Evaluation of School Bus Signalling Systems

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by

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Andrew Raczkowski provided technical assistance. The University of NSW conducted the photometric tests. The Road Safety Bureau library also assisted with this project.

EXECUTIVE SUMMARY

School children who are hurrying to catch a bus in the morning or who have just disembarked from a bus in the afternoon might not cross the road with care. Motorists in the vicinity of the bus should be alert to the possibility of children on the road. These motorists should be travelling at a speed which gives them a reasonable chance to stop in time if a hazardous situation arises.

During 1994 New South Wales implemented a range of measures to address this issue, including the fitting of "wig wag" flashing yellow lights and signs at the front and rear of school buses. An RTA technical specification sets out the requirements for the lamps and signs fitted to school buses in NSW. There has been considerable debate about the effectiveness of the systems.

The NSW Staysafe Committee, in a report on school children around school buses (Staysafe, 1994), made a series of recommendations on this subject.

The NSW Bus Safety Advisory Committee, in reviewing the Staysafe recommendations, decided to arrange for testing of several possible signalling systems. Subsequently, the authors were engaged by the NSW Department of Transport to carry out this work.

The project included a field evaluation of four types of school bus signalling systems and an examination of the functional requirements of a signalling system, together with photometric and visual ergonomic issues, leading to a model specification for school bus signals.

FIELD EVALUATION

Four system were evaluated; Current (yellow flashing lights plus signs with children in accordance with the current RTA Technical Specification 142), Bright Yellow (using high intensity signal units in place of the current yellow signal units), Moncrieff (illuminated pictograms of child) and Red & Yellow (current system plus red lights). The four systems were viewed from 250, 100 and 50 metres by 39 participants who completed a questionnaire.

In summary the results were:

a) Visibility of signal light

The Bright system was superior at all distances - this is to be expected as subsequent photometric measurements found it to have about ten times the luminous intensity of the other signal lights. Sufficiency, in terms of drawing attention to the bus, was poor (about 50% or less positive responses) for the Current and Moncrieff system, even at 50m.

b) Visibility of sign

From a distance of 100m 20% of participants indicated they could not see the sign (picture of children) for the Current, Bright and Red & Yellow systems; this sign being prescribed in RTA Technical Specification 142. Less than 50% of respondents indicated they could see the sign on the Moncrieff system from this distance. In all cases the signs were ineffective when viewed from 250m.

c) Effectiveness of total system

The Bright system was again superior at all distances but its superiority over the Red & Yellow system was reduced. In the case of both systems the poor visibility of the sign (see (b)) appears to have been compensated for somewhat by the enhanced signal lights, in one case by increased intensity and the other by the inclusion of a red signal. The effectiveness of the Moncrieff system was inferior to all the other systems.

d) Reaction to signal

The appropriate response (slow down and prepare to stop) was not made by a significant number of the participants. Relatively few participants nominated an appropriate speed to which they should slow down. About one third of the participants indicated they would stop and wait for the bus.

REQUIREMENTS OF A SIGNALLING SYSTEM FOR SCHOOL BUSES

Functional requirements

The function of a school bus signalling system is to alert motorists who are approaching from either direction to the possibility of children on the road in the immediate vicinity of a bus which is stationary or has just departed. This must occur at a **sufficient distance** to enable the motorist to take action to avoid an accident.

To be effective the system must satisfy each of three requirements:

A It must be **readily seen** by approaching motorists and it must **command their attention**. It must be conspicuous from other signals and signs and the general visual clutter at the front and the rear of buses. It must stand out in adverse lighting conditions such as bright daylight.

B It must be **recognised** as indicating the possibility of school children in the immediate vicinity of the bus, in a clear, credible and unambiguous manner.

C It must elicit an **appropriate response** from the motorists, such as slowing down and preparing to stop to avoid an accident.

Signalling system visibility

1. The signalling system requires a signal range of 250m
2. This range is not available from the systems specified in RTA Technical Specification 142 because the flashing signal lights are too dim and the sign is too small

Signalling system message

3. The message ("slow down and be prepared to stop to avoid an accident") should be based on flashing signal lights supplemented by a reinforcing message
4. Replacing the yellow signal lights of the current system with ones of higher intensity improves, somewhat, the effectiveness of the system but there is scope for further improvement.
5. A high-priority warning signal light system of yellow and red lights should be introduced, the precedence having been established for road signs. This system should be used for school bus signalling systems but not reserved exclusively for it.
6. A flashing "40" sign would provide positive reinforcement to the signals in both eliciting the desired response from motorists and unambiguously indicating the appropriate speed.

Signal configuration

7. The flashing signal lights should be mounted in red and yellow pairs at the front and rear of the bus, as high as possible in the locations as set out in RTA Technical Specification 142. In addition the signals must be mounted so that the reference axis of the signal unit is parallel to the longitudinal axis of the bus; the current signals on some buses are mounted on sloping surfaces such that the signals point up in the air.

System Specification

8. A photometric specification is necessary in order to realise the required signal range whilst controlling the potential for the signal to be over-bright. A model photometric specification for yellow and red signal lights is given in the following tables.

Degrees from Reference Axis		**Degrees from Reference Axis**								
		Left					**Right**			
		30	**15**	**10**	**2.5**	**0**	**2.5**	**10**	**20**	**30**
Up	**5**					500				
	3					700				
	1.5					1400				
	0		500	700	1400	1400	1400	700	500	
Down	**1.5**					1400				
	3					700				
	5					500				
	10	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*

Recommended Intensities for a flashing yellow signal light

Degrees from Reference Axis		**Degrees from Reference Axis**								
		Left					**Right**			
		30	**15**	**10**	**2.5**	**0**	**2.5**	**10**	**20**	**30**
Up	**5**					170				
	3					230				
	1.5					470				
	0		170	230	470	470	470	230	170	
Down	**1.5**					470				
	3					230				
	5					170				
	10	*70*	*70*	*70*	*70*	*70*	*70*	*70*	*70*	*70*

Recommended Intensities for a flashing red signal light

Notes:

(i) The intensities shown are minimum values except those at 10° down which are maximum (*italicised*).

(ii) The minimum intensities shall not be exceeded by more than 50%.

(iii) The intensity between test points shall change in a smooth manner.

(iv) The intensity shall be measured for a steady light run at the signal operating voltage (12.8V or 25.6V).

(v) The intensities include provision for a manufacturing tolerance.

9. Only yellow and red colours shall be used and these shall be in accordance with ADRs 6 and 49 respectively.

10. The flash rate of each signal shall be between 60 and 75 cycles per minute. The flash sequence shall be red-left, yellow-right then yellow-left, red-right (the start of operation can be at any part of the cycle). As one light is extinguished the next light shall be energised.

11. The provision of a black surround should not be mandatory, but if provided shall be of a matt finish.

12. Signs based on the current system shall be in accordance with RTA Technical Specification 142.

    If provided, a flashing "40" sign shall be red, shall flash in unison with the signal lights and shall have a minimum character height of 150mm.

14. High intensity flashing signal lights shall continue to operate for 5 seconds after the bus doors are closed.

Discretionary Signalling Systems

15. Signal lights and signs, other than those prescribed in clauses 7 to 14, should not be permitted.

Practical Realisation of System

16. The technology is readily available in Australia to produce both the high intensity signals and the flashing "40" sign.

    High intensity signals are routinely fitted to school buses in the USA. However, the relevant SAE Standard is deficient in guarding against the signal being excessively bright in that it does not specify maximum values and gives insufficient attention to the cut-off of light as motorists approach the bus.

RECOMMENDATIONS

The current system of school bus signals needs upgrading and better supervision. To this end the following recommendations are made:

1. A high priority warning system, consisting of red and yellow flashing lights, should be introduced for use on selected vehicles and roadside signalling systems.
2. RTA Technical Specification 142 should be amended to incorporate conclusions 7 to 14.
3. This amended specification should form the basis of a national standard.
4. If by doing so, there are likely to be delays in the implementation of the amended Technical Specification, then high intensity yellow lights should replace the signal lights in current use immediately, as an interim measure, and Technical Specification 142 should be amended to include clauses 8, 9, 10, 14 & 15 (with reference to a red signal deleted).
5. Greater attention should be paid to the supervision of the quality of installation of signalling systems:

   a) compliance of signal light units with the photometric specification should be demonstrated by the manufacturer by means of a test certificate from an accredited NATA measurement laboratory

   b) check procedures should be developed and carried out to ensure that signal units fitted to school buses are correctly aligned.

Introduction

School children who are hurrying to catch a bus in the morning or who have just disembarked from a bus in the afternoon might not cross the road with care. Motorists in the vicinity of the bus should be alert to the possibility of children on the road. These motorists should be travelling at a speed which gives them a reasonable chance to stop in time if a hazardous situation arises.

Each school day in NSW approximately 600,000 students are transported to and from school by bus (Henderson & Paine, 1994). Unlike the USA, relatively few buses in NSW are used exclusively for transport of school children. It has been estimated that 90% of the total NSW bus fleet (not including coaches) is used for transport of school children. The approximate break-up is 4,700 buses used in urban areas and 3,400 buses used in rural areas - over 8000 buses in total. In effect, virtually all NSW buses (other than coaches) are likely to be used as school buses on a frequent basis.

During 1994 New South Wales implemented a range of measures to address this issue, including the fitting of "wig wag" flashing yellow lights and signs at the front and rear of school buses. (For the purpose of this report, the combination of flashing lights and signs will be known as a "signalling system").

A technical specification (RTA, 1994) sets out the requirements for the lamps and signs fitted to school buses in NSW; see Appendix A. There has been considerable debate about the effectiveness of the systems. In January 1995 the Tasmanian Department of Transport & Works issued a report on a trial of alternative flashing lamp systems (DTW, 1995). The report recommends that a system similar to that specified in NSW be introduced but that the lamps be brighter, flash at a faster rate and be mounted on the off-side of the vehicle rather than the centre. The report also recommends that the signs (picture of children and/or the words SCHOOL BUS) be larger.

The NSW Staysafe Committee, in a report on school children around school buses (Staysafe, 1994), made a series of recommendations. The foreword to the report states that the principal recommendations include:

> "an enhancement of the current system of flashing lights to incorporate both red and amber flashing lights of increased brightness; and a 40km/h speed restriction on motorists nearing a school bus when the flashing lights are activated"

The NSW Bus Safety Advisory Committee, in reviewing the Staysafe recommendations, decided to arrange for testing of several possible signalling systems. Subsequently, the authors were engaged by the NSW Department of Transport to carry out this work.

This report is in three sections. The first sets out the results of a field evaluation of the visual effectiveness of the current signalling system, together with three alternative systems. The second records the requirements of a visually effective signalling system based on an analysis of the motorist/school bus situation, necessary visibility distances and the fundamentals of signal effectiveness together with photometric tests on some signal lights. Finally recommendations are made, based on the conclusions of the preceding sections.

Section 1. A Field Evaluation of the Visual Effectiveness of School Bus Signalling Systems

1.1 Types of Signalling Systems Tested

In accordance with the brief for this project four types of signalling system were evaluated:

A. Current System. A bus fitted with the current mandatory system, comprising standard (aftermarket) yellow flashing lights and signs, apparently in accordance with RTA Technical Specification 142.

B. Bright Yellow Lights. The bright yellow lights used in the Tasmanian trials were fitted in place of the yellow flashing lights in the Current System.

C. "Moncrieff" System. This consists of a horizontal rectangular box with five panels. Each panel has a picture of a child. The picture is cut out from a black plastic film which is affixed to a transparent yellow plastic sheet. Each panel is illuminated from behind by a headlamp. A clear prismatic sheet is located between the headlamp and the yellow sheet. The panels light up in turn from left to right at intervals of just under one second, the intention is to give the impression of a child running. The Moncrieff system was tested as a standalone system. Staysafe had recommended that it be allowed for discretionary display in addition to the mandatory system (Staysafe, 1994, Recommendation 8). The Moncrieff System was mounted about mid-height on the rear of the bus, whereas the other systems were mounted, as required, above the top of the rear window.

D. Red and Yellow Lights. A government bus which already had the system fitted for on-road trials was used in the test. Both red and yellow lamps were standard aftermarket lamps. The signal operation was red-left and yellow-right then yellow-left and red-right.

The flashing lights used in systems A & D were essentially the same in respect to size, shape and configuration.

Photographs of each of these systems are contained in Appendix B.

1.2 Site

The site chosen for the evaluation was the centre parking area of Gosford Racecourse. This site had ample level area for parking the buses and laying out viewing stations. Another factor in favour of Gosford was that local school bus operations involve both urban and rural travel. The four buses with the four signalling systems were parked, line-abreast, in the centre of the racecourse with the rear facing, essentially, north. The order of the buses was random in that it depended of the order of arrival at the site. Three viewing stations were established at distances of 50, 100 and 250 metres to the rear of the buses. A fifth bus was also used for trial purposes.

Some general views of the site are contained in Appendix B.

1.3 Participants

A total of 39 persons took part in the survey; 21 of these were from the bus industry (drivers, depot managers, mechanics etc), 5 were from government departments (e.g. Dept of School Education), 7 were parents from a local primary school and 6 were associated with community road safety organisations. There were also several observers associated with particular systems and officers from the Department of Transport.

