes the data considered in analysis and the process for variable selection used in this study. The fifth chapter presents an analysis and discussion, whereas the methodology discussed is used to interpret the model outputs obtained for each data. The results and limitations chapter compares the WBAPS output with the output from the best model developed in this research. This chapter goes on to recommend changes to the WBAPS formula, states the limitations of the study, and described future scope of study in the area.

CHAPTER 2: LITERATURE REVIEW

There have been several studies that have proposed alternative methods for the development of crash prediction formulas for rail-highway safety improvement. Alternative crash prediction models were developed for rail-highway interface that used Negative Binomial (NB) regression (similar to FRA crash prediction formula) and were simpler due to the one step process *(Austin and Carson, 2002).*

Statistical models using data from Korea were also developed to examine the relation between crashes and characteristics of rail-highway grade crossings. Their results showed the application of Gamma probability to deal with under-dispersed crash data *(Oh et al., 2006).* The model suggested that crashes increase with an increase in total traffic volume and average daily train volume. Further, the proximity of an industrial area and the time between signal and gate activation was observed to be associated with higher crash frequencies *(Oh et al., 2006).*

The use of zero-inflated models has also been proposed to quantify the effects of factors affecting rail-highway grade crossing crashes in order to tackle data scarcity even with large number of rail-highway grade crossings *(Nam and Lee, 2006)*. An analysis using data from Taiwan was carried out to quantify crash risk at rail-highway grade crossings that used various count models such as NB, Poisson, and Zero-inflated Poisson (ZIP). The ZIP model was found to perform well over the other models *(Hu and Lee, 200).* Logistic regression was used to predict rail-highway grade crossing crashes. The model also computed the number of crossings (over time) involving low capital along with the cost of a life saved and cost of upgrading a rail-highway grade crossing with gates *(McCollister and Pflaum, 2007).* A rail-highway grade crossing crash prediction formula that aids in prioritizing signal improvements was developed using stepwise regression analysis. Results were tested by comparing actual and predicted crashes. The actual crashes were found to be 70% of the predicted crashes *(Lavette, 1977).*

Versions of FRA rail-highway grade crossing crash prediction formula were tested for their accuracy, for a 5 and 10 year forecast period. The basic formula performed better when compared to the five year crash history adjusted model *(Mutubazi and Berg, 1995).* There have also been several works on the effect of the various countermeasures on rail-highway safety. Tree-based regression models have been developed to examine the change in crash frequency at passive rail-highway grade crossings with only crossbucks. The effect of stop sign installation at these locations was also studied. Their results showed that stop-sign treatment is a more effective countermeasure to improve safety at rail-highway grade crossings *(Yan et al., 2010).*

Data mining and statistical analysis to understand the main and interaction effects of various countermeasures (such as warning devices and posted speed limit) on safety at a rail-highway grade crossing was also researched *(Park and Saccomanno, 2005).* The effect of a less explored combination of countermeasures and control measures (highway class) on crash frequency was studied using a sequential analytical strategy. This strategy combines the tree based regression stratification of data with generalized linear regression models *(Park and Saccomanno, 2005).*

A model was proposed for evaluating countermeasures for rail-highway safety that categorizes the rail-highway grade crossing inventory variables into non-linear factors which are scored. These scores were used to cluster rail-highway grade crossings and then develop a separate model for each cluster with explanatory variables relevant to that cluster *(Saccomanno and Lai, 2005).* Bayesian data fusion method was used to tackle the problem of sparse crash data when evaluating countermeasure effectiveness. The method used previous research inferences for countermeasure effectiveness along with a calibrated model of the study area to finally give collision response and probability distribution for a particular countermeasure *(Saccomanno et al., 2007).*

Measures of effectiveness were developed for the three categories of rail-highway grade crossing update categories viz. passive systems to flashing lights on single track, passive systems to gates on single and multiple tracks, and flashing lights to gates on single and multiple track. In the past, researchers also examined the effect of characteristics such as variation in train speed on warning device performance. Results were similar to previous findings for the two categories except for the upgrade from flashing lights to gates on single and multiple tracks; effects being more for single track than multiple track. Train speed variation did not have much influence on effectiveness *(Eck and Halkias, 1985).*

NB model was found to be the best fit to the data to identify rail-highway grade crossing black-spots for three categories of warning devices (passive, flashing lights, and gates). A spatial distribution of black-spots on the basis of warning devices, previous crash history, and location was also examined in the past *(Saccomanno et al., 2004).*

While some new models for rail-highway crash prediction were developed, past research did not account for local factors such as geographic location or topography, which influence the crash trends to a great extent. The States (California, Texas, Illinois, Georgia, and New York) that have been chosen for research in the past are usually the ones with high train traffic. When such studies are conducted, often the geographic factors are overlooked. In this case, there may be certain variables that could not be accounted for due to data from States with diverse geographic patterns. This study aims at developing an approach to predict crashes at rail-highway grade crossing. Also, unlike most of the prediction models developed so far, the models developed in the study do not make use of crash history information. This is mainly because crashes at rail-highway grade crossings are sparse, which makes them of little use when predicting crashes in future.

Regional developments and geographic conditions play a role on risk at rail-highway grade crossings. Funds available and countermeasures implemented at rail-highway grade crossing also vary based train activity-levels and track design characteristics. Analyzing and modeling by track class could yield better results rather than developing models considering data for all track classes in a region. This research addresses the aforementioned aspects to add to the current state of knowledge on safety at rail-highway grade crossings.

CHAPTER 3: METHODOLOGY

The methodology to model crash risk at rail-highway grade crossings is comprised of five steps. Each of those steps is discussed next in detail.

3.1. Selection of Rail-road Crossings and Data

The selection of rail-highway grade crossings need to be performed so as to have the best representative sample of the population of all the rail-highway grade crossings in the study region. In case of scarce data, locations with both zero and non-zero crashes could be chosen. Another process to create a representative sample is choosing rail-highway grade crossings to represent all the categories of existing crossings based on track characteristics such as "track class." This representative sample was used in this research.

3.2. Selection of Explanatory Variables

The explanatory variables considered essentially should represent the characteristics of the highway, rail-track and the types of warning devices at the rail-highway grade crossings. The study tries not to use minimal warning device variables so as to avoid endogeneity, which means that the cause of crashes are the reason a particular warning device is installed at a rail-highway grade crossing. The selection of the variables in this research is mainly based on the correlations between the variables and the dependent variable ("crashes per five years") and amongst the other variables considered in the model.

3.3. Development Crash Risk Estimation Models

The dependent variable for all the models is the "number of crashes per five years" at a rail highway grade crossing. Both crash count and scale models need to be explored. The reason for considering count models is mainly due to their output; which is in terms of absolute number of crashes at a rail-highway grade crossing. If such an output is generated, it will be superior as compared to the decimal value output of 'predicted collisions in a year' by the WBAPS. The Poison, NB and Gamma models are the popular count models. While count models provide a sensible output, they suffer from certain limitations. The Poisson model assumes the mean and variance to be equal, while the NB model is capable of handling data with variance greater than the mean (over- dispersed). The Gamma model, however, is capable of dealing with both over-dispersed and under-dispersed data. In this study, the analysis is done using the SPSS software, in which the Gamma model excludes the zeroes in the dependent variable while modeling. As both the zero as well as non-zero values of the dependent variable are crucial, the use of a Gamma model has been avoided in the study.

When the data is such that there is under-dispersion, the count models considered in the study might not prove to be the best fit and other models, such as scale models, need to be explored. The crash data is seldom found to be normal and over-dispersion is highly common. Many researchers therefore considered zero inflated models when studying crash data. The zero inflated Poison models assume that the extra zeroes are generated by a group that has zero probability of generating an output greater than zero *(Paul Allison, 2012)*. The zero inflated NB model could be a special case of the NB model, and the difference in performance might be trivial *(Paul Allison, 2012)*. For these reasons, the generalized linear models have also been used in the study. This is mainly due to the flexibility provided by the generalized linear models under which the data can have a non-normal distribution. It is an extension of the general linear model under which the dependent variable is linearly related to the explanatory variables through a link function.

There are mainly three components of a count model (Saccamano et al. 2005; Saccamano et al. 2007):

Random Component: The random component gives the distribution of the response or dependent variable. Each observation is assumed independent of each other.

Systematic Component: It specifies the linear predictor of the model in which the explanatory variables are expressed in a linear fashion.

$\alpha+\beta_1 x_1+\beta_2 x_2+\cdots\ldots\ldots\ldots\ldots+\beta_n x_n$

Link Function: It links the random component to the systematic component (linear predictor) by representing the linear predictor as a function of mean of the explanatory variable (say, Y). $g(\mu)=\eta_i \ \alpha+\beta_1 x_1+\beta_2 x_2+\cdots\ldots\ldots+\beta_n x_n$

There are many types of link functions which can be used viz. identity, Log, Logit, Probit, Exponential, and Inverse. The Poisson regression is usually a good modeling starting point as crash data are often approximately Poisson distributed. When data is found to be over-dispersed i.e., mean is lesser than crash variance, the NB distribution would be more appropriate. Therefore, these two types of distributions were explored in addition to linear model in order to examine the relation between the number crashes per five years and various explanatory variables that are not correlated to each other. Multiple regression model was not considered owing to the discrete and nonnegative nature of the data.

3.4. Goodness of Fit Parameters

The following statistical parameters were used to assess the goodness of fit (Wikipedia Encyclopedia, 2014).

3.4.1. Akaike's Information Criterion (AIC)

It is used to measure the quality of various statistical models developed from the same data. The statistic provides an estimate of the information that has been lost as a result of using a particular model that generates the data. Given a set of candidate models for the data, the best model is the one with the minimum AIC value.

3.4.2. Corrected Akaike's Information Criterion (AICC)

It provides the corrected value of AIC, for a finite sample size. It is recommended that the AICC be preferred over just AIC as it tends to overfit the results i.e., there may be too many parameters in the model. Usually, only the difference between AIC and AICC is the most crucial and should be as low as possible.

3.4.3. Deviance

This statistic is also used to test the quality of fit of a model. This term is analogous to the "likelihood estimate", which uses least squares for testing model fit. In general, the model with lower value of deviance is considered as the best model.

3.4.4. Likelihood Chi-square Value

This is used to test the model against a null model. The Chi-square value, if lesser than the critical value or if the p value of the statistic is significant, indicates that the model is better than the null model. Here, the p-value is checked for in the models to be significant.

3.5. Validation of Models

The best fitting model was then validated using data set aside for model validation (not used for model development). The number of crashes at each of the rail-highway grade crossings were computed and compared with the actual number of crashes. To test the predictability of models compared to WBAPS, the number of crashes were compared to the analogous term “number of collisions per year” from the WBAPS output.

A t-test was then conducted in order to check if the two groups of data belong to same population or not. The null hypothesis is that the two groups being tested are statistically different while the alternate hypothesis is that the two groups are not statistically different. The null hypothesis cannot be rejected if the P-value is less than 0.05 (at a 95% confidence level).

CHAPTER 4: DATA, RAIL-HIGHWAY GRADE CROSSINGS AND VARIABLE SELECTION

4.1 Data and Selection of Rail-Highway Grade Crossings

The data for this study includes two databases: (i) The FRA Office of Safety rail-highway grade crossing inventory, and, (ii) The FRA Office of Safety crash/incident database, both for the state of North Carolina. The rail-highway grade crossing inventory provides site specific details of the rail-highway crossing and highway characteristics - the number of daily through trains, warning devices, annual average daily traffic (AADT), and posted highway speed limit. The crash history data is available for each year. This database includes details of each incident at any of the operational rail-highway grade crossing in that year. The database also includes the type of railway equipment involved in the crash (freight train, passenger train, and inspection car) and the circumstance of crash (if the rail-user was struck by the train or vice-versa). Crash history for the past five years (2009, 2010, 2011, 2012 and 2013) was considered to develop models in this research. Only rail-highway grade crossing where conditions remained same over this five-year period were selected for analysis and modeling.

The rail-highway grade crossings were identified using the unique rail-highway grade crossing ID number. This number is a common element in both the databases. The rail-highway grade crossing ID was used to merge the rail-highway grade crossing inventory data with the crash frequency information from crash/incident database to generate a database that was used for further analysis. Almost 97% of rail-highway grade crossings have warning devices installed at them. In such a case, including variables related to warning devices may pose endogeneity issues. This issue (simultaneity) arises when a variable X causes the dependent variable Y and vice versa. No matter how many control variables are included in the model, this problem might never get addressed. In this study, it would imply that the presence of warning devices may result in zero crashes (which is the frequency of crashes found in abundance at rail-highway grade crossings) and the zero crashes are caused at a rail-highway grade crossing due to the warning devices installed at these locations. Hence, warning device variables were avoided from being included in the models as far as possible. They also were observed to be correlated to other variables considered for modeling in this research.

Since WBAPS provides crash prediction for only public at-grade rail-highway grade crossings, the data thus obtained was further refined for the modeling process. The rail-highway grade crossing inventory has variables that describe the type of rail-highway grade crossing (private, public, and pedestrian) and its position (at-grade, under-railroad or over-railroad). A pedestrian crossing is one that is dedicated to non-vehicular traffic such as a recreational pathway (trail) or a rail-highway grade crossing at a passenger station for passengers to use when crossing from one side of the station to the other side. This does not include sidewalks that are associated with roadways. A private rail-highway grade crossing is one where the approaches on both sides of the rail-highway grade crossing are not owned and maintained by a public authority. At least one approach is owned by a private individual or company. A private rail-highway grade crossing is seldom open to the public. On a public rail-highway grade crossing, both approaches are owned and maintained by a public authority and rail-highway grade crossing is open to the general public.

Apart from the above criteria, the rail-highway grade crossing inventory also provides the reason of rail-highway grade crossing information update, which could either be a new rail-highway grade crossing being built, a warning device change, or a closed/ abandoned rail-highway grade crossing. All rail-highway grade crossings which did not have data for a five-year period were removed from the database and further analysis. In addition, only public and at-grade rail-highway grade crossings were retained in the database.

The data had certain variables that were categorical in nature. For example, “highway near crossing” had four fields - less than 75 ft, 75 to 200 ft, 200 to 500 ft, and no highway nearby. These variables were reduced to indicator variables i.e., one variable for each of the four fields. Also, AADT was converted to a rate of per 10,000 vehicles. All of the continuous variables were used in the analysis without any changes. Even after making all the above stated adjustments, the data still remained abundant with mostly zero crashes. This made it difficult to obtain any significant variables. In order to solve this issue, the data was used to prepare three different types of sample sets.

4.1.1. Data Based on Track Class

Data was classified into smaller sets based on track class. The FRA has defined operating speed limits for trains on each track class *(Code of Federal Regulations, 2014)*, according to which track classes were classified as per the following Table 3.

For the purpose of this research, the maximum time table speed of train was used as the operating speed of the train on each track class. Based on FRA guidelines, the following range of train time table speed were used for track classification: 0-10 mph -

Track class 1; 10-25 mph - Track class 2; 25-40 mph - Track class 3; 40-60 mph - Track class 4; 60-80 mph - Track class 5.

The track quality increases as the track class increases i.e., track class 1 being the most inferior of all the tracks types and track class 6 being the most superior. Data was segregated based on each track class, forming five subsets; one for each class. The data set had 681 rail-highway grade crossings in track class 1, 1,432 rail-highway grade crossings in track class 2, 870 rail-highway grade crossings in track class 3, 656 rail-highway grade crossings in track class 4, and 133 rail-highway grade crossings in track class 5. Data for validation purposes was set aside by randomly selecting 20% of the data from each track class.

Table 3: Track classification based on operating speed of train

Operating Speed	Track Class
0-10 mph	1
10-25 mph	2
25-40 mph	3
40-60 mph	4
60-80 mph	5
80-110 mph	6

4.1.2. All Track Class Data

The data from all track classes was combined for comparing the results for each track class with model results for data with all track classes taken together. This data was developed essentially to study the effect of track class on crash trends. If the model so developed proved to be better (based on statistical parameters) then it can be said that track class (track and rail-highway grade crossing design characteristics) do not have effect on crashes and risk at rail-highway grade crossing.

4.2. Variable Selection

Table 4 summarizes the list of variables considered in this research. The correlation between these variables was examined by constructing a Pearson correlation matrix. The maximum train time table speed was considered as a key variable influencing safety and risk at rail-highway grade crossing. The maximum train time table speed was included in the analysis and modeling process for the model considering data for all rail-highway crossings. The number of main tracks and AADT were also forced into this model. However, maximum train time table speed was not forced into model for each track class as the track class is based on maximum train time table speed. The AADT and/or number of main tracks were selected as key variables influencing safety risk at rail-highway grade crossing in this case. The variables that were found not to be correlated to the key variables were identified and used in the development of models.

Overall, modeling was carried on with only variables that were not correlated with each other. In cases where key variables were not found to be correlated to crashes (say, track Class 2) the other variables such as the number of traffic lanes and percentage of trucks were chosen as they are close indicators of AADT.

Correlated variables are highlighted in the tables, showing that they are significantly correlated (at a 95% confidence interval) to each other and hence cannot be included in the model at the same time. The matrices are related to three categories of variables i.e., the highway and rail track operational characteristics (AADT, number of main tracks, etc.), warning device characteristics (number of gates, number of crossbucks, etc.) and area characteristics (open, residential, institutional, highway within 75 feet, etc.).

Table 4: List of variables considered for analysis and modeling

CROSSING	crossing ID
Crashes	# of Crashes
LTM	Less than one train movement per day 1= yes, 0=no
MTS	Maximum time table speed
TRKCLS	Track class (1-5)
MNS	Minimum train speed
MTK	# of Main tracks
OTK	# of Other tracks
WDCD	Warning device code 1= no signs or signals, 2= other signs or signals, 3= crossbucks, 4= stop signs, 5 = special active warning devices, 6= wigwags ,bells 7= flashing lights, 8= all other gates (two and three quadrant gates*), 9= four quad (full barrier) gates
BL	# of Bells
NS	If there are no signs on the crossing 1= no signs or signals, 0= at least one sign or signal
SGEQ	Is track equipped with train signals 1= yes, 0= no
OS	Development type open 1=yes, 0= no
RS	Development type residential 1= yes, 0 =no
COM	Development type commercial 1=yes, 0 =no
INDUS	Development type industrial 1=yes, 0= no
INST	Development type institutional 1=yes, 0=no
STPL	If stop lines are present 1= yes, 0= no
RRX	If rail road crossing symbol is present 1= yes, 0 = no
NMK	If there are no pavement markings 1= yes, 0 = no
STPL	If there are stop lines and rail road crossing signals 1= yes, 0 = no
L75	If highway is less than 75 ft away 1= yes, 0 =no
B200-500	If highway is in the vicinity of 200 to 500 feet 1= yes, 0 = no
B75-200	If highway is in the vicinity of 75ft to 200 feet 1=yes, 0 =no
NHWY	If there is no highway nearby 1= yes, 0 = no
TRFLN	# of Traffic lanes
STHWY	Is crossing on state highway? 1 = yes, 0 = no
AADT	Average annual daily traffic
PCTRK	% truck traffic
SCHLB	Average number of school buses passing through the crossing on a school day
WHISTB	If there is a whistle ban 1= 24hr, 0= no ban
TTRN	Total number of trains
TSWT	Total number of switching trains
XBUCK	# of Crossbucks
GT	# Gates
FLP	# of Flashing light pairs
HWYSP	Posted highway speed limit

*Three quadrant gates: gates at rail-highway grade crossing along with a median on the approach to the rail-highway grade crossing that only has a gate on the entrance lane.

