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# Evaluation of illuminated 20 km/hr school-bus signs


Prepared for:
Road Safety Trust

October 2011

FINAL REPORT

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# SUMMARY

This research builds on the findings of a previous NZTA research report on the safety of children using school buses. As part of that project, a number of different school bus signs were evaluated, including a symbolic children sign with flashing lights and a LED based speed limit sign. What the speed limit should be was covered in the previous report and is outside of the scope of this investigation.

The goal of this research was to:

**Develop and evaluate an effective and affordable speed limit sign for school buses that can be activated near and while the bus is at a bus stop.**

Four key variations of a 20 km/hr speed roundel sign were developed for trial. Supplementary variations included adding flashing/alternating beacons and removing the standard "School" sign.

Data were collected in three ways:

1. The effects of different sign designs on passing traffic speed. The signs were mounted on a stationary school-bus outside a school on SH27.
2. Evaluation of speeds of vehicles travelling past a school bus, using a speed laser gun on actual and simulated school bus runs
3. A perceptions survey of school road safety personnel to further evaluate the potential effectiveness of the four main sign designs.

Overall, the signs had a significant effect on reducing traffic speed. There was also significant variation in speeds, which is of some concern as less homogenous speeds have been linked with a lower level of safety. However, a carefully planned approach to sign implementation should mitigate any potential safety issues. Recognisability is a key principle within the 'Self explaining roads' concept and motorists are more likely to react positively to things they understand and with which they are familiar. This means that introducing the signs to most buses within an area at the same time would result in motorists quickly becoming familiar with them, and accordingly, the speed variation should reduce. Publicity and enforcement campaigns may also help.

The best performing sign on the rear of the bus in terms of speed reduction was the smaller and more highly placed sign, with illuminated LED roundel, flashing beacons, and accompanying "School" sign (although overall the flashing beacons only had a marginal effect in reducing speed). A preference for this sign was also shown by the stakeholder perceptions survey. On the front of the bus, the large sign was more effective but may be difficult to fit on many buses because of its size.

## Recommendations

Based on the findings of this study and supporting knowledge from other studies, the following actions are recommended:

1. An LED speed limit school bus sign is supported and should be progressed for use as soon as practically possible. Based on the findings of this study a smaller sign with LED roundel and flashing beacons is recommended on the front and rear of the bus. This sign should be displayed in addition to the existing "School" sign to maximise comprehension and credibility.

2. In order to maximise the effectiveness of the signs and mitigate safety risks, the following steps are recommended as part of the introduction of LED speed limit school bus signs.

   It is recommended that:

   a) Approximately 50 buses should be fitted with the signs after testing to make sure the production units are suitable and robust. Speed and driver behaviour around buses within the area should then be monitored with the signs in service.

   b) At the same time an area-wide publicity campaign should be undertaken to raise awareness. Following a) and b) enforcement should be carried out as needed

   c) Long-term monitoring is recommended to ensure appropriate road-user behaviour is achieved and maintained.

   For all steps, special consideration should be given to the locations where school buses are likely to stop with the signs illuminated and Traffic Note 44 (Safe Siting of School Buses) addresses this. While motorists become familiar with them, the signs should only be illuminated when there is sufficient sight distance on approach to the bus.

3. The results should be used to determine the best mix of sign design, awareness campaign and enforcement activities for nationwide implementation.

# CONTENTS

# INTRODUCTION AND BACKGROUND

There is widespread concern about the number of children being killed when crossing the road to and from school buses. Several coroners' reports have recommended immediate action be taken, and many groups such as the National Council for Women of NZ, the New Zealand Society of Paediatric Surgeons, Rural Women NZ, Safe Kids, New Zealand Automobile Association, NZ School Trustees Association, local authority Road Safety Coordinators and bus operators, as well as asking for more to be done, have been trying to do what they can at a local level. There has also been a considerable amount of media attention given to school bus safety.

In the 23 years since 1987, twenty three children have been killed in New Zealand when crossing the road to or from school buses. In addition, 47 have been seriously injured and 92 have received minor injuries[1]. By comparison, six children were killed while actually on a school bus.

School bus crashes receive a high level of media attention. Research both in New Zealand and internationally shows that generally school buses are one of the safest ways for students to travel to and from school. In New Zealand, children travelling to school by car were 2.3 times more likely to be injured per trip than children travelling by bus in 2003-2005 (Schofield, Gianotti et al. 2008). However, bus travel in New Zealand is less safe than in similar countries such as the United Kingdom, Australia and the United States. Research from Scotland shows that a child travelling by car is 7 times more likely to be a road traffic casualty than a child travelling by bus (Granville, Laird et al. 2002). In Australia, bus travel is 14 times safer than travel in a private car (ACRS 2004) and in the United States bus travel is reported to be 8 times safer than car travel (NHTSA 2006). These figures indicate that New Zealand still has considerable scope for improving the safety of school buses. Given that approximately 23% of children travel to and from school by bus, an improvement in school bus safety has the potential to reduce road safety risk for a substantial proportion of New Zealand children.

## Previous research

Recently, TERNZ undertook NZTA funded research which examined various aspects of school bus safety (Baas et al. 2010). The results highlighted that the speed at which road users pass school buses that have stopped to pick up or drop off children is the issue of greatest concern. The current legal speed limit near school buses that have stopped to pick up or drop off children is 20 km/h. This is intended to ensure that children are not killed or seriously injured in the event of a pedestrian collision. However, almost no motorists comply with this speed limit and many appear unaware of it. Clearly, considerable safety benefits would result from reducing vehicle speeds around school buses.

As part of the NZTA funded study, a selection of school bus mounted signs were evaluated (Table 1). The signs ranged significantly in design from the existing "School" sign, through to a 40 km/hr 'school zone' sign (which is currently used at fixed locations mainly around urban schools). The signs were evaluated by parking a school bus opposite a school on SH 27 and measuring passing traffic speeds while the various signs were displayed.

[1] It should be noted that, although it is required by law, not all injury accidents are reported. The actual number injured may be higher.

Table 1. School bus signs evaluated by Baas et al. (2010). Note: Photos may be narrower than reality

| | |
|---|---|
| Sign 1. Currently used sign |     |
| Sign 2. Currently used sign with hazard lights |     |
| Sign 3. Children crossing sign |   |
| Sign 4. Children crossing sign with beacons |    |

| | | |
|---|---|---|
| Sign 5. Children crossing with flashing beacons and message |  |  |
| Sign 6. School Zone sign with currently used sign above |  |  |

The findings of this research showed that the existing "School" sign had little effect on passing traffic speed, nor did the same sign with the hazard lights on or a static 'children crossing' symbolic sign. A step change downward in speed came when flashing beacons were added to the children crossing symbolic sign and the most effective sign was an existing 40km/hr school zone sign. This sign was associated with a mean speed of 57 km/hr for traffic on the same side as the bus and 67 km/hr for traffic on the opposite side to the bus.

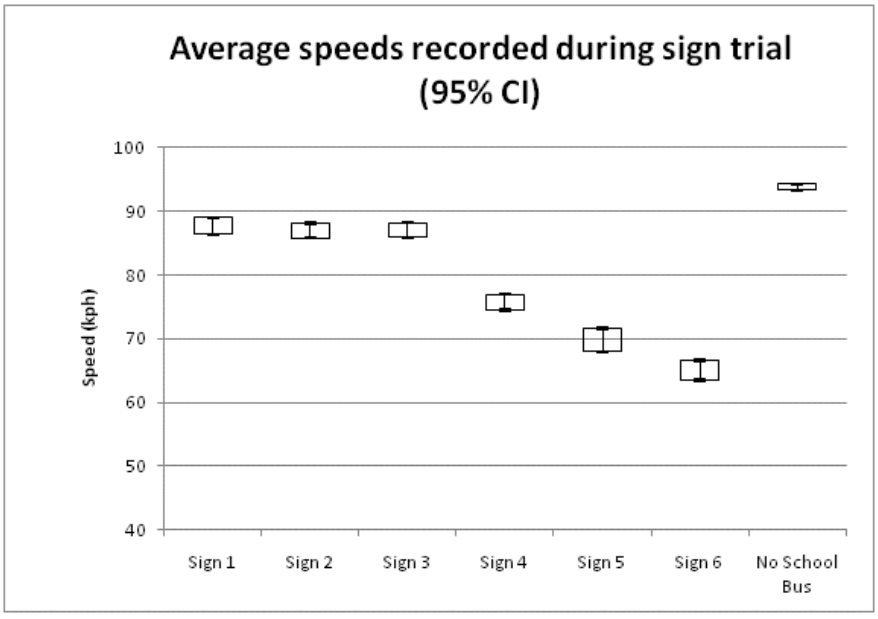


Figure 1. 95% confidence intervals for mean speed of traffic travelling opposite to the direction of the school bus

## Purpose of this study

The aim of this research was to build on the findings of previous TERNZ research by developing measures that will reduce vehicle speeds near school buses that are picking up or dropping off children. The findings of Baas et al. (2010) suggest that motorists are most responsive to an illuminated speed limit school bus sign. Therefore, the specific goal of this project was to:

**Develop and evaluate an effective and affordable, illuminated speed limit sign for school buses that can be activated near and while the bus is at a bus stop**

Note: The scope of this research was limited to evaluating driver responses to various sign designs. The research did not extend into the operational requirements for making the signs reliable and robust for day to day use. What the speed limit should be past school buses was covered in the previous report (Baas et al 2010) and is outside of the scope of this investigation.