The participants cannot be regarded as a random balanced sample of the motoring population. The participants were all persons with an interest in the issue; except in the case of parents from the local primary school, invitations to take part were made by the Department of Transport.

A profile of the participants is set out in Appendix C.

1.4 Evaluation Procedure

A copy of the instructions and questionnaire used in the evaluation are given in Appendix D. Each participant was asked to anonymously complete a registration form. They were then asked to read the instructions. The participants then proceeded to the 100m station and observed the trial bus on which the hazard lamps were operated. They completed the questionnaire, asked any questions and repeated the procedure so as to be familiar with the questionnaire and the timing. They then proceeded to the 250m station for the start of the evaluation. They stood in an extended line to observe the group of buses. The signalling system on a bus was operated for a period of 30 seconds and the participants completed a questionnaire. After about a minute they turned to the next blank questionnaire and the signalling system on another bus was activated for 30 seconds. This procedure was repeated until all four signalling systems had been observed. The order of activation of the signalling systems at each station had been determined by random selection in advance of the trials.

Once the observations from the 250m station had been completed all participants walked to the 100m station where the process was repeated (using a different order of activation of systems). They then repeated the procedures at the 50m station. These distances span those at which the signalling systems needs to be seen for relevant scenarios involving location, speed and deceleration, discussed in Section 2.

1.5 Weather Conditions

The weather was fine and dry; however the sky was mainly overcast, starting with eight-eighth cloud at the beginning of observations to five-eighth cloud at the end. This cloud obscured the sun, which was behind the participants. The ambient light level was rather high; the vertical illumination at the participants eyes ranged from 8,000 to 13,000 lux through the time of observation. This lasted about half and hour, around mid-day.

1.6 Difficulties with procedures

Due to the logistics of the trial there could not be complete control of the experimental procedures. Several difficulties were encountered during the evaluation:

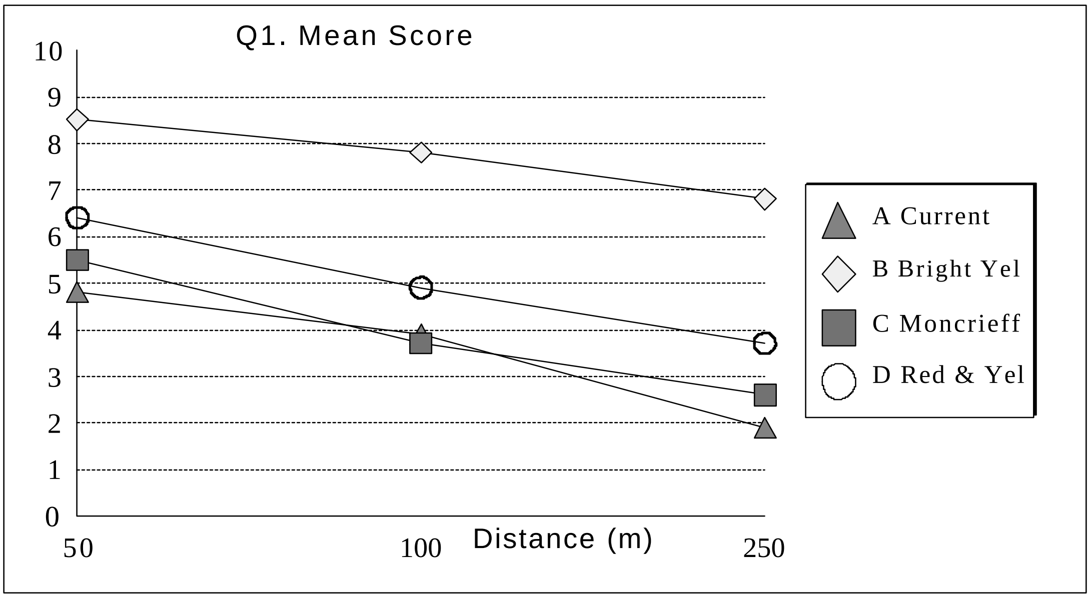
- one of the globes on the government bus had blown on the journey from Sydney and had to be replaced.
- the bus allocated and tested for the Moncrieff system the day before the evaluation was not available and a different bus was used. Due to the high current required for the Moncrieff system it is possible that there was a small voltage drop with the alternative wiring system (this could not be tested at the site).
- there was a delay in starting the evaluation because the bus fitted with the Current system (arranged by the Bus and Coach Association) turned out to have totally inadequate lights which could barely be seen in the bright daylight, even when standing near the bus. None of the other three non-government buses available at the site had "suitable" systems (as determined by BCA representatives) and neither did a fourth bus, organised at short notice from another local bus company. Finally a fifth bus arrived with a suitable system for evaluation.
- during the observations from the 250m station the wrong system was accidentally activated on the bus fitted with the Moncrieff system. The standard flashing lights on the bus were activated instead of the Moncrieff panel. Participants were asked to cross out their answers and repeat the procedures with the correct system activated. A check of the completed questionnaires indicated that they had all done this correctly.
- some buses had large educational posters on the rear of the buses concerning school bus/motorist protocol. The participants were asked to ignore these.

1.7 Results of Field Evaluation

The essential results of the field evaluations are set out in the following graphs and tables with respect to each question in turn. The data sets for the participants have been considered as a whole; mean scores or complete totals are used. Further details are contained in Appendix E.

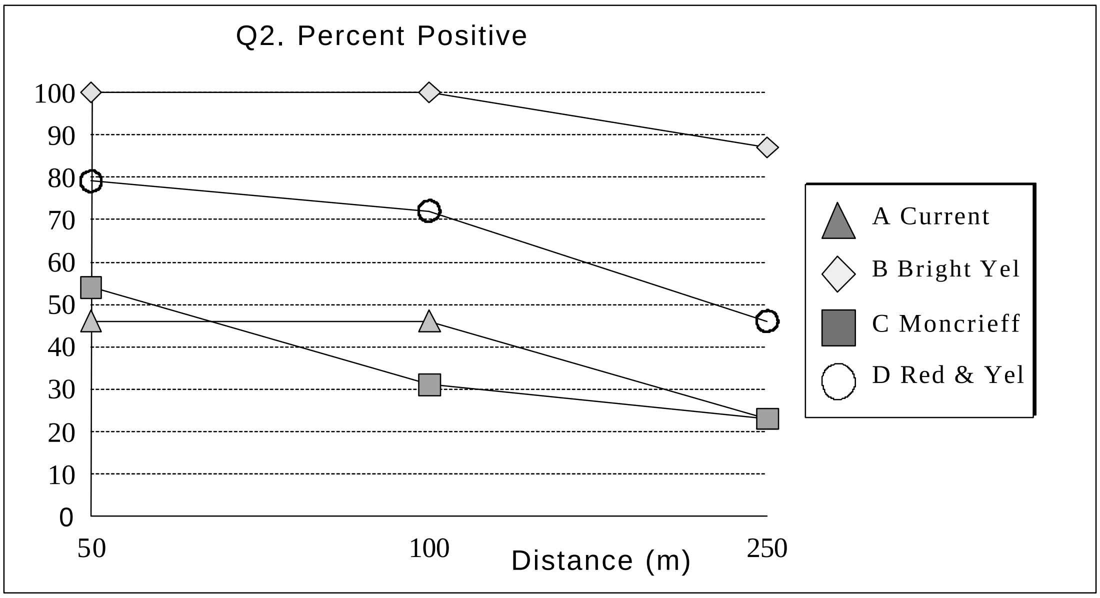
It transpired that the six persons associated with community road safety were enthusiastic about the Moncrieff system and their responses may have been so biased (see Appendix E, Tables E3 and E4).

Q1. How effective are the *flashing signal lights* on this bus in drawing your attention to the bus - how eye-catching are they *at this distance?* (score 0-not at all to 10-extremely effective)



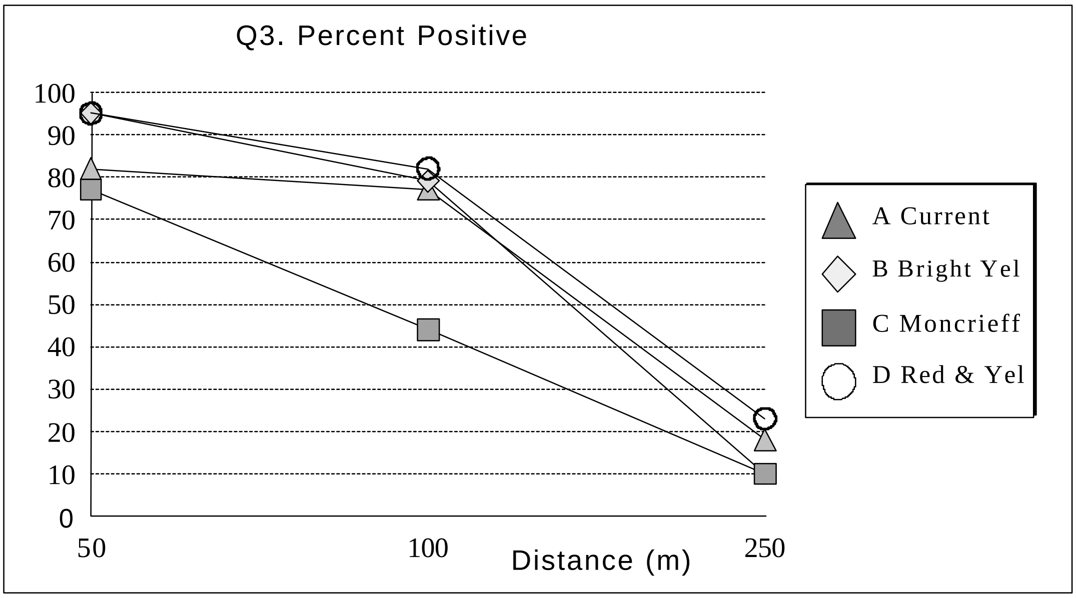
All systems scored at about half scale or above at 50m. At 100m the Current and Moncrieff systems had a mean score below half scale and at 250m only the Bright Yellow system scored in the top half of the scale. This system maintained a high scale rating over all distances.

Q2. Do you think these lights are sufficiently *eye-catching* to draw your attention to the bus *at this distance?* (Yes/No)



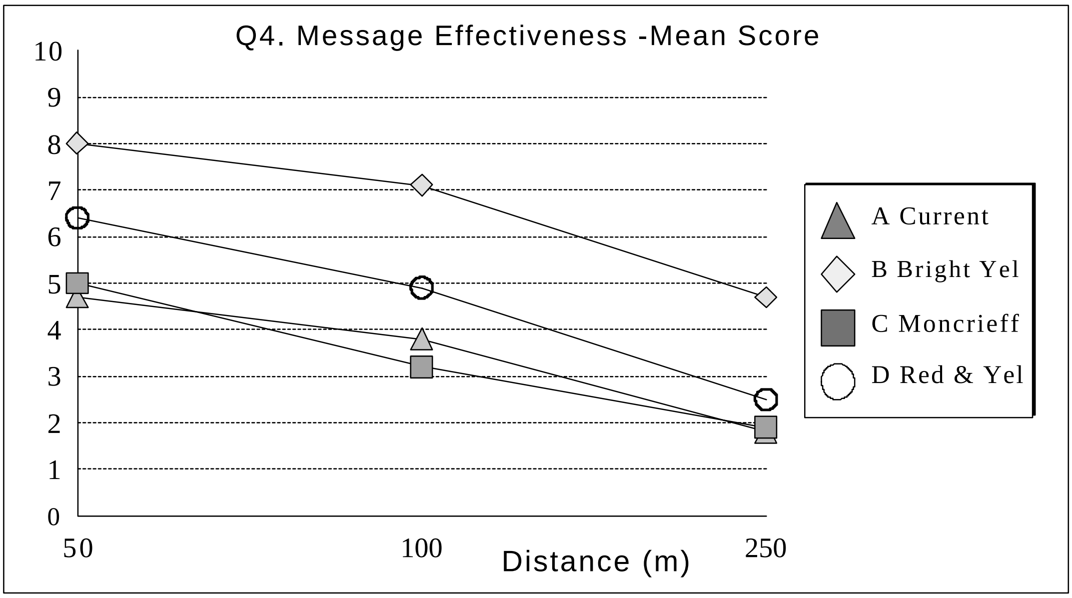
The effectiveness is translated into sufficiency in question 2; the Bright Yellow was rated sufficient by 100% of participants at 50m whereas the Current system was rated so by less than 50% of participants. The Moncrieff system rated similarly to the Current system. The Red & Yellow system rated between them and the Bright Yellow system. This system appears to be rated somewhat higher in sufficiency than might be expected from the results of the previous question. All levels of sufficiency appear to be maintained at 100m. At 250m the sufficiency ratings of the Current, Moncrieff and Red & Yellow systems fall to 50% or less whereas the Bright Yellow system is rated as sufficient by some 90% of participants at this distance.

