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EVALUATING THE RISK OF SKIDDING FROM CONFLICT STUDIES

SUMMARY

Being situated near Equator, the island-republic of Singapore experiences hot climatic conditions with frequent spells of rain. These characteristics cause the road pavements to have alternating periods of dry and wet surfaces. To avoid skidding on the road pavements and the possibility of an accident, drivers normally maneouvre their vehicles with greater care while travelling on the wet pavements. They are often advised to drive with caution but it is difficult to determine specifically and quantitatively what is involved in "driving with caution".

This paper describes how traffic conflict studies can be used to examine the issue of skidding on the roadway and to apply the results to analyze the impact of wet pavements on road safety. To illustrate this, conflict data from an on-ramp merging into an expressway were used. The quantitative measure used to describe conflicts was the minimum deceleration required to avoid collision. For each pair of observed vehicles in the merging process, the value of this conflict measure was computed over a number of intervals so that a nearly continuous evaluation of the conflict measure was possible. The value corresponding to the most severe instant of conflict was regarded as a measure of the severity of the conflict in each merging encounter.

From the severity values determined, a mathematical distribution of conflict severity was then derived. With this it was possible to derive the probability of a near-collision once the threshold for near-collision was specified. The threshold chosen for the study was the limiting deceleration of vehicles just before skidding and this was assumed to follow a normal distribution.

The probability of near-collision is affected by the threshold distributed chosen. If the behaviour of drivers travelling on wet surfaces remains the same as on dry surfaces, then the increase in risk level on wet days can be evaluated. It is also possible to study the influence of changes in driver behaviour expressed in terms of reduction in speeds on the probability of near-collision.

1. INTRODUCTION

One of the major causes of accidents on the road is the low skid resistance of the pavement surface. A site with low skid resistance is particularly hazardous during wet-weather conditions. Although not all accidents occurring on wet roads result from skidding, there is evidence (WAMBOLD et al 1986) that the accident rates are higher during wet periods than dry periods.

This paper examines the risk of skidding, not from the point of view of accident occurrence but from the likely increase in traffic conflict potential. This approach requires a definition of conflict which is suitable for indicating the risk of skidding. Furthermore, the risk of skidding is evaluated in probabilistic terms based on a modelled distribution of conflict occurrence rather than direct measurement of conflict counts. The problem is considered for the case of merging traffic and in particular for an expressway situation.

2. DEFINITION OF CONFLICT

Consider a merging situation on the expressway in which a vehicle on the expressway is in potential conflict with a vehicle merging into the expressway from the on-ramp. Suppose that at a given time t, the offending (merging) vehicle is at position $x_m(t)$ downstream from the ramp nose of the expressway and the conflicted (expressway) vehicle is at position $x_e(t)$. If $x_m(t)$ is measured with reference to the rear bumper of the merging vehicle and $x_e(t)$ is measured with reference to the front bumper of the expressway vehicle, then there will be a clear spacing between the vehicles Δx which will vary with time during the entire period of merging interaction, i.e,

$$\Delta x(t) = x_m(t) - x_e(t)$$

No collision has occurred as long as $\Delta x(t)$ remains positive throughout the merging process.

Denote the speeds of the expressway and merging vehicles at this time as $v_e(t)$ and $v_m(t)$ respectively. Provided that $v_e(t) > v_m(t)$, there is a likelihood of a collision should the speed and path of the vehicles remain unchanged with time. Under such a condition the collision will occur after a time interval τ given by

$$\tau = \frac{\Delta x(t)}{v_e(t) - v_m(t)}$$

This time duration is also known as the time measured to collision or time to collision. However the collision can be avoided, if among other things, the expressway vehicle will reduce its speed to that of the merging vehicle within a time 2τ. This will require an average deceleration, α such that

