Intelligent Roads

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D 2.1 – Model for Estimating Expectable Braking Distance- Executive Summary

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PP	Restricted to other programme participants (including the Commission	X
RE	Restricted to a group specified by the consortium (including the Commission	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Executive summary

Pavement skid-resistance is an essential factor of road safety. It is defined as the maximum value of the coefficient of friction between a wheel and the pavement surface. As the friction coefficient itself may be a concept which is too abstract for the driver to grasp during driving, it would be desirable with a more intuitive measure of the available grip between tyres and road.

It has been the purpose of INTRO Task 2.2, to link pavement skid-resistance to vehicle stopping-distance. It should be noted that even if the relationship between skid-resistance and stopping distance is intuitive, its quantification is not straightforward. Actually, stopping distance depends on many factors other than pavement skid-resistance: vehicle type, braking system, tyre, etc. A realistic model had then to be developed. It should be nevertheless simple enough to be easily implemented in a warning system.

A procedure to estimate the braking distance of a passenger vehicle using a reference friction value as input has been worked out. The procedure have been tested and validated on both high and low friction surfaces (summer and winter conditions) using two different types of reference vehicles. Arsenal's ROADSTAR and VTI's BV12 represent the first type, which uses a 5^{th} wheel to monitor the tyre/road friction. The second type, represented by an Audi A3 equipped with NIRA Dynamics micro slip solution for estimating the available tyre/road friction using only the standard components of the vehicle's ABS and ESP system.

The braking distance is defined as the distance travelled by the vehicle from the moment when the driver starts pushing the brake pedal until the vehicle is at complete stand still. The braking distance is obviously driver dependent since applying different pressures on the braking pedal yields different braking distances. The model developed and validated in this report concerns a panic braking situation where maximum possible brake pressure is applied on the brake pedal. It is also important to realise that the total stopping distance, comprising both the distance travelled during the time it takes for the driver to react to an emergency and start hitting the brakes and the braking distance, can be much longer than the actual braking distance.

The proposed braking distance model is based on a simplification of the deceleration curve in two regions: a transient and a stabilised region (Figure 1). Key values of the model are transient time t_s, and coefficients a and b, where the two coefficients represent the link between the vehicle and the reference vehicle. The transient time t_s is affected by the choice of brake system of the vehicle, but could also depend on the vehicle's weight and the tyres.

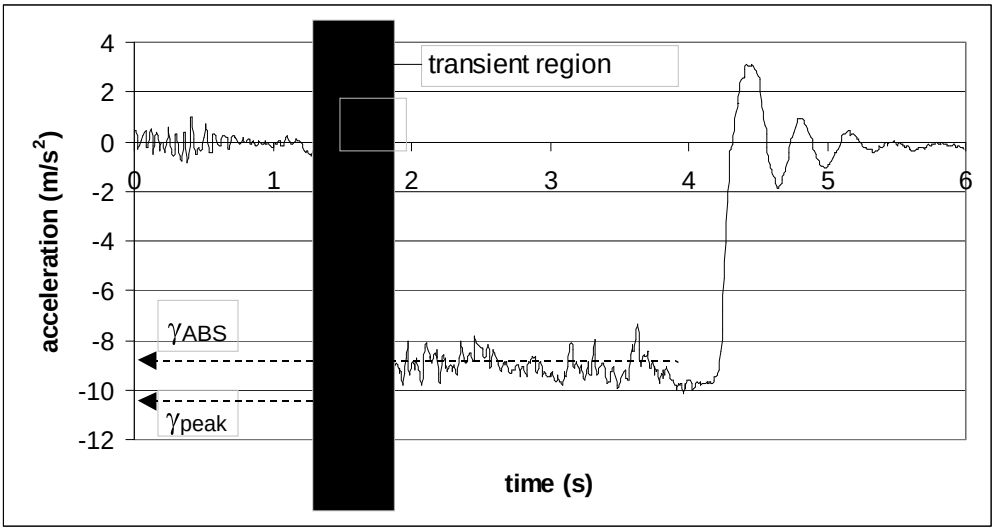


Figure 1. Measured deceleration curve and approximation

INTRO WP2 deals with slippery risks due to water, snow or ice. The model has then two components: “summer” and “winter” (Figure 2). Theoretically, both components must use the same inputs. However, their development was executed as two separate sub-tasks since the physical phenomena during tire/wet-road and tire/snowy- or icy-road contacts are not the same. This difference can have significant consequences on *a, b* and t_s determination. The “summer” part covered wet asphalt surfaces with friction values ranging from intermediate to high, while the “winter” part covered icy and snowy surfaces with low to intermediate friction levels. Ideally, there should have been a crossover between the intermediate friction intervals of “summer” and “winter” surfaces to see if wet surfaces and snow surfaces with the same friction coefficient results in identical parameter values, or if there exist a fundamental difference. Unfortunately this was not possible.

