Evaluating Railway Safety By Observing the Current Condition of Level Crossings in the Western Cape

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Study leader: Ms Tanya Visser

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Acknowledgements

Firstly I would like to thank Ms. Tanya Visser for her guidance and advice through this project.

Then I would like to thank Prof. Steel for his time and guidance in the project. I would also like to thank James Denton for always being willing to answer all my questions.

Lastly I would like to thank my mother, Annelize Malan, Hein Bester and friends for their support, patience and understanding during my time of study.

Declaration

I, the undersigned, hereby declare that the work contained in this final year project is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

……………………….. ………………………

Ilse Malan **Date**

ECSA Exit Level Outcomes References

The following table include references to sections in this report where ECSA exit level outcomes are addressed.

Exit level outcome	Section(s)	Page(s)
1. Problem solving	1.2 1.3 1.5 2.1-2.8 3.1 3.6 5.1 5.3 5.6 5.7 5.8 6.1 6.2	2 2 4-10 11-33 34 41 45-46 47 49 51 52 53 53
5. Engineering methods, skills & tools, incl. IT	2.4-2.7 4 5.3-5.7	14-20 42-44 48-51
6. Professional & Technical communication	Whole document	
9. Independent learning ability	1.5 2.1 3.1 5.1 6.3	4-10 11 34 45 54
10. Engineering professionalism	6.3	54

Explanation on satisfaction of ECSA Exit Level Outcomes:

1. Problem solving is evident in of the definition of the problem and formulation of the methodology. From the literature study, problem solving was used to determine how to apply the methods identified in the methodology correctly. In the reworking of the data problems were identified that was sorted out on an ad hoc basis.

5. Engineering methods, skills & tools were used in the process of understanding the available methodologies to perform statistical calculations such as correlation- and logistical regression calculations. The data was then fed into R to be reworked to get a meaningful outcome. Furthermore, a case study and a survey was done.

6. Professional and technical communication is demonstrated in this final report as well as the final presentation at the oral examination.

9. This project displays the independent learning with successful identification of the literature required to find a solution to an engineering problem and the application of this knowledge. I had to figure out how to approach the problem by myself and how to execute the proposed methodology.

10. When collecting data I had to be professional. Interviews with different people required professional behaviour. Lastly, I completed a reflection on the whole process of completing my final year project.

Abstract

Annually a number of fatal accidents occur at level crossings in South Africa. It is assumed that these kinds of accidents could be avoided if the road and rail systems and intersections are managed properly. This final year project evaluates railway safety by observing the current condition of level crossings in the Western Cape.

The goal of this study is to identify contributing factors that increase the likelihood of an injury occurring in a collision between a vehicle and a train. Once the factors have been identified plans of action can be developed to strive to decrease level crossing collisions from occurring. This could save numerous lives and lots of money.

The research problem at hand is to try and determine why this class of accidents occur and to indicate how management can be improved to reduce the number of incidents annually. Accident data was collected from the Western Cape area between the period 1999 and 2010. A correlation study was performed on the different contributing variables. Logistical regression was used with the occurrence of an injury set as dependent variable. Variables that influence the occurrence of an injury was identified as day of the week, time of the day, good visibility, type of road and type of vehicle.

Stellenbosch's biggest level crossing was evaluated against the South African Traffic Road Signs Manual (Brain, 1999). It was found that the level crossing met the standards that were set by the South African Department of Transport. Then a case study of one accident was done to determine the reason for the accident. Driver error was found to be the main cause of the accident.

A survey study was done to determine whether people are making errors due to lack of knowledge. The study indicated that people do not know what to do at level crossings. Furthermore it was found that the South African driving test is out-dated and failing at educating drivers.

The recommendation at hand is to restructure South Africa's driver tests. A new more advanced test should be developed. Proper driver education is necessary to increase safety at level crossings. The interim solution would be to put up traffic lights at level crossings.

Opsomming

Daar is jaarliks 'n aantal noodlottige ongelukke wat by spoorwegkruisings in Suid-Afrika voorkom. Daar word aanvaar dat hierdie soort van ongelukke voorkom kan word indien die pad en spoor stelsels en kruisings behoorlik bestuur word. Hierdie finale jaar projek evalueer spoorweg veiligheid deur na die huidige spooroorgang toestand van die Wes-Kaap te kyk.

Die doel van hierdie studie is om bydraende faktore wat die waarskynlikheid van 'n besering wat tydens ‘n botsing tussen ‘n voertuig en trein opgedoen word verhoog, te identifiseer. Wanneer die faktore geïdentifiseer is moet ‘n oplossing ontwikkel word wat streef om spooroorgang botsings te voorkom. Die oplossing sal baie lewens red en baie geld spaar.

Die navorsings probleem ter sprake is om te bepaal waarom hierdie klas van ongelukke nog voorkom en om te bepaal hoe die bestuur van hierdie stelsels verbeter kan word om die aantal voorvalle jaarliks te verminder. Ongelukdata is versamel in die Wes-Kaap vir die tydperk tussen 1999 en 2010. 'n Korrelasie studie is uitgevoer op die verskillende veranderlikes. Logistieke regressie is hierna toegepas, met die voorkoms van 'n besering as afhanklike veranderlike. Veranderlikes wat 'n invloed op die voorkoms van 'n besering het is geïdentifiseer as die dag van die week, die tyd van die dag, goeie sigbaarheid, die tipe pad en tipe voertuig.

Stellenbosch se grootste spooroorgang was teen die “South African Traffic Road Signs Manual (Brain, 1999)“ geëvalueer. Daar is gevind dat die spooroorgang aan die huidige standaarde wat deur die Departement van Vervoer van Suid Afrika neergele is voldoen. Toe is 'n gevallestudie van 'n ongeluk by hierdie spooroorgang gedoen. Bestuurders foute is bevind dat die hoofoorsaak van ongelukke.

'n Opname studie is gedoen om te bepaal of mense foute maak as gevolg van ‘n gebrek aan kennis. Die studie het aangedui dat mense nie weet wat om te doen by spooroorgange nie. Verder is gevind dat die Suid-Afrikaanse bestuurders toets is verouderd en faal daarin om bestuurders op te voed.

Aanbevelings is om Suid-Afrika se bestuurder toetse te herstruktureer. 'n Nuwe, meer gevorderde toets moet ontwikkel word. Behoorlike bestuurder opleiding en opvoeding is nodig om veiligheid te verhoog by spooroorgange.

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1. Introduction

1.1 Background

The term level crossing is a crossing on one level— without a bridge or tunnel as alternative — of a railway line by a road, path, or another railroad (www.arrivealive.co.za).

In South Africa there are various types of level crossings, such as farm level crossings, national-, provincial-, municipal- and private road level crossings (www.arrivealive.co.za).

There are approximately 8620 level crossings in total at present (State of Railway Safety In South Africa Annual Report 2008/2009, 2009). Level crossings present a significant safety risk to railway users and especially road user. A total of 181 level crossing collisions were recorded during the 2009/10 reporting period of the Railway Safety Regulator whereof 125 injuries and fatalities were reported (South African Railway State of Safety 2009/10, 2010).

Knowing how level crossings operate could save lives. Up to 95% of crashes at level crossings are caused by driver error, according to international police statistics. It was found that this is largely attributable to inattention, driver distraction, risk taking, disobeying and lack of knowledge of the road rules and sometimes suicide attempts (www.arrivealive.co.za). These behaviours are affected by several attributes, such as: the category of warning device, volume of vehicular traffic, volume of train traffic, visibility conditions, age of driver, driver's gender, driver's population group, day of the week, time of the day, road type and vehicle type. There is very little the train driver can do to prevent a collision or minimise its effects, as it takes about up to 1 kilometre for a train that is traveling between 70 - 80km/h to come to a complete stop (Rail Safety Core Issues, 2007).

To prevent and manage accident at level crossings, traffic control for road users at level crossings uses a combination of warning signs, lights and boom gates in South Africa. Because of the few level crossing deaths as percentage of total road deaths, it is difficult to obtain money for building infrastructure that eliminates level crossings. However, due to the severity of the incidents they are all extensively reported in the media. During the 2008/9 reporting period of the Railway Safety Regulator Metrorail spent R800 000 on level crossing collisions and R400 000 during the 2009/10 reporting period. While Transnet spent R16.4 million during the 2008/9 reporting period and R25.9 million during the 2009/10 reporting period of the Railway Safety Regulator on level crossings in general (South African Railway State of Safety 2009/10, 2010).

1.2 Aim

The aim of this project is to determine the key causal factors of accidents at level crossings in South Africa. The contribution of each factor to accident occurrence is investigated and potential management interventions are proposed.

1.3 Problem Statement

Annually, a number of fatal accidents occur at level crossings in the South Africa. It is postulated that many of these accidents could be avoided if the road and rail systems and intersections are managed better. The research problem at hand is to try and determine why this class of accidents still occur and to indicate how management can be improved to reduce the number of incidents annually.

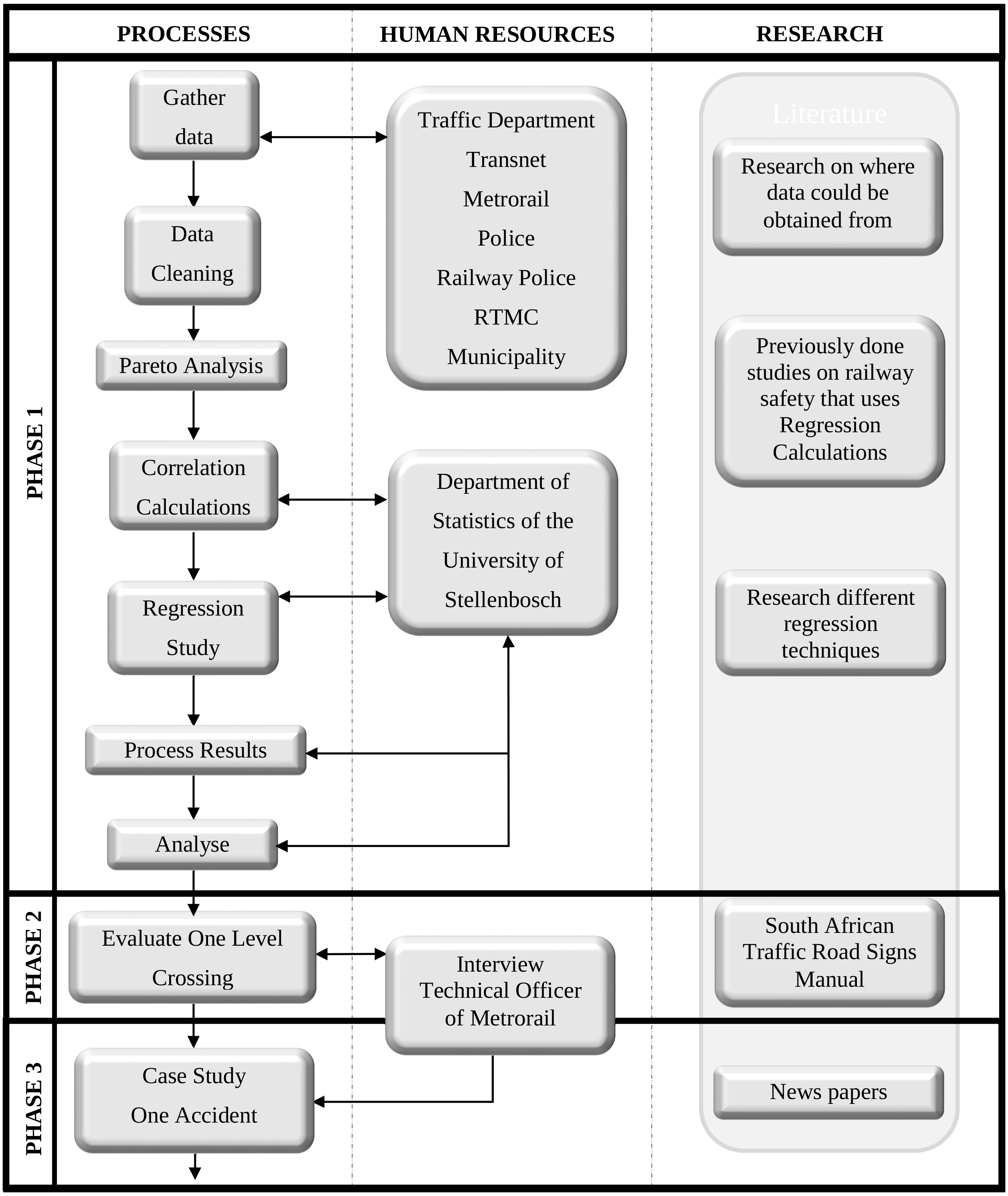
The objective of this project is to propose a suitable management intervention strategy with a view to reduce the annual number of collisions at level crossings in South Africa.
Some key research questions to be answered include:

- What are the main causes for level crossing collisions occurring?
- Do these causes influence each other?
- What safety measures should be enforced?
- Why have these safety measures not been implemented yet?

1.4 Limitations and Scope of Study

The project is constrained by time, budget and data availability. The time constraints are 300 working hours and no budget was available to this study. Data on level crossing collisions are not made public, it is against the railway police's policy to share this class of information. The Provincial Government of the Western Cape supplied data of accidents on level crossings from 1999 till 2010. It was not able to collect the same degree of data from the rest of the country. The 135 accidents from the Western Cape are enough data to perform statistical calculations on and make statistically significant conclusions of.

1.5 *Methodology*



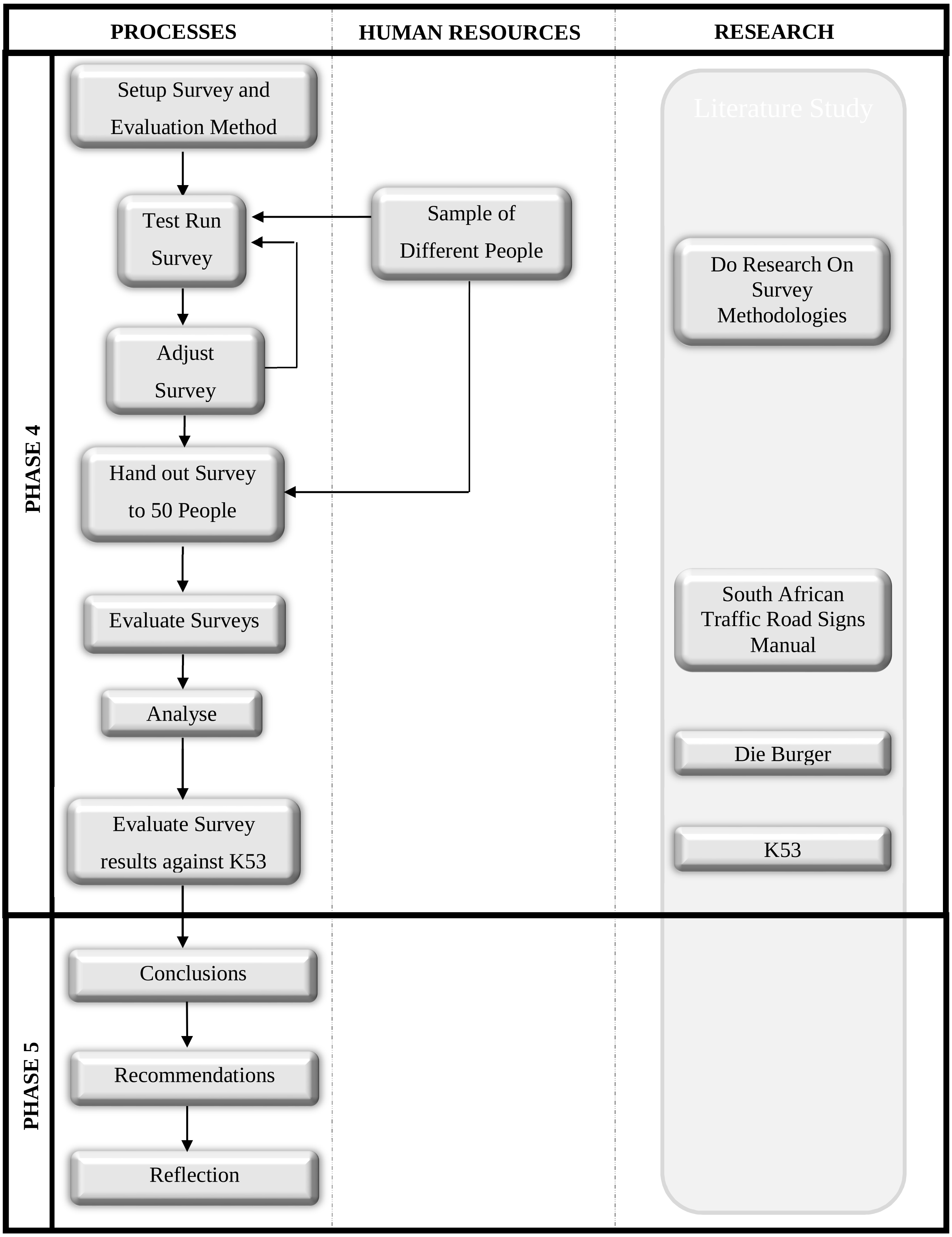


FIGURE 1: METHODOLOGY FLOWCHART

1.5.1 Phase 1

1.5.1.1 Gather Data

Firstly data will be needed for this study. It is important to start gathering data from the start because this could be a time consuming job. The study cannot commence before data is collected. Once data has been collected the specifics of the study can be planned by looking at the degree of the data.

