Improving Telematics Analysis of Heavy Vehicle Speed Behavior on Structures



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Abstract
This report introduces a method using data that Transport Certification Australia (TCA) receives from service providers to track Heavy Vehicle (HV) speed, particularly when speed limits change between telematics records. It identifies instances where HVs exceed speed limits, providing insights beyond direct measurements like speed cameras. A key focus is hill descents, where HVs must slow down. Applied to the Princes Motorway in Mt Ousley, NSW, with 138,156 descents in 2023, 27,155 (19.7%) exceeded the speed limit. These statistics show a significant number of calculated speed limit non-adherence instances, and can help inform infrastructure managers and authorities of the general speed limit adherence behaviour on their infrastructure. These figures likely underestimate occurrences as confirmed by case studies where more granular speed data was used for comparison. TCA will not identify individual vehicle operators, only offering aggregated data on HV speed behaviour.
Keywords: Speed Monitoring, Safety, Telematics, Bridges, Hill Descents

1. Introduction

1.1 Problem Statement

On stretches of road with more than one speed limit in a short distance, it is not currently possible to provide speed limit adherence statistics using current methods.

1.2 Research Contribution

This paper outlines a new method of determining speed limit adherence on these complex speed limit intervals by calculating how long the *fast-as-possible* traversal would take(assuming it were travelling at the speed limits), and checking whether the vehicle has taken less than this time. This allows infrastructure managers and authorities to see speed-limit adherence statistics on stretches of road that were not previously able to be analyzed.

2. Background

2.1 TCA’s Telematics Capabilities

Much of Australia’s heavy vehicle fleet is monitored by TCA in accordance with Australia’s National Telematics Framework (NTF). One aspect of the monitoring is the collection of the position data of these heavy vehicles. This is achieved through the vehicles’ on-board, TCA approved telematics devices, which record the GPS position of the vehicle. These devices typically record the position of a vehicle approximately once every 30-seconds (TCA-S01-3.02).

The records generated by this activity are called *position records*. TCA refers to the portion of road between two position records as an *interval*. A common statistic generated by this technology is the average speed of the vehicle on an interval. This is calculated by dividing the distance between two position records by the time elapsed between the two position records. It is critical to stress that this is the average speed of the vehicle over a 30-second period, not the instantaneous speed of a vehicle at a given moment.

TCA's previous speed analysis method has only been able to provide estimates of speed limit adherence on intervals with a single speed limit. TCA has not been able to provide statistics on speed limit adherence over intervals with two or more speed limits. The reason for this is illustrated in Figure 1, which shows the speed of a vehicle as it decelerates from its road speed to meet the speed limit of a bridge it is approaching. Note: In Figures 1 to 3, PR is the abbreviation for position record.

