

TRUCK SPEEDS ON DOWNGRADES

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ABSTRACT

Very little research has been done in South Africa on the speeds of trucks on downgrades. However, a thorough knowledge of this subject is essential in a number of areas namely the justification of arrestor beds and escape lanes for run-away trucks, the development of speed profiles on roads and the provision of passing lanes on downgrades.

In a recent study in the Western Cape the speeds of trucks were measured on various downgrades related to mountain passes. Two types of downgrades were investigated namely those that are followed by a straight section of road on an upgrade and those that are followed by a section with restricted horizontal alignment and sight distance. Since it was not possible to determine the mass of the trucks the number of axles was used as a substitute for the size of the trucks.

The paper will describe the data collection, analyses and the results of the analyses for the two different cases and the different axle classes.

1. INTRODUCTION

To the Traffic and Road Safety Engineer the free-flow speed of vehicles on any point along the length of a road is important. Such a speed versus distance graph is often referred to as a speed profile. By using the speed profile of different vehicles and vehicle types it is possible to derive important design characteristics of the road under investigation. One such characteristic is the design consistency which can be improved by reducing the speed variability over distance or between vehicle types. A good example of the use of a speed profile is to determine the extent of truck climbing (passing) lanes by the point where the truck speeds become unacceptably lower than that of the lighter vehicles so that they can be removed from the normal through lanes.

Truck drivers approaching a downgrade are faced by two conflicting choices – an economic and a safety choice. The economic choice in terms of the cost of time and fuel would be to let go and get the most out of the potential energy presented to them. The safety choice would involve the decision of whether it would be possible to reduce the speed of the truck at any point along the downgrade to enable the driver to negotiate horizontal curves or to maintain a safe stopping sight distance. The latter choice is sometimes made for the driver by the provision of signs proposing the use of lower gears or the introduction of a stop sign at the top of the downgrade. This decision is made in terms of the efficiency of the brakes of trucks. When the brakes are applied for a sufficiently long time, they can get too hot which can lead to brake fade/failure. The increase in brake temperature is dependent on the steepness and length of the downgrade, the mass and speed of the truck and the condition of the brakes. This is determined by means of the Grade Severity Rating System (GSRS) developed by the

Federal Highway Administration (Bowman and Coleman, 1990). This comprises a computer program (Bowman, 1989) that calculates the brake temperature along any downgrade and proposes speeds for different truck masses to avoid temperatures in excess of 500°F. These speeds are called weight specific speed (WSS) and are sign-posted as shown in Figure 1.

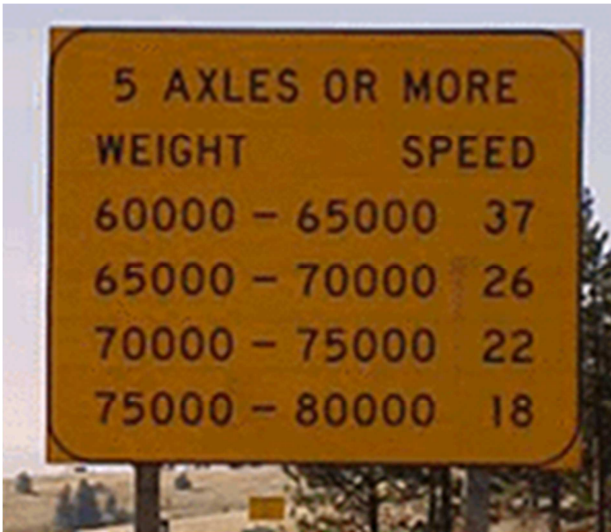


Figure 1: Example of a weight specific speed sign (Source FHWA, 1989)

It is interesting to note from the sign that the speed is a function of the mass and that vehicles with four axles or less are excluded. Research in the USA (Fancher et al, 1981) has shown approximately 73% of trucks involved in runaway events was carrying loads greater than 60 000 lbs (27 ton).

In South Africa the ENGAGE LOWER GEAR (GS 505) sign is recommended (SADC, 1997) at downgrades where a history of heavy vehicle incidents was reported. No recommendation regarding magnitude or length of gradient is made.

In the only reference (St John, 1978) that could be found, where the truck crawl speed on a downgrade is given as a function of gradient it shows that the speed will decrease with an increase in gradient:

$$V_s = -c/G \quad \text{for } G > G_m \quad \dots\dots\dots(1)$$

Where:

- V_s = Truck crawl speed on downgrade (m/s)
- G = Gradient of downgrade (m/m)
- G_m = Minimum value of G (m/m)
- c = parameter of the model.