Q3. In addition to any flashing lights, can you see a sign on this bus with a picture, words or numbers on it? (Yes/No)



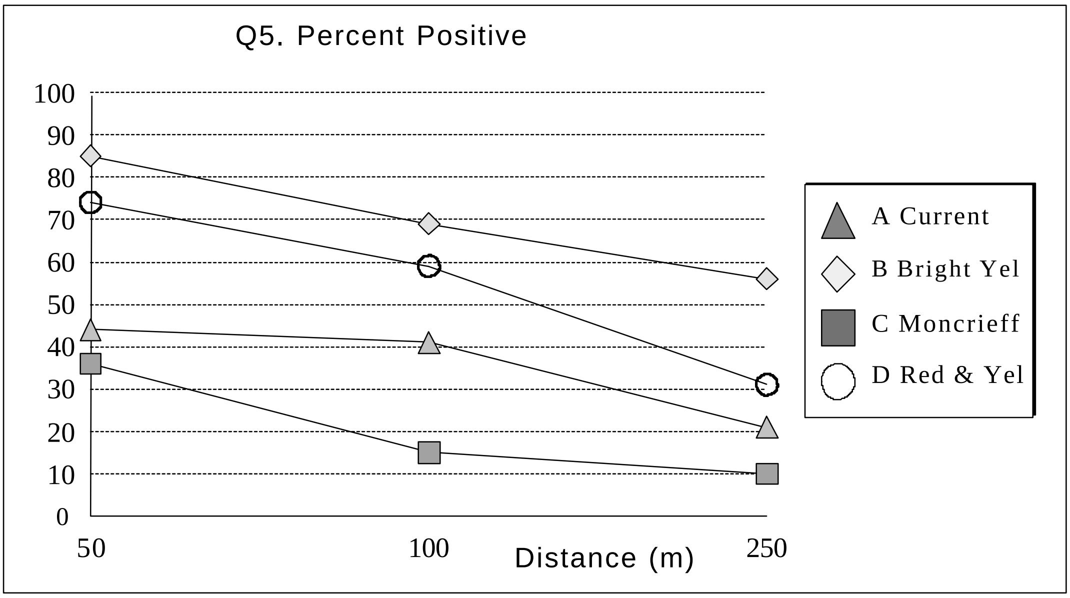
One might reasonably expect the percentage positive responses to be similar for the Current, Bright Yellow and Red & Yellow systems since the size, format and position of the sign was essentially the same. This is evident in the graph. There were some 80 to 90 percent positive responses at 50m and some 80 to 85 percent at 100m. The positive responses fell off sharply at 250m. Although the latter result is to be expected by virtue of the small size of the sign, it is worth noting the relatively high number of negative responses at the shorter distances. At 50m and 250m the Moncrieff system elicited responses which were similar to the other system but a much lower positive response at 100m.

Q4. How effective is the combination of signal *and* sign on this bus in giving you the message of the possibility of children crossing the road in the vicinity of the bus *from this distance?* (score 0 to 10)



The effectiveness of the *total* system - the combination of signal and sign - is generally scored lower than the signal alone (question 1). This is to be expected in view of the number of participants not reporting seeing a sign, especially at the longer distances.

Q5 Do you think that the combined signal and sign on this bus is *sufficiently clear* in giving you the message of the possibility of children crossing the road in the vicinity of the bus, *from this distance?* (Yes/No - if NO give reason)



The sufficiency of the *total* system is given in the response to this question. Again the ratings for the sufficiency of combination of signal and sign are generally lower than those for signal alone. However the Bright Yellow and the Red & Yellow systems maintain a clear superiority over the other two systems; the Bright Yellow over all distances and the Red & Yellow at 50m and 100m. The Moncrieff system is rated the poorest with some 15% of participants rating the system as sufficient at distances of 100m and 250m; even at 50m only some 35% of participants indicated sufficiency. It should be noted that, even at 50m, the Current system is rated sufficient by less than 50% of participants.

Table 1.7a shows that, at the 100m distance, the main reasons for answering NO to question 5 were; Lights not bright enough, lights seen but meaning not clear and confusing message. Reasons at other distances are included in Appendix E, Table E6.

Reason	A Current	B Bright	C Moncr.	D -Red & Yel
Confused with roadside lights			1	
Confused with other lights on bus	2	1		1
Confusing message			10	
Lights seen but meaning unclear	2	6	3	1
Lights and/or sign barely visible	3		2	
Looks like advertisement			1	
Lights not bright enough	14		4	8
Picture too small		2	5	1

Table 1.7a Reason for Negative Q5 (at 100m distance)

For the Current and Red & Yellow systems, the main reason for a negative response, at all distances, was inadequate brightness of the lights. For the Bright Yellow system the main reason, at all distances , was the lack of a message associated with the lights. For the Moncrieff system, the main reason, at 50m and 100m, for the negative responses was that it gave a confusing message. At 250m the main reason for a negative response was inadequate brightness of the lights.

Q6. If you answered YES to question 5, how would you react? (tick up to three choices out of ten options for rural and urban situation)

The following table indicates the total number of selections for each type of reaction.

Item	Reaction	Rural	Urban
A	Continue at same speed	3	8
B	Slow down gradually	99	75
C	Pay more attention	117	104
D	Blow horn as a warning	0	1
E	Pull out to give more space when passing	30	20
F	Slow down quickly	61	46
G	Slow to to a specific speed	28	33
H	Flash headlights as a warning	0	1
I	Stop behind bus until it proceeds	22	30
J	Slow down & prepare to stop	76	86

Table 1.7b Participants nominated reactions

The appropriate action, according to the Road Users Handbook (RTA 1993,1994), is to slow down and prepare to stop to avoid an accident. A total of 11 participants indicated that they would stop and wait for the bus. This suggests that the purpose of the signalling system is not well understood by these participants. In particular 5 out of the 7 parents indicated that they would stop. A situation where some motorists stop and others pass the bus is highly undesirable. The responses to question 6 suggest a lack of an informed, uniform reaction.

Relatively few participants selected "G - Slow down to a specific speed". For those participants who did, the distribution of nominated speeds was:

Speed	**Rural**	**Urban**
10	1	1
20	2	-
30	1	1
40	9	29
60	11	-
70	1	-
80	2	-

Table 1.7c Participants nominated speed to which they would slow

(not all participants nominated a speed when they selected item G)

1.8 Conclusions from the field evaluation

a) Visibility of signal light (Questions 1 & 2)

The Bright system (B) was superior at all distances - this is to be expected as subsequent photometric measurements found it to have about ten times the luminous intensity of the other signal lights (see Section 2). Sufficiency was poor (about 50% or less positive responses) for the Current and Moncrieff system, even at 50m.

b) Visibility of sign (Question 3)

From a distance of 100m 20% of participants indicated they could not see the sign (picture of children) for the Current, Bright and Red & Yellow systems; this sign being prescribed in RTA Technical Specification 142. Less than 50% of respondents indicated they could see the sign on the Moncrieff system from this distance. In all cases the signs were ineffective when viewed from 250m.

c) Effectiveness of total system (Questions 4 & 5)

The Bright system was again superior at all distances but its superiority over the Red & Yellow system was reduced. In the case of both systems the poor visibility of the sign (see (b)) appears to have been compensated for somewhat by the enhanced signal lights, in one case by increased intensity and the other by the inclusion of a red signal.The sufficiency of the Moncrieff system was inferior to all the other systems.

d) Reaction to signal (Question 6)

The appropriate response (slow down and prepare to stop) was not made by a significant number of the participants. Relatively few participants nominated an appropriate speed to which they should slow down. About one third of the participants indicated they would stop and wait for the bus.

Section 2. Analysis of the Requirements of a Signalling System for School Buses

2.1 Functional requirements

The function of a school bus signalling system is to alert motorists who are approaching from either direction to the possibility of children on the road in the immediate vicinity of a bus which is stationary or has just departed. This must occur at a **sufficient distance** to enable the motorist to take action to avoid an accident.

To be effective the system must satisfy each of three requirements (after Lay, 1981):

A. It must be **readily seen** by approaching motorists and it must **command their attention**. It must be conspicuous from other signals and signs and the general visual clutter at the front and the rear of buses. It must stand out in adverse lighting conditions such as bright daylight.

B. It must be **recognised** as indicating the possibility of school children in the immediate vicinity of the bus, in a clear, credible and unambiguous manner.

C. It must elicit an **appropriate response** from the motorists, such as slowing down and preparing to stop to avoid an accident.

2.2 What is a sufficient distance?

Assume that a motorist is to be travelling at no more than 40km/h when passing a bus with its flashing lamps operating (this speed is taken from regulation and practice in some USA and Australian States). Then the motorist will require a distance away to see the signal (the signal range) which takes into account the distance travelled during the response time to the signal, the distance travelled during slowing down to 40km/h and the distance over which to stop from 40km/h, if necessary (the buffer zone).

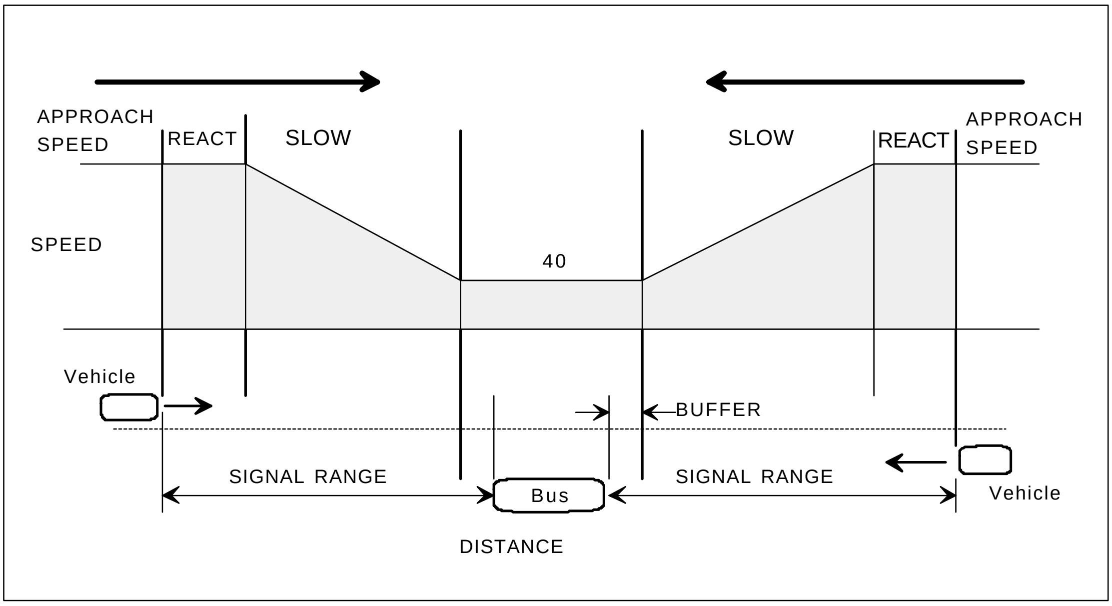


Figure 2.1 - Derivation of Signal Range

The response time (driver's reaction time to the signal plus time before vehicle starts to decelerate) is typically taken to be 2.5 seconds in Australian traffic engineering practice (Lay, 1981). This, and a shorter, more optimistic time of 1.5s, will be used in the analysis.

It is preferable that the motorist does not brake heavily because this may be a hazard to following traffic and it could also lead to reluctance to slow down if school buses with lights flashing are repeatedly encountered on the road. On a level road at 100km/h a typical vehicle will decelerate at between 0.5 and 1 metres per second per second (m/s/s) without the use of brakes. Under gentle braking a deceleration of 2m/s/s is regarded as comfortable. Heavy braking involves decelerations of around 5m/s/s (all decelerations in this report are the average for the event, not the peak).

An appropriate value for the buffer zone would be 30m, assuming that the vehicle is travelling at a speed of 40km/h, because this would enable an alert motorist to brake heavily and stop just before reaching the bus.

From these values the distance at which a signalling system on the bus has to be first seen by an approaching motorist can be calculated. The formula is:

$$s = ((V^2 - v^2)/2a) + Vt + d$$

Where s = distance from motorist to bus, signal range (metres)

V = initial speed (metres per second)

v = final speed (metres per second, 11.1m/s = 40km/h)

a = average deceleration (metres per second per second)

t = motorist response time (seconds)

d = distance before bus at which the final speed is to be achieved (metres, buffer=30m)

The following tables show the application of this formula to several scenarios:

Type of braking	**Deceleration m/s/s**	**Distance for typical reaction time (2.5s)**	**Distance for alert reaction time (1.5s)**
None (engine braking)	1.0	424	396
Gentle	2.0	261	234
Heavy	5.0	164	136

Table 2.2a Required distance to slow from 100km/h to 40km/h (metres)
(Includes a 30m buffer zone before bus)

Type of braking	Deceleration m/s/s	Distance for typical reaction time (2.5s)	Distance for alert reaction time (1.5s)
None (engine braking)	1.0	149	132
Gentle	2.0	110	94
Heavy	5.0	87	70

Table 2.2b Required distance to slow from 60km/h to 40km/h (metres)
(Includes a 30m buffer zone before the bus)

The distances involved are often not appreciated by motorists. In order to slow down, without braking, from 100km/h to 40km/h the motorist must first see the signal some 400m away. If the motorist does not see the signal until he or she is about 250m from the bus then gentle braking will be required in order to slow to 40km/h. Any closer than about 150m and heavy braking will be required.

