Fall 2014

Use on multinomial logistic regression in work zone crash analysis for Missouri work zones

Paul Robin

Recommended Citation

Robin, Paul, "Use on multinomial logistic regression in work zone crash analysis for Missouri work zones" (2014). *Masters Theses*. 7341.
https://scholarsmine.mst.edu/masters_theses/7341

USE OF MULTINOMIAL LOGISTIC REGRESSION IN WORK ZONE CRASH ANALYSIS FOR MISSOURI WORK ZONES

by

PAUL ROBIN

A THESIS

Presented to the Faculty of the Graduate School of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE IN ENGINEERING MANAGEMENT
2014

Approved by

Dr. Brian K Smith, Advisor

Dr. Suzanna Long

Dr. Ruwen Xin

ABSTRACT

This study focuses on the use of statistical data analysis procedures in identifying factors which affect the severity of crashes in work zones. Work zones are unsafe for the traffic passing through as well as the workers. Multinomial Logistic Regression has been used to analyse Missouri work zone crash data to identify significant factors which affect the severity of crashes. This particular type of regression analysis was used due to the mixed nature of data. Multinomial regression was used to compare crashes with severity Property Damage Only against crashes with Minor Injuries and Disabling Injuries/ Fatal. The factors considered were two-vehicle analysis, weather conditions, road conditions, light conditions, road profile, road alignment, traffic conditions, accident type and vision obscurity. The analysis show different factors having a statistically significant impact on the severity of crashes.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr. Brian Smith, Dr. Suzanna Long and Dr. Ruwen Qin for giving me this opportunity, guiding me and helping me to successfully complete this research. I would also like to thank Sean Schmidt for his valuable advice and help. This project was funded by the Missouri Department of Transportation under TR201312.

I would like to acknowledge the Engineering Management and its outstanding staff and faculty. All this would not have been possible without the love and support of my parents, colleagues and loved ones- Ronak, Geetha, Geethu, Pratap, Vivek, Janessa, Richie, Michele, Birdie, Lonna, Teresa, Stephane and of course, my friends back home.

TABLE OF CONTENTS

Page

SECTION

LIST OF ILLUSTRATIONS

Page

LIST OF TABLES

Page

1. INTRODUCTION

Work zones are dangerous to both workers and traffic passing through. Work zones are particularly hazardous as they involve lane closures, lane transitions, varying speed limits, traffic congestions and distractions. Work zones can be of variable lengths and for indefinite periods of time. This study is aimed at identifying factors which have an impact on the severity of crashes in work zones. The literature review discusses relevant information on the structures of work zones and the research conducted in different work zones all over the US. Multinomial Regression was used on data modified from the Missouri Transportation Management System to compare factors involved with Property Damage Only (PDO) crashes with Disabling Injury and Fatal crashes and PDO with Minor Injuries. The results of the statistical data analysis were then interpreted to see the factors which influence the severity of crashes. By identifying these factors, steps can be taken to improve safety in work zones and also schedule work zones with a safer environment.

2. LITERATURE REVIEW

There is a wide range of literature available on work zones in the US. This literature provides important usable information on different aspects of work zone crashes and modeling information. According to the Fatality Analysis Reporting System (FARS) maintained by the National Highway Traffic Safety Administration (NHTSA), the number of fatal motor vehicle traffic crashes in the state of Missouri in 2012 was 826 of which 7 of them took place in work zones. In 2013, 8 people were killed in Missouri work zones. 16 MoDOT employees have been killed in work-related accidents (MoDOT). According to Federal Highway Administration (FHWA), Motor vehicle fatal injuries in work zones average around 900 persons every year and fatalities increased more than 50 percent in a span of 5 years. Workers in work zones are vulnerable as their attention is more focused on the task at hand than passing traffic.

The Federal Highway Department's facts show that work zones lead to increases in traffic congestion that leads to increases in crash rates (FHWA, 1998). Congestion and crashes are closely tied. Congestion leads to crashes and crashes lead to congestion. Work zones are estimated to cause about 10% of nationwide traffic congestion which leads to an annual fuel loss of about $0.714 billion. Most work zones have Temporary Traffic Control (TTC) zones. Most TTC zones are divided into four areas. They are the advance warning area, the transition area, the activity area, and the termination area (FHWA, 2009).