# RESEARCH APPROACH

## Sign development

The methodology used for this trial was similar to that used for the previous school bus signs trial (Baas et al. 2010). The main difference was that for this trial, speed limit roundel signs were developed based on likely effectiveness for slowing traffic and also costs and other practical considerations.

An application for a Traffic Control Devices (TCD) trial was submitted to NZTA for approval. As part of the approval process advice was given on the design of the signs. The TCD committee advised that a 20 km/hr sign would be the most appropriate speed to display on the signs, in line with the current law for traffic speed past a stationary school bus.

Four main variations of a 20 km/hr speed roundel sign were developed for trial:

1) Small LED sign with LED roundel (400mm diameter)
2) Small LED sign with retro-reflective roundel
3) Large LED sign with LED roundel (600mm diameter)
4) Large LED sign with retro-reflective roundel

Figure 2. Examples of signs used in study. Small sign with retro-reflective roundel (left) and large sign with LED roundel (right). The CD in the frame of view demonstrates the size difference of the signs.

Variations of these four signs during the trials included:

- Adding flashing/alternating beacons
- Removing the standard “School” sign

A road sign manufacturer was engaged to build the signs. They were built for the purpose of this trial and did not include the usual waterproofing and other features that improve durability, although they needed to be robust enough to be fitted to the rear and front of a school bus for a school run. The signs were powered via a battery which was stored on-board the bus during all trials. A separate flasher unit with associated beacons was designed as a stand-alone unit which could be added to or removed from the signs as needed.

## Data collection

There were three main parts to data collection for this study:

1. The effects of different sign designs on passing traffic speed. The signs were mounted on a static school-bus outside a school on SH27. The same school and school bus were used as that for the previous school bus safety report (Baas et al. 2010).
2. Evaluation of realistic speeds of vehicles travelling past a school bus, using a speed laser gun, during actual and simulated school bus runs.
3. A perceptions survey of school road safety personnel to further evaluate the potential effectiveness of the four main sign designs.

## *SH 27 Static school-bus sign comparison*

For this part of the study, signs were displayed on a parked school bus directly opposite a school (Te Kura Kaupapa Māori o Te Rau Aroha) on SH 27 (Figure 3). The reason for parking the bus on the opposite side of the road was to create the possibility in the minds of drivers that children may cross the road.


Figure 3. Location (marked with X) where school bus was located for the sign comparison trials

A sign configuration schedule (Table 2) for trialling each sign type and combination was developed and used over two days (30th, 31st March, 2011) of data collection, between 9am and 2pm (times when the school bus was not being used for school runs). All data were collected during fine weather conditions.

The main focus was to evaluate the four main (key) sign types including small, large, LED roundel and retro-reflective roundel variations. For the signs on the rear of the bus, beacons were used with the LED roundel configuration (small sign on day 1, large sign on day 2) and then removed for the retro-reflective roundel configuration. By doing this a comparison of the highest level of signage could be made with the lowest level of signage – representing the extremes of possible sign designs. Additional supplementary configurations sought to evaluate the effects of adding or removing the standard "School" sign and beacons (from the LED roundel condition). Less time (and data) was given to these and so conclusions about the effectiveness of including/excluding

flashing beacons and the “School” sign, based on speed data, are not likely to be as strong as for the four main conditions explained above.

For the front of the bus, identical sign configurations were displayed at two different times of the day (tests 1 and 3 on day 1 and tests 5 and 7 on day 2). This allowed a limited evaluation of any time of day effects that may have been present.

Table 2. Sign configuration test schedule. The key data sign configurations are shaded in blue.

| Test | Front of bus sign | Rear of bus sign | |
|---|---|---|---|
| **Day 1** | | | **Time** |
| 1 (key) | Large sign with:<br>• LED roundel<br>• No beacons<br>• School sign | Small sign with:<br>• LED roundel<br>• Beacons<br>• School sign | 09:30 -11:10am |
| 2 (supplementary) | Large sign with:<br>• LED roundel<br>• No beacons<br>• No school sign | Small sign with:<br>• LED roundel<br>• Beacons<br>• No School sign | 11:12 – 11:35am |
| 3 (supplementary) | Large sign with:<br>• LED roundel<br>• No beacons<br>• School sign | Small sign with:<br>• LED roundel<br>• No beacons<br>• School sign | 12:02-12:40pm |
| 4 (key) | Large sign with:<br>• Retro roundel<br>• No beacons<br>• School sign | Small sign with:<br>• Retro roundel<br>• No beacons<br>• School sign | 12:42-2:00pm |
| **DAY 2** | | | |
| 5 (key) | Small sign with:<br>• LED roundel<br>• No beacons<br>• School sign | Large sign with:<br>• LED roundel<br>• beacons<br>• School sign | 09:30-11:00am |
| 6 (supplementary) | Small sign with:<br>• LED roundel<br>• No beacons<br>• No School sign | Large sign with:<br>• LED roundel<br>• beacons<br>• No School sign | 11:01-11:21am |
| 7 (supplementary) | Small sign with:<br>• LED roundel<br>• No beacons<br>• School sign | Large sign with:<br>• LED roundel<br>• No beacons<br>• School sign | 11:22-12-31pm |
| 8 (key) | Small sign with:<br>• Retro roundel<br>• No beacons<br>• School sign | Large sign with:<br>• Retro roundel<br>• No beacons<br>• School sign | 12:32-2:06pm |


Figure 4. Example of sign displayed (from Test 1) as part of static school bus trial

Traffic speed data were collected using tubes laid across both lanes of the roadway, with the bus straddling the tubes (Figure 4). When the data were processed, only headways of greater than three seconds were used, ensuring that traffic speed was influenced by the environment rather than any leading vehicles.

## *School bus run speed measurements*

This part of the study involved measuring passing traffic speeds during an actual school bus run around the Matamata area, using a speed laser gun (and estimating the speed when the bus was still moving), while the 'Test 1' signs (rear small sign with LED roundel and flashing beacons, front large sign with LED roundel and no flashing beacons) were being displayed. Because, the estimated speeds were interspersed among the speed gun readings, estimating the traffic speeds to within 10 km/hr was relatively straightforward. Periodically, estimated speeds were checked against speed gun measurements when the bus was stationary. Independent estimated speeds from two researchers were combined to provide an average. Only free running vehicles that were not following other vehicles were included for both speed gun and estimated speeds. The purpose of this part was to evaluate realistic vehicle passing speeds, acknowledging that the SH27 static tests may not be completely realistic (because the focus was on comparing signs rather than realistic school bus run conditions).

Following the school bus run, a further simulated school bus run was carried out to obtain supplementary speed radar measurements within various speed zones on SH 27, North of Matamata, on the way to the sign comparison data collection site.

## *Perceptions survey*

A perceptions survey, seeking feedback on the four main sign configurations and inviting further comment on school bus signs in general, was developed and distributed to rural schools (through school travel coordinators) and attendees at the annual Rural Women's conference in Auckland. The survey form is shown in Appendix A.

# RESEARCH FINDINGS

## SH 27 Static school-bus sign comparison

### *Overall findings*

The findings can be described using speed frequency distributions. Figure 5 shows the speed of the traffic without the school bus. Figure 6 shows the speeds with the standard "School" sign only, from Baas et al. 2010. The presence of the school bus with the LED 20 km/hr signs (including all variations of the sign as shown in Table 3) is shown in Figure 7.

