

## **Technical Note - Curve Advisory Speeds in New Zealand**

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### ***Abstract***

*Recent research investigated the use of curve advisory speed signs in New Zealand. A comprehensive literature review identified key issues to examine. Current traffic speed behaviour was observed at the site of curve advisory speed signs, using a series of optical sensors, in order to determine effectiveness and compliance. Alternative methods for determining curve advisory speeds, using road geometry data or accelerometer/gyro-based systems, were compared with ball-bank surveys. The existing criteria and methods used for setting curve advisory speeds in New Zealand were assessed in light of the above findings, and changes suggested.*

## 1. Introduction

In New Zealand, there are often sub-standard curves out of character with the surrounding environment. Many curves are posted with advance curve warning signs and a plate showing a suggested “advisory speed”; this is usually a speed ending in five between 15 and 95 km/h. In common with many countries, New Zealand relies on a “ball-bank indicator” (or “side-thrust gauge”) as the standard way of determining the need for and appropriate value of advisory speeds.

Opus Central Laboratories carried out research for Transfund New Zealand to investigate the use of curve advisory speed signs in New Zealand. The specific objectives for the research were to:

- To study the current traffic behaviour at the location of curve advisory speed signs in New Zealand, to determine their effectiveness and compliance with them.
- To assess the feasibility of using alternative methods to the ball-bank indicator for determining curve advisory speeds, e.g. road geometry data or accelerometer/gyro-based systems.
- To assess the existing ball-bank criteria used for setting curve advisory speeds in New Zealand, in light of the above findings.

This technical note summarises the key findings and recommendations. Further details can be found in the related research report<sup>1</sup>.

## 2. Literature Review

A review of local and international literature on relevant topics revealed:

- Curve speeds adopted in New Zealand are generally less conservative than measurements used elsewhere, such as most parts of Australia and the US. The relationship used between advisory speed ( $V_A$ ) and ball-bank indicator value ( $b_A$ ) is  $b_A = 20.4 - 0.125V_A$ .
- Driver compliance with curve advisory speed signs is historically poor throughout the world. This brings into question the friction criteria that have been used to determine the speeds.
- There is little guidance or documentation available locally to inform road practitioners of the “correct” ball-bank survey procedure.
- Posted advisory speeds may have modest effects on speeds, compared with equivalent curves that are unsigned or have only curve warning signs.
- The relative safety effect of curve warning signs and advisory speed signs separately is unclear.
- There are many concerns about the accuracy of posted speeds in relation to the standard test procedures. Only about half of the signs locally have been found to have posted speeds matching those determined by ball-bank surveys, with some sites not warranting a sign at all.
- Multiple ball-bank test runs are required to reduce random errors, with ideally at least one run very close to the true advisory speed.
- Although truck speeds through curves are lower than for light vehicles, curves that pose dangers for less stable trucks may warrant specific signing.
- No appreciable differences in curve speeds between dry and wet weather or between day and night have been observed in most studies.

## 3. Site Surveys of Curve Speed Profiles

Site surveys were conducted at curves both with and without advisory speed signs. Comparing actual vehicle speed profiles through the curve could determine the effectiveness of advisory speeds. Sites were selected on state highway and local road sections in the Wellington, Wairarapa

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<sup>1</sup> Koorey G.F., Page S.J., Stewart P.F., Gu J., Ellis A.S., Henderson R.J., Cenek P.D., 2002. Curve Advisory Speeds in New Zealand. *Transfund New Zealand Research Report No. 226*, 112 pp.

or Manawatu regions, within easy travelling distance of Opus Central Laboratories. For state highways, road geometry data was used beforehand to identify all possible curves and their attributes; the roads were then driven to identify and confirm the sites to be used. A couple of minor non-state highway routes were also surveyed to identify potential local road sites. These were selected on-site following field measurement and assessment.

To get a good indication of speed changes through the curve, ideally a series of speeds should be recorded through the curve, as well as an approach speed far enough away from the curve. Traditional physical speed surveys using tubes or wires, or radar-gun observation surveys have various practical problems for long survey periods at curves. A series of red-light optical beams and sensors across the road was therefore identified as a practical solution for this type of survey.