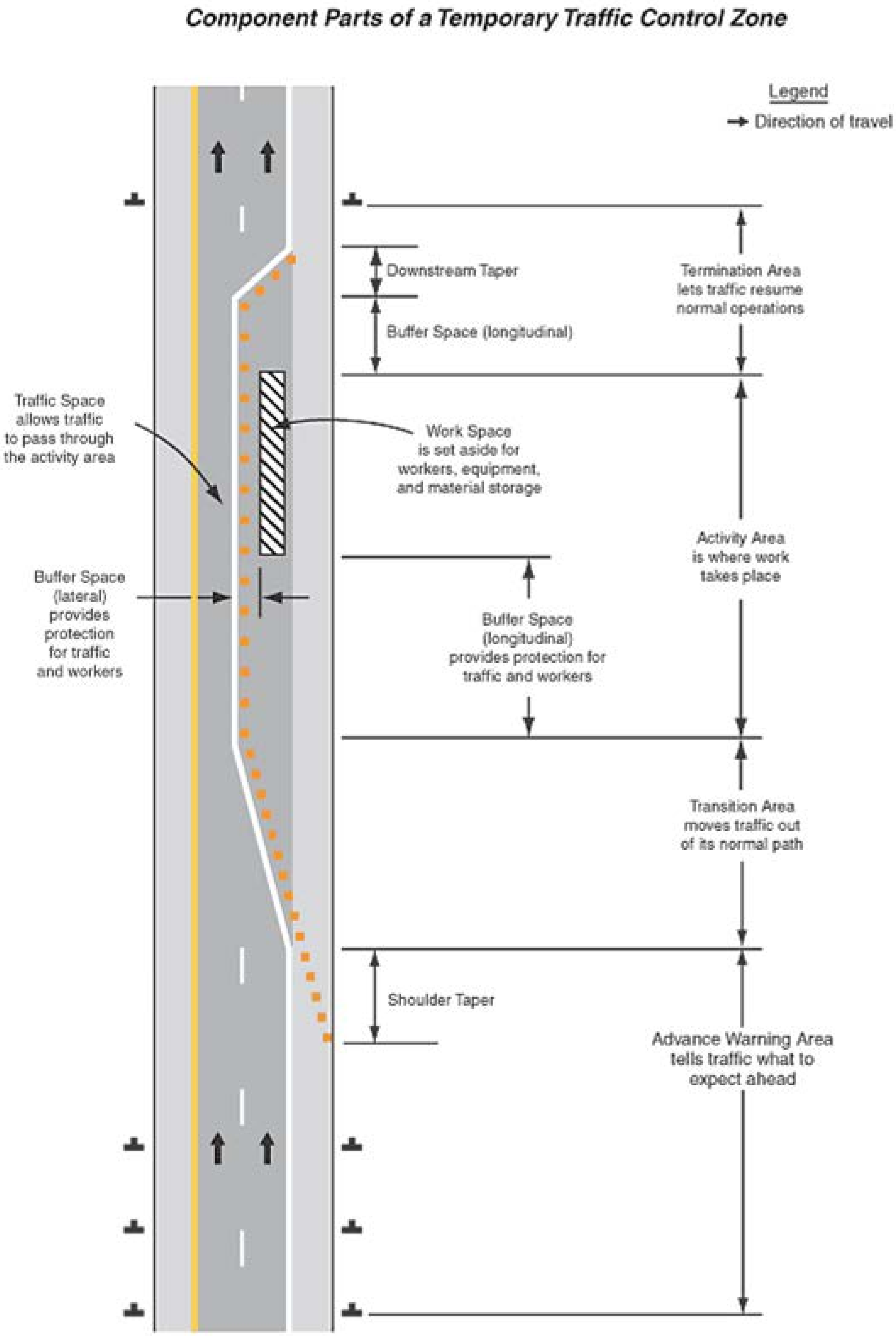

Figure 2.1 Component parts of a TTC zone in a work zone

The advance warning area is where road users are warned of an upcoming work zone. The transition area is the zone where the road users are redirected from their regular path. The activity area is where the construction activity takes place. Activity area can be further divided into workspace, traffic space and buffer space. The workspace is closed to road users and has the workers, equipment, construction vehicles and construction activity. It is not stationery and may move as the work progresses. There may be multiple workspaces in an activity area. The traffic space is where the regular traffic is directed through a work zone. The buffer space is the area which separates the workspace and the traffic space. It may also provide some recovery space for errant vehicles. The termination area is where the activity area ends and the road users can transition from the temporary path to the normal path (FHWA, 2009). Garber and Zhou stated that most of the crashes are found in the activity area (Garber and Zhou, 2002). 62% of the injury and fatal accidents at interstate freeways in Ohio occurred within activity area and 13% in the advance warning area (Salem, 2006).

An analysis of freeway work zones shows that the advance-warning area is unsafe during peak traffic conditions and during bad weather. Exit area is also unsafe particularly during the off-peak periods. This implies reinforcing speed limits might be beneficial to improve safety. Queuing crashes are more likely to involve two or more vehicles and tend to be rear-end crashes. Descriptive analyses of crashes in work zone queues also shows that queuing crashes are likely to be more severe when compared to regular work-zone crashes. The research concluded that counter measures vary for different segments of the work zone depending on the time and season (Srinivasan, 2008).

Washburn and Carrick point out that the crash reports of most of the states do not have data elements to capture adequate details about the work zone in which a crash may have occurred (Washburn, 2006). FDOT Construction Office observed that with both the original paper form and the new computer system, there was a lack of compliance in completing the MOT forms. Studies confirm that effective data collection and data analysis can help improve and increase safety in work zone area for both workers and traffic passing through the work zones (Spainhour, 2002).