Table 3. Vehicle count and speed data for all speed limit signs and baseline traffic conditions for traffic approaching from the rear (same side of road) and front (opposite side of road) of the bus.

| | Rear of bus | | Front of bus | |
|---|---|---|---|---|
| **Northbound (back of bus)** | **All signs** | **Baseline** | **All signs** | **Baseline** |
| **Vehicle Count** | 1019 | 1088 | 933 | 1045 |
| **Average Speed (km/hr)** | 64 | 95 | 82 | 98 |
| **Standard Deviation** | 23 | 11 | 19 | 9 |
| **Minimum Speed (km/hr)** | 17 | 15 | 25 | 40 |
| **Maximum Speed (km/hr)** | 114 | 130 | 113 | 135 |

Some of the key findings from these comparisons are:

- The signs on the back of the bus resulted in a 31km/hr reduction in the average speed of traffic in the same direction and side of the road as the bus. The signs on the front of the bus resulted in a 16 km/hr reduction in the average speed of traffic in the opposite direction and side of the road as the bus.
- The signs on both the back and front of the bus resulted in greater variability of traffic speeds. A comparison of Figure 5 and Figure 7 shows this very clearly.
- These findings show that a large number of motorists don't react to the sign, while others react to varying degrees. For motorists on the same side of the road as the bus, there appears to be a continuum of reactions, with some reacting very little through to others achieving or getting very close to the posted 20 km/hr. For motorists on the opposite side of the road, fewer motorists respond, but some motorists attempt to slow down significantly.

These findings suggest that, with this new type of sign (which most motorists will not have seen before), there are currently varying levels of comprehension and therefore varying levels of response.

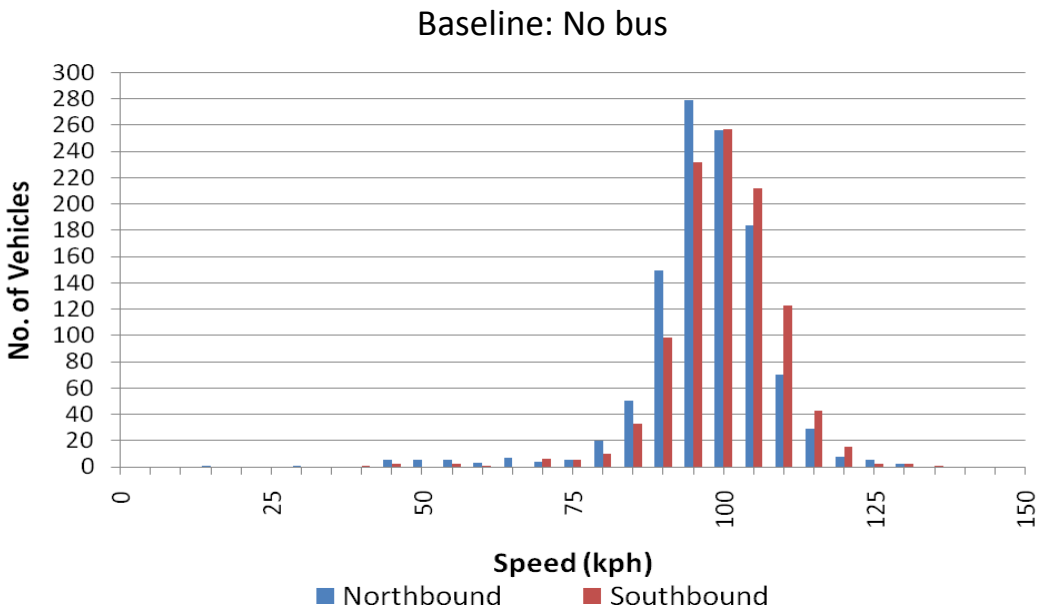


Figure 5. Speed frequency distribution for baseline (no bus) conditions in front of school on SH 27.

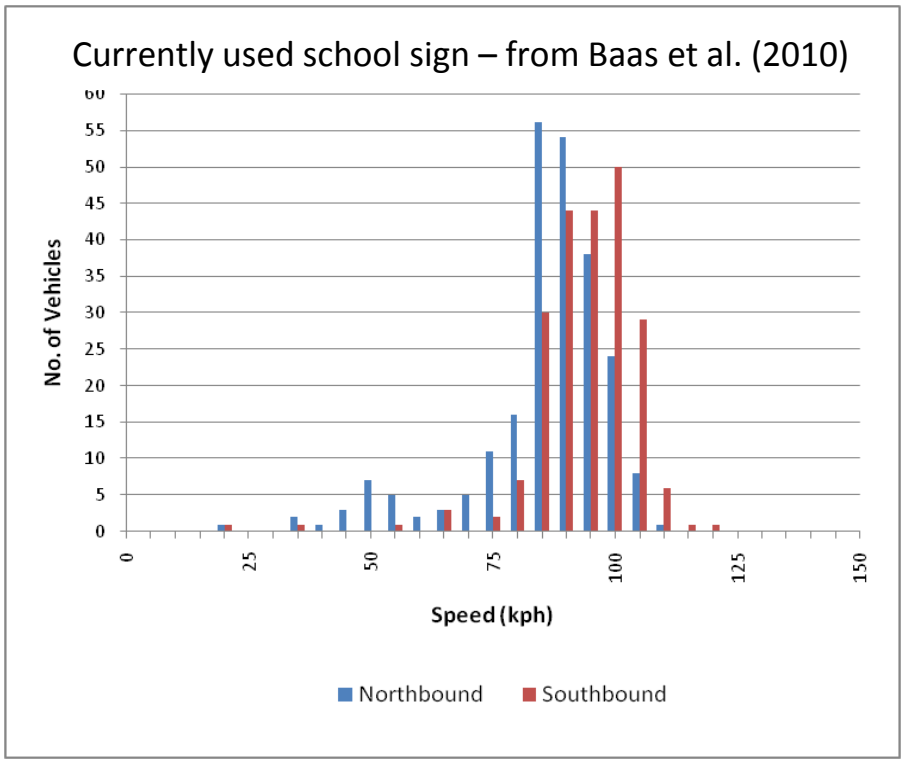


Figure 6. Speed frequency distribution for currently used "School" sign only taken from Baas et al. (2010).

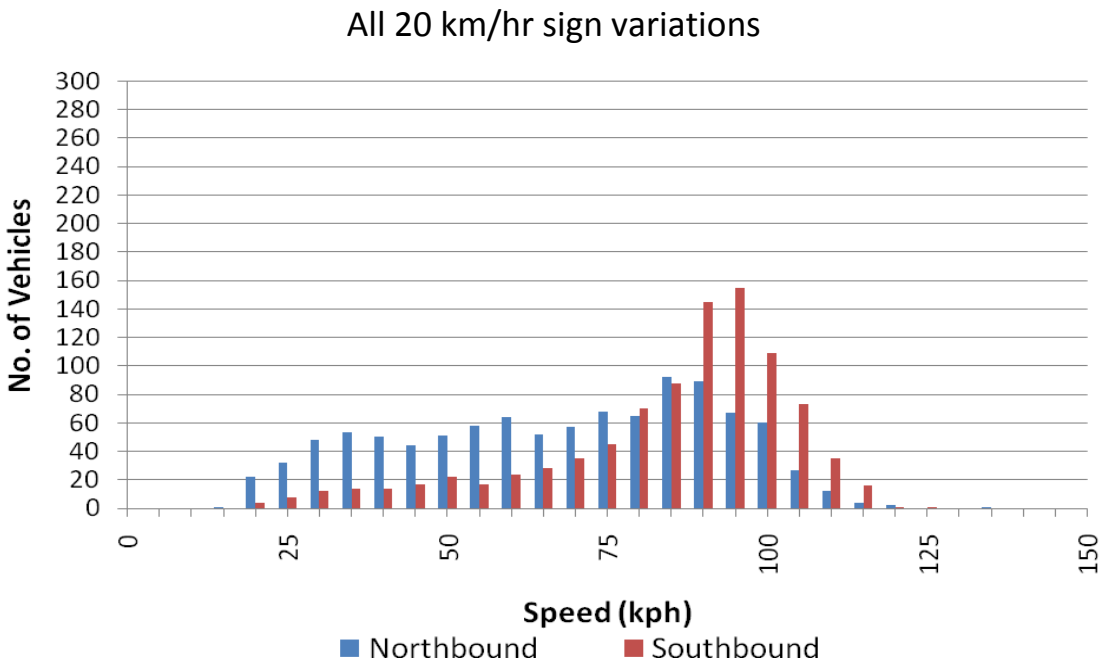


Figure 7. Speed frequency distribution for all of the trial speed limit school bus signs displayed on a parked bus in front of school on SH 27.

## *Comparison of sign variations*

Table 4 and Table 5 show the summarised count and speed data for each of the test conditions. For detailed data, including speed distribution graphs for each sign combination that was evaluated, please see Appendix B.

The key sign configuration that resulted in the slowest traffic speed was the small sign with LED roundel and flashing alternating beacons with the standard “School” sign displayed beneath, mounted on the rear of the bus (in a high position). The relative effects of individual sign features are explained in the following sections.

Table 4. Vehicle count and speed data for signs mounted on the back of the bus (Northbound, same direction traffic). Note: The blue columns represent the key (most different) sign comparisons.