4.2.1. Correlation Matrix Based on All Track Class Data

Tables 5 (a) to (f) show the correlations between variables considering data for all the selected rail-highway grade crossings. The correlated variables are highlighted in bold in the table, showing that they are significantly correlated (at 95% confidence interval) and hence cannot be included with each other in the model based on all track class data. Based on these correlations number of main track and posted highway speed limit were selected to be included in developing the models for all track class data. These numbers of main tracks and posted highway speed are not correlated to each other and represent the characteristics of the highway and rail-track at a particular rail- highway grade crossing.

Table 5 (a): Correlation matrix based on all track class data

Variable	LTM	MTS	TRKCLS	MTK	OTK	TRFLN	AADT	PCTRK	SCHLB	WHISTB	TTRN	TSWT
Crashes	**-.063**	**.154**	**.140**	**.171**	0.015	**.086**	**.071**	0.012	-0.001	0.033	**.222**	**.084**
LTM	1	**-.328**	**-.343**	**-.192**	0.003	0.002	0.009	**.063**	0.017	-0.027	**-.354**	**-.267**
MTS	**-.328**	1	**.963**	**.392**	**-.043**	**-.068**	**-.076**	**-.055**	**-.043**	-0.012	**.582**	**.048**
TRKCLS	**-.343**	**.963**	1	**.359**	**-.038**	**-.059**	**-.069**	**-.041**	-0.032	-0.01	**.545**	**.049**
MTK	**-.192**	**.392**	**.359**	1	**-.122**	-0.032	**-.058**	**-.102**	-0.013	**.071**	**.344**	**-.063**
OTK	0.003	**-.043**	**-.038**	**-.122**	1	0.001	0.011	0.015	-0.011	-0.003	**.068**	**.142**
TRFLN	0.002	**-.068**	**-.059**	-0.032	0.001	1	**.670**	**.060**	**.153**	-0.001	0.007	**.066**
AADT	0.009	**-.076**	**-.069**	**-.058**	0.011	**.670**	1	**.067**	**.239**	0.007	0.018	**.066**
PCTRK	**.063**	**-.055**	**-.041**	**-.102**	0.015	**.060**	**.067**	1	0.005	0.005	**-.065**	0.028
SCHLB	0.017	**-.043**	-0.032	-0.013	-0.011	**.153**	**.239**	0.005	1	0.002	**-.049**	**.051**
WHISTB	-0.027	-0.012	-0.01	**.071**	-0.003	-0.001	0.007	0.005	0.002	1	**.073**	**.043**
TTRN	**-.354**	**.582**	**.545**	**.344**	**.068**	0.007	0.018	**-.065**	**-.049**	**.073**	1	**.484**
TSWT	**-.267**	**.048**	**.049**	**-.063**	**.142**	**.066**	**.066**	0.028	**.051**	**.043**	**.484**	1
HWYSP	0.032	0.035	0.031	-0.032	**-.111**	-0.03	**-.074**	0.032	**-.054**	**-.047**	**-.113**	**-.117**
WDCD	**-.170**	**.334**	**.323**	**.200**	0	**.198**	**.258**	0.016	**.137**	0.011	**.283**	**.111**
BL	**-.111**	**.227**	**.212**	**.168**	0.008	**.241**	**.280**	0.026	**.147**	0.023	**.182**	**.092**

Table 5 (b): Correlation matrix based on all track class data

Variable	HWYSP	WDCD	BL	NS	SGEQ	XBUCK	GT	FLP	STPL	RRX	NMK	NHWY
Crashes	**-.046**	**.079**	**.054**	-0.022	**.154**	**-.051**	**.120**	**.137**	0.009	0.016	**-.039**	**-.047**
LTM	0.032	**-.170**	**-.111**	0.001	**-.177**	0.006	**-.183**	**-.145**	0.031	-0.016	**.048**	**.045**
MTS	0.035	**.334**	**.227**	**-.088**	**.501**	**-.090**	**.410**	**.225**	-0.031	0.008	**-.114**	-0.015
TRKCLS	0.031	**.323**	**.212**	**-.065**	**.489**	**-.059**	**.388**	**.222**	-0.029	0.007	**-.102**	-0.033
MTK	-0.032	**.200**	**.168**	**-.109**	**.247**	**-.039**	**.253**	**.174**	-0.033	-0.033	**-.045**	**-.046**
OTK	**-.111**	0	0.008	0.033	**.054**	0.009	0.013	0.01	0.007	0.009	0.03	0.001
TRFLN	-0.03	**.198**	**.241**	**-.060**	**-.038**	0.013	**.158**	**.494**	-0.02	-0.027	**-.177**	**-.060**
AADT	**-.074**	**.258**	**.280**	**-.043**	-0.008	**-.045**	**.212**	**.449**	-0.022	-0.02	**-.190**	**-.070**
PCTRK	0.032	0.016	0.026	0.004	**-.050**	-0.021	-0.011	0.028	0.025	-0.004	-0.024	0.018
SCHLB	**-.054**	**.137**	**.147**	**-.048**	**-.054**	**-.054**	**.095**	**.174**	-0.034	-0.014	**-.105**	**-.180**
WHISTB	**-.047**	0.011	0.023	0.03	0.006	-0.03	-0.014	0.006	-0.012	-0.011	**.049**	-0.012
TTRN	**-.113**	**.283**	**.182**	**-.043**	**.520**	**-.130**	**.345**	**.228**	-0.013	0.026	**-.066**	**-.050**
TSWT	**-.117**	**.111**	**.092**	-0.013	**.134**	**-.071**	**.098**	**.117**	-0.009	-0.001	**-.065**	**-.053**
HWYSP	1	**.055**	**.050**	-0.035	-0.008	0.014	**.050**	**-.048**	**-.036**	**-.069**	**-.203**	**.240**
WDCD	**.055**	1	**.794**	**-.364**	**.235**	**-.192**	**.828**	**.776**	**-.045**	-0.029	**-.422**	-0.02
BL	**.050**	**.794**	1	**-.191**	**.189**	**-.190**	**.647**	**.725**	**-.052**	-0.033	**-.339**	-0.032

Table 5 (c): Correlation matrix based on all track class data

Variable	STPLX	STHWY	OS	RES	COM	INDUS	INST	L75	B200-500	B75-200
Crashes	0.023	-0.034	**-.041**	**-.044**	**.042**	0.029	0.011	**.068**	-0.005	-0.005
LTM	**-.050**	-0.035	**.042**	**-.039**	-0.033	**.038**	0.021	**-.100**	0.03	0.03
MTS	**.111**	**.116**	**.067**	0.019	0.013	**-.074**	-0.028	**.106**	**-.082**	**-.082**
TRKCLS	**.100**	**.114**	**.064**	0.01	0.027	**-.075**	-0.034	**.104**	**-.072**	**-.072**
MTK	**.069**	-0.009	-0.002	**.057**	**.070**	**-.142**	0.012	**.138**	**-.068**	**-.068**
OTK	-0.033	**-.134**	**-.071**	**-.089**	0.018	**.141**	-0.021	-0.022	0.019	0.019
TRFLN	**.175**	**.049**	**-.098**	**-.184**	**.258**	-0.021	0.034	0.005	**.063**	**.063**
AADT	**.185**	**.098**	**-.137**	**-.245**	**.321**	0.014	0.017	-0.017	**.065**	**.065**
PCTRK	0.011	0.009	0.013	**-.104**	-0.012	**.128**	-0.024	**-.063**	0.018	0.018
SCHLB	**.114**	**.049**	**-.049**	**-.037**	**.096**	**-.048**	**.047**	-0.008	**.126**	**.126**
WHISTB	-0.032	**-.061**	-0.021	**-.039**	**.086**	-0.032	-0.011	0.011	0.009	0.009
TTRN	**.053**	**-.046**	**-.036**	**-.068**	**.046**	**.057**	-0.012	**.092**	**-.043**	**-.043**
TSWT	**.062**	**-.139**	**-.071**	**-.116**	0.01	**.166**	0.012	-0.006	0.036	0.036
HWYSP	**.224**	**.469**	**.381**	**.094**	**-.281**	**-.069**	**-.040**	**-.197**	**-.073**	**-.073**
WDCD	**.402**	**.204**	-0.027	**-.105**	**.101**	0.012	0.028	-0.035	0.025	0.025
BL	**.335**	**.188**	-0.034	**-.118**	**.112**	0.018	0.033	-0.016	0.007	0.007

Table 5 (d): Correlation matrix based on all track class data

Variable	LTM	MTS	TRKCLS	MTK	OTK	TRFLN	AADT	PCTRK	SCHLB	WHISTB	TTRN	TSWT
NS	0.001	**-.088**	**-.065**	**-.109**	0.033	**-.060**	**-.043**	0.004	**-.048**	0.03	**-.043**	-0.013
SGEQ	**-.177**	**.501**	**.489**	**.247**	**.054**	**-.038**	-0.008	**-.050**	**-.054**	0.006	**.520**	**.134**
XBUCK	0.006	**-.090**	**-.059**	**-.039**	0.009	0.013	**-.045**	-0.021	**-.054**	-0.03	**-.130**	**-.071**
GT	**-.183**	**.410**	**.388**	**.253**	0.013	**.158**	**.212**	-0.011	**.095**	-0.014	**.345**	**.098**
FLP	**-.145**	**.225**	**.222**	**.174**	0.01	**.494**	**.449**	0.028	**.174**	0.006	**.228**	**.117**
STPL	0.031	-0.031	-0.029	-0.033	0.007	-0.02	-0.022	0.025	-0.034	-0.012	-0.013	-0.009
RRX	-0.016	0.008	0.007	-0.033	0.009	-0.027	-0.02	-0.004	-0.014	-0.011	0.026	-0.001
NHWY	**.045**	-0.015	-0.033	**-.046**	0.001	**-.060**	**-.070**	0.018	**-.180**	-0.012	**-.050**	**-.053**
NMK	**.048**	**-.114**	**-.102**	**-.045**	0.03	**-.177**	**-.190**	-0.024	**-.105**	**.049**	**-.066**	**-.065**
STPLX	**-.050**	**.111**	**.100**	**.069**	-0.033	**.175**	**.185**	0.011	**.114**	-0.032	**.053**	**.062**
STHWY	-0.035	**.116**	**.114**	-0.009	**-.134**	**.049**	**.098**	0.009	**.049**	**-.061**	**-.046**	**-.139**
OS	**.042**	**.067**	**.064**	-0.002	**-.071**	**-.098**	**-.137**	0.013	**-.049**	-0.021	**-.036**	**-.071**
RES	**-.039**	0.019	0.01	**.057**	**-.089**	**-.184**	**-.245**	**-.104**	**-.037**	**-.039**	**-.068**	**-.116**
COM	-0.033	0.013	0.027	**.070**	0.018	**.258**	**.321**	-0.012	**.096**	**.086**	**.046**	0.01
INDUS	**.038**	**-.074**	**-.075**	**-.142**	**.141**	-0.021	0.014	**.128**	**-.048**	-0.032	**.057**	**.166**
INST	0.021	-0.028	-0.034	0.012	-0.021	0.034	0.017	-0.024	**.047**	-0.011	-0.012	0.012
L75	**-.100**	**.106**	**.104**	**.138**	-0.022	0.005	-0.017	**-.063**	-0.008	0.011	**.092**	-0.006
B200-500	0.03	**-.082**	**-.072**	**-.068**	0.019	**.063**	**.065**	0.018	**.126**	0.009	**-.043**	0.036
B75-200	0.03	**-.082**	**-.072**	**-.068**	0.019	**.063**	**.065**	0.018	**.126**	0.009	**-.043**	0.036

Table 5 (e): Correlation matrix based on all track class data

Variable	HWYSP	WDCD	BL	NS	SGEQ	XBUCK	GT	FLP	STPL	RRX	NMK	NHWY
NS	-0.035	**-.364**	**-.191**	1	**-.055**	**-.192**	**-.177**	**-.185**	0.013	-0.005	**.196**	**-.043**
SGEQ	-0.008	**.235**	**.189**	**-.055**	1	0.017	**.261**	**.160**	-0.027	**.044**	**-.049**	0.018
XBUCK	0.014	**-.192**	**-.190**	**-.192**	0.017	1	**-.178**	**-.147**	0.025	0.023	**.049**	**.054**
GT	**.050**	**.828**	**.647**	**-.177**	**.261**	**-.178**	1	**.655**	**-.051**	-0.028	**-.349**	-0.03
FLP	**-.048**	**.776**	**.725**	**-.185**	**.160**	**-.147**	**.655**	1	**-.047**	-0.026	**-.342**	**-.103**
STPL	**-.036**	**-.045**	**-.052**	0.013	-0.027	0.025	**-.051**	**-.047**	1	**-.041**	**-.098**	-0.02
RRX	**-.069**	-0.029	-0.033	-0.005	**.044**	0.023	-0.028	-0.026	**-.041**	1	**-.090**	**-.051**
NHWY	**.240**	-0.02	-0.032	**-.043**	0.018	**.054**	-0.03	**-.103**	-0.02	**-.051**	-0.021	1
NMK	**-.203**	**-.422**	**-.339**	**.196**	**-.049**	**.049**	**-.349**	**-.342**	**-.098**	**-.090**	1	-0.021
STPLX	**.224**	**.402**	**.335**	**-.175**	**.036**	**-.064**	**.341**	**.332**	**-.360**	**-.331**	**-.790**	**.050**
STHWY	**.469**	**.204**	**.188**	**-.048**	0.033	-0.015	**.169**	**.142**	**-.063**	**-.106**	**-.340**	**.150**
OS	**.381**	-0.027	-0.034	-0.013	0.021	-0.01	-0.024	**-.099**	0.005	**-.049**	-0.031	**.213**
RES	**.094**	**-.105**	**-.118**	**-.057**	-0.029	**.063**	**-.098**	**-.177**	-0.012	0.002	**.059**	**.043**
COM	**-.281**	**.101**	**.112**	0.026	0.024	-0.03	**.075**	**.217**	-0.013	-0.007	-0.027	**-.193**
INDUS	**-.069**	0.012	0.018	**.057**	0.009	-0.034	0.031	0.008	0.022	**.050**	-0.002	0.012
INST	**-.040**	0.028	0.033	-0.029	**-.045**	0.012	0.029	**.054**	0.005	-0.018	-0.022	-0.023
L75	**-.197**	-0.035	-0.016	0.035	0.015	-0.021	-0.028	**.071**	**.043**	**.053**	**.076**	**-.536**
B200-500	**-.073**	0.025	0.007	0.002	**-.059**	0.005	**.037**	**.038**	-0.002	0.011	-0.014	**-.265**
B75-200	**-.073**	0.025	0.007	0.002	**-.059**	0.005	**.037**	**.038**	-0.002	0.011	-0.014	**-.265**

Table 5 (f): Correlation matrix based on all track class data

Variable	STPLX	STHWY	OS	RES	COM	INDUS	INST	L75	B200-500	B75-200
NS	**-.175**	**-.048**	-0.013	**-.057**	0.026	**.057**	-0.029	0.035	0.002	0.002
SGEQ	**.036**	0.033	0.021	-0.029	0.024	0.009	**-.045**	0.015	**-.059**	**-.059**
XBUCK	**-.064**	-0.015	-0.01	**.063**	-0.03	-0.034	0.012	-0.021	0.005	0.005
GT	**.341**	**.169**	-0.024	**-.098**	**.075**	0.031	0.029	-0.028	**.037**	**.037**
FLP	**.332**	**.142**	**-.099**	**-.177**	**.217**	0.008	**.054**	**.071**	**.038**	**.038**
STPL	**-.360**	**-.063**	0.005	-0.012	-0.013	0.022	0.005	**.043**	-0.002	-0.002
RRX	**-.331**	**-.106**	**-.049**	0.002	-0.007	**.050**	-0.018	**.053**	0.011	0.011
NHWY	**.050**	**.150**	**.213**	**.043**	**-.193**	0.012	-0.023	**-.536**	**-.265**	**-.265**
NMK	**-.790**	**-.340**	-0.031	**.059**	-0.027	-0.002	-0.022	**.076**	-0.014	-0.014
STPLX	1	**.372**	**.045**	**-.047**	0.032	-0.03	0.024	**-.109**	0.008	0.008
STHWY	**.372**	1	**.209**	0.034	**-.040**	**-.149**	-0.012	**-.100**	**-.047**	**-.047**
OS	**.045**	**.209**	1	**-.243**	**-.244**	**-.200**	**-.070**	**-.160**	**-.073**	**-.073**
RES	**-.047**	0.034	**-.243**	1	**-.446**	**-.365**	**-.127**	0.01	-0.029	-0.029
COM	0.032	**-.040**	**-.244**	**-.446**	1	**-.366**	**-.128**	**.167**	**.051**	**.051**
INDUS	-0.03	**-.149**	**-.200**	**-.365**	**-.366**	1	**-.104**	**-.080**	0.014	0.014
INST	0.024	-0.012	**-.070**	**-.127**	**-.128**	**-.104**	1	0.019	**.040**	**.040**
L75	**-.109**	**-.100**	**-.160**	0.01	**.167**	**-.080**	0.019	1	**-.342**	**-.342**
B200-500	0.008	**-.047**	**-.073**	-0.029	**.051**	0.014	**.040**	**-.342**	1	**1.000**
B75-200	0.008	**-.047**	**-.073**	-0.029	**.051**	0.014	**.040**	**-.342**	**1.000**	1

4.2.2. Correlation Matrices by Track Class Data

Tables 6 (a) through 10 (b) show correlation between variables for each track class. The numbers highlighted in the tables indicate that the corresponding two variables are not correlated to each other. For track classes 1, 3, 4 and, 5 variables such as AADT, the number of main tracks, the number of traffic lanes, and no highway nearby are not correlated and could be considered for modeling. These variables are usually easily available and less prone to incorrect or missing values due to manual errors in data collection. For track class 2, variables such as the number of main tracks and total trains were not included in the final set of variables. These rail track characteristics along with AADT were not found to be affecting crashes in a significant manner in this class. Variables such as the percentage of trucks and presence of stop lines (if stop lines are present) were selected along with the number of traffic lanes for developing models for track class 2.The highest number of rail-highway grade crossings has this track class. There is a good mix of all types of crossings characteristics that are present in this class.

The study tries not to focus much on warning devices. However, in this case the warning devices might be the only category, which show a clear separation in crash trends in this track class. Also, the number of traffic lanes was found to be a significant contributor to the model. Table 10 summarizes the key variables selected to develop models for each track class.

