DEVICES TO REDUCE THE RISK TO YOUNG PEDESTRIANS FROM REVERSING MOTOR VEHICLES

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for
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Contents

INTRODUCTION

This report describes possible technical solutions to reduce the risk of young children being run over by reversing motor vehicles. It includes the results of preliminary investigations into the rearward field of view of typical vehicles and the effectiveness of several potential countermeasures.

The countermeasures fall into two broad categories:

- Proximity sensors that alert the driver when an object is sensed within a certain distance of the rear of the vehicle.
- Visual aids to give the driver an improved rearward field of view

REVIEW OF TECHNOLOGY

Proximity sensors

A review of the Internet revealed more than a dozen products that are marketed as proximity sensors for reversing motor vehicles. Of these only three specifically mention the potential for reducing the risk of running over small children. Most appear to be designed to reduce the risk of damage to vehicles.

There are currently three types of proximity sensors *for vehicles*:

- Ultrasonic - uses similar technology to sonar location. Low cost and popular.
- Microwave - uses radar technology. Can be set up to detect doppler shift and therefore only trigger when there is relative movement between the vehicle and the object.
- Capacitive - detects change in electric field near the vehicle. No further information could be obtained.

All systems appear to involve a compromise between sensitivity (mainly detection distance) and suppressing false or nuisance alarms. For example, a system that scans too close to the ground may trigger when the vehicle approaches small bumps or ramps. It is claimed that some systems are more directionally precise than others and that these can be adjusted for larger detection distances. As will be shown, this is an important factor when considering countermeasures to child injuries.

Technically there is a difference between a 'false alarm' - when the alarm triggers with nothing present, and a 'nuisance alarm' - when the an unimportant object triggers the alarm (for example, the ground or an object to the side). For the purpose of this report both types are regarded as 'false alarms', unless otherwise stated.

The suppliers of microwave sensors claim that these are less likely to experience false alarms because they only trigger when there is relative movement. It is not clear how this claim can be substantiated - its main advantage would be that the alarm should not trigger when the vehicle is stationary. On the other hand, microwave beams may be more directional than some ultrasonic systems. Also a higher priority warning signal could be given if the gap is closing for a close object.

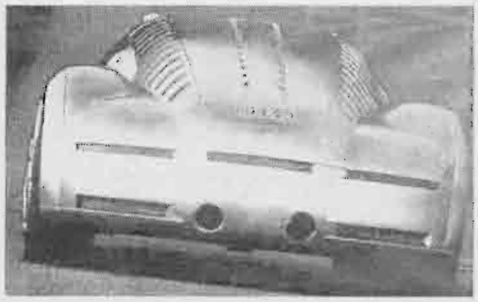
The security industry also uses infrared detectors that are intended to discriminate between people and inanimate objects. No vehicular applications of this technology were encountered but it might provide a useful long-range detection system that is less prone to false alarms.

Visual Aids

Additional mirrors, wide-angle lenses on the rear window and video systems can be used to give the driver a better view to the rear of the vehicle.

Wide-angle lenses can be purchased for around $20 from automotive shops. One style simply sticks to the rear window, which must be substantially vertical in order for the lens to work as intended. An improved type clips into a hinged bracket that is affixed to the rear window. This enables the angle of the lens to be adjusted to the optimum (vertical) position.

Video camera reversing systems have been available for trucks and buses for many years but their cost has been prohibitive for general use. Cheap CCD cameras are now available for home/factory security systems and for internet conferencing with computers. There is potential for this technology to be used on vehicles. Some vehicle manufacturers are apparently experimenting with the use of cameras in place of rear vision mirrors. The regulations would need to be changed to make such systems legal in Australia.



Rear view of Audi Rosemeyer concept car "cameras replace exterior mirrors". Automotive Engineering, Jan 2001

As discussed later, each vision system has limitations as an injury prevention countermeasure.

The most effective solution may be a combination of proximity sensor and visual aid.

REQUIRED DETECTION DISTANCES

The system must provide sufficient time for the driver to react to the alarm or image, apply the brakes and stop the vehicle. There are several factors that come into play in this situation:

- Initial speed of vehicle
- Distance at which the sensor detects the child or the child first comes into clear view
- The delay before the sensor systems activates an audible alarm.
- The time it takes for the driver to react to the alarm or image and apply the service brakes. This time is likely to be greater if the driver's foot is on the throttle at the time.
- The braking distance of the vehicle.

Williams (1999) has analysed these factors for use in mining industry vehicles. During the mid-1990s several projects of the US National Highway Safety Administration (NHTSA) looked at the issue of backup sensors on cars (for example Eberhard et al 1995). Their data have been used in the following analysis. Driver reaction times vary considerably. Williams therefore used a stochastic approach to determine the probability that a given system would result in avoidance of a collision. Figure 1 illustrates the approximate distribution for 'alert' driver reaction times. These agree with the graph presented by Eberhard et al. and are apparently based on prior work by Rumar (reference unknown). 'Surprise' reaction times are about 0.3 s greater according to the graphs presented by Eberhard. It is noted that Australian road design practice tends to use driver reaction times between 1 and 1.5 s (Paine and Fisher 1996). However, this allows for drivers to be somewhat 'relaxed' during normal driving. Reversing drivers could be expected to be more cautious.

Alert reaction times may be somewhat optimistic but they serve to illustrate that the effectiveness of these systems is highly sensitive to initial vehicle speed.

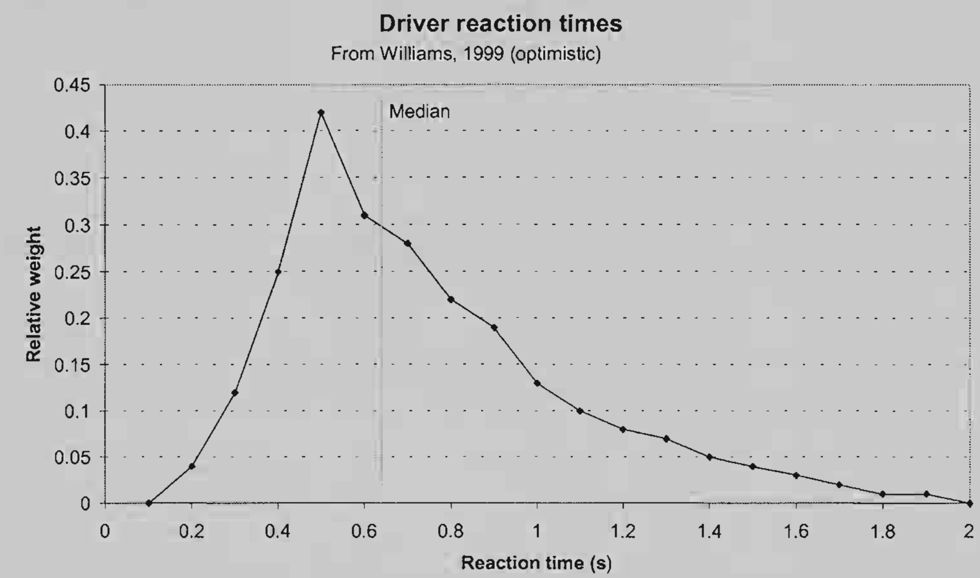


Figure 1. Distribution of driver reaction times

For the purpose of the analysis it is assumed that the device takes 0.2 seconds to detect the object and activate the alarm (based on Eberhard et al 1995 - oddly this delay does not appear to be quantified in any of the reports). It is also assumed that, once the brakes are applied, the average deceleration is 0.5g (Eberhard et al use a range 0.65 to 0.75g but this is considered too optimistic for a wide range of vehicles and drivers).

Given these inputs the probability of avoiding a collision can be calculated for a range of initial speeds and sensor detection distances. These are tabulated overleaf and illustrated in Figure 2.

Table 1. Proportion of Collisions Avoided

Initial speed		Detection distance (m)							
km/h	m/s	0.5	1	1.5	2	2.5	3	3.5	4
1	0.28	98%	100%	100%	100%	100%	100%	100%	100%
2	0.56	53%	98%	100%	100%	100%	100%	100%	100%
3	0.83	9%	78%	97%	100%	100%	100%	100%	100%
4	1.11	1%	47%	84%	97%	100%	100%	100%	100%
5	1.39	0%	15%	64%	87%	96%	100%	100%	100%
6	1.67	0%	3%	39%	72%	88%	96%	99%	100%
7	1.94	0%	0%	15%	52%	77%	89%	95%	99%
8	2.22	0%	0%	4%	31%	60%	79%	89%	95%
9	2.50	0%	0%	1%	12%	42%	65%	80%	89%
10	2.78	0%	0%	0%	4%	21%	48%	68%	81%
11	3.06	0%	0%	0%	1%	8%	31%	53%	69%
12	3.33	0%	0%	0%	0%	3%	14%	37%	56%
13	3.61	0%	0%	0%	0%	1%	5%	19%	41%
14	3.89	0%	0%	0%	0%	0%	1%	8%	24%
15	4.17	0%	0%	0%	0%	0%	0%	3%	11%

Approx 95% value (km/h)	1	2	3	4	5	6	7	8

Assumptions:

- Driver reaction times distributed as in Figure 1
- Sensor reaction time 0.2 s
- Average deceleration $5 m/s^2$

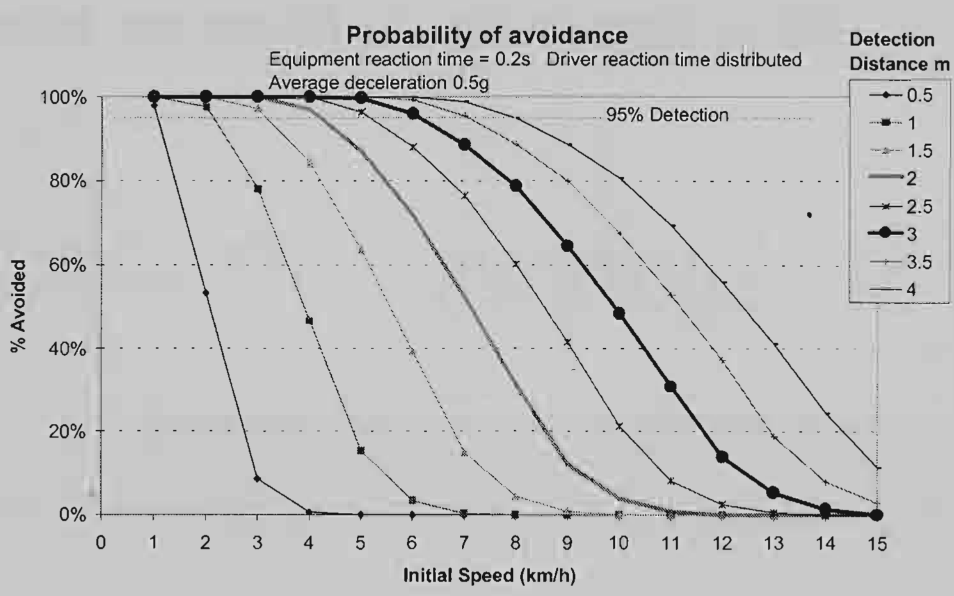


Figure 2. Derived values for % of collisions avoided

For the optimistic reaction times used in the analysis, detection distances less than about 2 metres are likely to be ineffective for vehicle speeds of 5km/h and above. For example, a detection distance of 1.5m would result in only about two thirds of collisions being avoided from an initial speed of 5km/h.

8km/h is probably a more realistic speed at which the child accidents are occurring (Eberhard et al estimate that 90% of backing accidents involving pedestrians were at speed of 8km/h or more). At this speed it is predicted that a 2m detection distance will prevent just 25% of collisions. Even a 3m detection distance will only prevent 80% of collisions.

Using 95% avoidance as a desirable level, a rough rule of thumb is that the reversing speed, in km/h, should not exceed twice the detection distance, in metres. For the 8km/h (5mph) case this matches the value derived from a formula given by Harpster et al (1996).

The analysis suggests that a 4m detection distance would be the most appropriate (95% avoidance for a vehicle travelling at 8km/h).

VISUAL ERGONOMICS

The driver's main source of information about hazards behind the vehicle is the field of view to the rear. This field of view is provided by directly looking through the rear window, by the interior rear view mirror and by external rear view mirrors. Each of these provides only a limited view of the area behind the vehicle. Even when these sources are used in combination there are blind spots behind the vehicle. The extent of these blind spots depends on numerous characteristics of the vehicle, together with the size of the driver (mainly eye height when seated) and the height of the object to be detected. The characteristics of several vehicles are discussed in the next section.

For our purposes a reasonable minimum detection height needs to be established. Henderson (2000) refers to a Canadian study: "children aged one to four were found to be involved disproportionately in daytime collisions occurring on or near a private driveway". Research in the US and Australia supports this finding. This is not unexpected since infants begin to walk between one and two years of age but up to five (at the earliest) they are unable to comprehend dangerous situations.

Dreyfuss (1993) provides the following information about young children:

Typically walks at 11 months

Typically walks up steps at 14 months

Average Standing Height

Age	Height (mm)
9 to 11 months	730
12 to 15 months	737
16 to 19 months	790
20 to 23 months	825

The driver will need to see more than the top of a child's head in order to recognise a hazard. Allowing for this, and some variation from average standing height, it is considered that the minimum detection height should be 600mm.

A further hazard is infants riding toys such as tricycles but since, for young children, their legs are nearly straight when riding these toys their riding height will not be much less than standing height.

On this basis the primary objective is to provide a field of view that enables the driver to see objects that are at least 600mm in height from the ground. It is noted that this could also represent an adult kneeling on the ground (there have been reports of people being run over while weeding driveways).

Regions immediately to the rear of the vehicle where a 600mm high object is not within the field of view are therefore considered to be hazardous locations for young children. Such regions need to be covered by proximity sensors and/or visual aids. Detection of lower objects would be useful in some unusual circumstances (such as crawling children) but this must be balanced against nuisance alarms or visual clutter.

Cognitive load on the driver

The driver cannot simultaneously look directly through the rear window and also observe the view in the rear view mirrors. When reversing under these circumstances the driver would rarely use the rear view mirrors. Sometimes drivers reverse solely using rear view mirrors (this is essential with many commercial vehicles). The use an interior rear view mirror in conjunction with side mirrors probably provides the best overall field of view (without extra devices) but can make control of the vehicle more difficult.

Countermeasures need to consider each of these modes of reversing a vehicle.

By giving an audible alarm a proximity warning device can be useful with either mode of reversing. A staged alarm that gives a higher priority warning sound for close objects is useful because drivers have a better idea of the location of the detected object. The difficulty is convincing the driver that an object that cannot be seen is worthy of caution - to the extent of stopping the vehicle, getting out and taking a look. Nuisance alarms will undermine this aim.

Visual aids must work in conjunction with the driver's mode of reversing. Wide angle lenses are suitable for reversing while looking directly through the rear window but, as discussed below, the image size and quality are marginal. This image is reduced further if the wide-angle lens is viewed via the interior rear view mirror.

Camera/monitor systems have the advantage that the position of both the camera and the monitor can be optimised. The camera can be placed in a location that gives the best view to the rear and the monitor can be located so that it is easily viewed by the driver. The size of the screen determines how close the monitor should be to the driver.

If the vehicle is being reversed by looking directly through the rear window then the monitor should be to the rear of the driver and should face forward. For the 12cm (diagonal) monitor evaluated a theoretically ideal location would be to attach it to the roof above the centre rear passenger seat. This location has obvious practical difficulties. One possibility is to have a mechanical device that only deploys the monitor when reverse gear is selected. At other times it would be flush with the roofline and out of the way.

If the vehicle is being reversed using the rear view mirrors then the monitor could be located forward of the driver and face rearward. An ideal location would be adjacent to the interior rear view mirror but again this has practical difficulties. It would also be necessary to consider whether the image in the monitor should be reversed to match the image in the mirrors. Alternatively, the monitor could be mounted to the rear of the driver and face forwards so that it is visible in the internal rear view mirror. Such a system could then be used for either mode of reversing.

A compound video system, like that used on the Audi Rosemeyer concept car, which replaces all rear view mirrors and provides the driver with simultaneous views to the side and rear may be the best long term solution.

EVALUATION OF SAMPLE VEHICLES

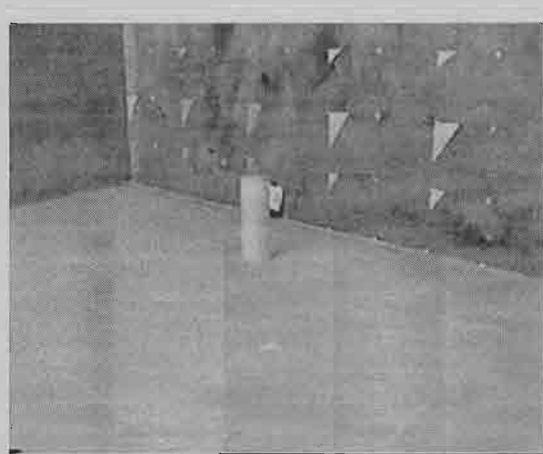
Several models of vehicle were evaluated to determine the driver's field of view to the rear.