**Northbound (Back of bus)**

| | Day 1 | | | | Day 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **TEST** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **Baseline** |
| **Test Description** | Small sign LED roundel Beacon School sign | Small sign LED roundel Beacon No School sign | Small sign LED roundel No beacon School sign | Small sign Retro Roundel No beacon School sign | Large sign LED roundel Beacon School sign | Large sign LED Roundel Beacon No School sign | Large sign LED Roundel No beacon School sign | Large sign Retro roundel No beacon School sign | No bus |
| **Vehicle Count** | 173 | 47 | 70 | 167 | 159 | 44 | 140 | 219 | 1088 |
| **Average Speed (km/hr)** | 57 | 64 | 60 | 73 | 63 | 56 | 64 | 72 | 95 |
| **Standard Dev** | 25 | 22 | 23 | 25 | 25 | 20 | 20 | 23 | 11 |
| **Minimum Speed (km/hr)** | 17 | 20 | 17 | 15 | 15 | 19 | 19 | 17 | 15 |
| **Maximum Speed (km/hr)** | 119 | 103 | 110 | 115 | 131 | 108 | 107 | 117 | 130 |

Table 5. Vehicle count and speed data for signs mounted on the front of the bus (Southbound, opposite direction traffic). Note: The blue columns represent the key (most different) sign comparisons

**Southbound (Front of bus)**

| | Day 1 | | | | Day 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **TEST** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **Baseline** |
| **Test Description** | Large sign LED roundel No beacon School sign | Large sign LED roundel No beacon No School sign | Large sign LED roundel No beacon School sign | Large sign Retro Roundel No beacon School sign | Small sign LED roundel No beacon School sign | Small sign LED Roundel No beacon No School sign | Small sign LED Roundel No beacon School sign | Small sign Retro roundel No beacon School sign | No bus |
| **Vehicle Count** | 171 | 44 | 86 | 149 | 132 | 44 | 140 | 167 | 1045 |
| **Average Speed (km/hr)** | 74 | 81 | 82 | 85 | 82 | 84 | 82 | 87 | 98 |
| **Standard Deviation** | 21 | 18 | 18 | 20 | 17 | 16 | 20 | 21 | 9 |
| **Minimum Speed (km/hr)** | 20 | 26 | 31 | 19 | 34 | 28 | 25 | 18 | 40 |
| **Maximum Speed (km/hr)** | 113 | 109 | 111 | 121 | 105 | 112 | 111 | 119 | 135 |

## *Effects of sign size*

On the front of the bus, the small and large signs were placed in identical locations, whereas on the rear of the bus, the small sign was mounted high and closer to the traffic side on the rear window and the large sign was mounded more centrally and lower on the bus due to sign mounting constraints. For a comparison of sign size only, the Day 1 and Day 2 data for the font of the bus (Southbound, traffic opposite to bus) can be compared between days. For a comparison of the combination of sign size with sign placement, the back of bus data can be compared between days.

Table 6. Effect of sign size (front) and combined sign size with placement (back) on traffic speed

| | **Day 1** | **Day 2** |
|---|---|---|
| **Back of bus** | **Small/high** | **Large/lower** |
| **Speed (km/hr)** | 63 | 70 |
| **Front of bus** | **large** | **small** |
| **Speed (km/hr)** | 81 | 84 |

Table 6 shows that when sign size only is compared (front of bus between days), then the larger sign was associated with slightly lower traffic speeds ($P<0.001$, unpaired two-tailed t-test). Although this finding was statistically significant, it may not be significant in practice as 81 km/hr may be too fast to react to a child who runs out from behind a school bus.

When a combination of sign size and position is compared, the smaller/higher sign was associated with a significantly lower traffic speed compared with the large lower sign ($P<0.001$, unpaired two-tailed t-test). These findings suggest that the placement of the sign on the bus may be more important that its size. A higher sign that is also placed to the right and therefore closer to the traffic path, may be more visible to vehicles that are following other vehicles.

## *Effects of roundel and overall sign illumination*

A comparison of the LED roundel and retro-reflective roundel conditions only was carried out by comparing tests 1 and 4 in day 1 and 5 and 8 in day 2 for the front of the bus only.

Table 7. Effects of roundel type on traffic speeds

| | **Roundel type** | |
|---|---|---|
| | **LED** | **Retro-reflective** |
| **Large sign (speed km/hr)** | 74 | 85 |
| **Small sign (speed km/hr)** | 82 | 87 |

Table 7 shows that the LED roundel conditions resulted in lower traffic speeds ($P<0.001$, unpaired two-tailed t-test).

To examine the effects of a generally higher level of illumination (LED roundel plus beacons vs retro-reflective roundel without beacons) a comparison between tests 1 and 4 in day 1 and between tests 5 and 8 in day 2 for the back of the bus (Northbound) was carried out.

Table 8. Effects of level of illumination (roundel type plus beacons) on traffic speed

| | Level of illumination | |
|---|---|---|
| | **LED roundel plus beacon** | **Retro roundel No beacon** |
| **Small sign (speed km/hr)** | 57 | 73 |
| **Large sign (speed km/hr)** | 63 | 72 |

Table 8 shows, in a similar way to Table 7, that a higher level of illumination (LED roundel plus beacons) resulted in lower traffic speeds.

### *Effects of "school" sign and beacons*

Supplementary trials of a lower time duration (and less data) were carried out to examine the effects of removing the standard "School" sign, and also to examine the effects of the flashing/alternating beacons. Because less data was collected for these supplementary trials, less emphasis is given to their findings.

In most cases the effects of removing the "School" sign resulted in higher traffic speeds. An exception to this was on Day 2 for the rear of the bus when the large sign was being trialled. In this case, removing the "School" sign resulted in average traffic speeds of 7km/hr lower. However, only 44 vehicle passes were collected for the 'no School sign' condition, so this finding should be treated with caution.

The removal of the beacons for otherwise identical trials (rear of bus only), caused modest increases in traffic speeds. During Day 2, with the large sign on the rear of the bus, a 'no beacons' condition of 140 vehicle passes resulted in an increased average speed of only 1 km/hr. The previous day's 'no beacons' conditions resulted in a 3km/hr reduction in average speed (but there were only 70 vehicle passes for this condition).

## School bus run speed measurements

For school bus run measurements the bus was fitted with the 'Test 1' sign configuration, that is, rear small sign with LED roundel and flashing beacons, front large sign with LED roundel and no flashing beacons. A total of 19 vehicles (not including following vehicles) passed the school bus when it was either stationary or close to stationary. Seven of these vehicle passes were on rural high speed roads and twelve were on urban roads (within Matamata). The average rural passing speed was 46 km/hr (approx. 40m from the bus) and the average urban passing speed was 29 km/hr.

Although the bus run gave an indication of likely realistic traffic speed past the school bus, the data was very limited and time consuming to obtain. This data was therefore supplemented with 'simulated bus run' data where the bus pulled over at various locations along SH 27 immediately following the school bus run (Table 9). Speed gun measurements (speed and measurement distance from the gun) were taken within 50, 70 and 100 km/hr areas, for traffic travelling in the same and opposite directions.

Table 9. Simulated 'bus run' measurements

| Zone | count same direction | Ave speed same direction (km/hr) | Ave measure dist same (m) | Count Opposite direction | Ave speed Opposite direction (km/hr) | Ave measure dist opp (m) |
|---|---|---|---|---|---|---|
| 50km/hr | 16 | 41 | 46 | 8 | 42 | 51 |
| 70km/hr | 7 | 39 | 41 | 4 | 37 | 50 |
| 100km/hr | 11 | 55 | 42 | 10 | 77 | 67 |

The actual and simulated bus run measurements show that overall realistic speeds past a school bus with the LED 20 km/hr signs are likely to be lower than the sign comparison speeds on SH 27 only, mainly because an actual bus run is likely to involve a significant amount of travel on lower speed roads. When the 100 km/hr zone data from the simulated bus run is compared with the data for 'Test 1' from the static bus speed data, the results are very similar. This indicates that the static bus data is likely to be representative of the speeds that would be expected on the same road type during a school bus run.

## Perceptions survey

A total of 34 people responded to the stakeholder perceptions survey. The following section summarises responses to each of the survey questions.