Table 6 (a): Correlation matrix based on track class 1 data

Variable	LTM	MTS	MTK	OTK	WDCD	BL	NS
Crashes	-0.019	0.043	0.053	0.006	0.024	0.049	-0.034
LTM	1	0.067	-0.026	**-0.085**	**-0.217**	**-0.196**	-0.012
MTS	0.067	1	**0.192**	**-0.107**	-0.001	-0.027	-0.07
MTK	-0.026	**0.192**	1	**-0.486**	**0.188**	**0.175**	**-0.162**
OTK	**-0.085**	**-0.107**	**-0.486**	1	**-0.1**	**-0.088**	**0.225**
WDCD	**-0.217**	-0.001	**0.188**	**-0.1**	1	**0.821**	**-0.439**
BL	**-0.196**	-0.027	**0.175**	**-0.088**	**0.821**	1	**-0.211**
NS	-0.012	-0.07	**-0.162**	**0.225**	**-0.439**	**-0.211**	1
SGEQ	0.006	-0.007	0.025	0.051	**0.097**	**0.111**	0.023
OS	**0.132**	**0.087**	0.031	**-0.13**	**-0.117**	**-0.116**	-0.039
RES	-0.045	**0.108**	**0.204**	**-0.223**	-0.075	**-0.099**	-0.067
COMM	**-0.087**	-0.025	**0.094**	-0.075	**0.214**	**0.18**	**-0.088**
INDUS	0.048	**-0.146**	**-0.314**	**0.379**	**-0.086**	-0.036	**0.183**
INST	-0.006	0.057	0.065	**-0.087**	0.048	0.053	-0.046
STPL	0.005	-0.029	-0.067	**0.103**	-0.017	-0.063	0.065
RRXS	-0.071	-0.008	-0.057	-0.012	-0.037	-0.061	0.039
NMK	0.077	0.071	-0.034	**0.105**	**-0.429**	**-0.379**	**0.174**
STPX	-0.042	-0.047	**0.086**	**-0.137**	**0.412**	**0.398**	**-0.204**
L75	-0.066	0.074	**0.111**	-0.007	-0.019	-0.038	-0.035
B200-500	**-0.095**	-0.04	-0.065	**0.085**	**0.086**	**0.092**	0.01
B75-200	**-0.095**	-0.04	-0.065	**0.085**	**0.086**	**0.092**	0.01
NHWY	**0.165**	-0.022	-0.038	-0.047	**-0.103**	**-0.124**	-0.021
TRFLN	-0.06	**-0.132**	0.022	-0.062	**0.311**	**0.349**	**-0.124**
STHWY	**0.105**	0.042	-0.041	**-0.163**	**0.207**	**0.232**	**-0.107**
AADT	-0.072	**-0.145**	-0.06	-0.044	**0.331**	**0.354**	-0.048
PCTRK	-0.02	**-0.228**	**-0.31**	**0.154**	-0.013	-0.006	0.068
SCHLB	-0.056	-0.008	0.032	0.021	**0.179**	**0.206**	-0.045
WHISTB	-0.06	0.021	0.04	-0.049	0.012	-0.007	-0.017
TTRN	**-0.398**	**-0.084**	0.036	**0.1**	**0.171**	**0.171**	-0.076
TTSWT	**-0.388**	**-0.274**	**-0.183**	**0.245**	**0.125**	**0.09**	-0.049
XBUCK	0.068	**0.105**	**0.103**	-0.063	**-0.123**	**-0.163**	**-0.322**
GT	**-0.196**	0.011	**0.214**	-0.051	**0.767**	**0.669**	**-0.172**
FLP	**-0.229**	-0.036	**0.169**	-0.071	**0.782**	**0.803**	**-0.202**
HWYSPD	**0.147**	0.011	-0.047	**-0.163**	0.022	0.064	-0.02

Table 6 (b): Correlation matrix based on track class 1 data

Variable	SGEQ	OS	RES	COMM	INDUS	INST	STPL	RRXS	NMK
Crashes	0.063	-0.046	-0.054	**0.099**	-0.059	**0.1**	-0.034	-0.031	0.036
LTM	0.006	**0.132**	-0.045	**-0.087**	0.048	-0.006	0.005	-0.071	0.077
MTS	-0.007	**0.087**	**0.108**	-0.025	**-0.146**	0.057	-0.029	-0.008	0.071
MTK	0.025	0.031	**0.204**	**0.094**	**-0.314**	0.065	-0.067	-0.057	-0.034
OTK	0.051	**-0.13**	**-0.223**	-0.075	**0.379**	**-0.087**	**0.103**	-0.012	**0.105**
WDCD	**0.097**	**-0.117**	-0.075	**0.214**	**-0.086**	0.048	-0.017	-0.037	**-0.429**
BL	**0.111**	**-0.116**	**-0.099**	**0.18**	-0.036	0.053	-0.063	-0.061	**-0.379**
NS	0.023	-0.039	-0.067	**-0.088**	**0.183**	-0.046	0.065	0.039	**0.174**
SGEQ	1	-0.046	-0.054	0.072	0.019	-0.03	0.023	-0.031	-0.053
OS	-0.046	1	**-0.224**	**-0.219**	**-0.196**	**-0.068**	-0.011	-0.041	0.029
RES	-0.054	**-0.224**	1	**-0.435**	**-0.389**	**-0.135**	-0.023	-0.041	0.05
COMM	0.072	**-0.219**	**-0.435**	1	**-0.379**	**-0.132**	-0.026	0.029	**-0.095**
INDUS	0.019	**-0.196**	**-0.389**	**-0.379**	1	**-0.118**	0.042	0.051	0.042
INST	-0.03	**-0.068**	**-0.135**	**-0.132**	**-0.118**	1	0.039	-0.02	-0.033
STPL	0.023	-0.011	-0.023	-0.026	0.042	0.039	1	-0.045	**-0.118**
RRXS	-0.031	-0.041	-0.041	0.029	0.051	-0.02	-0.045	1	**-0.102**
NMK	-0.053	0.029	0.05	**-0.095**	0.042	-0.033	**-0.118**	**-0.102**	1
STPX	0.05	-0.004	-0.016	**0.085**	**-0.078**	0.019	**-0.35**	**-0.302**	**-0.795**
L75	-0.041	**-0.138**	0.025	**0.143**	**-0.086**	0.011	**0.063**	**0.067**	**0.071**
B200-500	-0.068	**-0.068**	-0.028	0.036	0.018	0.048	-0.022	0.034	-0.034
B75-200	-0.068	**-0.068**	-0.028	0.036	0.018	0.048	-0.022	0.034	-0.034
NHWY	0.038	**0.168**	0.021	**-0.17**	0.05	-0.022	-0.015	**-0.073**	0.026
TRFLN	0.014	**-0.097**	**-0.191**	**0.315**	**-0.065**	0.007	-0.032	-0.051	**-0.213**
STHWY	-0.02	**0.188**	**0.065**	-0.007	**-0.192**	-0.001	**-0.058**	**-0.081**	**-0.32**
AADT	**0.113**	**-0.113**	**-0.24**	**0.344**	-0.022	-0.015	-0.022	-0.025	**-0.203**
PCTRK	-0.036	0.015	**-0.133**	-0.03	**0.175**	-0.025	**0.074**	0.001	**-0.058**
SCHLB	-0.008	-0.024	-0.043	**0.124**	**-0.084**	0.035	-0.04	-0.005	**-0.14**
WHISTB	-0.011	-0.018	-0.036	**0.082**	-0.031	-0.011	-0.012	-0.011	**0.071**
TTRN	0.058	**-0.082**	-0.003	**0.057**	0.003	-0.007	0.018	-0.012	**-0.056**
TTSWT	**0.09**	**-0.09**	**-0.1**	0.004	**0.163**	0.001	0.009	-0.023	**-0.061**
XBUCK	-0.076	-0.012	**0.064**	-0.035	-0.03	0.017	0.033	0.036	**0.078**
GT	0.071	**-0.056**	-0.046	**0.139**	**-0.062**	0.007	**-0.07**	-0.034	**-0.348**
FLP	**0.124**	**-0.128**	**-0.16**	**0.28**	**-0.06**	**0.056**	-0.052	-0.029	**-0.361**
HWYSPD	-0.035	**0.354**	**0.083**	**-0.227**	**-0.08**	-0.036	-0.049	**-0.066**	**-0.197**

Table 6 (c): Correlation matrix based on track class 1 data

Variable	STPX	L75	B200-500	B75-100	NHWY	TRFLN	STHWY	AADT
Crashes	-0.003	0.014	-0.034	-0.034	0.012	**0.183**	-0.045	**0.104**
LTM	-0.042	-0.066	**-0.095**	**-0.095**	**0.165**	-0.06	**0.105**	-0.072
MTS	-0.047	0.074	-0.04	-0.04	-0.022	**-0.132**	0.042	**-0.145**
MTK	**0.086**	**0.111**	-0.065	-0.065	-0.038	0.022	-0.041	-0.06
OTK	**-0.137**	-0.007	**0.085**	**0.085**	-0.047	-0.062	**-0.163**	-0.044
WDCD	**0.412**	-0.019	**0.086**	**0.086**	**-0.103**	**0.311**	**0.207**	**0.331**
BL	**0.398**	-0.038	**0.092**	**0.092**	**-0.124**	**0.349**	**0.232**	**0.354**
NS	**-0.204**	-0.035	0.01	0.01	-0.021	**-0.124**	**-0.107**	-0.048
SGEQ	0.05	-0.041	-0.068	-0.068	0.038	0.014	-0.02	**0.113**
OS	-0.004	**-0.138**	**-0.068**	**-0.068**	**0.168**	**-0.097**	**0.188**	**-0.113**
RES	-0.016	0.025	-0.028	-0.028	0.021	**-0.191**	**0.065**	**-0.24**
COMM	**0.085**	**0.143**	0.036	0.036	**-0.17**	**0.315**	-0.007	**0.344**
INDUS	**-0.078**	**-0.086**	0.018	0.018	0.05	**-0.065**	**-0.192**	-0.022
INST	0.019	0.011	0.048	0.048	-0.022	0.007	-0.001	-0.015
STPL	**-0.35**	**0.063**	-0.022	-0.022	-0.015	-0.032	**-0.058**	-0.022
RRXS	**-0.302**	**0.067**	0.034	0.034	**-0.073**	-0.051	**-0.081**	-0.025
NMK	**-0.795**	**0.071**	-0.034	-0.034	0.026	**-0.213**	**-0.32**	**-0.203**
STPX	1	**-0.121**	0.027	0.027	0.014	**0.227**	**0.347**	**0.202**
L75	**-0.121**	1	**-0.346**	**-0.346**	**-0.513**	0.005	**-0.073**	-0.025
B200-500	0.027	**-0.346**	1	**1**	**-0.297**	**0.063**	-0.04	**0.075**
B75-200	0.027	**-0.346**	**1**	1	**-0.297**	**0.063**	-0.04	**0.075**
NHWY	0.014	**-0.513**	**-0.297**	**-0.297**	1	**-0.067**	**0.09**	**-0.074**
TRFLN	**0.227**	0.005	**0.063**	**0.063**	**-0.067**	1	**0.097**	**0.72**
STHWY	**0.347**	**-0.073**	-0.04	-0.04	**0.09**	**0.097**	1	**0.139**
AADT	**0.202**	-0.025	**0.075**	**0.075**	**-0.074**	**0.72**	**0.139**	1
PCTRK	0.017	-0.049	-0.033	-0.033	0.027	0.041	0.037	**0.074**
SCHLB	**0.146**	-0.025	**0.133**	**0.133**	**-0.202**	**0.214**	**0.064**	**0.267**
WHISTB	**-0.053**	0.042	0.012	0.012	-0.036	-0.016	-0.046	-0.007
TTRN	0.047	**0.066**	0.012	0.012	**-0.079**	0.05	**-0.106**	0.007
TTSWT	**0.06**	-0.029	0.043	0.043	**-0.059**	**0.068**	**-0.152**	0.046
XBUCK	**-0.1**	0.047	-0.033	-0.033	0.039	-0.013	-0.023	**-0.091**
GT	**0.358**	**-0.067**	**0.075**	**0.075**	**-0.081**	**0.157**	**0.225**	**0.231**
FLP	**0.359**	0.033	**0.053**	**0.053**	**-0.12**	**0.533**	**0.211**	**0.5**
HWYSPD	**0.227**	**-0.137**	**-0.054**	**-0.054**	**0.168**	0.001	**0.495**	-0.028

Table 6 (d): Correlation matrix based on track class 1 data

Variable	PCTRK	SCHLB	WHISTB	TTRN	TTSWT	XBUCK	GT	FLP	HWYSPD
Crashes	-0.005	-0.017	-0.011	**0.171**	**0.143**	0.06	0.01	**0.138**	-0.022
LTM	-0.02	-0.056	-0.06	**-0.398**	**-0.388**	0.068	**-0.196**	**-0.229**	**0.147**
MTS	**-0.228**	-0.008	0.021	**-0.084**	**-0.274**	**0.105**	0.011	-0.036	0.011
MTK	**-0.31**	0.032	0.04	0.036	**-0.183**	**0.103**	**0.214**	**0.169**	-0.047
OTK	**0.154**	0.021	-0.049	**0.1**	**0.245**	-0.063	-0.051	-0.071	**-0.163**
WDCD	-0.013	**0.179**	0.012	**0.171**	**0.125**	**-0.123**	**0.767**	**0.782**	0.022
BL	-0.006	**0.206**	-0.007	**0.171**	**0.09**	**-0.163**	**0.669**	**0.803**	0.064
NS	0.068	-0.045	-0.017	-0.076	-0.049	**-0.322**	**-0.172**	**-0.202**	-0.02
SGEQ	-0.036	-0.008	-0.011	0.058	**0.09**	-0.076	0.071	**0.124**	-0.035
OS	0.015	-0.024	-0.018	**-0.082**	**-0.09**	-0.012	**-0.056**	**-0.128**	**0.354**
RES	**-0.133**	-0.043	-0.036	-0.003	**-0.1**	**0.064**	-0.046	**-0.16**	**0.083**
COMM	-0.03	**0.124**	**0.082**	**0.057**	0.004	-0.035	**0.139**	**0.28**	**-0.227**
INDUS	**0.175**	**-0.084**	-0.031	0.003	**0.163**	-0.03	**-0.062**	**-0.06**	**-0.08**
INST	-0.025	0.035	-0.011	-0.007	0.001	0.017	0.007	**0.056**	-0.036
STPL	**0.074**	-0.04	-0.012	0.018	0.009	0.033	**-0.07**	-0.052	-0.049
RRXS	0.001	-0.005	-0.011	-0.012	-0.023	0.036	-0.034	-0.029	**-0.066**
NMK	**-0.058**	**-0.14**	**0.071**	**-0.056**	**-0.061**	**0.078**	**-0.348**	**-0.361**	**-0.197**
STPX	0.017	**0.146**	**-0.053**	0.047	**0.06**	**-0.1**	**0.358**	**0.359**	**0.227**
L75	-0.049	-0.025	0.042	**0.066**	-0.029	0.047	**-0.067**	0.033	**-0.137**
B200-500	-0.033	**0.133**	0.012	0.012	0.043	-0.033	**0.075**	**0.053**	**-0.054**
B75-200	-0.033	**0.133**	0.012	0.012	0.043	-0.033	**0.075**	**0.053**	**-0.054**
NHWY	0.027	**-0.202**	-0.036	**-0.079**	**-0.059**	0.039	**-0.081**	**-0.12**	**0.168**
TRFLN	0.041	**0.214**	-0.016	0.05	**0.068**	-0.013	**0.157**	**0.533**	0.001
STHWY	0.037	**0.064**	-0.046	**-0.106**	**-0.152**	-0.023	**0.225**	**0.211**	**0.495**
AADT	**0.074**	**0.267**	-0.007	0.007	0.046	**-0.091**	**0.231**	**0.5**	-0.028
PCTRK	1	-0.011	0.03	-0.004	**0.095**	-0.009	-0.011	0.02	**0.062**
SCHLB	-0.011	1	0.004	0.004	**0.075**	**-0.141**	**0.182**	**0.211**	-0.044
WHISTB	0.03	0.004	1	**0.059**	0.004	-0.017	-0.022	0.016	-0.036
TTRN	-0.004	0.004	**0.059**	1	**0.724**	-0.028	**0.103**	**0.141**	**-0.164**
TTSWT	**0.095**	**0.075**	0.004	**0.724**	1	**-0.06**	0.028	**0.076**	**-0.151**
XBUCK	-0.009	**-0.141**	-0.017	-0.028	**-0.06**	1	**-0.238**	**-0.179**	-0.01
GT	-0.011	**0.182**	-0.022	**0.103**	0.028	**-0.238**	1	**0.631**	0.048
FLP	0.02	**0.211**	0.016	**0.141**	**0.076**	**-0.179**	**0.631**	1	-0.013
HWYSPD	**0.062**	-0.044	-0.036	**-0.164**	**-0.151**	-0.01	0.048	-0.013	1