$$\alpha = [v_e(t) - v_m(t)] \,/\, 2\tau$$

Therefore at any time t, the conflicted vehicle must apply a deceleration $\alpha(t)$ to avoid a collision if the offending merging vehicle does not alter its speed and if both vehicles remain in the same path of motion. Generalising this to include cases in which $v_e(t) \leq v_m(t)$ for which non-positive deceleration will result and when collisions are inadmissible, we may adopt a measure of conflict between the vehicles as the average deceleration to avoid collision which can be written as

$$\alpha(t) = \frac{|v_e(t) - v_m(t)|\,[v_e(t) - v_m(t)]}{2\,\Delta x(t)}$$

If one were to trace the vehicles throughout the entire duration of the merge, it is possible to obtain varying values of $\alpha(t)$ at different instants of the merging process. The series of values obtained are necessarily correlated. If a particular merging process constitute a conflict event, then we can define the severity of that conflict as the maximum recorded value of the average deceleration to avoid collision i.e.,

$$s = \max_{t \in T} \{\alpha(t)\}$$

where s is the severity of the conflict in the merge and T the duration of the merging process.

If sufficient samples of vehicle merging can be obtained, a distribution of s may be derived. Since the non-positive values of s are not important for the purpose of describing conflict severity, it may be sufficient to derive a distribution function $F_S(s)$ defined only in the positive domain of s.

Consider now the reaction of the driver of the following vehicle in the midst of a conflict. Should the driver respond, at the most critical instant of conflict as defined above, by decreasing his speed to avoid a collision, a minimum deceleration of s must be applied for at least the duration of the time to collision, τ. Skidding will occur if such a deceleration exceeds the limiting deceleration s^* governed by the coefficient of friction for braking μ_b between the pavement surface and the tyres, i.e.

$$s^* = \mu_b g$$

where g is the gravitational constant. It follows then that it is possible to interpret the risk of skidding as the probability of occurrence of conflicts at which s exceeds s^*.

The coefficient of braking friction depends on not only the conditions of the road surface but also the type and condition of the tyres of the vehicles. If μ_b follows a particular statistical distribution so that we may express the probability density function of s^* as $h(s^*)$, the risk of skidding can then be expressed as

$$p_s = (1 - p_0) \int_{s=0}^{\infty} (1 - F_s(s))\, h(s)\, ds$$

where p_0 is the probability in which $v_e(t) \leq v_m(t)$ for all t.

3. COLLECTION OF CONFLICT DATA

To understand the conflict behaviour of merging, traffic maneouvres at the merging area of the Paya Lebar on-ramp in Singapore were observed (see Figure 1).