**Question 1)** In terms of effectiveness, please score each sign below by *circling your chosen number*. 1 = not at all effective → 5 = very effective

Table 10. Ratings of sign effectiveness. Note: This question was limited to pictures of signs on the rear of the school bus.

| | **Sign A** Small sign, reflective red circle around illuminated number | **Sign B** Small sign, illuminated red circle around illuminated number | **Sign C** Large sign, reflective red circle around illuminated number | **Sign D** Large sign, illuminated red circle around illuminated number |
|---|---|---|---|---|
| **Sign is noticeable/catches attention** | 2.6 | 4.4 | 3.0 | 3.9 |
| **Sign is easy to understand** | 3.0 | 4.3 | 3.4 | 4.2 |
| **Sign would slow traffic** | 2.5 | 4.4 | 3.2 | 4.0 |
| **Overall sign effectiveness** | 2.6 | 4.5 | 3.1 | 3.9 |

Sign B (below) ranked the highest for all four measures of effectiveness.


**Sign B.** Small sign, illuminated red circle around illuminated number

Comments supporting this question included (with most frequent comment in **bold**):

reflected red circle not effective if car behind doesn't have lights on
Need education - drivers don't know 20km past school bus rule
**Needs to be higher so it can be seen from further back**
Flashing lights catch the drivers eyes

**Question 2)** Do you think it is important to display the existing yellow "School" sign along with the illuminated speed limit signs? (Please circle Y/N). What was the reason for you answer above?

100% of respondents answered "Yes" to this question. Supporting comments included:

to make sure that people realise it's a school bus and children around
everything helps
so they know why they are slowing down
it makes it clear to approaching traffic why the 20 sign is there

**Question 3)** Do you think flashing alternating orange lights are an important feature of these signs? (Please circle Y/N). What was the reason for you answer above?

100% of respondents answered "Yes" to this question. Supporting comments included:

shows up in the distance
attracts your attention more

**Question 4)** If any of these signs were to be used on school buses in the future a number of practical things need to be considered in terms of set-up and maintenance costs and ease of integration with school bus etc. It may be that the signs are more likely to be used or get used on more buses if some of these practical considerations are kept to reasonable levels. For example, a bigger sign might seem more effective but would cost more and be more difficult to fit to the bus. Comparing these practical considerations

with the overall sign effectiveness, which sign do you believe would be the best option (please tick)?

Table 11. Chosen sign option given practical considerations

| | **Sign A** Small sign, reflective red circle around illuminated number | **Sign B** Small sign, illuminated red circle around illuminated number | **Sign C** Large sign, reflective red circle around illuminated number | **Sign D** Large sign, illuminated red circle around illuminated number |
|---|---|---|---|---|
| Which sign best option? | 1 | 22 | 3 | 2 |

Table 11 shows a clear preference for Sign B, as per Question 1.

**Question 5)** Do you have any further comments or suggestions about signs on school buses?

Comments included:

Suggestion - sign D raised to position of A or B for visibility of drivers behind the vehicle immediately following the bus.

It's the height of the sign that's more important than size. I've seen lights on top of school buses in America when flashing you do not pass

A great idea and I hope it will be taken up by the government and education board

Not signs on buses but speed limits past schools at critical times need to be reduced greatly

Should be accompanied by flashing lights as high on the bus as possible. Lights should be turned on as soon as the bus starts to slow down

TV education of public about the signs and the laws of passing a school bus

# DISCUSSION AND RECOMMENDATIONS

## Overall findings

It is clear that a 20 km/hr illuminated sign mounted on a school bus has a significant effect on average traffic speed and speed distribution. The more effective variations resulted in similar speed reductions reported by Baas (2010), who used a 40 km/hr illuminated school zone sign. The significant variation in motorist speed responses to the signs is a concern as less homogenous speeds have been linked with a lower level of safety (Aarts and van Schagen, 2006). It is not known whether the overall reduced mean traffic speed would have an impact on road safety sufficient to offset any negative effects caused by the increased speed distribution. The variation in speeds is likely because many motorists have forgotten what the speed limit is when passing school buses.

However, if the signs were used in greater numbers, motorists would come to expect their presence, and would be more likely to act as required. Recognisability is a key principle within the 'Self explaining roads' concept (Charlton et al 2010, Theeuwes & Godthelp 1995, van Vliet and Schermers 2000) where motorists are more likely to react positively to things they understand and with which they are familiar.

### *Comparison of sign variations*

The stationary school bus evaluation and the perceptions survey suggest that the smaller sign with an LED roundel and beacons is likely to be the most effective and supported sign variation. Based on these findings, this sign variation is recommended for implementation. Although the beacons alone provided only modest reductions in traffic speeds, flashing alternating beacons may also improve driver awareness state. The extent of this effect is still unclear although some supporting evidence for their use comes from the previous school bus safety study (Baas et al. 2010), where a step-change downward in passing traffic speeds resulted from the introduction of signs that included flashing beacons.

The lowest quoted cost per unit of the small sign with LED roundel is approximately $256 without the flashing beacons and $422 with the beacons if purchased in lots of 100 or more. The other two quotes obtained were much higher.

## Recommendations

Based on the findings of this study and supporting knowledge from other studies, the following actions are recommended:

1. An LED speed limit school bus sign is supported and should be progressed for use as soon as practically possible. Based on the findings of this study a smaller sign with LED roundel and flashing beacons is recommended on the front and rear of the bus. This sign should be displayed in addition to the existing "School" sign to maximise comprehension and credibility.
2. In order to maximise the effectiveness of the signs and mitigate safety risks, the following steps are recommended as part of the introduction of LED speed limit school bus signs:

   It is recommended that:

   a) Approximately 50-100 buses should be fitted with the signs after testing to make sure the production units are suitable and robust. Speed and driver behaviour around buses within the area should then be monitored with the signs in service.

   b) At the same time an area-wide publicity campaign should be undertaken to raise awareness. Following a) and b) enforcement should be carried out as needed

c) Long-term monitoring is recommended to ensure appropriate road-user behaviour is achieved and maintained.

For all steps, special consideration should be given to the locations where school buses are likely to stop with the signs illuminated and Traffic Note 44 (Safe Siting of School Buses) addresses this. While motorists become familiar with them, the signs should only be illuminated when there is sufficient sight distance on approach to the bus.

3. The results should be used to determine the best mix of sign design, awareness campaign and enforcement activities for nationwide implementation.

# References


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Australasian College of Road Safety (2004) ACRS policy position. Canberra: Australasian College of Road Safety. Accessed 27 August 2009. *www.acrs.org.au/collegepolicies/people/alcohol.html*

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Charlton, S.G., Mackie, H.W., Baas, P.H., Hay, K., Menezes, M. and Dixon, C. (2010). Using endemic road features to create self-explaining roads and reduce vehicle speeds. Accident Analysis and Prevention, 42, 1989–1998.

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National Highway Traffic Safety Administration (NHTSA) (2006) Traffic safety facts. Washington DC: NHTSA. Accessed 27 August 2009. *www-nrd.nhtsa.dot.gov/Pubs/810809.PDF*

Schofield, GM, S Gianotti, HM Badland and EA Hinckson (2008) The incidence of injuries travelling to and from school by travel mode. *Preventive Medicine 46*: 74–76