For trucks, a typical value of c would be 0.90 and G_m would be 0.04 m/m. The values derived from this formula have a correlation with the rule of thumb that drivers should use the upgrade crawl speed on a downgrade with the same gradient.

With this background it was decided to measure truck speeds on downgrades in South Africa.

2 METHODOLOGY

The spot-speeds of heavy vehicles in free-flow conditions while descending a downgrade were measured by means of a radar gun. The reason being that a radar gun is easy to use, since it is a handheld device and requires no setting up. Secondly a radar gun is easily concealable which allows true speed measurement, due to the low possibility of alerting the driver. Lastly, there is no risk of third party damage to the measuring equipment, a real risk that exists for measuring equipment such as roadside radar and piezoelectric strips.

Two types of downgrades were investigated namely those that are followed by a straight section of road on an upgrade and those that are followed by a section with restricted horizontal alignment and sight distance. Since it was not possible to determine the mass of the trucks the number of axles was used as a substitute for the size of the trucks. This was done visually and was recorded for each vehicle.

The specific gradients of the road were measured by means of land survey equipment and checked by means of a Geographic Positioning System (GPS) and Google Earth.

3 DATA COLLECTION AND ANALYSES

During the data collection phase of the project, six different mountain pass segments have been identified as locations for field surveys. They were chosen inter alia, because of the large number of heavy vehicles that make use of them. Three of the locations are situated on the N7, another one on the N2 and the remaining two on the R46 en route to Ceres. Furthermore these locations provide sufficient variance in road alignment at different gradients. Three locations have been identified as suitable for the study of downgrades that are followed by a section with restricted horizontal alignment and sight distance (Type 1) and the remaining locations were suitable for the study of downgrades followed by a change in vertical alignment only (type 2).

3.1 Survey Locations

3.1.1 *Houwhoek Pass*

Houwhoek pass is situated on the N2 near the town of Botrivier. The pass consists of several medium to steep gradient slopes, as well as several sharp curves. At the summit of the pass road signs instruct the drivers of heavy vehicles to select low range gears upon descending. The pass is also subject to an 80 km/h speed limit, which is reduced to 70 km/h for the sharp curves. The downgrade on the eastbound lane, ahead of the last sharp curve, was used to conduct the field survey (Site 1). This road section has been chosen since the speeds achieved while descending will be affected by the restricted horizontal alignment and sight distance. This location is shown in Figure 1.



Figure 1: Houwhoek Pass – Survey site 1

3.1.2 Piekenierskloof Pass

Piekenierskloof pass is situated on the N7, between the towns of Piketberg and Citrusdal. The pass is approximately 15 kilometres in length and consists of medium to steep gradients with a wide range of horizontal curves. Speed limits on the pass range from 60 km/h to 80 km/h. The various combinations of gradient and horizontal alignment make this pass an ideal location to conduct field surveys. Three surveys were done here, two (Sites 2 & 3) at sections with restricted horizontal alignment and sight distance and one (Site 4) at a section where the downgrade is followed by a change in vertical alignment only. At this point the general speed limit is increased to 120 km/h. The locations are shown in Figure 2.

3.1.3 Nuwekloof Pass

On route R46, between the Gouda and Tulbagh turnoffs, is the Nuwekloof Pass. This pass is situated in a valley, descending from both ends to cross the Klein Berg River. The pass is characterised by a long, low gradient slope, winding down from the western side of the valley and medium gradient slopes on the eastern side with a general speed limit of 100 km/h. The sight distance is good with little restrictions on the horizontal alignment. Two survey sites (5 & 6) were identified here, one on either side of the bridge over the Klein Berg River. The locations are shown in Figure 3.



Figure 2: Piekenierskloof Pass – Survey sites 2, 3 & 4



Figure 3: Nuwekloof Pass – Survey sites 5 & 6

3.2 Survey Statistics

The characteristics of the different survey sites are given in Table 1.

Table 1: Survey site characteristics

Site Number	Type*	Gradient (%)	Sample size
1	1	-6.8	218
2	1	-6.7	88
3	1	-4.0	163
4	2	-5.1	134
5	2	-1.6	269
6	2	-4.6	262

* Type 1 sites have sharp horizontal curves following the downgrade.

*Type 2 sites have good sight distance with no sharp curves following the downgrade and are followed by an upgrade which can assist in reducing speed.

The length of the curves were sufficient to allow the trucks to reach a stable speed.