Human resources such as Traffic Departments, Transnet, Metrorail, Police, Railway Police, RTMC and Municipalities will be approached for their data.

1.5.1.2 Data Cleaning

The gathered data has to be 'cleaned' in preparation for the use of it in the study. It is cleaned in Excel. Only data on the driver will be used, since passenger data will be useless for the purpose of this study. There should be no duplicated accidents in the data. Duplications needs to be removed.

1.5.1.3 Pareto Analysis

After the data has been cleaned a pareto analysis needs to be done to determine which attributes of the data are the most important. A pareto analysis will eliminate those variables of a collision that will have no effect on the study. It also ensures that no unnecessary time is wasted. The pareto analysis will identify the independent variables.

1.5.1.4 Correlation Calculations

Correlation calculations are done to compare two variables of a collision to each other, it can be done in R. If the correlation between the variables the correlation coefficient is equal or close to -1 or 1 then the two variables have a strong correlation. It is necessary to do this for all the variables. A strong correlation between variables indicates that not both of those variables have to appear in the regression study. The University of Stellenbosch's Department of Statistics can be approached for help.

1.5.1.5 Regression Study

A regression study has to be done on the data obtained. The correlation study done previously pointed out which variables are strongly correlated. One of the strongly correlated variables can be left out of the regression study. A dependent variable needs to be identified. For this study it injury will be the dependent variable. Methods on what type of regression will be researched, finally logistical regression will be identified. The regression calculations will be done in R. The statistically significant variables will form part of an equation. This equation will state which variables contribute to the chance of a injury occurring in a collision and what weight they carry. The University of Stellenbosch's Department of Statistics can be approached for help.

1.5.1.6 Process Results

The results can be analysed by looking at the previously mentioned equation. The contribution of one of the categorical variable's presence or absence contributes to the likelihood of an accident occurring can be determined by analysing the equation. The University of Stellenbosch's Department of Statistics can be approached for help.

1.5.1.7 Analyse the Results

The meaning and implication of the results will be discussed in this section. Possible reasons for the outcome will be identified.

1.5.2 Phase 2

1.5.2.1 Evaluating One Level Crossing

A sample of one level crossing will be evaluated to determine whether it conforms to the standards that are set by the South African Department of Transport in the South African Traffic Road Signs Manual (Brain, 1999). This is necessary to determine whether the fault lies with the system or the driver. James Denton, a technical officer at the level crossing in question will be interviewed.

1.5.3 Phase 3

1.5.3.1 Case Study

One accident, which occurred at the level crossing in question, will be discussed. The case study will point out where the fault lies. Once again the question can be asked if it was due to driver error or the system that failed.

James Denton will be interviewed on this matter. Newspaper articles will be used as sources to discuss the accident.

1.5.4 Phase 4

1.5.4.1 Setup the Survey and Evaluation Methods

A survey is setup to determine whether people understand road signs and markings applicable to railway crossings. If it turns out that people do not understand road signs and markings, it indicates that people are uneducated. It is necessary to determine this because this could be a major cause of collisions occurring.

Methods for setting up a survey should be studied. Furthermore an evaluation method should be setup. The survey population will be defined as all people of different ages, genders and population groups who have valid driver's licences.

1.5.4.2 Test Run Survey

It is important to perform a test run to make sure the required outcome of the study is achieved. The survey should be handed out to a sample of about five people. These people should represent the population in question. If there is any confusion on some of the questions, the survey should be restructured. A test run should be done on as many people as required until the required results are acquired. These people are required to give comments or any pointers on the survey.

1.5.4.3 Adjust Survey

After handing the survey out to a small sample of people the results should be evaluated. If the results are not satisfactory the survey should be restructured in the necessary manner. After restructuring the survey another test run should be done to make sure the survey has the required outcome.

1.5.4.4 Hand Survey Out

When the survey is complete it should be handed out to 50 people. These people should represent the population in question.

1.5.4.5 Evaluate Surveys

The survey should be evaluated according to the set evaluation technique determined in section 1.5.4.1. The K53 (McDonald, 1999), the South African Traffic Road Signs Manual (Brain, 1999) and an article from Die Burger (Snyders, 2009) will be used to evaluate the answers. A histogram should be drawn up to show the results.

1.5.4.6 Analyse

A correlation calculation can be done in Excel to determine whether there is a correlation between the age of the driver and the result they obtained. Furthermore, the same degree of a correlation calculation can be done between the year the driver obtained his licence and result scored. This will show whether there is a relationship between the time the driver has been driving and the score he obtained.

The individual sign and road marking results should be calculated to determine which signs and road markings are the problem.

1.5.4.7 Evaluate Survey Results against the K53

The K53 (McDonald, 1999) book is the only knowledge that South African drivers obtain when learning road signs and markings. By computing the results of each individual sign and road marking a good understanding can be obtained from where the problem lies.

This can be done by evaluating the particular signs and markings against that displayed in the K53 (McDonald, 1999) book. This part of the study will show whether the learning system of South Africa's road signs and markings are up to standard or not.

1.5.5 Phase 5

1.5.5.1 Conclusions

This section is necessary to coordinate results of all phases and to give an overview of the bigger picture.

1.5.5.2 Recommendations

After a conclusion is reached, recommendations can be made on how to address the problem at hand.

1.5.5.3 Reflection

In this section the student will reflect on the whole process of doing a final year project.

2. Phase 1: Logistic Regression

2.1 Literature Review

2.1.1 Calculation of Hazard Indices for Highway-Railway Crossings in Canada

This study proposes a technique for determining the probability of future accidents at a particular crossing based on several crossing characteristics. A collision history of 31000 crossings is used to determine the formula. Six categories were identified to describe each crossing's 30 different attributes. The study was done in two phases. First, an 8% sample of the crossings were used to reduce the number of independent variables, to determine what transformations are needed for what variables and lastly to identify the important interactions between variables. The second phase was to calibrate the model. The first phase was done by fitting a multiple regression model to determine the forecasting of m_i accidents occurring in a time interval t at a crossing i. This model makes a distinction between rural and urban areas (Zalinger, 1977).

2.1.2 The Calculations of Hazard Indices for Level Crossings in South Africa Was Considered

All of the required data was available to complete the Canadian study, but what happens when data is limited? The already reworked stats are published in StatsSA and the State of Railway Safety of South Africa, but this does not help to do a regression study.

The data that was found on South African level crossing collisions was restricted. It was impossible to find data on one level crossing's collision history. The data obtained includes 135 accidents of the past 12 years in the Western Cape. A way to evaluate the data should be developed.

The Canadian study's method for determining hazard indices cannot be followed due to lack of data. The data that was obtained is incomplete, and for calculating a hazard index complete data on at least one level crossing is necessary.

2.1.3 Logistic Regression

Logistic regression is part of a category of statistical models called generalised linear models. Logistic regression allows one to predict a discrete outcome from a set of variables that may be continuous, discrete, dichotomous, or a mix of any of these. Generally, the dependent variable is dichotomous, such as presence/absence or success/failure. Discriminant analysis is also used to predict group membership with only two groups. Discriminant analysis can however only be used with continuous independent variables. In instances where the independent variables are a categorical, or a mix of continuous and categorical, logistic regression is preferred.

The dependent variable in logistic regression is usually dichotomous, that is, the dependent variable can take the value 1 with a probability of success p, or the value 0 with probability of failure 1-p. This type of variable is called a Bernoulli (or binary) variable. Logistic regression makes no assumption about the distribution of the independent variables. They do not have to be normally distributed, linearly related or of equal variance within each group. The relationship between the predictor and response variables is not a linear function in logistic regression, instead the logistic regression function is used, which is the logit transformation of p, expressed by:

$$\theta = \frac{e^{\alpha+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_i x_i}}{1+e^{\alpha+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_i x_i}} \qquad (1)$$

Where α = the constant of the equation, β_i = the coefficient of the predictor variables and x_i = the various independent variables

An alternative form of the logistic regression equation is:

$$logit[\theta(x)] = log\frac{\theta(x)}{1-\theta(x)} = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_i x_i \qquad (2)$$

The goal of logistic regression is to correctly predict the category of outcome for individual cases using the most sparing model. To accomplish this goal, a model is created that includes all predictor variables that are useful in predicting the response variable.

Theory testing is the testing of hypotheses of the relationships between variables. Exploratory testing makes no assumptions regarding the relationships between the variables, thus the goal is to discover relationships.

One of the main uses of logistic regression is the prediction of group membership. Since logistic regression calculates the probability or success over the probability of failure, the results of the analysis are in the form of an odds ratio. For example, logistic regression is often used in epidemiological studies where the result of the analysis is the probability of developing cancer after controlling for other associated risks. Logistic regression also provides knowledge of the relationships and strengths among the variables (e.g., smoking 10 packs a day puts you at a higher risk for developing cancer than working in an asbestos mine)   (Logisic Regression, 2009).

The process by which coefficients are tested for significance for inclusion or elimination from the model involves several different techniques. Most statistical software packages can calculate which coefficients are statistically significant. One could look at the p value, if it is below 0.05 the variable is statistically significant at a 95% confidence level. Or the z value could also be used, if it lies outside the -2 to 2 interval it is statistically significant. The standard error is also important to keep in mind.

2.1.4 Appropriate Method for This Study

When looking closer at the data obtained it is clear that the degree of the seriousness of a collision can be used in a regression study to determine what variables contribute to increasing the damage caused by an accident. The data specifies if an injury has occurred in the collision or not.

There are many different ways to perform a regression study, multiple regression was used in the Canadian study. After research it was found that a logistic regression is the best way to go.

Statistical software packages that could perform logistic regression and that is available to the student is Statistica, R, Minitab, Matlab and Excel.

2.2 Introduction

The aim of this phase of the study is to identify factors that contribute to serious collisions between cars and trains that could cause injuries. Logistic regression will be used to identify this. The degree of the injury is ignored, it is assumed that a collision is serious when an injury was obtained. It does not acknowledge the difference between a slight injury and a fatality. This study merely focuses on whether a collision has an injury as result or not

2.3 The Data

Data of car accidents with trains was collected of the Western Cape area from the period of 1999 till 2010. 135 incidents were reported in this period.

Each collision's data set consists of the following fields: capturing authority, accident number, road name, road description, node description, kilometre value, police station, date, weekday, time, obstructions, road type, sign visibility, accident type, specified cause, vehicle reference number, vehicle type, vehicle registration number, manoeuvre, travel direction, person type, injuries, population group, gender and age.

2.4 Data Cleaning

Data cleaning was needed. The 135 accidents include data on the driver and passengers of the car. It is postulated that in a collision that is serious enough to injure the passenger, the driver will also be injured. In order to make useful conclusions from the data, the passengers needed to be removed. There were a few cases where one accident was reported more than once and thus duplicate accidents had to be removed. In the end data on 83 collisions remained. The study was thus performed on a population of 83 cases.

2.5 Pareto Analysis

After data cleaning it was necessary to decide which variables will contribute to the likelihood of an injury occurring. It was decided to look at weekday, time, obstructions, road type, sign visibility, vehicle type, injuries, population group, gender and age as the independent variables. The rest of the variables will not contribute to this study.

Time and age are quantitative data. The rest of the variables are categorical. Table 1 shows the different categories for each variable.

TABLE 1: UNSORTED CATEGORICAL VARIABLES OF ACCIDENT DATA

Name of Category	Attributes
Day of the week	Monday Tuesday Wednesday Thursday Friday Saturday Sunday
Obstructions	None Road works Other
Road type	Gravel Tarmac Dirt Concrete Other Unknown
Sign visibility	Yes No N/A
Vehicle type	Motor car/station wagon Other vehicle Light delivery vehicle GVM>3500Kg: (greater than) Tractor Truck : Articulated multiple Truck: Articulated Bus-train Unknown
Population group	White Coloured Black Asian Unknown
Gender	Male Female Unknown

Some of these categories have very low frequencies and thus have no effect to the occurrence on an injury. Such categories should be grouped to give more meaningful output. The pareto analysis' outcome determined that the category obstructions was removed as a whole due to its low counts. The grouping was done as shown in Table 2.

TABLE 2: SORTED CATEGORICAL VARIABLES OF ACCIDENT DATA

Name of Category	Attributes
Day of the week	Monday Tuesday Wednesday Thursday Friday Saturday Sunday
Road type	Gravel Tarmac Other RdType (Dirt + Concrete + Other + Unknown)
Sign visibility	Yes No N/A
Vehicle type	Motor car/station wagon Other vehicle (Other vehicle + Unknown) Light delivery vehicle Big Vehicles (GVM>3500Kg: (greater than) + Tractor + Truck : Articulated multiple + Truck: Articulated + Bus-train)
Population group	White Coloured Black Unknown PopGroup (Asian + Unknown)
Gender	Male Female Unknown

2.6 Correlation Calculations

Correlation calculations were performed in R, a statistical software package. The data is fed into R. Injury is defined as the dependent, binary variable Y, where

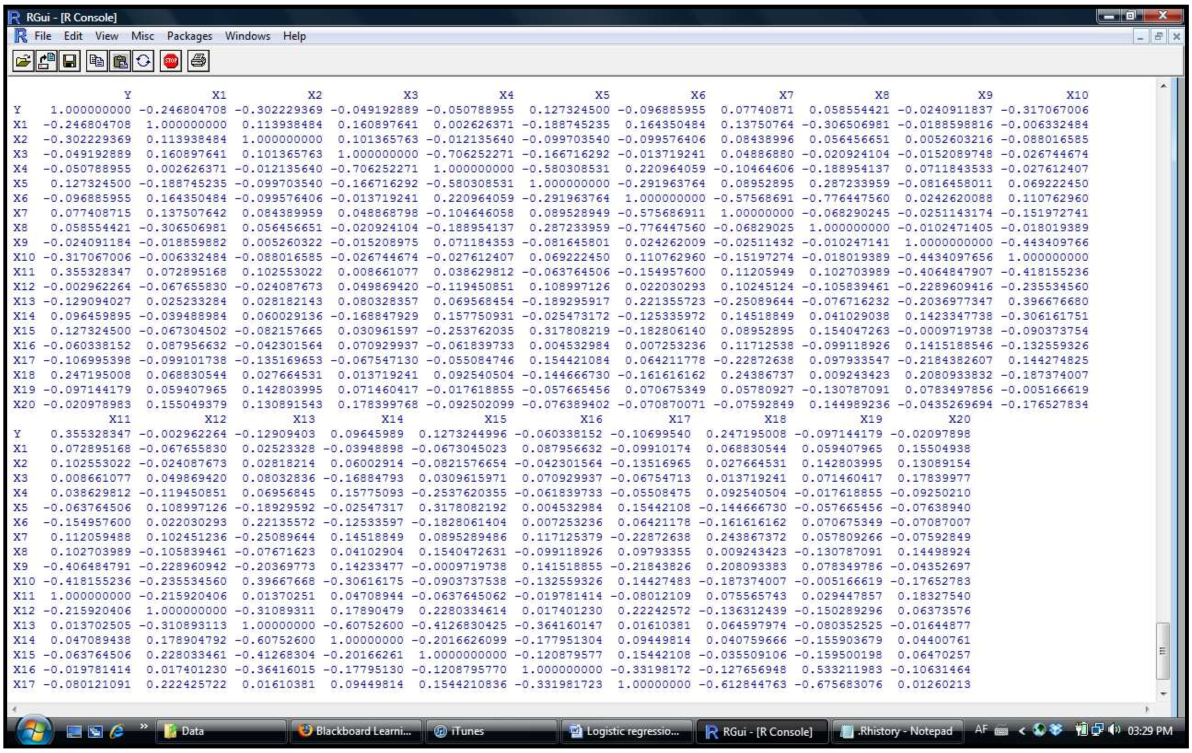
$$Y = \begin{cases} 1, \text{ if an injury occurs} \\ 0, \text{ if there is no injury} \end{cases}$$

The independent variables, can be seen in Table 3, are fed into R to perform a correlation calculation.

TABLE 3: INDEPENDENT VARIABLES

Variable	Category of Variable	Variable Description	Variable Type	Value of Variables
X_1	Day of the Week	Day	Integer	1 - 7
X_2	None	Time	Decimal	0 - 24
X_3	Road Type	Gravel	Binary	0 - 1
X_4		Tarmac	Binary	0 - 1
X_5		Other Road Type	Binary	0 - 1
X_6	Visibility	Yes	Binary	0 - 1
X_7		No	Binary	0 - 1
X_8		N/A	Binary	0 - 1
X_9	Vehicle Type	Motorcar or Station wagon	Binary	0 - 1
X_{10}		Other	Binary	0 - 1
X_{11}		Light Delivery Vehicle	Binary	0 - 1
X_{12}		Big Vehicle	Binary	0 - 1
X_{13}	Population Group	White	Binary	0 - 1
X_{14}		Black	Binary	0 - 1
X_{15}		Coloured	Binary	0 - 1
X_{16}		Unknown	Binary	0 - 1
X_{17}	Gender	Male	Binary	0 - 1
X_{18}		Female	Binary	0 - 1
X_{19}		Unknown Gender	Binary	0 - 1
X_{20}	None	Age	Integer	$0 - \infty$

A correlation study is done to determine whether there are underlying correlations between the variables. If a strong correlation is found between two variables, one of them can be thrown out of the regression calculation.