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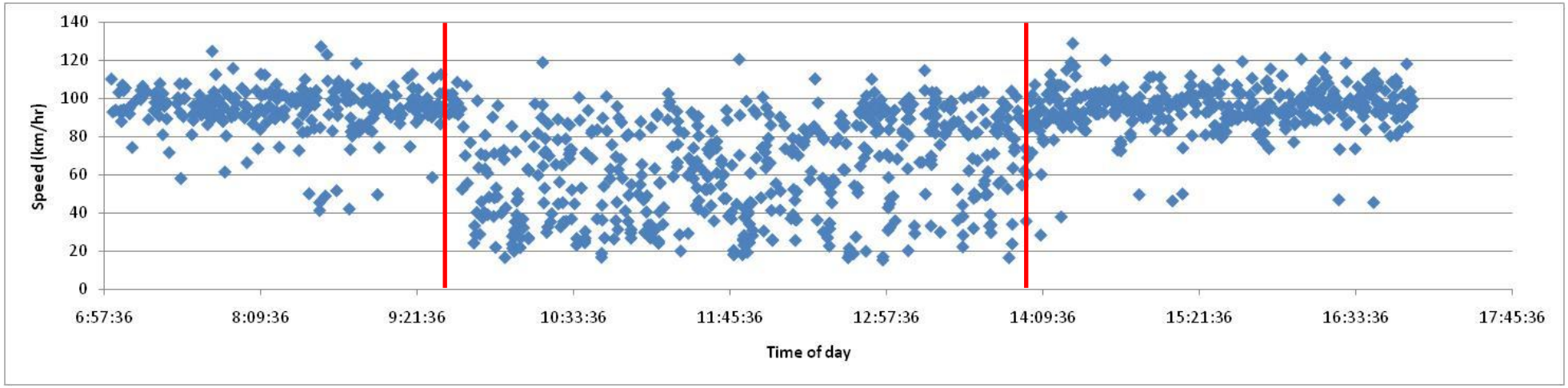
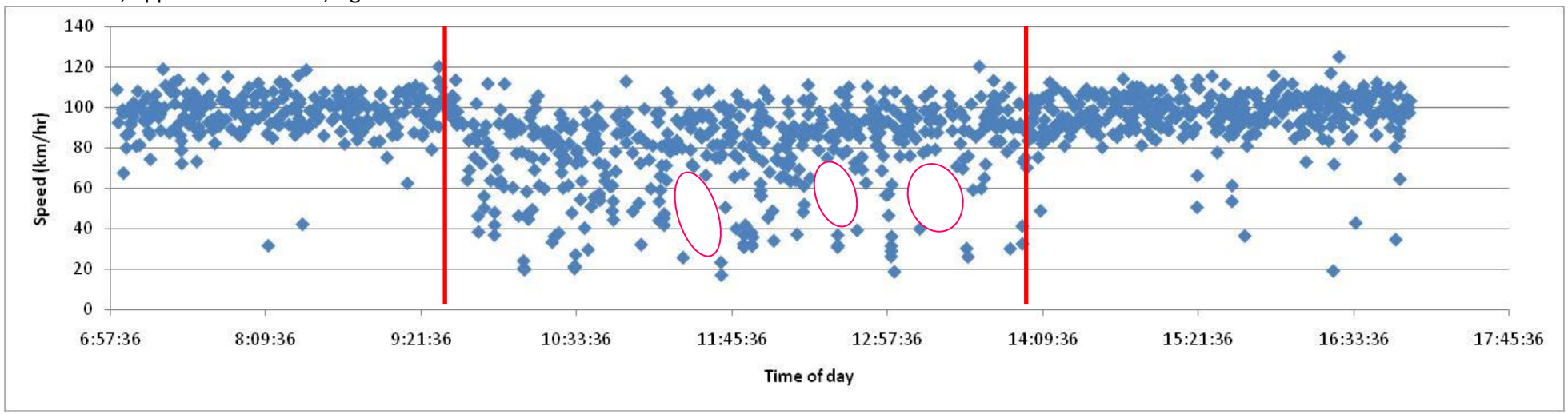
# Appendix A. Raw data

Northbound, same side as bus, sign on rear of bus




Southbound, opposite side to bus, sign on front of bus




Raw data for Day 1, showing effects of school bus signs (between red lines) and the differences between northbound and southbound sign effectiveness. The pink circles show periods of time where relatively fewer vehicles slowed for the signs. The reason for this is unclear.

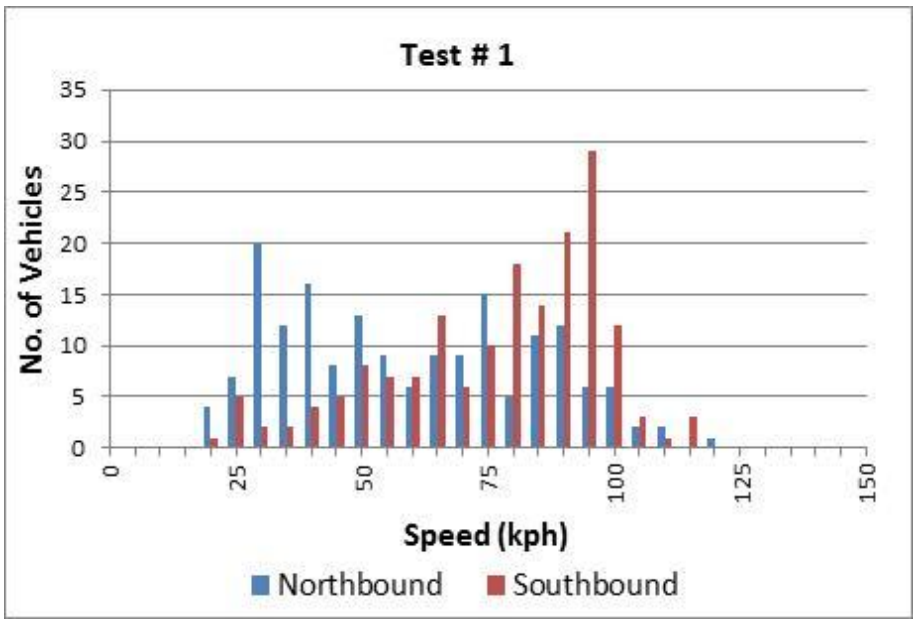
## Appendix B. Data for individual sign variations

# Key Tests

**Test 1: Small sign, LED roundel, beacon, school sign (northbound, rear of bus)**
**Large sign, LED roundel, no beacon, school sign (southbound, front of bus)**



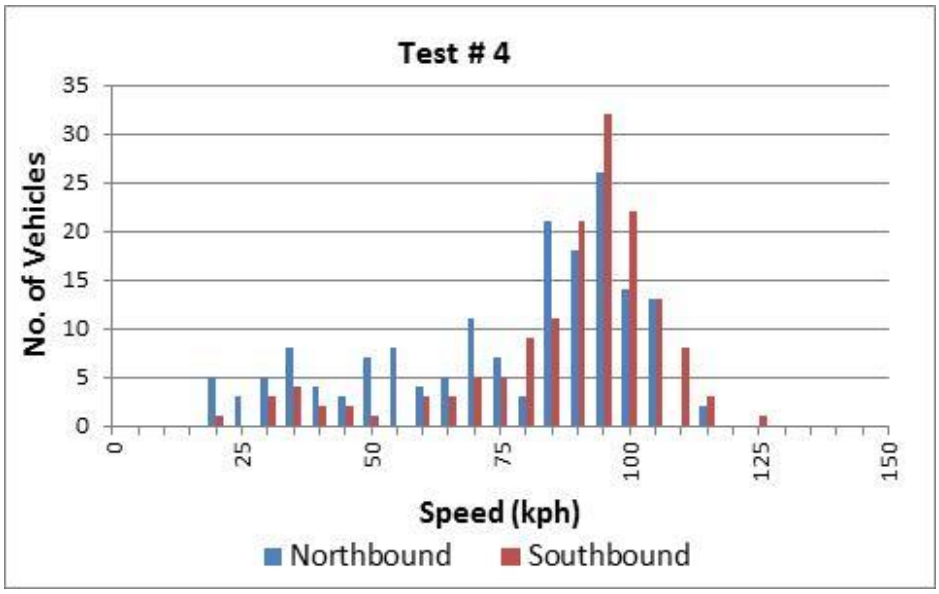
| Test 1 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 173 | 171 |
| Average Speed | 57 | 74 |
| Standard Deviation | 25 | 21 |
| Minimum Speed | 17 | 20 |
| Maximum Speed | 119 | 113 |



**Test 4: Small sign, retro reflective roundel, no beacon, school sign (northbound, rear of bus)**
**Large sign, retro reflective roundel, no beacon, school sign (southbound, front of bus)**



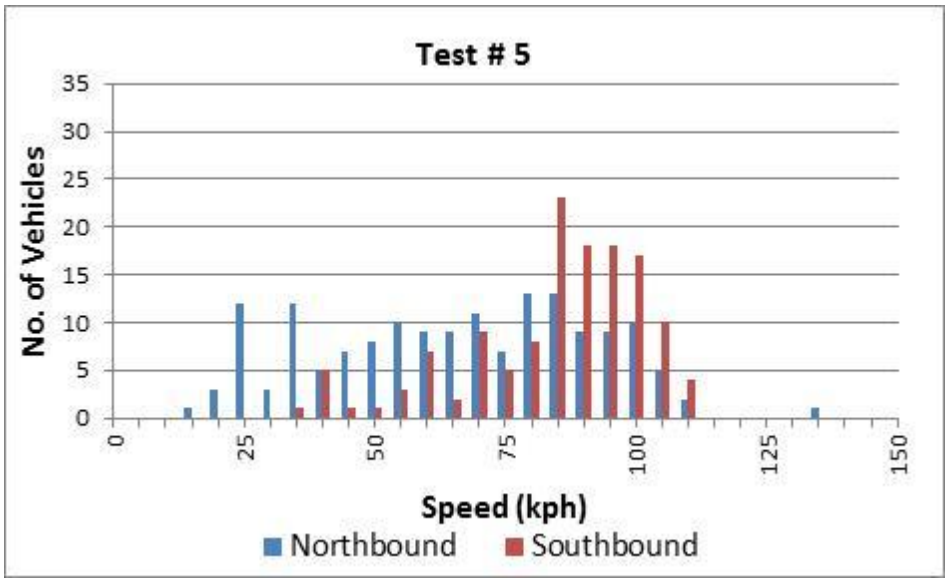
| Test 4 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 167 | 149 |
| Average Speed | 73 | 85 |
| Standard Deviation | 25 | 20 |
| Minimum Speed | 15 | 19 |
| Maximum Speed | 115 | 121 |



