Required Passing Sight Distance for Rural Roads: A Risk Analysis

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Abstract

A model describing the kinematics of vehicle trajectories during the passing (overtaking) manoeuvre on two-lane, two-way rural roads and highways was developed. This model was then used to determine the total required sight distance in terms of exogenous model parameters.

Using this model a risk assessment analysis was conducted using Monte Carlo computer simulation software and the results examined. These results provide insight into those parameters that influence the required sight distances more strongly than others. It is shown that the acceleration characteristics of the passer vehicle may not have a significant affect on required passing sight distance and that further research into the actual behaviour of drivers performing the passing manoeuvre may be required to develop appropriate required passing sight distance standards

Introduction

The provision of passing opportunities, passing lanes and no passing markings are very topical issues, as they can materially affect the efficiency and safety of highways. There are inconsistencies between countries in their required safe passing distance (Proudlove, 1990), with the Austroads (1989) guidelines in particular requiring very large sight distances in comparison with other countries. Most of the standards are also based on studies performed in the 1940s or very simplified mathematical procedures. the aim of this study was to identify the important parameters influencing the sight distance required for overtaking.

The passing model used here was largely based on the model of Lieberman (1982), who hypothesised that there exists a point in the passing manoeuvre that can be identified as a critical position, at which point the decision to complete the passing manoeuvre will provide the same factor of safety relative to the oncoming vehicle as will the decision to abort the manoeuvre. This hypothesis is compatible with the establishment and continuation sight distance concepts underlying the Austroads (1989) guidelines.

To understand how different variables affect the total passing sight distance, a risk assessment approach, involving using the risk analysis software @RISK, was adopted.

Study Method

The passing model considered only passing manoeuvres from a following position where the passing vehicle has the same initial speed as the impeding vehicle. The formulation of the model involved two expressions that which were subsequently combined to form an expression for total sight distance. One expression is a model for the passing and abort manoeuvres from the critical position to the completion of the manoeuvre, and allows for either the passing manoeuvre being aborted or completed, with the calculated distance representing the continuation sight distance. The second expression is a model for the distance required for the passing manoeuvre from its inception until the critical position is reached, with the distance representing the establishment sight distance.

There are a number of input variables in the combined model, and to ensure realistic results were obtained from the simulation it was endeavoured to find appropriate statistical distributions for each variable. Unfortunately though, there appears to have been little in the way of research into the actual characteristics of driver passing behaviour, and characteristics that apply in one country may not be particularly relevant to New Zealand conditions, while there are also differences in the definitions of the parts of the manoeuvre. Where distributions of the variables were unable to be obtained, or the information was incomplete, a significant amount of judgement was used in defining the distribution. This was done in part by altering the parameters and viewing the physical change in the distributions in @RISK. The resulting distributions that were used for each variable used are shown in Table 1.

Impeder vehicle speed Normal distribution, Mean: 84.1 km/hr, Std deviation: 8.59 km/hr, Truncated at 100.1 km/hr
Oncoming vehicle speed Normal distribution, Mean: 100.1 km/hr, Std deviation: 8.59 km/hr
Speed difference between passer and impeder vehicles Log-normal distribution, Mean: 26.9 km/hr, Std deviation: 6.78 km/hr
Abort deceleration Triangular distribution, Min: 3.2 m/s^2, Max: 4.2 m/s^2, Mode: 3.6 m/s^2
Distance between passer and impeder at completion of manoeuvre Lognormal distribution, Mean: 10 m, Std dev: 3 m, Truncated at 5 and 25 m
Length of impeder Lognormal distribution, Mean: 4.5 m, Std dev: 2 m, Truncated at 2 and 22 m
Perception-reaction time of passer Normal distribution, Mean: 2.5 s, Std dev: 1 s, Truncated at 0.5 and 4 s
Headway between passer and impeder at start of manoeuvre Normal distribution, Mean: 1 s, Std dev: 0.5 s, Truncated at 0.5 and 2 s.
Time between passer and oncoming vehicles at completion of manoeuvre Normal distribution, Mean: 2 s, Std dev: 1 s, Truncated at 0.5 and 4 s
Vehicle acceleration coefficient 'alpha' Normal distribution, Mean 3.6 m/s^2, Std dev: 0.45 m/s^2, Truncated at 2.0 and 4.9 m/s^2 This coefficient is the maximum acceleration at zero velocity. Acceleration was assumed to decrease linearly with speed. The slope of the relationship was estimated analysing maximum acceleration and speed data for a range of vehicles in use in NZ.
Acceleration reduction factor Normal distribution, Mean 70%, Std dev: 10%, Truncated at 50% and 100%. This factor allowed for drivers and vehicles not accelerating at their maximum rate. It was assumed to be correlated (correlation coefficient -0.7) with the vehicle acceleration coefficient 'alpha'.