On the basis of this analysis, the signal on a school bus should be visible and recognisable at no less than 250m for buses operating in 100km/h areas (this assumes some gentle braking will be required). A minimum of 100m is required for buses operating in 60km/h areas. Many urban buses operate in higher speed zones from time to time and longer sight distances are required for these zones. For example, at 80km/h, a sight distance of 180m is required if gentle braking is acceptable. Therefore overall the signal system on a school bus requires a signal range of 250m.

2.3 Signs and/or lights

A signalling system may consist of a sign or lights or both.

2.3.1 Sign

To be both conspicuous and legible at a distance a sign needs to be large in area. The norm that optometrists use for the visual acuity (discrimination of detail) aspect of vision in the general population is 6/6 vision or the ability to read, from a distance of 6 metres, letters with a stroke width of 1 minute of arc and an overall height of 5 minutes of arc. This equates to a reading distance of 7 metres for every 10mm of letter height, with black letters on a white background. (This value may be conservative for a pictogram; it is known that some familiar and simple pictograms are recognised at a greater distance than equivalent letter messages). However, only about two-thirds of the population have 6/6 vision; in NSW the eye test for the initial driving licensing procedure is based on 6/12 vision - that is, a reading ability of 3.5m per 10mm of letter height.

Thus, applying the same standard as that used in driver license testing, the overall height of a message on a sign will need to be about 285mm for a viewing distance of 100m and 715mm for a viewing distance of 250m, to be legible. On a standard roadside warning sign with the "children on road" pictogram, the height of the largest child is 500mm. However, to be conspicuous or eye-catching, in the first place the message will need to be seen against a background of sufficient area and brightness to isolate it from the surrounds. The standard roadside warning sign is of side 0.75m (area $0.56m^2$) but there is provision for signs of side 1.2m (area $1.44m^2$) for use in visually demanding circumstances (AS1991). The background is colour coded yellow and shape coded diamond to denote a warning sign.

By comparison, the sign prescribed in Technical Specification 142 (RTA, 1994) has a minimum height for the child symbol of 250mm and a rectangular yellow background of 400mm by 250mm ($0.1m^2$ minimum area).

It should be noted that roadside warning signs are located well in advance of the potential hazard to which they refer and the motorist has this extra distance in which to take appropriate action, such as slowing down, after reacting to the sign. Obviously, in the case of a school bus, the sign must be attached to the bus and the extra warning distance provide by roadside signs is not available.

Thus on the basis of signage requirements and application of current road signing practice, a standalone sign on a bus, for the signal range in question, would need to be of considerable area - of such an area as not to be compatible with the space available on the front or rear of buses.

2.3.2 Signal Lights

Signal lights can be small in area and can be coded by colour and flash regime to impart both conspicuity *and* legibility. In addition their activation can be readily confined to times when there is a potential hazard.This will improve the credibility of a signal with motorists.

Again there is a sound knowledge of signal light requirements and much practical experience on which to base requirements of signal lights.

The human eye is more sensitive to a light source the closer that source is to the line of sight. This means that the further a signal is from the line of sight the brighter it will need to be to elicit a response. The necessary luminous intensity of a signal will also increase as the square of the distance away. However, for a given signal offset (see Figure 2.3.2a), the signal will be proportionally closer to the line of sight as the distance increases. The relationship is:

$$I = 2Kd^2L_B x10^{-6} \text{ cd} \quad \text{. . . . . . Equation 2.1}$$

where

I = Optimum luminous intensity of a steady red signal for a required signal range

$K = (a/3)^{1.33}$

a = angle of the signal from line of sight (degrees, minimum 1^0)

d = required signal range (metres)

L_B= background brightness (cd/m^2)

The formula is the outcome of considerable research in Australia (Cole & Brown, 1968, Fisher & Cole, 1974). The optimum intensity is that which invokes, essentially, 100% probability of seeing, coupled with a near minimum reaction time. This and other data forms the basis of Australian Standard AS2144 (AS 1989) and international recommendations (CIE 1988) on the photometric specification for traffic signals.

It should be noted that the intensity is directly proportional to the brightness of the background to the signal. Note that typical values of background luminance range from 10,000 cd/m2 on a bright day to 100 cd/m2 or less around dusk. Therefore the range of a signal of given intensity can vary by a factor of more than 10 depending on background lighting conditions. This is why signals of relatively low intensity can appear quite adequate for long distances under favourable (dull) lighting conditions but they are unsuitable for bright conditions.

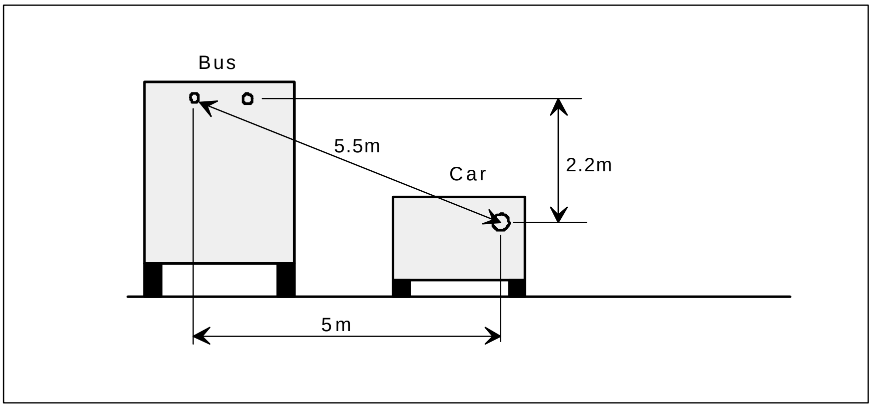


Figure 2.3.2a - Derivation of offset distance

(Typical car/bus geometry)

In accordance with the formula, the luminous intensity requirements for a *steady red signal light* for various signal ranges are given in Figure 2.3.2b. These are shown for an offset of 5.5m, which is typical for a car approaching a school bus which is pulled off to the side of the road (see figure 2.3.2a), and an offset of 2m, which is more typical of a car following another car.

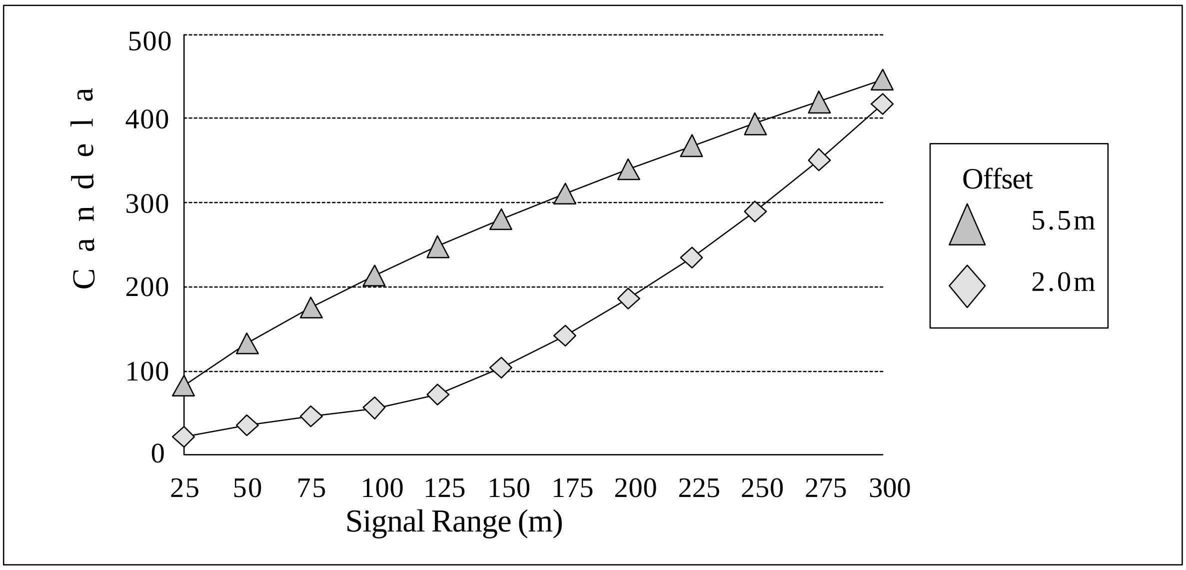


Figure 2.3.2b Relationship between Signal Intensity & Signal Range

Note the graph is based on constant offset and a background brightness of 10,000cd/m^2.

It has been found that over the range of angular size of practical signals, the intensity requirements are independent of the size of the signal. Thus these data can be confidently applied to transport signals in general. Further, it should be noted that the data in Figure 2.3.2b are for a red signal; the intensity values for yellow signals need to be 3 times that for red for equal visual performance (Fisher & Cole, 1974)[1]. This will not normally be a problem in practice since a yellow lens can transmit about 3 times the light from an incandescent lamp over that for a red lens.

Using Equation 2.1, the following signal intensity requirements can be deduced, as shown in Table 2.3a.

Signal Range (m)	**Signal Intensity (cd)**	
	Steady Red Signal	**Steady Yellow Signal**
100	210	630
250	390	1170

Table 2.3a. Signal intensities for two signal ranges with *steady* signals viewed against a sky background of 10,000cd/m^2 and an offset of 5.5m.

These intensities relate to in-service equipment; some addition on these values is needed to take into account dirt and deterioration of the signals. On the other hand, these intensities are for a high, but not uncommon, brightness of sky background (Fisher & Cole, 1974), without any black backboard. They also allow for the observers gaze to be not directly towards the signal.

2.3.2.1 Road Traffic Control Signals

In AS2144 (1989) the minimum luminous intensity of traffic signals are specified, as shown in Table 2.3b:

Type of signal	**Range (m)**	**Red**	**Yellow**
General Purpose	100	200	600
Extended range	240	600	1800

Table 2.3b AS2144 Minimum Traffic Signal Intensity (cd)

These values apply to new equipment, are on-axis values and provide the range when viewed against a sky background of 10,000cd/m^2, the signals being fitted with black backboards.

The values at 100m signal range match those of table 2.3a. The values for extended range traffic signals exceed those of Table 2.3a since traffic signals have a greater offset (Hulscher 1975).

[1] Some writers have concluded that a yellow light must be intrinsically the best signal (Hillier 1993). This results from a misunderstanding or misuse of the relative sensitivity function of the human eye. This relates the sensitivity of the eye to radiant energy (not light) of various wavelengths.

2.3.2.3 Vehicle Signals

Australian Design Rules

The intensity values specified in the Third Edition Australian Design Rules (ADR 1992) for various types of vehicle lamps are given in Table 2.3c. These values are for on-axis, new equipment operated as a steady light.

Type of lamp	Min. cd	Max cd	Signal Range m (see note)
Front turn signal	175	700	200
Rear turn signals for both day & night	50	200	100
Rear turn signal for day only	175	700	
Rear turn signal for night only	40	120	
Red brake lamps for both day & night	40	100	150
Red brake lamp for day only	130	520	>300
Red brake lamp for night only	30	80	
Red rear fog lamp	150	300	250
White daylight running lamp	130	520	

Table 2.3c -ADR Requirements for Lamps

Note: Table 2.3c includes the signal range for some of the lamps, at the maximum intensity permitted by the ADRs and viewed in bright daylight. The lower curve of Figure 2.3.2b is used (2.0m offset - typical of a car following another car) rather than the upper curve, which is more typical of high-mounted lights on a bus or traffic signal lights. Allowance has been made for a lower effective intensity of yellow flashing turn signals (see 2.4.1).

The large majority of vehicles in Australia are fitted with single intensity lamps which are used day and night. These are a compromise between the necessity of a relatively high intensity by day and limiting the intensity at night so lamps are not excessively bright.

In the case of yellow aftermarket lamps intended for use as either front or rear vehicle turn signals, a manufacturer would logically aim for an intensity between 175cd (minimum front) and 200cd (maximum rear). In bright daylight these would provide a signal range of about 100m when used on a car or small trailer but they become ineffective when high-mounted on a large vehicle such as a bus.

There are no effective controls to ensure that aftermarket lamps meet ADR requirements (the ADRs apply to the vehicle, not products offered for sale) and intending purchasers have no simple way of establishing the photometric properties of a signal.

SAE Standard

Many school buses in the USA are fitted with bright red and yellow flashing warning lamps. The method of operation is that yellow signals are activated by the driver as the bus approaches a stop. Once the bus stops the red signals are activated (in some States alone and in others, in conjunction with the yellow signals). Also in some States, motorists must stop and wait while the red lights are flashing (Staysafe 1994).