4 RESULTS AND DISCUSSION

The average speeds for the different sites and trucks are shown in Table 2. It should be noted that because of an insufficient number of eight-axle trucks, their speeds are not reported. From the literature it is clear that run-away trucks are, because of their mass, usually those with five or more axles. For this reason the average speeds of two-to-four axle and of five-to-seven axle truck groups are reported separately.

As far as the effect of the number of axles are concerned it is interesting to note that on the Type 1 sites (1,2&3) the longer (and heavier) trucks are travelling at a lower speed than the shorter (and lighter) trucks. This is clearly as a result of a fear (by the driver) of brake fade/failure. This difference is very small at Site 3 where the gradient is 4.0%, which can be a confirmation of the cut-off gradient (Equation 1) of St John (1978). On the Type 2 sites with the exception of Site 4, where all speeds are in excess of the truck speed limit of 80 km/h, the heavier trucks are faster than the lighter trucks. Here there is clearly no fear of brake fade/failure. This phenomenon can often be witnessed on straight roads in rolling terrain where the drivers of large trucks use the downgrades to accelerate to speeds well in excess of the speed limit to enable them to enter the next upgrade at a higher speed. This can make it difficult for the drivers of light vehicles to overtake them when passing sight distance is available.

The relationships between truck speed and gradient are shown in Figures 4 and 5 for downgrade Types 1 and 2 respectively. The increase in speed with negative gradient was expected for the Type 2 sites. The fact that the speeds did not decrease with negative gradient for the Type 1 sites as would be expected from Equation 1, could be as a result of the fact that the downgrades chosen were not long enough for the brakes to reach critical temperatures or because the horizontal alignment was allowing relatively high speeds. At Site 1 (Houwhoek Pass) the limiting curve has a 70 km/h design speed.

Table 2: Truck speeds at the different sites (km/h)

Axles	Sites					
	1	2	3	4	5	6
2	67.4	69.6	60.7	92.8	75.3	71.8
3	68.8	66.0	55.3	87.2	76.4	75.5
4	67.7	58.0	46.8	83.6	72.7	79.5
5	61.4	59.8	48.0	82.6	77.3	81.1
6	62.4	56.3	58.5	85.3	77.9	80.4

7	57.5	61.6	55.4	81.8	76.9	83.2
2-4	68.0	64.5	54.3	87.9	74.8	75.6
5-7	60.4	59.2	54.0	83.2	77.4	81.6
Average	64.6	63.1	54.1	86.3	76.5	79.3

