Use of New Materials to Reduce Traffic Sign Lighting

Final Report

Highways Agency

October 2010
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Document History

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Executive Summary

This project “Use of New Materials to Reduce Traffic Sign Lighting” is to identify sustainable solutions to minimise the energy used to directly light traffic signs without impeding their performance or comprising road safety.

The aims of the project are to:

- undertake a literature review, taking into account the existing Regulations, Standards and Highways Agency Policy;
- determine the optimum locations for various types of retroreflective sign materials and methods of direct lighting to reduce energy costs without compromising sign performance or road safety;
- assess the feasibility of reducing costs associated with direct sign lighting from overhead motorway gantries;
- produce a research report and guidance based on the results of off-road trials;
- consider the implications of replacing existing lighting technology with updated products and technologies taking into account maintenance, strategy, energy savings and whole life costs, and;
- consider the use of alternative energy sources where there is no existing infrastructure.

The project required the completion of a number of tasks, namely:

- production of a scoping report;
- review of relevant literature and publication of report;
- set-up and undertake off-road trials, and;
- analyse results and publish final report.

Key background information and literature has been reviewed, the details of which were published in October 2009: “Use of New Materials to Reduce Traffic Sign Lighting – Literature Review”. The information proved valuable in preparing for and undertaking a series of off-road trials which were completed in November 2009.

This final report considers the results of the off-road trials together with other aspects of the project including:

- information detailed in previous reports (inception, interim and literature review);
- results of consultations with suppliers and manufacturers of reflective sheeting and lighting products;
- preparation and undertaking of the off-road trials;
- interpretation of results obtained from the off-road trials;
- the advantages and disadvantage of alternative direct lighting technologies;
- maintenance implications, and
- whole life costs.
1. Definitions

**Basis Luminance**
This is the amount of luminance a driver requires at a given distance from a sign. It is used to calculate the luminance index.

**Binocular field**
The field of view seen by two eyes together.

**Co-efficient of retroflection**
The luminous intensity of the sheeting in the direction of observation divided by the product of the illuminance on a plane perpendicular to the direction of incident light and the area of the sheeting.

**Conspicuity Distance (Threshold Viewing Distance)**
This is the distance from which the sign can first be seen, it occurs sooner and at a longer distance from the sign than the Legibility Distance. Engel (1971) originally proposed the concept proposing that a conspicuous object is one which will, for any given background, be seen with certainty within a short (250ms) observation time regardless of the location of the object in the line of sight.

**Contrast**
This is the difference in luminance of different coloured parts of a sign.

**Cut-off distance**
The distance from the sign where a driver is expected to stop reading the sign – i.e. the point where a driver would turn their head through 10° or more. The distance is calculated as the cotangent of 10° multiplied by the offset from the centre of the vehicle to the centre of the sign.

**Daytime Running Lamps**
These are headlamps that are either low beams at full or reduced intensity or high beams at reduced intensity. Scandinavian countries were the first to make it mandatory to have these lamps on at all times with the purpose of increasing the conspicuity of vehicles given that these countries experience long periods of low light levels. Other countries are following the practice but seeing fewer benefits.

**Direct lighting**
Either an internal or external light source (non-vehicular) provided to illuminate the face of a sign.

**Electroluminescence (EL)**
Light output resulting from a current passing through a coated sheeting material, stimulating electrons which release energy in the form of light.
**Entrance angle**

The angle between the direction of light and the normal (perpendicular) to the reflective face. (See figure 1.1).

**Killed or seriously injured (KSI)**

The term given to a road accident in which one or more individuals are killed or seriously injured.

**Legibility Distance (Confident Viewing Distance)**

This is the distance from the sign at which the message can be correctly read. A sign with a Legibility Index of 30 means that it should be legible at 30 feet (9.1m) with one inch (2.5cm) capital letters, or legible at 300 feet (91.4m) with ten inch (25.4cm) capital letters.