61% of Fatal and injury crashes within interstate work zones in Ohio occurred in daylight conditions and 15% in dark conditions. About 75% of fatal and injury crashes in Ohio interstate work zones occurred on the level roadway when the roads were dry. (Salem, 2006). In Maryland, Work zone accidents were relatively more frequent between 8 AM and 4 PM, compared to all types of accidents (SHA-MDOT, 2005). 79% of work zone crashes occurred in daylight conditions and 58.4% of crashes occurred in clear weather conditions (Akepati, 2010). Inattentive driving and following too closely are two major factors of crash causes. Most crashes are Property Damage Only (PDO) type. In a study of 5 states, 72.2% of them were PDO (Dissanayake and Akepati, 2007). 82% of injury crashes were due to driver error. Rear end collision was the most common cause for crash injuries and head-on collision was the most common cause for fatal work zone accidents (Bai and Li, 2007). FHWA facts show that rear end collisions are the most common type of crashes in work zones. Research suggests that following too close, failure to control and improper lane change/improper passing accounted for 71% of all fatal and injury crashes at interstate freeways in Ohio work zones (Salem, 2007). From 2003-2007, around 70% of the accidents occurred between 8 AM to 4:59 PM (Pegula, 2010). In Ohio, Over 80% of rear end crashes occurred in urban areas and over the work week. Between 2005 and 2007, more than a third of the crashes in were rear end crashes and are the most common type of crashes in work zones (MORPC, 2010). Bai and Li conducted research on fatal and injury crashes on Kansas Highway work zones from 1992 to 2004. Their research shows that day time non-peak hours between 10 AM to 4 PM have the highest crash injuries (42%) and second highest number of fatal injuries (32%). A large percentage of fatal injuries (37%) occur in night time between 8 PM to 6 AM. Most of the fatal work zone crashes occur on roads with speed limits greater than 50 mph (FHWA). For fatal work zone accidents, the predominant accident types were the pedestrian, fixed object, angle, rear end, and opposite direction which accounted for 75% of all fatal accidents in work zones from 1994 to 2003 in Marlyland (SHA-MDOT, 2005).

The number of fatalities in work zone crashes involving trucks has been increasing. From 2000-2008, 25% of work zone motor vehicle fatalities involved trucks. For single-vehicle crashes, trucks and large trucks are 44.6% more likely to be involved in a work-zone single-vehicle crash compared to trucks and large trucks in non-work-zone locations.(Harb,2008). 65% of the fatal crashes occurred during the day. Angle, Rear-End and Head-On are the most common types of crashes involving large trucks in work zones (FHWA).

For a truck travelling at 55 Mph, the stopping distance is almost 50% greater than that required for a car. 30% of all work zone crashes involve large trucks (FHWA). Asad Khattak found that North Carolina Truck related work zone crashes had relatively more fatalities than all work zone crashes (Khattak 2004).

Work zone crashes are unique events which may or may not be affected by the presence of work zones. An analysis of 77 fatal work zone crash sites in Texas between 2003 and 2004 showed that 8 percent of the crashes were directly influenced by the work zone and 39 percent were influenced indirectly by the work zone. Also, their investigations concluded that 45 percent of them were not influenced by the presence of a work zone (Schrock, 2004).

Implementation of Motor Awareness System (MAS) has seen a steady decline in the number of fatal crashes since 2005. 64 % of the fatal crashes involved people in the age groups of 25-64. The factors which tend to increase severity of injury are: Curved and Graded geometric design, Vision obstruction, High speed, Alcohol or Drugs involved (FDOT/University of South Florida). Research shows that the crash frequency on limited-access roadways increased with longer work zone durations. This implies that longer work zone durations increase the number of injury and non-injury crashes in a work zone (Khattak, 2002).

3. METHODOLOGY

Data analysis is the process of observing the data, transforming it, and modeling it to obtain useful information. This modeling process allows the identification of statistically significant factors that contribute to work zone crashes. Regression Analysis is a statistical process of estimating relationships between variables. There are different types of regression analysis for different type of data. The methodology used to model the crash data was Multinomial Logistic Regression (MLR). The raw data set consists of values which are ordinal and nominal. Multinomial Regression is used when the dependant variable is nominal and for which the number of categories are more than two. There is no natural ordering in the independent variables. One of the assumptions of MLR is that the dependent variable cannot be perfectly predicted by the independent variables for any case. It is an extension of the Binomial Logit model. Multinomial Regression uses the maximum likelihood ratio to determine the probability of the categorical membership of the dependent variable. One of the reasons why Multinomial Logistic Regression is a good choice for this data is that it does not assume normality, linearity, or homoscedasticity (Starkweather, 2011).

There are multiple ways to mathematically model the Multinomial Logistic Regression. But the concept behind all of them is to construct a linear predictor function which constructs a score from a set of weights that are linearly combined with independent or explanatory variables using a dot product.

Score $(X_i, k) = \beta_k \cdot X_i$,

Where X_i is the Vector of independent variables of the observation i

β_k is the vector of regression co-efficients corresponding to outcome k

and Score (X_i, k) is the score associated with assigning observation i to category k.