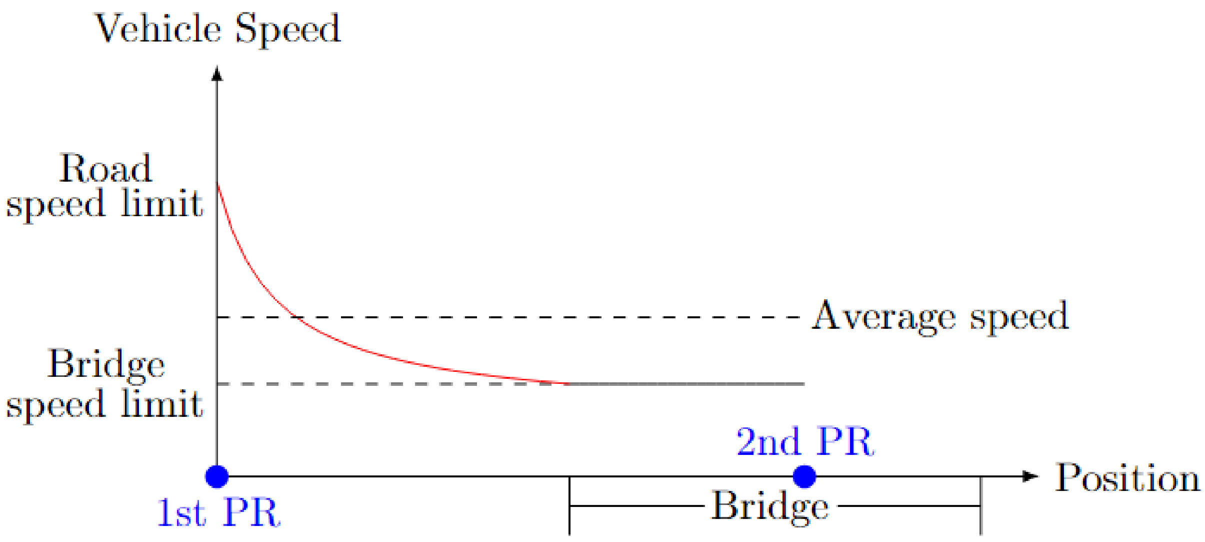

Figure 1: Limitations of Average Speed on a Bridge Crossing

As shown above, the vehicle has complied perfectly with the speed limits - it has remained below the road speed limit (red line segment) and travelled at the bridge speed limit on the bridge (black line segment). However, the red segment brings the average speed up so that it is higher than the bridge speed limit. This means there is no way of determining whether the vehicle sped over the bridge or not using average speed alone. This report provides an alternative speed analysis to solve this issue.

2.2 Use Cases

Two examples where this method of speed analysis is useful are hill descents and bridges.

Hill descents in this context refer to stretches of road on hills which have a lower HV speed limit on the descent to reduce the likelihood of the vehicle losing control. Secondly, bridges often have lower speed limits than the rest of the road which they are a part of. It is important that HVs adhere to this speed limit because travelling at higher speeds can cause significant strain on the bridge.

2.3 Importance of Speed Monitoring

In the case of hill descents, it is important that heavy vehicles stay below the given speed limit as high speeds can lead to loss of control. This is highly dangerous for the vehicle operator and other drivers. In some cases, a significantly lower speed limit is given for trucks compared to heavy vehicles. For example, the Mt. Ousley hill descent in New South Wales, where the speed limit is 40-km/h for heavy vehicles, and 80-km/h for regular traffic, highlighting the necessity of speed control.

In the case of bridges, heavy vehicle impact is well studied, and usually quantified using a metric called *dynamic increment* (DI) defined by Cantieni. R. (1992) as follows:

$$DI = \frac{\sigma_{dynamic} - \sigma_{static}}{\sigma_{static}}$$

Road agency practice is informed by Standards, such as AS5100.7, which guide limits on bridge DI to reduce structural strain.

Heavy vehicle speed influences DI, and can cause spikes in the DI experienced by bridges. Generally these spikes are induced at speeds between 40-km/h and 80-km/h on short span bridges.

It has been noted by Wekezer. J.W. and Taft. E.E. (2011) that DI does not increase monotonically with speed. However, this method can find instances where a heavy vehicle is in the speed range at which the aforementioned spikes in DI occur.

3. ‘Minimum Time’ Detection Method

3.1 Details

Remark: The term *overspeed event* refers to a vehicle surpassing a given speed of interest, and it is not necessarily the speed limit. Speed limits are used in the following examples for illustrative purposes.

The way we can detect an overspeed event is by considering the fastest traversal that is legally possible between the two position records. For the example of a bridge on a road, a vehicle would travel at exactly the road speed limit whilst on the road, and exactly the bridge speed limit whilst on the bridge, as shown in Figure 2.