	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Y	1.000000000	-0.246804708	-0.302229369	-0.049192889	-0.050788955	0.127324500	-0.096885955	0.07740871	0.058554421	-0.0240911837	-0.317067006
X1	-0.246804708	1.000000000	0.113938484	0.160897641	0.002626371	-0.188745235	0.164350484	0.13750764	-0.306506981	-0.0188598816	-0.006332484
X2	-0.302229369	0.113938484	1.000000000	0.101365763	-0.012135640	-0.099703540	-0.099576406	0.08438996	0.056456651	0.0052603216	-0.088016585
X3	-0.049192889	0.160897641	0.101365763	1.000000000	-0.706252271	-0.166716292	-0.013719241	0.04886880	-0.020924104	-0.0152089748	-0.026744674
X4	-0.050788955	0.002626371	-0.012135640	-0.706252271	1.000000000	-0.580308531	0.220964059	-0.10464606	-0.188954137	0.0711843533	-0.027612407
X5	0.127324500	-0.188745235	-0.099703540	-0.166716292	-0.580308531	1.000000000	-0.291963764	0.08952895	0.287233959	-0.0816458011	0.069222450
X6	-0.096885955	0.164350484	-0.099576406	-0.013719241	0.220964059	-0.291963764	1.000000000	-0.57568691	-0.776447560	0.0242620088	0.110762960
X7	0.077408715	0.137507642	0.084389959	0.048868798	-0.104646058	0.089528949	-0.575686911	1.00000000	-0.068290245	-0.0251143174	-0.151972741
X8	0.058554421	-0.306506981	0.056456651	-0.020924104	-0.188954137	0.287233959	-0.776447560	-0.06829025	1.000000000	-0.0102471405	-0.018019389
X9	-0.024091184	-0.018859882	0.005260322	-0.015208975	0.071184353	-0.081645801	0.024262009	-0.02511432	-0.010247141	1.0000000000	-0.443409766
X10	-0.317067006	-0.006332484	-0.088016585	-0.026744674	-0.027612407	0.069222450	0.110762960	-0.15197274	-0.018019389	-0.4434097656	1.000000000
X11	0.355328347	0.072895168	0.102553022	0.008661077	0.038629812	-0.063764506	-0.154957600	0.11205949	0.102703989	-0.4064847907	-0.418155236
X12	-0.002962264	-0.067655830	-0.024087673	0.049869420	-0.119450851	0.108997126	0.022030293	0.10245124	-0.105839461	-0.2289609416	-0.235534560
X13	-0.129094027	0.025233284	0.028182143	0.080328357	0.069568454	-0.189295917	0.221355723	-0.25089644	-0.076716232	-0.2036977347	0.396676680
X14	0.096459895	-0.039488984	0.060029136	-0.168847929	0.157750931	-0.025473172	-0.125335972	0.14518849	0.041029038	0.1423347738	-0.306161751
X15	0.127324500	-0.067304502	-0.082157665	0.030961597	-0.253762035	0.317808219	-0.182806140	0.08952895	0.154047263	-0.0009719738	-0.090373754
X16	-0.060338152	0.087956632	-0.042301564	0.070929937	-0.061839733	0.004532984	0.007253236	0.11712538	-0.099118926	0.1415188546	-0.132559326
X17	-0.106995398	-0.099101738	-0.135169653	-0.067547130	-0.055084746	0.154421084	0.064211778	-0.22872638	0.097933547	-0.2184382607	0.144274825
X18	0.247195008	0.068830544	0.027664531	0.013719241	0.092540504	-0.144666730	-0.161616162	0.24386737	0.009243423	0.2080933832	-0.187374007
X19	-0.097144179	0.059407965	0.142803995	0.071460417	-0.017618855	-0.057665456	0.070675349	0.05780927	-0.130787091	0.0783497856	-0.005166619
X20	-0.020978983	0.155049379	0.130891543	0.178399768	-0.092502099	-0.076389402	-0.070870071	-0.07592849	0.144989236	-0.0435269694	-0.176527834

	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20
Y	0.355328347	-0.002962264	-0.12909403	0.09645989	0.1273244996	-0.060338152	-0.10699540	0.247195008	-0.097144179	-0.02097898
X1	0.072895168	-0.067655830	0.02523328	-0.03948898	-0.0673045023	0.087956632	-0.09910174	0.068830544	0.059407965	0.15504938
X2	0.102553022	-0.024087673	0.02818214	0.06002914	-0.0821576654	-0.042301564	-0.13516965	0.027664531	0.142803995	0.13089154
X3	0.008661077	0.049869420	0.08032836	-0.16884793	0.0309615971	0.070929937	-0.06754713	0.013719241	0.071460417	0.17839977
X4	0.038629812	-0.119450851	0.06956845	0.15775093	-0.2537620355	-0.061839733	-0.05508475	0.092540504	-0.017618855	-0.09250210
X5	-0.063764506	0.108997126	-0.18929592	-0.02547317	0.3178082192	0.004532984	0.15442108	-0.144666730	-0.057665456	-0.07638940
X6	-0.154957600	0.022030293	0.22135572	-0.12533597	-0.1828061404	0.007253236	0.06421178	-0.161616162	0.070675349	-0.07087007
X7	0.112059488	0.102451236	-0.25089644	0.14518849	0.0895289486	0.117125379	-0.22872638	0.243867372	0.057809266	-0.07592849
X8	0.102703989	-0.105839461	-0.07671623	0.04102904	0.1540472631	-0.099118926	0.09793355	0.009243423	-0.130787091	0.14498924
X9	-0.406484791	-0.228960942	-0.20369773	0.14233477	-0.0009719738	0.141518855	-0.21843826	0.208093383	0.078349786	-0.04352697
X10	-0.418155236	-0.235534560	0.39667668	-0.30616175	-0.0903737538	-0.132559326	0.14427483	-0.187374007	-0.005166619	-0.17652783
X11	1.000000000	-0.215920406	0.01370251	0.04708944	-0.0637645062	-0.019781414	-0.08012109	0.075565743	0.029447857	0.18327540
X12	-0.215920406	1.000000000	-0.31089311	0.17890479	0.2280334614	0.017401230	0.22242572	-0.136312439	-0.150289296	0.06373576
X13	0.013702505	-0.310893113	1.00000000	-0.60752600	-0.4126830425	-0.364160147	0.01610381	0.064597974	-0.080352525	-0.01644877
X14	0.047089438	0.178904792	-0.60752600	1.00000000	-0.2016626099	-0.177951304	0.09449814	0.040759666	-0.155903679	0.04400761
X15	-0.063764506	0.228033461	-0.41268304	-0.20166261	1.0000000000	-0.120879577	0.15442108	-0.035509106	-0.159500198	0.06470257
X16	-0.019781414	0.017401230	-0.36416015	-0.17795130	-0.1208795770	1.000000000	-0.33198172	-0.127656948	0.533211983	-0.10631464
X17	-0.080121091	0.222425722	0.01610381	0.09449814	0.1544210836	-0.331981723	1.00000000	-0.612844763	-0.675683076	0.01260213

FIGURE 2: SCREENSHOT OF CORRELATION CALCULATION IN R

It is clear from Figure 2 that each category has a correlation with itself. Thus X_5, X_8, X_{12}, X_{16} and X_{19} will most likely have to be removed from the data in order to perform a regression study. The data will be left untouched, until the regression study confirms this theory.

2.7 Regression Study

The zero hypothesis (H_o) of the regression study is that states that there are no specific variables that contribute to the likelihood of an injury occurring. If a p value smaller than 0.2 is found the hypothesis can be rejected.

The regression calculations is done in R, see Figure 3.

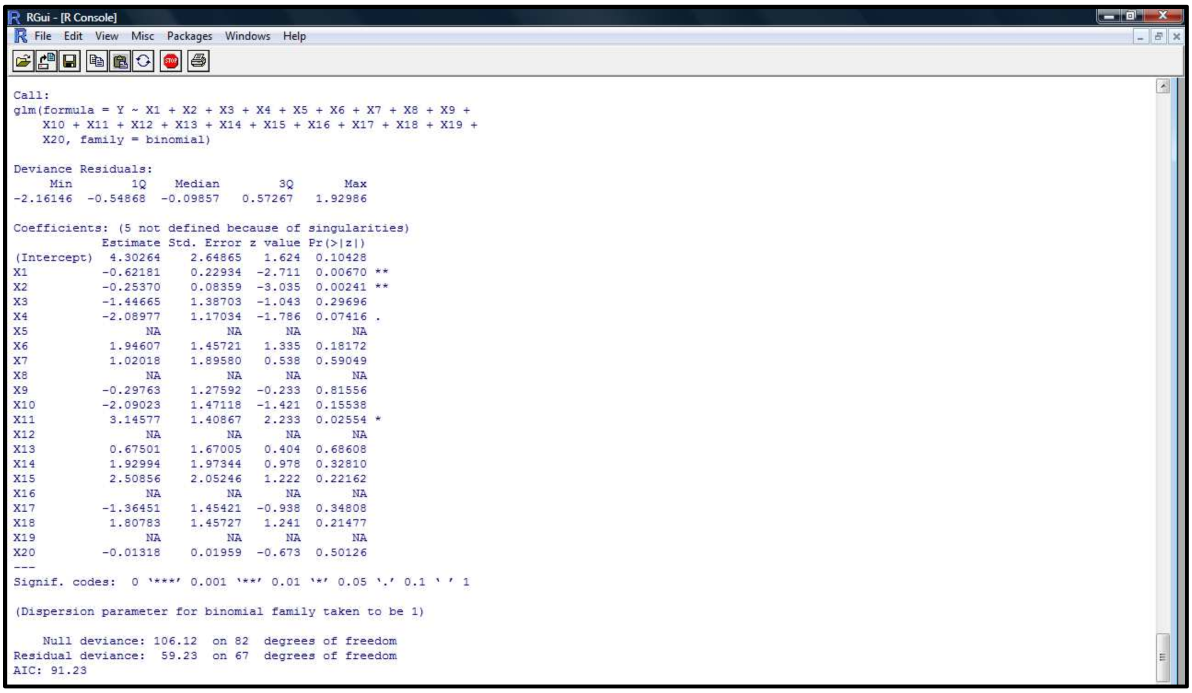


Figure 3 : SCREENSHOT OF FIRST REGRESSION CALCULATION IN R

From Figure 3 X_5, X_8, X_{12}, X_{16} and X_{19} do not produce an output due to the correlation between the variables of one category. This output is supported by what was found in the correlation calculations. Thus these variables should be left out of the regression calculation. A modified regression calculation is repeated in R and the resulting output can be seen in Figure 4.

```
RGui - [R Console]
File  Edit  View  Misc  Packages  Windows  Help

> Afvoer = glm(formula = Y ~ X1 + X2 + X3 + X4 + X6 + X7 + X9 + X10 + X11 + X13 + X14 + X15 + X17 + X18  + X20, family = binomial)
> summary(Afvoer)

Call:
glm(formula = Y ~ X1 + X2 + X3 + X4 + X6 + X7 + X9 + X10 + X11 +
    X13 + X14 + X15 + X17 + X18 + X20, family = binomial)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-2.16146  -0.54868  -0.09857   0.57267   1.92986

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  4.30264    2.64865   1.624  0.10428
X1          -0.62181    0.22934  -2.711  0.00670 **
X2          -0.25370    0.08359  -3.035  0.00241 **
X3          -1.44665    1.38703  -1.043  0.29696
X4          -2.08977    1.17034  -1.786  0.07416 .
X6           1.94607    1.45721   1.335  0.18172
X7           1.02018    1.89580   0.538  0.59049
X9          -0.29763    1.27592  -0.233  0.81556
X10         -2.09023    1.47118  -1.421  0.15538
X11          3.14577    1.40867   2.233  0.02554 *
X13          0.67501    1.67005   0.404  0.68608
X14          1.92994    1.97344   0.978  0.32810
X15          2.50856    2.05246   1.222  0.22162
X17         -1.36451    1.45421  -0.938  0.34808
X18          1.80783    1.45727   1.241  0.21477
X20         -0.01318    0.01959  -0.673  0.50126
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 106.12  on 82  degrees of freedom
Residual deviance:  59.23  on 67  degrees of freedom
AIC: 91.23

Number of Fisher Scoring iterations: 6
```

Figure 4: SCREENSHOT OF MODIFIED REGRESSION CALCULATION IN R

From Figure 4 we can make the conclusion that X_1, X_2, X_4, X_6, X_{10} and X_{11} are statistically significant and thus reject H_0 for these variables. Thus the likelihood of an injury occurring when in an accident with a train can be represented by equation 5.

(3)

$$\text{Logit}\,[P(Y=1\mid X)] = \text{Log}\frac{P(Y=1\mid X1, X2, \ldots X20)}{P(Y=0\mid X1, X2, \ldots X20)}$$

$$= 4.30264 - 0.62181X1 - 0.25370X2 - 2.08977X4 + 1.94607X6 - 2.09023X10 + 3.14577X11$$

(4)

$$\frac{P(Y=1\mid X)}{P(Y=0\mid X)} = odds$$

$$= e^{4.30264 - 0.62181\text{X1} - 0.25370\text{X2} - 2.08977\text{X4} + 1.94607\text{X6} - 2.09023\text{X10} + 3.14577\text{X11}}$$

(5)

$$P(Y=0\mid X) = 1 - P(Y=1\mid X)$$

$$P(Y=1\mid X) = \frac{e^{4.30264 - 0.62181\text{X1} - 0.25370\text{X2} - 2.08977\text{X4} + 1.94607\text{X6} - 2.09023\text{X10} + 3.14577\text{X11}}}{1+e^{4.30264 - 0.62181\text{X1} - 0.25370\text{X2} - 2.08977\text{X4} + 1.94607\text{X6} - 2.09023\text{X10} + 3.14577\text{X11}}}$$

Where X_1 is the day of the week, X_2 is the time of the day, X_4 denotes driving on tarmac, X_6 denotes good visibility, X_{10} denotes driving in another type of vehicle and X_{11} denotes driving in a light delivery vehicle.

From the regression study's results, X_1's coefficient is -0.62181, it can be postulated that as Y increases (an injury occurs) the day of the week decreases. This means that it is more likely to be injured early in the week. Even though there are more accidents towards the middle of the week according to the data, these accidents are not as serious. This can be seen in Figure 5. The percentage of injuries versus accidents on a specific day can be seen in Figure 6.

X_2's coefficient is -0.25370 from the regression study's results, it can be postulated that as Y increases (an injury occurs) the time of the day decreases. This means that it is more likely to be injured earlier in the day according to the data. Even though there are more accidents later in the day, these accidents are not as serious. This can be seen in Figure 7. The percentage of injuries versus accidents in a specific time interval can be seen in Figure 8.

From the regression study's result, X_4's coefficient is - 2.08977, it can be postulated that if driving on tarmac the likelihood of an injury occurring decreases. This means that it is less likely to be injured when driving in on tarmac than on any other road surface. This can be seen in Figure 9. Figure 10 shows the percentage on injuries versus the collisions attributable to the type of road. It is not clear from this figure that this has the lowest injury history, this is due to the low frequencies of the other two types of roads. The low frequencies cause a big standard error when doing the regression study.

From the regression study's results, X_6's coefficient is + 1.94607, it can be postulated that if there is good visibility the likelihood of an injury occurring increases. This can be seen in Figure 11 and Figure 12. It is not clear from Figure 12 that the visibility increases the chance of being injured when comparing it to the other two categories. This is once again due to the low frequencies of the other two categories, the low frequencies cause a big standard error when doing the regression study. Figure 12 shows that when the visibility conditions are good then there is a 32% chance of being injured. This result merely indicates that lack of visibility is not a main cause of injuries occurring.

From the regression study's results, X_{11}'s coefficient is + 3.14577, it can be postulated that if a light delivery vehicle is present, the likelihood of an injury occurring increases. This means that it is more likely to be injured when driving in a light delivery vehicle than in any other form of vehicle. This can be seen in Figure 13. In contrast to this, it can be said that when driving in any other form of vehicle other than a motor car/station wagon, light delivery vehicle, GVM>3500Kg, tractor, truck: articulated multiple, truck: articulated and a bus-train the chance of being injured decreases. This conclusion is derived from X_{10}'s coefficient which is - 2.09023. This can also be seen in Figure 13. A clear illustration of these results can be seen in Figure 15. Figure 14 shows that light delivery vehicles have the highest injury percentage of 61% and other vehicles have a low injury percentage of 12%. Both of these categories have high frequencies.