This method of operation is different to that of the Red & Yellow system which was included in the field evaluation.The operation USA system does not fulfil the aim of having a simple unambiguous message; it is likely to be confusing for motorists in the Australian situation. Further, it depends on action by the driver to activate the yellow signals. However, of interest for the present project is SAE Standard J887 School Bus Warning Lamps (SAE 1987) which sets out performance requirements for these signal lights. Pertinent technical requirements are:

- Lighted area of the lens not less than 120cm^2
- Signal units to have aiming pads for alignment of the reference axis
- "on" period sufficient to enable bulb filament to reach full brightness
- audible or visual indicator for driver
- pairs of lamps spaced as far apart as possible, with yellow lamps inboard of red lamps
- high-mounted at front and rear
- unobstructed through a vertical range of 10^o down to 10^o up and a horizontal range of 30^o left to 30^o right
- black surrounds extending approximately 70mm beyond the edge of the lens
- aimed parallel to the centreline of the road (0,0). "Inspection limits" prescribed as "5 up to 5 down and 10 right to 10 left"

In addition photometric performance is specified.The signal units are tested at operational voltage (e.g 12.8V or 25.6V). Requirements are for total luminous intensity in prescribed zones. The Standard also includes guidelines for meeting the zonal requirements. These guidelines are summarised in Tables 2.3d & 2.3e.

Degrees Up & Down(-ve)	**Degrees Left(-ve)/Right Yellow Signal Unit**								
	-30	**-20**	**-10**	**-5**	**0**	**5**	**10**	**20**	**30**
10				50	125	50			
5		375	750	750	750	750	750	375	
0	75	450	1000	1250	1500	1250	1000	450	75
-5	75	500	750	1125	1125	1125	750	500	75
-10				100	100	100			

Table 2.3d SAE J887 Guidelines for Yellow Signal Units

Degrees Up & Down(-ve)	Degrees Left(-ve)/Right Red Signal Unit								
	-30	**-20**	**-10**	**-5**	**0**	**5**	**10**	**20**	**30**
10				20	50	20			
5		150	300	300	300	300	300	150	
0	30	180	400	500	600	500	400	180	30
-5	30	200	300	450	450	450	300	200	30
-10				40	40	40			

Table 2.3e SAE J887 Guidelines for Red Signal Units

The intensities at the reference axis (0,0) in Tables 2.3d and 2.3e are similar to the required values for red and yellow signals at 250m signal range given in Table 2.3a. The values are even closer if the reduced effective intensity of flashing signals is taken into account in evaluating the requirements of the SAE standard(see Section 2.4.1). The values in the standard are minima, no maximum values are given. There appears to be no guard against the signals being excessively bright at night.

2.4 Intensity requirements for school bus signal range

Intensities required to fulfil the signal range requirements, derived in section 2.3 from experimental data, appear to be rather demanding when compared to the intensities of signalling lamps on in-service vehicles, as prescribed in the ADRs (comparing Table 2.3a and 2.3c). The intensities are more in line with those pertaining to traffic control signal practice (Table 2.3b) and those applying to signal lights on school buses in the USA (Tables 2.3d and e).

The requirements set out in Table 2.3a are for steady lights against a bright background sky, without target or backboard. Several factors would need to be taken into account when applying these requirements to the school bus scenario.

2.4.1 Flashing signals

Lights may be made to flash. Contrary to popular belief, a flashing light is more difficult to detect initially than a steady one of the same intensity. However, once detected a flashing light is more likely to demand inquiry or be taken notice of than a steady light. In order to maintain the same signal range, the intensity of a flashing light will need to be increased over that of a steady light (Cole 1972, Holmes 1971).

Assuming a signal to flash at 60 cycles per minute (Technical Specification 142), with the off time equal to the on time, then the intensity will need to be increased by a factor of about 1.4 times to that derived from Equation 2.1. Even greater intensity would be required for a faster rate of flashing but, in any case, there are technical limits to the rate at which automotive lamps can be flashed (e.g. losses due to incomplete heating up of the filament and decreased service life).

A property related to flashing rate is cycle time. With all systems the message should become unambiguous when a complete cycle has elapsed. In the case of single colour wig-wag signals this will be after three light operations (e.g. left, right then left) and the total time will be less than two seconds. In the case of the Moncrieff pictogram system the cycle does not repeat until six light operations, during which time about five seconds will have elapsed. At 100km/h the motorist will have travelled about 150m during this time. It could be argued that a motorist will recognise the Moncrieff signal before a full cycle is completed but the field evaluation indicated that it can easily be confused with other lights, such as those in advertisements.

A combination of red and yellow flashing lights (e.g. System D) has the advantage that its meaning should be evident after one half cycle because the effect is that the red and yellow lights swap places (red-left, yellow-right then yellow-left and red-right).

2.4.2 Dirt & deterioration

The signal may become dirty and the hardware deteriorate over time. The bus signal is mounted high above the roadway and buses are cleaned regularly. To achieved the required intensities it is likely that quartz-halogen globes will be used and these have a low light loss during their service life. Taking these factors into account a nominal factor of 1.1is used to cover the in-service deterioration of signal intensity.

2.4.3 Derived signal intensities

Applying these two factors to the values in Table 2.3a, and rounding the results, leads the values in Table 2.4

Signal Range (m)	**Signal Intensity (cd)**	
	Red	**Yellow**
250	600	1800
100	300	900
(50)	200	600

Table 2.4 - Necessary signal intensities for *flashing* signals on school buses
(values for signal range of 50m given to cover whole approach to a bus)

2.4.4 Backboards with signals

It has been suggested that a black backboard be used in an attempt to make the signal more conspicuous (Staysafe ,1994). For such a device to effectively isolate the signal from its surrounds it needs to be impractically large (Fisher & Cole, 1974). This is because the angle between the edge of the signal and the outer edge of the backboard needs to be about 1^{o}; this translates to a backboard area with a diameter of about 1.75m at 100m range. The relatively small backboards provided for traffic control signals (180mm from edge of signal to outer edge of backboard) have only a small effect at long ranges but they do improve signal conspicuity at short distances, where the offset angles are greater.(Fisher & Cole, 1974, Hulscher, 1975).

2.4.5 Day-night signal intensity

The intensity requirements for the school bus signals are those for a bright day background. For low ambient brightness, particularly at night, care needs to be taken to guard against the possibility that high intensity signals might be overbright (this assumes that it will be impractical and undesirable to restrict use of the signalling systems to daytime use only). This has the potential to produce glare, manifested by making the view of the signal discomforting to the approaching motorist and possibly degrading visibility.

The limitation of these adverse effects is generally given much attention in the provision of lighting and signalling at night. Light directly towards the eyes of motorists is kept to the minimum practicable.

The specified maximum intensity limit for red traffic signals is 1000cd (AS 1989), there being no limit to the yellow signal "in view of the relatively short intervals for which such signals are normally displayed". The standard suggests that the 1000cd should normally satisfactorily limit glare, at night, from signals used on roads where traffic route lighting is installed. However where roads have local road lighting or are unlit authorities are advised to consider installing signals with intensities not greater than 350cd.

Essentially similar values of intensity are embodied in road lighting standards (AS 1973, 1988) viz, 1000cd and 500cd maximum intensities for the light emitted at the horizontal from luminaires used for traffic route and local road lighting respectively.

The maximum value for (yellow) turn signals (Table 2.3c) are 700cd and 200cd for front and rear signals respectively. The maximum intensity from the (white) low beam headlight in the direction of oncoming motorists is 437.5cd (Zone III of ADR46).

There is evidence that the intensity of a yellow light can be higher than that of a white light before being deemed unsatisfactory; the results of some investigations suggest that it can be 40% greater (van Bommel & de Boer 1980).

Practice leads to the conclusion that, in order for a light not to be glaring when viewed at night, it should have a maximum intensity of about 1000cd in the direction of view, preferably less if the road is poorly lit or unlit. Reference to Table 2.6c shows that the required peak intensity of the light beam of the bus signal (1800cd) needs to be greater than this in order to fulfil its alerting role.

Thus there arises the common problem in road traffic signalling of reconciling the need for high intensity by day and low intensity by night. This problem has been tackled in a number of ways. One is by the use of a dual day-night system, with dimming of the signal at night, as allowed for in the ADR (Table 2.3c); this remedy has not found favour in application in Australia. Another is to have a compromise day-night system (Table 2.3c). This has been generally applied to vehicle lighting in Australia.

A third way is to give careful attention to the light beam shape. This is done for vehicle low headlight beams where the high intensity portion for forward seeing and the low intensity portion for limiting glare are sharply separated. This approach can be applied to the school bus signal.

Investigations into the phenomenon of glare have shown that the adverse effects produced by an overly bright light will decrease as the distance away increases, will decrease as the light recedes off the line of sight, as the light is approached, and, of course, will decrease as the light intensity decreases.

Unlike the signals on a car, the school bus signalling lights will be high mounted so, on approach, the signalling will increasingly recede well above the line of sight of the approaching motorist. Thus the motorist will ride under the main signal beam on approach, if the beam is carefully designed. Only at 250m away is it necessary for the motorist to experience the elevated intensity (1800cd), whilst closer to the bus (100m) the required signal intensity decreases substantially (900cd), even though still producing a clear signal. When very close to the bus (50m and less) the motorist should only be subjected to the same intensity as would be experienced with conventional turn signals, i.e 700 to 200cd.

In order to take into account the two requirements (high intensity for alerting by day whilst controlling glare at night) the final specification of the school bus signal light distribution will be based on these principles (Section 2.6).

2.4.6 Rural Vs urban

From an implementation point of view, it is preferable to have only one signal type suitable for both urban and rural application. Such a system should be capable of being effective under the most adverse conditions (bright daylight) at the largest signal range required; 250m. In any case, most urban buses operate, at times, on roads with speed limits higher than 60km/h.

2.4.7 Colour of signals and signs

Conventions have been established for the use of different colour signals and signs. This aids in unambiguous recognition of the meaning of the signal or sign and in eliciting an appropriate response from motorists

In practice there are only four signal light colours (besides white) which can be used effectively: red , yellow, green and blue. Other colours, such as purple (magenta) lose definition when they are bright and/or viewed from a distance. In particular purple should be avoided because it is a combination of red and blue light and, looking through a windscreen, two images can be formed due to refraction effects.The chromaticities of these signal colours have been universally standardised (CIE 1975) and so used in Australia (AS 1989).

Red conventionally indicates stop or give way. Red flashing lights are used on ambulances, fire-fighting vehicles and police vehicles (the latter in conjunction with blue flashing lights). Red traffic signals mean, of course, stop. Red is used for brake lights and rear-facing position lights on all vehicles. Red wig-wag signals are used at railway level crossings.

Yellow conventionally indicates proceed with caution and prepare to stop. Yellow flashing lights are used on tow trucks, service vehicles, roadwork signals and oversize vehicles (and their escort vehicles). Yellow traffic signals mean stop unless sudden braking might cause a crash (RTA Road User Handbook, 1994). Flashing yellow is used for turn signals on all vehicles and for optional hazard warning lights

Similar conventions are also used in roadside signs. Yellow is used for warning signs and red is used for regulatory traffic control signs ("Stop", "Give way" and the circle on speed limits signs).

There are an increasing number of dual colour (red and yellow) warning signs in use in NSW. These are apparently intended to convey a higher priority warning message than all-yellow signs in situations where there is a heightened risk of a serious accident. Examples are traffic signal warning signs in combination with a red "Prepare to stop" sign, wig-wag yellow lights in combination with a red "Traffic signals - Prepare to stop" sign and diamond yellow warning signs with a rectangular red background (see photographs in Appendix F).

At present a formal combination of red and yellow (flashing or steady) lights is not used on any vehicle or roadside signal (other than the transition of a traffic signal from yellow to red). It can be anticipated, however, that there will be pressure for the introduction of such signalling systems given the trends with roadside signs. The main disadvantage of a combination of red and yellow lights is that they might be confused with an emergency vehicle. This will need be to be weighed against the advantage of providing a high priority warning message. In any case, the use of a combination of red and yellow signals and signs should be strictly controlled to ensure motorists do not become desensitised to the extra warning they provide and the signals lack credibility.

A red-yellow flashing signal light system should not be exclusively assigned to one type of user because there is a practical limit to number of unique signals. Rather it should be reserved to impart a higher priority warning message than is the case when using yellow alone, as is the case with signage applications discussed above.

The appropriate response by the motorist to a red and yellow signal will be conditioned by publicity and experience of the signal lights, reinforced by the context in which they are seen (i.e. on a bus) and/or by supplementary signs.

2.5 Photometric performance of signals

Some of the signal units used in the field evaluation were measured for their luminous intensity distribution. That is, intensities at various angles to the reference axis which, for the signals in question, is taken to be a line perpendicular to the centre of the light-emitting face. The tests were performed by an photometric laboratory with NATA (National Association of Testing Authorities, Australia) accreditation.

Descriptions of the signal units are given in Table 2.5a.

System	Signal Unit	Optics	Lamp	Colour
B* Bright Yellow	Rectangular 100mm x 75mm	Reflector plus coloured spreader in horizontal plane	12V/35W Halogen	Yellow
C Moncrieff	Rectangular 150mm x 205mm	Reflector, prismatic lens panel and coloured filter with a cut-out figure (135mm high, approx area 500mm^2)	24V/70w Halogen	Yellow
D# Red & Yellow	Circular 117mm diameter	Fresnel lens	24V/18W festoon	Yellow Red

Table 2.5a Details of Signal Units

* A unit fitted with a red light spreader was also tested

Yellow and red units were from different manufacturers

The tests were made at nominal voltage (12 or 24 volts) and at operational voltage (12.8 or 25.6 volts). The results are given in Figures 2.5.1 & 2.5.2 and summarised in Table 2.5b. Values in the figures are given for the nominal voltage since the field trials were conducted with the bus engines not running. The intensity values at operational voltage will be increased by a factor of about 1.2. These are shown in brackets in Table 2.5b.