Table 7 (a): Correlation matrix based on track class 2 data

Variable	LTM	MTS	MTK	OTK	WDCD	BL	NS	SGEQ	OS	RES	COMM	INDUS	INST	STPL
Crashes	-0.01	**-.072**	-0.03	0.00	-0.02	0.01	-0.02	-0.01	-0.02	0.02	-0.02	0.03	-0.03	**.079**
LTM	1.00	**-.150**	**-.151**	-0.01	0.02	0.03	-0.04	-0.06	0.04	-0.04	0.01	-0.01	0.02	0.04
MTS	**-.150**	1.00	**.337**	**-.105**	0.04	-0.03	-0.05	-0.04	**.104**	**.080**	**-.061**	**-.117**	0.02	-0.05
MTK	**-.151**	**.337**	1.00	**-.086**	0.03	0.05	**-.067**	0.03	-0.01	**.072**	0.03	**-.129**	0.03	0.00
OTK	-0.01	**-.105**	**-.086**	1.00	0.01	0.01	0.01	**.141**	-0.05	-0.03	0.02	**.067**	-0.02	-0.01
WDCD	0.02	0.04	0.03	0.01	1.00	**.830**	**-.231**	**.097**	-0.02	**-.139**	**.117**	0.03	0.04	**-.068**
BL	0.03	-0.03	0.05	0.01	**.830**	1.00	**-.117**	**.084**	-0.04	**-.166**	**.154**	0.04	0.03	-0.05
NS	-0.04	-0.05	**-.067**	0.01	**-.231**	**-.117**	1.00	0.01	0.04	-0.04	-0.02	0.05	-0.02	0.02
SGEQ	-0.06	-0.04	0.03	**.141**	**.097**	**.084**	0.01	1.00	0.02	-0.04	0.04	0.01	-0.05	-0.03
OS	0.04	**.104**	-0.01	-0.05	-0.02	-0.04	0.04	0.02	1.00	**-.262**	**-.237**	**-.178**	**-.076**	0.00
RES	-0.04	**.080**	**.072**	-0.03	**-.139**	**-.166**	-0.04	-0.04	**-.262**	1.00	**-.476**	**-.358**	**-.153**	0.00
COMM	0.01	**-.061**	0.03	0.02	**.117**	**.154**	-0.02	0.04	**-.237**	**-.476**	1.00	**-.324**	**-.139**	-0.02
INDUS	-0.01	**-.117**	**-.129**	**.067**	0.03	0.04	0.05	0.01	**-.178**	**-.358**	**-.324**	1.00	**-.104**	0.00
INST	0.02	0.02	0.03	-0.02	0.04	0.03	-0.02	-0.05	**-.076**	**-.153**	**-.139**	**-.104**	1.00	0.04
STPL	0.04	-0.05	0.00	-0.01	**-.068**	-0.05	0.02	-0.03	0.00	0.00	-0.02	0.00	0.04	1.00
RRXS	0.03	-0.04	**-.087**	0.01	**-.072**	-0.05	-0.02	0.05	-0.04	-0.05	0.05	0.03	-0.01	-0.04
NMK	-0.02	**-.068**	0.01	0.02	**-.382**	**-.328**	0.05	0.01	-0.01	**.085**	-0.05	-0.02	-0.05	**-.103**
STPX	-0.01	**.099**	0.03	-0.02	**.400**	**.335**	-0.05	-0.02	0.02	-0.06	0.03	0.00	0.03	**-.355**
L75	**-.062**	0.04	**.092**	-0.02	**-.129**	**-.073**	**.064**	0.01	**-.166**	0.02	**.121**	-0.05	0.05	0.05
B200-500	0.05	-0.02	0.00	-0.01	0.04	0.00	0.00	-0.05	**-.081**	-0.02	0.05	0.01	0.03	-0.03
B75-200	0.05	-0.02	0.00	-0.01	0.04	0.00	0.00	-0.05	**-.081**	-0.02	0.05	0.01	0.03	-0.03
NHWY	-0.05	0.01	-0.04	0.03	0.03	-0.01	-0.05	0.03	**.222**	0.05	**-.163**	-0.03	-0.05	0.02
TRFLN	0.00	**-.102**	**-.099**	0.01	**.214**	**.265**	-0.04	-0.02	**-.108**	**-.188**	**.261**	0.00	0.03	-0.03
STHWY	**-.084**	**.105**	0.03	**-.108**	**.243**	**.201**	-0.05	-0.02	**.215**	0.04	**-.076**	**-.129**	-0.01	-0.05
AADT	0.03	**-.122**	**-.104**	0.00	**.308**	**.324**	-0.03	0.03	**-.121**	**-.259**	**.357**	0.00	0.00	-0.02
PCTRK	**.068**	**-.169**	**-.078**	0.00	0.02	0.03	-0.01	-0.02	0.02	**-.109**	0.00	**.117**	-0.01	0.03
SCHLB	0.04	**-.068**	0.00	-0.02	**.176**	**.177**	-0.04	-0.04	**-.076**	**-.083**	**.155**	-0.03	0.01	-0.04
WHISTB	-0.02	-0.04	0.01	0.03	0.04	0.01	0.00	**.130**	-0.01	-0.02	0.05	-0.02	-0.01	-0.01
TTRN	**-.382**	-0.06	**.070**	**.141**	**.103**	**.081**	0.01	**.273**	**-.067**	-0.06	0.05	0.04	0.05	-0.04
TTSWT	**-.296**	**-.186**	**-.127**	**.111**	0.04	**.069**	**.102**	**.102**	**-.065**	**-.117**	0.06	**.101**	0.05	**-.071**
XBUCK	-0.04	-0.02	0.04	0.02	**-.287**	**-.292**	**-.144**	0.05	**-.061**	**.066**	0.00	-0.04	0.02	0.01
GT	0.01	**.065**	0.03	0.02	**.849**	**.703**	**-.109**	**.085**	0.00	**-.122**	**.083**	0.04	0.02	**-.067**
FLP	0.01	-0.03	0.02	0.00	**.798**	**.771**	**-.113**	**.068**	**-.086**	**-.193**	**.219**	0.03	0.03	**-.077**
HWYSPD	-0.03	**.108**	-0.01	**-.085**	**.078**	**.060**	-0.01	0.01	**.393**	**.063**	**-.278**	**-.066**	-0.01	-0.01

Table 7 (b): Correlation matrix based on track class 2 data

Variable	RRXS	NMK	STPX	L75	B200-500	B75-200	NHWY	TRFLN	STHWY
Crashes	**0.069**	0	**-0.065**	0.01	-0.02	-0.02	0	**0.058**	-0.02
LTM	0.03	-0.02	-0.01	**-0.062**	0.05	0.05	-0.05	0	**-0.084**
MTS	-0.04	**-0.068**	**0.099**	0.04	-0.02	-0.02	0.01	**-0.102**	**0.105**
MTK	**-0.087**	0.01	0.03	**0.092**	0	0	-0.04	**-0.099**	0.03
OTK	0.01	0.02	-0.02	-0.02	-0.01	-0.01	0.03	0.01	**-0.108**
WDCD	**-0.072**	**-0.382**	**0.4**	**-0.129**	0.04	0.04	0.03	**0.214**	**0.243**
BL	-0.05	**-0.328**	**0.335**	**-0.073**	0	0	-0.01	**0.265**	**0.201**
NS	-0.02	0.05	-0.05	**0.064**	0	0	-0.05	-0.04	-0.05
SGEQ	0.05	0.01	-0.02	0.01	-0.05	-0.05	0.03	-0.02	-0.02
OS	-0.04	-0.01	0.02	**-0.166**	**-0.081**	**-0.081**	**0.222**	**-0.108**	**0.215**
RES	-0.05	**0.085**	-0.06	0.02	-0.02	-0.02	0.05	**-0.188**	0.04
COMM	0.05	-0.05	0.03	**0.121**	0.05	0.05	**-0.163**	**0.261**	**-0.076**
INDUS	0.03	-0.02	0	-0.05	0.01	0.01	-0.03	0	**-0.129**
INST	-0.01	-0.05	0.03	0.05	0.03	0.03	-0.05	0.03	-0.01
STPL	-0.04	**-0.103**	**-0.355**	0.05	-0.03	-0.03	0.02	-0.03	-0.05
RRXS	1	**-0.088**	**-0.304**	**0.083**	0.02	0.02	**-0.076**	-0.01	**-0.142**
NMK	**-0.088**	1	**-0.804**	**0.074**	0	0	0	**-0.178**	**-0.34**
STPX	**-0.304**	**-0.804**	1	**-0.123**	0	0	0.03	**0.174**	**0.381**
L75	**0.083**	**0.074**	**-0.123**	1	**-0.366**	**-0.366**	**-0.491**	-0.01	**-0.123**
B200-500	0.02	0	0	**-0.366**	1	**1**	**-0.27**	-0.04	-0.04
B75-200	0.02	0	0	**-0.366**	**1**	1	**-0.27**	-0.04	-0.04
NHWY	**-0.076**	0	0.03	**-0.491**	**-0.27**	**-0.27**	1	-0.03	**0.178**
TRFLN	-0.01	**-0.178**	**0.174**	-0.01	-0.04	-0.04	-0.03	1	0.05
STHWY	**-0.142**	**-0.34**	**0.381**	**-0.123**	-0.04	-0.04	**0.178**	0.05	1
AADT	-0.04	**-0.205**	**0.204**	-0.03	-0.03	-0.03	-0.04	**0.685**	**0.114**
PCTRK	0	0.02	-0.03	-0.01	0.01	0.01	-0.02	0.06	0
SCHLB	-0.01	**-0.15**	**0.158**	-0.01	**0.087**	**0.087**	**-0.175**	**0.191**	0.04
WHISTB	-0.01	-0.01	0.02	-0.02	-0.01	-0.01	-0.02	-0.01	-0.04
TTRN	0.04	0	0	0.04	-0.01	-0.01	-0.01	0.02	**-0.088**
TTSWT	0.01	-0.02	0.04	0.03	0	0	-0.05	**0.119**	**-0.116**
XBUCK	0.03	**0.1**	**-0.108**	0.03	-0.02	-0.02	0.03	-0.03	-0.03
GT	**-0.08**	**-0.333**	**0.359**	**-0.151**	**0.068**	**0.068**	0.03	**0.155**	**0.22**
FLP	**-0.063**	**-0.334**	**0.357**	-0.02	0.02	0.02	-0.05	**0.512**	**0.183**
HWYSPD	**-0.101**	**-0.166**	**0.194**	**-0.179**	**-0.073**	**-0.073**	**0.234**	-0.01	**0.525**

Table 7 (c): Correlation matrix based on track class 2 data

Variable	AADT	PCTRK	SCHLB	WHISTB	TTRN	TTSWT	XBUCK	GT	FLP	HWYSPD
Crashes	-0.01	**0.103**	-0.02	0	-0.01	0.01	**0.065**	-0.05	0.02	0
LTM	0.03	**0.068**	0.04	-0.02	**-0.382**	**-0.296**	-0.04	0.01	0.01	-0.03
MTS	**-0.122**	**-0.169**	**-0.068**	-0.04	-0.06	**-0.186**	-0.02	**0.065**	-0.03	**0.108**
MTK	**-0.104**	**-0.078**	0	0.01	**0.07**	**-0.127**	0.04	0.03	0.02	-0.01
OTK	0	0	-0.02	0.03	**0.141**	**0.111**	0.02	0.02	0	**-0.085**
WDCD	**0.308**	0.02	**0.176**	0.04	**0.103**	0.04	**-0.287**	**0.849**	**0.798**	**0.078**
BL	**0.324**	0.03	**0.177**	0.01	**0.081**	**0.069**	**-0.292**	**0.703**	**0.771**	**0.06**
NS	-0.03	-0.01	-0.04	0	0.01	**0.102**	**-0.144**	**-0.109**	**-0.113**	-0.01
SGEQ	0.03	-0.02	-0.04	**0.13**	**0.273**	**0.102**	0.05	**0.085**	**0.068**	0.01
OS	**-0.121**	0.02	**-0.076**	-0.01	**-0.067**	**-0.065**	**-0.061**	0	**-0.086**	**0.393**
RES	**-0.259**	**-0.109**	**-0.083**	-0.02	-0.06	**-0.117**	**0.066**	**-0.122**	**-0.193**	**0.063**
COMM	**0.357**	0	**0.155**	0.05	0.05	0.06	0	**0.083**	**0.219**	**-0.278**
INDUS	0	**0.117**	-0.03	-0.02	0.04	**0.101**	-0.04	0.04	0.03	**-0.066**
INST	0	-0.01	0.01	-0.01	0.05	0.05	0.02	0.02	0.03	-0.01
STPL	-0.02	0.03	-0.04	-0.01	-0.04	**-0.071**	0.01	**-0.067**	**-0.077**	-0.01
RRXS	-0.04	0	-0.01	-0.01	0.04	0.01	0.03	**-0.08**	**-0.063**	**-0.101**
NMK	**-0.205**	0.02	**-0.15**	-0.01	0	-0.02	**0.1**	**-0.333**	**-0.334**	**-0.166**
STPX	**0.204**	-0.03	**0.158**	0.02	0	0.04	**-0.108**	**0.359**	**0.357**	**0.194**
L75	-0.03	-0.01	-0.01	-0.02	0.04	0.03	0.03	**-0.151**	-0.02	**-0.179**
B200-500	-0.03	0.01	**0.087**	-0.01	-0.01	0	-0.02	**0.068**	0.02	**-0.073**
B75-200	-0.03	0.01	**0.087**	-0.01	-0.01	0	-0.02	**0.068**	0.02	**-0.073**
NHWY	-0.04	-0.02	**-0.175**	-0.02	-0.01	-0.05	0.03	0.03	-0.05	**0.234**
TRFLN	**0.685**	0.06	**0.191**	-0.01	0.02	**0.119**	-0.03	**0.155**	**0.512**	-0.01
STHWY	**0.114**	0	0.04	-0.04	**-0.088**	**-0.116**	-0.03	**0.22**	**0.183**	**0.525**
AADT	1	0.05	**0.306**	0.01	0.03	**0.107**	**-0.077**	**0.266**	**0.504**	-0.04
PCTRK	0.05	1	-0.02	-0.01	**-0.06**	-0.02	-0.02	0.02	0.03	0.02
SCHLB	**0.306**	-0.02	1	0.06	0.05	**0.143**	**-0.118**	**0.119**	**0.227**	**-0.092**
WHISTB	0.01	-0.01	0.06	1	**0.075**	0.02	**0.077**	0.03	0	-0.04
TTRN	0.03	**-0.06**	0.05	**0.075**	1	**0.65**	**-0.062**	**0.103**	**0.087**	**-0.099**
TTSWT	**0.107**	-0.02	**0.143**	0.02	**0.65**	1	**-0.179**	0.04	**0.084**	**-0.093**
XBUCK	**-0.077**	-0.02	**-0.118**	**0.077**	**-0.062**	**-0.179**	1	**-0.218**	**-0.25**	-0.02
GT	**0.266**	0.02	**0.119**	0.03	**0.103**	0.04	**-0.218**	1	**0.648**	**0.102**
FLP	**0.504**	0.03	**0.227**	0	**0.087**	**0.084**	**-0.25**	**0.648**	1	-0.01
HWYSPD	-0.04	0.02	**-0.092**	-0.04	**-0.099**	**-0.093**	-0.02	**0.102**	-0.01	1

Table 8 (a): Correlation matrix based on track class 3 data

Variable	LTM	MTK	OTK	WDCD	BL	NS	SGEQ	OS	RES	COMM	INDUS	INST	STPL
Crashes	**-.076**	**.138**	**.073**	**.063**	**.106**	-0.008	**.146**	-0.03	0.019	-0.015	0.004	0.034	0.03
LTM	1	**-.182**	0.025	**-.077**	-0.03	-0.038	**-.088**	**.087**	-0.027	-0.029	0.004	-0.017	0.032
MTK	**-.182**	1	**-.148**	**.092**	**.126**	-0.048	**.105**	-0.045	0.03	0.056	**-.094**	0.058	-0.026
OTK	0.025	**-.148**	1	0.057	**.077**	-0.054	**.105**	**-.096**	**-.189**	**.087**	**.212**	-0.015	-0.039
WDCD	**-.077**	**.092**	0.057	1	**.799**	**-.401**	**.096**	-0.029	**-.115**	**.083**	**.062**	0.004	-0.033
BL	-0.03	**.126**	**.077**	**.799**	1	**-.214**	**.101**	-0.049	**-.140**	**.121**	**.071**	-0.009	-0.044
NS	-0.038	-0.048	-0.054	**-.401**	**-.214**	1	-0.035	-0.013	**-.092**	**.139**	-0.029	-0.032	-0.017
SGEQ	**-.088**	**.105**	**.105**	**.096**	**.101**	-0.035	1	-0.035	-0.018	0.057	-0.007	-0.023	0.01
OS	**.087**	-0.045	**-.096**	-0.029	-0.049	-0.013	-0.035	1	**-.262**	**-.248**	**-.173**	**-.067**	-0.011
RES	-0.027	0.03	**-.189**	**-.115**	**-.140**	**-.092**	-0.018	**-.262**	1	**-.498**	**-.348**	**-.134**	0.019
COMM	-0.029	0.056	**.087**	**.083**	**.121**	**.139**	0.057	**-.248**	**-.498**	1	**-.329**	**-.127**	0.007
INDUS	0.004	**-.094**	**.212**	**.062**	**.071**	-0.029	-0.007	**-.173**	**-.348**	**-.329**	1	**-.089**	-0.032
INST	-0.017	0.058	-0.015	0.004	-0.009	-0.032	-0.023	**-.067**	**-.134**	**-.127**	**-.089**	1	0.022
STPL	0.032	-0.026	-0.039	-0.033	-0.044	-0.017	0.01	-0.011	0.019	0.007	-0.032	0.022	1
RRXS	0.021	**-.061**	0.058	-0.014	0.006	-0.033	**.092**	-0.039	0.022	-0.018	0.043	-0.035	-0.045
NMK	0.031	0.009	0.018	**-.460**	**-.349**	**.287**	-0.003	**-.072**	0.043	0.05	-0.04	-0.028	**-.115**
STPX	-0.052	0.03	-0.02	**.426**	**.326**	**-.230**	-0.04	**.084**	-0.056	-0.04	0.034	0.028	**-.378**
L75	**-.097**	**.101**	0.015	**-.106**	-0.035	**.114**	0.035	**-.151**	-0.001	**.160**	**-.068**	0.005	**.090**
B200-500	0.039	-0.015	0.032	0.055	0.022	-0.008	-0.035	-0.057	-0.018	0.013	0.049	0.011	-0.026
B75-200	0.039	-0.015	0.032	0.055	0.022	-0.008	-0.035	-0.057	-0.018	0.013	0.049	0.011	-0.026
NHWY	0.002	-0.042	-0.057	0.012	-0.036	**-.092**	-0.019	**.167**	0.042	**-.162**	0.006	-0.001	**-.070**
TRFLN	-0.02	0.004	0.027	**.218**	**.235**	-0.054	-0.01	-0.056	**-.196**	**.230**	0.015	-0.013	-0.04
STHWY	-0.037	-0.052	**-.156**	**.190**	**.134**	-0.005	-0.012	**.194**	0.057	**-.091**	**-.120**	0	**-.092**
AADT	-0.023	**-.077**	**.070**	**.283**	**.286**	**-.066**	0.025	**-.109**	**-.279**	**.327**	0.043	-0.013	-0.045
PCTRK	**.084**	-0.036	0.003	**.063**	0.043	-0.026	-0.046	**.103**	**-.096**	-0.049	**.106**	-0.033	-0.014
SCHLB	0.023	**-.067**	0.056	**.168**	**.145**	**-.067**	-0.056	-0.054	**-.063**	**.100**	-0.01	0.026	-0.03
WHISTB	-0.029	**.206**	-0.014	0.02	**.060**	**.060**	0.02	-0.026	-0.053	**.106**	-0.035	-0.013	-0.017
TTRN	**-.355**	**.239**	**.106**	**.151**	**.127**	**.062**	**.399**	**-.077**	**-.077**	**.108**	0.028	0	0.033
TTSWT	**-.254**	0.023	**.211**	**.120**	**.092**	-0.03	**.188**	-0.044	**-.124**	0.054	**.115**	0.015	-0.028
XBUCK	-0.052	0.026	0.034	**-.185**	**-.233**	**-.221**	**.082**	-0.039	**.064**	**-.061**	0.002	0.054	0.023
GT	**-.090**	**.097**	0.05	**.827**	**.653**	**-.199**	**.086**	-0.021	**-.103**	**.058**	**.077**	-0.008	-0.055
FLP	**-.093**	**.096**	**.059**	**.794**	**.741**	**-.212**	**.101**	**-.088**	**-.186**	**.205**	0.042	0.026	-0.032
HWYSPD	**.069**	-0.031	**-.186**	0.052	0.015	-0.05	-0.053	**.370**	**.099**	**-.304**	-0.045	-0.033	**-.070**