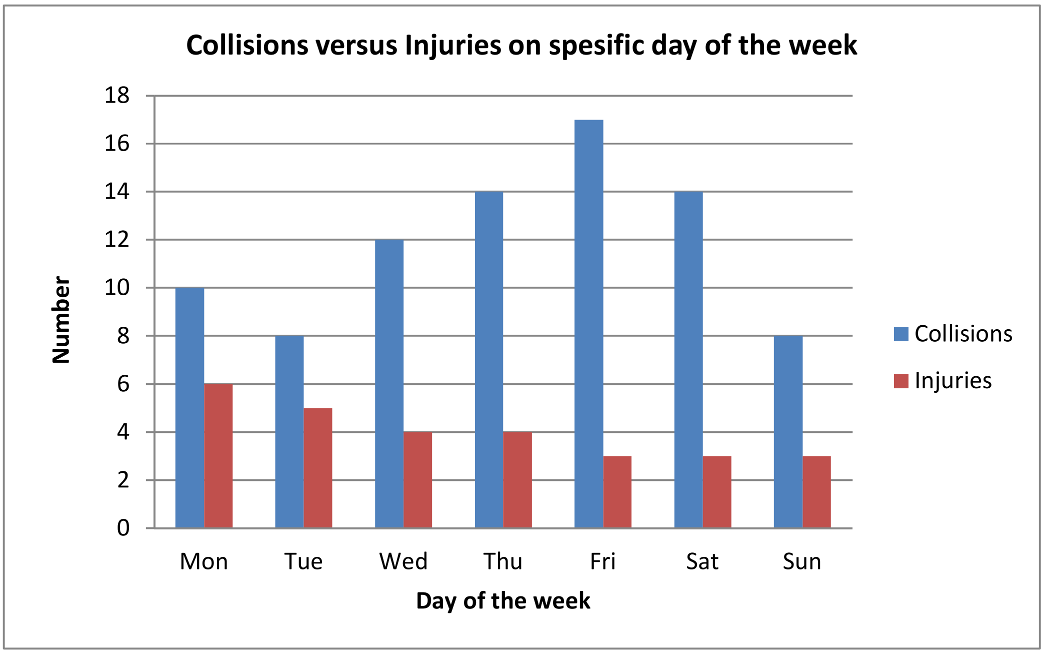


FIGURE 5: COLLISIONS VERSUS INJURIES ON A SPECIFIC DAY OF THE WEEK

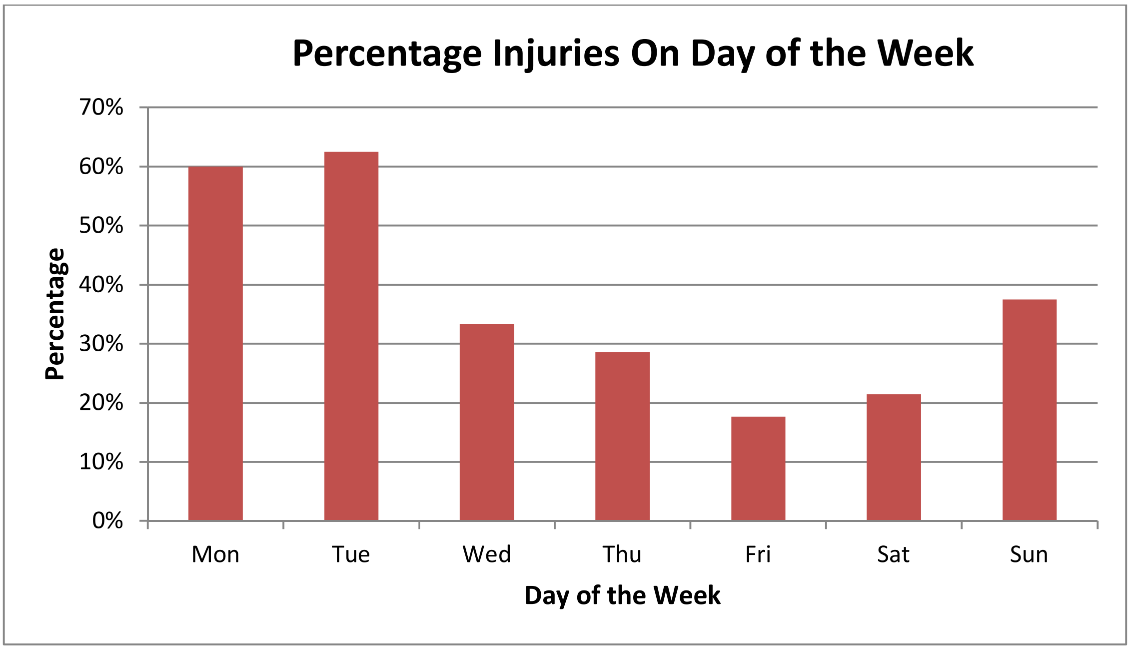


FIGURE 6: PERCENTAGE INJURIES ON DAY OF THE WEEK

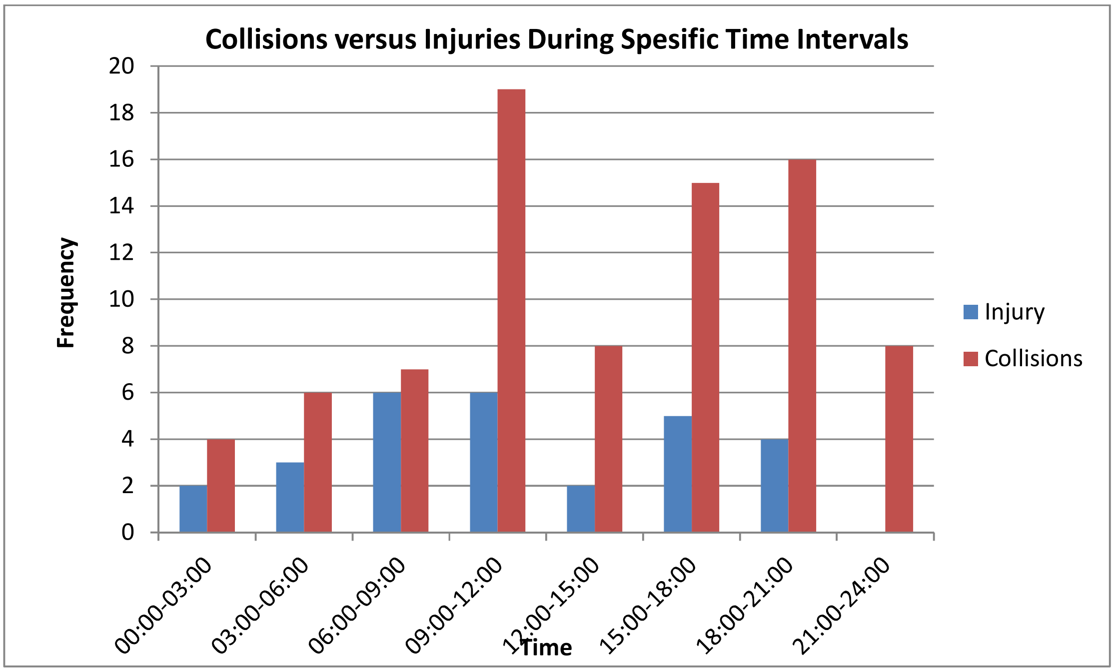


FIGURE 7: COLLISIONS VERSUS INJURIES IN SPECIFIC INTERVALS

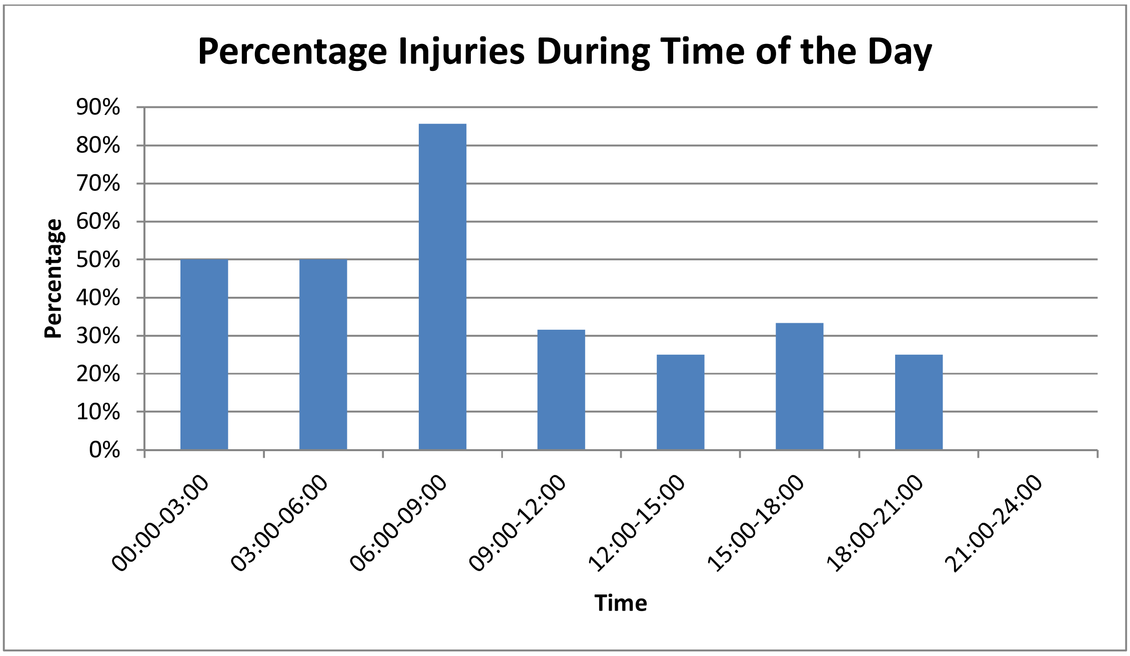


FIGURE 8: PERCENTAGE INJURIES DURING TIME OF THE DAY

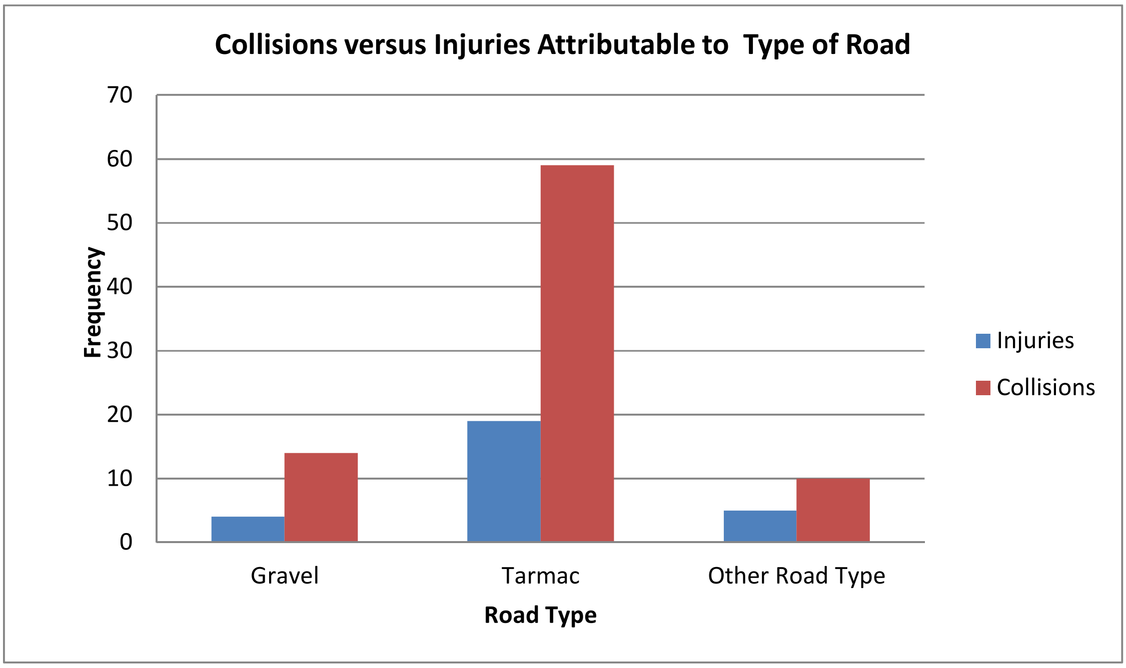


FIGURE 9: COLLISIONS VERSUS INJURIES ATTRIBUTABLE TO TYPE OF ROAD

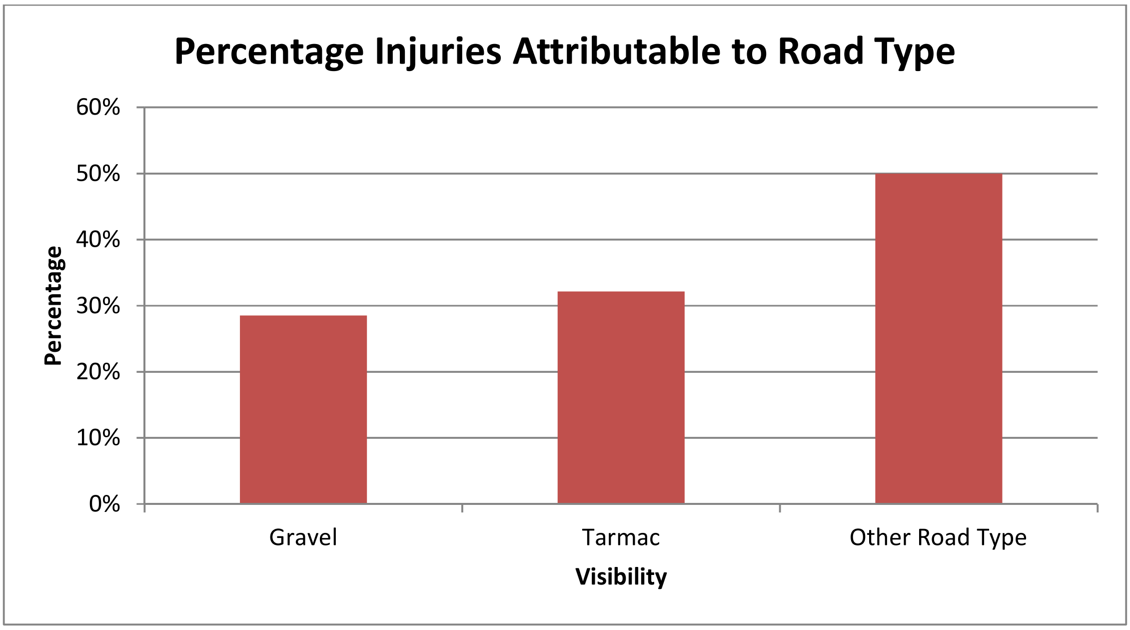


FIGURE 10: PERCENTAGE INJURIES ATTRIBUTABLE TO ROAD TYPE

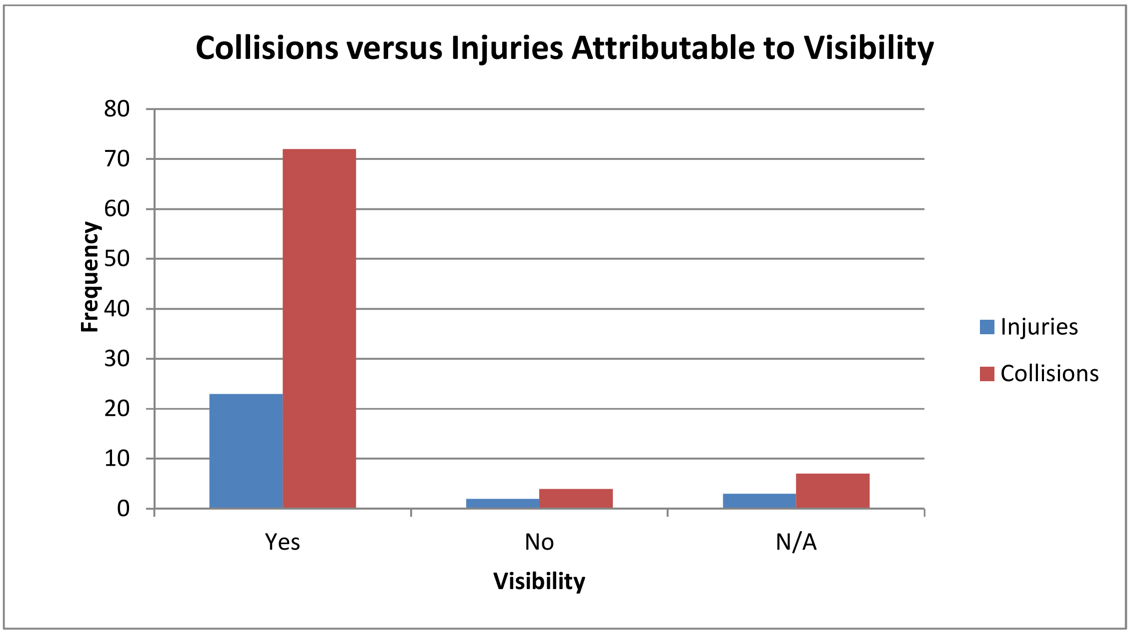


FIGURE 11: COLLISIONS VERSUS INJURIES ATTRIBUTABLE TO VISIBILITY

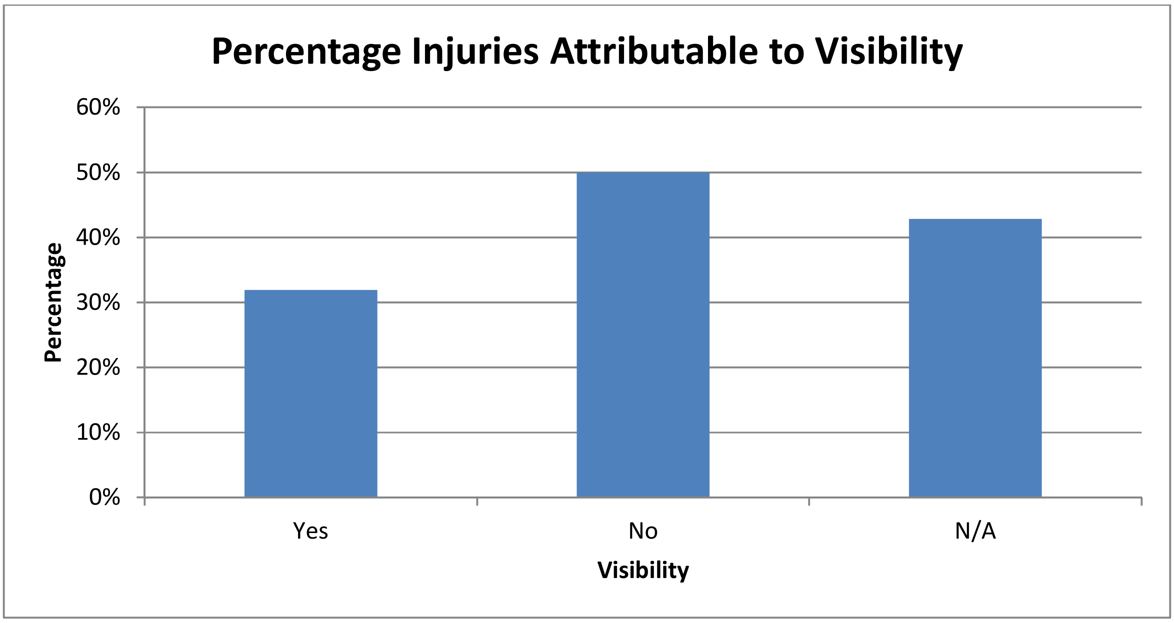


FIGURE 12: PERCENTAGE INJURIES ATTRIBUTABLE TO VISIBILITY

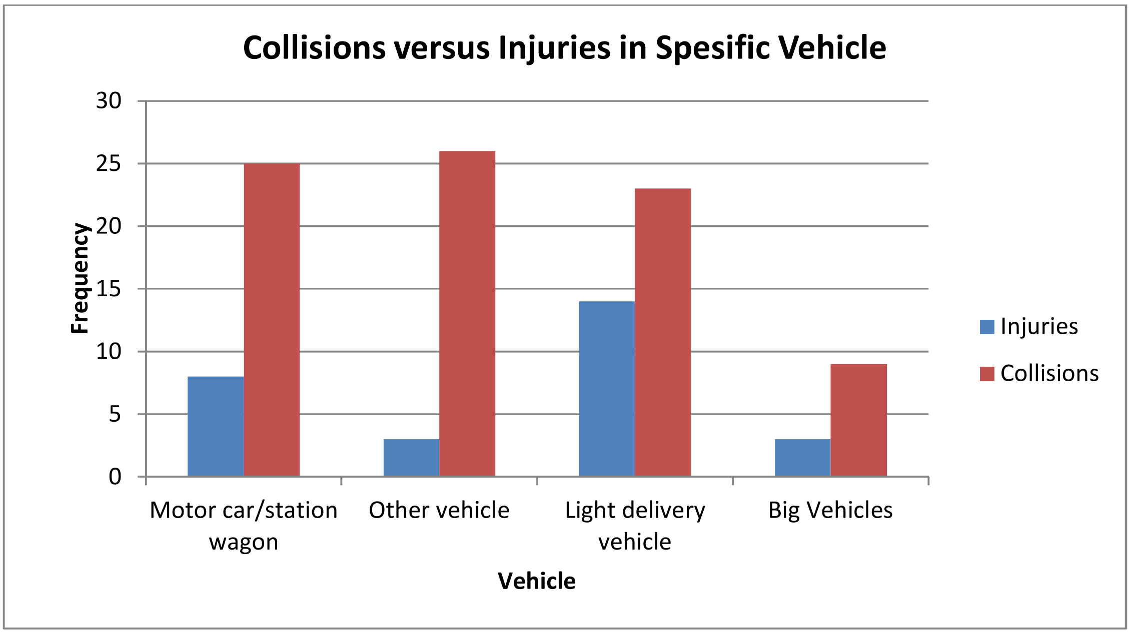


FIGURE 13: COLLISIONS VERSUS INJURIES ATTRIBUTABLE TO TYPE OF VEHICLE

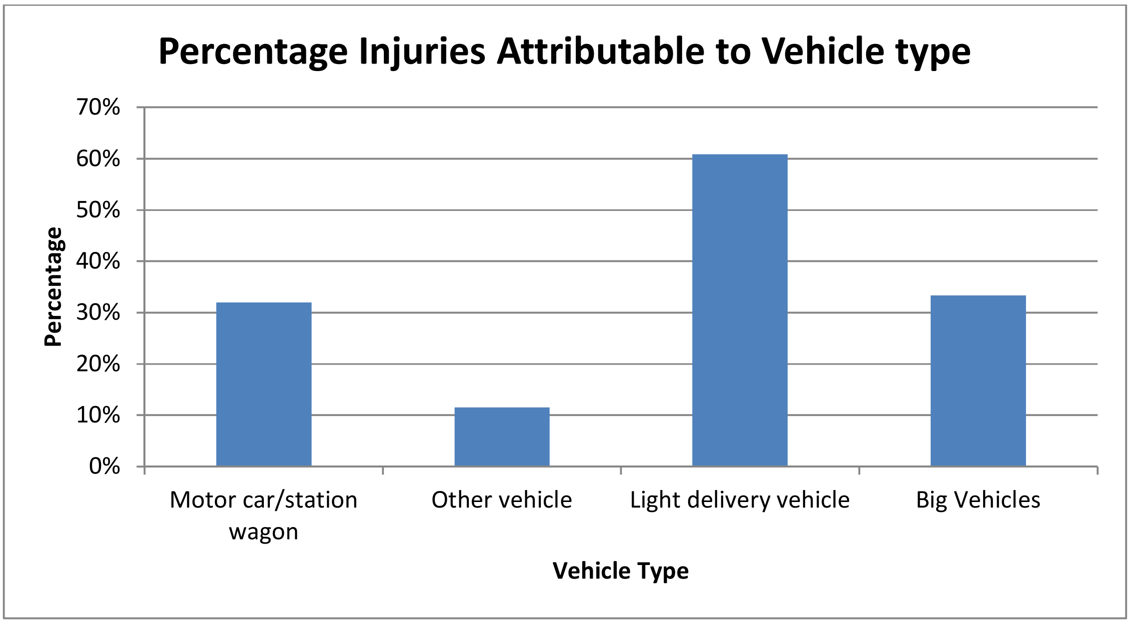


FIGURE 14: PERCENTAGE INJURIES ATTRIBUTABLE TO VEHICLE TYPE

2.7.1 Process the results

The odds equation as calculated from the regression study, this is equation 4:

$$odds = e^{4.30264 - 0.62181X1 - 0.25370X2 - 2.08977X4 + 1.94607X6 - 2.09023X10 + 3.14577X11}$$

The following analysis of the results is necessary to determine what the effect of changing variables on the odds would have.

1. Day of the week

How would the odds be influenced by changing the day of the collision?

$$odds_{new} = odds_{old} \times e^{-0.62181n} \tag{6}$$

Where n is the number of days changed to (it should be noted that this number could be positive or negative)

2. Time of the day

How would the odds be influenced by changing the time of the collision?

(7)

$$odds_{new} = odds_{old} \times e^{-0.25370t}$$

Where t is the number of hours changed to (it should be noted that this number could be positive or negative)

3. Road surface = Tarmac

How would the odds be influenced by changing the road surface to or from tarmac?

(8)

$$odds_{new} = odds_{old} \times e^{-2.08977\mathrm{r}}$$

Where r is presence or absenteeism of tarmac (it should be noted that this number could be 1 or -1)

4. Visibility = Yes

How would the odds be influenced by changing the visibility to or from yes?

(9)

$$odds_{new} = odds_{old} \times e^{-1.94607\mathrm{v}}$$

Where v is presence or absenteeism of good visibility (it should be noted that this number could be 1 or -1)

5. Vehicle type = Other type of vehicle

How would the odds be influenced by changing the vehicle type to or from other type of vehicle?

(10)

$$odds_{new} = odds_{old} \times e^{2.09023\mathrm{a}}$$

Where a is presence or absenteeism of other type of vehicle (it should be noted that this number could be 1 or -1)

6. Vehicle type = Light delivery vehicle

How would the odds be influenced by changing the vehicle type to or from light delivery vehicle?

(11)

$$odds_{new} = odds_{old} \times e^{3.14577\mathrm{b}}$$

Where b is presence or absenteeism of other type of vehicle (it should be noted that this number could be 1 or -1)

2.7.2 Analyse for results

The reason injuries are more likely to occur a certain time of the week is hard to clarify. From the data it seems to be more likely to get injured earlier in the week even though there are a great deal more collisions towards Friday. This is merely a postulation. Further analysis is recommended.

Declaring the reason for the time of the day when injuries are most likely to occur is more straightforward than the day of the week. Firstly the reason why there are fewer collisions late at night and in the early morning hours are due to the fact that there is far less train traffic at night the same goes for vehicle traffic. The most vehicular and train traffic is during peak hours (06:00 till 09:00 and 16:00 till 19:00). The fact that injuries are more likely to occur in the early morning hours, until about 09:00, could be due to people who are in a hurry to get to work driving fast. The visibility is also much less before 09:00, thus it could be hard to see warning devices and trains. The last possible reason why the injury rate is high between 00:00 and 06:00 could be due to people driving intoxicated.

Tarmac decreases the chance of being injured according to this study. Even though tarmac has the most collisions it is the least likely road type to be injured on. This could be as a result of good warning devices or trains and cars traveling slower in urban areas, tarmac level crossings can mostly be found in urban areas.

The fact that the results of the regression study points out that good visibility increases the chance of an injury occurring could be misleading. This result merely means that bad visibility is not the main cause of injuries occurring. If the visibility is good, but collisions and injuries still occur one of the reasons for this could be driver error as being the cause of the collision. This could be due to failure of understanding of the warning signs. The other possibility could be due to bad warning devices implemented.

Any vehicle that is not a motor car/station wagon, light delivery vehicle, has a GVM>3500Kg, tractor, truck: articulated multiple, truck: articulated and a bus-train decreases the chance of being injured according to the results of the regression study. This is only a postulation. These vehicles could include motorcycles, bicycles, quadru-cycles or any other vehicle not included in this study. The reason for this could be due to the size of the these vehicles, like motorcycles are small and even though the driver is more exposed to injuries they are more agile than big vehicles.

Light delivery vehicles tend to increase the chance of injury. This type of vehicle does not the highest frequency of accident, but has the highest percentage of injuries occurring at 61%. This could be because these vehicles are in a competitive industry and therefore travel at higher speeds and could thus ignore warning devices. The driver could be distracted by trying to find his destination or just merely be taking chances. Furthermore, an assumption could be made that delivery vehicles are designed to deliver items and not necessarily have good safety features. This could also be a reason for the high injury rate.

2.8 Conclusion

In this phase variables were identified that contribute to the likelihood of an injury occurring, these variables were identified as day of the week, time of the day, good visibility, type of road and type of vehicle. Of all the variables playing a role in the likelihood of an injury occurring, visibility was the only one that pointed out that driver error and, thus, a possibility of lack of knowledge or just ignorance, this is a variable that can be controlled. Driver error could be caused by bad signage at level crossings.