Table 1: Passing Model Variables and Their Distributions

The passing model was constructed in a Microsoft Excel spreadsheet and, using @RISK and distributions for the model variables, a probability distribution for the required passing sight distance was derived. The @RISK program uses Monte Carlo simulation, which involves recalculating the required sight distance many times (10000 times for this study), each time taking a randomly selected value for each input variable based on the distribution assigned to the variable. Once the probability distribution for the required sight distance has been found, the likely mathematical form and parameter values can be found.

As well as producing the distribution for required sight distance through simulation, @RISK can also perform sensitivity analysis, where all other parameters are held constant while one parameter is varied, to determine the effect of each variable on the required sight distance.

Results

Figure 1 is a histogram of the required sight distance for the input distributions (Table 1). This sight distance distribution is approximately gamma distributed, with a mean of 707m, a standard deviation of 190m, and an 85%-ile of 903m (c.f. the Austroads 70%-ile values of 920m and 430m for establishment and continuation sight distances, respectively).

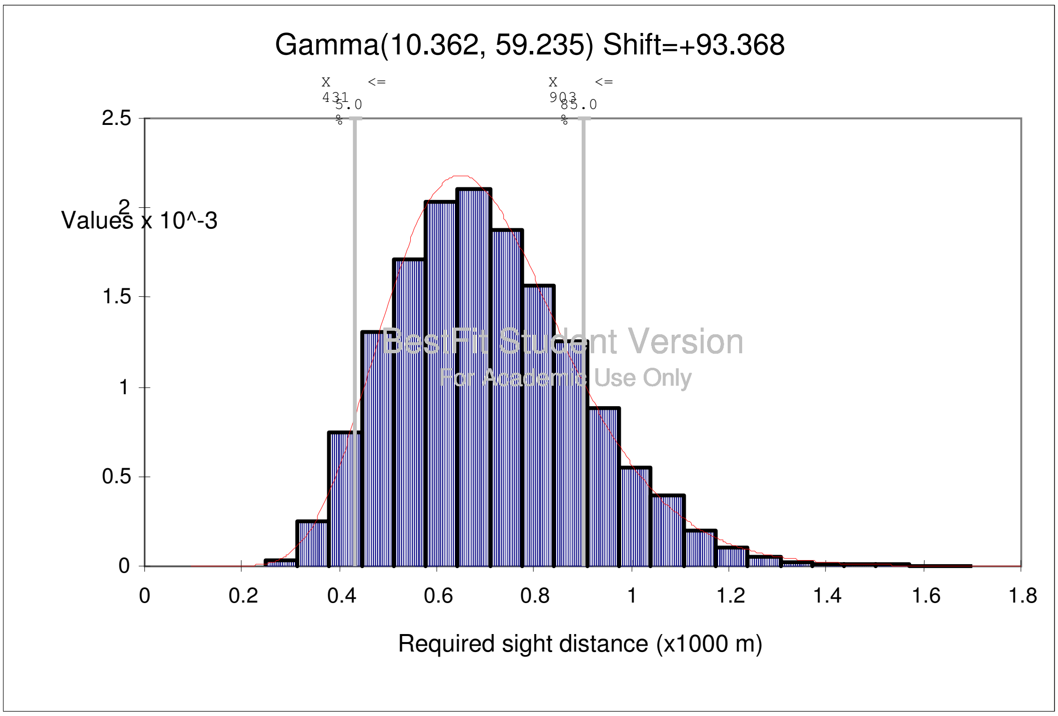

Figure 1: Histogram of Required Passing Sight Distance

Figure 2 shows the ranked correlation coefficients, calculated between the selected input variables and the distribution found for the required passing sight distance. The higher the correlation between the input variables and the required passing sight distance, the more significant the variable is in determining the value of the required passing sight distance.