It is assumed that there are N data points. Each data point has m independent variables and a dependant variable Y which can take on one of K possible values. The goal of the multinomial logistic regression is to construct a model that explains the relationship between the independent variables and the dependent variable. When using this regression, one category of the dependent variable is selected as the reference category. Separate odds ratios, the odds of an event occurring given some factor compared to the odds of an event occurring in the absence of that factor, are determined for all independent variables for each category of the dependent variable with the exception of the reference category, which is omitted.

4. MODELING THE DATA

The data used for the Multi Logit Model is from the Missouri Transportation Management System (TMS). The data is for the years 2009-2011. The original data set had 64 independent variables. They included factors like – Year, On-location speed limit, vehicle-model, GPS coordinates, MoDOT district number. For modeling the data, we choose the independent variables which might have significance on the severity of crash and we convert them, coding it to our convenience. Accident Severity is our dependent variable. The original data has four categories of Severity. They are Property Damage Only (PDO), Minor Injury (MI), Disabling Injury (DI) and Fatal. For our research we combine Disabling Injury and Fatal as one independent variable. Table 3.1 displays the three dependent variables modeled. The nine independent variables, their categories and codes used in the regression are presented in Table 4.2.

Table 4.1 Dependent variable categories

Severity	**Code**
Property Damage Only (PDO)	1
Minor Injury (MI)	2
Disabling Injury (DI) and Fatal	4

Table 4.2 Independent Variables

Variable Name	**Categories**	**Code**
Accident Type	Animal	1
	Pedalcycle	2
	Fixed object	3
	Other object (moveable)	4
	Pedestrian	5
	Train	6
	MV in transport	7
	MV on other roadway	8
	Parked MV	9
	Overturning	10
	Other non-collision (Eg: Fire)	11
Two Vehicle Analysis	Head on	60
	Rear end	61
	Sideswipe- meeting	62
	Sideswipe-passing	63
	Angle	64
	Backed into	65
	Other	67
Road Alignment	Straight	1
	Curve	2
Road profile	Level	1
	Grade	2
	Hillcrest	3
Light conditions	Daylight	1
	Dark with streetlights on	2
	Dark with streetlights off	3
	Dark with no streetlights	4
	Indeterminate	5
Weather	Clear	1
	Cloudy	2

Table 4.2 Independent Variables (Cont.)

Variable Name	**Categories**	**Code**
	Rain	3
	Snow	4
	Sleet	5
	Freezing (temp)	6
	Fog/mist	7
	Indeterminate	8
Road Condition	Dry	1
	Wet	2
	Snow	3
	Ice	4
	Slush	5
	Mud	6
	Standing water	7
	Moving water	8
	Other	9
Vision Obscurity	Windshield	1
	Load on vehicle	2
	Tree/bush	3
	Building	4
	Embankment	5
	Signboards	6
	Hillcrest	7
	Parked cars	8
	Moving cars	9
	Glare	10
	Other	11
	Not-obscured	12
Traffic Condition	Normal	1
	Accident ahead	2
	Congestion ahead	3

4.1 PERFORMANCE MEASURES

The analysis of the model uses three performance measures:

1) P value: This is a significance test. It is normally tested at a threshold value of 5% or 1%. If the p-value is less than the threshold value, we reject the null hypothesis and accept the test hypothesis to be valid. For our model, we test at a 5% level. Therefore, if the p-value is less than 0.05, we can conclude that it is statistically valid.
2) ß value: The beta coefficients show the effect of the independent variables on the dependent variable. A positive coefficient for B, shows a positive impact while a negative coefficient shows a negative impact. For our analysis, a positive B value shows that the category is more likely to impact category of dependent variable with respect to the reference category. If $B > 0$, it is more likely to impact the dependent variable. If $B < 0$, it is less likely to impact the dependent variable. If $B=0$, the particular category and the reference category are equally likely to impact the dependent variable.
3) Exponential Beta value: This value gives us the odds ratio for the independent variables. It is an exponentiation of the regression coefficients (B). The odds ratio shows the change in odds of the dependent variable being in a particular category compared to the reference category, corresponding to one unit change of independent variable. An odds ratio > 1 indicates that the risk of the outcome falling in the comparison group relative to the risk of the outcome falling in the referent group increases as the variable increases. So it is more likely to fall in the comparison group. An odds ratio < 1 indicates that the risk of the outcome falling

in the comparison group relative to the risk of the outcome falling in the referent group decreases as the variable increases. In general, if the odds ratio < 1, the outcome is more likely to be in the referent group.

Table 4.3 presents the descriptive statistics of the data set. The descriptive statistics display the quantitative features of the sub-groups in the sample. The data set contains a total of 225,383 observations. Of these, 198,836 are valid and 26,547 were missing or blank. Valid observations are those observations in the data set which do not have any of the dependent or independent variables missing. The missing observations are observations in which data is missing from either the dependent or independent variables or both.

N- This gives us the total number of observations corresponding to a particular category. For example, the first three values in the table can be interpreted as, among the 198,836 crashes, 129,032 were PDO, 60,646 were MI and 9,158 were DI and Fatal.

Marginal Percentage: This gives an estimate of the proportion of valid observations found in the dependent variable’s group. For example, looking at the first three values in the group, among all the crashes, 64.9% were PDO, 30.5% were MI and 4.6% were DI and Fatal.