A vacant factory was leased for the tests. A 3D grid was marked out on the walls and floor to enable measurements to be taken. Michael Paine, who is 176cm tall, performed all tests.

Field of view to the rear

Each vehicle was parked so that the rear bumper was 5m from the factory wall. Looking at the view through the rear window, key points such as extremities of the rear window and any obstructions (such as rear head restraints, wipers and high-mounted brake lights) were noted. The coordinates, on the rear wall, that aligned with each of these points were recorded. This gave two points on an imaginary line: the driver's eye position and the point on the rear wall.

Some mathematics was applied to give the 3D coordinates of a point on this imaginary line that was a given height from the ground. The output was a contour map of rearward field of view for a range of heights from the ground.



View of factory layout showing the colour-coded grid on the rear wall that was used to measure rearward field of view. Large triangles are 1m apart and high. Small triangles are 0.5 and 1.5m high. The 600mm high test cylinder is also shown.

Detailed results for each vehicle are set out in Appendix A. Test objects were used to verify the theoretical predictions.

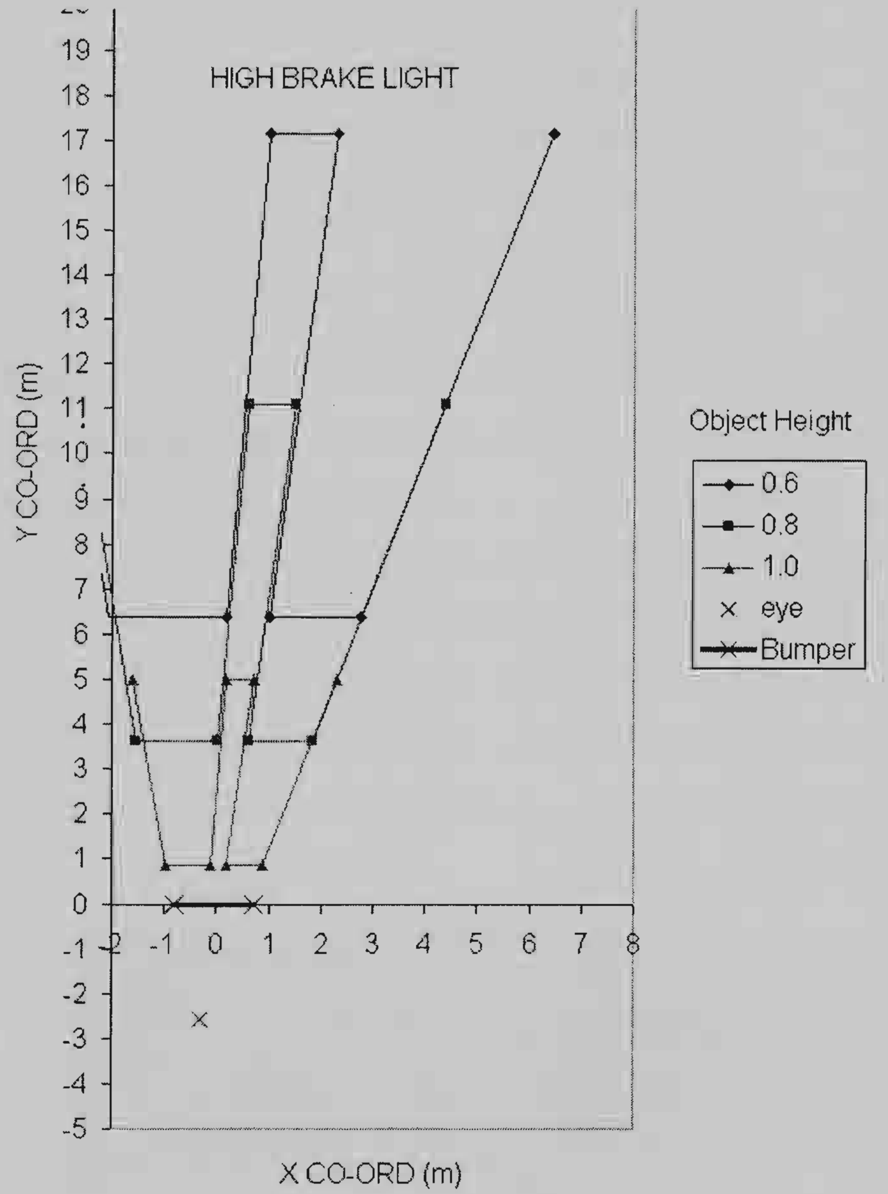


Figure 3. Rearward field of view for a 1995 Holden Commodore Station Wagon. This is a plan view. The rear bumper bar of the vehicle is along the x-axis and the vehicle is located below the axis. The driver's eye position is shown as an X, below the axis. Above the x-axis are the contours for three heights of object: 1m, 800mm and 600mm. The 600mm contour is furthest from the back of the vehicle and represents a small child. From this diagram it is evident that a 600m high object could not be seen any closer than 6.5m from the rear of this particular vehicle. The field of view is highly sensitive to visual obstructions along the bottom of the rear window. In this case the 600mm contour extends back to 17m due to the effect of the high mounted brake light on the rear window. It is also sensitive to driver's eye height.

This analysis revealed that, in many cases, the field of view is very sensitive to relatively small obstructions. The figure above shows that the high mounted brake light on the Commodore Station Wagon, although only about 80mm high, resulted in a 6m increase in sight distance for an object 600mm above the ground. This results from the very shallow angle between the driver's eye and the high mounted brake light. This also means that the field of view is highly sensitive to the height of the driver's eye. Head restraints mounted on rear seats and spare wheels mounted on the rear door of a 4WD were found to be particularly detrimental to rear field of view.

Although large four-wheel-drives and commercial vans have relatively high rear windows their field of view is not necessarily worse than that of smaller vehicles. This is because the driver generally sits higher in these vehicles and the angle between the eye and the bottom of the rear window is usually greater than that with cars. Of the limited sample of vehicles checked the Commodore VT sedan and the Honda Integra Coupe were found to be the worst. In both cases the height of the driver's eye was only marginally above the height of the bottom edge of the rear window.

Even with the best vehicle, a Peugeot 306 hatchback, a 600mm test cylinder was only visible when it was more than 3 metres from the rear of the vehicle. A small child closer than this distance would not be seen by the driver.

EVALUATION OF DETECTION SYSTEMS

Four models of proximity sensor were acquired and tested. Four types of visual aid were also tested.

Proximity sensors

The features of the proximity sensors are set out in the table.

Models of Proximity Sensor

Model	**Sensor Type**	**Cost (AU $)**
"Reverse Sensor" from Williams Geddes & Co P/L, Belrose NSW	Ultrasonic	$60 supply. Easily self-installed
"Smart Park" from MKP P/L, Neutral Bay, NSW	Ultrasonic	$649 supply and installed. Specialist installation required
"Safe Reverse" from Global Accents, Canada	Ultrasonic	$400 supply (ex GST). Easily self-installed.
"Guardian Alert" from S & S Distributing, USA	Microwave (doppler)	$700 supply (ex GST). Designed to be easily fitted as a number plate surround but does not fit Australian number plates.

Each system was, in turn, mounted at the back of the test vehicle. The vehicle was parked so that the rear bumper was aligned with the grid on the factory floor. The range of each of the systems was evaluated by the assessor slowly walking towards the rear of the vehicle along lines parallel to the vehicle longitudinal. The point at which the alarm first sounded was noted. The assessor continued to approach the vehicle and noted when higher-priority alarms sounded. In this way the detection pattern across the rear of the vehicle was determined. The results are set out in Appendix B.

In summary the Guardian Alert had the longest range (3m maximum but down to 2.2m at the offside plane). As intended, the alarm for this device only sounds when there is relative movement between the vehicle and the object. This is useful for minimising false alarms.

Of the ultra-sonic devices the Smart Park had the longest range (1.5m). The other two were set for a maximum range of 1m. It may be possible to extend this slightly with a sensitivity adjustment but this would be at the expense of more false alarms.

Applying the detection distance theory set out previously, the following table sets out the best performance that could be expected from each of the systems under ideal conditions. It is evident that only the Guardian Alert has sufficient range to enable a collision to be avoided. This is at the (relatively slow) reversing speed of 5km/h, with an alert driver.

Performance of the Proximity Sensor Systems

Model	Maximum Range	% Avoided @ 5km/h	Max speed for 95% avoidance
Guardian Alert	3m	100%	6km/h
Smart Park	1.5m	64%	3km/h
Safe Reverse	1m	15%	2km/h
Reverse Sensor	1m	15%	2km/h

Comments about the systems

Each of the systems was triggered by a 15mm high plank placed transversely 1m rearward of the vehicle. With the Guardian Alert there had to be relative movement (the object was moved towards the vehicle). This means that it still produces a nuisance alarm under operational conditions.

It appears that, for all of the systems, the vertical angular range is too large for the task of discriminating children from bumps and other small obstacles.

The Smart Park was fitted to a Honda Odyssey by an approved installer. Operational experience confirmed that too many nuisance alarms take place. For example, it was noticed that the alarm did not sound when reversing on smooth surfaces such as concrete but that it usually sounds when reversing on coarse bitumen. It is possible that the sensors have not been aligned correctly but it is doubted whether the incidence of false alarms could be significantly reduced by adjustment of the sensors. For example, the driveway where the vehicle is garaged has a dip and the alarm always sounds at high priority when traversing the dip. This is at the time that the vehicle is entering the street and is a bad time to receive a nuisance alarm.

Visual Aids

The visual aids that were tested are described in the table.

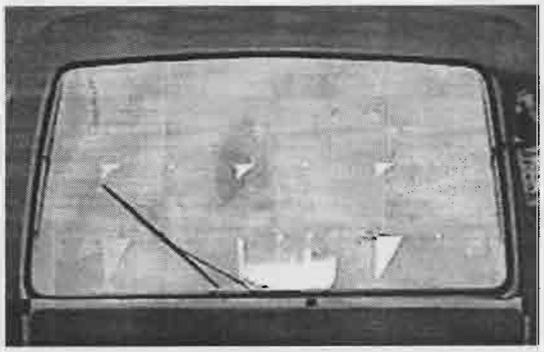
Visual Aids

Model	Cost	Comments
Vanscope wide angle lens for fixing to rear window.	$20	Only suitable for vehicles with near-vertical rear windows. Tends to obscure normal view to the rear.
Kwik Park wide angle lens with swivel mount.	$20	Can be adjusted for optimum angle irrespective of the slope of the rear window. Tends to obscure normal view to the rear.
Motorguard Blind Spot Mirror	-	Acquired to simulate a convex mirror attached to an arm over the rear window (available as an option for some vans).
Altec Video Security System.	$180	Black and white CCD camera and 12cm black and white monitor. Designed for stationary installations but able to be operated on 12VDC.

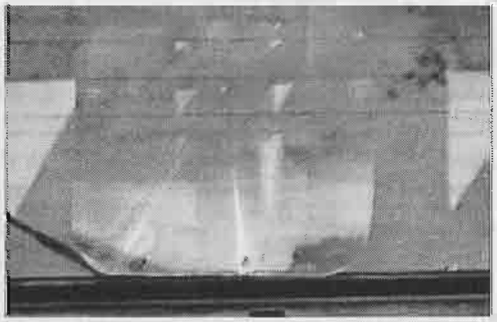
Comments about each of the systems

Vanscope

This was fitted to a Hiace commercial van. After several weeks of operation the owner was reasonably satisfied with its performance as a reversing aid.



View of rear window with Vanscope lens. The coloured target marks are on the rear wall and were used to establish rearward field of view.



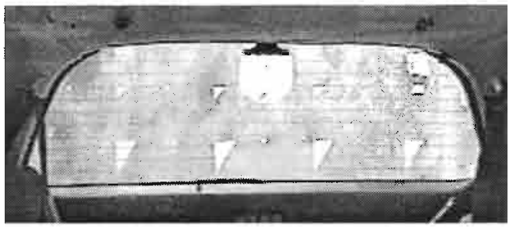
Close up of image in Vanscope. The object at lower right is 2.1m from the vehicle. The cylinder is 4m away.

Although with this particular vehicle the view through the lens covered much of the area of concern at the rear of the vehicle there are concerns about its effectiveness with children. The image tends to be very distorted and fuzzy and the presence of a child might not be evident to the driver. Also at certain angles of sunlight the lens becomes very milky.

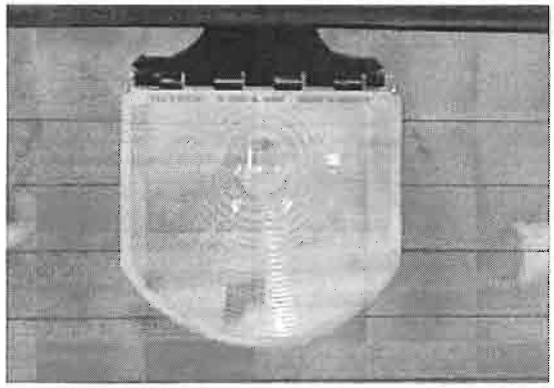
The lens was also trialled on a Honda Odyssey that has a sloping rear window. The lens was found to be ineffective at this angle. The same problem would arise with sedans and hatchbacks.

Kwik Park

The Kwik Park lens was fitted to a Honda Odyssey. It was adjusted to a vertical orientation (the angle was found to make a significant difference to the quality of the image). After several weeks the drivers were not satisfied with the performance of the device. The image was too small and distorted and the optimum location of the device for image quality resulted in the normal view to the rear being obscured.



View of rear window with Kwik Park lens

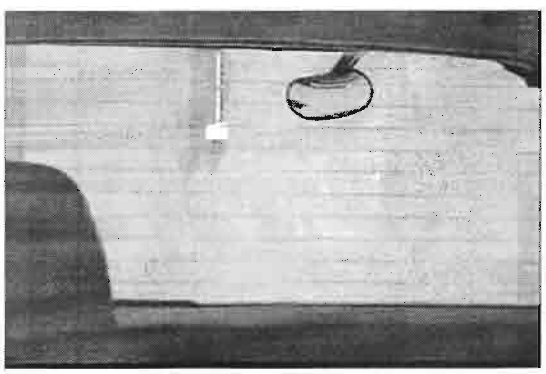


Close of of image in Kwik Park lens. The bag (black object) is 3m from the vehicle. The cylinder (orange top) is 2 m away. The edges of the curved section are 4m away.

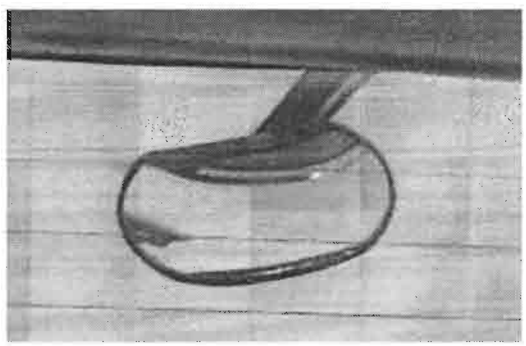
Under the evaluation conditions the factory lights caused the lens to appear milky, further aggravating the poor performance.

External mirror

Some commercial vans are fitted with an external mirror over the rear door. In order to evaluate this type of system a convex mirror was acquired and attached to a Honda Odyssey so that it could be adjusted for an optimum view. This system might be useful for close parking manoeuvres but it is not effective for detecting children while reversing.



View of rear window with external mirror



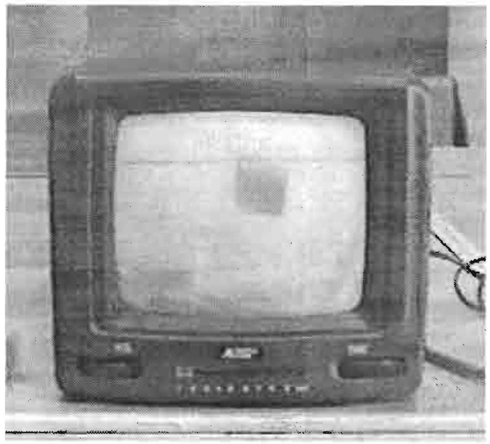
Close up of image in convex mirror. Highly distorted and upside down (the curved object is the bumper bar). The bag is 1m away and the furthest distance (the bottom of the image) is about 1.5m away.

Video camera and monitor

This system has the potential to provide the driver with a good view of the critical areas to the rear of the vehicle. The device, as tested, was not intended for this application. Components that provide better performance should be available, although cost might be a factor.