There is nothing that can be done to reduce the number of injuries occurring on a certain day of the week. A level crossing is designed for every day of the week. It was identified that injuries occur earlier in the day. Peak hours will always have lots of traffic, thus nothing can be done to prevent injuries during morning peak hours. But to prevent after midnight injuries authorities should clamp down on drunk drivers, assuming that some of these collisions were due to driving under the influence. A level crossing’s warning devices are designed to regulate traffic when the most traffic is present. Furthermore there is nothing that can be done to prevent injuries from happening on tarmac roads, the surface cannot be changed, it is consistent. There is also nothing that can be done to the types of vehicles that pass over the level crossing.

The next phase will evaluate a sample of a level crossing to see whether it complies with set standards on warning devices and signage to determine whether driver error is due to inadequate signing.

3. Phase 2: Evaluation of One Level Crossing

3.1 Literature review

3.1.1 South Africa's Level Crossings

"The South African Road Traffic Signs Manual is set up to illustrate and give guidelines on how road traffic signs i.e. road signs, road markings and traffic signals may be utilised collectively at railway crossings." (Brain, 1999).

If a level crossing does not comply with the standards set in The South African Road Traffic Signs Manual (Brain, 1999), the level crossing is illegal.

Additionally, South African National standards were approved by National Committee StanSA TC 5120.66, National steering committee for railway safety standards, in accordance with procedure of Standards South Africa, in compliance with annex 3 of the WTO/TBT agreement. SANS 3000 consists documents, under the general title Railway Safety management (Standards, 2011).

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3.1.2 International Level Crossing Awareness Day

Thursday the 9th of June has been earmarked as the 2011 International Level Crossing Awareness Day (ILCAD) with the motto "Act safely at level crossings". This a joint commitment continuing from the success of the first European Level Crossing Awareness Day held on 25th June 2009 in 28 countries to raise public awareness on the dangers of misbehaviour at level crossings. The purpose of this campaign is because, when compared to other rail operational statistics, an acceptable high percentage of people die or are injured in accidents at level crossings.

In the majority of cases due to misuse by motorists and pedestrians whilst the popular misconception is that these fatal accidents are a railway problem. Conferences on the issue show that the only really effective way to decrease the number of accidents, short of closing all level crossings, is education -highlighting the risks and making people aware of the potential consequences if they do not follow the simple rules of the road (International Level Crossing, 2011).

3.1.3 Does Public Education Improve Rail-Highway Crossing Safety?

Improvements in rail–highway level crossing safety have resulted from engineering, law enforcement, and educating the public about the risks and the actions they should take. The primary form of education is a campaign called Operation Lifesaver in America, which started in the 1970s. Savage (2006) used a negative binomial regression to estimate whether variations in Operation Lifesaver activity across states and from year-to-year in individual states are related to the number of collisions and fatalities at crossings. Annual data on the experience in 46 states from 1996 to 2002 are used. The analysis finds that increasing the amount of educational activity will reduce the number of collisions with a point elasticity of −0.11, but the effect on the number of deaths cannot be concluded with statistical certainty (Savage, 2006).

3.2 Introduction

Guidelines on how road traffic signs (i.e. road signs, road markings and traffic signals) should be utilised collectively at a railway crossing are given in chapter 7 of the South African Road Traffic Signs Manual (Brain, 1999), published by the department of transport of South Africa in 1999. This study is focussed on the winelands area, a sample will be taken of the biggest level crossing in the area. The study will check whether the level crossing complies with the guidelines set by of the South African Road Traffic Signs Manual (Brain, 1999). If it does however comply it indicates that when a collision happens the fault lies with the driver of the vehicle.

The level crossing at Bergkelder is one of Stellenbosch's biggest level crossings. It is situated next to Adam Tas drive and connects the Plankenbrug industrial area to the rest of Stellenbosch. Figure 15 is a map indicating the location of it (for a whole picture of Stellenbosch see Appendix A and for photos of Belgkelder level crossing see Appendix E). Bergkelder crossing falls under urban crossing of parallel railway lines, see Appendix D. There has been one fatal accident since 2009, but many near misses. According to the technical maintenance officer, James Denton, there are weekly near misses (a near miss is defined as when a car collides with the boom) that damage the booms. The repair of these booms is costly. The question should be asked: “Why do so many near misses happen?”

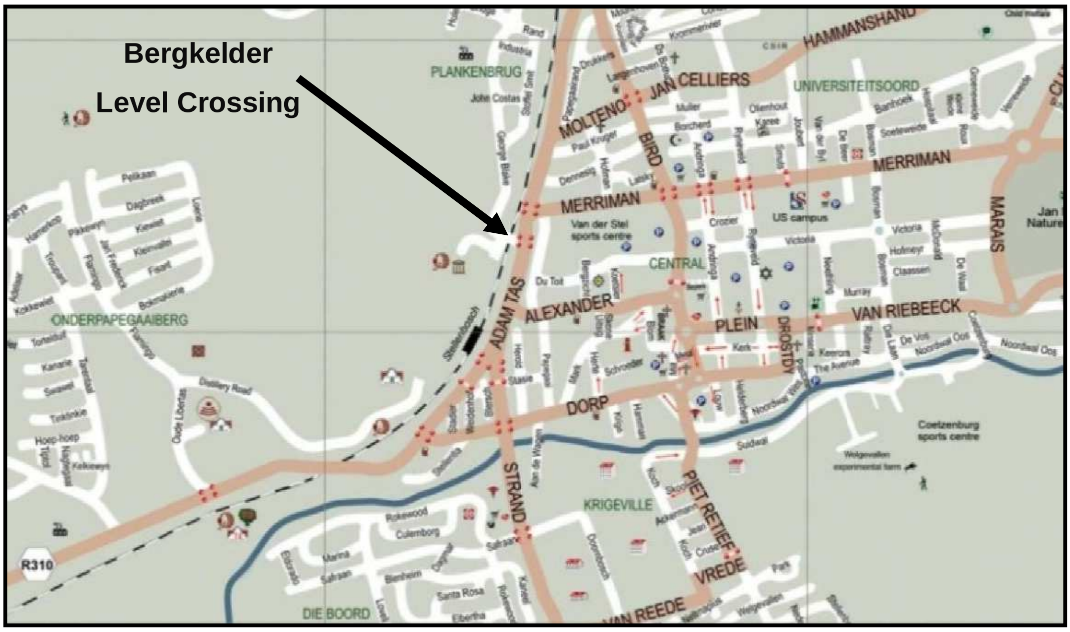


FIGURE 15: STELLENBOSCH ROAD MAP

There are various circumstances that may affect the level of signing recommended at a road/rail crossing point. The most relevant factors are: a poor accident record, the approach speed of the vehicle and train, visibility of approaching trains by vehicle drivers, the presence of overhead electrical power cables, the vehicle and train traffic volumes, the number of rail lines and the proximity to a station. (Brain, 1999)

Due to the high risk of fatalities or serious injuries for the occupants of the car it is extremely important to firstly achieve the highest form of conformity with the recommended standard signing practice at level crossings, and, secondly, high standards of maintenance of signs, markings and signals should be upheld. (Brain, 1999)

3.3 Bergkelder Level Crossing

A census was done in October 2008 that identified roughly 1144 cars crossing this level crossing from 07:00 to 08:00 and 1268 cars crossing it between 16:30 and 17:30.