Figure 2.5.1 - Results of Photometric Measurements for System C (Moncrieff) and System D (Red & Yellow)

Figure 2.5.2 - Results of Photometric Measurements for System B (Bright Yellow) and same signal unit with a red refractor. Note scale is 10 times that of Figure 5.2.1.

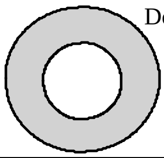
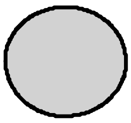
System	Shape of light beam	Colour	Intensity along reference axis (cd) nominal voltage (op.voltage)	Maximum Intensity (cd)
B Bright Yellow	Ellipse 	Yellow	2053 (2481)	4772
		Red	614 (735)	1458
C Moncrieff	Doughnut 	Yellow	95 (113)	275
D Red & Yellow	Circular 	Yellow	165 (206)	175
		Red	26 (32)	30

Table 2.5b Summary of Photometric Chraracteristics of Signal Units

System B - Bright Yellow

System B produces a beam with a much greater spread of light horizontally than vertically with very high intensities relative to the other two systems. The direction of maximum intensity is slightly skew with respect to the reference axis. In the horizontal plane, away from the direction of maximum intensity, the intensity falls off sharply at first but then less so, there being still some 1000cd (yellow) at about 20 degrees from the reference axis (figure 2.5.2). In the vertical plane the intensity falls off sharply to, essentially, the limit of distribution at about 10 degrees down. However, at 5 degrees down the intensity is still about 1000cd (yellow).

System D - Red & Yellow

System D has intensities less than one tenth of those for System B. The maximum intensities are slightly skew to the reference axis. The light beam is circular, being symmetrical in the horizontal and vertical planes. The fall off in intensity away from the peak is rather severe; at 10 degrees from the reference direction the intensity has fallen to only some 50cd for the yellow light (figure 2.5.1).

No measurements were possible on System A. However, the bus concerned had a signal of similar construction to the yellow signal used on System D and was also fitted with an 18 Watt lamp. It can therefore be reasonably assumed that the results for the yellow System D signal unit also apply to System A.

System C - Moncrieff

System C produced similar peak intensities to System D (yellow). However, the maximum intensities lie some 15 degrees from the reference direction. The intensity along the reference axis is less than half that at 15 degrees off-axis (figure 2.5.1). The beam is circular but there is a hole in the centre so that, in effect, it is a doughnut shape. This appears to result from poor optical design.

2.5.1 Comparison of photometric results with required performance

The necessary angular coverage of the signal for various signal ranges are given in Table 2.5c, together with the necessary signal light values (Table 2.4) and those obtained for the various systems tested. In computing the angular coverage the relationship between motorist and bus given in Figure 2.3.2a is used.

Signal Range (m)	Angular Coverage from reference axis (degrees)		Required Signal Intensity (cd)	Approximate Signal Intensity Delivered (cd) (op. voltage)	
	Sideways	Downwards			
250	1.0	0.5	1800	B C D	2310 115 195
100	3.0	1.0	900	B C D	1980 120 170
50	6.0	2.5	600	B C D	1600 155 125

Table 2.5c Required & measured signal characteristics - Yellow signal units

It can be seen that only System B fulfils the intensity requirements over the necessary angular coverage. The other systems are poor by this criterion.

2.5.2 Practical realisation of signal requirements

In order to obtain the relatively high intensities necessary a signal unit needs to consist of a light source of modest wattage (such as a halogen lamp), a reflector to efficiently collect and project the light and a front refractor (to spread the light into the required beam shape to provide angular coverage and to colour the light).

This is the basis of the signal unit used for the successful System B. A yellow signal unit used by the RTA in arrays for flashing warning arrows on roadworks vehicles also appears to exceed the required signal intensities. It consists of a sealed beam with a 35W light source and yellow glass front refractor incorporated in the sealed beam unit (RTA, 1991).

System C uses a high wattage lamp in a reflector but the light is used to transilluminate a large area in an attempt to accomplish the dual aim of providing both a signal and a sign. The light is also wasted in a beam of unnecessary angular coverage with a hole in the centre. During the photometric tests, where a steady light was needed, the diffuser panel of the light under test started to melt due, apparently, to the proximity of the very hot halogen lamp. Following this incident another panel had to be tested and the tests were limited to durations of no more than 30 seconds. Depending on the flammability properties of the diffuser panel, if the flashing function of a unit in service ceased to work and one lamp was on continuously, then *it is possible that the unit may catch fire*.

System D utilises an outmoded optical system which is essentially a circular fresnel lens in front of an inefficient festoon lamp. As well as the system being inherently inefficient, the light is also wasted in a beam of unnecessary angular coverage. Increasing the lamp wattage from 18W to 21W (the maximum value for this type of lamp) would only increase intensity by about 15% - well below the necessary intensity.

Whilst the signal technology is readily available to produce the required performance, this will need careful specification and monitoring of its implementation

RTA Technical Specification 142 specifies that the photometric performance of the signals should comply with ADR6/00. In accordance with this ADR, rear turn signals must have an intensity of at least 50cd and a maximum intensity of 200cd if they are designed for day and night use. Notwithstanding that these intensities are insufficient for school bus signals, it was clear from the field evaluation that a variety of aftermarket signal units have been fitted to buses and some are unlikely to meet the ADR requirements for intensity and distribution of light. All of the units observed to date employ inefficient optical assemblies and some have been fitted without regard to the correct orientation of the unit - on one of the buses intended to be used in the evaluation the light was so inconspicuous that there was a question about whether the lights were operating at all. In some cases the lights have been fitted to sloping surfaces so that the reference axis was pointing upwards.

2.6 Specification of signal requirements

In order to set out a specification for the complete angular light intensity distribution for a signal light it is necessary to document the angular position of the signal in the field of view as the motorist approaches the bus. A desirable outcome is that motorists are in the high-intensity part of the beam some distance from the bus in order to be alerted and then move into a lower intensity portion of the beam when they get closer to the bus, to alleviate any potential over brightness of the signal.

Using the offsets of the motorist to the bus shown in figure 2.3.2c (viz eyes to far signal light; 2.2m vertical and 5.0m horizontal), the angular offsets during approach to a bus are obtained as shown in Table 2.6a.

Distance Away d (m)	**Angular Offset (degrees)**		**Required Signal Intensity (cd)**
	Horizontal a_H	**Vertical a_V**	
250	1.2	0.5	1800 min
100	2.8	1.3	900 min
50	5.7	2.5	600 min

25	11.3	5.0	(600 max)
12.5	21.8	10.0	200 max

Table 2.6a Angular offsets for various distances from the bus and the required signal intensity for a yellow flashing signal

Also shown are the required signal intensities on approach to the signal, taken from Table 2.4. On approach the motorist should ride out of the signal beam so that the signal is not over bright. The value at 12.5m is the maximum allowed by the ADRs for a night/day rear turn signal; see Table 2.3c.

The values do not allow for any additional angular displacements of the bus with respect to the motorist i.e. the bus may be at an angle into the kerb or a bus bay or on a curve (horizontal displacement); it may be on a slope relative to the motorist (vertical displacement). The motorist may have a greater horizontal offset than that shown in Figure 2.3.2c e.g. approaching the bus on a multi-lane road. The horizontal displacements will be larger than the vertical ones.

To cope with some vertical displacement the intensity requirements at d=25m. ($\mathbf{a}_v$=5^o) should also be 600cd; this value will provide the required signal intensity but will also restrict potential over-brightness (the maximum intensity for front turn signals is 700cd; see Table 2.3c).

Turning to the intensities that are potentially available from a high-intensity signal, Figure 2.5.2 shows the intensities measured for System B, which are reproduced in Table 2.6b.

Degrees Down	**Degrees Left/Right**						
	20	10	5	0	5	10	20
0	1004	1545	1993	2481	1637	1479	620
3				3354			
5				1466			
10				147			

Table 2.6b Intensity distribution (cd) for high intensity yellow signal

Note: measurements carried out for steady light at 12.8V. Maximum intensity of 5790cd occured at 2^o down and 2^o left to reference axis.

It can be seen that in the vertical high intensities occur down to 5^o down and thereafter there is a sharp fall off in intensity to 10^o down.The effective beam width in the horizontal is about 20^o left and right. Therefore, taking into account the angular coverage afforded in azimuth by a practical signal light, it is possible to extend the intensity requirements across a greater angular range in the horizontal than shown in Table 2.6a in order to allow for the additional angular displacement.

The values of the required intensities are minimum values. These need to be associated with maximum values to avoid excessive brightness of the signal. In Table 2.3c it can be seen that the ratio between minimum and maximum values for signals and lamps fitted to vehicles regulated by ADRs ranges from 2 to 4. Such large ratios cannot be justified in the case of the bus signal, since the resulting maximum value would lead to excessive brightness.

Taking into account available technology a ratio of 1.5 will be applied. However the minimum values in Table 2.6a will be reduced by half this tolerance (i.e. by 25%). Thus the maximum values will be only 25% above the values in Table 2.6a. The adjusted minimum values will result in only a 10% reduction in signal range, whilst providing a tolerance in design and manufacture. In practice manufacturers are likely to design signal lights well within the tolerance range and the resulting intensities are likely to be close to those given inTable 2.6a.

A model specification based on these considerations can be constructed and is given in Tables 2.6c and 2.6d.

Degrees from Reference Axis		**Degrees from Reference Axis**								
		Left					**Right**			
		30	**15**	**10**	**2.5**	**0**	**2.5**	**10**	**20**	**30**
Up	**5**					500				
	3					700				
	1.5					1400				
	0		500	700	1400	1400	1400	700	500	
Down	**1.5**					1400				
	3					700				
	5					500				
	10	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*

Table 2.6c Recommended intensities for a flashing yellow signal light

Degrees from Reference Axis		**Degrees from Reference Axis**								
		Left					**Right**			
		30	**15**	**10**	**2.5**	**0**	**2.5**	**10**	**20**	**30**
Up	**5**					170				
	3					230				
	1.5					470				
	0		170	230	470	470	470	230	170	
Down	**1.5**					470				
	3					230				
	5					170				
	10	*70*	*70*	*70*	*70*	*70*	*70*	*70*	*70*	*70*

Table 2.6d Recommended intensities for a flashing red signal light

Notes:

(i) The intensities shown are minimum values except those at 10^{o} down which are maximum (*italicised).*

(ii)The minimum intensities shall not be exceeded by more than 50%.

(iii) The intensity between test points shall change in a smooth manner.

(iv) The intensity shall be measured for a steady light run at the signal operating voltage (12.8V or 25.6V).

(v) The intensities include provision for a manufacturing tolerance.

By reference to Tables 2.3d and 2.3e it can be seen that there are similarities between this specification and the SAE standard for school bus signals. The axial (0,0) values and the horizontal spread of the light distribution are very similar. However the fall off in intensity vertically downwards is much less in the SAE standard, the intensity at 5^{o} being more than twice that required. In addition there are no maximum limits to the intensities given in the SAE standard; it appears that insuffcient attention has been given to specifying a signal light which has sufficient range but that is not excessively bright when close to it.

The bright yellow signal used in the field evaluation would not conform with the model specification in that the maximum intensities in the peak of the signal light beam are too great; the signal would be photmetrically overdesigned.

2.7 The complete school bus signalling system

An *optimum* school bus signalling system would rely on signal lights in order to alert the motorist and to, largely, impart the message. A sign would supplement the lights by reinforcing the message. It is doubtful whether a composite signal-sign (using a pictogram in the manner of the Moncrieff system) could be successfully made without being impractically large and bulky.

The *optimum* system consists of yellow and red flashing signal lights of high intensity, as specified in Tables 2.6c & 2.6d, such as being capable of alerting the motorist 250m away. This would impart a high priority warning.

If a simple upgrading of the current system is required then the current yellow flashing signal lights should be replaced with bright yellow signals as specified in Table 2.6c. However the system is likely to be less effective than the optimum system.

Other relevant aspects of the system need to be addressed as well.

2.7.1 Flash Rate

Whilst the flashing of the signal is likely to command attention, the flashing will reduce the effective intensity of the signal. It is therefore important to limit the flash rate to counter this effect whilst having a flash rate which engenders a sense of urgency and limits the total cycle time of the system. A flash rate of 60 to 75 cycles per minute would fulfil these requirements and be within the normal requirements for vehicle signals.

2.7.2 Delay for flashing lights to extinguish

Technical Specification 142 requires the signalling system to remain activated for between 20 and 30 seconds after the bus doors close. It is understood that this is based on the findings of the School Bus Safety Task Force (RTA, 1992) and is intended to provide extended warning for oncoming motorists whose view of children crossing the road might be obscured by the bus as it moves back onto the carriageway. The tender specification for NSW STA buses requires buses to have sufficient power and suitable gearing to accelerate from 0 to 60km/h in 25 seconds on a level road, fully laden. During this time the bus will have travelled about 200m so the warning provided to oncoming motorists will be similar to that derived in Section 2.2.