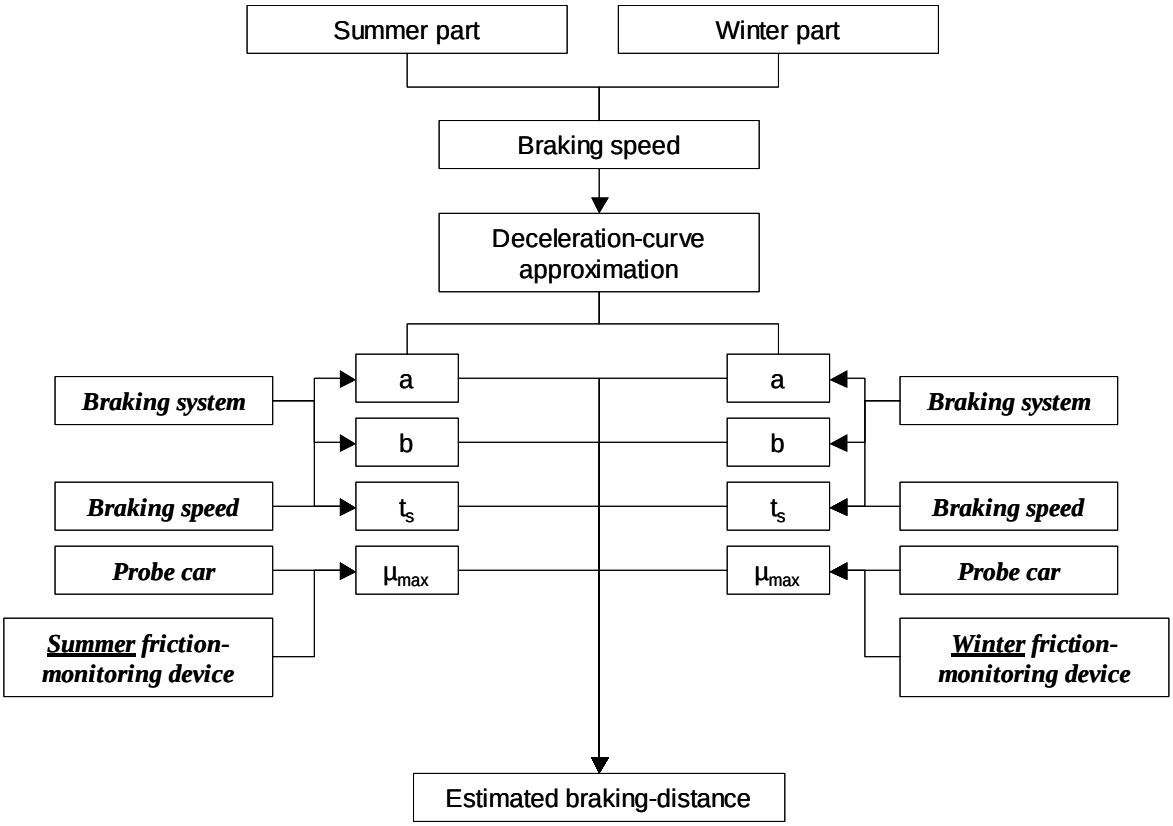


Figure 2. Braking-distance model flowchart

Due to the restricted budget of the INTRO WP 2.1 we could only use one tyre for determining the parameters of the model. We chose an all season tyre, the Vredestein Quatrac. It was also not possible to distinguish between the individual effects on the parameter values from using different braking systems, or different vehicle weights. Instead, complete parameter sets for three different cars were determined to see how sensitive the model is to different vehicle properties. Three cars belonging to three different vehicle classes were chosen: the Renault Clio, the Peugeot 306 and the Peugeot 406. The effect tyre wear has on the tyre/road friction has not been targeted in this study.