Table 8 (b): Correlation matrix based on track class 3 data

Variable	RRXS	NMK	STPX	L75	B200-500	B75-200	NHWY	TRFLN
Crashes	0.009	**-0.062**	0.036	0.041	0.032	0.032	**-0.059**	0.036
LTM	0.021	0.031	-0.052	**-0.097**	0.039	0.039	0.002	-0.02
MTK	**-0.061**	0.009	0.03	**0.101**	-0.015	-0.015	-0.042	0.004
OTK	0.058	0.018	-0.02	0.015	0.032	0.032	-0.057	0.027
WDCD	-0.014	**-0.46**	**0.426**	**-0.106**	0.055	0.055	0.012	**0.218**
BL	0.006	**-0.349**	**0.326**	-0.035	0.022	0.022	-0.036	**0.235**
NS	-0.033	**0.287**	**-0.23**	**0.114**	-0.008	-0.008	**-0.092**	-0.054
SGEQ	**0.092**	-0.003	-0.04	0.035	-0.035	-0.035	-0.019	-0.01
OS	-0.039	**-0.072**	**0.084**	**-0.151**	-0.057	-0.057	**0.167**	-0.056
RES	0.022	0.043	-0.056	-0.001	-0.018	-0.018	0.042	**-0.196**
COMM	-0.018	0.05	-0.04	**0.16**	0.013	0.013	**-0.162**	**0.23**
INDUS	0.043	-0.04	0.034	**-0.068**	0.049	0.049	0.006	0.015
INST	-0.035	-0.028	0.028	0.005	0.011	0.011	-0.001	-0.013
STPL	-0.045	**-0.115**	**-0.378**	**0.09**	-0.026	-0.026	**-0.07**	-0.04
RRXS	1	**-0.093**	**-0.306**	**0.063**	-0.007	-0.007	-0.05	-0.044
NMK	**-0.093**	1	**-0.783**	**0.187**	-0.034	-0.034	**-0.107**	**-0.178**
STPX	**-0.306**	**-0.783**	1	**-0.235**	0.046	0.046	**0.149**	**0.194**
L75	**0.063**	**0.187**	**-0.235**	1	**-0.368**	**-0.368**	**-0.553**	-0.015
B200-500	-0.007	-0.034	0.046	**-0.368**	1	**1**	**-0.24**	0.029
B75-200	-0.007	-0.034	0.046	**-0.368**	**1**	1	**-0.24**	0.029
NHWY	-0.05	**-0.107**	**0.149**	**-0.553**	**-0.24**	**-0.24**	1	-0.043
TRFLN	-0.044	**-0.178**	**0.194**	-0.015	0.029	0.029	-0.043	1
STHWY	**-0.12**	**-0.291**	**0.35**	**-0.178**	-0.002	-0.002	**0.182**	0.033
AADT	-0.023	**-0.184**	**0.193**	-0.023	0.024	0.024	-0.051	**0.66**
PCTRK	-0.009	**-0.073**	**0.075**	**-0.076**	-0.042	-0.042	**0.059**	0.046
SCHLB	-0.013	**-0.12**	**0.126**	0.012	**0.097**	**0.097**	**-0.177**	**0.165**
WHISTB	-0.014	0.026	-0.009	0.006	0.006	0.006	0.011	0.017
TTRN	0.002	-0.016	-0.003	0.049	-0.011	-0.011	-0.041	0.052
TTSWT	-0.021	**-0.065**	**0.08**	-0.001	0.048	0.048	-0.045	**0.091**
XBUCK	0.035	0.043	**-0.064**	-0.009	0.031	0.031	0.027	0.03
GT	0.01	**-0.381**	**0.358**	**-0.07**	**0.059**	**0.059**	-0.015	**0.191**
FLP	-0.023	**-0.361**	**0.342**	0.015	0.038	0.038	**-0.064**	**0.525**
HWYSPD	-0.053	**-0.222**	**0.252**	**-0.224**	-0.014	-0.014	**0.216**	-0.008

Table 8 (c): Correlation matrix based on track class 3 data

Variable	STHWY	AADT	PCTRK	SCHLB	WHISTB	TTRN	TTSWT	XBUCK	GT	FLP	HWYSPD
Crashes	-0.043	0.035	-0.006	0.004	**0.102**	**0.162**	**0.079**	-0.009	0.058	**0.121**	-0.02
LTM	-0.037	-0.023	**0.084**	0.023	-0.029	**-0.355**	**-0.254**	-0.052	**-0.09**	**-0.093**	**0.069**
MTK	-0.052	**-0.077**	-0.036	**-0.067**	**0.206**	**0.239**	0.023	0.026	**0.097**	**0.096**	-0.031
OTK	**-0.156**	**0.07**	0.003	0.056	-0.014	**0.106**	**0.211**	0.034	0.05	**0.059**	**-0.186**
WDCD	**0.19**	**0.283**	**0.063**	**0.168**	0.02	**0.151**	**0.12**	**-0.185**	**0.827**	**0.794**	0.052
BL	**0.134**	**0.286**	0.043	**0.145**	**0.06**	**0.127**	**0.092**	**-0.233**	**0.653**	**0.741**	0.015
NS	-0.005	**-0.066**	-0.026	**-0.067**	**0.06**	**0.062**	-0.03	**-0.221**	**-0.199**	**-0.212**	-0.05
SGEQ	-0.012	0.025	-0.046	-0.056	0.02	**0.399**	**0.188**	**0.082**	**0.086**	**0.101**	-0.053
OS	**0.194**	**-0.109**	**0.103**	-0.054	-0.026	**-0.077**	-0.044	-0.039	-0.021	**-0.088**	**0.37**
RES	0.057	**-0.279**	**-0.096**	**-0.063**	-0.053	**-0.077**	**-0.124**	**0.064**	**-0.103**	**-0.186**	**0.099**
COMM	**-0.091**	**0.327**	-0.049	**0.1**	**0.106**	**0.108**	0.054	**-0.061**	**0.058**	**0.205**	**-0.304**
INDUS	**-0.12**	0.043	**0.106**	-0.01	-0.035	0.028	**0.115**	0.002	**0.077**	0.042	-0.045
INST	0	-0.013	-0.033	0.026	-0.013	0	0.015	0.054	-0.008	0.026	-0.033
STPL	**-0.092**	-0.045	-0.014	-0.03	-0.017	0.033	-0.028	0.023	-0.055	-0.032	**-0.07**
RRXS	**-0.12**	-0.023	-0.009	-0.013	-0.014	0.002	-0.021	0.035	0.01	-0.023	-0.053
NMK	**-0.291**	**-0.184**	**-0.073**	**-0.12**	0.026	-0.016	**-0.065**	0.043	**-0.381**	**-0.361**	**-0.222**
STPX	**0.35**	**0.193**	**0.075**	**0.126**	-0.009	-0.003	**0.08**	**-0.064**	**0.358**	**0.342**	**0.252**
L75	**-0.178**	-0.023	**-0.076**	0.012	0.006	0.049	-0.001	-0.009	**-0.07**	0.015	**-0.224**
B200-500	-0.002	0.024	-0.042	**0.097**	0.006	-0.011	0.048	0.031	**0.059**	0.038	-0.014
B75-200	-0.002	0.024	-0.042	**0.097**	0.006	-0.011	0.048	0.031	**0.059**	0.038	-0.014
NHWY	**0.182**	-0.051	**0.059**	**-0.177**	0.011	-0.041	-0.045	0.027	-0.015	**-0.064**	**0.216**
TRFLN	0.033	**0.66**	0.046	**0.165**	0.017	0.052	**0.091**	0.03	**0.191**	**0.525**	-0.008
STHWY	1	**0.075**	**0.062**	**0.07**	**-0.06**	**-0.074**	**-0.089**	-0.019	**0.167**	**0.123**	**0.458**
AADT	**0.075**	1	0.042	**0.268**	0.022	**0.064**	**0.124**	0	**0.222**	**0.483**	**-0.093**
PCTRK	**0.062**	0.042	1	-0.001	0	**-0.064**	-0.035	-0.047	0.043	0.049	**0.107**
SCHLB	**0.07**	**0.268**	-0.001	1	-0.033	-0.018	**0.131**	-0.039	**0.131**	**0.204**	-0.041
WHISTB	**-0.06**	0.022	0	-0.033	1	**0.334**	**0.185**	**-0.093**	0.011	0.008	**-0.063**
TTRN	**-0.074**	**0.064**	**-0.064**	-0.018	**0.334**	1	**0.596**	-0.021	**0.161**	**0.145**	**-0.157**
TTSWT	**-0.089**	**0.124**	-0.035	**0.131**	**0.185**	**0.596**	1	-0.035	**0.075**	**0.127**	**-0.121**
XBUCK	-0.019	0	-0.047	-0.039	**-0.093**	-0.021	-0.035	1	**-0.181**	**-0.16**	0.003
GT	**0.167**	**0.222**	0.043	**0.131**	0.011	**0.161**	**0.075**	**-0.181**	1	**0.664**	**0.073**
FLP	**0.123**	**0.483**	0.049	**0.204**	0.008	**0.145**	**0.127**	**-0.16**	**0.664**	1	-0.034
HWYSPD	**0.458**	**-0.093**	**0.107**	-0.041	**-0.063**	**-0.157**	**-0.121**	0.003	**0.073**	-0.034	1

Table 9 (a): Correlation matrix based on track class 4 data

Variable	MTS	MTK	OTK	WDCD	BL	NS	SGEQ	OS	RES	COMM	INDUS	INST	STPL
Crashes	**.197**	**.259**	0.021	0.074	-0.053	-0.019	0.071	-0.071	**-.146**	**.124**	0.065	0.005	-0.028
MTS	1	**.251**	0.025	**.235**	**.132**	-0.055	-0.003	**-.087**	0.01	-0.02	0.056	0.064	-0.005
MTK	**.251**	1	**.096**	**.153**	**.086**	-0.022	**.210**	**-.106**	**-.106**	**.098**	**.091**	-0.025	-0.002
OTK	0.025	**.096**	1	0.074	**.094**	-0.034	-0.005	**-.134**	**-.191**	**.098**	**.188**	-0.003	0.032
WDCD	**.235**	**.153**	0.074	1	**.537**	**-.354**	0.076	**-.141**	-0.071	**.086**	0.059	0.078	**-.087**
BL	**.132**	**.086**	**.094**	**.537**	1	**-.146**	**.164**	-0.014	-0.039	0.037	-0.022	**.089**	-0.068
NS	-0.055	-0.022	-0.034	**-.354**	**-.146**	1	-0.066	0.068	0.034	-0.043	-0.037	-0.01	-0.011
SGEQ	-0.003	**.210**	-0.005	0.076	**.164**	-0.066	1	-0.005	-0.002	-0.017	0.049	-0.073	-0.024
OS	**-.087**	**-.106**	**-.134**	**-.141**	-0.014	0.068	-0.005	1	**-.227**	**-.269**	**-.229**	-0.061	0.002
RES	0.01	**-.106**	**-.191**	-0.071	-0.039	0.034	-0.002	**-.227**	1	**-.411**	**-.350**	**-.094**	-0.022
COMM	-0.02	**.098**	**.098**	**.086**	0.037	-0.043	-0.017	**-.269**	**-.411**	1	**-.415**	**-.111**	0.026
INDUS	0.056	**.091**	**.188**	0.059	-0.022	-0.037	0.049	**-.229**	**-.350**	**-.415**	1	**-.095**	0.002
INST	0.064	-0.025	-0.003	0.078	**.089**	-0.01	-0.073	-0.061	**-.094**	**-.111**	**-.095**	1	-0.027
STPL	-0.005	-0.002	0.032	**-.087**	-0.068	-0.011	-0.024	0.002	-0.022	0.026	0.002	-0.027	1
RRXS	0.025	0.044	0.049	-0.011	-0.015	-0.013	0.05	-0.055	0.002	-0.05	**.106**	-0.034	-0.037
NMK	**-.097**	0.005	-0.011	**-.332**	**-.218**	**.179**	0.062	0.014	0.051	-0.057	0.019	-0.055	-0.059
STPX	0.067	-0.027	-0.031	**.311**	**.213**	**-.132**	-0.067	0.017	-0.032	0.061	-0.073	0.074	**-.367**
L75	**.119**	**.205**	-0.006	**.108**	0.032	-0.055	-0.079	**-.243**	0.007	**.150**	-0.018	**.104**	0.03
B200-500	-0.07	**-.131**	0.06	0.008	-0.033	-0.023	-0.015	-0.057	-0.033	**.100**	-0.036	0.016	0.041
B75-200	-0.07	**-.131**	0.06	0.008	-0.033	-0.023	-0.015	-0.057	-0.033	**.100**	-0.036	0.016	0.041
NHWY	0.042	-0.064	-0.075	-0.058	0.023	0.034	0.032	**.287**	0.047	**-.221**	-0.007	-0.067	-0.05
TRFLN	0.064	0.038	-0.022	**.157**	**.205**	-0.02	-0.067	**-.150**	**-.155**	**.277**	-0.083	**.157**	0.051
STHWY	0.06	**-.177**	**-.287**	0.07	**.130**	-0.027	-0.004	**.238**	0.068	-0.043	**-.202**	-0.004	-0.039
AADT	0.07	**.137**	0.022	**.229**	**.187**	-0.046	-0.059	**-.243**	**-.225**	**.348**	0.008	0.085	-0.017
PCTRK	**-.110**	-0.065	-0.003	-0.038	0.027	0.058	-0.012	-0.007	-0.039	-0.026	**.089**	-0.047	0.079
SCHLB	**-.090**	-0.048	-0.054	0.026	0.051	-0.019	-0.084	-0.065	0.078	**.086**	**-.115**	-0.013	-0.017
TTRN	**.380**	**.433**	**.143**	**.117**	-0.081	-0.031	**.318**	**-.163**	**-.108**	0.026	**.208**	-0.013	0.018
TTSWT	0.016	0.049	**.274**	**.098**	**.087**	0.024	0.004	-0.077	**-.145**	0.02	**.183**	-0.005	-0.048
XBUCK	**-.371**	**-.163**	-0.052	**-.121**	0.044	-0.069	0.04	0.074	0.047	-0.025	-0.067	-0.029	-0.004
GT	**.347**	**.280**	0.082	**.745**	**.362**	**-.144**	0.036	**-.154**	**-.138**	**.087**	**.108**	**.156**	-0.037
FLP	**.199**	**.192**	**.127**	**.568**	**.362**	**-.130**	-0.009	**-.228**	**-.190**	**.265**	0.027	**.151**	-0.083
HWYSPD	-0.051	**-.196**	**-.214**	-0.012	0.041	0.036	-0.041	**.407**	**.146**	**-.337**	-0.06	**-.104**	-0.033

Table 9 (b): Correlation matrix based on track class 4 data

Variable	RRXS	NMK	STPX	L75	B200-500	B75-200	NHWY	TRFLN
Crashes	-0.005	-0.026	0.036	**0.154**	0	0	**-0.1**	**0.135**
MTS	0.025	**-0.097**	0.067	**0.119**	-0.07	-0.07	0.042	0.064
MTK	0.044	0.005	-0.027	**0.205**	**-0.131**	**-0.131**	-0.064	0.038
OTK	0.049	-0.011	-0.031	-0.006	0.06	0.06	-0.075	-0.022
WDCD	-0.011	**-0.332**	**0.311**	**0.108**	0.008	0.008	-0.058	**0.157**
BL	-0.015	**-0.218**	**0.213**	0.032	-0.033	-0.033	0.023	**0.205**
NS	-0.013	**0.179**	**-0.132**	-0.055	-0.023	-0.023	0.034	-0.02
SGEQ	0.05	0.062	-0.067	-0.079	-0.015	-0.015	0.032	-0.067
OS	-0.055	0.014	0.017	**-0.243**	-0.057	-0.057	**0.287**	**-0.15**
RES	0.002	0.051	-0.032	0.007	-0.033	-0.033	0.047	**-0.155**
COMM	-0.05	-0.057	0.061	**0.15**	**0.1**	**0.1**	**-0.221**	**0.277**
INDUS	**0.106**	0.019	-0.073	-0.018	-0.036	-0.036	-0.007	-0.083
INST	-0.034	-0.055	0.074	**0.104**	0.016	0.016	-0.067	**0.157**
STPL	-0.037	-0.059	**-0.367**	0.03	0.041	0.041	-0.05	0.051
RRXS	1	-0.074	**-0.458**	0.033	0.006	0.006	-0.021	-0.026
NMK	-0.074	1	**-0.74**	0.013	-0.034	-0.034	-0.023	**-0.139**
STPX	**-0.458**	**-0.74**	1	-0.041	0.007	0.007	0.051	**0.104**
L75	0.033	0.013	-0.041	1	**-0.334**	**-0.334**	**-0.533**	0.014
B200-500	0.006	-0.034	0.007	**-0.334**	1	**1**	**-0.221**	**0.132**
B75-200	0.006	-0.034	0.007	**-0.334**	**1**	1	**-0.221**	**0.132**
NHWY	-0.021	-0.023	0.051	**-0.533**	**-0.221**	**-0.221**	1	-0.077
TRFLN	-0.026	**-0.139**	**0.104**	0.014	**0.132**	**0.132**	-0.077	1
STHWY	**-0.166**	**-0.342**	**0.381**	**-0.13**	-0.063	-0.063	**0.187**	-0.01
AADT	-0.005	**-0.158**	**0.137**	0.059	0.065	0.065	**-0.098**	**0.597**
PCTRK	0.021	-0.003	-0.043	**-0.11**	**0.088**	**0.088**	0.045	0.018
SCHLB	-0.014	-0.021	0.031	-0.025	**0.117**	**0.117**	**-0.132**	**0.204**
TTRN	0.073	0.067	**-0.101**	**0.165**	-0.043	-0.043	**-0.105**	-0.015
TTSWT	0.037	-0.084	0.069	-0.01	0.056	0.056	-0.016	0.063
XBUCK	0.002	-0.012	0.01	**-0.096**	0.062	0.062	0.052	0.026
GT	-0.056	**-0.247**	**0.245**	**0.101**	0.008	0.008	-0.035	**0.285**
FLP	0.02	**-0.185**	**0.175**	**0.206**	0.071	0.071	**-0.164**	**0.52**
HWYSPD	-0.07	**-0.138**	**0.162**	**-0.261**	**-0.108**	**-0.108**	**0.288**	**-0.108**