It is understood that there has been criticism of the relatively long delay time of current systems, particularly in urban areas where the bus might reach the next bus stop before the lights stop flashing. This can result in loss of credibility of the signalling system.

The use of brighter lights, with at least 250m signal range would allow the delay time to be substantially reduced. In theory, with brighter lights, no delay is required in order to provide the same warning as that available from current systems. There is, however, an advantage in having the lights operate while the bus moves back onto the carriageway because the sight angles are improved and a moving bus is also more conspicuous. A delay of about 5 seconds would be appropriate.

2.7.3 Location and mounting of signal lights

To provide as much warning as possible to approaching motorists, particularly where the road has a crest, the signalling systems should be mounted as high as possible on the rear and front of the bus. The fact that a high-mounted light is less visible to a motorist in close proximity to the bus is of little consequence - the motorist should see and react to the signal when he or she is at least 100m from the bus.

A low-mounted flashing light is likely to be distracting and counter-productive at close range (this is a possible concern with the Moncrieff system), particularly when the ambient light levels are low.

It is preferable that all signal lights on school bus signalling systems have the same transverse spacing in that motorists use the angular separation to judge subconsciously the distance to the bus. In practice this may not be possible due to the variations in bus designs (between buses and between the front and rear of the same bus). In the circumstances, the location requirements prescribed in Technical Specification should be retained.

It is most important that the signal lights be mounted so that the reference axis is parallel to the axis of the road. A general inspection of buses shows a cause for concern to be the number having current signals mounted on sloping surfaces with the reference axis pointing up in the air, compounding the problem of the poor intensity of these signal lights.

A well-designed high-intensity signal will have an elliptical beam to spread the light across the road, in elevation the beam will be narrow. Therefore correct mounting alignment of the signal unit is essential. It is desirable that a means of physically checking the vertical alignment of a signal unit be incorporated in its design.

2.7.4 Possible mandatory speed limit near school buses

Roads adjacent to many NSW school now have a 40km/h speed limit which applies during school travel hours. A prototype roadside warning system, which incorporates solar powered flashing lights, is currently being trialed by the RTA in Harbord Road, Brookvale (see photographs - Appendix F).

If a 40km/h speed limit was introduced for school buses, in accordance with Staysafe (Staysafe 1994, Rec 16), then consideration should be given to the provision of an illuminated 40km/h speed limit sign which would operate in conjunction with the flashing lights on the bus (a non-illuminated sign would cause confusion because many trucks and coaches already have a 100km/h sign on the rear to indicate that they are speed-limited).

Such a sign would act as a supplement to the signals but would not only reinforce the message of "slow down and stop if necessary to avoid an accident" but indicate what speed it is necessary to slow to. This type of **positive** reinforcement is a well established principle in ergonomic design. The sign cannot be impractically large; it needs to be readily legible at a sufficient distance so that approaching motorists can check their rate of deceleration, already triggered by the flashing lights, and further adjust their speed if necessary.

Using the current norm of 7m per 10mm of letter height, the lettering on the sign would need to 150mm high to be legible from 100m. A prototype sign with letters of this height has been observed. This sign consists of an array of bright red light emitting diodes (LEDs) which flash in unison with the flashing signal lights (see photograph - Appendix F). This imparts an effective message.

Even without a mandatory speed limit, a flashing 40 sign would be of benefit, given that lack of a uniform reaction amongst the participants in the field evaluation. The space taken up by the current sign could be better utilised for this purpose.

2.7.5 Supervision

The application of an amended Technical Specification will need close supervision. The signal lights offered for fitment to buses will need to be verified that they indeed have the prescribed light beam intensities; this may be achieved by requesting a manufacturer to supply a test certificate for the signal unit from an NATA accredited photometric laboratory (as for ADR compliance). In addition, fitting of the equipment needs to be checked for correct alignment and operation.

2.8 Conclusions of Section 2

a) Function of signalling system

The function of a school bus signalling system is to alert motorists who are approaching from either direction to the possibility of children on the road in the immediate vicinity of a bus which is stationary or has just departed. To be effective the signalling system must satisfy three requirements viz, it must be readily seen, its purpose must be recognised and it must elicit an appropriate response.

b) Signal range

The distance away that a signalling system needs to be readily seen is 250m; this value will cover all the various speed limits of roads over which school buses operate.

c) Sign

For a sign to be seen *and recognised* at this distance (and even at intermediate distances) it would need to be impractically large, therefore it can only be used to reinforce the message essentially provided by the signals

d) Signal lights

For a yellow flashing signal to be seen at a distance of 250m it must have an intensity of 1800 candela. This value appears relatively high when compared to the ADR requirements for vehicle turn signals. This results from two main factors; the relatively long signal range required and the relatively large offset of the signal on the bus from the motorist's line of sight.

e) Day-night signal intensities

In order that the school bus signal lights are not potentially glaring at night to approaching motorists the signal light beam must be carefully controlled.

f) Flashing signals

Contrary to popular belief, a flashing signal is more difficult to detect initially than a steady one. However, once detected a flashing signal is more likely to be taken notice of. Care needs to be taken in the specification of the flash rate and cycle time to limit loss of signal range and increase in driver reaction time. A flash rate of 60 to 75 cycles per minute is recommended.

g) Backboards

For a black surround to a signal to noticeably improve the conspicuity of the signal it needs to be impractically large.

h) Colours

Only the colours red and yellow should be considered. These colours have universal conventional meanings. Yellow by itself will fulfil the purpose of providing a warning of a hazard whereas red by itself warns of danger.

A combination of yellow and red can convey a higher priority warning than yellow alone. This is currently being implemented in roadside signage. This combination could be used likewise in signal lights. Such a signal (yellow and red) should not be exclusively assigned to one type of use.

The school bus situation is one where this higher priority yellow/red combination could be applied.

i) Achievement of necessary signal intensities

The value of signal intensity given in (d) is much higher than that required in the current technical specification, viz about ten times. The value is also much higher than that produced by both the Current and Moncrieff signal systems. However, this value can be readily achieved using current technology.

j) Specification of photometric requirements

The preceding conclusions, together with considerations of the angular coverage required of the signal and the light intensities available from a high intensity signal, lead to a model specification of the signal light intensity distribution shown in Tables 2.6c and 2.6d.

k) Delay for flashing lights to extinguish

The use of a high intensity signal with greatly enhanced signal range obviates the need for the signal to operate for a long period after the bus doors close. A time of 5 seconds is recommended.

l) Mounting of signal lights

The correct alignment of a high intensity signal unit is essential. A cause for concern is the number of buses having the current signals mounted on a sloping surfaces with the signals pointing up in the air.

m) Speed limit near school buses

The speed to which motorists should be expected to slow down should be incorporated in a school bus sign. These signs could be a red flashing "40"; technology is readily available to achieve this.

n) The complete school bus signalling system

An *optimum* school bus signalling system would rely on signal lights in order to alert the motorist and to, largely, impart the message. A sign would supplement the lights by reinforcing the message. It is doubtful whether a composite signal-sign (using a pictogram in the manner of the Moncrieff system) could be successfully made without being impractically large and bulky.

The *optimum* system consists of yellow and red flashing signal lights of high intensity, as specified in Tables 2.6c and 2.6d, such as being capable of alerting the motorist 250m away. This would impart a high priority warning.

If a simple upgrading of the current system is required then the current yellow flashing signal lights should be replaced with bright yellow signals as specified in Table 2.6c. However the system is likely to be less effective than the optimum system.

m) Supervision

The application of an amended Technical Specification will need close supervision. The signal lights offered for fitment to buses will need to be verified that they indeed have the prescribed light beam intensities. In addition, fitting of the equipment needs to be checked for correct alignment and operation.

Section 3 - Conclusions & Recommendations

This section is based on the findings of Sections 1 and 2.

Conclusions

Signalling system visibility

1. The signalling system requires a signal range of 250m (Section 2.2)
2. This range is not available from the systems specified in RTA Technical Specification 142 because the flashing signal lights are too dim and the sign is too small (Sections 1.7, 2.3.2, 2.5.2)

Signalling system message

3. The message ("slow down and be prepared to stop to avoid an accident") should be based on flashing signal lights supplemented by a reinforcing message (Section 1.7, 2.3.2, 2.7.4).
4. Replacing the signal lights of the current system with ones of higher intensity improves, somewhat, the effectiveness of the system but there is scope for further improvement (Section 1.7).
5. A high-priority warning signal light system of yellow and red lights should be introduced, the precedence having been established for road signs. This system should be used for school bus signalling systems but not reserved exclusively for it (Section 2.4.7).
6. A flashing "40" sign will provide positive reinforcement to the signals in both eliciting the desired response from motorists and unambiguously indicating the appropriate speed (Section 2.7.4).

Signal configuration

7. The flashing signal lights should be mounted in red and yellow pairs at the front and rear of the bus, as high as possible in the locations as set out in RTA Technical Specification 142. In addition the signals must be mounted so that the reference axis of the signal unit is parallel to the longitudinal axis of the bus (Section 2.7.3).

System Specification

8. A photometric specification is necessary in order to realise the required signal range whilst controlling the potential for the signal to be over-bright (Sections 2.4.5, 2.6). A model photometric specification for yellow and red signal lights is given in the following tables.

Degrees from Reference Axis		**Degrees from Reference Axis**								
		Left					**Right**			
		30	**15**	**10**	**2.5**	**0**	**2.5**	**10**	**20**	**30**
Up	**5**					500				
	3					700				
	1.5					1400				
	0		500	700	1400	1400	1400	700	500	
Down	**1.5**					1400				
	3					700				
	5					500				
	10	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*	*200*

Recommended Intensities for a flashing yellow signal light

Degrees from Reference Axis		**Degrees from Reference Axis**								
		Left					**Right**			
		30	**15**	**10**	**2.5**	**0**	**2.5**	**10**	**20**	**30**
Up	**5**					170				
	3					230				
	1.5					470				
	0		170	230	470	470	470	230	170	
Down	**1.5**					470				
	3					230				
	5					170				
	10	*70*	*70*	*70*	*70*	*70*	*70*	*70*	*70*	*70*

Recommended Intensities for a flashing red signal light

Notes:

(i) The intensities shown are minimum values except those at 10º down which are maximum (*italicised).*

(ii)The minimum intensities shall not be exceeded by more than 50%.

(iii) The intensity between test points shall change in a smooth manner.

(iv) The intensity shall be measured for a steady light run at the signal operating voltage (12.8V or 25.6V).

(v) The intensities include provision for a manufacturing tolerance.

9. Only yellow and red colours shall be used and these shall be in accordance with ADRs 6 and 49 respectively (Section 2.4.7).

10. The flash rate of each signal shall be between 60 and 75 cycles per minute (Section 2.7.1). The flash sequence shall be red-left, yellow-right then yellow-left, red-right (the start of operation can be at any part of the cycle). As one light is extinguished the next light shall be energised (Sections 2.4.1).

11. The provision of a black surround should not be mandatory, but if provided shall be of a matt finish (Section 2.4.4).

12. Signs based on the current system shall be in accordance with RTA Technical Specification 142.

    If provided, a flashing "40" sign shall be red, shall flash in unison with the signal lights and shall have a minimum character height of 150mm (Section 2.7.4).

14. High intensity flashing signal lights shall continue to operate for 5 seconds after the bus doors are closed (Section 2.7.2)

Discretionary Signalling Systems

15. Signal lights and signs, other than those prescribed in clauses 7 to 14, should not be permitted (Sections 1.7, 2.4.1, 2.5.1, 2.5.2).

Practical Realisation of System

16. The technology is readily available in Australia to produce both the high intensity signals and the flashing "40" sign (Sections 2.5.2, 2.7.4).

    High intensity signals are routinely fitted to school buses in the USA. However, the relevant SAE Standard is deficient in guarding against the signal being excessively bright in that it does not specify maximum values and gives insufficient attention to the cut-off of light as motorists approach the bus (Sections 2.3.2.3, 2.6).

Recommendations

The current system of school bus signals needs upgrading and better supervision. To this end the following recommendations are made:

1. A high priority warning system, consisting of red and yellow flashing lights,should be introduced for use on selected vehicles and roadside signalling systems.
2. RTA Technical Specification 142 should be amended to incorporate conclusions 7 to 14.
3. This amended specification should form the basis of a national standard.
4. If by doing so, there are likely to be delays in the implementation of the amended Technical Specification, then high intensity yellow lights should replace the signal lights in current use immediately, as an interim measure, and Technical Specification 142 should be amended to include clauses 8, 9, 10, 14 & 15 (with reference to a red signal deleted).
5. Greater attention should be paid to the supervision of the quality of installation of signalling systems:

   a) compliance of signal light units with the photometric specification should be demonstrated by the manufacturer by means of a test certificate from an accredited NATA measurement laboratory

   b) check procedures should be developed and carried out to ensure that signal units fitted to school buses are correctly aligned.

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APPENDIX A

Roads & Traffic Authority Technical Specification 142
Signs & Flashing Lights for School Buses

APPENDIX B

Photographs of Signalling Systems & Site

Site & Participants

View of the buses used in the evaluation. In order from left to right: System D, System A, System C (note location of the Moncrieff panel at mid-height) and System B. The fifth bus was used for a test run.