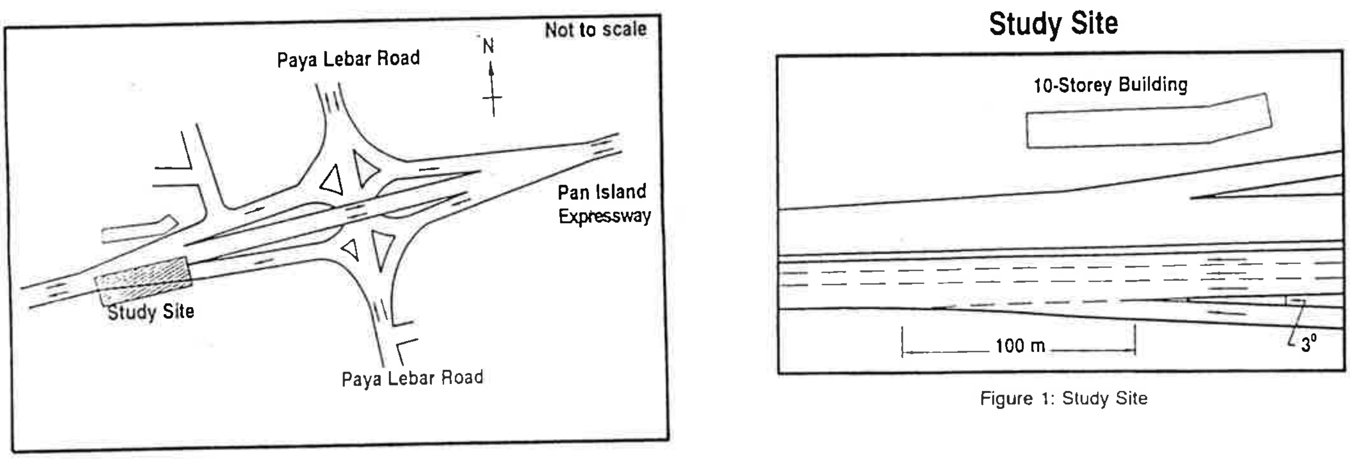

Figure 1: Study Site

The space-time information of vehicles on the on-ramp and the near-side lane of the expressway were obtained over eight separate periods corresponding to different flow conditions. This represents a total of about 1600 merging events. The process of data gathering and data extraction using video and computer equipment is described elsewhere (CHIN et al 1991). From the space-time data, the kinematics of the vehicles throughout the merging process were derived from which the average deceleration to avoid collision α at various instances of the merge is computed for each pair of vehicles involved. Figure 2 shows the variation of α throughout the merging area for some typical cases of merge. Notice that as in most cases observed, the most severe instant of conflict occurs in the beginning section of the merging area.

For each merge event, the maximum value of α, i.e., s is located and fitted to a theoretical distribution. The function for $F_s(s)$ that best fit the data was found to be the WEIBULL distribution, a maximal value function of the form

$$F_s(s) = 1 - e^{-(s/w)^k}$$

where k and w are the shape and scale factors. Using all the merge events observed, p_0 was found to be 0.2422 and the best fitted Weibull distribution has a shape and scale factor of 0.6286 and 0.1818 respectively (see Figure 3).

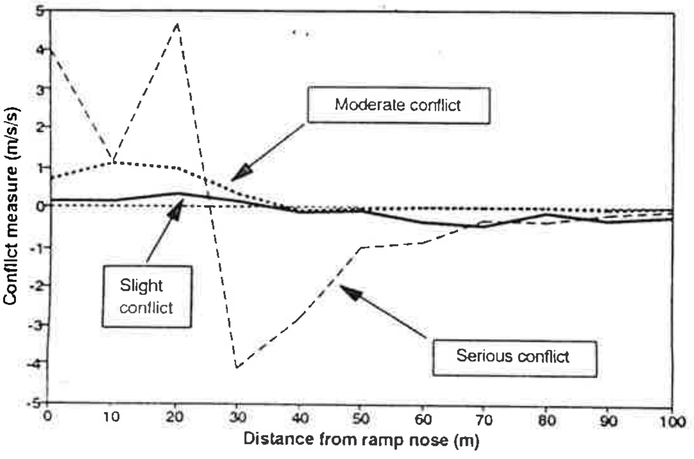

Figure 2: Variation of conflict (average deceleration to avoid collision)