The CCD camera was temporarily mounted on the rear of the vehicle and, after experimenting, it angled down so that the closest point in the image (along the bottom of the monitor) was 1.4m from the rear of the vehicle. The area covered by the monitor is shown later in the section that discusses composite systems. In brief it covered an area greater than the width of the vehicle at the 1.4m line and the factory wall 5m from the rear of the vehicle was also visible.

Camera temporarily mounted above rear window



Monitor showing a bag 1m from the rear of the vehicle. The range is too limited at this steep angle and the camera was adjusted to a higher angle for the evaluation.

The monitor image quality was poor and had low contrast but the experiment showed that the system had the potential to provide a very good rearward field of view.

COMBINED SYSTEMS

Individually, none of the evaluated proximity sensors and visual aids provided complete coverage of the critical blind spots. An analysis was therefore conducted into the potential for combining proximity sensors and visual aid for a complete detection system. The best proximity sensor (Guardian Alert) and the best visual aid (video camera and monitor) were considered. It was assumed that a higher quality TV picture could be obtained with equipment designed for the purpose and so the visual range of the evaluated system was used in the analysis. The illustration overleaf shows the results.

This particular combination of proximity sensor and video system fully covers the main danger area at the rear of the vehicle. Objects between about 5m and 1.5m rearward of the back of the vehicle are in view on the video monitor. Objects closer than about 2.5m are detected by the proximity sensor. Therefore, provided that the driver uses the video monitor and heeds an alarm from the proximity sensor while reversing *slowly*, a collision with a child should be able to be avoided.

REAR VISION ASSESSMENT

HONDA ODYSSEY WITH REAR HEAD RESTRAINTS
GUARDIAN ALERT DETECTOR AND VIDEO CAMERA

DISCUSSION

Effectiveness of existing proximity sensors

It is evident that many current proximity systems have detection distances that are too small to be effective for the typical circumstances under which children are being injured. This is confirmed by Huey et al (1996) "These warning devices should be distinguished from parking aids...[that primarily are intended to] provide the driver with quantitative information about the distance to known objects...This is not a safety application. A backup warning device, in contrast, must capture the attention of an unalerted driver about the presence of an unexpected and unseen object behind the vehicle". Huey raises another difficulty - "a driver may see a vehicle eight feet behind him but not be aware that there is a child only two feet behind [the vehicle]. The driver could receive a warning but misinterpret it to be related to the more distant object".

It is also clear that drivers must be informed about the need to drive *very* slowly when children might be about, irrespective of whether a proximity sensor is fitted to the vehicle. It is a concern that a proximity sensor might make some drivers complacent about reversing safely. Harpster et al (1996) report that, during supervised tests, elderly drivers reversed more slowly than younger drivers (average reversing speed 2.1mph compared with 3.3mph) but the overall stopping times were the same. They suggest that older drivers compensated for slower reaction times. The converse might hold - driver's who think that a sensor will alert them to a hazard might travel at a higher speed in reverse.

It is highly unlikely that a proximity sensor could be developed that would work as a complete countermeasure. A combination of proximity sensor and visual aid is needed to cover all crucial blind spots to the rear of the vehicle.

Visual aids

Wide angle lenses and auxiliary mirrors do not provide sufficient coverage or clear enough images to enable drivers to reliably see that a child is to the rear of the vehicle. A video camera and monitor could achieve this task. The evaluated system was not intended for this purpose and the image quality was poor but it showed potential effectiveness of a higher quality video system.

Some thought would need to go into finding a suitable location for the monitor so that it is in ready view of the driver when reversing the vehicle.

Guidelines for evaluation of commercial systems

Our work should be regarded as a provisional investigation, to assess the feasibility of using technology as a countermeasure to the problem. A more rigorous evaluation would be appropriate for assessing commercial systems. We therefore propose that guidelines be developed for such evaluations. A draft technical specification has been prepared for this purpose and is included as an appendix. This section provides background on the specification.

The evaluation involves determining blind spots to the rear of the vehicle and testing whether visual aids and/or sensor systems can effectively cover these blind spots.

Blind spots

The blind spot test involves locating a test cylinder on a marked-out grid to the rear of the vehicle. The test cylinder is 200mm in diameter and 600mm in length. These dimensions were chosen to represent a small toddler. An average size driver sits in the driver's seat and observes whether the test cylinder is in view for each grid point.

An alternative method is to analyse the limits of the view through the rear window. Mathematics are then applied to determine the blind spots.

Where a system is not evaluated and marketed for specific vehicle models then the whole of the rear of the vehicle is deemed to be a "blind spot" and the system must cover all locations within 5m of the rear of the vehicle.

Tests of proximity sensors

Before testing the detection capabilities of a sensor system it is necessary to check that the sensor is not so sensitive that it will result in false/nuisance alarms Such false alarms desensitise the driver and can render the system ineffective. A reasonable false alarm test is to try backing the vehicle towards a shallow object placed across the path. A piece of wood 30mm high and about 1m long is proposed for this purpose.

Once the system has passed the false alarm test a sequence of detection tests is conducted, using the test cylinder. For simple systems it should only be necessary to switch the ignition on and place the transmission in reverse gear. For systems that only trigger when movement is detected a slightly more complicated procedure is necessary.

It is also necessary to separately check the activation time. This cannot be done by selecting reverse gear because most systems have self-testing features that will result in additional activation time.

Visual aids

Visual aids can be assessed using the same procedures as that used for determining blind spots. However, it is also necessary to check the quality of the image, to ensure that the driver will recognise the presence of a child. A methodology set out in a US Federal Motor Vehicle Safety Standard for school buses has been applied for this purpose. It involves determining the angular size of the top of a test cylinder, viewed via the mirror or visual aid. A minimum angular size is specified that is equivalent to directly viewing the cylinder at a distance of 30m.

Complete systems

No system should be marketed as "preventing" reversing accidents involving children unless it provides a complete solution to the problem. Proximity sensors alone are unlikely to fulfil this purpose and will probably need to be combined with a visual aid in order to provide the necessary protection – such combined systems must be marketed as one product. It might, however, be possible to develop a visual aid system that covers all blind spots.

CONCLUSIONS AND RECOMMENDATIONS

We have evaluated possible technical solutions to reduce the risk of young children being run over by reversing motor vehicles. We have also reviewed theoretical and experimental work on the human factors involved in preventing such accidents.

A technical solution to the problem is feasible. A combination of short-range (and low cost) proximity sensor and a wide-angle video camera system appears to be a viable countermeasure. Such a system should cost no more than $1000 installed. However, it is unlikely that any commercially available systems currently meet the requirements for a complete system.

With such a system in place it is important that drivers realise that they must still reverse very carefully. A maximum reversing speed of 10km/h would be appropriate for the combined system that was evaluated. The detection range (of the video system) was about 5m and a rule of thumb is that the reversing speed, in km/h, should not exceed twice the detection range in metres.

Wide-angle lenses do not offer the range and clarity of image of video cameras. It is unlikely that they could be further developed for this purpose. Video cameras provide the best opportunity for technological improvement. Some vehicle manufacturers are developing prototype camera systems that could eventually replace rear view mirrors on vehicles. Several manufacturers are looking at pedestrian detection systems as part of their Intelligent Transport System (ITS) programs and they would be interested in the outcome of our work.

Dr Henderson (2000) made a range of recommendations to address the problem of children being run over by reversing vehicles. The following items build on those recommendations:

1. This report and the draft performance specification should be circulated to stakeholders (transport authorities, motorist organisations, vehicle manufacturers and component manufacturers/suppliers) for comment and advice about available technology. The specification should then be reviewed and published (possibly by RTA).
2. Companies should be invited to develop, at their own cost, complete systems that comply with the specification. Such systems should then be independently evaluated.
3. If suitable systems become available, the MAA and other organisations should promote their availability, along with educational material on the risk of driveway injuries to small children.
4. The MAA should monitor the uptake of these devices and obtain feedback from motorists who install them. It should then review the specification, if necessary, and promotional campaigns.
5. The RTA should seek to have the specification adopted at a national level, as an optional accessory for motor vehicles. It is unlikely that mandatory fitting of the systems could be justified on current cost-benefit criteria but there may be a case for requiring that vehicle manufacturers make such systems available as an option.

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APPENDIX A – EVALUATION OF FIELD OF VIEW OF SAMPLE VEHICLES

Honda Odyssey passenger van

Holden Commodore station wagon

Toyota Hiace commercial van

Subaru Outback station wagon

Honda Integra coupe

Mitsubishi Express 4WD commercial van

Holden Commodore VT sedan

Toyota Prado 4WD

Peugeot 306 Hatchback

Details of the measurements for each of the sample vehicles are given on the following pages.

The graphs show plan views. The rear bumper bar of the vehicle is along the x-axis and the vehicle is located below the axis. The driver's eye position is shown as an X, below the axis. Above the x-axis are the contours for three heights of object: 1m, 800mm and 600mm. The 600mm contour is furthest from the back of the vehicle (highest on the graph) and represents a small child.

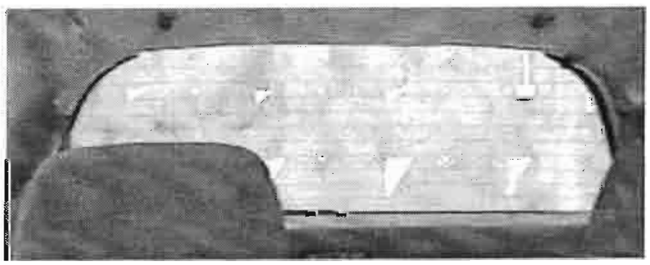
HONDA ODYSSEY

Test No: C0 Regn: MP717 Year: 1997

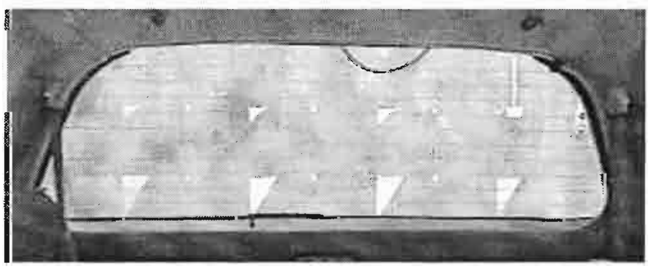
Position	X	Y	Z
Driver's eye position	-0.3	-2.4	1.3
Centre rear	0	0	0
NS rear	-0.8	0	0.6
OS rear	0.8	0	0.6
NS mirror	0.9	-3	1.1
OS mirror	-0.9	-3	1.1
Centre lowest obstruction	0	0	1.1