Table 4.3 Independent Variable Descriptive Statistics

Variable	**Code**	**N**	**Marginal Percentage**
SEVERITY	1	129032	64.90%
	2	60646	30.50%
	4	9158	4.60%
ACCIDENT_TYPE	7	195936	98.50%
	8	136	0.10%
	9	2764	1.40%
TWO_VEH_ANALYSIS	60	2486	1.30%
	61	137725	69.30%
	62	2928	1.50%
	63	20277	10.20%
	64	28080	14.10%
	65	3954	2.00%
	66	120	0.10%
	67	3266	1.60%
ROAD_ALIGNMENT	1	180460	90.80%
	2	18376	9.20%
ROAD_PROFILE	1	123829	62.30%
	2	71276	35.80%
	3	3731	1.90%
LIGHT_CONDITION	1	164568	82.80%
	2	16768	8.40%
	3	1037	0.50%
	4	15417	7.80%
	5	1046	0.50%
WEATHER	1	145960	73.40%
	2	45072	22.70%
	3	6169	3.10%
	4	455	0.20%
	5	20	0.00%
	6	392	0.20%
	7	620	0.30%
	8	148	0.10%
ROAD_CONDITION	1	178752	89.90%
	2	18274	9.20%
	3	571	0.30%

Table 4.3 Independent Variable Descriptive Statistics (Cont.)

Variable	**Code**	**N**	**Marginal Percentage**
	4	382	0.20%
	5	76	0.00%
	6	24	0.00%
	7	12	0.00%
	9	745	0.40%
VISION_OBSCURITY	1	301	0.20%
	2	400	0.20%
	3	87	0.00%
	4	40	0.00%
	5	62	0.00%
	6	52	0.00%
	7	687	0.30%
	8	483	0.20%
	9	2372	1.20%
	10	919	0.50%
	11	2288	1.20%
	12	191145	96.10%
TC	1	90619	45.60%
	2	7222	3.60%
	3	100995	50.8%

5. ANALYSIS

The Appendix displays the results of the model analysis. The reference category of the dependent variable is 1 which is Property Damage Only. The model compares PDO with Minor Injuries and PDO with DI and Fatal crashes. All these results are based on the P-values, Beta Coefficients and the Exponential Beta Coefficients. PDO is treated as the reference group and therefore models are estimated for MI relative to PDO and a model for DI and Fatal to PDO. Since the last category of each independent variable is used as the reference category, its β value is denoted as 0b.

5.1 MINOR INJURIES VERSUS PDO

Motor Vehicle (MV) in transport is more likely to cause a MI than a parked MV. It has a B value of 0.642. This is the multinomial logit estimate comparing MV in transport to parked MV for MI relative to PDO given the other variables in the model are held constant. The multinomial logit for MV in transport relative to parked MV is 0.642 units higher for MI relative to PDO given all other independent variables in the model are held constant. So, MV in transport are more likely than parked MV to cause MI than PDO.

It has an Odds-Ratio of 1.901. This is the relative risk ratio comparing MV in transport to parked MV for MI relative to PDO given that the other variables in the model are held constant. For MV in transport relative to parked MV, the relative risk of being involved in a MI relative to PDO would be expected to increase by a factor of 1.901 given the other variables in the model are held constant. In other words, MV in transport is more likely than parked MV to be in a MI over PDO. MV in other roadway is not a statistically significant factor.

Similarly, Two vehicle analysis shows that head-on, rear-end, sideswipe (meeting and passing), angle and backed into were all more likely to cause a MI when compared to other type of collisions. Most likely factor was head on collision. It has a B value of 2.964 and an odds ratio of 19.379. Straight roads are more likely to cause MI than a curved road. Level and grade roads are more likely to cause MI than a hill-crest.

Light conditions: Daylight, dark with streetlights on and ark with streetlights off and dark with no streetlights are all less likely to cause MI than indeterminate conditions.

Weather: Clear, cloudy, rain, snow, sleet and fog are most likely to cause a MI. Of the above conditions, Sleet the biggest positive regression coefficient and has the highest odd's ratio and so is more likely to cause MI than a PDO.

Road Conditions: Dry, wet and snow are more likely to cause a MI with dry Condition being the most likely. Ice is less likely to cause a MI.

Vision obscured by Embankment, glare and other factors were less likely to cause a MI. Vision obscured by moving cars are more likely to be involved in a MI. Other categories are not statistically significant.

MI is less likely to happen under normal conditions and more likely to occur when there is an accident ahead when compared to congested traffic conditions.

5.2 FATAL AND DISABLING INJURIES VS PDO:

MV in transport and MV on other roadway are more likely to cause a DI and/or Fatal accident than a parked MV. Of the two, MV on other roadways has a higher odds ratio. This interprets as the there is a much higher possibility of an MV on other roadway causing a DI and/or Fatal accident than a parked MV when compared to the reference category of PDO. Head-on, Rear end, angle and Sideswipe collision (Meeting and passing) categories of two vehicle analyses are more likely to cause a DI and/or Fatal accident. Head on was the most likely cause of a fatal/Disabling injury with a regression coefficient of 6.124.