Participants observing signalling systems from 100m

Participants observing signalling systems from 250m

Line of participants observing signalling systems from 250m

System A - Current NSW Signalling System

Bus fitted with a system which apparently complies with Technical Specification 142. Note the "children crossing" sign wraps under the top panel. Also note the "Slow down" advertisement which was not intended to be part of the evaluation.

Type of lamp used for System A and System D

System B - Current System with brighter yellow lights

Bus fitted with bright yellow lamps in place of the type of lamp used for System A.

Type of lamp used for System B.

System C - Moncrieff Panel

Bus about to be fitted with the Moncrieff panel. It was attached to the gutter (dark line) just above the words "Red Bus Services".

Moncrieff panel. Note that the "40" signs were covered during the trial

System D - Current system plus red lights

Examples of systems not included in the evaluation

This was the bus intended to be used for System A but the lights could barely be seen from a few metres away and it evidently does not meet the requirements of Technical Specification 142. Note also that the sign wraps around the top panel.

This is the bus to which the Moncrieff system was fitted. The signalling system of the bus was not used in the evaluation. Note wrap-around sign and narrow lights.

APPENDIX F

Photographs of roadside signs and high-priority warning signs

Examples of Roadside Signs & Signals

1. System on trial in Harbord Road Brookvale (Manly High School)

Examples of Roadside Signs & Signals

2. Combination Red & Yellow Warning Signs

Examples of Roadside Signs & Signals

2. Combination Red & Yellow Warning Signs

Prototype unit with a flashing "40"

The system uses an array of high-intensity LEDs to display the numerals "40". The unit also incorporates high-intensity red and yellow signal lights and the LEDs flash in unison with the lights. It is intended to be mounted near the top of the vehicle.

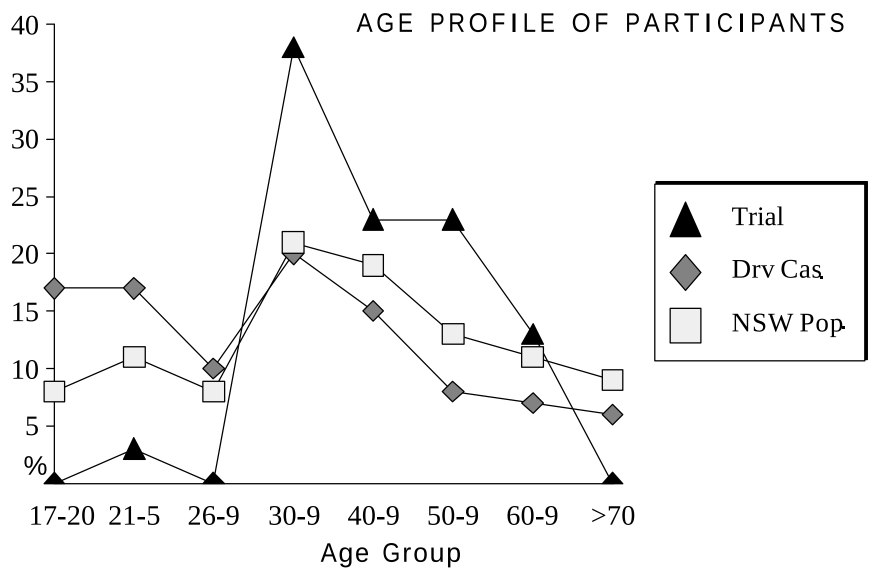
APPENDIX C

PARTICIPANTS

This appendix sets out the characteristics of the 39 participants in the trial of four signalling systems.

AGE

Age Group	Number in trial	% in Trial	% 1993 Driver Casualties	% 1993 NSW Population (age 17+)
17-20	0	0	17	8
21-25	1	3	17	11
26-29	0	0	10	8
30-39	15	38	20	21
40-49	9	23	15	19
50-59	9	23	8	13
60-69	5	13	7	11
>70	0	0	6	9



Sex

Eleven participants were female (28%). 28 were male.

Type of vehicle driven

Vehicle	Number of Participants
Bus	8
Car	29
Truck	1
None	1

Spectacles & Sunglasses

14 participants wore spectacles or contacts during the trial (36%). 17 participants wore sunglasses (44%), including 4 with prescription sunglasses.

Of the participants who indicated they were wearing coloured sunglasses, two indicated the colour was green, four indicated brown and one indicated amber.

Three participants wore a hat with a brim during the trial.

Interest Groups

Five interest groups were represented amongst the participants:

Interest Group	Number
Bus drivers	3
Bus industry (managers, mechanics & associations)	18
Community road safety	6
Government (e.g. Dept School Education)	5
Local parents	7

APPENDIX D

Instructions & Questionnaire

APPENDIX E

Results of Field Evaluation

Table E1 Mean Scores (Q1 & Q4) and Percent Positive (Q2, Q3 & Q5)					
Item	**Distance m**	**A Current**	**B Bright Current**	**C Mon-crieff**	**D Red & Yellow**
Q1. Mean Score (0=not at all effective 10=extremely effective)	50	4.8	8.5	5.5	6.4
	100	3.9	7.8	3.7	4.9
	250	1.9	6.8	2.6	3.7
Q2. Percent positive ("Yes")	50	46%	100%	54%	79%
	100	46%	100%	31%	72%
	250	23%	87%	23%	46%
Q3. Percent positive ("Yes")	50	82%	95%	77%	95%
	100	77%	79%	44%	82%
	250	18%	10%	10%	23%
Q4. Mean Score (0=not at all effective 10=extremely effective)	50	4.7	8.0	5.0	6.4
	100	3.8	7.1	3.2	4.9
	250	1.8	4.7	1.9	2.5
Q5. Percent positive ("Yes")	50	44%	85%	36%	74%
	100	41%	69%	15%	59%
	250	21%	56%	10%	31%

Table E2 - Frequency Distribution for Question 1												
Score for Q1	**A- Current**			**B- Bright Yellow**			**C- Moncrieff**			**D - Red & Yellow**		
	50m	**100 m**	**250 m**	**50m**	**100 m**	**250 m**	**50m**	**100 m**	**250 m**	**50m**	**100 m**	**250 m**
0	3	3	12		1			2	11			2
1	5	5	10				3	5	2	1	1	3
2	1	6	5			1	1	2	8	3	2	5
3	5	6	4	1		3	6	14	8	1	8	10
4	4	3	2		2	3	6	4	3	3	9	9
5	5	3	2	1	4	5	4	5	3	7	5	5
6	2	5	3	6	2	4	4	4	1	2	5	1
7	3	5	1	3	5	6	7	1	1	9	1	1
8	8	3		3	6	7	1			4	7	1
9	1			7	9	5	2			4	1	
10	2			18	10	5	5	2	2	5		2

Mean	4.8	3.9	1.9	8.5	7.8	6.8	5.5	3.7	2.6	6.4	4.9	3.7

Table E3 - Mean Score for Question 1 by Interest Group

Interest Group		A- Current			B- Bright Yellow			C- Moncrieff			D - Red & Yellow		
		50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m
BUS DRIVER	3	7.3	5.0	1.7	9.3	8.0	7.3	6.0	2.0	0.7	6.7	4.0	3.0
BUS MNG	18	6.4	5.1	2.9	9.1	8.6	7.3	4.4	3.2	2	7.0	5.7	3.9
COM.R.SAFE	6	1.0	1.2	0.2	6.0	4.5	5.0	9.3	6.5	6.5	4.7	3.5	2.0
GOVT	5	4.8	3.6	2.4	9.0	8.4	6.4	6.4	4.4	3.4	6.6	5.6	3.6
PARENT	7	3.0	2.7	0.7	8.4	8.0	7.1	4.3	2.7	1.1	6.1	4.0	5.0
Mean		4.8	3.9	1.9	8.5	7.8	6.8	5.5	3.7	2.6	6.4	4.9	3.7

Table E4 - Mean Score for Question 4 by Interest Group

Interest Group		A- Current			B- Bright Yellow			C- Moncrieff			D - Red & Yellow		
		50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m
BUS DRIVER	3	7.3	4.7	1.7	9.3	7.3	6.7	6.0	3.0	0.7	6.7	4.7	2.7
BUS MNG	18	6.4	5.1	2.9	8.8	7.9	5.4	3.9	2.8	1.4	6.9	5.8	2.9
COM.R.SAFE	6	1.0	0.7	0.0	5.2	5.0	3.3	9.2	5.0	5.3	4.5	3.3	0.7
GOVT	5	4.2	3.6	1.4	8.6	6.8	2.2	4.6	3	1.2	6.8	5.6	1.8
PARENT	7	2.6	3.0	0.7	7.6	7.1	5.1	4.1	2.4	1.0	6.3	3.9	3.1
Mean		4.7	3.8	1.8	8.0	7.1	4.7	5.0	3.2	1.9	6.4	4.9	2.5

Table E5 - Frequency Distribution for Question 4

Score for Q4	A- Current			B- Bright Yellow			C- Moncrieff			D - Red & Yellow		
	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m
0	2	3	12	1	1	5	3	3	14	1	1	7
1	6	6	11		1	2	3	4	5		1	9
2	2	7	6			3	1	8	8	1	1	7
3	5	3	3		4	5	5	10	6	2	7	6
4	5	3	2	2	2	3	6	5	1	5	10	6
5	3	4	2	4	2	4	4	6	2	8	5	
6	5	7	1	4	3	4	8	1	2	2	3	1
7	1	4	2	2	5	4	1	1		4	4	
8	7	1		3	4	5	1		1	8	5	2

9	1	1		7	8	2	2			3	2	1
10	2			16	9	2	5	1		5		
Mean	4.7	3.8	1.8	8.0	7.1	4.7	5.0	3.2	1.9	6.4	4.9	2.5

Table E6 - Reason for Negative Q5						
Reason	**A- Current**			**B- Bright Yellow**		
	50m	**100 m**	**250 m**	**50m**	**100 m**	**250 m**
CONFUSED WITH LIGHTS NOT ON BUS						
CONFUSED WITH OTHER LIGHTS ON BUS	2	2		1	1	
CONFUSING MESSAGE				1	1	
LIGHTS SEEN BUT MEANING NOT CLEAR		2		2	6	14
LIGHTS/SIGN BARELY VISIBLE		3	17			
LOOKS LIKE AN ADVERTISEMENT						
MORE/LARGER LIGHTS NEEDED	1					
NOT BRIGHT ENOUGH	15	14	4			
NOT NEEDED AT THIS DISTANCE						
PICTURE TOO SMALL	1		2	1	2	1
TOO BRIGHT				1		
Reason	**C- Moncrieff**			**D - Red & Yellow**		
	50m	**100 m**	**250 m**	**50m**	**100 m**	**250 m**
CONFUSED WITH LIGHTS NOT ON BUS		1				
CONFUSED WITH OTHER LIGHTS ON BUS					1	2
CONFUSING MESSAGE	8	10	2	3		
LIGHTS SEEN BUT MEANING NOT CLEAR	1	3	4		1	3
LIGHTS/SIGN BARELY VISIBLE		2	13			12
LOOKS LIKE AN ADVERTISEMENT	2	1	1			
MORE/LARGER LIGHTS NEEDED						
NOT BRIGHT ENOUGH	2	4	6	6	8	2
NOT NEEDED AT THIS DISTANCE			1			1
PICTURE TOO SMALL	6	5	2		1	1
TOO BRIGHT						

Table E7 - Question 6: Reactions for Rural Situation (where Q5 positive)												
Reaction Code	A- Current			B- Bright Yellow			C- Moncrieff			D - Red & Yellow		
	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m
A					1						1	1
B	5	9	6	11	11	15	4	3	4	9	13	9
C	9	9	4	17	17	13	8	3	2	16	12	7
D												
E	3	2	1	4	5	4	2	1		5	2	1
F	7	5		13	6	2	6	2		13	6	1
G	4	4		5	3	3	3			3	3	
H												
I				4	2	2	4	2		3	2	3
J	6	3	3	16	12	8	4		1	12	8	3

Table E8 - Question 6: Reactions for Urban Situation (where Q5 positive)												
Reaction Code	A- Current			B- Bright Yellow			C- Moncrieff			D - Red & Yellow		
	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m	50m	100 m	250 m
A	1	1				1	1			2	1	1
B	4	4	5	10	12	10	4	1	3	8	9	5
C	9	9	3	15	14	10	7	3	1	16	10	7
D								1				
E	2	1	1	3	2	2	1			5	2	1
F	5	4		10	4	2	4	2		9	5	1
G	4	3		6	5	2	4			5	4	
H												1
I	1			6	3	4	5	2		3	3	3
J	8	5	2	18	14	7	4	1	1	14	9	3

A CONTINUE SAME SPEED
B SLOW GRADUALLY
C PAY MORE ATTENTION
D BLOW HORN
E GIVE BUS SPACE
F SLOW QUICKLY
G SLOW SPECIFIC SPEED
H FLASH HEADLIGHTS
I STOP & WAIT
J SLOW & PREPARE TO STOP