General view of vehicle

With rear seat head restraints

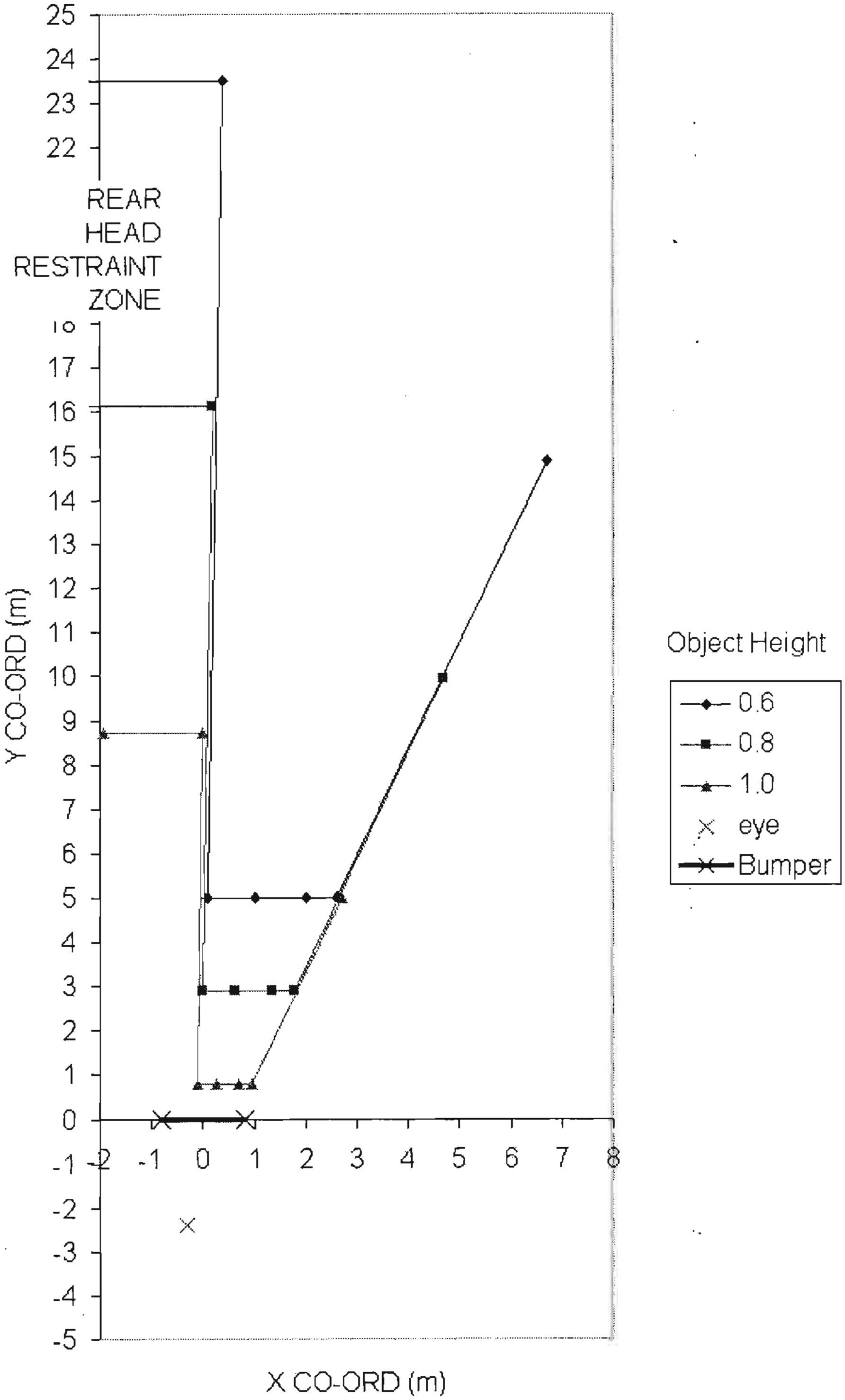


Without rear seat head restraints



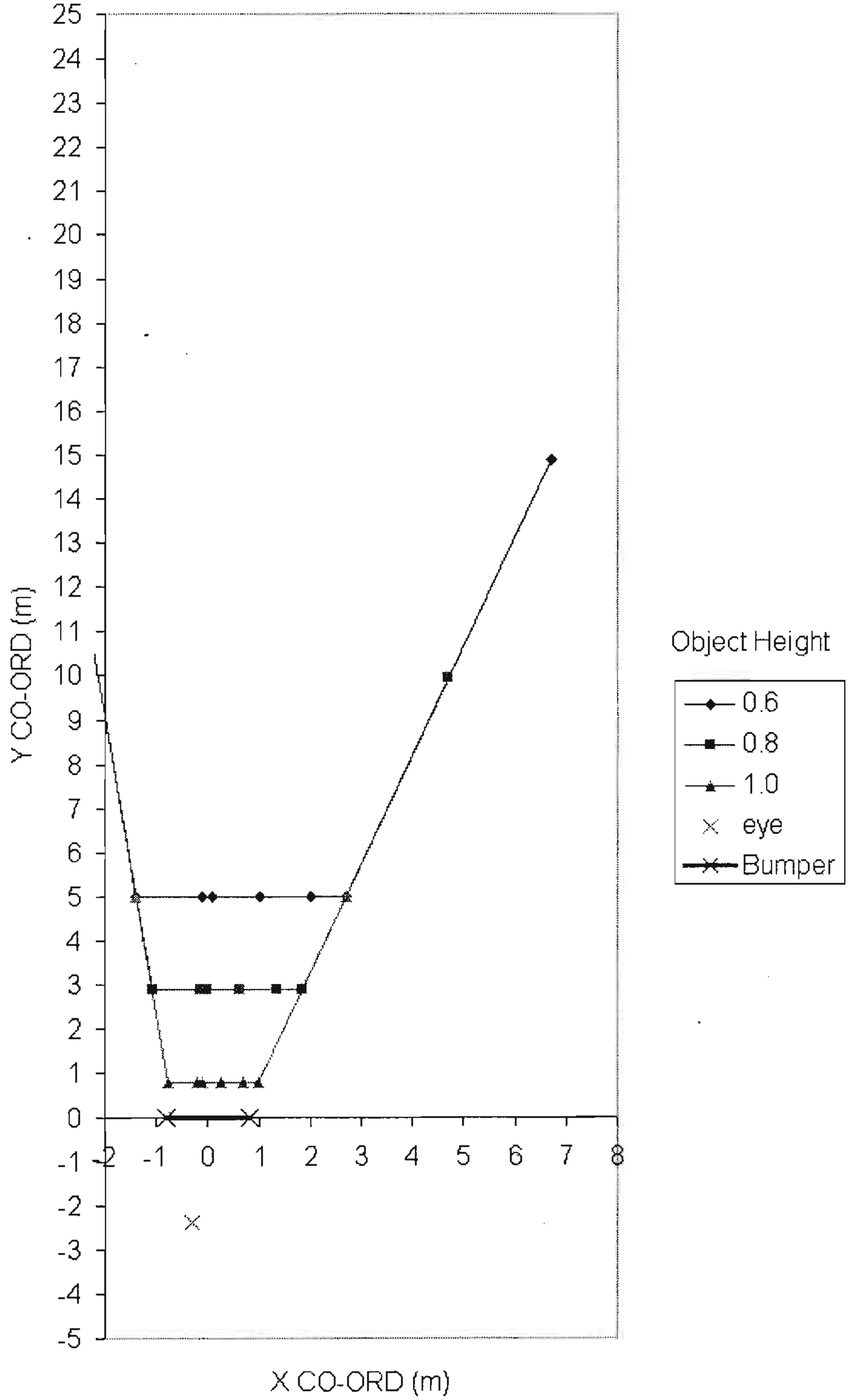
REAR VISION ENVELOPE

HONDA ODYSSEY WITH REAR HEAD RESTRAINTS



REAR VISION ENVELOPE

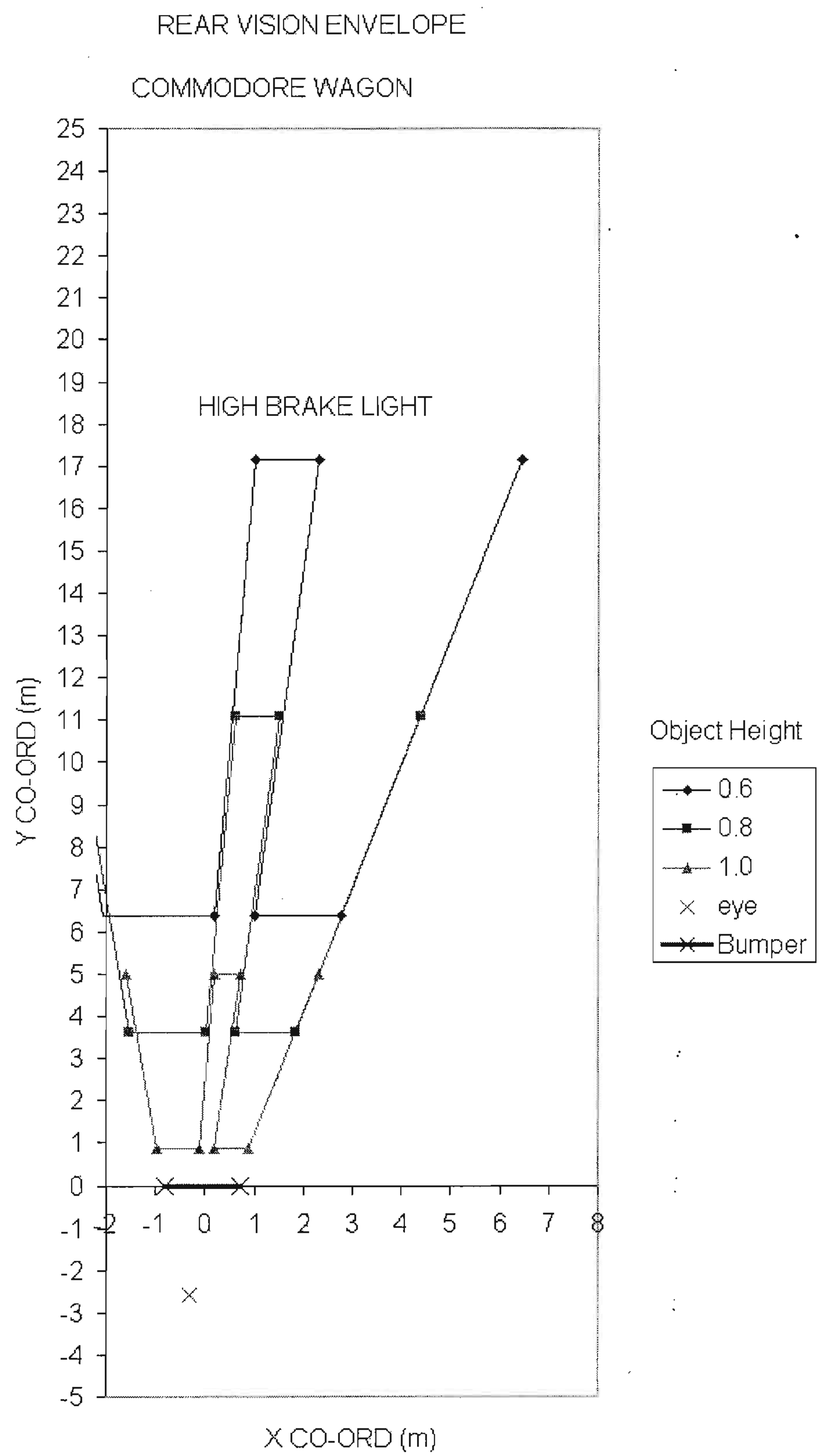
HONDA ODYSSEY (NO REAR HEAD RESTRAINTS)



COMMODORE WAGON

Test No C1 Regn TQQ483 Year: 1996

Position	X	Y	Z
Driver's eye position	-0.3	-2.6	1.25
Centre rear	0	0	0
NS rear	0.7	0	0.6
OS rear	-0.8	0	0.6
NS mirror	0.8	-3.2	1
OS mirror	-0.9	-3.5	1
Centre lowest obstruction	-0.1	0	1.06



REAR VISION ENVELOPE
COMMODORE WAGON
HIGH BRAKE LIGHT
Y CO-ORD (m)
X CO-ORD (m)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-2 -1 0 1 2 3 4 5 6 7 8
Object Height
0.6
0.8
1.0
eye
Bumper

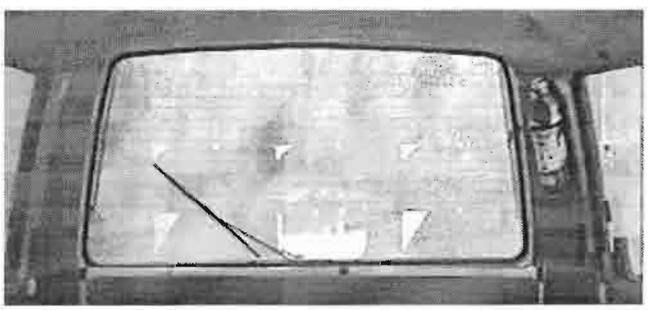
HIACE COMMERCIAL VAN

Test No: C2 Regn: EJS666 Year: 1989

Position	X	Y	Z
Driver's eye position	-0.4	-3.3	1.65
Centre rear	0	0	0
NS rear	0.8	0	0.5
OS rear	-0.9	0	0.5
NS mirror	0.9	-4.1	1.3
OS mirror	-1	-4.1	1.3
Centre lowest obstruction	0	0	1.2

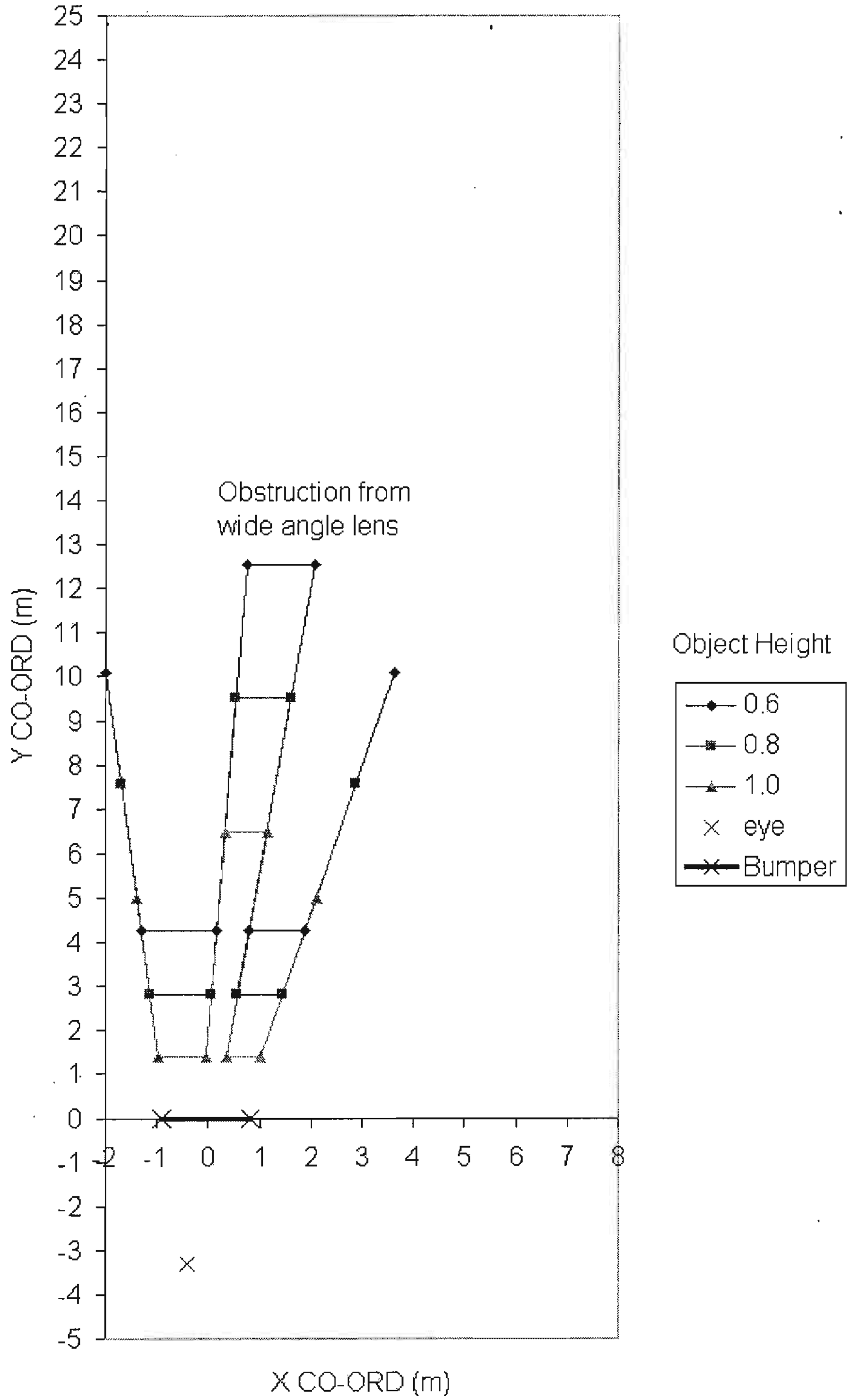
General view of vehicle

View from driver's position



REAR VISION ENVELOPE

TOYOTA HIACE VAN



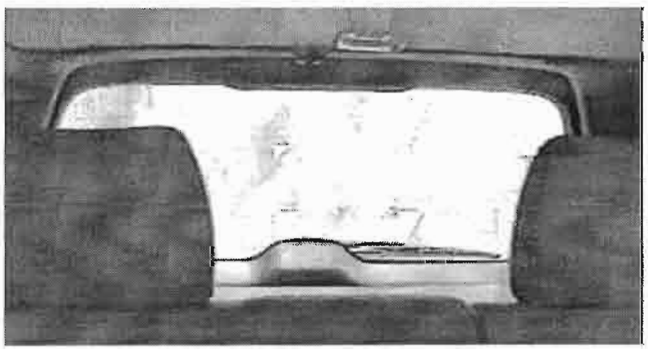
SUBARU OUTBACK WAGON

Test No: C3 Regn: AFW73B Year: 1998

Position	X	Y	Z
Driver's eye position	-0.2	-2.3	1.23
Centre rear	0	0	0
NS rear	0.8	0	0.5
OS rear	-0.8	0	0.5
NS mirror	0.9	-2.9	1.04
OS mirror	-0.9	-2.9	1.04
Centre lowest obstruction	0	0	1.1