A straight road was more likely to cause a DI and/or Fatal accident than a curved road. Level and graded roads are more likely to cause DI and/or fatal accidents compared to a hill crest. Of the two, grade roads are more likely than level. It has an odds ratio of 3.263. Light Conditions: Daylight and dark with no streetlights are the most likely light conditions in which DI and/or Fatal accidents occur. Dark with no streetlights has the highest odds ratio of 27.467. Fog/Mist is less likely to cause a DI and/or Fatal accident compared to indeterminate weather conditions. Sleet is most likely to cause a DI and Fatal accident. However it is not statistically significant.

Dry, wet and snowy road conditions are more likely conditions for a DI and/or Fatal Accident. Snow has the highest odds ratio of 6.107. Standing water is also highly likely to cause a DI and Fatal accident. However, it is not statistically significant.

Vision obscured by windshield, load on vehicle, glare, hillcrest, moving cars and other factors were less likely to cause a DI and/or Fatal accident. All other categories under vision obscurity are not statistically significant. Normal traffic conditions and accident ahead are more likely to cause a DI and/or Fatal accident when compared with congested traffic conditions.

6. CONCLUSION

The objective of this study was to perform a statistical data analysis on work zone crash data for Missouri Work zones and identify attributes associated with severity of crashes. Crash Data from the Transportation Management System for the years 2009 to 2011 was used. Statistical models using Multinomial Logistic Regression were developed to analyze the influence of Light Conditions, Road Conditions, Traffic Conditions, Weather Conditions, Road Profile, Road Alignment and Two-Vehicle Analysis on Severity of the crash. The model gives us the descriptive statistics of the features of the crashes and a comparison of attributes of Crashes with severity MI relative to PDO and DI/Fatal relative to PDO.

- Majority of the crashes were PDO with a percentage of 64.9%.
- Rear-end collision was the most common type of crash with a percentage of 69.3%.
- Two vehicle analysis showed that Head-on collision was the most likely factor to cause MI relative to PDO.
- Clear, cloudy, rain, snow, sleet and fog are more likely to cause a MI. Dry, Wet and Snow on the road are more likely to cause an MI.
- MV in transport and MV on other roadway are both more likely to cause DI and Fatal accidents.
- Head-On collision is the most likely factor for DI and Fatal crashes.
- Daylight and Dark with no streetlights ON are more likely factors for DI and Fatal crashes.

- Snow on road is more likely to be associated with DI and Fatal crashes than PDO crashes.
- Accident ahead and normal traffic conditions are also associated with DI and Fatal accidents.
- There are some limitations with the data set like errors in data collection and missing data. Some variables can also interact with each other.
- Careful driving and paying attention can greatly increase safety in work zones.

Seat belts are extremely important. Lack of Seat-belt use was a factor in 383 of the 720 work zone fatal accidents in 2008 (FHWA).

APPENDIX

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
2 Intercept	-4.474	1	0.000	
[ACCIDENT_TYPE=7]	0.642	1	0.000	1.901
[ACCIDENT_TYPE=8]	-1.289	1	0.431	0.276
[ACCIDENT_TYPE=9]	0b	0	0	0
[TWO_VEH_ANALYSIS=60]	2.964	1	0.000	19.379
[TWO_VEH_ANALYSIS=61]	1.624	1	0.000	5.073
[TWO_VEH_ANALYSIS=62]	1.146	1	0.000	3.144
[TWO_VEH_ANALYSIS=63]	0.518	1	0.000	1.678
[TWO_VEH_ANALYSIS=64]	1.498	1	0.000	4.474
[TWO_VEH_ANALYSIS=65]	0.490	1	0.000	1.632
[TWO_VEH_ANALYSIS=66]	0.177	1	0.597	1.193
[TWO_VEH_ANALYSIS=67]	0b	0	0	0
[ROAD_ALIGNMENT=1]	0.377	1	0.000	1.458
[ROAD_ALIGNMENT=2]	0b	0	0	0
[ROAD_PROFILE=1]	0.622	1	0.000	1.863

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
[ROAD_PROFILE=2]	0.565	1	0.000	1.759
[ROAD_PROFILE=3]	0b	0	0	0
[LIGHT_CONDITION=1]	-0.726	1	0.000	0.484
[LIGHT_CONDITION=2]	-0.757	1	0.000	0.469
[LIGHT_CONDITION=3]	-0.745	1	0.000	0.475
[LIGHT_CONDITION=4]	-0.293	1	0.000	0.746
[LIGHT_CONDITION=5]	0b	0	0	0
[WEATHER=1]	0.629	1	0.005	1.875
[WEATHER=2]	0.801	1	0.000	2.228
[WEATHER=3]	0.795	1	0.000	2.214
[WEATHER=4]	0.984	1	0.000	2.676
[WEATHER=5]	4.664	1	0.000	106.051
[WEATHER=6]	0.397	1	0.135	1.487
[WEATHER=7]	1.611	1	0.000	5.008
[WEATHER=8]	0b	0	0	0