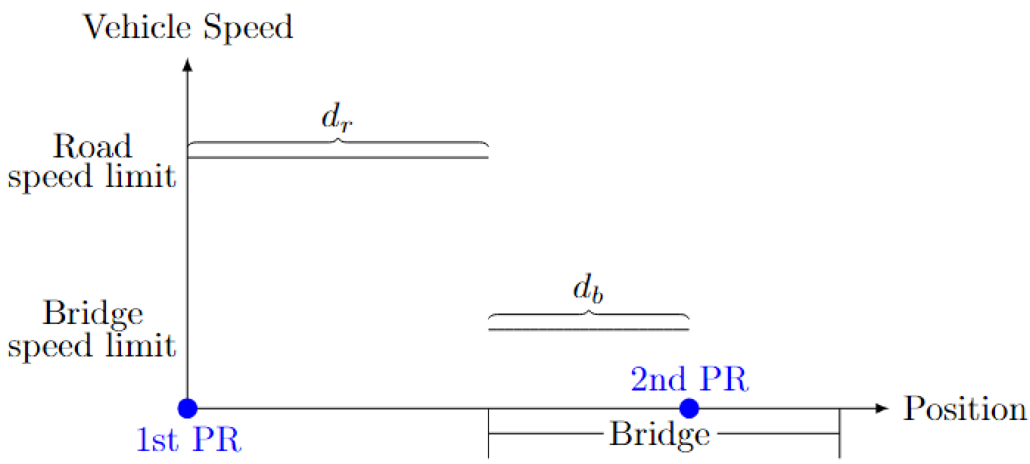

Figure 2: Fastest Possible Legal Traversal

We may then consider how much time this `fast-as-possible' traversal would take. We call this the minimum time (MT) because this is the shortest amount of time this traversal can take without surpassing the speed of interest. The example in Figure 2 is calculated as follows:

Let SL_r be the road speed limit, and SL_b be the bridge speed limit.

$$MT = \frac{d_r}{SL_r} + \frac{d_b}{SL_b}$$

And more generally for any distances (stretches of road) $d_1, d_2, \ldots, d_n$ and corresponding speed limits $SL_1, SL_2, \ldots, SL_n$:

$$MT = \sum_{k=1}^{n} \frac{d_k}{SL_k}$$

This method allows us to use this principle for any interval with any number of speed limits inside it in any arrangement.

3.2 Assessing Accuracy

The accuracy of this algorithm can be roughly gauged by considering the second-by-second data created by some telematics devices under certain conditions. A *telematics devic*e is the primary telematics unit which monitors parameters such as location, speed, vehicle category or mass.

Under certain conditions, a telematics device will produce records once every 3 seconds (TCA-S01-3.02) (which we shall call second-by-second data for the sake of brevity), compared with every 30 seconds if the vehicle is exceeding a speed threshold. It should be noted that these instances are very rare.

When there is second-by-second data we may still use the algorithm by considering one of the second-by-second records, then considering the record which occurs approximately 30 seconds later, and then using these two records to apply the algorithm. Then we can use the more granular second-by-second data to check if there really was an instance of speeding. This allows us to gauge an approximate idea of the accuracy of this algorithm.

4. Results

The main case study this algorithm is applied to is ‘Mt Ousley, NSW’ (Hill Descent) which has a speed limit of 40-km/h for heavy vehicles. A summary of the results is shown in Tables 1 and 2.

Table 1: Overspeed Statistics Summary

	Mt Ousley
Total Number of Traversals	138,135
Number of Overspeed Events	27,155
Percentage of Traversals	19.7

Table 2: Mt Ousley Confusion Matrix

	Calculated Overspeed	Calculated not Overspeed
Sped	7	6
Did not Speed	0	2

The determination of whether a vehicle sped in Table 2 was made as described in Section 3.3.

5. Discussion

5.1 High Frequency of Overspeed Events

The result that just under 20% of traversals were over-speed events is notably high. This indicates that the method can calculate many instances of overspeed events in order to create valuable statistics for relevant stakeholders such as infrastructure managers. Statistics like this can inform infrastructure management decisions such as whether the speed limit signage placement is adequate, or whether a runaway truck ramp may be necessary for safety.

5.2 Under-Reporting

The method may also produce many false negatives (genuine overspeed events not labelled as overspeed). This is because a vehicle which spends a prolonged period significantly under the higher of the speed limits may then speed over the lower speed limit without being detected. Moreover , consider the following example of under-reporting shown in Figure 3.