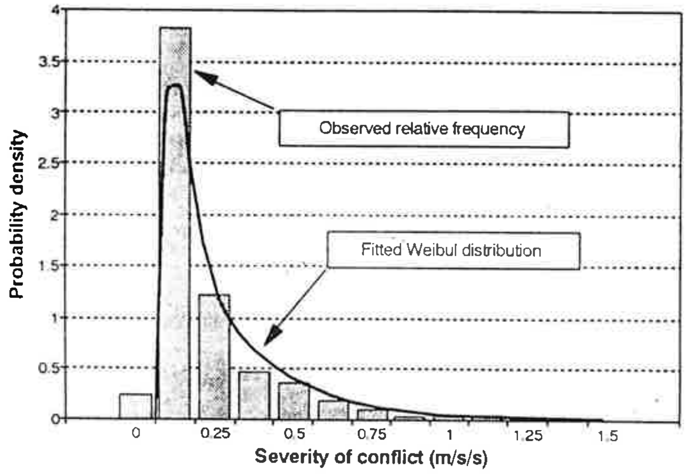

Figure 3: Distribution of severity of conflict

4. RISK OF SKIDDING

To obtain the skid resistance of the pavement, a British Pendulum Tester was employed. The test gives the skid resistance in terms of the British Pendulum Number (BPN) which can be taken to represent the skid friction at low speed. From the in-situ measurements, it was found that the BPN obtained on the dry surface has a mean of 65.2 and a standard deviation of 6.2. Based on the exponential model of skid variation (SHAH et al 1978) and a measured average speed of expressway vehicles of 49.3 km/hr, the coefficient of braking friction for the pavement surface investigated works out to be 0.52 with a standard deviation of 0.05.

Making use of these information, and assuming that μ_b is normally distributed, $h(s^*)$ has a mean of 5.1 m/s^2 and a standard deviation of 0.49 m/s^2. The risk of skidding as defined earlier can be determined for the data set of 1600 merging events. The probability of skidding, based on all the observed merging events was 0.000254 or about 2.5 in ten thousand merges. It must be noted that this does not represent the expected or actual number of skids but rather the potential number of skids.

5. APPLICATIONS

When the pavement surfaces are wet and have been subjected to polishing action of the traffic, the coefficient of friction between the tyres and the pavement will drop. Based on skid studies done in Singapore (RAMASWAMY et al 1988), the BPN may vary from 80 for very good conditions to below 40 for wet polished conditions. This range of BPN translate to a corresponding range of μ_b of 0.32 to 0.64. The change in the level of risk with reference to the existing condition is shown in Figure 4.

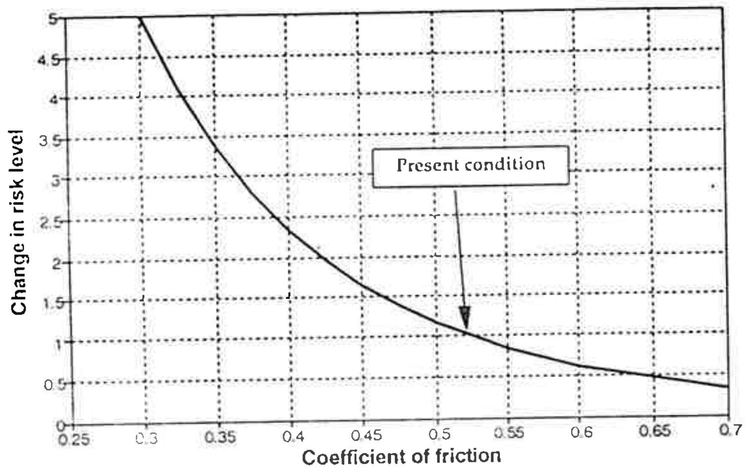

Figure 4: Predicted change in risk level

On average the risk of skidding doubles for every drop of 0.1 in the coefficient of braking friction. In the life of a pavement, the coefficient of friction will degenerate with increasing traffic usage until a new surface dressing is applied. During this period, it is unlikely, however, that the drivers will respond to such changes especially when the pavement surface remains visually similar. When the surfaces are wet the coefficient of friction will be lower thereby increasing the risk of skidding. However, the magnitude of this increase in risk is debatable since drivers may alter their behaviour to account for the increased risk potential.

6. CONCLUDING REMARKS

The procedure developed in this paper illustrates how the risk of skidding can be examined using conflict studies. The numerical values presented here are obviously specific to the location investigated and therefore certain findings may not be generalized. Nonetheless, it is important to note that since the risk of skidding is dependent on the coefficient of friction of the surface and that this is decreasing on average, the level of risk, at least from the point of view of skidding is unlikely to remain constant even if traffic factors remain invariant.

The prediction of risk level during wet weather conditions is particularly interesting. At present, this can only be done in this method by assuming the drivers behave in the same way as on a dry surface. Currently, work is underway to examine wet-weather risk level which takes into account possible responses of the drivers.

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