Furthermore, there are roughly between 25 and 30 trains passing through this level crossing per day. Most trains travel during peak hours, according to James Denton. These counts can be seen in Appendix B.

This is an urban area; cars may travel a maximum speed of 60 km/h and trains travel at 40km/h. According to the definition of road classes George Blake, this is the road that has the Bergkelder level crossing in, is a class C road (the classification of roads can be found in Appendix G). Adam Tas road is a class B road, it is served by George Blake road.

At Bergkelder all the signs, markings and signals are tested every Thursday. If one of the warning devices has been damaged it is repaired within the same day as reported.

3.4 Modes of Control

Road traffic signs provided at railway crossings for the protection of users fall into two basic functional groups. The first being warning signs and markings comprising of advance warning signs, which may be varied according to the specific site circumstances, together with various hazard maker warning signs. The second is regulatory control signs, markings and signals for the control of vehicular traffic at crossings.

There is a formal classification of railway crossings set by the South African Road Traffic Signs Manual for the purpose of establishing the required level of signing protection and mode of control. This formal railway crossing classification is detailed in Table 4.

Bergkelder crossing has multiple low speed lines and is 15m wide. The visibility does not comply with specifications in Table 5, thus the sight distance is restricted. Therefore a class 4A/B is recommended with a possibility of an upgrade to a higher level 4C/D if the crossing has a bad accident history.

TABLE 4: RAILWAY CROSSING CLASSIFICATION

RAILWAY CROSSING CLASSIFICATION

Class (1)	Description	Sight Distance (2)	Minimum (3) Protection	Accident (4) Upgrade
SSH	Single Shunt	N/A	1	3B
MSH	Multiple Shunt	N/A	1	3B
SLS	Single ≤ 60km/h	Excellent	2A	4C
		Adequate	2A/3A	4C
		Restricted	4A	4C
MLS	Multiple ≤ 60km/h	Excellent	3A/3B	4C
		Adequate	3C	4C
		Restricted	4A/4B	4C/4D
SHS	Single ≥ 60km/h	Excellent	3A	4C
		Adequate	3C/3D	4D/5
		Restricted	4A/4B	4D/5
MHS	Multiple ≥ 60km/h	Excellent	3A	4D
		Adequate	3C/3D	4D/5
		Restricted	4C/4D	5

NOTE:

(1) The railway crossing class designations are abbreviations of the broader class descriptions as follows:

SSH = single shunt line
MSH = multiple shunt lines
SLS = single low speed line
MLS = multiple low speed lines
SHS = single high speed line
MHS = multiple high speed lines

(Brain, 1999)

TABLE 5: VISIBILITY DISTANCE ALONG RAIL LINE FOR STOP CONTROL

VISIBILITY DISTANCE ALONG RAIL LINE FOR STOP CONTROL

Train Speed (km/h)	X(m)	S(m)	
		7,5m	15m
120	5	460	500
100	5	385	420
80	5	310	335
60	5	230	250

NOTE:

(1) Distance X(m) is the distance from the near side of the crossing from which drivers must be able to see distance S(m) along the rail line
(2) S(m) is the sight distance for drivers of single unit trucks and trailers for 7,5 m and 15 m wide crossings.
(3) These conditions also apply for drivers who have stopped at a YIELD sign R2.

(Brain, 1999)

The protection classification can be found in Table 6. These signs and markings can be found in Appendix C. Furthermore, the train driver is required to give sufficient warning to users of the roadway of its intent to cross the roadway. This warning is normally given by a whistle or hooter or other sound device. Bergkelder's whistle boards are located 500m- and the next at 100m from the level crossing.

TABLE 6: PROTECTION CLASSIFICATION

PROTECTION CLASSIFICATION

Class	Sub-class	Mode of Control (1)	Advance Warning		
			Level 1	Level 2	Level 3
1		Flagsman (SS2)	–	–	–
2		Locked gates	–	–	–
	A	YIELD R2	W318	–	–
	B	YIELD R2	W318 + WM1	–	–
	C	YIELD R2	W318 + WM1	WM5	–
3	A	STOP R1	W318 + WM1	–	–
	B	STOP R1	W318 + WM1	GM7(2)	–
	C	STOP R1	W318 + WM1	W302 + GM7	–
	D	STOP R1	W318 + WM1	W302 + GM7	Flashing Light SS3(3)
4	A	2 x FRD + STOP R1	W318 + WM1	–	–
	B	2 x FRD + STOP R1	W318 + WM1	GM7	–
	C	2 x FRD + STOP R1	W318 + WM1	W302 + GM7	–
	D	2 x FRD + STOP R1	W318 + WM1	W302 + GM7	Flashing Light SS3
5		2 x FRD + STOP R1 plus BOOM	W318 + WM1	W302 + GM7	Flashing Light SS3

NOTE:

(1) All modes of control to be supported by the appropriate RAILWAY CROSSING hazard marker sign W403 or W404.

(2) GM7 WORD MESSAGE "STOP AHEAD".

(3) Flashing warning light signal SS3 is a yellow flashing warning light (or several) used in conjunction with an advance warning sign

(4) **At high frequency accident locations additional measures such as site specific advance warning signs, HIGH VISIBILITY signs or RUMBLE STRIPS may be warranted.**

(Brain, 1999)

3.5 Signing Applications for Urban Situations

Since the potential for train-vehicle collisions is somewhat greater at urban crossings than at rural crossings, the level of signing at main line urban crossings should commonly include the signs classified as optional for rural crossings, thus Bergkelder crossing should have class 4C/D protection. This type of protection can also be found in

Table 6 as the Mode of Control. The appropriate road signs and markings can be found in Appendix C.

The choice or the method of control for an urban railway crossing will be dictated by a combination of three factors. Firstly, what are the road traffic volumes, secondly what the road to rail visibility is and lastly, what is the frequency and speed of train traffic?

It is likely that urban railway crossings will operate with significantly lower train and vehicle approach speeds than rural crossings, but on the other hand they are likely to have higher road and rail traffic volumes. The result is that a large percentage of mainline railway crossings in urban areas require flashing red disc signals and a stop sign R1 control, see Appendix C.

Bergkelder crossing falls under urban crossing of parallel railway lines, see Appendix D. This is a particularly difficult urban situation to sign with clarity. The railway lines are commonly very close to the parallel road, so that very little warning can be given on one of the crossing road approaches if the presence of the lines is not obvious from the parallel road. Special attention must therefore be given to the need for optional signing.

The method of traffic control must conform to the normal requirements, in Bergkelder's case is a stop sign R1 and a flashing red disc signal. It occurs on a class C road (George Blake road, see Appendix G for road class definitions) parallel to a class B road (Adam Tas road). The class of the level crossing is a MLS (Multiple Low Speed lines). The level of protection is a class 4C, in addition a half width boom has been added due to the really bad visibility conditions and is not a regular form of railway crossing control.

When parallel road and rail lines are close together it may be advisable to provide a specially designed illustrative sign to inform drivers of the level crossing. The Adam Tas junction turn off has a traffic light which helps regulate the traffic. When a train is approaching the traffic lights regulate the approaching traffic from Adam Tas towards Plankenbrug to stop.

3.6 Conclusion

The signages at Bergkelder level crossing comply with those specifications given by South African Road Traffic Signs Manual (Brain, 1999), see Appendix D for all Bergkelder's warning devices and signs. Inadequate signage is thus not a factor when it comes to collisions. Still, there are collisions and numerous of near misses that occur here. A case study needs to be done to confirm this. Newspaper articles have to be observed of the collision that took place in 2009 to get information on it.

4. Phase 3: Case Study

4.1 Introduction

This chapter discusses the last fatal accident that occurred at the Bergkelder level crossing to further investigate causes of an actual collision. This case study will reveal why typical collisions occur. On 9 October 2009 there was a fatal accident at the Bergkelder level crossing. The following article reveals the details.

4.2 Collision Details

Excerpt from an article published in Die Burger on 10 September 2009.

The motorist who died at the level crossing on 09-09-09 at 09:20 drove that particular road daily. Mark Hartzenberg, 43, and passenger Mthunzi Maxiniva, 32, died when their bakkie was hit by a train on the outskirts of Stellenbosch. The bakkie was dragged for 476m.

FIGURE 16: TRAIN CRASH AT BERGKELDER

(Gerber, 2009)

A co-worker of the deceased said that he could not understand how the accident could have happened, as Hartzenberg knew the road well. A bystander saw one of the men moving in the bakkie. The other man was unconscious. The police was called almost immediately.

Emergency rescue personnel, fire-fighters, police and traffic officers as well as Metrorail employees also arrived. Hartzenberg and Maxiniva both died on the scene. The force of the collision tore the cabin of the white Isuzu bakkie apart. "The deceased had to be cut from the vehicle," said ER24 spokesperson Tristan Wadeley.

The train was travelling from Muldersvlei to Cape Town. No passengers were injured but the railway line was closed for several hours, said Metrorail spokesperson, Riana Scott. The railway line was reopened at 12:43.

According to Riana all 34 railway crossings in the area met the necessary requirements. There were warning signs and flashing lights at each of the crossings.

The train driver and a train guard were treated for shock. Stellenbosch police spokesperson, Captain René Matthee said a case of culpable homicide was being investigated but was found not guilty according to Mr. James Denton (Gerber, 2009).

The following articles backup the previous article “Two die in level crossing accident” (Gerbi, 2009) and “Union urges action at dangerous level crossings” (Gerbi, Union urges action at dangerous level crosings, 2009).

It seems to be common knowledge that drivers can be held accountable for most accidents. “Most crashes involved cars, four-wheel drives, vans and utilities and a study shows that the driver's failure to take sufficient care or action was the major cause.“ (www.arrivealive.co.za).

Metrorail are doing a lot to try and prevent accidents on level crossings. Riana Scott, head of Marketing & Communication at Metrorail Western Cape Region, said that the signals are checked every week to make sure they work properly. “There are regular safety campaigns to raise awareness so that our commuters and stakeholders can know the dangers involved.” Scott added that Metrorail is working closely with the law enforcement agency to increasingly clamp down on motorists who disobey the law. Offenders will be fined (Snyders, 2009).

Near misses and booms being damaged have happened a lot since 2000. The hot spots are Military Road crossing, Butskop Road crossing, Bergkelder crossing and Vlaeberg Road according to Scott (Snyders, 2009).

4.3 Conclusion

According to Riana Scott, Bergkelder level crossing met the necessary requirements during that time and currently does as well as determined in the previous chapter. According to Arrive Alive, “the driver's failure to take sufficient care or action was the major cause” of collisions occurring at level crossings.

Accidents still happen even though adequate warning devices and signage are installed. The fact that there are sufficient warning systems points to driver ignorance or it could point to lack of knowledge. Driver ignorance cannot be determined, but lack of knowledge can be tested by doing a survey test. This is covered in the next phase.

5. Phase 4: Survey

5.1 Literature Review

5.1.1 Establishing the Aims of Your Research

Establishing the aims of your research is the single most important step in a survey study, every single element of the survey must refer back to the design, otherwise the output of the survey will be weak (Shuttleworth, 2008).

5.1.2 Researching and Determining Your Sample Group

This is the next crucial step is ensuring accuracy in the survey. The success of the research is dependent on the representativeness of the population of concern, since survey research is always based on a sample of the population (www .wikipedia.org). Quantity is not the best way to achieve accuracy, rather focus on a covering all the representatives of a population (Shuttleworth, 2008).

5.1.3 Structuring and Designing the Questionnaire

The design of the questionnaire depends upon the type of survey and the target audience. The questionnaire must be kept as short as possible; people will either refuse to fill in a long questionnaire or get bored or distracted halfway through. If the survey does have lots of information then it may be preferable to offer multiple-choice or rating questions (Shuttleworth, 2008).

5.1.4 Rules for Writing Good Survey

There are a few simple rules that should be followed when designing a survey (Dillman, 1978).

- Rule 1: Use correct spelling, punctuation and grammar style.
- Rule 2: Use specific questions

- Rule 3: Use a short introduction to question behaviours. In this way you cannot only refresh the memory of the respondent, but also explain what you mean with the concept you are using.
- Rule 4: Avoid the use of technical terms and jargon.
- Rule 5: Avoid questions that do not have a single answer.
- Rule 6: Avoid negative phrasing. This could lead to confusion.
- Rule 7: Avoid words and expressions with multiple-meanings, like any and just.
- Rule 8: Avoid stereotyping, offensive and emotionally loaded language.

5.1.5 Response Formats

Usually, a survey consists of a number of questions that the respondent has to answer in a set format. A distinction is made between open-ended and closed-ended questions. An open-ended question asks the respondent to formulate his own answer, whereas a closed-ended question has the respondent pick an answer from a given number of options. The response options for a closed-ended question should be exhaustive and mutually exclusive. Four types of response scales for closed-ended questions are distinguished:

- Dichotomous, where the respondent has two options (e.g. true or false)
- Nominal-polytomous, where the respondent has more than two unordered options
- Ordinal-polytomous, where the respondent has more than two ordered options
- Continuous, where the respondent is presented with a continuous scale

A respondent's answer to an open-ended question can be coded into a response scale afterwards, or analysed using more qualitative methods (www.wikipedia.org).

5.2 Introduction

South Africa's traffic department expects licence holders to study traffic signs and rules when doing their learners licence. For most people this test was taken when they were 17 years old. This is a long time ago for many road users.

A survey is a good way to test people's knowledge. This test will determine whether road users understand road signs and rules when it comes to level crossings. If their knowledge is bad, it could indicate why drivers are responsible for accidents despite good signage practise.

South African's different educations have been left out to simplify the study. It is assumed that all South African's with a drivers licence studied the same K53 (McDonald, 1999) book when obtaining their licence.

5.3 Setup of Survey

A short survey was developed to determine road user's knowledge of road signs and rules when it comes to level crossings. The population is identified as all South Africans with a valid driver's licence. It is important to select an appropriate sample that represents the population. Because this study focuses on people's knowledge on road signage it is important to cover people of all age groups. Furthermore, people of different genders and races should also be tested to ensure all the different variables are covered for an accurate representation of the population.

The survey is very short, but it covers all the basics of traffic rules and signs for level crossings. Keeping it short is a tactic to keep people focussed, it is short enough to keep people interested. The questions are ordered in a specific way, they flow logically from one to the next. It consists of open-ended and one closed-ended question.

Open-ended questions are harder to evaluate, but is necessary for testing people's level of knowledge. Multiple-choice questions sometimes guide people in the right direction. The purpose of this study is to determine whether people are informed on what to do when entering a level crossing. Closed-ended questions could cause this study to defeat its purpose. Only one question consists of four close-ended sub questions, because it cannot be asked in a different way.

A respondent's answer to an open-ended question is coded into a response scale afterwards. It is done in this way:

1 → No idea
2 → Some knowledge
3 → Fully understand

The close-ended question is also evaluated on this scale. The question consists of 4 multiple-choice questions. If zero or only one or two are correct, a score of 1 is awarded. If three are correct a score of 2 is awarded and if the person got all four correct then only a score of 3 is awarded.

There is one question that consists of two parts. If zero or only one of these questions is answered correctly a score of 1 is awarded. This might seem harsh, but if only half of this sign is understood then the person has no idea really. Only when a person answers both correctly is a score of 3 awarded.

5.4 Distribution of Surveys

Before handing out the survey to a sample of people, it first needs to go through a test run of about 5 people. This step makes sure that the desired results are achieved. The survey is modified after each test run until no more misinterpretations are encountered. The survey is then handed out to a sample of 50 people with valid driver's licenses. These people should be of different nationalities, ages and genders. The survey form can be found in Appendix F.

Table 7 shows the different properties of the sample. The sample is not a 100% correct representation of South Africa's population, but it is an acceptable representation of the population, all the different properties such as population group, gender and age is accounted for.

TABLE 7: THE SAMPLE PROPERTIES COVERED IN THE SURVEY

Sample Properties					
Age	Number of people	Population Group	Number of people	Gender	Number of people
18-30	11	White	20	Male	23
30-40	10	Coloured	16	Female	22
40-50	12	Black	8		
50-60	7	Other	1		
60-70	2				
70->	2				

5.5 Evaluating the Surveys

Finally, the scores are awarded by marking the answers according to the South African Road Traffic Signs Manual (Brain, 1999), the K53 (McDonald, 1999) book and the explanation of Metrorail Marketing and Communication Manager Riana Scott found in Die Burger 22 July 2009 that follows.

“Even though the booms are up which indicates no train is approaching, the driver still needs to stop at the stop street. After they have stopped at the stop street they can continue driving. If a motorist approaches the level crossing and the signals are flashing, it means a train is approaching from either side. The signals flash for ten seconds before the booms go down. This is a safety precaution for motorists.