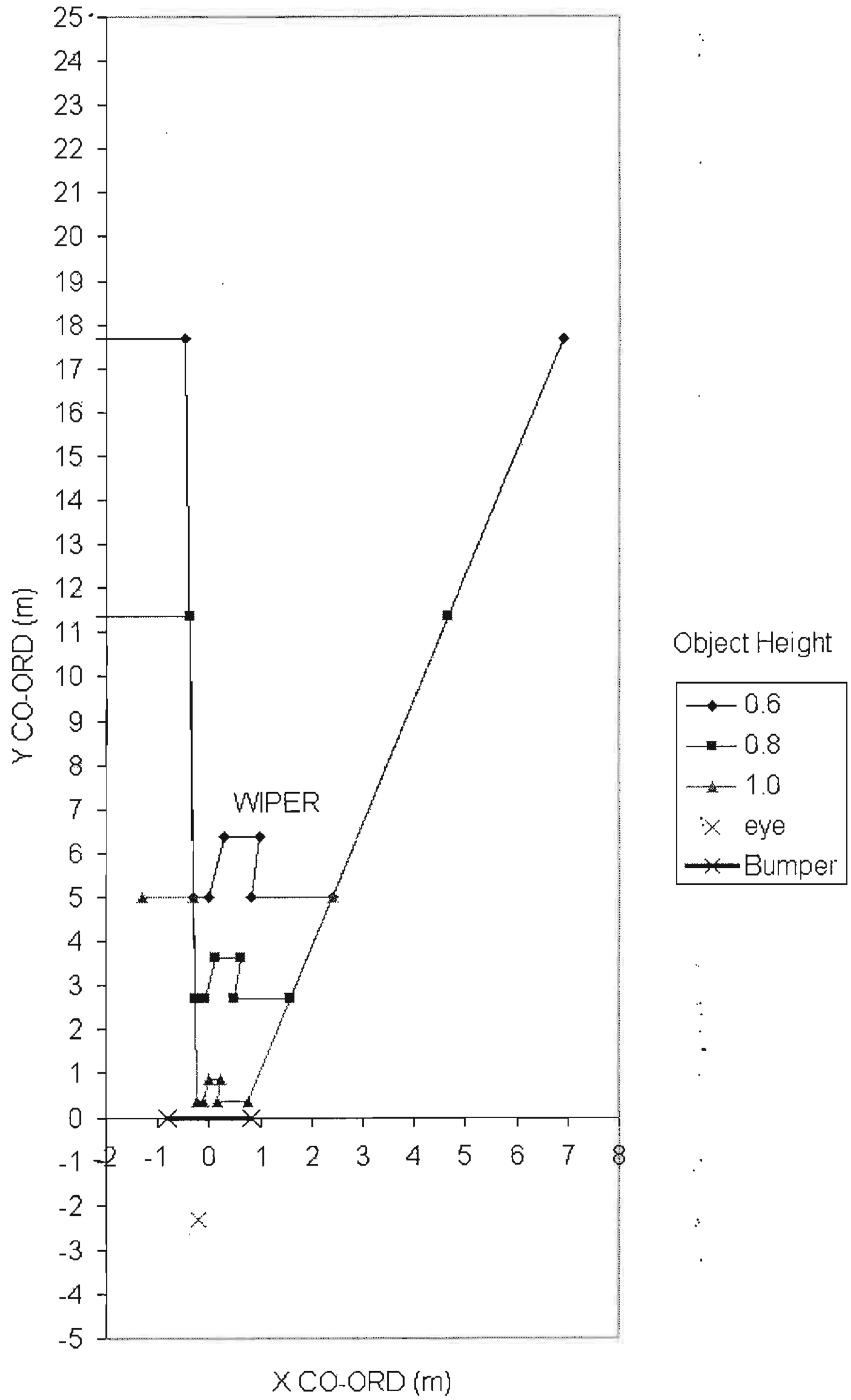
General view of vehicle

View from driver's position



REAR VISION ENVELOPE

SUBARU OUTBACK 4WD WAGON



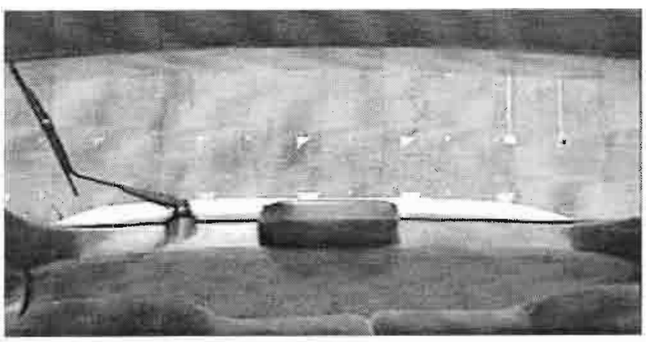
HONDA INTEGRA COUPE

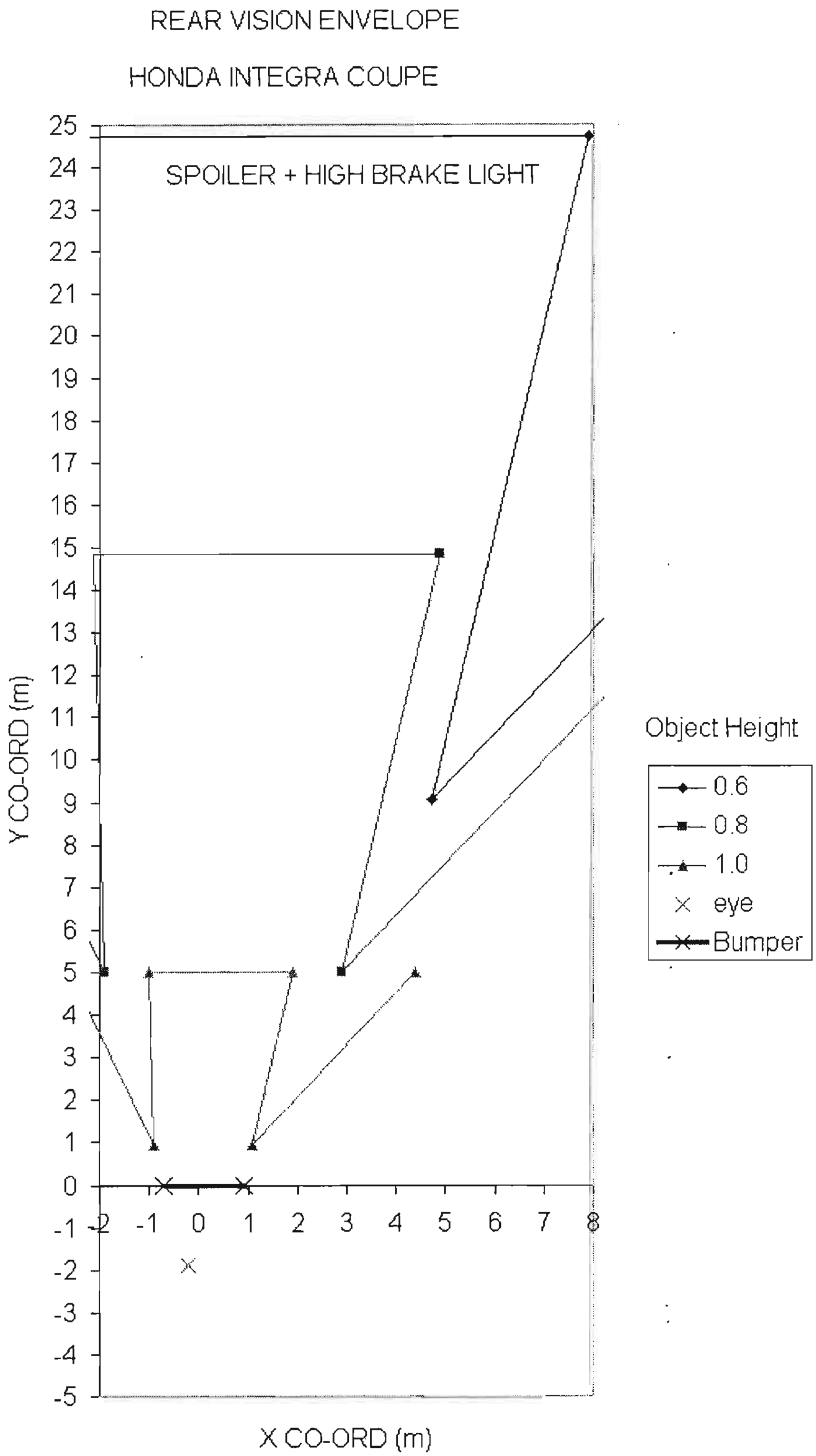
Test No: C4 Regn: AEH42N Year: 1996

Position	X	Y	Z
Driver's eye position	-0.2	-1.9	1.14
Centre rear	0	0	0
NS rear	0.9	0	0.6
OS rear	-0.7	0	0.6
NS mirror	1	-2.5	0.93
OS mirror	-0.8	-2.5	0.93
Centre lowest obstruction	0	-0.5	1.1

General view of vehicle

View from driver's position




REAR VISION ENVELOPE
HONDA INTEGRA COUPE
SPOILER + HIGH BRAKE LIGHT
Y CO-ORD (m)
X CO-ORD (m)
Object Height
0.6
0.8
1.0
eye
Bumper

MITSUBISHI EXPRESS 4WD VAN

Test No: C5 Regn: SFE056 Year: 1990

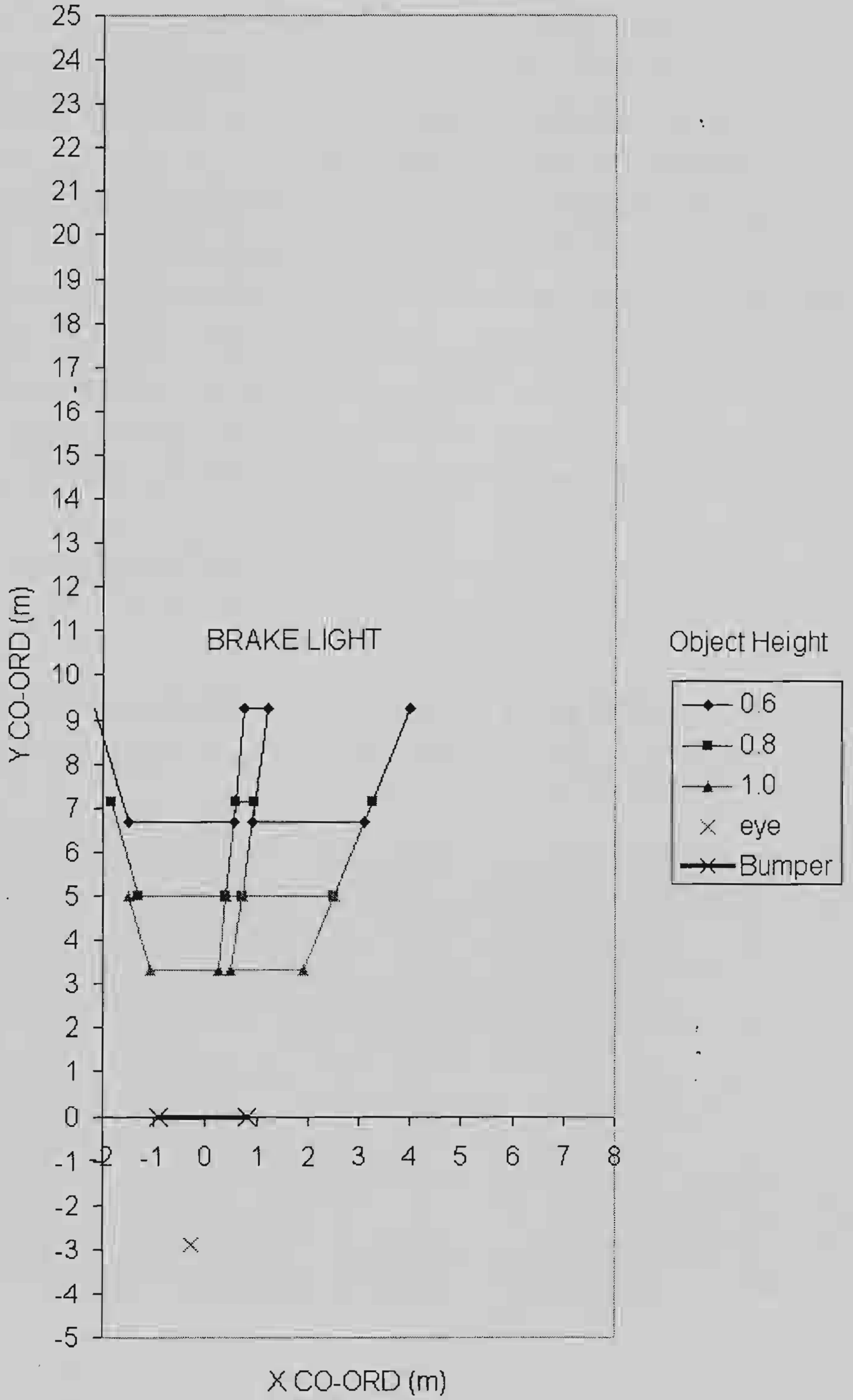
Position	X	Y	Z
Driver's eye position	-0.27	-2.9	1.74
Centre rear	0	0	0
NS rear	0.8	0	0.65
OS rear	-0.9	0	0.65
NS mirror	0.9	-3.7	1.4
OS mirror	-1	-3.7	1.4
Centre lowest obstruction	0	-0.1	1.48

General view of vehicle

View from driver's position

REAR VISION ENVELOPE

MITSUBISHI EXPRESS (4WD)



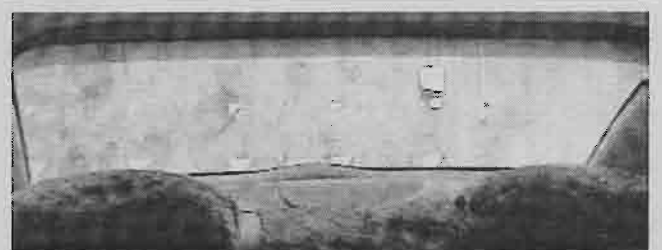
COMMODORE VT SEDAN

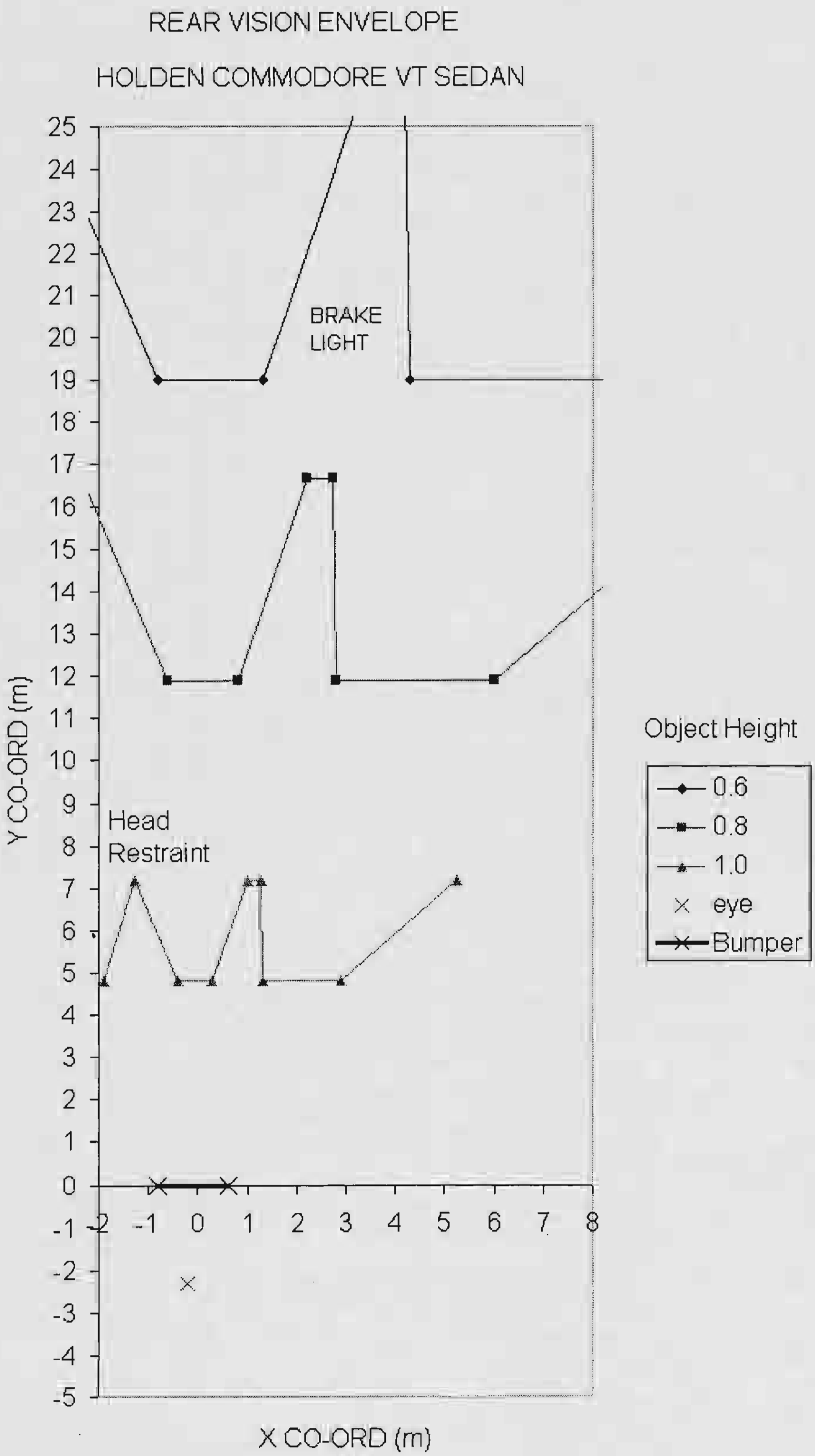
Test No: C6 Regn: AGS39H Year: 1999

Position	X	Y	Z
Driver's eye position	-0.2	-2.3	1.2
Centre rear	0	0	0
NS rear	0.6	0	0.65
OS rear	-0.8	0	0.65
NS mirror	0.7	-3	1
OS mirror	-0.9	-3	1
Centre lowest obstruction	0	-0.6	1.13

General view of vehicle

View from driver's position





REAR VISION ENVELOPE
HOLDEN COMMODORE VT SEDAN
BRAKE LIGHT
Head Restraint
Y CO-ORD (m)
X CO-ORD (m)
Object Height
0.6
0.8
1.0
eye
Bumper

TOYOTA PRADO 4WD

Test No: C7 Regn: JSC318 Year: 1998

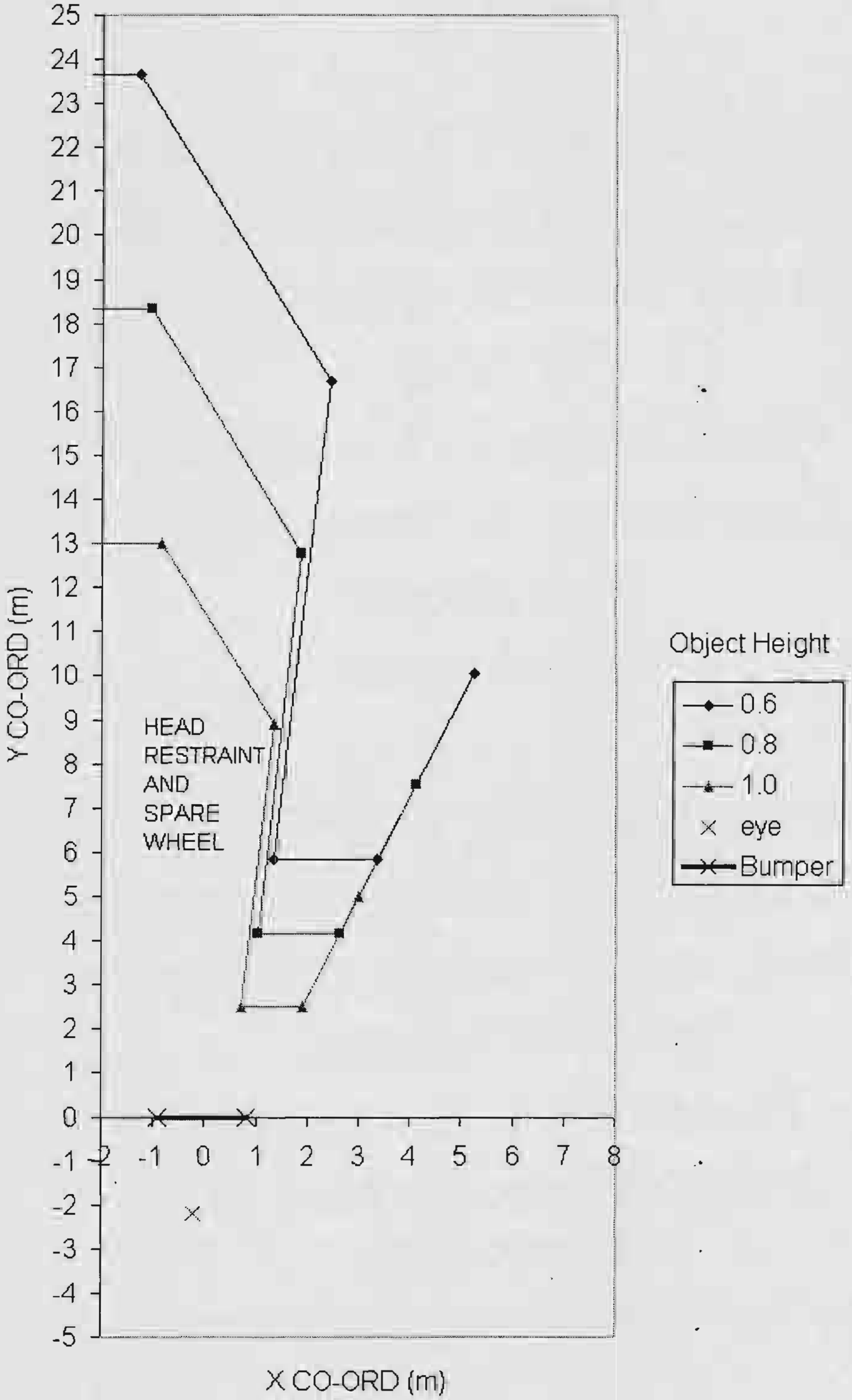
Position	X	Y	Z
Driver's eye position	-0.2	-2.2	1.57
Centre rear	0	0	0
NS rear	0.8	0	0.65
OS rear	-0.9	0	0.65
NS mirror	0.9	-3	1.34
OS mirror	-1	-3	1.34
Centre lowest obstruction	0	-0.1	1.42