The “summer” braking tests (Figure 3) were performed on 5 sections with various friction levels, using the three test vehicles, the Renault Clio, the Peugeot 306 and the Peugeot 406. The ROADSTAR and the NIRA car was used as friction measuring reference vehicles. The friction levels as reported by the ROADSTAR at 80 km/h were in the range 0,69-0,92. The NIRA car failed to distinguish between the different surfaces, and hence no model parameters using NIRA friction values as input were determined.



LCPC Nantes test track during wetting



Arsenal test vehicle ROADStar



Peugeot 406 during braking tests

Figure 3. Test tracks and vehicles involved in “summer” tests

The “winter” braking tests (Figure 4) were performed on two different surfaces: polished ice and packed snow using the NIRA car. The BV12 and the NIRA car was used as friction measuring reference vehicles. The friction level as reported by the BV12 at 15% slip at various speeds, was on average 0,11±0,015 on ice and 0,37 ±0,02 on snow. The NIRA car reported a friction level of 0,41±0,09 on snow, but failed to measure the friction of the ice, possibly because the ice track was too short. Hence no model parameters for braking on ice using NIRA friction values as input were determined.



Ice track at Colmis test centre



VTI test vehicle BV12



NIRA car with speed sensor mounted at the front

Figure 4. Test tracks and vehicles involved in “winter” tests

The results of the parameter fitting to measured braking distances can be summarised as

High friction tests (“summer”):

- It was possible to obtain *a* and *b* coefficients of the proposed model for each of the three tested vehicles, so that together with ROADSTAR friction levels the braking distance could be estimated within 10% accuracy on the five tested high friction (“summer”) surfaces.
- The *a* and *b* coefficients, different for each vehicle, are proportional to the reference friction value, but they are independent on vehicle speed.
- The t_s parameter, different for each vehicle, are proportional to vehicle speed, but they are independent on the reference friction value.

This suggests that other vehicles than the tested ones can be used with the proposed braking distance model, and the procedure to be followed for determining the parameters on “summer” conditions is:

1. select a least 3 sections of different friction coefficient (low, medium, high);
2. perform three emergency braking for two speeds;
3. from the deceleration curves evaluate t_s versus speed and the coefficient a and b;
4. check out the estimator on another section.

If different loads are possible these tests have to be preformed for each load case.

It should be noted that the NIRA car failed to distinguish between the different surfaces, and hence no model parameters using NIRA friction values as input were determined. One possible reason for this could be the relatively short test tracks for measurements on wet surfaces giving the NIRA algorithm not enough values for a good estimation. As this algorithm is knowledge belonging to the subcontractor NIRA it is not possible to verify this assumption.

Low friction tests (“winter”):

- It was possible to obtain *a* and *b* coefficients of the proposed model for braking with the NIRA car on ice, so that together with BV12 friction levels at 15% slip the braking distance could be estimated within 20% accuracy.

- It was possible to obtain *a* and *b* coefficients of the proposed model for braking with the NIRA car on snow, so that together with BV12 friction levels at 15% slip the braking distance could be estimated within 10% accuracy.
- It was possible to obtain *a* and *b* coefficients of the proposed model for braking with the NIRA car on ice, so that together with NIRA friction levels at the braking distance could be estimated within 28% accuracy.
- The best fit is obtained with using the same value for *a* and *b*. This value is the same for both ice and snow, which suggests that it is not friction dependent (at least for low friction).
- No dependence on vehicle speed was found for the t_s parameter.
- Since only two different test surfaces were available, no friction dependence on the t_s parameter could be established, although t_s takes a low value on ice and a higher one on snow.

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The values of the parameters for low and high friction can not be directly compared since different test vehicles have been used, so it is not possible to draw the conclusion that a common set of parameters can be used with the model for estimating the braking distance on both “summer” and “winter conditions with only a reference friction value as input. Additional input regarding the road conditions (ice, snow or wet/dry) is needed. It would take more testing using surfaces with friction in between pure polished ice and packed snow, as well as really low friction asphalt surfaces for a conclusion whether a reference friction value is enough for braking distance estimation.