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
[ROAD_CONDITION=1]	0.828	1	0.000	2.288
[ROAD_CONDITION=2]	0.265	1	0.008	1.303
[ROAD_CONDITION=3]	0.420	1	0.016	1.522
[ROAD_CONDITION=4]	-0.610	1	0.002	0.543
[ROAD_CONDITION=5]	-0.600	1	0.214	0.549
[ROAD_CONDITION=6]	-0.128	1	0.862	0.880
[ROAD_CONDITION=7]	-0.727	1	0.491	0.484
[ROAD_CONDITION=9]	0b	0	0	0
[VISION_OBSCURITY=1]	0.022	1	0.881	1.022
[VISION_OBSCURITY=2]	0.004	1	0.976	1.004
[VISION_OBSCURITY=3]	-0.460	1	0.132	0.631
[VISION_OBSCURITY=4]	-53.407	1	0	0
[VISION_OBSCURITY=5]	-1.668	1	0.000	0.189
[VISION_OBSCURITY=6]	-0.362	1	0.275	0.696
[VISION_OBSCURITY=7]	0.052	1	0.587	1.053

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
[VISION_OBSCURITY=8]	-0.105	1	0.328	0.900
[VISION_OBSCURITY=9]	0.800	1	0.000	2.226
[VISION_OBSCURITY=10]	-0.551	1	0.000	0.577
[VISION_OBSCURITY=11]	-0.405	1	0.000	0.667
[VISION_OBSCURITY=12]	0b	0	0	0
[TC=1]	-0.138	1	0.000	0.871
[TC=2]	0.139	1	0.000	1.149
[TC=3]	0b	0	0	0
4 Intercept	-7.393	1	0.000	
[ACCIDENT_TYPE=7]	0.621	1	0.000	1.861
[ACCIDENT_TYPE=8]	5.698	1	0.000	298.406
[ACCIDENT_TYPE=9]	0b	0	0	0
[TWO_VEH_ANALYSIS=60]	6.124	1	0.000	456.675
[TWO_VEH_ANALYSIS=61]	0.853	1	0.000	2.348
[TWO_VEH_ANALYSIS=62]	2.281	1	0.000	9.789

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
[TWO_VEH_ANALYSIS=63]	1.329	1	0.000	3.778
[TWO_VEH_ANALYSIS=64]	0.781	1	0.000	2.183
[TWO_VEH_ANALYSIS=65]	-0.235	1	0.120	0.790
[TWO_VEH_ANALYSIS=66]	-0.137	1	0.826	0.872
[TWO_VEH_ANALYSIS=67]	0b	0	0	0
[ROAD_ALIGNMENT=1]	0.647	1	0.000	1.910
[ROAD_ALIGNMENT=2]	0b	0	0	0
[ROAD_PROFILE=1]	0.237	1	0.031	1.268
[ROAD_PROFILE=2]	1.183	1	0.000	3.263
[ROAD_PROFILE=3]	0b	0	0	0
[LIGHT_CONDITION=1]	0.408	1	0.020	1.504
[LIGHT_CONDITION=2]	0.205	1	0.256	1.227
[LIGHT_CONDITION=3]	0.305	1	0.219	1.357
[LIGHT_CONDITION=4]	3.313	1	0.000	27.467
[LIGHT_CONDITION=5]	0b	0	0	0

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
[WEATHER=1]	0.426	1	0.522	1.531
[WEATHER=2]	0.831	1	0.211	2.295
[WEATHER=3]	-0.599	1	0.370	0.549
[WEATHER=4]	1.241	1	0.071	3.460
[WEATHER=5]	2.523	1	0.472	12.472
[WEATHER=6]	-0.371	1	0.595	0.690
[WEATHER=7]	-2.522	1	0.000	0.080
[WEATHER=8]	0b	0	0	0
[ROAD_CONDITION=1]	0.836	1	0.003	2.307
[ROAD_CONDITION=2]	0.890	1	0.002	2.434
[ROAD_CONDITION=3]	1.809	1	0.000	6.107
[ROAD_CONDITION=4]	0.475	1	0.149	1.608
[ROAD_CONDITION=5]	-0.256	1	0.805	0.774
[ROAD_CONDITION=6]	0.363	1	0.842	1.437
[ROAD_CONDITION=7]	3.983	1	0.126	53.693

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
[ROAD_CONDITION=9]	0b	0	0	0
[VISION_OBSCURITY=1]	-2.192	1	0.000	0.112
[VISION_OBSCURITY=2]	-0.888	1	0.007	0.411
[VISION_OBSCURITY=3]	-0.950	1	0.293	0.387
[VISION_OBSCURITY=4]	-42.294	1	0	1.000E-013
[VISION_OBSCURITY=5]	-1.669	1	0.134	0.189
[VISION_OBSCURITY=6]	-0.449	1	0.658	0.638
[VISION_OBSCURITY=7]	-2.701	1	0.000	0.067
[VISION_OBSCURITY=8]	-0.144	1	0.571	0.866
[VISION_OBSCURITY=9]	-0.758	1	0.000	0.469
[VISION_OBSCURITY=10]	-0.466	1	0.008	0.627
[VISION_OBSCURITY=11]	-0.890	1	0.000	0.411
[VISION_OBSCURITY=12]	0b	0	0	0
[TC=1]	0.194	1	0.000	1.214
[TC=2]	0.788	1	0.000	2.199

SEVERITYa	**ß**	**Df**	**Sig.**	**Exp(ß)**
[TC=3]	0b	0	0	0

BIBLIOGRAPHY

Akepati, S. R. (2010). *Characteristics and Risk Factors Associated with Work Zone Crashes*. M.S. Thesis, Kansas State University. http://krex.k-state.edu/dspace/handle/2097/6821. Last accessed 5/20/2014

Dissanayake, S., and Akepati, S. R. (2009). *Identification of Work Zone Crash Characteristics, Final Report*. Smart Work Zone Deployment Initiative.