Table 9 (c): Correlation matrix based on track class 4 data

Variable	STHWY	AADT	PCTRK	SCHLB	TTRN	TTSWT	XBUCK	GT	FLP	HWYSPD
Crashes	-0.056	**0.17**	-0.014	0.021	**0.238**	0.057	**-0.177**	**0.191**	**0.19**	**-0.127**
MTS	0.06	0.07	**-0.11**	**-0.09**	**0.38**	0.016	**-0.371**	**0.347**	**0.199**	-0.051
MTK	**-0.177**	**0.137**	-0.065	-0.048	**0.433**	0.049	**-0.163**	**0.28**	**0.192**	**-0.196**
OTK	**-0.287**	0.022	-0.003	-0.054	**0.143**	**0.274**	-0.052	0.082	**0.127**	**-0.214**
WDCD	0.07	**0.229**	-0.038	0.026	**0.117**	**0.098**	**-0.121**	**0.745**	**0.568**	-0.012
BL	**0.13**	**0.187**	0.027	0.051	-0.081	**0.087**	0.044	**0.362**	**0.362**	0.041
NS	-0.027	-0.046	0.058	-0.019	-0.031	0.024	-0.069	**-0.144**	**-0.13**	0.036
SGEQ	-0.004	-0.059	-0.012	-0.084	**0.318**	0.004	0.04	0.036	-0.009	-0.041
OS	**0.238**	**-0.243**	-0.007	-0.065	**-0.163**	-0.077	0.074	**-0.154**	**-0.228**	**0.407**
RES	0.068	**-0.225**	-0.039	0.078	**-0.108**	**-0.145**	0.047	**-0.138**	**-0.19**	**0.146**
COMM	-0.043	**0.348**	-0.026	**0.086**	0.026	0.02	-0.025	**0.087**	**0.265**	**-0.337**
INDUS	**-0.202**	0.008	**0.089**	**-0.115**	**0.208**	**0.183**	-0.067	**0.108**	0.027	-0.06
INST	-0.004	0.085	-0.047	-0.013	-0.013	-0.005	-0.029	**0.156**	**0.151**	**-0.104**
STPL	-0.039	-0.017	0.079	-0.017	0.018	-0.048	-0.004	-0.037	-0.083	-0.033
RRXS	**-0.166**	-0.005	0.021	-0.014	0.073	0.037	0.002	-0.056	0.02	-0.07
NMK	**-0.342**	**-0.158**	-0.003	-0.021	0.067	-0.084	-0.012	**-0.247**	**-0.185**	**-0.138**
STPX	**0.381**	**0.137**	-0.043	0.031	**-0.101**	0.069	0.01	**0.245**	**0.175**	**0.162**
L75	**-0.13**	0.059	**-0.11**	-0.025	**0.165**	-0.01	**-0.096**	**0.101**	**0.206**	**-0.261**
B200-500	-0.063	0.065	**0.088**	**0.117**	-0.043	0.056	0.062	0.008	0.071	**-0.108**
B75-200	-0.063	0.065	**0.088**	**0.117**	-0.043	0.056	0.062	0.008	0.071	**-0.108**
NHWY	**0.187**	**-0.098**	0.045	**-0.132**	**-0.105**	-0.016	0.052	-0.035	**-0.164**	**0.288**
TRFLN	-0.01	**0.597**	0.018	**0.204**	-0.015	0.063	0.026	**0.285**	**0.52**	**-0.108**
STHWY	1	-0.013	-0.047	0.044	**-0.147**	**-0.194**	-0.013	-0.004	**-0.1**	**0.39**
AADT	-0.013	1	0.035	**0.252**	0.075	**0.091**	-0.048	**0.314**	**0.431**	**-0.214**
PCTRK	-0.047	0.035	1	0.065	**-0.11**	-0.039	0.068	**-0.092**	-0.007	-0.01
SCHLB	0.044	**0.252**	0.065	1	**-0.131**	-0.014	**0.125**	-0.062	**0.117**	-0.04
TTRN	**-0.147**	0.075	**-0.11**	**-0.131**	1	**0.168**	**-0.273**	**0.224**	**0.139**	**-0.234**
TTSWT	**-0.194**	**0.091**	-0.039	-0.014	**0.168**	1	-0.027	**0.092**	**0.195**	**-0.095**
XBUCK	-0.013	-0.048	0.068	**0.125**	**-0.273**	-0.027	1	**-0.139**	**-0.086**	0.043
GT	-0.004	**0.314**	**-0.092**	-0.062	**0.224**	**0.092**	**-0.139**	1	**0.573**	-0.076
FLP	**-0.1**	**0.431**	-0.007	**0.117**	**0.139**	**0.195**	**-0.086**	**0.573**	1	**-0.239**
HWYSPD	**0.39**	**-0.214**	-0.01	-0.04	**-0.234**	**-0.095**	0.043	-0.076	**-0.239**	1

Table 10 (a): Correlation matrix based on track class 5 data

Variable	LTM	MTS	MTK	OTK	WDCD	BL
Crashes	-0.013	0.045	**0.197**	0.017	**0.104**	-0.048
LTM	1	**0.089**	-0.018	**0.096**	0.007	0.069
MTS	**0.089**	1	**0.237**	-0.014	**0.191**	**0.333**
MTK	-0.018	**0.237**	1	**0.086**	**0.152**	**0.112**
OTK	**0.096**	-0.014	**0.086**	1	**0.087**	**0.102**
WDCD	0.007	**0.191**	**0.152**	**0.087**	1	**0.503**
BL	0.069	**0.333**	**0.112**	**0.102**	**0.503**	1
NS	-0.003	-0.054	-0.026	-0.033	**-0.367**	**-0.141**
SGEQ	-0.049	**0.131**	**0.172**	-0.012	0.072	**0.156**
OS	-0.018	0.073	-0.079	**-0.156**	**-0.141**	-0.02
RES	-0.026	0.066	-0.063	**-0.22**	-0.072	-0.013
COMM	0.063	-0.075	0.054	**0.118**	0.077	0.012
INDUS	-0.024	-0.057	0.085	**0.24**	0.082	-0.015
INST	-0.007	0.029	-0.037	-0.036	0.068	**0.086**
STPL	-0.007	-0.009	-0.016	0.048	**-0.102**	-0.061
RRXS	-0.009	-0.006	0.052	0.017	-0.049	-0.074
NMK	-0.015	-0.059	0.001	0.009	**-0.314**	**-0.183**
STPX	0.021	0.055	-0.021	-0.038	**0.325**	**0.214**
L75	-0.038	0.05	**0.129**	0.02	**0.108**	0.068
B200-500	**0.119**	**-0.102**	**-0.138**	0.069	0.038	-0.015
B75-200	**0.119**	**-0.102**	**-0.138**	0.069	0.038	-0.015
NHWY	-0.028	**0.168**	0.015	**-0.109**	-0.078	0.013
TRFLN	0.058	-0.041	-0.001	0.004	**0.148**	**0.188**
STHWY	-0.071	**0.13**	**-0.138**	**-0.288**	0.039	**0.118**
AADT	0.076	-0.063	**0.114**	0.051	**0.221**	**0.155**
PCTRK	-0.019	**-0.116**	-0.043	-0.004	-0.032	0.016
SCHLB	-0.021	-0.067	-0.051	-0.035	0.032	0.055
TTRN	-0.083	**0.348**	**0.459**	**0.103**	**0.168**	0.005
TTSWT	-0.043	0	0.051	**0.275**	**0.09**	**0.089**
XBUCK	0.028	**-0.251**	**-0.201**	-0.002	**-0.116**	0.043
GT	-0.003	**0.196**	**0.238**	**0.114**	**0.741**	**0.351**
FLP	-0.024	0.068	**0.139**	**0.162**	**0.548**	**0.366**
HWYSPD	-0.06	**0.104**	**-0.125**	**-0.192**	-0.015	**0.092**

Table 10 (b): Correlation matrix based on track class 5 data

Variable	NS	SGEQ	OS	RES	COMM	INDUS	INST	STPL
Crashes	-0.019	0.074	**-0.089**	**-0.125**	**0.108**	0.081	0.008	0.001
LTM	-0.003	-0.049	-0.018	-0.026	0.063	-0.024	-0.007	-0.007
MTS	-0.054	**0.131**	0.073	0.066	-0.075	-0.057	0.029	-0.009
MTK	-0.026	**0.172**	-0.079	-0.063	0.054	0.085	-0.037	-0.016
OTK	-0.033	-0.012	**-0.156**	**-0.22**	**0.118**	**0.24**	-0.036	0.048
WDCD	**-0.367**	0.072	**-0.141**	-0.072	0.077	0.082	0.068	**-0.102**
BL	**-0.141**	**0.156**	-0.02	-0.013	0.012	-0.015	**0.086**	-0.061
NS	1	-0.07	0.062	0.033	-0.043	-0.034	-0.01	-0.011
SGEQ	-0.07	1	0.025	-0.006	-0.022	0.03	-0.057	-0.056
OS	0.062	0.025	1	**-0.248**	**-0.287**	**-0.229**	-0.066	0.027
RES	0.033	-0.006	**-0.248**	1	**-0.421**	**-0.335**	**-0.096**	-0.052
COMM	-0.043	-0.022	**-0.287**	**-0.421**	1	**-0.388**	**-0.111**	0.002
INDUS	-0.034	0.03	**-0.229**	**-0.335**	**-0.388**	1	**-0.089**	0.039
INST	-0.01	-0.057	-0.066	**-0.096**	**-0.111**	**-0.089**	1	-0.027
STPL	-0.011	-0.056	0.027	-0.052	0.002	0.039	-0.027	1
RRXS	-0.013	0.031	-0.059	0.046	-0.045	0.063	-0.033	-0.036
NMK	**0.175**	0.03	0.01	0.049	-0.065	0.019	-0.017	-0.06
STPX	**-0.132**	-0.016	0.011	-0.041	0.075	-0.065	0.043	**-0.365**
L75	-0.054	-0.052	**-0.253**	-0.001	**0.163**	0.008	0.058	0.034
B200-500	-0.023	-0.046	-0.067	-0.047	**0.122**	-0.037	0.018	0.044
B75-200	-0.023	-0.046	-0.067	-0.047	**0.122**	-0.037	0.018	0.044
NHWY	0.028	0.075	**0.327**	0.072	**-0.265**	-0.045	-0.023	-0.036
TRFLN	-0.018	-0.067	**-0.145**	**-0.146**	**0.256**	-0.066	**0.151**	0.061
STHWY	-0.031	0.077	**0.241**	0.052	-0.035	**-0.211**	-0.012	-0.048
AADT	-0.045	-0.068	**-0.247**	**-0.229**	**0.35**	0.027	0.078	-0.006
PCTRK	0.062	-0.028	-0.032	-0.042	-0.001	**0.088**	-0.046	**0.102**
SCHLB	-0.021	-0.028	**-0.096**	**0.087**	0.081	**-0.112**	0.031	-0.02
TTRN	-0.037	**0.268**	-0.082	**-0.105**	-0.011	**0.188**	0.003	-0.058
TTSWT	0.025	-0.009	-0.084	**-0.148**	0.03	**0.201**	-0.027	-0.011
XBUCK	-0.066	**0.098**	0.002	0.054	-0.015	-0.025	-0.044	-0.026
GT	**-0.148**	0.03	**-0.166**	**-0.129**	0.078	**0.137**	**0.133**	-0.064
FLP	**-0.131**	-0.017	**-0.241**	**-0.17**	**0.256**	0.045	**0.132**	-0.082
HWYSPD	0.031	0.048	**0.395**	**0.171**	**-0.358**	**-0.088**	-0.058	-0.032

Table 10 (c): Correlation matrix based on track class 5 data

Variable	RRXS	NMK	STPX	L75	B200-500	B75-200	NHWY	TRFLN
Crashes	0.002	-0.023	0.017	**0.125**	0.012	0.012	-0.082	**0.141**
LTM	-0.009	-0.015	0.021	-0.038	**0.119**	**0.119**	-0.028	0.058
MTS	-0.006	-0.059	0.055	0.05	**-0.102**	**-0.102**	**0.168**	-0.041
MTK	0.052	0.001	-0.021	**0.129**	**-0.138**	**-0.138**	0.015	-0.001
OTK	0.017	0.009	-0.038	0.02	0.069	0.069	**-0.109**	0.004
WDCD	-0.049	**-0.314**	**0.325**	**0.108**	0.038	0.038	-0.078	**0.148**
BL	-0.074	**-0.183**	**0.214**	0.068	-0.015	-0.015	0.013	**0.188**
NS	-0.013	**0.175**	**-0.132**	-0.054	-0.023	-0.023	0.028	-0.018
SGEQ	0.031	0.03	-0.016	-0.052	-0.046	-0.046	0.075	-0.067
OS	-0.059	0.01	0.011	**-0.253**	-0.067	-0.067	**0.327**	**-0.145**
RES	0.046	0.049	-0.041	-0.001	-0.047	-0.047	0.072	**-0.146**
COMM	-0.045	-0.065	0.075	**0.163**	**0.122**	**0.122**	**-0.265**	**0.256**
INDUS	0.063	0.019	-0.065	0.008	-0.037	-0.037	-0.045	-0.066
INST	-0.033	-0.017	0.043	0.058	0.018	0.018	-0.023	**0.151**
STPL	-0.036	-0.06	**-0.365**	0.034	0.044	0.044	-0.036	0.061
RRXS	1	-0.074	**-0.445**	0.046	0.012	0.012	-0.052	-0.014
NMK	-0.074	1	**-0.75**	0.021	-0.054	-0.054	-0.002	**-0.131**
STPX	**-0.445**	**-0.75**	1	-0.055	0.019	0.019	0.044	**0.088**
L75	0.046	0.021	-0.055	1	**-0.322**	**-0.322**	**-0.569**	0.019
B200-500	0.012	-0.054	0.019	**-0.322**	1	**1**	**-0.237**	**0.179**
B75-200	0.012	-0.054	0.019	**-0.322**	**1**	1	**-0.237**	**0.179**
NHWY	-0.052	-0.002	0.044	**-0.569**	**-0.237**	**-0.237**	1	**-0.126**
TRFLN	-0.014	**-0.131**	**0.088**	0.019	**0.179**	**0.179**	**-0.126**	1
STHWY	**-0.17**	**-0.383**	**0.421**	**-0.122**	-0.066	-0.066	**0.192**	-0.022
AADT	-0.004	**-0.162**	**0.137**	0.064	**0.109**	**0.109**	**-0.166**	**0.564**
PCTRK	-0.033	-0.017	-0.013	**-0.09**	**0.109**	**0.109**	-0.008	0.037
SCHLB	-0.022	-0.017	0.034	-0.013	**0.125**	**0.125**	**-0.12**	**0.176**
TTRN	**0.104**	0.018	-0.043	**0.138**	**-0.095**	**-0.095**	-0.019	-0.059
TTSWT	0.027	-0.079	0.055	0.007	0.081	0.081	-0.068	0.045
XBUCK	0.005	0.02	-0.007	-0.08	0.055	0.055	0.029	0.068
GT	-0.058	**-0.235**	**0.25**	**0.1**	0.052	0.052	-0.066	**0.278**
FLP	0.003	**-0.193**	**0.191**	**0.223**	**0.115**	**0.115**	**-0.222**	**0.51**
HWYSPD	**-0.104**	**-0.136**	**0.179**	**-0.278**	**-0.12**	**-0.12**	**0.333**	**-0.099**

Table 10 (d): Correlation matrix based on track class 5 data

Variable	STHWY	AADT	PCTRK	SCHLB	TTRN	TTSWT	XBUCK	GT	FLP	HWYSPD
Crashes	-0.051	**0.2**	0.005	0.039	**0.214**	0.045	**-0.165**	**0.199**	**0.196**	**-0.115**
LTM	-0.071	0.076	-0.019	-0.021	-0.083	-0.043	0.028	-0.003	-0.024	-0.06
MTS	**0.13**	-0.063	**-0.116**	-0.067	**0.348**	0	**-0.251**	**0.196**	0.068	**0.104**
MTK	**-0.138**	**0.114**	-0.043	-0.051	**0.459**	0.051	**-0.201**	**0.238**	**0.139**	**-0.125**
OTK	**-0.288**	0.051	-0.004	-0.035	**0.103**	**0.275**	-0.002	**0.114**	**0.162**	**-0.192**
WDCD	0.039	**0.221**	-0.032	0.032	**0.168**	**0.09**	**-0.116**	**0.741**	**0.548**	-0.015
BL	**0.118**	**0.155**	0.016	0.055	0.005	**0.089**	0.043	**0.351**	**0.366**	**0.092**
NS	-0.031	-0.045	0.062	-0.021	-0.037	0.025	-0.066	**-0.148**	**-0.131**	0.031
SGEQ	0.077	-0.068	-0.028	-0.028	**0.268**	-0.009	**0.098**	0.03	-0.017	0.048
OS	**0.241**	**-0.247**	-0.032	**-0.096**	-0.082	-0.084	0.002	**-0.166**	**-0.241**	**0.395**
RES	0.052	**-0.229**	-0.042	**0.087**	**-0.105**	**-0.148**	0.054	**-0.129**	**-0.17**	**0.171**
COMM	-0.035	**0.35**	-0.001	0.081	-0.011	0.03	-0.015	0.078	**0.256**	**-0.358**
INDUS	**-0.211**	0.027	**0.088**	**-0.112**	**0.188**	**0.201**	-0.025	**0.137**	0.045	**-0.088**
INST	-0.012	0.078	-0.046	0.031	0.003	-0.027	-0.044	**0.133**	**0.132**	-0.058
STPL	-0.048	-0.006	**0.102**	-0.02	-0.058	-0.011	-0.026	-0.064	-0.082	-0.032
RRXS	**-0.17**	-0.004	-0.033	-0.022	**0.104**	0.027	0.005	-0.058	0.003	**-0.104**
NMK	**-0.383**	**-0.162**	-0.017	-0.017	0.018	-0.079	0.02	**-0.235**	**-0.193**	**-0.136**
STPX	**0.421**	**0.137**	-0.013	0.034	-0.043	0.055	-0.007	**0.25**	**0.191**	**0.179**
L75	**-0.122**	0.064	**-0.09**	-0.013	**0.138**	0.007	-0.08	**0.1**	**0.223**	**-0.278**
B200-500	-0.066	**0.109**	**0.109**	**0.125**	**-0.095**	0.081	0.055	0.052	**0.115**	**-0.12**
B75-200	-0.066	**0.109**	**0.109**	**0.125**	**-0.095**	0.081	0.055	0.052	**0.115**	**-0.12**
NHWY	**0.192**	**-0.166**	-0.008	**-0.12**	-0.019	-0.068	0.029	-0.066	**-0.222**	**0.333**
TRFLN	-0.022	**0.564**	0.037	**0.176**	-0.059	0.045	0.068	**0.278**	**0.51**	**-0.099**
STHWY	1	-0.043	-0.068	0.026	**-0.09**	**-0.148**	-0.039	-0.025	**-0.102**	**0.38**
AADT	-0.043	1	0.054	**0.263**	0.038	0.085	-0.007	**0.31**	**0.423**	**-0.233**
PCTRK	-0.068	0.054	1	0.05	**-0.096**	-0.035	0.068	-0.076	0.016	-0.02
SCHLB	0.026	**0.263**	0.05	1	**-0.133**	0.008	**0.1**	-0.06	**0.103**	-0.075
TTRN	**-0.09**	0.038	**-0.096**	**-0.133**	1	**0.189**	**-0.329**	**0.244**	**0.138**	**-0.146**
TTSWT	**-0.148**	0.085	-0.035	0.008	**0.189**	1	-0.002	**0.087**	**0.207**	-0.078
XBUCK	-0.039	-0.007	0.068	**0.1**	**-0.329**	-0.002	1	**-0.115**	-0.033	0.025
GT	-0.025	**0.31**	-0.076	-0.06	**0.244**	**0.087**	**-0.115**	1	**0.555**	-0.075
FLP	**-0.102**	**0.423**	0.016	**0.103**	**0.138**	**0.207**	-0.033	**0.555**	1	**-0.258**
HWYSPD	**0.38**	**-0.233**	-0.02	-0.075	**-0.146**	-0.078	0.025	-0.075	**-0.258**	1

Table 11: Key variables considered in each track class model

Track class 1	Track Class 2	Track Class 3	Track Class 4	Track Class 5
AADT Total number of trains # of main tracks	If stop lines present # of traffic lanes % of trucks	# of main tracks Total number of switching trains No highway nearby	# of main tracks No highway nearby	# of main tracks # of traffic lanes

CHAPTER 5: ANALYSIS AND DISCUSSION

This chapter summarizes the descriptive statistics along with the coefficients obtained from the models considered for each of the analytical scenarios. The performance of models for each track class has been assessed based on the statistical parameters defined in Chapter 3 (parameters for goodness of fit). Finally, the discussion compares the models to come up with a combination of the best fitting model for the data used in this study.