General view of vehicle

View from driver's position

REAR VISION ENVELOPE

TOYOTA PRADO 4WD



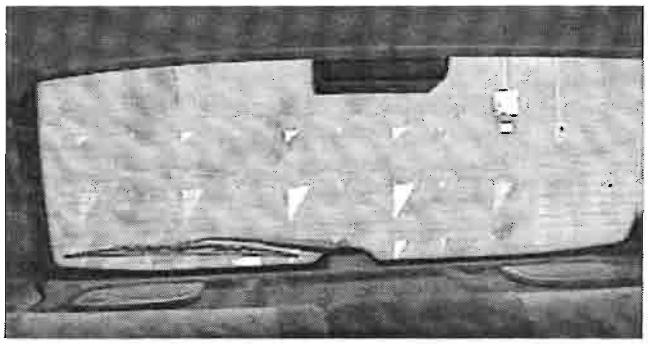
PEUGEOT 306 HATCHBACK

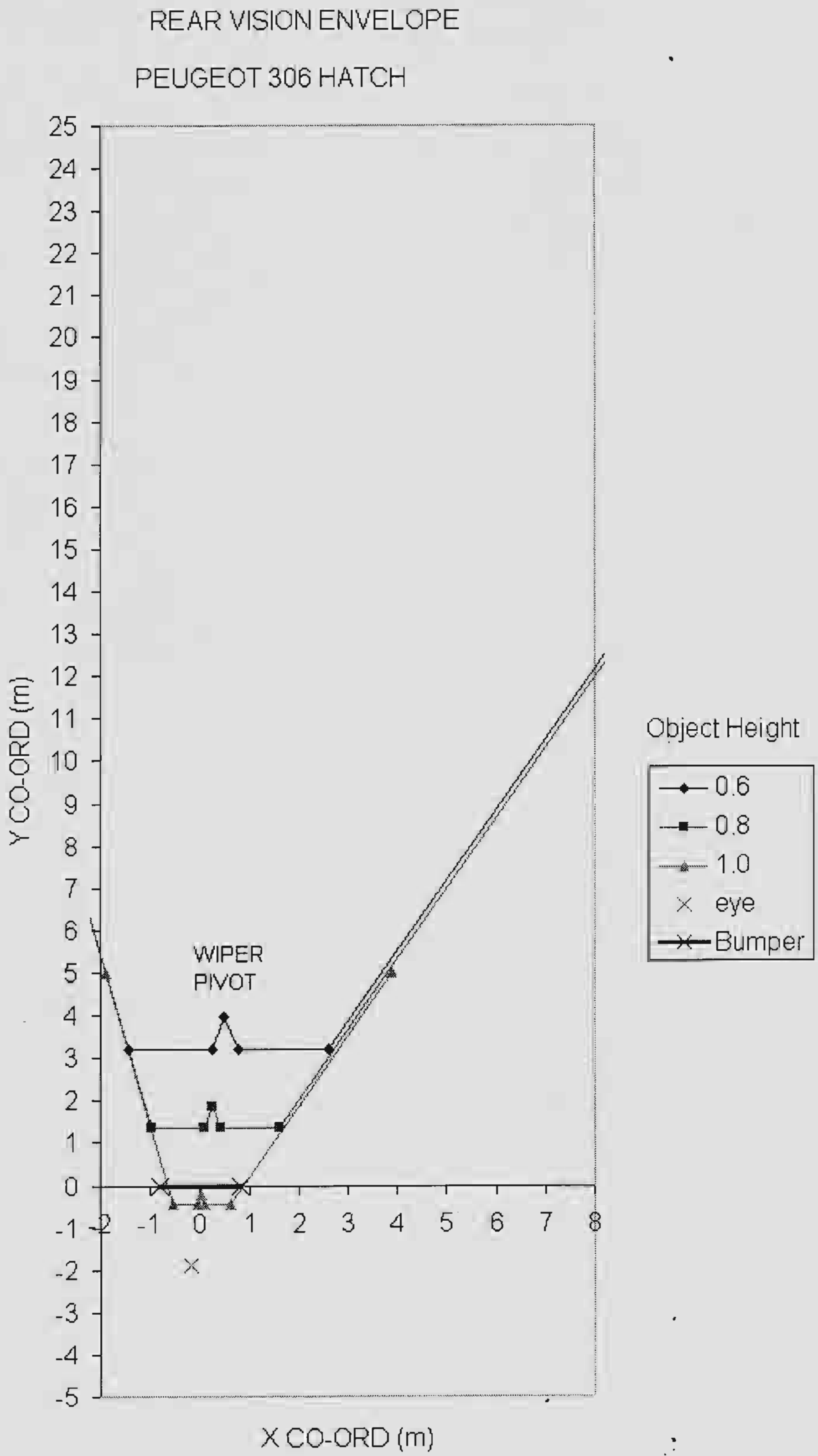
Test No: C9 Regn: MIY578 Year: 1995

Position	X	Y	Z
Driver's eye position	-0.17	-1.9	1.16
Centre rear	0	0	0
NS rear	0.8	0	0.55
OS rear	-0.8	0	0.55
NS mirror	0.9	-2.5	0.95
OS mirror	-0.9	-2.5	0.95
Centre lowest obstruction	0	-0.2	1

General view of vehicle

View from driver's position




REAR VISION ENVELOPE
PEUGEOT 306 HATCH
WIPER
PIVOT
Y CO-ORD (m)
X CO-ORD (m)
Object Height
0.6
0.8
1.0
eye
Bumper

APPENDIX B – EVALUATION OF PROXIMITY SENSORS

Reverse Sensor

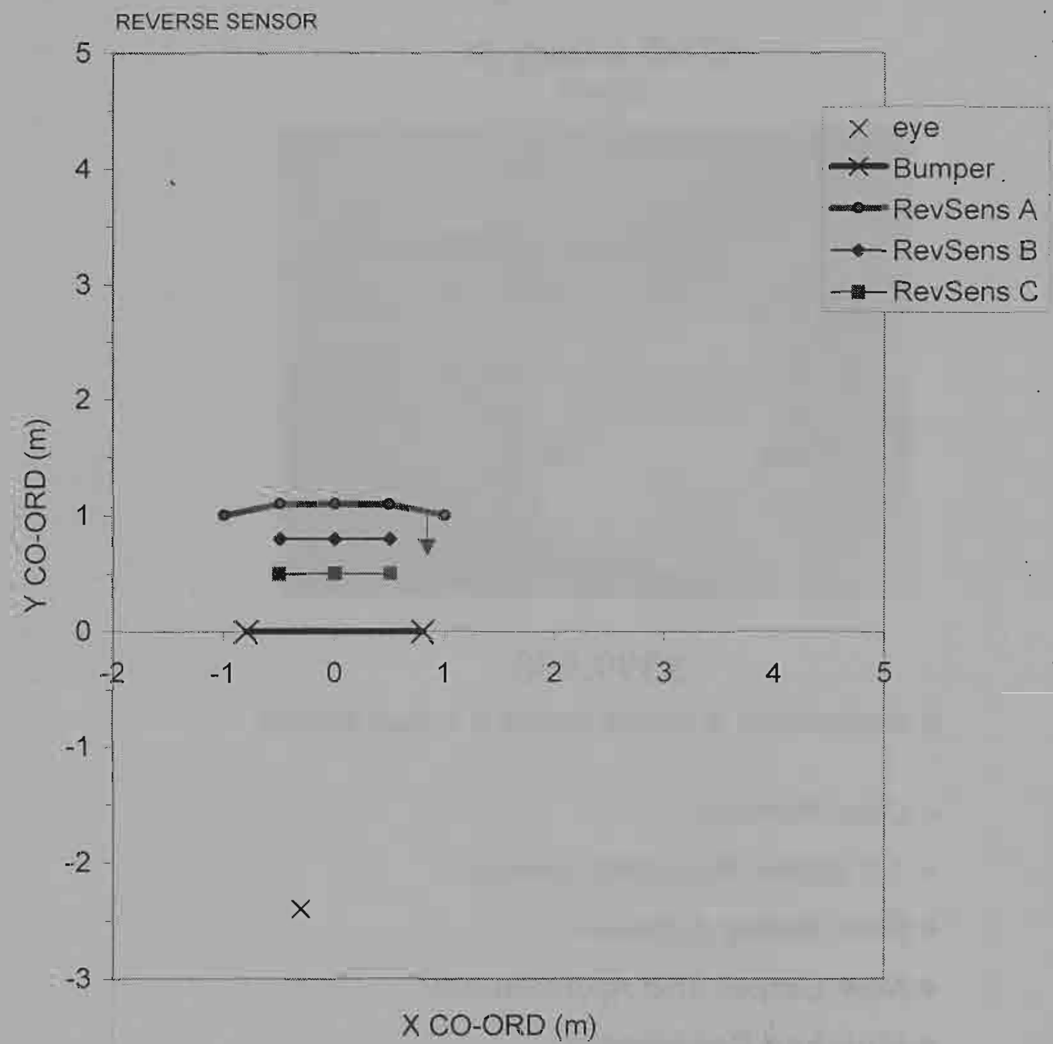
Smart Park

Safe Reverse

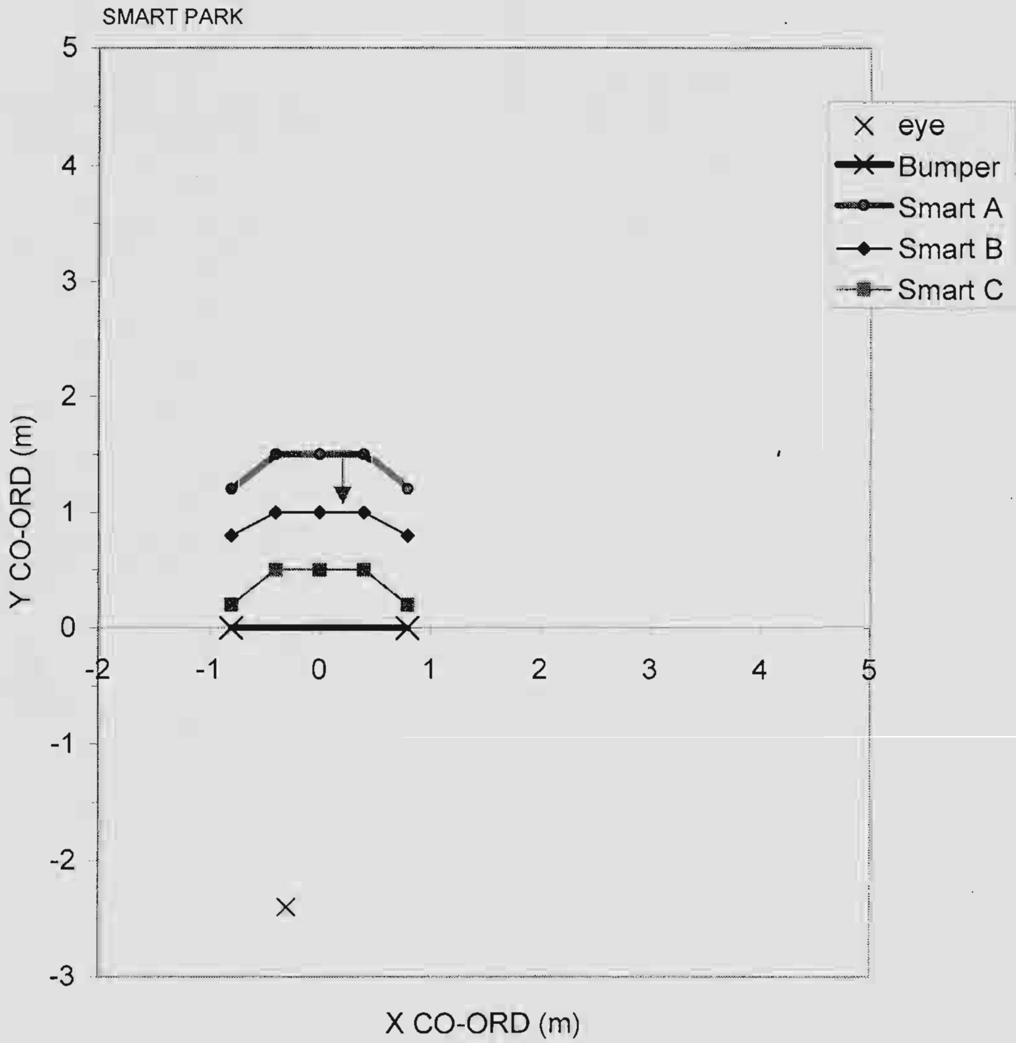
Guardian Alert

Each of the proximity sensor systems had three detection ranges, corresponding with different types of audible alarms. The boundaries of these three ranges are illustrated in the following graphs. This feature is considered to be more useful for parking manoeuvres than for detecting children. Only the longest range ("A") was considered in the analysis.