At two sites, ordinary tube-based counters were used to collect approach speeds and vehicle types, with six optical sensors placed around the curve at pre-determined locations to calculate average speeds between points. At subsequent sites, only three optical sensors were used to pick up two sets of speeds near the middle of the curve, with vehicle types determined by calculated vehicle length.

Field surveys at 28 rural curves (14 sites), recording vehicles' speed profiles, showed:

- Posted speeds generally underestimate mean observed speeds by approximately 5–10 km/h, and 85th percentile speeds by ~10–20 km/h. However, at about a quarter of the sites mean speeds seem to follow the posted speeds quite well.
- Ball-bank derived speeds appear to provide a reasonable measure of observed mean speeds up to about 60 km/h, with a disparity between the two measurements at higher speeds of ~10–15 km/h.
- Posted speeds matched ball-bank derived speeds to within 10 km/h in most cases. However, only half of the ball-bank readings produced exactly the same (rounded) posted speed.
- Curve speeds collected produced reasonably normal distributions, usually with slightly longer tails at the low end. Standard deviations were generally about 12% of the mean speed, indicating no reduction in the coefficient of variation from speeds on straights.
- Heavy vehicles were slower than light vehicles by 4 km/h on average, with no noticeable change in this difference as the mean speeds increased.
- Driver compliance with the posted advisory speed, 10 km/h above the posted speed and the ball-bank speed averaged 17%, 51% and 27% respectively. However, between sites there was a wide variation from almost no compliance to almost total compliance.
- It is estimated that 40–50% compliance of vehicle speeds with the posted speed is likely if the ball-bank speed is actually less than that posted. Approximately double that proportion would comply within 10 km/h of the posted speed.
- Sharp 90° curve (PW-16) signs and the second curve for multiple curve signs appeared to have good levels of compliance, albeit from few observed sites.
- Vehicles making the greatest speed drops when approaching a curve were still likely to travel faster through the curve.

#### **4. Surveys Using Alternative Methods**

In an attempt to provide a more accurate measure of curve speeds, an accelerometer/gyro-based system was developed that could be fitted to a vehicle and connected to a data logger. This device could then be used to record data continuously as the vehicle traversed a corner, including lateral and longitudinal accelerations, vehicle body-roll and travel speed. Analysis software on a connected laptop could then be used to record the data and ultimately derive an advisory speed for the curve. For monitoring vehicle speeds throughout each curve, a speed profiler device was used, previously developed by Opus Central Laboratories for applications such as travel-time surveys.

Two sites (four curves) from the previous surveys were run using the gyro device. Each curve was also tested using the ball-bank indicator for accuracy and repeatability, particularly at different survey speeds. Several different surveyors were used to identify any operator biases or inconsistencies inherent in the process. Three different vehicles – hatchback, van and small rigid truck – were also compared. At each site, approximately 36 different combinations of travel speeds (4), vehicles (3) and drivers (3) were used.

Measured road geometry data for state highway and local road sections can also theoretically be used to derive curve advisory speed measurements. To confirm the validity of this approach, advisory speeds calculated using road geometry were compared with the ball-bank indicator speeds. Fifty curves at 25 sites were investigated, including all of the sites surveyed in the previous tasks.

Analysis of measurements taken during the repeated drive-over surveys found:

- Comparison between the nominal test speed the driver attempted to travel at and the actual recorded speed at the point of maximum lateral acceleration suggested that driver observation of the speedometer is a sufficient way to ensure consistent vehicle speeds.
- Observed ball-bank values underestimated those identified by an electronic gyro, by an average factor of 20%. This may be due to the water damping of the ball-bank indicator or to observers ignoring any isolated ‘jumps’ in the ball-bank readings.
- Advisory speeds calculated from the gyro were generally less than the equivalent ball-bank speeds, by ~9% on average. A means of ‘smoothing’ the automatically recorded gyro readings may reduce the lateral acceleration peaks and produce less conservative values.
- Predicted curve advisory speeds were largely insensitive to the relative body-roll angle chosen. Comparing the assumed 3° angle with 0° found computed speeds only 1.3% lower on average.
- Ball-bank surveys provide a fairly consistent measure, irrespective of driver, vehicle or test speed. One-way Anova tests, comparing differences between factors, found significant differences half of the time but generally no major patterns.
- The ball-bank surveys carried out showed a range of up to 12 km/h between individual tests. When grouped by driver, vehicle used or test speed, the groups still differed by  $\pm 3$  km/h.
- Minimum speed values calculated using road geometry data produced a fairly good relationship with measured ball-bank advisory speeds, with road geometry tending just to underestimate advisory speeds. Using a rolling average of 50–100 m produced a more accurate fit.