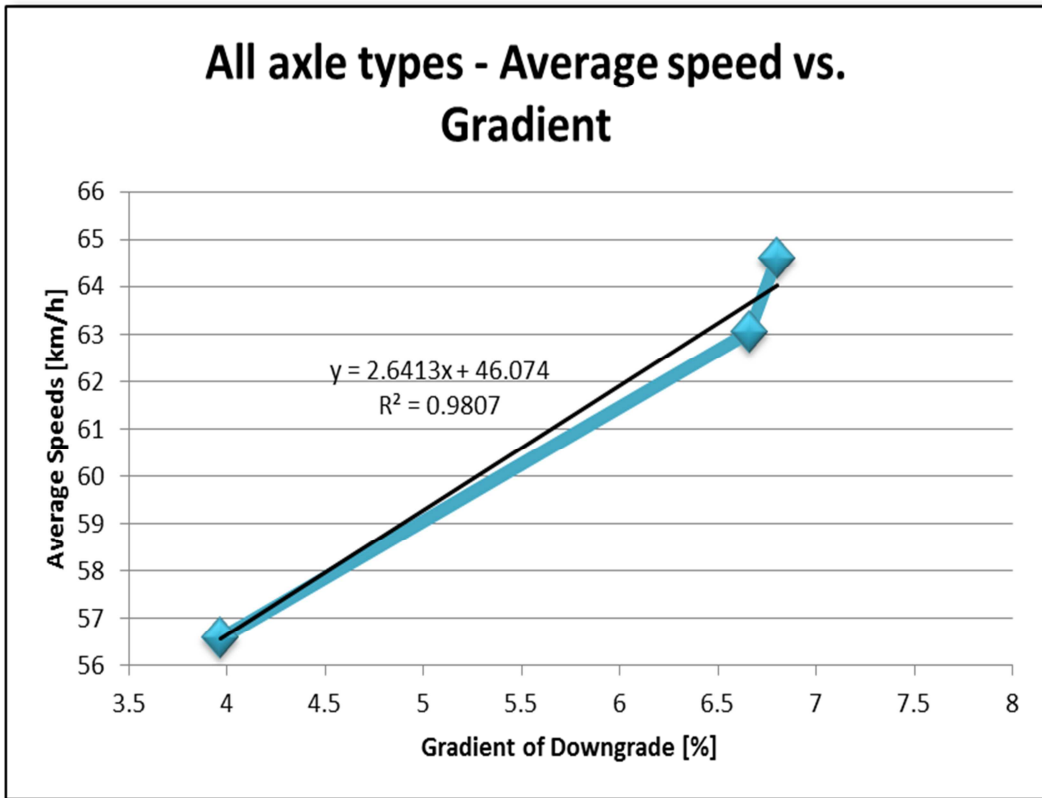


Figure 4: Truck speeds versus gradient – downgrade Type 1

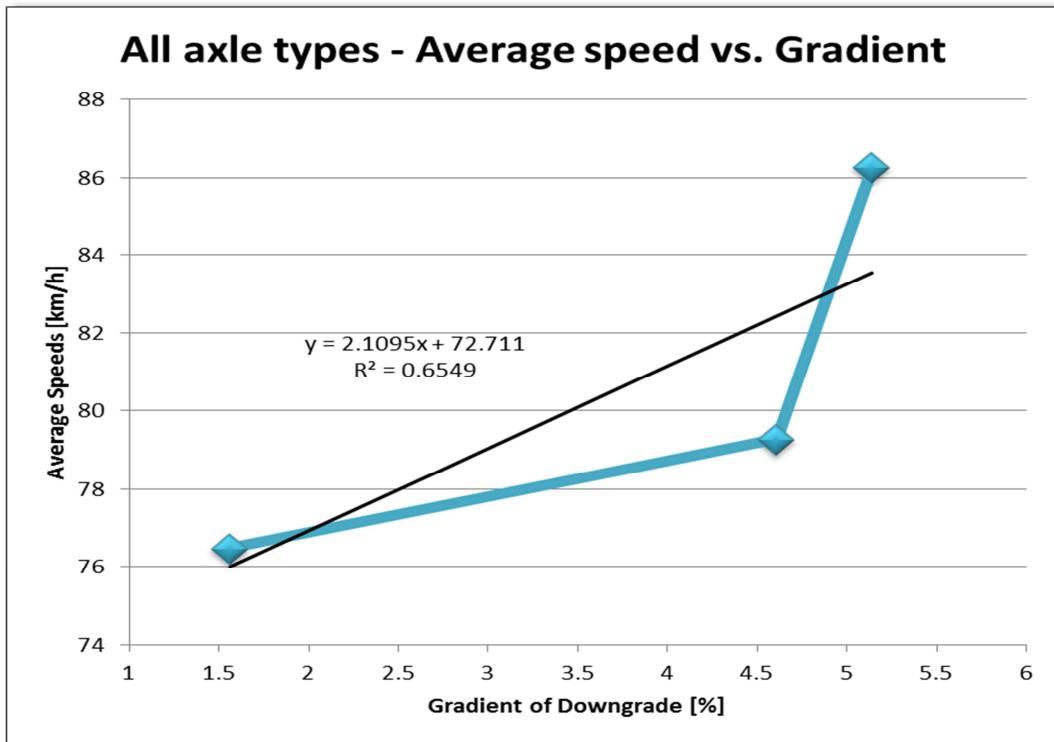


Figure 5: Truck speeds versus gradient – downgrade Type 2

5 CONCLUSIONS

From the study the following can be concluded:

- Truck drivers will accelerate within speed limit restrictions on downgrades when:
 - the horizontal curves will allow it;
 - they have sufficient sight distance; and
 - the mass of their vehicle is such (less than 27 ton) that the brakes are unlikely to over-heat.
- The study did not reach a conclusion about heavy truck speeds when the brakes are likely to over-heat. Longer downgrades with restricted horizontal curves will have to be tested.

6 RECOMMENDATIONS

It is recommended that the speed profile for trucks on downgrades be handled as follows:

- The speed profile for two-, three- and four-axle trucks should be calculated in the same way as for upgrades with the limitations of the speed limit and the horizontal curves.
- It is proposed that the speed profiles for heavy trucks (five-axle and more) on downgrades, where a history of run-away incidents are apparent, be calculated by means of Equation 1 (St John, 1978) as given in the Introduction. Alternatively the crawl speeds on the upgrades of similar magnitude can be used.

It is further recommended that additional studies be done on long steep downgrades to determine the validity of Equation 1 for South African conditions. In such a study other characteristics of the downgrade will have to be investigated. These can include aspects such as radius of curves, sight distance and the need to be able to stop anywhere along the downgrade. These downgrades will have to be identified according to the American Grade Severity Rating System.

7 ACKNOWLEDGEMENT

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