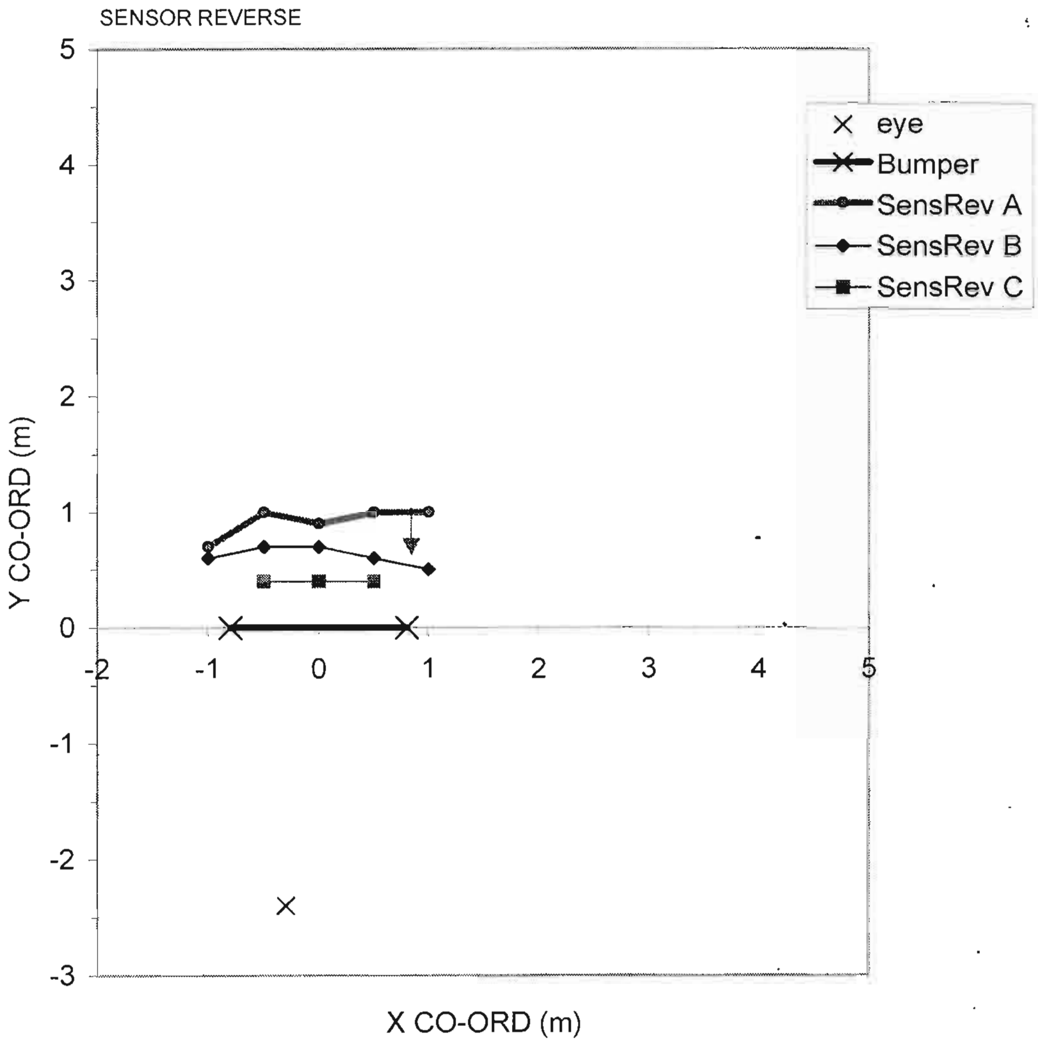
SENSOR DETECTION PATTERN



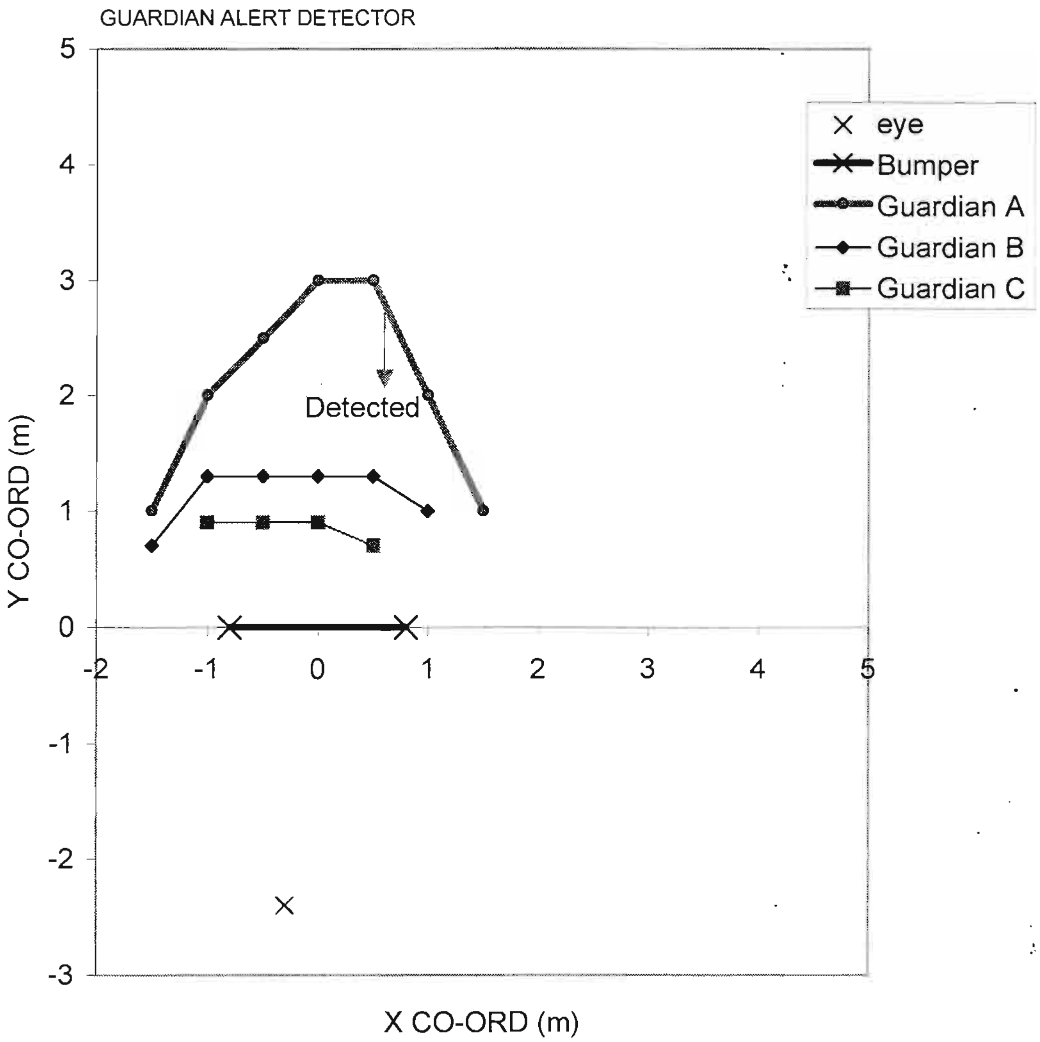
SENSOR DETECTION PATTERN



SENSOR DETECTION PATTERN



SENSOR DETECTION PATTERN



APPENDIX C – EVALUATION OF VISUAL AIDS

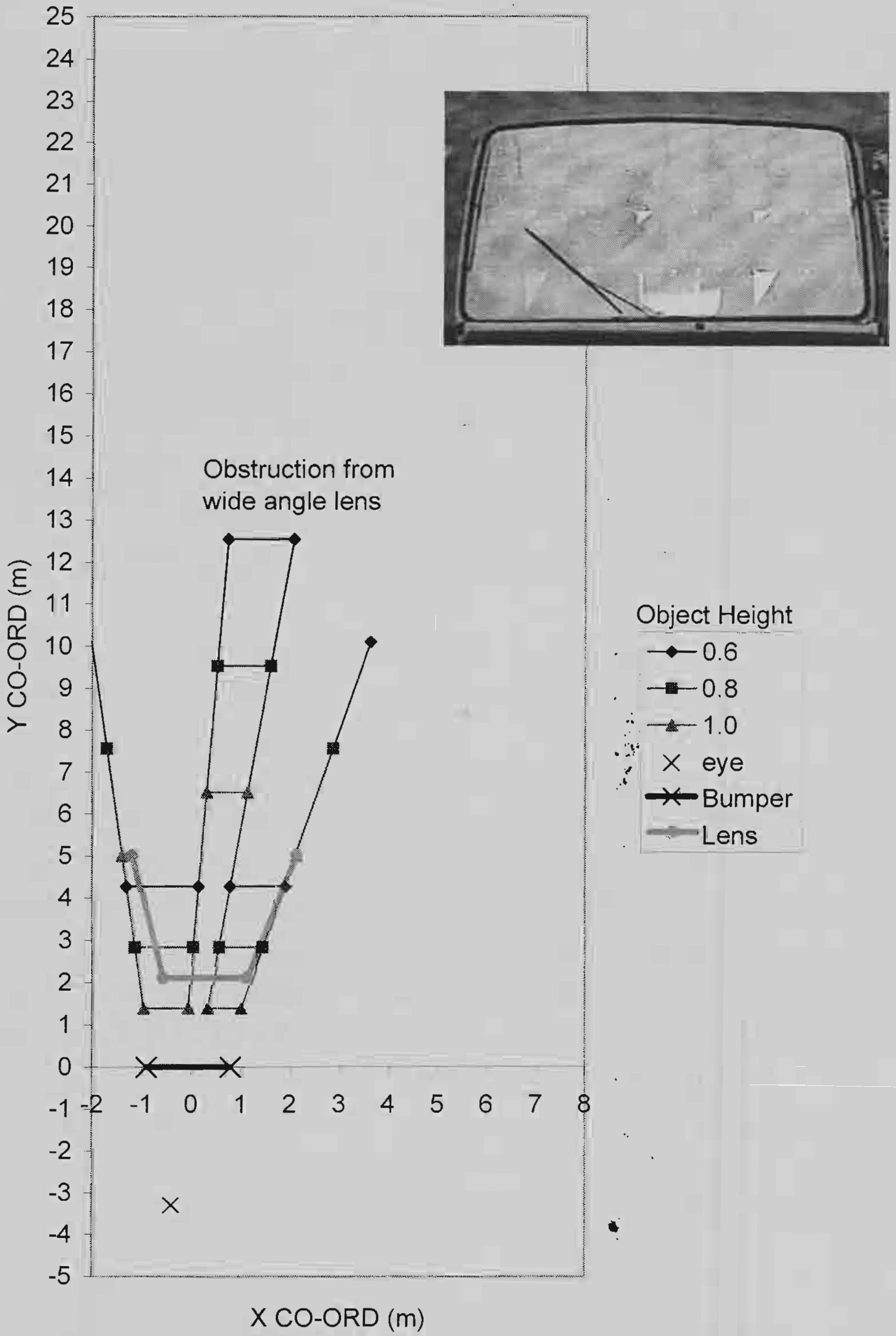
Vanscope

Kwik Park wide angle lens

Video camera

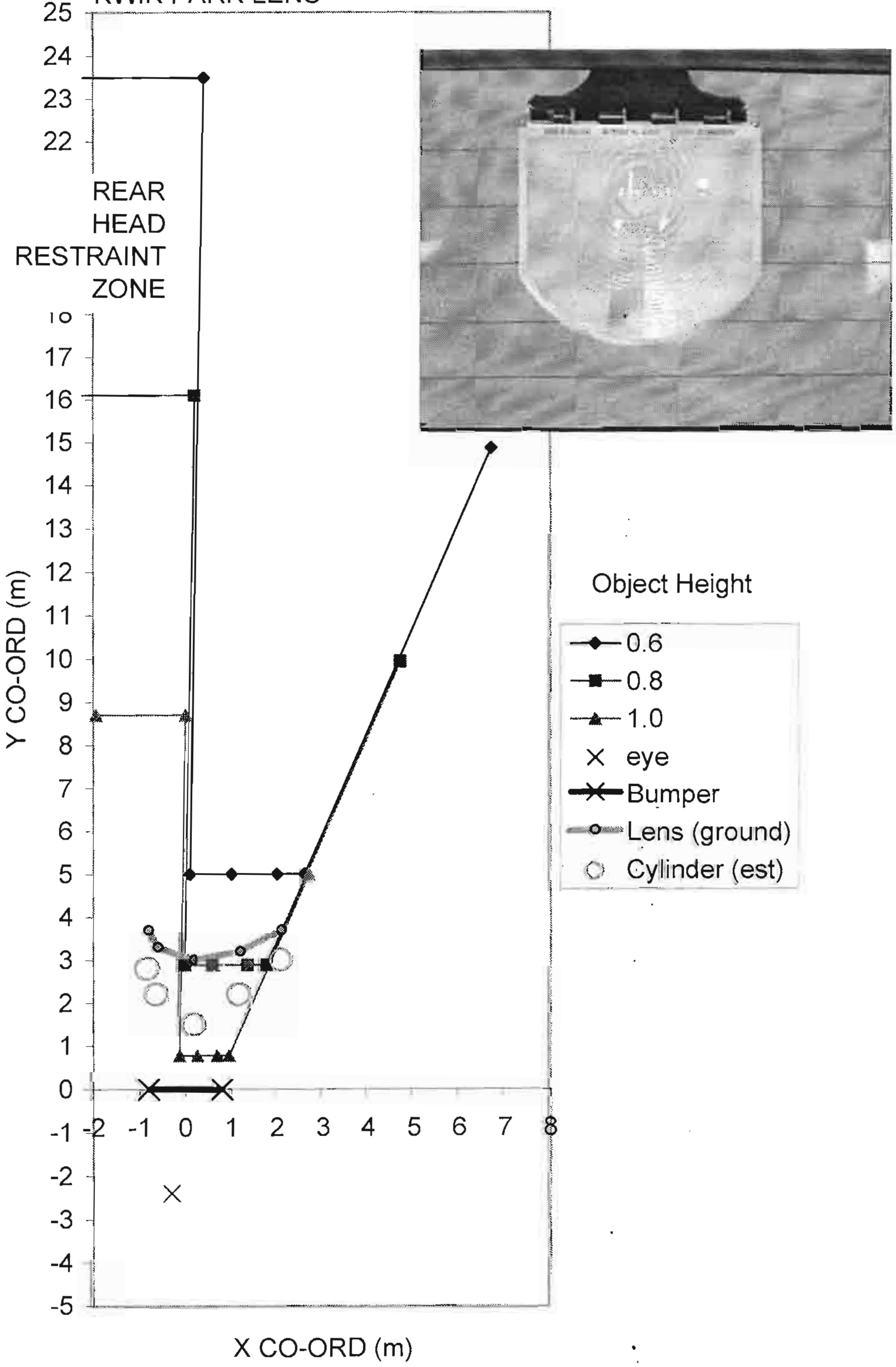
REAR VISION ENVELOPE

HI ACE SHOWING LENS VIEW



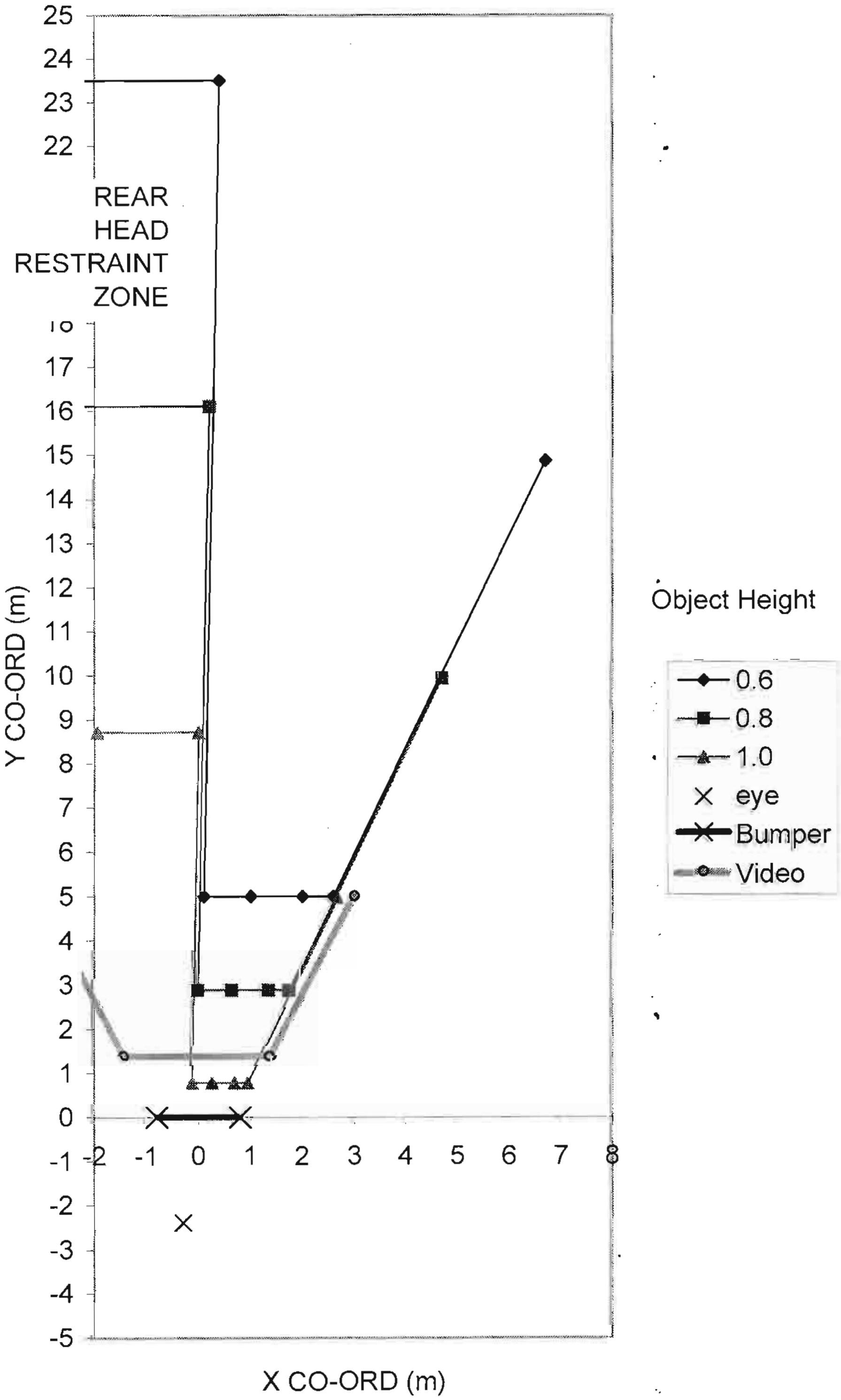
REAR VISION ENVELOPE

HONDA ODYSSEY WITH REAR HEAD RESTRAINTS
KWIK PARK LENS



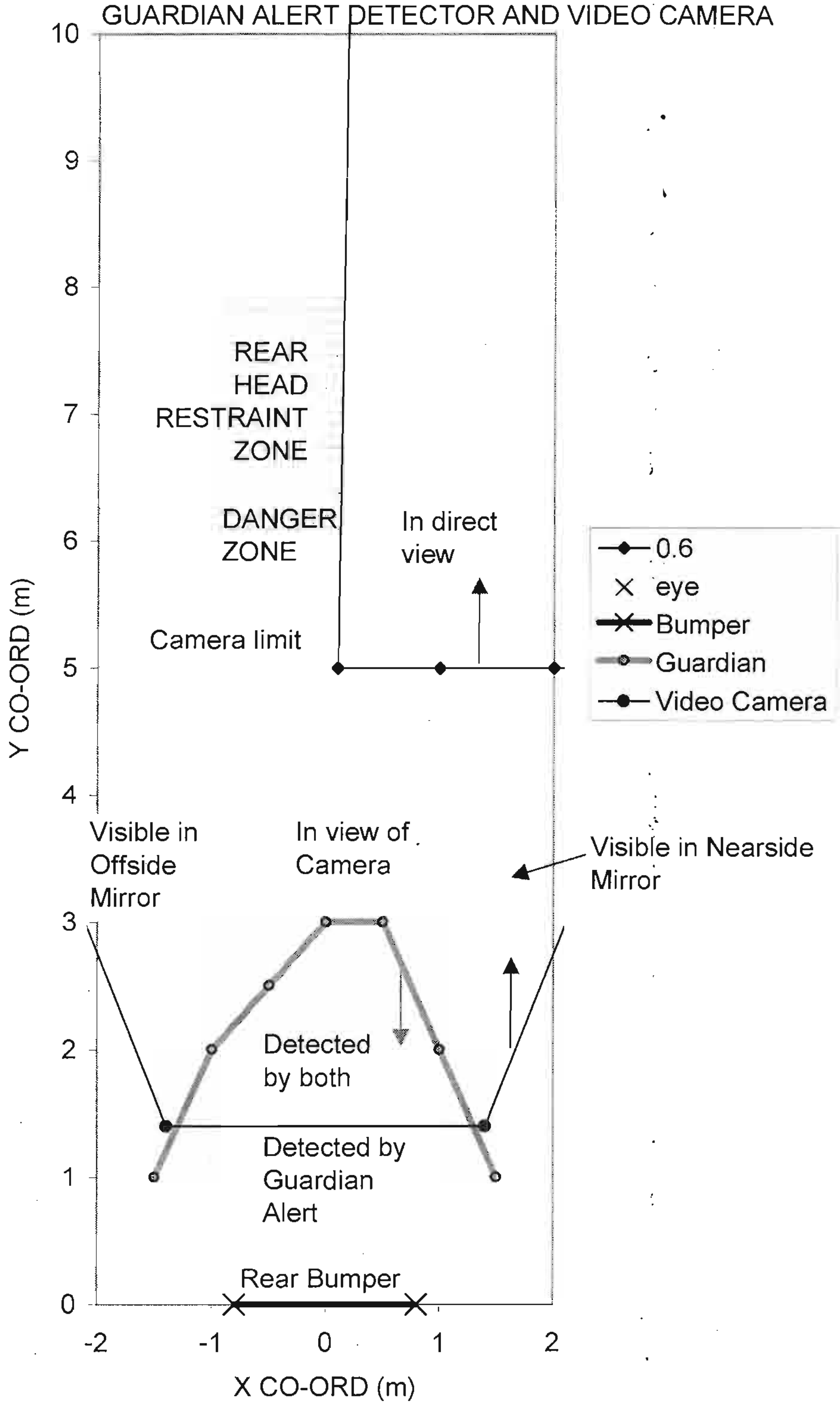
REAR VISION ENVELOPE

HONDA ODYSSEY WITH REAR HEAD RESTRAINTS AND CAMERA



REAR VISION ASSESSMENT

HONDA ODYSSEY WITH REAR HEAD RESTRAINTS
GUARDIAN ALERT DETECTOR AND VIDEO CAMERA



APPENDIX D – DRAFT PERFORMANCE SPECIFICATION

This following document is a draft technical specification that describes performance requirements for a complete system that is intended to reduce the risk of young children being run over by reversing vehicles.

It is subject to review.

DRAFT SPECIFICATION

Devices to reduce the risk to young pedestrians from reversing motor vehicles

This document is intended for comment by stakeholders and does not represent the views or policy of any organisation.

INTRODUCTION

This draft specification sets out proposed requirements for devices to assist drivers when reversing a vehicle and to alert the driver to the presence of a small child behind a vehicle. In their present form these requirements are intended to be used for evaluation of various systems that are currently available.

In the longer term this specification could form the basis for an Australian Standard or a government technical specification covering such devices for optional or mandatory fitting to motor vehicles.

PURPOSE

The primary purpose of the system is to reduce the risk of small children being run over by reversing vehicles.

OBJECTIVES

There are two types of systems that may be used: aiding driver visibility and detecting the presence of an object behind the vehicle. A combination of systems might provide the most reliable solution.

A. Aiding driver visibility.

The device:

- Must provide the driver with a reasonable view of crucial blind spots to the rear of the vehicle.
- Must avoid obstructing views that are needed for normal driving of the vehicle.
- Must be effective in the full range of environmental conditions.
- Should be simple to check for correct operation.
- Should be durable with minimal maintenance.

B. Detecting a small child behind the vehicle and alerting the driver.

The device:

- Must reliably detect a small child standing in blind spots to the rear of the vehicle
- Need not discriminate between humans and other objects (the alarm may sound when any object is detected)
- Must only operate when reverse gear is engaged.

- Need not (but may) alert the driver if there is no relative movement between the vehicle and the object.
- Must promptly alert the driver with an audible signal that an object has been detected.
- Preferably, give some indication of the range to the object.
- Optionally, give a visual signal to the driver that an object has been detected. This should be visible when the driver is looking to the rear.
- Must be effective in the full range of environmental conditions.
- Should give a minimum of false alarms.
- Should be simple to check for correct operation.
- Should be durable with minimal maintenance.

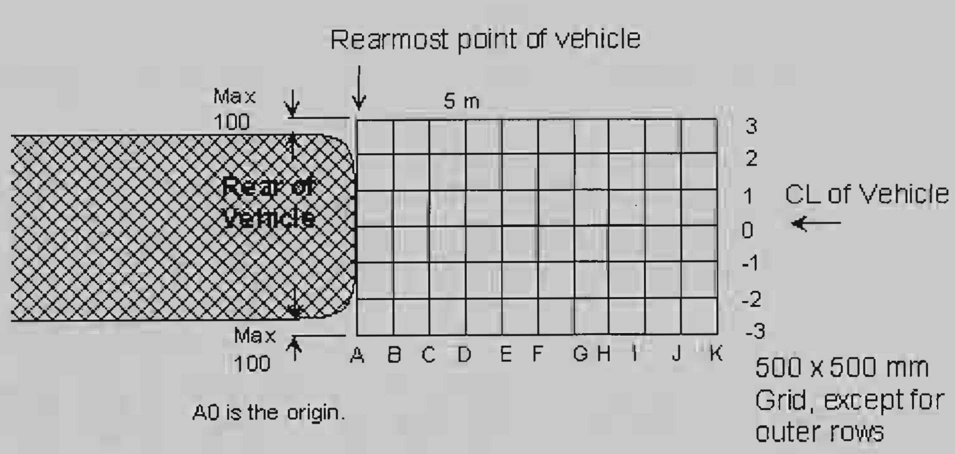
The warning signal may also be audible to a person located to the rear of the vehicle [young children may not take heed of this but older children and adults would].

DETERMINATION OF BLIND SPOTS BEHIND VEHICLE

In order to test the effectiveness of a system it is necessary to establish the blind spots for the particular vehicle to which it is to be fitted. This is done by marking out a 500x500mm grid on the ground to the rear of the vehicle, sequentially placing a test cylinder at each intersection of grid lines and determining whether the cylinder can be detected from the driver's seat. Any grid point where the cylinder is not visible is deemed to be a "blind spot".

Location of grid

The grid origin is on the ground in line with the centreline of the vehicle and the rearmost point of the vehicle (excluding towbars). A 500 by 500 mm grid is marked out from this point and extends to a longitudinal line that is 100mm beyond the extreme width of the vehicle on each side and 3 m rearward of the origin. The width out the outmost rows of the grid may be reduced for this purpose.



Test cylinder

The test cylinder is 200mm (+/-20mm) in diameter and 600mm in length (+/-50mm) [based on the standing height of a small two-year old or a kneeling adult]. If used for testing detection systems it must be made from timber or cardboard and should not be painted or have any other surface coating that may affect sensor performance [untreated timber or cardboard is assumed to have similar characteristics to a human body but this might not be the case with microwave systems - advice on a suitable test material is sought].

Preparation

The driver's seat should be adjusted to suit the person conducting the test, who should be no more than 1800mm in height.

All driving mirrors should be adjusted for normal view of traffic, to suit the person conducting the test.

The vehicle should not be loaded in such a way that its attitude is unusual.

The ground should be flat and sealed over the area where the vehicle is standing and continue without change over the area covered by the grid.

Method of determining blind spots

Method 1 - Using a test cylinder and marked grid on the ground

Starting with the transverse gridline B (500mm to the rear of the origin) test each grid point along this line as follows.

- Place the test cylinder with the centre of one end located over the intersection of the gridlines (+/-20mm).
- Sit in the driver's seat and try to observe the cylinder by looking through the rear window, the internal rear view mirror and the external rear view mirrors.
- If any portion of the cylinder can be observed note the method(s) of observation (D=direct, I=internal mirror, L=left hand external mirror, R=right hand external mirror) for that gridpoint. Otherwise record an X, indicating a blind spot.
- Test the remaining gridpoints along that transverse gridline, unless it is evident that they will also be blindspots.

Move to the next rearward transverse gridline (eg C) and repeat the process. At the end of the process all gridpoints up to 3m rearward of the origin should have been assessed.

Method 2- Using a grid on a vertical wall to the rear of the vehicle

An alternative to the grid method is to use 3D mathematics to analyse the rearward field of view. The vehicle is parked so that it is approximately a vertical wall are the rear. The wall is marked with a grid and the location on this grid, of the extremities of the field of view through the rear window are noted. Mathematics is applied to the imaginary line between the observers eye and the point on the rear wall to determine the X and Y coordinates of a point on this line that is 600mm in height from the ground.

Let X_1, Y_1, Z_1 be the coordinates of the driver's eye and

X_2, Y_2, Z_2 be the coordinates of the point on the wall

Let $t = (h - Z_1) / (Z_2 - Z_1)$ where h is the height of the point of interest i

Then $X_i = (X_2 - X_1)t + X_1$ and $Y_i = (Y_2 - Y_1)t + Y_1$

REQUIREMENTS FOR DEVICES TO AID DRIVER VISIBILITY

General

This section covers auxiliary mirrors, wide-angle lenses and video equipment.

Applicable vehicles

Because of the wide range of designs of vehicles it is necessary to test the visual aid on each type of vehicle for which it is intended to be used and to nominate such vehicles in marketing brochures for the system, including instructions for specific vehicles, if appropriate.