**Test 5: Large sign, LED roundel, beacon, school sign (northbound, rear of bus)**
**Small sign, LED roundel, no beacon, school sign (southbound, front of bus)**



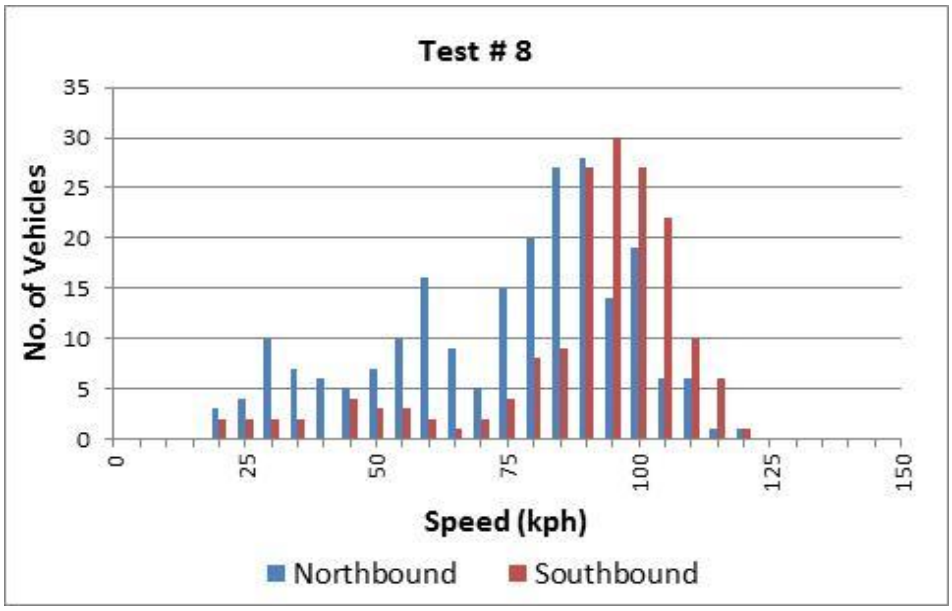
| Test 5 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 159 | 132 |
| Average Speed | 63 | 82 |
| Standard Deviation | 25 | 17 |
| Minimum Speed | 15 | 34 |
| Maximum Speed | 131 | 105 |



**Test 8: Large sign, retro reflective roundel, no beacon, school sign (northbound, rear of bus)**
**Small sign, retro reflective roundel, no beacon, school sign (southbound, front of bus)**



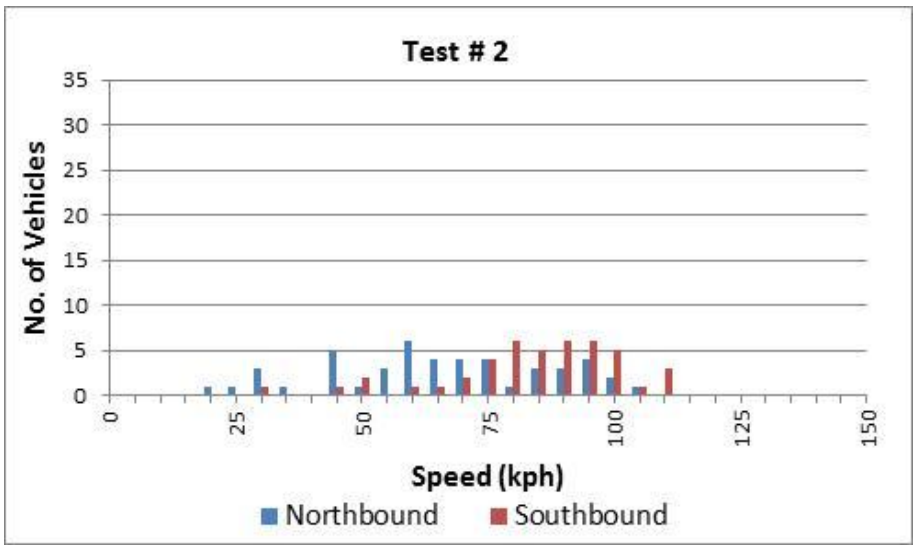
| Test 8 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 219 | 167 |
| Average Speed | 72 | 87 |
| Standard Deviation | 23 | 21 |
| Minimum Speed | 17 | 18 |
| Maximum Speed | 117 | 119 |



# Supplementary tests

**Test 2: Small sign, LED roundel, beacon, no school sign (northbound, rear of bus)**
**Large sign, LED roundel, no Beacon, no school sign (southbound, front of bus)**

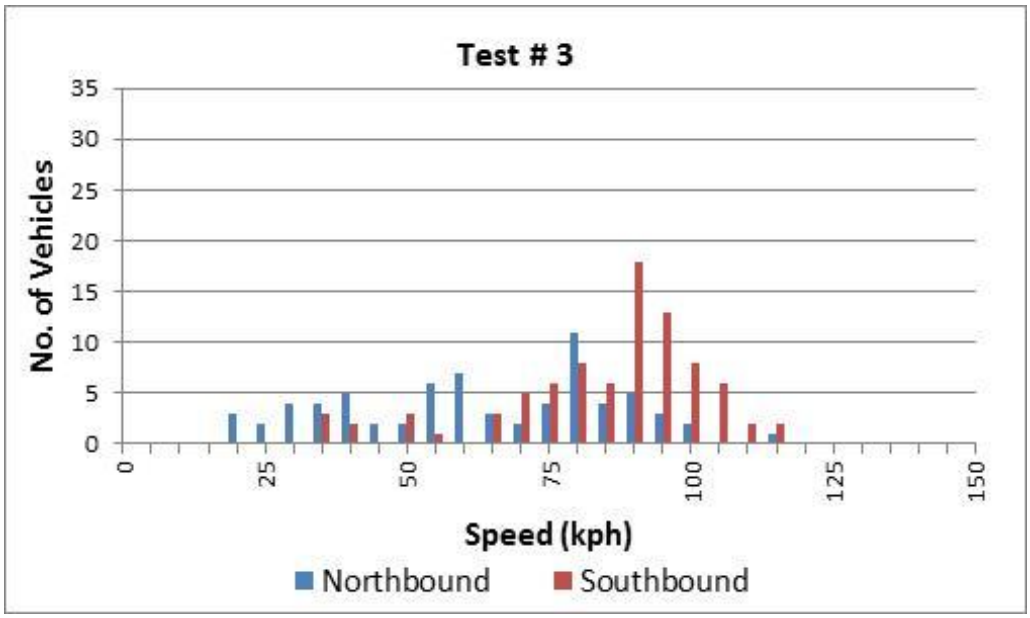

| Test 2 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 47 | 44 |
| Average Speed | 64 | 81 |
| Standard Deviation | 22 | 18 |
| Minimum Speed | 20 | 26 |
| Maximum Speed | 103 | 109 |



**Test 3: Small sign, LED roundel, no beacon, school sign (northbound, rear of bus)**
**Large sign, LED roundel, no beacon, school sign (southbound, front of bus)**



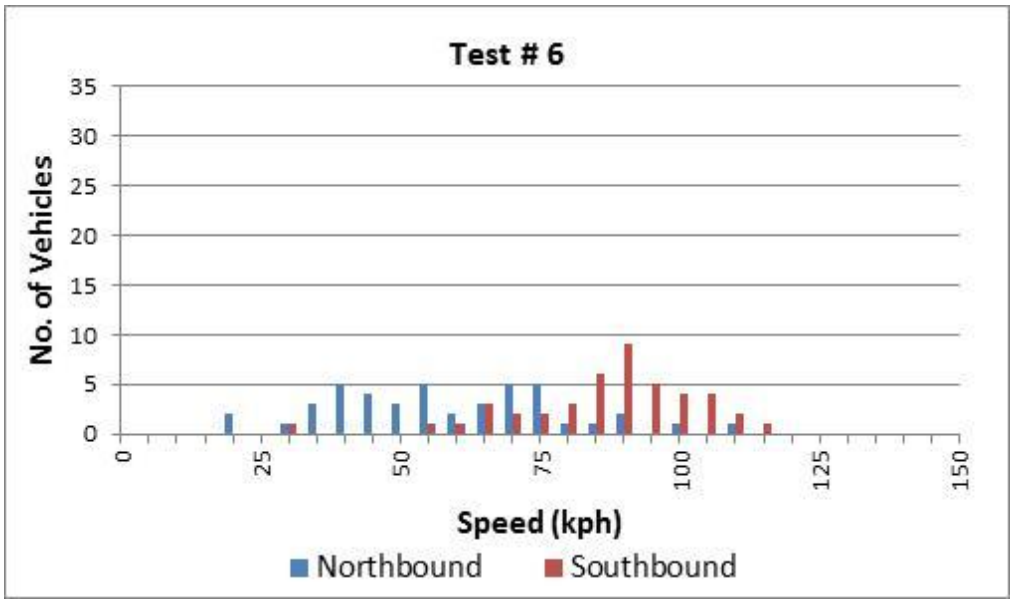
| Test 3 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 70 | 86 |
| Average Speed | 60 | 82 |
| Standard Deviation | 23 | 18 |
| Minimum Speed | 17 | 31 |
| Maximum Speed | 110 | 111 |