## 5. Review of Existing Advisory Speed Criteria

This research provided some up-to-date local field data on a difficult topic. By combining these findings with the background information found, the merits or otherwise of the existing system in New Zealand could be ascertained. Consideration of the above findings in the context of existing procedures concluded:

- Ball-bank speeds derived assuming a constant advisory ball-bank reading of 17° (i.e. irrespective of advisory speed) appeared to fit observed mean speeds very well, i.e. relationship is  $b_A = 17.0$ . This suggests that drivers do not change their level of comfort for different curves.
- Road geometry data can provide a reasonable alternative to field survey measures and appears to present no less accurate a method for assessing curve speeds. In particular, as a desktop task to minimise the amount of field surveying done, it is very cost-effective.
- Automated devices for determining curve speeds should be allowed in New Zealand, provided they can replicate a wide range of speeds consistently. This should be confirmed by a series of test runs for each device that compared their results to the equivalent ball-bank standard.
- A move to change the existing curve speed criteria to produce more realistic posted speeds would have a potential impact on safety for drivers unaware of the change. A possible longer-

term approach instead would be to change the standard subtly by very small increments over time, causing only a few “borderline” posted speeds to be increased to the next level.

- The existing criteria for determining advisory speeds cannot be applied to unsealed roads, as driver discomfort is not likely to be reached before insufficient friction causes loss of control.
- Many of the problems that have affected trucks at curves are being dealt with through improvements in the relative stability of truck design and truck-driver education. However, sites at which less stable trucks experience problems but do not meet the normal advisory speed signing criteria should be considered for truck-specific warning signs.
- Ball-bank surveys are not accurate enough to warrant allowing a curve advisory speed system with intervals of 5 km/h.
- Several alternative curve warning devices have the potential to provide more effective guidance, including various road delineation countermeasures and dynamic vehicle-warning systems.

## 6. Recommendations

The following items are recommended for further investigation or action:

- Make available for local practitioners a standard methodology for carrying out ball-bank survey procedures correctly, e.g. in the *Manual of Traffic Signs and Markings* (MOTSAM).
- Identify the relative safety benefits of curve advisory speed signs separately from those of curve warning signs, using local crash data.
- Promote driver education on the dangers of travelling at the same curve speeds in the wet.
- Study the effect of changing curve signing on driver behaviour. Before and after surveys at suitable sites (where a speed plate was changed, added, or removed) would eliminate differences between sites that can mask the underlying effect of the advisory speed.
- Allow a documented road geometry method as an alternative for deriving curve advisory speeds in New Zealand. Also make allowance for using automated inclinometer devices instead of ball-bank indicators, provided it can be demonstrated that the device has been properly calibrated.
- Investigate further the merits of non-mechanistic linear curve speed formulae, e.g. using approach speed and curve radius only to predict curve speed.
- Carry out further tests using the in-vehicle gyro on flat and constantly sloped surfaces to identify the amount of body-roll in typical New Zealand vehicles.
- Develop guidelines for curve advisory speeds on unsealed roads, using available design friction values. Observe traffic behaviour at unsealed sites to confirm the feasibility of applying these.
- Develop guidelines for truck-specific warning signs at sites where the combination of typical speed, radius and superelevation exceed the rollover threshold for a typical high truck.
- Consider changing the curve advisory speed system to round to posted speeds ending in zero. This could be done in conjunction with making a slight change in speed criteria.
- Trial in New Zealand alternative curve warning devices, such as the road marking countermeasures investigated in Australia and dynamic warning systems.
- Investigate further development of the optical speed-detection equipment, to produce a more robust system with fewer data collection errors.

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