Design and durability

The device must be designed to withstand the harsh conditions encountered in vehicle operation. It must be durable and corrosion-resistant.

It should be resistant to vandalism and theft.

The device must not constitute a hazard to occupants within the vehicle due to exposed hard or sharp edges and must be constructed from shatterproof materials.

Location of screen/lens

It is preferred that the screen (or lens) is located and aligned so that it is close to the direct field of view to the rear. That is, the driver should not have to turn his or her head in order to see both the device and the direct view to the rear (or the view in a rear view mirror if the direct view is not suitable).

A possible solution is to mount the screen of the ceiling of the cabin, to the rear of the driver with the screen facing forward. In this location it would probably be above the centre rear passenger seat. If this is the case then, to avoid injury to passenger, it may need to be on a mechanical device that only swings down when reverse gear is engaged.

Effect on driver's vision of traffic

With the device located and adjusted to provide vision of blind spots (see next section) the driver's normal view of traffic to the rear and side should not be adversely affected.

Performance test

Using the vehicle/grid configuration shown in the figure, assess each of the locations that was found to be a blind spot without the device.

- Place the test cylinder with the centre of one end located over the intersection of the gridlines (+/-20mm).
- Sit in the driver's seat and try to observe the cylinder using the device.
- If any portion of the cylinder can be observed note the method(s) of observation (D=direct view of device, I=device observed via internal mirror , L=device observed via left hand external mirror, R=device observed via right hand external mirror) for that gridpoint. Otherwise record an X, indicating a blind spot.
- Test the remaining "blind spot" gridpoints.

Image size

For a gridpoint that is furthest from the vehicle (transverse line J), check the size of the image of the top of the cylinder, as viewed with the device. The angle subtended by this image must not be less than the angle subtended by the cylinder top when it is placed 20 metres from the rear of the vehicle. In effect the width of the image at the device should not be less than 0.01 times the distance between the device and the driver's eye.

Assessment

To comply with this specification the device must provide a view of the cylinder for all grid locations that were found to be blind spots without the device. If grid points that are close to the vehicle are not observable then it may be possible to use a sensor system in combination with the visual aid (see next section).

REQUIREMENTS FOR PROXIMITY SENSORS

General

This section covers proximity sensor systems mounted on the rear of the vehicle.

Applicable vehicles

Because of the wide range of designs of vehicles it is usually necessary to test the device on each type of vehicle for which it is intended to be used and to nominate such vehicles in marketing brochures for the system, including instructions for specific vehicles, if appropriate. However, it is acceptable for worst-case vehicles to be assessed and for the device to be marketed for other vehicles of the same type (principally the mounting height of the sensor). The worst case vehicle will normally be the one for which a blind spot exists further from the rear of the vehicle than other types of vehicle in its class.

Design and durability

The device must be designed to withstand the harsh conditions encountered in vehicle operation. It must be durable and corrosion-resistant.

It should be resistant to vandalism and theft.

Audible warning

The sound level of the alarm, when activated, should be sufficient to be heard beyond the normal noise level within the vehicle. A minimum of 90dBA at 1 m distance is recommended. Specifications of the audible alarm may be used for this purpose.

Performance tests

False alarm test

The system must be designed to minimise the occurrence of false alarms. In particular small bumps and irregularities on the ground should not cause the alarm to trigger. This can be tested by placing a rectangular piece of wood, or similar object, across the path and reversing the vehicle towards and over the object. The height of the object should be 30mm (+/-5mm) and its width, across the path, should be at least 1m. If the alarm sounds then the system should be adjusted so that it no longer triggers (system that cannot be adjusted to prevent such false alarms should be rejected). The detection zone test may then proceed.

False alarms to the side are undesirable but are not a reason for non-compliance with this specification.

Detection zone test

Using the vehicle/grid configuration shown in the figure, assess each of the longitudinal gridlines as follows.

- Place the test cylinder on applicable longitudinal gridline at a distance that is beyond the detection range, or 5m.
- With the ignition on, select reverse gear.
- Record the response from the alarm system (type of audible alarm, type of visual warning).
- Slowly move the cylinder towards the vehicle along the longitudinal gridline until the alarm sounds. Note this distance. Continue moving the cylinder towards the vehicle and note any change in the type of alarm. Keeping approaching the vehicle until the cylinder touches the rear of the vehicle.
- Test the remaining longitudinal gridlines.
- With the cyclinder at a location where the alarm sounds disengage reverse gear and check that the alarm deactivates.

Activation time test

This test is intended to determine the time it takes to detect an object and trigger the audible alarm. Remove the cylinder from the grid. With the ignition on, engage reverse gear. The alarm should not activate in these circumstances. Quickly place the cylinder on the B gridline and note the time it takes for the alarm to activate. Repeat for another point on the B gridline (500mm from vehicle).

The device must not take more than 0.5 seconds to activate.

Assessment

It is unlikely that a sensor device will be able to cover all blind spots to the rear of a vehicle and not be subject to false alarms. Therefore it will usually be necessary to assess a sensor system in combination with a visual aids. The intention is that the proximity sensor will cover blind spots that are close to the vehicle and are not within the field of view of the visual aid.

A plan view of the rear of the vehicle should be produced. This should show, for the test cylinder situation (that is the 600mm contour line):

- The boundaries of the blind spots, out to 5m from the rear of the vehicle.
- The limits of any visual aid
- The limits of any proximity sensor

To comply with this specification the system must cover all blind spots within 5m of the rear of the vehicle by either visual aid, proximity sensor or both.

Labelling

All systems must include a label that is affixed to the vehicle. The label should contain words such as:

"This vehicle is fitted with a system to assist the driver when reversing. Regardless of the operation of the system, drivers must ensure that they reverse in a safe manner at all times. Speed should be no more than walking pace or you will not have time to react to an emergency. Always check mirrors and look to the rear when reversing.

This system was not tested for objects less 600mm in height or 200mm in width."

Reporting

[format of test report]

Comments on this draft

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