A motorist must stop when the signals are flashing, even though you don’t see a train coming along. The reason for the flashing signals and the booms being lowered in advance is because it takes 500m for a train to come to a complete stop. This is why so much warning is given.” (Snyders, 2009).

5.6 Analysing the Survey

The histogram in Figure 17 represents the sample of the population’s knowledge of traffic rules and signs when it comes to level crossings. It should be noted that the minimum score is 7 and the maximum score is 21.

The average score of the sample is 48%. This means that on average people only know 48% of level crossing rules and signage. This implies that people do not know what to do at a level crossing 52% of the time. This indicates that that the South African driver education system is flawed.

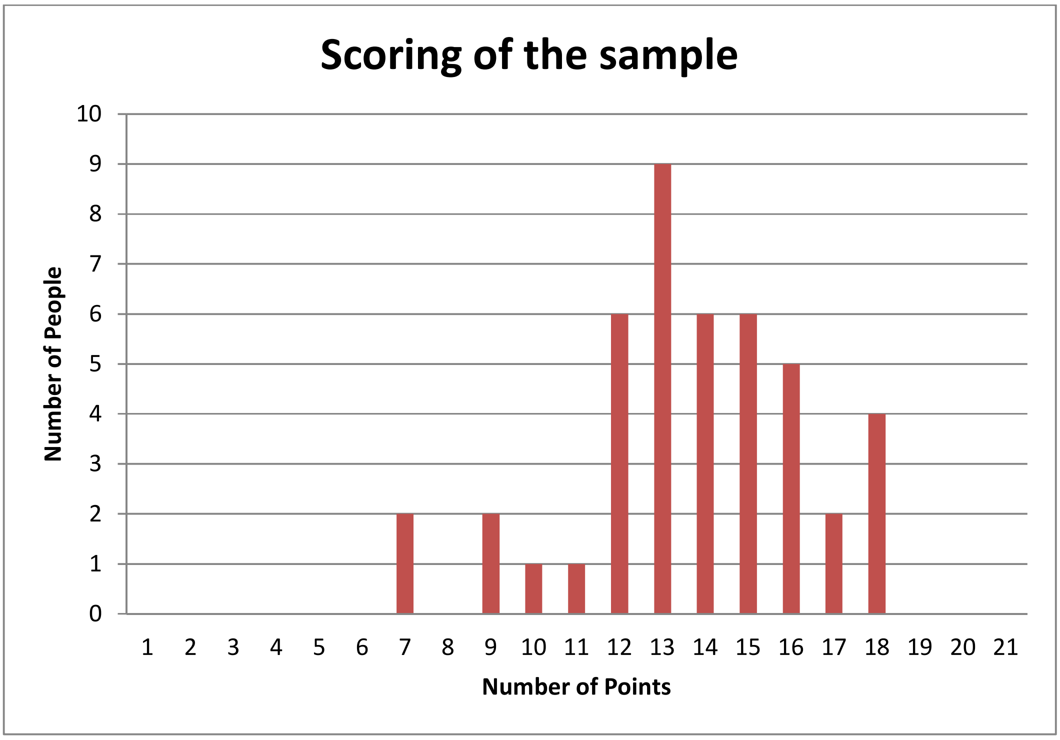


FIGURE 17: THE RESULTS OF THE SURVEY BY THE SAMPLE OF PEOPLE

By doing correlation calculations it was found that, interestingly enough, age or the year of obtaining a licence has no relation to people's knowledge on road signs or rules. The correlation calculation's results can be seen in Table 8. The assumption that people who have recently studied the road signs and rules will know more is discarded, the correlation coefficients prove this. The closer the coefficient is to 0 the less correlated it is. The correlation coefficient can be between -1 and 1.

TABLE 8: RESULTS OF CORRELATION CALCULATION ON SCORES

	Score
Year of obtaining licence:	0.1454
Age:	-0.1428

When looking closer, the problem can be broken up into subdivisions. Results obtained by the sample of the population can be observed of each individual sign. See Table 9 for these results. See Appendix F for each individual sign.

TABLE 9: INDIVIDUAL RESULTS OF DIFFERENT SIGNS

Sign	Result
1	48%
2	53%
3	72%
4	38%
5	16%
6	31%
7	78%

It is clear from Table 9 that the railway related signs (4, 5 and 6) are not understood.

5.7 Evaluating the K53

The K53 (McDonald, 1999) is the book that all people study when applying for a learners licence. This is the only knowledge South African drivers obtain when it comes to road signage and rules.

The K53 (McDonald, 1999) test is a based on what was done in the United Kingdom in the 1980's. It was published by the then National Road Safety Council. The K53 (McDonald, 1999) was later published as part of the Road Traffic Act Regulations. It was updated in 2005 and then in 2006 again (Fore Sight Publications).

Now the results from the survey will be evaluated in terms of its description in the K53 (McDonald, 1999). Sign 1, as defined in Table 9, is partially defined in the K53 (McDonald, 1999). This sign is a combination of warning signs and the arrow at the bottom of the sign is not explained in the K53 (McDonald, 1999). From the survey it was obvious that the arrow confused people, people only have 48% understanding of this sign.

Sign 2 is defined in the K53 (McDonald, 1999), but still only 53% of people know what this sign means. Sign 3 is well understood by 72% of people. It is a combination sign and is not explained in the K53 (McDonald, 1999).

Road marking 4 is not mentioned anywhere in the K53 (McDonald, 1999) and only 38% of respondents understood it. This is a troubling figure. On the other hand only 16% is understood sign 5, but it is well defined in the K53 (McDonald, 1999).

Sign 6 is a combination sign, this combination is not explained in the K53 (McDonald, 1999). This combination sign has an additional flashing lighting feature. Nowhere in the K53 (McDonald, 1999) do they mention or explain what flashing lights indicate.

The last question in the survey (see Appendix F) is of a boom system. Even though 78% of people know what should be done when a boom is encountered, it is not mentioned in the K53 (McDonald, 1999).

These results are troubling, because some signs, such as sign 2, are well defined by the K53 (McDonald, 1999) but people still do not know what it indicates. On the other hand there is the boom system that is not mentioned in the K53 (McDonald, 1999) but most people understand it. The logical conclusion why these signs are understood is due to them being rather self-explanatory. This is no way to educate people though. It should rather be assumed that people do not know anything and they should be taught from scratch.

5.8 Conclusion

After performing the survey test, it is safe to say that the K53 (McDonald, 1999) test is failing at educating people with regard to road signs and rules.

6. Phase 5: Conclusions & Recommendations

6.1 Conclusions

This study identified certain attributes that could increase the likelihood of a serious collision occurring, these attributes are day of the week, time of the day, road surface, vehicle type.

Adequate warning devices have been installed at the level crossing considered according to what seems to be good set of standards set by the Department of Transport. It was clear from this study that collisions occur despite this, due to drivers' lack of knowledge on how to act at a level crossing or just ignorance. A survey study identified that drivers lack knowledge on railway signs and markings. The lack of knowledge apparently has nothing to do with the age of the driver or how long ago the licence was obtained. The problem seems to lie with the educating process and the literature that goes with it.

Even though there are regular safety campaigns held by Metrorail and the Railway Regulator, it is not sufficient. In South Africa you have to first pass the K53 (McDonald, 1999) test before you can become a learner driver. It was found that the K53 (McDonald, 1999) test is out-dated and inadequate.

6.2 Recommendations

Driving is dangerous, thus you should take care when doing so for your own safety and for the safety of others. You cannot be expected to take care if you have not been properly educated.

The obvious thing to be done is to restructure South Africa's driver tests. A new more advanced test should be developed. Good education material should be provided as support.

However, the suggested solution is a costly and time consuming process. In the meantime, something else should be done for temporary relief. It is a well-known fact that all drivers understand a traffic light. Drivers obey the law of stopping at a red light even though the coast is clear to drive. The most practical proposed solution is to install traffic lights at level crossings. It should turn orange then red when a train is approaching. It is a simple yet effective solution to saving lives.

The reason why this has not been addressed is because there is a gap in South Africa's level crossing system. It is unclear who is responsible for the level crossing. There is an on-going dispute between the traffic department and rail operators such as Metrorail and Transnet on this topic and no-one wants to claim full responsibility.

6.3 Reflection

I have learned so much from this final year project. Not only did I learn about level crossing safety, but also on how to go about doing a study and writing a report. I really enjoyed the statistical part of this project. I wish I had more data to work with so more of the report could be on reworking and analysing more in-depth data. I learned that people do not like to help others if they do not gain something from it. The hardest part of my project was to gather data.

Doing this study was hard for me, but once I had my data and knew what I wanted to do with it the rest was easy and fast. In future I would plan better before choosing a topic. I believe that in future studies I perform I will research more efficiently and not struggle as much as I did this time round. I really do believe that doing a study for a specific company will be easier, because data will be more accessible.

I have always liked statistics, but after doing this project it made me realise that I can use it for something meaningful and that I would enjoy doing my Master's degree on something that is statistically related.

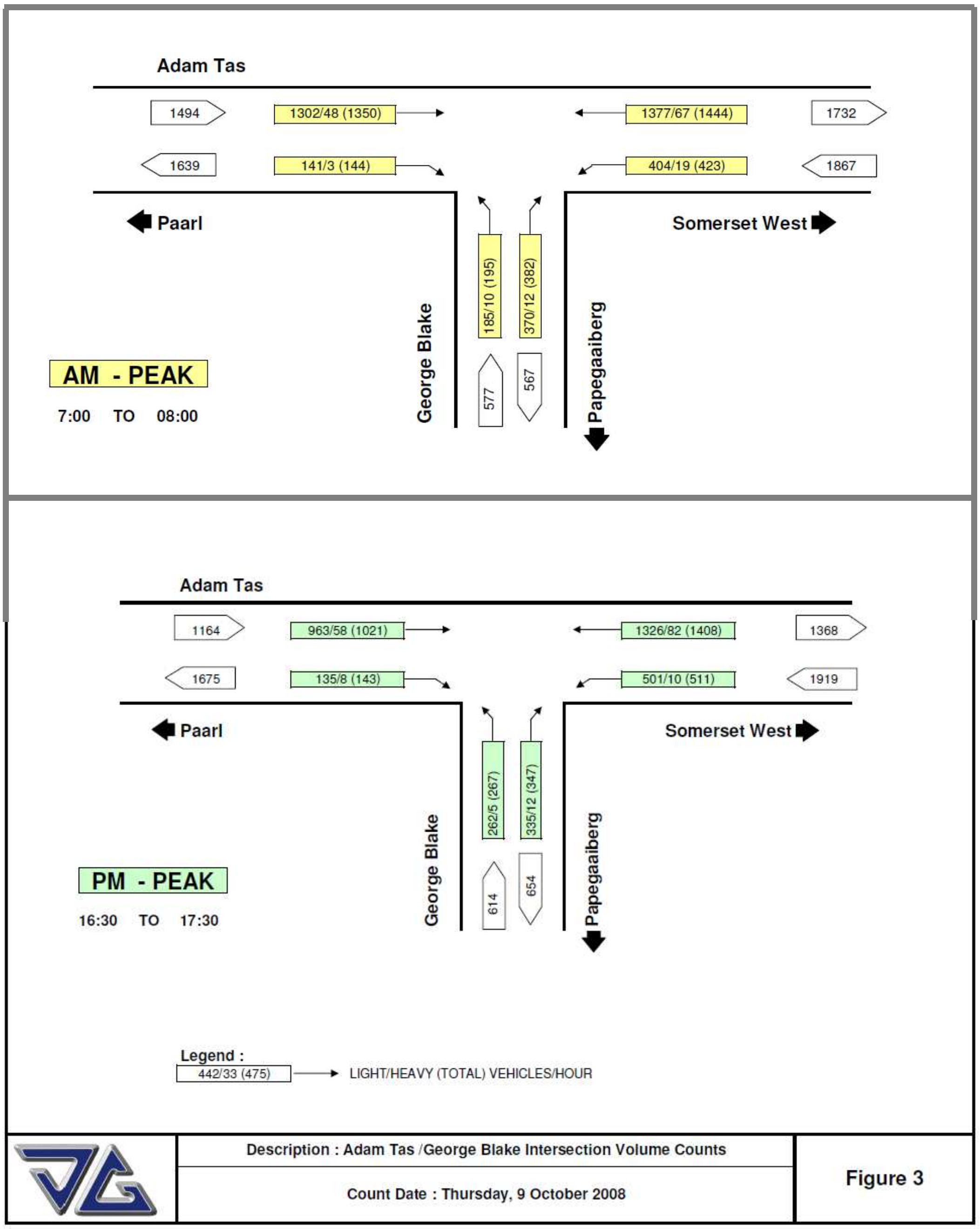
References

1. *Traffic Calming Policy.* (2005, December). Retrieved October 26, 2011, from Stellenbosch Municipality: www.stellenbosch.gov.za/jsp/util/document.jsp?id=722
2. *Rail Safety Core Issues*. (2007). Retrieved October 21, 2011, from Metrorail: http://www.metrorail.co.za/SafetyMore4.html
3. *Logisic Regression*. (2009, February 26). Retrieved September 05, 2011, from San Francisco State University: http://userwww.sfsu.edu/~efc/classes/biol710/logistic/logisticreg.htm
4. (2009). *State of Railway Safety In South Africa Annual Report 2008/2009.* Railway Safety Regulator.
5. (2010). *South African Railway State of Safety 2009/10.* Railway Safety Regulator.
6. International Level Crossing. (2011, March 11). *Newsflash*, p. 4.
7. (2011). *Railway Safety Regulator Annual Report 2010/2011.* Railway Safety Regulator.
8. *Standards*. (2011). Retrieved October 22, 2011, from Railway Safety Regulator: http://www.rsr.org.za/RSR/railway_safety_regulator_standards.php
9. Brain, D. (1999). *South African Road Traffic Signs Manual.* Pretoria: Department of Transport.
10. Dillman, D. (1978). *Mail and Telephone Surveys: The total design method.* Wiley.
11. *Fore Sight Publications*. (n.d.). Retrieved October 14, 2011, from Driving test (K53): http://www.foresightpublications.co.za/Drivtest.html
12. Gerber, J. (2009, September 10). *Shock over train crash deaths*. Retrieved 09 11, 2011, from News24: http://www.news24.com/SouthAfrica/News/Shock-over-train-crash-deaths-20090910
13. Gerbi, G. (2009, 09 09). *Two die in level crossing accident*. Retrieved 09 11, 2011, from Eye Witness News: http://www.ewn.co.za/Story.aspx?Id=21598
14. Gerbi, G. (2009, 09 10). *Union urges action at dangerous level crosings*. Retrieved 09 11, 2011, from Eye Witness News: http://www.ewn.co.za/articleprog.aspx?id=21663
15. McDonald, K. (1999). *K53 Learner's & Driver's Manual.* Cape Town: Lighthouse Publishing.
16. *Road Safety and Rail Crossings/ Level Crossings*. (n.d.). Retrieved April 11, 2011, from Arrive Alive: http://arrivealive.co.za/pages.aspx?i=2863

17. Savage, I. (2006). Does Public Education Improve Rail-Highway Crossing Safety? In *Accident Analysis and Prevention* (pp. 310-316). Evanston, USA: Elsevier.
18. Shuttleworth, M. (2008). *Survey Research Design*. Retrieved September 05, 2011, from Experiment Resources: http://www.experiment-resources.com/survey-research-design.html#ixzz1ZfFEyx4b
19. Snyders, L. (2009, 07 22). *Be wary at crossings*. Retrieved 09 23, 2011, from Die Burger: http://152.111.1.87/argief/berigte/dieburger/2009/07/22/BTBT/1/btlevel.html
20. *Statistical Survey*. (n.d.). Retrieved September 05, 2011, from Wikipedia: http://en.wikipedia.org/wiki/Statistical_survey
21. *Survey Methodology*. (n.d.). Retrieved September 05, 2011, from Wikipedia: http://en.wikipedia.org/wiki/Survey_methodology
22. Zalinger, D. A. (1977). Calculation of hazard indices for highway-railway crossings in Canada. *Accident Analysis & Provention, Volume 9*, 257-273.