FHWA (2004). *Work Zone Facts and Statistics*. http://ops.fhwa.dot.gov/wz/resources/facts_stats.htm. Last accessed 6/9/2014.

FHWA (2007). *Creating Safe Work Zones*. . http://safety.fhwa.dot.gov/wz/resources/fhwasa03007/. Last accessed 6/9/2014.

FHWA (2009). *Manual On Uniform Traffic Control Devices (MUTCD).* Section 6C.03, Figure 6C-1, *Components of Temporary Traffic Control Zones* http://mutcd.fhwa.dot.gov/htm/2009r1r2/part6/part6c.htm

FHWA (1998). *Meeting the Customer's Needs for Mobility and Safety During Construction and Maintenance Operations*. Office of Program Quality Coordination, FHWA-PR-98-01-A.

Garber, N.J., and Zhao, M. (2002). *Crash Characteristics at Work Zones, Final Report*. VTRC 02-R12. Virginia Transportation Research Council.

Harb, R., Radwan, E., Yan, X., Pande, A., and Abdel-Aty, M. (2008). *Freeway work-zone crash analysis and risk identification using multiple and conditional logistic regression.* Journal of Transportation Engineering.

IDRE (2014) *Annotated SPSS output, Multinomial Logistic Regression*. UCLA. http://www.ats.ucla.edu/stat/spss/output/mlogit.htm. Last accessed 3/20/2014.

Khattak, A., Khattak, A., Council, F.M. (2002). *Effects of work zone presence on injury and non-injury crashes.* University of North Carolina.

Khattak, A., Targa, F. (2004). *Injury Severity and Total Harm in Truck-Involved Work Zone Crashes.* University of North Carolina.

Li, Y., and Bai, Y. (2007b). *Fatal and Injury Crash Characteristics in Highway Work Zones*. http://www.workzonesafety.org/files/documents/database_documents/Publication9950.pdf

Li, Y., and Bai, Y. (2007a). *Determining the Major Causes of Highway Work Zone Accidents in Kansas (Phase 2): Final Report*. Kansas Department of Transportation. www.iri.ku.edu/publications/KTRAN.pdf.

MORPC (2010). *Regional Crash Fact Sheets (2005-2007 Crash Data).*

Pegula, S. (2010). *Fatal Occupational Injuries at Road Construction Sites, 2003-07.* Monthly Labor Review. November, http://www.bls.gov/opub/mlr/2010/11/art3full.pdf.

Salem, O.M., Genaidy, A.M., Wei, H., and Deshpande, N. (2006). *Spatial Distribution and Characteristics of Accident Crashes at Work Zones of Interstate Freeways in Ohio.* Proceedings of the IEEE ITSC. September 17-20. Toronto, Canada. dmkd.cs.wayne.edu/Compendium/Compendium_Files/12/12-2888.pdf

Schrock, S., Ullman, G., Cothron, S., Kraus, E., Voigt, A. (2004). *An Analysis of Fatal Work Zone Crashes in Texas.* Texas Department of Transportation.

Srinivasan, S., Carrick, G., Zhu, X., Heaslip, K., and Washburn, S. (2008). *Analysis of Crashes in Freeway Work Zone Queues.*

Starkweather, J., and Moske, A. K. (2011). *Multinomial Logistic Regression.* www.unt.edu/rss/class/Jon/Benchmarks/MLR_JDS_Aug2011.pdf

Traffic Safety Analysis Division (2005). *Maryland Work Zone Accidents Comparision,1994-2003.* Maryland State Highway Administration, Hanover, Maryland. http://www.roads.maryland.gov/OOTS/16AppGMdWorkZonesMay242005.pdf

Washburn, S., and Carrick, G. T. (2006). *Data Collection Needs for Work Zone Incidents*. Final Report. Southeast Transportation Center, Univ. of Tennessee, Knoxville, TN. pp. 104

http://www.modot.org/workzones/. Last accessed 4/20/2014

VITA

Paul Robin was born in Hyderabad, India, on August 13, 1990. In August, 2012, he received his B. Tech degree in Electronics and Communication Engineering from Karunya University, Coimbatore, India. He received his MS in Engineering Management in December, 2014, from Missouri S&T, Rolla, Missouri.

Paul worked for the Office of International and Cultural Affairs from May 2013 till December 2014 and was a core committee member for Celebration of Nations, one of Rolla's biggest events.