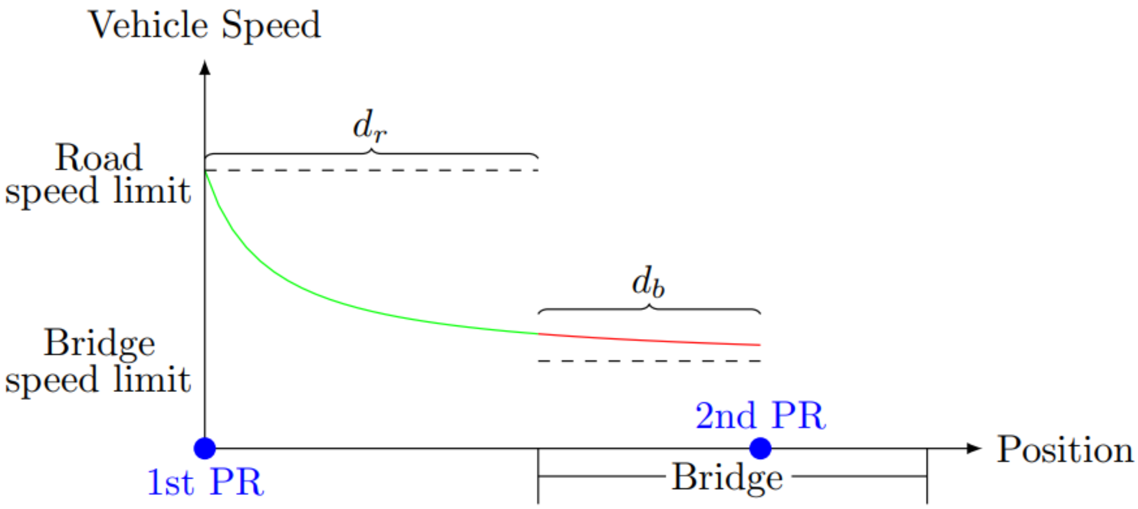

Figure 3: Under-Reporting Scenario

Figure 3 shows a vehicle which is significantly under the road speed limit while on the road (represented by the green line segment), and has gone above the bridge speed limit while on the bridge (represented by the red line segment).

To consider how this may lead to under-reporting, consider the following:

Let the fastest legally possible traversal of d_r take t_r seconds, and that of d_b take t_b seconds (clearly $MT = t_r + t_b$).

If the vehicle took longer to traverse d_r by k seconds (that is, it took $t_r + k$ seconds), then it may traverse d_b in $t_b - k$ seconds without the entire traversal being less than the MT (in this instance *time taken* $= (t_r + k) + (t_b - k) = t_r + t_b =$ MT).

Therefore, this method has a clear tendency to under-report and all results are almost certainly under-estimations.

5.3 Over-Reporting

The algorithm does not distinguish which section of road has been sped over, only that speeding has occurred somewhere in the interval. As a result, if a transport operator speeds on the section with a higher speed limit but complies with the section with a lower speed limit, then we would label this as an overspeed event. However, the purpose of this algorithm is to detect speeding in the lower speed limit region such as a hill descent. As such if this occurs, we will have labelled this as an overspeed event on the hill descent, when it was really an overspeed event on the road segment preceding the hill descent.

5.4 Overall Under/Over-Reporting Comments

Under-reporting is much more frequent than over-reporting—this is true both in principal and in empirical analysis (Table 2). This is because the situation outlined in Section 5.2 can be expected to be the most common – that is, we can clearly expect most vehicles to decelerate before the bridge because this is necessary to follow the bridge speed limit.

6. Conclusion

In conclusion, this report has outlined a method for much more granular speed reporting on sensitive structures and road segments than previously possible. This allows the general speed behavior of HVs to be gauged without the need for direct measurement. This can give relevant stakeholders such as public infrastructure managers and engineers much more detailed information about the speed of monitored vehicles than previously possible.

7. References

- Cantieni. R. (1992), "Dynamic Behaviour of Highway Bridges Under the Passage of Heavy Vehicles", Report No. 220. Swiss Federal Laboratories for Materials Testing and Research (EMPA), Switzerland
- Transport Certification Australia (2013), "Intelligent Access Program Functional and Technical Specification" (TCA-S01-3.02), TCA, Melbourne, Australia, 2018, 16, 111-112
- Standards Australia (2017), "Bridge design, Part 7: Bridge assessment" (AS5100.7), Standards Australia, Sydney, Australia
- Wekezer. J.W. and Taft. E.E. (2011), "DYNAMIC LOAD ALLOWANCE FOR REINFORCED CONCRETE BRIDGES " in III ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, eds . M. Papadrakakis, M. Fragiadakis, V. Plevris, Corfu, Greece, 9-10