**Test 6: Large sign, LED roundel, beacon, no school sign (northbound, rear of bus)**
**Small sign, LED roundel, no beacon, no school sign (southbound, front of bus)**



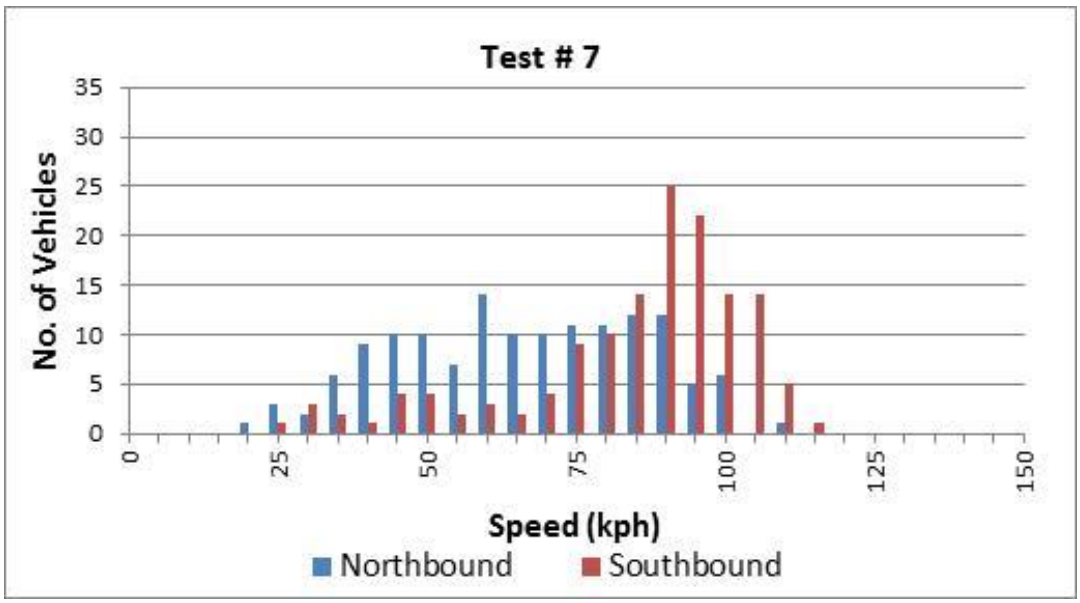
| Test 6 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 44 | 44 |
| Average Speed | 56 | 84 |
| Standard Deviation | 20 | 16 |
| Minimum Speed | 19 | 28 |
| Maximum Speed | 108 | 112 |



**Test 7: Large sign, LED roundel, no beacon, school sign (northbound, rear of bus)**
**Small sign, LED roundel, no beacon, school sign (southbound, front of bus)**



| Test 7 | Northbound, rear of bus | Southbound, front of bus |
|---|---|---|
| Vehicle Count | 140 | 140 |
| Average Speed | 64 | 82 |
| Standard Deviation | 20 | 20 |
| Minimum Speed | 19 | 25 |
| Maximum Speed | 107 | 111 |



## Appendix C. Perceptions survey

# School bus signs

## – Stakeholder perceptions survey

Thank you for agreeing to provide feedback on school bus signs that are currently being trialled as part of a Road Safety Trust research project. Your valuable feedback is an important part of this project.

Please study the following trial school bus signs and answer the questions over the page. When answering the questions please assume the ***signs are being used in rural high speed environments.***


**Sign A.** Small sign, reflective red circle around illuminated number


**Sign B.** Small sign, illuminated red circle around illuminated number


**Sign C.** Large sign, reflective red circle around illuminated number


**Sign D.** Large sign, illuminated red circle around illuminated number

***You are welcome to keep this page for your future reference***

# Questions:

1) In terms of effectiveness, please score each sign below by *circling your chosen number*.
   1 = not at all effective → 5 = very effective

| | **Sign A** | **Sign B** | **Sign C** | **Sign D** |
|---|---|---|---|---|
| Sign is noticeable / catches attention | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 |
| Sign is easy to understand | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 |
| Sign would slow down traffic | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 |
| Overall sign effectiveness | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5 |

Do you have any comments to support your choices above?

_____
_____
_____

2) Do you think it is important to display the existing yellow "School" sign along with the illuminated speed limit signs? (Please circle) Y / N

What was the reason for you answer above?

_____
_____
_____

3) Do you think flashing alternating orange lights are an important feature of these signs? (Please circle) Y / N

What was the reason for you answer above?

_____
_____
_____

4) If any of these signs were to be used on school buses in the future a number of practical things need to be considered in terms of set-up and maintenance costs and ease of integration with school bus etc. It may be that the signs are more likely to be used or get used on more buses if some of these practical considerations are kept to reasonable levels. For example, a bigger sign might seem more effective but would cost more and be more difficult to fit to the bus. Comparing these practical considerations with the overall sign effectiveness, which sign do you believe would be the best option (please tick)?

**Sign A_____** **Sign B_____** **Sign C_____** **Sign D_____**

5) Do you have any further comments or suggestions about signs on school buses?

_____
_____
_____

# Appendix D. Gazette Notice for school bus sign trial

## Land Transport Rule: Traffic Control Devices 2004

## Traffic sign – active speed limit for school buses trial

Pursuant to subclause 3.4(1) of the Land Transport Rule: Traffic Control Devices 2004 (the Rule) and pursuant to a sub-delegation to me by the New Zealand Transport Agency, I, Glenn Bunting, Network Manager, hereby authorise the installation and maintenance of alternative traffic signs:

(i) for the purpose described in Schedule 1;
(ii) in the form and layout, set out in Schedule 2;
(iii) at the location stated in Schedule 3;
(iv) for the period specified in Schedule 4; and
(v) subject to the terms and conditions detailed in Schedule 5.

The alternative signs shall be used for the purpose of evaluating their use and the trial shall be called the "Active speed limit for school buses trial".

**Schedule 1—Purpose of trial**

The purpose of the trial is to evaluate the effectiveness and safety of signs that differ from that specified in:

(a) subclauses 4.4(14) to (16) in relation to their use; and

(b) Schedule 1 in relation to their format.

**Schedule 2—Form and layout of signs**

The signs will be one of the following descriptions:

*When illuminated the sign indicates to drivers that the speed limit passing the school bus upon which it is installed is 20km/h.*

***Option A*** (small sign)

Shape and Size: Rectangle 450 x 450 mm

Background: Black

Border: none

Legend:

| *Description* | *Colour* | *Size* |
|---|---|---|
| R1-1 with a speed limit of '20' | Roundel red (R) OR red (lit) | Diameter 350mm Width 30mm Effective width 30 mm |
| | '20' white (lit) | 150/effective 20mm |
| Optional lights top left and right that flash alternately | Yellow or white when lit | Effective40 mm |

***Option B*** (large sign)

Shape and Size: Rectangle 750 x 750 mm

Background: Black

Border: none

Legend:

| *Description* | *Colour* | *Size* |
|---|---|---|
| R1-1 with a speed limit of '20' | Roundel red (R) OR red (lit) | Diameter 600mm Width 75mm Effective width 30 mm |
| | '20' white (lit) | 200/effective 30mm |
| Optional lights top left and right that flash | Yellow or white when lit | Effective65 mm |

alternately

**Schedule 3—Location**

The locations approved for this trial are as follows:

(a) Static trial – State highway 27 adjacent to Te Kura Kaupapa Maori o Te Rau Aroha School.

(b) Mobile trials – selected school bus routes within Matamata-Piako District.

**Schedule 4—Period of trial**

The trial shall start after the publication of this notice and, unless terminated earlier, end by 30 June 2011.

**Schedule 5—Conditions**

An evaluation will be undertaken consisting of a series of speed measurements as outlined in the proposal received from Transport Engineering Research NZ Ltd, Auckland dated 21 December 2010 with the title "Development of an active speed limit sign for school buses".

Dated at Wellington this 1st day of February 2011.

GLENN BUNTING, Network Manager