At first, a normality check was performed. Figure 1 shows the histogram for crash data. It indicates that the data fails to meet the assumption of normality. Therefore, the generalized linear models were considered for model development in this study. Models with and without intercept were explored in the study.

Table 12 shows the distribution of rail-highway grade crossings based on warning device code (WDCD =1 to 9) across the various track classes.

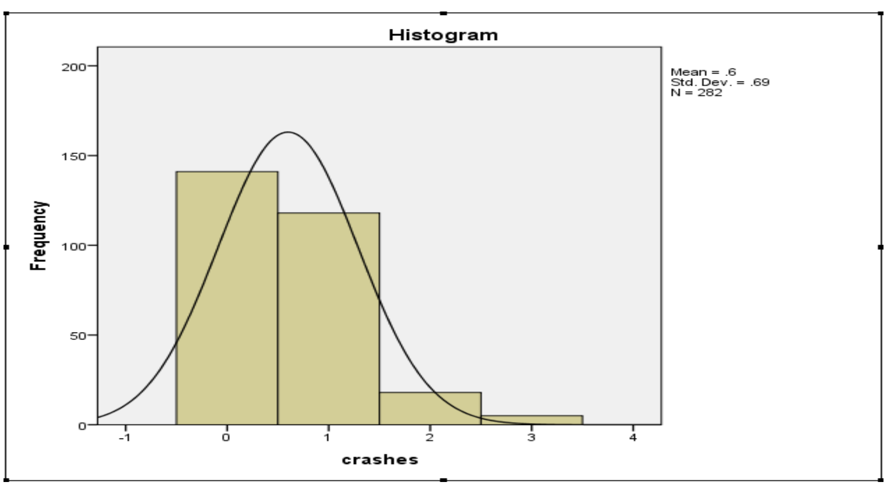


Figure 1: Histogram of data

Table 12: distribution of rail-highway grade crossings based on warning device code

Track Class		Warning Device Code (WDCD)									Total
	Crashes	1	2	3	4	5	6	7	8	9	
1	0	0	2	157	24	34	10	78	193	8	506 (97.6%)
	1	0	0	3	0	2	0	3	4	0	12 (2.3%)
	Total	0 (0%)	2 (0.4%)	160 (30.9%)	24 (4.6%)	36 (6.9%)	10 (1.9%)	81 (15.6%)	197 (38.3%)	8 (1.5%)	518
2	0	0	5	349	37	11	7	115	573	11	1108 (97.8%)
	1	0	0	7	1	0	1	6	9	0	24 (2.1%)
	2	0	0	1	0	0	0	0	0	0	1 (0.1%)
	Total	0 (0%)	5 (0.4%)	357 (31.5%)	38 (3.4%)	11 (0.9%)	8 (0.7%)	121 (10.7%)	582 (51.4%)	11 (0.5%)	1133
3	0	0	0	129	0	16	2	71	411	8	637 (94.9%)
	1	0	0	2	0	1	0	6	21	1	31 (4.6%)
	2	0	0	0	0	0	0	1	1	1	3 (0.4%)
	Total	0 (0%)	0 (0%)	131 (19.5%)	0 (0%)	17 (2.5%)	2 (0.3%)	78 (11.6%)	433 (64.5%)	10 (1.5%)	671
4	0	0	0	20	3	0	1	14	395	34	467 (89.3%)
	1	0	0	1	0	0	0	0	32	8	41(7.8%)
	2	0	0	1	0	0	0	0	6	5	12 (2.3%)
	3	0	0	0	0	0	0	0	2	1	3 (0.6%)
	Total	0 (0%)	0 (0%)	22 (4.2%)	3 (0.57%)	0 (0%)	1 (0.19%)	14 (2.67%)	435 (83.17%)	48 (9.17%)	523
5	0	0	0	1	0	0	0	1	73	3	78 (93.9%)
	1	0	0	0	0	0	0	0	4	1	5 (6%)
	Total	0 (0%)	0 (0%)	1 (1.2%)	0 (0%)	0 (0%)	0 (0%)	1 (1.2%)	77 (92.7%)	4 (4.8%)	83

Note: Warning device code 1= no signs or signals, 2= other signs or signals, 3= crossbucks, 4= stop signs, 5 = special active warning devices, 6= wigwags / bells, 7= flashing lights, 8= all other gates (two and three quadrant gates), 9= four quad (full barrier) gates

Track class 1 has two quadrant gates and crossbucks installed at 38.3% and 30.9% of the total rail-highway grade crossings. Similarly, track class 2 has 51.4% and 31.5% rail-highway grade crossings with two quadrant gates and crossbucks, respectively. Track class 1 has 15.6% rail-highway grade crossings with flashing lights installed while track class 2 has a higher number i.e., 121 rail-highway grade crossings with flashing lights installed. Further, for track class 3 and above, more rail-highway grade crossings have flashing lights and gates installed at them rather than just crossbucks. Track class 5 has 92.7% of its total rail-highway grade crossings with two quadrant gates. Although the four quadrant gates are rarely installed at rail-highway grade crossings, two quadrant gates are observed to be abundant in all track classes. The distribution warning devices across track classes is justified because as track class is related to the speed of the train.

Table 13 shows distribution of the number of main tracks across the various track classes considered.

Track classes 1, 2 and 3 have rail-highway grade crossings with mostly 0 or 1 main tracks while track classes 4 and 5 have a quite a few rail-highway grade crossings with 1 and 2 main tracks. There are fairly a low number of rail-highway grade crossings in any of the classes with 3 and 4 main tracks. Also, more number of rail-highway grade crossings with one main track are found to have crashes at them. This can be mainly due to the abundance of rail-highway grade crossings in this category (# of main tracks = 1) or may be due to some other underlying trend.

Table 14 shows the distribution of rail-highway grade crossings by main tracks and warning devices in all the track classes put together. As the number of main tracks increases, more and more rail-highway grade crossings have two quadrant gates at them instead of just crossbucks. The rail-highway grade crossings with 2 main tracks have more than 90% of the rail-highway grade crossings with two quadrant gates.

Table 13: Distribution of rail-highway grade crossings across track classes

Track Class	Crashes	# of Main tracks					
		0	1	2	3	4	Total
1	0	133	397	3	0	0	533 (97.8%)
	1	2	9	1	0	0	12 (2.2%)
	Total	135 (24.7%)	406 (74.5%)	4 (0.7%)	0 (0%)	0 (0%)	545
2	0	72	1023	12	1	0	1108 (97.8%)
	1	3	21	0	0	0	24 (2.1%)
	2	0	1	0	0	0	1 (0.08%)
	Total	75 (6.6%)	1045 (92.2%)	12 (1.06%)	1 (0.1%)	0 (0%)	1133
3	0	8	624	5	0	0	637 (94.9%)
	1	1	26	4	0	0	31 (4.6%)
	2	0	1	2	0	0	3 (0.45%)
	Total	9 (1.3%)	651 (97%)	11 (1.6%)	0 (0%)	0 (0%)	671
4	0	5	411	51	0	0	467 (89.29%)
	1	0	24	16	0	1	41 (7.84%)
	2	0	7	4	1	0	12 (2.29%)
	3	0	2	1	0	0	3 (0.57%)
	Total	5 (0.9%)	444 (84.9%)	72 (13.7%)	1 (0.1%)	1 (0.1%)	523
5	0	0	56	22	0	0	78 (0.94%)
	1	0	1	4	0	0	5 (6.2%)
	Total	0 (0%)	57 (68.7%)	26 (31.3%)	0 (0%)	0 (0%)	83

Table 14: Distribution of rail-highway grade crossings by # of main tracks and warning device code

# of Main Tracks	Warning Device Code								
	1	2	3	4	5	6	7	8	9
0	19 (8.3%)	2 (0.9%)	69 (30.3%)	10 (4.4%)	25 (10.9%)	4 (1.8%)	32 (14%)	58 (25.4%)	9 (3.95%)
1	48 (1.82%)	5 (0.19%)	595 (22.5%)	72 (2.73%)	22 (0.83%)	17 (0.6%)	261 (9.9%)	1568 (59.4%)	51 (1.9%)
2	0 (0%)	0 (0%)	7 (5.6%)	0 (0%)	0 (0%)	0 (0%)	2 (1.6%)	97 (77.6%)	19 (15.2%)
3	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (50%)	1 (50%)
4	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0	1 (100%)

5.1. Modeling based on All Track Class Data

A model was first developed considering data for all track classes together. The model developed is shown in Table 15. The results from each of the models are discussed in detail in the following sections.

- Linear Model

The linear model results look quite promising with a low deviance. The all track class data model has the number of main tracks and posted highway speed limit in the final model. The number of main tracks is positively correlated to the number of crashes while posted highway speed limit has a counter-intuitive negative coefficient (as higher highway speed limit increases risk, in general). It also has a negative intercept to account for the missing factors in the model. The AIC and AICC are close and Likelihood Chi-square value is significant. The deviance is not as low as in the models for each track class.

- Poisson Distribution Based Model

The Poisson all track class data model has the number of main tracks and posted highway speed limit in the final model. The number of main tracks is positively correlated to crashes, while the highway speed limit has a counter-intuitive coefficient as in the previous linear model. It also has a negative intercept to account for the missing factors in the model. The AIC and AICC are close and Likelihood Chi-square value is significant. The deviance is not as low as models for each track class.

- Negative Binomial (NB) Distribution Based Model

The NB based all track class data model has the number of main tracks and posted highway speed limit in the final model. The trends in coefficients are same for other models using the dataset for all rail-highway grade crossings. It also has a negative intercept to account for the missing factors in the model. The AIC and AICC are close and Likelihood Chi-square value is significant. The deviance is higher than the linear model for the same dataset but lower than that of the poisson model.

In summary the NB model is the best fitting model for predicting crashes for the all track class data.

Table 15: All track class data model

PARAMETER	LINEAR		POISSON WITH LOG LINK		NEGATIVE BINOMIAL (NB) WITH LOG LINK	
	COEFFICIENT	P-value	COEFFICIENT	P-value	COEFFICIENT	P-value
Intercept	-.030	.176	-3.922	<0.00	-4.172	<0.00
# of main tracks	.124	.000	1.490	<0.00	1.675	<0.00
Posted highway speed Limit	-.001	.023	-.017	.032	-.016	.050
LIKELIHOOD RATIO CHI-SQUARE	94.011	<0.00	90.193	<0.00	84.373	<0.00
AKAIKE'S INFORMATION CRITERION (AIC)	262.221		1176.630		1157.408	
FINITE SAMPLE CORRECTED AIC (AICC)	262.234		1176.638		1157.416	
DEVIANCE	190.891		891.835		760.732	

Table 16: Descriptive statistics of data based on track class

		Track Class				
		I	II	III	IV	V
	Mean	0.02202	0.02269	0.0546	0.14095	0.06024
	Variance	0.02153	0.02392	0.06024	0.20147	0.05661
Frequency	0	97.80%	97.90%	95.40%	89.30%	94%
	1	2.20%	2.09%	4.60%	7.80%	6%
	2	0%	~0%	~0%	2.30%	0%
	3	0%	0%	0%	0.60%	0%

5.2. Models based on Each Track Class Data

The crash distribution, mean and variance in each track class are shown in Table 16. The track class 1 and 5 are found to be under-dispersed, while track classes 2, 3, and 4 were found to be over-dispersed.

Tables 17 through 21 shows model results for track class 1, 2, 3, 4 and 5, respectively. The results from models for each track class are discussed in detail in the following sections.

5.2.1. Model for Track Class 1

The data from track class 1 is used to develop models including variables mentioned in Chapter 4. The results obtained are shown in Table 17 and discussed in detail in the following subsections.

- Linear Model

The linear model for track class 1 has AADT and total number of trains in the final model, both positively correlated with the number of crashes. These variables are analogous to the variable exposure index (product of highway and train traffic) included in the USDOT Crash Prediction Formula. Since track class 1 does not have a very high number of rail-highway grade crossings with active warning devices when compared to other track classes, it makes sense that no warning device is a significant factor on safety here. This relation is also justified as an increase in AADT and total number of trains increase exposure to system users. The model also has a negative intercept, which accounts for any missing factors which could not be included in crash prediction. The Likelihood ratio Chi-square is also significant, indicating the model is better than null model. The AIC and AICC values are close to each other while the deviance is as low as

11.26.

- Poisson Model

The Poisson based model using data for track class 1 has the total number of trains and the number of main tracks in the final model. Both the parameters, the number of main tracks and the total number of trains, are positively correlated to crashes. An increase in the total number of trains increases the number of crashes. Total number of trains running on a track governs the exposure to drivers at the rail-highway grade crossings and hence increased train traffic must lead to higher crash risk. As the number of main tracks increase, there are more tracks for the trains to run on the rail-highway grade crossing hence increasing the risk of a crash. The model has a negative intercept that accounts for any missing factors not considered in crash prediction. The Likelihood ratio Chi-square is also significant indicating the model is better than null model. The AIC and AICC values are close to each other while the deviance is higher than that of linear models.

- Negative Binomial (NB) Model

The NB based model using data for track class 2 has the total number of trains and the number of main tracks in the final model. The total number of trains and the number of main tracks are again positively correlated to crashes here like in the Poisson distribution based model. The model also has a negative intercept to account for missing factors. The Likelihood ratio Chi-square is also significant indicating the model is better than null model. The AIC and AICC values are close to each other while the deviance is higher than that of linear models.

In summary, the NB model is found to be the best fit for crash prediction in track class 1 rail-highway grade crossings.

Table 17: Models for track class 1

PARAMETER	LINEAR		POISSON WITH LOG LINK		NEGATIVE BINOMIAL (NB) WITH LOG LINK	
	COEFFICIENT	P-value	COEFFICIENT	P-value	COEFFICIENT	P-value
Intercept	-1.121E-005	.999	-4.827	.000	-4.768	.000
AADT	0.002	.013				
Total # of trains	.003	<0.00	.061	.001	.062	.003
# of main tracks			.679	.367	.605	.411
LIKELIHOOD RATIO CHI-SQUARE	22.328	<0.00	9.348	.009	8.915	.012
AKAIKE'S INFORMATION CRITERION (AIC)	-559.473		112.233		112.928	
FINITE SAMPLE CORRECTED AIC (AICC)	-559.399		112.278		112.972	
DEVIANCE	11.265		82.233		73.657	

5.2.2 Model for Track Class 2

Model results from track class 2 data are shown in Table 18. The results obtained are discussed in detail in the following subsections.

- Linear Model

The linear model using data for track class 2 has the number of traffic lanes and the percentage of trucks in the final model. Both these variables are positively related to crashes, which is justified as an increase in the number of traffic lanes increases vehicular traffic and exposure. Likewise, roads with high number of trucks are also a contributing factor towards reduced safety at rail-highway grade crossings. The model has a negative intercept which has a fairly low value indicating that most of the factors have been included in modeling. The AIC and AICC are close enough and the Likelihood Chi-square values are significant. The model has a very low deviance as compared to the Poisson and NB models.

- Poisson Model

The Poisson based model using data for track class 2 has the variables stop lines present, the number of traffic lanes, and the percentage of trucks in the final model. All these parameters are positively related to crashes. The coefficient for stop lines present is counter-intuitive here. Similar to total number of trains in track class 1, the number of traffic lanes governs the exposure to the drivers and hence as the highway traffic increases, the crash risk at rail-highway grade crossings is expected to increase. As the percentage of truck traffic on rail-highway grade crossing increases, the crashes are again expected to increase for the same reason. According to Manual of Uniform Traffic Control Devices guidelines on Stop and Yield Lines (Section 8B.28), on paved roadways at grade crossings that are equipped with active control devices such as flashing-light signals, gates, or traffic control signals, a stop line (Section 3B.16) shall be installed to indicate the point behind which highway vehicles are or might be required to stop *(United States Department of Transportation - Federal Highway Administration, 2013).* The increase in the number of crashes at rail-highway grade crossings with stop lines may be linked to failure to yield, poor roadway design, and crossing alignment. It is thus not advisable to predict crashes based on the parameter stop lines present as it may not be the actual factor responsible for the observed trend. The model has a negative intercept that accounts for missing factors in the prediction.

- Negative Binomial (NB) Model

The NB based model using data for track class 2 has the variables stop lines present, the number of traffic lanes, and the percentage of trucks in the final model. The relations of the variables are similar to that in the Poisson distribution based model. The NB model also has a negative intercept. The AIC, AICC are close and Likelihood Chi-square values are significant but the deviance is higher than the linear models.

In summary, the NB Model is the best fitting model to predict crashes on track class 2 rail-highway grade crossings.

Table 18: Models for track class 2

PARAMETER	LINEAR		POISSON WITH LOG LINK		NEGATIVE BINOMIAL (NB) WITH LOG LINK	
	COEFFICIENT	P-value	COEFFICIENT	P-value	COEFFICIENT	P-value
Intercept	-.012	.406	-4.962	.000	-4.987	.000
Stop lines present			1.449	.008	1.470	.010
# of Traffic Lanes	.003	.001	.362	.040	.372	.044
% of trucks	.012	.072	.041	.002	.041	.005
LIKELIHOOD RATIO CHI-SQUARE	15.339	<0.00	13.360	.004	12.903	0.005
AKAIKE'S INFORMATION CRITERION (AIC)	-1033.288		244.895		244.551	
FINITE SAMPLE CORRECTED AIC (AICC)	-1033.253		244.930		244.586	
DEVIANCE	15.339		186.282		166.190	

5.2.3. Model for Track Class 3

Model results from track class 3 data are shown in Table 19. The results obtained are discussed in detail in the following subsections.