Appendix : Stellenbosch Roadmap

Appendix : Traffic Count at Bergkelder Level Crossing at Peak Hours



Appendix : Road Signs and Markings

R2 YIELD sign
Ref:Vol1-2.2.10 Vol4-2.2.5

R1 STOP sign
Ref:Vol1-2.2.1 Vol4-2.2.1

R1 STOP Sign + FLASHING
RED DISC Signal

Slow Down

Stop

Proceed

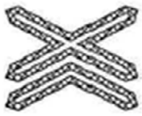
SS2 FLAG signals
Ref:Vol1-6.7.3

W318 RAILWAY CROSSING
Ref:Vol1-3.4.14

W314 GATE
Ref:Vol1-3.4.12 Vol4-3.4.14

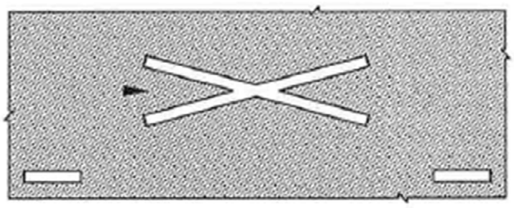
W361 ELECTRICAL SHOCK
Ref:Vol1-3.4.27 Vol4-3.4.61

ONE LINE



TWO OR MORE LINES

W403 RAILWAY CROSSING W404
Ref:Vol1-3.5.3 Vol4-3.5.2



WM1 RAILWAY CROSSING AHEAD
Ref:Vol1-7.3.1 Vol4-12.4.7

► = direction of travel
of road traffic

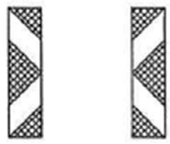
R2/W403 Combination

R1/W404 Combination

R1/FRD/W403 Combination

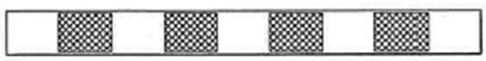
W202-W211

W302 + 1N11.3

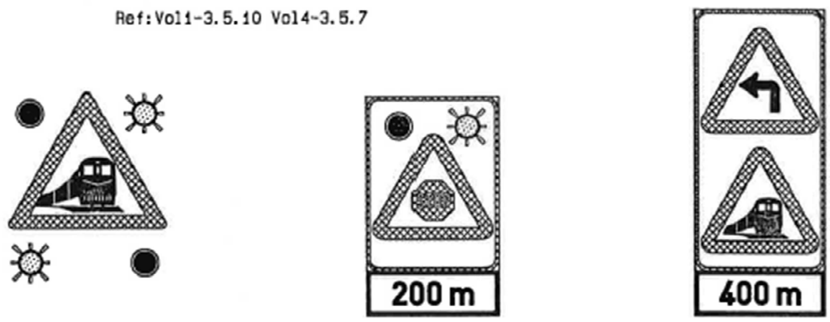


W401 W402

DANGER PLATES



W411 RAILWAY CROSSING BOOM BARRICADE
Ref:Vol1-3.5.10 Vol4-3.5.7



HIGH VISIBILITY AND/OR FLASHING YELLOW WARNING LIGHTS SS3

GD9

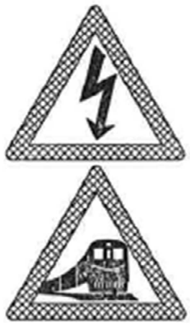
W320

R204

WW7

W361+IN11.4

W361+IN11.4



W318+W361

NOTE:
Sign WW7 is an SABS warning class sign

W404+IN11.4

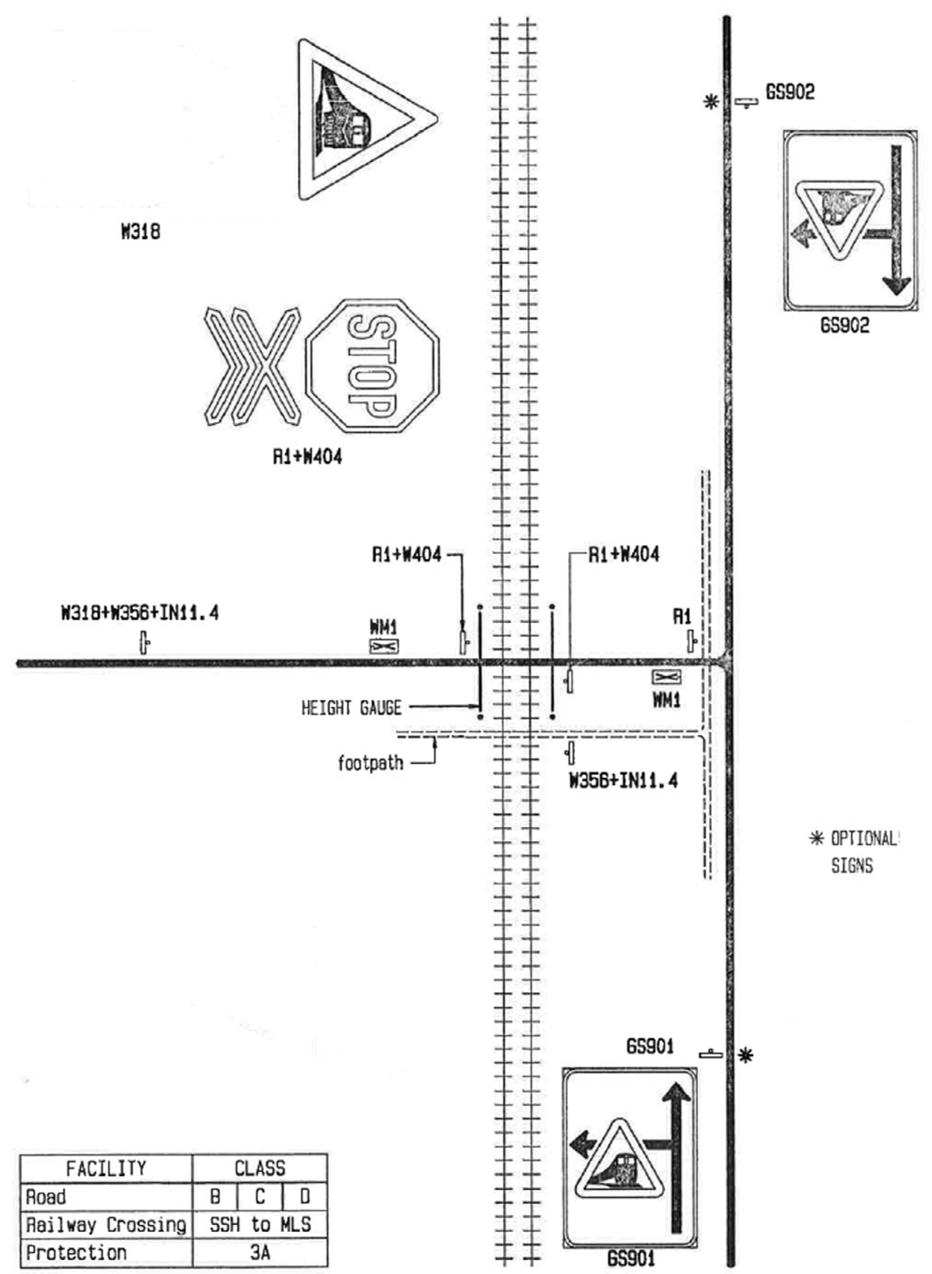
GS901

RR2/WR3+IN11.4

NOTE:
Signs RR2/WR3 are not road traffic signs but are used on railway property.

Appendix : Crossing of Parallel Railway Lines

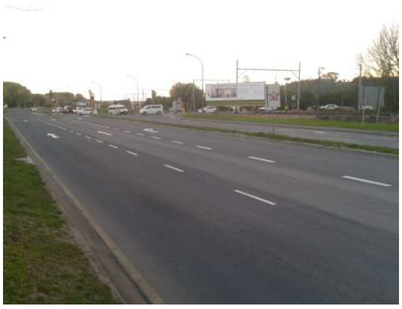
URBAN



FACILITY	CLASS		
Road	B	C	D
Railway Crossing	SSH to MLS		
Protection	3A		

Urban Crossing of Parallel Railway Lines

Appendix : Photos of Bergkelder Crossing



Appendix : Survey

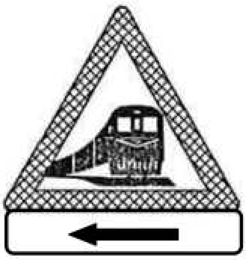
Road Traffic Signs

Please fill in this form as honest as possible, do not change answers once they have been written down.

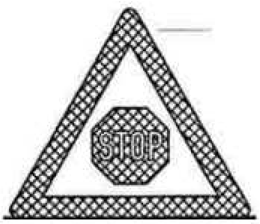
Age :	Year of obtaining licence:		☐ Female	☐ Male
Population Group:	☐ White	☐ Black	☐ Coloured	☐ Other

The term **level crossing** is a crossing on one level— without the alternative of a bridge or tunnel — of a railway line by a road, path, or another railroad.

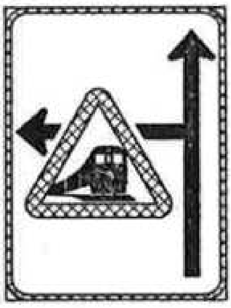
Look at the following signs and complete the related questions.



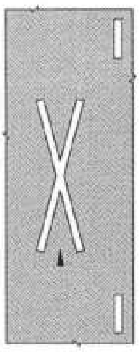
This sign is encountered on the side of a road; ahead the road bends to the left (like in the above picture). What does this sign indicate?



What does this sign indicate when encountered on the side road?

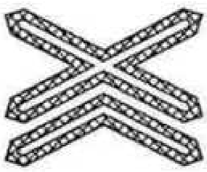


This sign is encountered on the side of a road; there is a turn-off to the left in the road. What does this sign indicate?

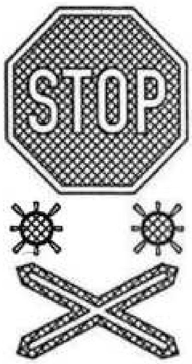


What does this marking on the road indicate? The black arrow indicates the direction of traffic.

What does this sign indicate when erected at a level crossing?



What should be done when this sign is encountered at a level crossing when the lights are flashing?



What should be done when the lights are off and not flashing?

Observe the following picture of a level crossing. The rest of the questions refer to it.

1. If the boom is in this position (up), and the lights are not flashing (lights are off), what should you do (scenario in the picture)?
   - ☐ Drive, because there are no trains
   - ☐ Stop, and check for trains, then drive

2. If the boom is in this position (up), but the lights are starting to flash, what should you do?
   - ☐ Stop then drive, because the boom is up
   - ☐ Drive faster, because a train is on its way
   - ☐ Stop, because a train is on its way
   - ☐ Drive, the system is most likely malfunctioning.

3. If the boom is starting to close, and there is no train insight, what should you do?
   - ☐ Drive faster to make it across
   - ☐ Stop and wait for it to lift
4. If the boom is down, and no train is in sight, what should be done?
   - ☐ Drive around it, it is wasting your time
   - ☐ Stop and wait for it to lift

Appendix G: Class Definition of a Road

(Traffic Calming Policy, 2005)

1. CLASS A: Trunk Roads (National and Inter Regional Distributors)

(a) Freeways, expressways, dual carriageways and dual single carriageway main roads.

(b) Generally rural.

(c) Facilitate regional mobility of traffic.

(d) Characterized by regional route continuity.

(e) Defined as Freeways, National or Provincial Roads

Examples: N1, N3, and Provincial Roads.

2. CLASS B: Primary Distributors or Major Arterials

(a) Form part of primary road network in urban areas.

(b) Facilitate long distance traffic mobility within the city.

(c) Characterized by high traffic volumes, limited access and fairly high speeds.

(d) Characterized by urban route continuity.

(e) Defined as Major Arterials and Metropolitan Routes

3. CLASS C: District Distributors

(a) Links primary roads with residential areas or development nodes.

(b) Links residential areas with commercial and industrial work places.

(c) Characterized by high traffic volumes, limited access, moderate speeds and mobility.

(d) Public transport routes for buses and taxis.

(e) Serve in excess of 400 equivalent dwelling units (EDU’s).

(f) Distribute traffic to and from Class D and E Roads.

(g) Provide access to community facilities (sport fields, entertainment centre, etc.).

(h) Characterized by local route continuity.

(i) Defined as Minor Arterials or Major Collectors.

4. CLASS D: Local Distributors

(a) Link Class C and Class E Roads.

(b) Characterized by low traffic volumes, low speeds and high accessibility.

(c) Serve less than 400 equivalent dwelling units (EDU's)

(d) Distribute traffic to and from Class E Roads.

(e) Characterized by not having route continuity.

(f) Defined as Minor Collectors

5. CLASS E: Residential Access Roads (Lightly Trafficked Roads)

(a) Provide direct access to properties.

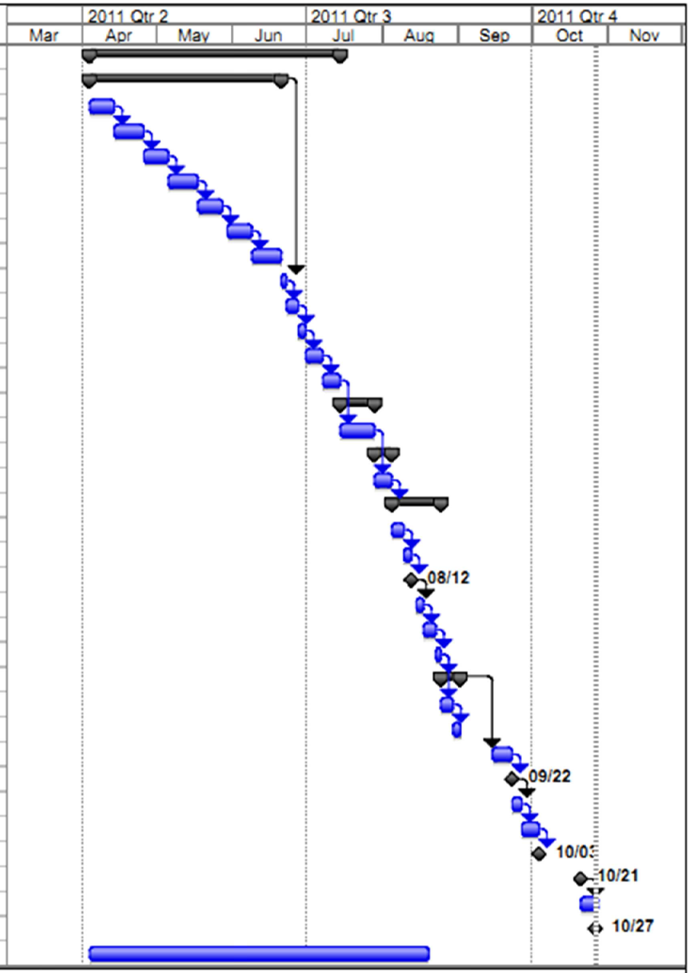
(b) Provide for other non-vehicle-related uses (running, cycling, walking, etc).

(c) Serve less than 200 equivalent dwelling units (EDU's).

(d) Defined as local Streets

Appendix H: Project Plan

ID		Task Name	Duration	Start	Finish	Predecessors
1		**Phase 1**	**74 days**	**Mon 11/04/04**	**Thu 11/07/14**	
2		**Gather data**	**56 days**	**Mon 11/04/04**	**Mon 11/06/20**	
3		Contact Traffic Departments	8 days	Mon 11/04/04	Wed 11/04/13	
4		Contact Transnet	8 days	Thu 11/04/14	Mon 11/04/25	3
5		Contact Metrorail	8 days	Tue 11/04/26	Thu 11/05/05	4
6		Contact Police	8 days	Fri 11/05/06	Tue 11/05/17	5
7		Contact Railway Police	8 days	Wed 11/05/18	Fri 11/05/27	6
8		Contact RTMC	8 days	Mon 11/05/30	Wed 11/06/08	7
9		Contact Municipality	8 days	Thu 11/06/09	Mon 11/06/20	8
10		Data cleaning	2 days	Tue 11/06/21	Wed 11/06/22	2
11		Pareto analysis	3 days	Thu 11/06/23	Mon 11/06/27	10
12		Correlation calculations	3 days	Tue 11/06/28	Thu 11/06/30	11
13		Regression study	5 days	Fri 11/07/01	Thu 11/07/07	12
14		Analyse	5 days	Fri 11/07/08	Thu 11/07/14	13
15		**Phase 2**	**10 days**	**Fri 11/07/15**	**Thu 11/07/28**	
16		Evaluate One Level Crossing	10 days	Fri 11/07/15	Thu 11/07/28	14
17		**Phase 3**	**5 days**	**Fri 11/07/29**	**Thu 11/08/04**	
18		Case Study	5 days	Fri 11/07/29	Thu 11/08/04	16
19		**Phase 4**	**14 days**	**Fri 11/08/05**	**Wed 11/08/24**	**18**
20		Setup Survey and Evaluation Method	3 days	Fri 11/08/05	Tue 11/08/09	
21		Test Run	3 days	Wed 11/08/10	Fri 11/08/12	20
22		Handout	0 days	Fri 11/08/12	Fri 11/08/12	21
23		Evaluate Surveys	3 days	Mon 11/08/15	Wed 11/08/17	22
24		Analyse	3 days	Thu 11/08/18	Mon 11/08/22	23
25		Evaluate Survey results against K53	2 days	Tue 11/08/23	Wed 11/08/24	24
26		**Phase 5**	**6 days**	**Thu 11/08/25**	**Thu 11/09/01**	**25**
27		Conclusions	3 days	Thu 11/08/25	Mon 11/08/29	25
28		Recommendations	3 days	Tue 11/08/30	Thu 11/09/01	27
29		Put everything together	6 days	Thu 11/09/15	Thu 11/09/22	26
30		Submit 99% draft	0 days	Thu 11/09/22	Thu 11/09/22	29
31		Wait for feedback	2 days	Fri 11/09/23	Mon 11/09/26	30
32		Work on 100% draft	5 days	Tue 11/09/27	Mon 11/10/03	31
33		Submit 100% draft	0 days	Mon 11/10/03	Mon 11/10/03	32
34		Receive Feedback from study leader	0 days	Fri 11/10/21	Fri 11/10/21	
35		Do final touches on skripsie	5 days	Fri 11/10/21	Thu 11/10/27	34
36		Submit skripsie	0 days	Thu 11/10/27	Thu 11/10/27	
37		Literature Study	100 days	Mon 11/04/04	Fri 11/08/19	



Project: Time Frame(10-06-2011).mpp
Date: Thu 11/10/27

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Page 1