Conclusion

The distribution (Figure 1) has a greater skew towards large required passing sight distances, as well as a wider range, than we would possibly expect. Assuming that the distributions in Table 1 are realistic, a likely contributing factor to this is the lack of correlations between the various variables in the analysis, with only the acceleration reduction coefficient and the acceleration coefficient being correlated. However, in reality there may be more correlations between variables, for example, the acceleration reduction factor might depend upon the initial headway.

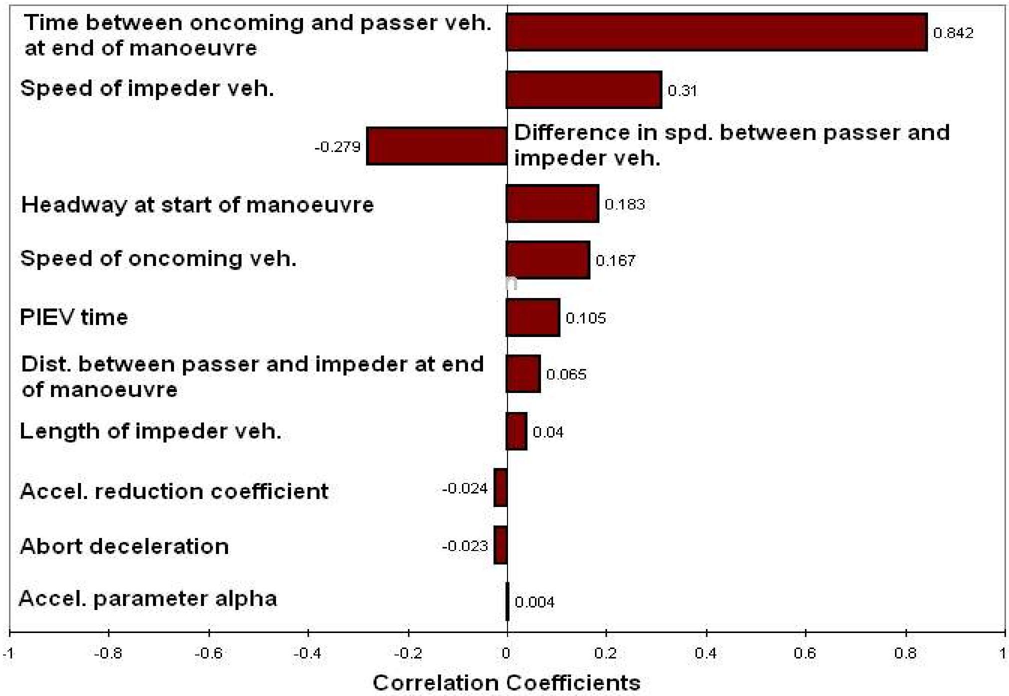

Figure 2: Tornado Graph of Correlations Between Variables and the Required Sight Distance

The tornado graph of correlation coefficients (Figure 2) shows some possibly unexpected results, in that some of the variables that have low correlation coefficients are related to the acceleration characteristics of the passing vehicle and the length of the impeding vehicle. These results however should be treated with a degree of caution, especially in the case of lengths of vehicles, as this variable was assigned a log normal distribution (Table 1), meaning a low probability of a vehicle having a length in the upper range, which may be inappropriate given the increasing frequency of long vehicles on our highways. Of interest is the fact that the allowable time between the oncoming and passing vehicles colliding at the end of the manoeuvre has the largest correlation coefficient. This variable was not included in a number of other models, but this analysis indicates it is important and therefore should not be ignored.

This analysis has shown that the current methods used by many roading authorities worldwide, with safe passing distances being determined by simplistic kinematic formulation and outdated studies, may be inappropriate, especially if those kinematic models use the mean values of variables. A more appropriate approach may be to identify the range of driver overtaking behaviour, and to determine the required overtaking sight distance of a suitable proportion (say 85%) of drivers. Clearly further investigation may be warranted.

References

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