- Linear Model

The linear model using data for track class 3 has the number of main tracks, total switching trains and no highway near the rail-highway grade crossing in the final model. The model has positive coefficients for the number of main tracks and the total number of trains. The coefficients make sense because an increase in the number of main tracks means increased tracks for trains to run at a rail-highway grade crossing and an increase in the total switching trains would mean added risk from trains changing tracks. If there is no highway nearby, the number of crashes would be lower. This is mainly due to lesser traffic volume and hence less exposure. The model also has a negative intercept to account for any missing factors in the crash modeling. The AIC and AICC are close enough and the Likelihood Chi-square values are significant. The model has a very low deviance as compared to the Poisson and NB models. The negative number of crashes as a result of a crossing not near a highway, with no main tracks and zero switching trains is not so favorable.

- Poisson Model

The Poisson based model using data for track class 3 has the number of main tracks, total switching trains and no highway near the rail-highway grade crossing in the final model. The coefficients for these parameters are positively related to number of crashes just as in the case of linear model. An increase in total switching trains increases the number crashes. Likewise, similarly an increase in the number of main track increases the number of crashes. If there is no highway nearby, the number of crashes could potentially be lower or decrease. The model has a high negative intercept showing that there might be many factors that could not be included in the model. The AIC and AICC are close enough and the Likelihood Chi-square values are significant.

- Negative Binomial (NB) Model

The NB based model using data for track class 3 has the number of main tracks, total switching trains and no highway near the rail-highway grade crossing in the final model. The parameters are again related similar to the Poisson model; the model also has a negative intercept. But the NB model has a lower deviance and is hence superior when compared to the Poisson model. Also the NB and Poisson model would not give a negative number of crashes due to the intercept as they have a log link.

In summary, the NB model is the best choice for predicting crashes in track class 3.

Table 19: Model for track class 3

PARAMETER	LINEAR		POISSON WITH LOG LINK		NEGATIVE BINOMIAL (NB) WITH LOG LINK	
	COEFFICIENT	P-value	COEFFICIENT	P-value	COEFFICIENT	P-value
Intercept	-.254	<0.00	-5.289	<0.00	-5.350	<0.00
# of main tracks	.303	<0.00	2.241	<0.00	2.241	<0.00
Total # of switching trains	.017	.011	.156	.082	.204	.024
No highway nearby	-.040	.043	-1.172	.027	-1.232	.026
LIKELIHOOD RATIO CHI-SQUARE	49.976	<0.00	32.843	<0.00	30.149	<0.00
AKAIKE'S INFORMATION CRITERION (AIC)	-20.198		276.306		276.879	
FINITE SAMPLE CORRECTED AIC (AICC)	-20.112		276.364		276.937	
DEVIANCE	39.020		196.465		168.699	

5.2.4. Model for Track Class 4

Model results from track class 4 data are shown in Table 20. The results obtained are discussed in detail in the following subsections.

- Linear Model

The linear model using data for track class 4 has the number of main tracks and no highway near the rail-highway grade crossing in the final model. The coefficients suggest that an increase in the number of main tracks leads to an increase in the number crashes, while the number of crashes reduce if there is no highway near the rail-highway grade crossing. The increase in the number of crashes with an increase in the number of main tracks can be attributed to the increased tracks for trains to run at a rail-highway grade crossing. The model suffers from a negative intercept but the AIC and AICC are close enough and the Likelihood Chi-square values are significant.

- Poisson Model

The Poisson based model using data for track class 4 has the number of main tracks and no highway near rail-highway grade crossing in the final model. Both the parameters have intuitive coefficients. An increase in the number of main tracks leads to an increase in the number of crashes which can again be attributed to increased risk from more trains running on the tracks, while the number of crashes reduces if there is no highway nearby the rail-highway grade crossing resulting from the reduced exposure. The model has a negative intercept which accounts for any missing factors in the crash modeling.

- Negative Binomial (NB) Model

The NB based model using data for track class 4 has the number of main tracks and no highway near the rail-highway grade crossing in the final model. The model has lower deviance than Poisson with intuitive coefficients, and is hence superior to it. It also has a negative intercept which is not an issue due to its count output. This makes the model more desirable than the Linear model.

In summary, the NB model is the best choice for predicting crashes in track class 4.

Table 20: Models for track class 4

PARAMETER	LINEAR		POISSON WITH LOG LINK		NEGATIVE BINOMIAL (NB) WITH LOG LINK	
	COEFFICIENT	P-value	COEFFICIENT	P-value	COEFFICIENT	P-value
Intercept	-.168	.005	-3.161	<0.00	-3.365	<0.00
# of main tracks	.292	<0.00	1.069	<0.00	1.234	<0.00
No highway nearby	-.085	.047	-.813	.023	-.859	.022
LIKELIHOOD RATIO CHI-SQUARE	40.466	<0.00	38.510	<0.00	33.999	<0.00
AKAIKE'S INFORMATION CRITERION (AIC)	615.305		432.858		419.954	
FINITE SAMPLE CORRECTED AIC (AICC)	615.382		432.904		420.000	
DEVIANCE	97.738		304.518		240.953	

5.2.5. Model for Track Class 5

Model results from track class 3 data are shown in Table 21. The results obtained are discussed in detail in the following subsections.

- Linear Model

The linear model using data for track class 5 has only the number of main tracks in the model, which is positively related to the number of crashes. For track class 5, crashes were modeled using a no intercept model as there were no rail-highway grade crossings with zero number of main tracks in this class. Hence it would make little sense to include an intercept in this case. The AIC and AICC values are close. The Likelihood Chi-square value is also significant. The deviance of linear model is far lower than other models for this track class.

- Poisson Model

The Poisson based model using data for track class 5 has only the number of main tracks in the model. The coefficient of number of main tracks is counter intuitive as an increase in number of main tracks reduces the number of crashes. The AIC and AICC values are close. The Likelihood Chi-square value is also significant. The models suffer from high deviance when compared to the linear model for this track class.

- Negative Binomial (NB) Model

The NB based model using data for track class 5 has only the number of main tracks in the model. As in the case of Poisson based distribution model, the coefficient is negatively related to the number of crashes (counter intuitive). The AIC and AICC values are close. The Likelihood Chi-square value is also significant. The model has lower deviance as compared to Poisson.

The Linear model is thus the best fitting model with intuitive coefficients and low deviance for crash prediction in track class 5.

Table 21: Models for track class 5

PARAMETER	LINEAR		POISSON WITH LOG LINK		NEGATIVE BINOMIAL (NB) WITH LOG LINK	
	COEFFICIENT	P-value	COEFFICIENT	P-value	COEFFICIENT	P-value
# of main tracks	0.056	0.002	-1.966	<0.00	-1.885	<0.00
LIKELIHOOD RATIO CHI-SQUARE	8.802	0.003	113.631	<0.00	70.3	<0.00
AKAIKE'S INFORMATION CRITERION (AIC)	-2.439		54.369		53.694	
FINITE SAMPLE CORRECTED AIC (AICC)	-2.289		54.419		53.744	
DEVIANCE	4.497		42.369		37.831	

5.3. Discussion

The NB crash prediction based on each track class had the most satisfying results. These models have count outputs and also have intuitive coefficients. The all track class data model results are inferior to the models for each track class. This confirms that it is best to predict crashes based on the track class of a rail-highway grade crossing. The results for the track class models indicate that the AIC and AICC are close and the

Likelihood Chi-square statistic is also significant for all track classes. The different parameters in each track class model also indicate that the crash trends vary by track class. The two step procedure for crash prediction as suggested by the study requires the user to first determine the maximum time table speed of the train so as to define the track class. Then the appropriate formula from the best fitting model for the track class must be used to calculate crashes per five year at the rail-highway grade crossing. Table 22 shows the best fitting models in each track class as well as the all track class data with the parameters and formula to be used for calculating predicted crashes per five years.

Table 22: Best Fitting Models for Each Track Class

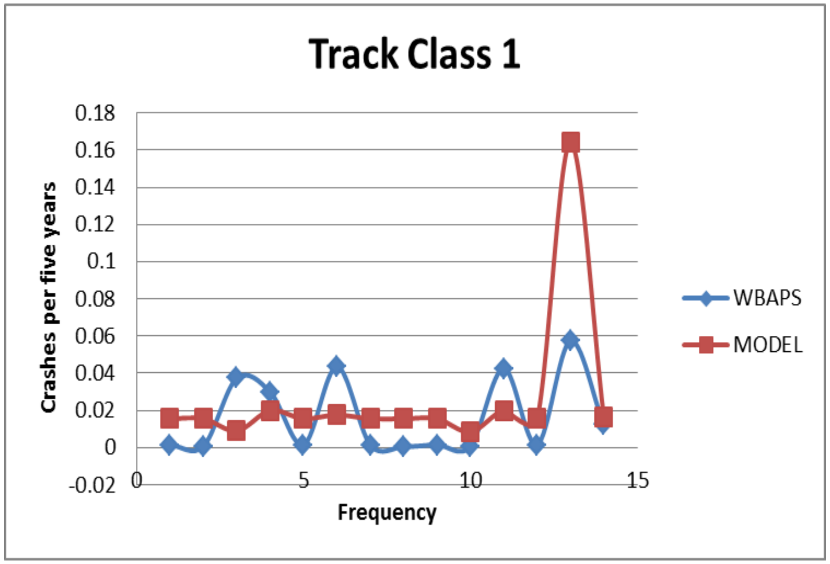
Track Class	**Model**	**Parameters**	**Formula**
1	Negative Binomial	AADT, Total # of Trains	Exp {-4.768+(0.062*Total # of Trains)+(0.605**# of Main Tracks)}
2	Negative Binomial	Stop Lines Present, # of Traffic Lanes, % of Trucks	Exp {-4.987+(1.47*Stop lines present)(0.372*# of Traffic lanes)+(0.041*% of Trucks)}
3	Negative Binomial	# of Main Tracks, Total # of Switching Trains	Exp{-5.350(-2.241*# of Main Tracks)+(0.204*Total # of switching Trains)+(-1.232*No Highway Nearby)}
4	Negative Binomial	No Highway Nearby, # of Main Tracks	Exp{-3.365(2.234*# of Main Tracks)+(-0.859*No Highway Nearby)}
5	Linear	# of Main Tracks	(-1.885*# of Main Tracks)
All Track Class	Negative Binomial	# of Main Tracks, Posted Highway Speed Limit	Exp{-4.172 +(# of Main Tracks *1.675)+(Posted highway speed Limit * -.016)}

Model validation was done using data set aside from each track class. Table 23 shows the root mean square error comparing model output and WBAPS output with the actual number of crashes over five years. The error is lesser for track class 1 model, while for all other track classes the model has a higher error value compared to WBAPS. Similarly the error of the all track class model is also higher than the WBAPS model, indicating that it is better to use the track class models. The predictions of the models developed are compared with WBAPS predictions for five year period by computing the error in prediction with reference to actual prediction (prediction subtracted by actual crashes). WBAPS collision per year was converted to a five year scale by multiplying the value by 5 (assuming conditions remain constant over the five-year period).

Table 23: Root Mean Square Error of Model and WBAPS Output

Track Class	Model	WBAPS
1	0.0902	0.09293
2	0.1601	0.138776
3	0.313	0.234766
4	0.447	0.366594
5	0.3137	0.23104

Figures 2 and 3 show that the number of crashes from the models are mostly higher than the WBAPS output. The figures help visualize the RMSE values for the model and WBAPS. In track class 1, 3, 4 the number of crashes from the WBAPS and model outputs are very close. Also, in track class 1, the model outputs are mostly closer to zero when compared to the WBAPS output. Given the fact that Track class 1 has fewer crashes, the model predictions are better as also suggested by the RMSE value.



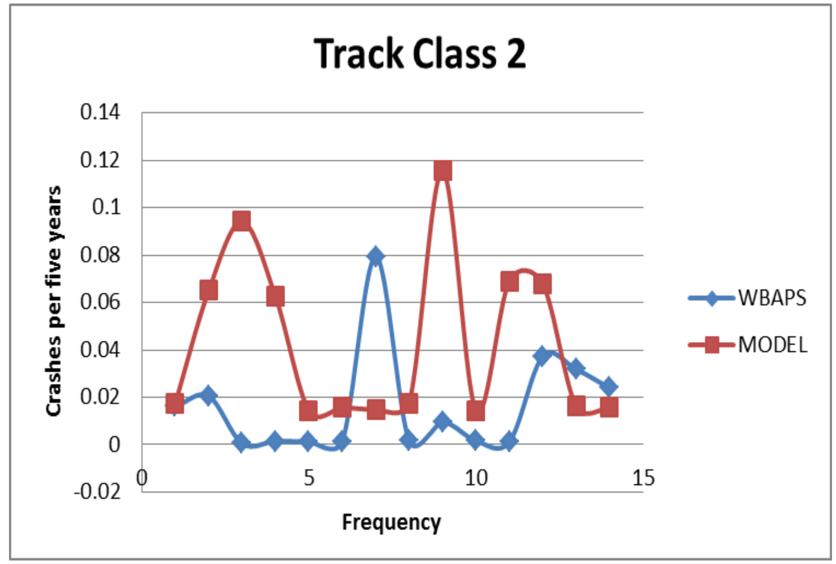


Figure 2: Comparison of model results for Track class 1 and 2 with WBAPS output

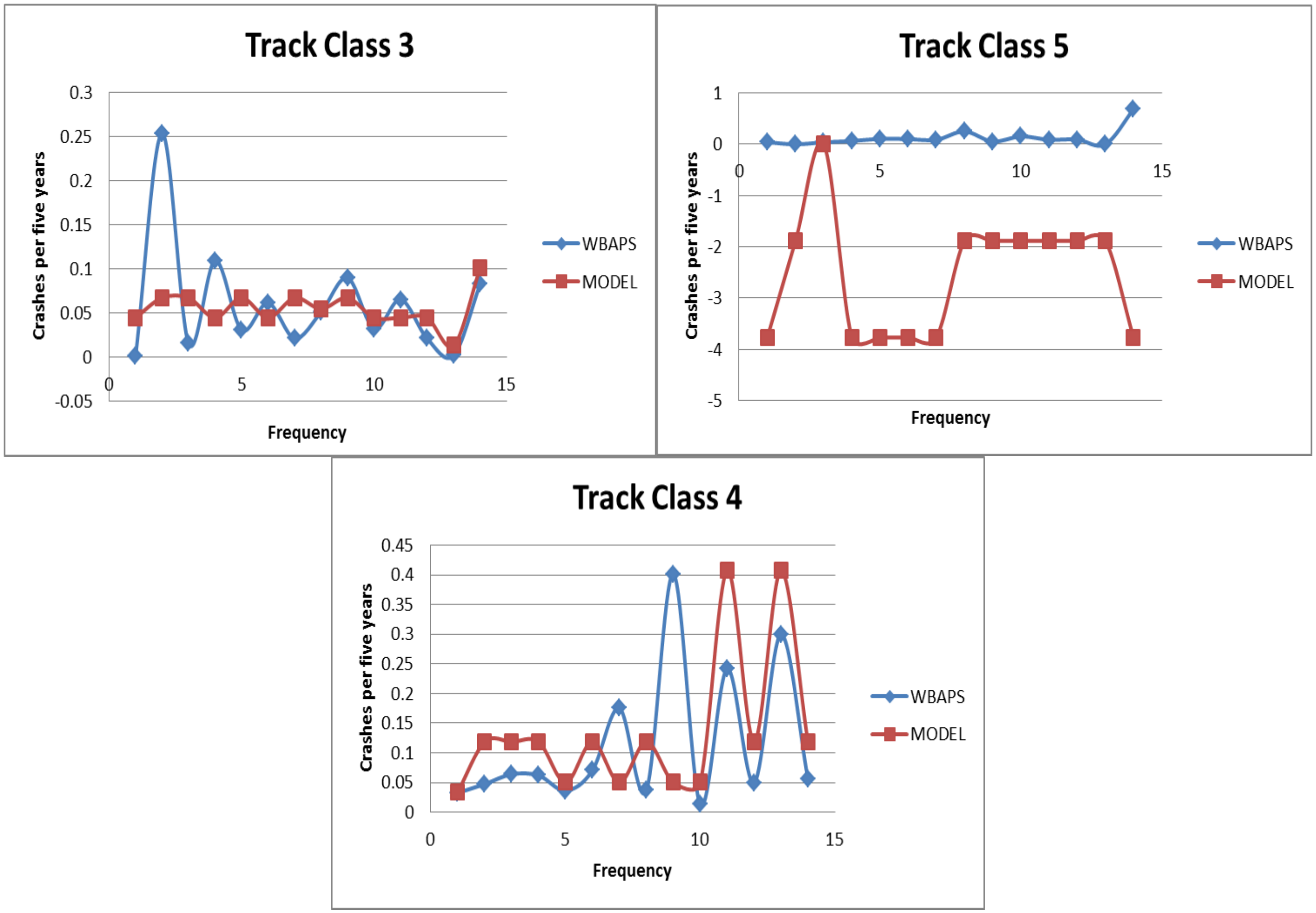


Figure 3: Comparison of model results for Track class 5 with WBAPS output

For all track classes except track class 1, the model outputs are marginally higher than the actual crashes. This conservative approach may yield greater safety benefits than obtaining underestimated results from WBAPS.

The study proposes a model which is simple and consists of only two steps (choosing track class and model coefficients), unlike FRA rail-highway grade crossing crash prediction formula that has a lengthy three step process. Also, the model is capable to support the agencies in preliminary decision making in a relatively convenient manner.

CHAPTER 6: CONCLUSIONS AND LIMITATIONS

The research found the NB model for each track class model to be the best fitting model to predict crashes at rail-highway grade crossings. The explanatory variables for track class 1 are AADT and the total number of trains; track class 2 are stop lines present, number of traffic lanes and percentage of trucks; track class 3 are the number of main tracks, total switching trains; track class 4 are the number of main tracks, no highway near rail-highway grade crossing; and track class 5 are the number of main tracks. The variables in each track class are different from one another, which support the fact that rail-highway grade crossings from a track class must be considered separately when modeling crash risk at rail-highway grade crossings.

The comparison of WBAPS with developed model outputs suggests that these models give a more conservative picture of the crashes. It also shows that track class is a critical factor related to risk at rail-highway grade crossing. The track class governs the number of crashes at rail-highway grade crossings largely and should thus always be considered in rail-highway safety issues for region such as North Carolina.

The models suffer from certain limitations as they have been developed using data available which is very scarce in nature. In the models based on track class, there are classes in which only a marginal number of rail-highway grade crossings exist and so a very accurate estimate cannot be made.

In the absence of funds, the agencies make the decision of closing a rail-highway grade crossing. This leads to an increase in the vehicular traffic and hence risk at the other nearby rail-highway grade crossings. The explanatory variables such as the number of traffic lanes and AADT would be able to account for this trend.

There are other factors that contribute to crash reduction which could not be accommodated in the models developed and can be potential topics for future research. These include driver behavior at rail-highway grade crossings, driving under the influence of alcohol, and rail-highway safety awareness among users. The increased awareness may be a reason for rapid decline in crashes at rail-highway grade crossings in recent years.

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