**Light Emitting Diode (LED)**

A Light Emitting Diode is an electronic semiconductor device that emits light when an electric current passes through it. They are considerably more efficient than incandescent bulbs, and rarely burn out.

**Luminance**

The physical measure of stimulus which produced the sensation of brightness measured by the luminous intensity of light emitted or reflected in a given direction from a surface element divided by the area of the element projected in the same direction. The SI unit for luminance is candela per square meter (cd-m⁻²).

**Luminance Index**

A unit-less rating for sign sheeting based on the varying luminance of a sign made from that sheeting as observed through a distance range.

**Microprismatic**

A type of reflective sign sheeting which uses shaped prisms rather than more traditional glass beads (micro-spheric technology), to either direct more light, or in the case of premium grade micro-prismatic material, provide an increased level of performance under certain conditions.

**MIRA**

Motor Industry Research Association. A comprehensive range of circuits located in the Midlands enabling testing and research by the automotive industry.

**Monocular vision**

In which each eye sees a different view.
Observation angle
The angle between the illumination axis and the observation axis (see figure 1.1).

Optical Light Film
A translucent reflective sign sheeting which allows light to pass through, used for internally illuminated signs

Performance Index
The luminance index multiplied by the sign location correction factor.

Retroreflection
This is a process by which an object reflects light back towards the source, unlike a mirror which only reflects light back to the source if it is perpendicular to the light source.

Sign location correction factor
A factor which takes into account the varying illuminance on signs resulting from different lateral and vertical sign locations.

Specular reflection
Is the reflection of light from a surface, in which the direction of incoming light (the incident ray), and the direction of outgoing light reflected (the reflected ray) make the same angle with respect to the surface normal.

System of street lighting
A road furnished by means of at least three lamps placed no more than 183 metres (185 metres in Scotland) apart.

Transport Research Laboratory (TRL)
A private consultancy that provides research, consultancy, testing and certification for all aspects of transport.

Uniformity of luminance
The ratio of the minimum to maximum luminance values on a sign face.

VMS
Variable Message Sign, a generic term which is given to a sign that is able to display multiple legends or images.
2. Introduction

2.1 Original project brief

This report is in response to the final task outlined in the Client brief “Use of New Materials to Reduce Traffic Sign Lighting” that was awarded to Atkins on 27th November 2008 by the Highways Agency (herein after referred to as “the Agency”) under the National Framework Contract.

The main aim of this research and development project is to identify sustainable solutions to reduce the need for direct lighting of traffic signs and the associated energy consumption, without impeding their performance or compromising road safety.

The project encompassed a number of key elements, some of which have been reported separately, but are summarised in this report:

- literature review of existing regulations, standards and policies;
- research into the various systems and specifications for reflecting sheeting and technologies that offer the opportunity to sign highways in a more sustainable manner, as well as identification and filling gaps in existing knowledge;
- off-road trials of the various systems commercially available to determine the optimum locations for the use of sign lighting technologies;
- consultation with stakeholders to identify where new technologies have been installed on the network;
- consideration of how energy might be generated through the use of sustainable energy sources, particularly for use in areas with no mains infrastructure, and
- consideration of the maintenance implications of such changes in technology in order to ensure the effectiveness of traffic signs including consideration of initial purchase costs, whole life costs and energy savings.

2.2 Background to the brief

For signing to be effective it needs to be seen and be legible at all times including during the hours of darkness. The need to illuminate certain road traffic signs has been a basic requirement since the publication of the Regulations for Traffic Signs in 1933 under powers created by the 1930 Road Traffic Act.

At that time, reflective sheeting was unavailable, with sign makers using button reflectors placed on individual letters to reflect light from passing vehicle headlights. The 1970’s saw the introduction of retroreflective sheeting, which is made up of miniature reflectors designed to reflect light back to its source.

Combined with improvements in vehicle lighting technologies, the introduction of reflective sheeting transformed the effectiveness of unlit traffic signs.

More recently, ambient lighting levels have increased, with improvements in street lighting technologies and more emphasis being placed on the illumination of shop frontages, petrol station forecourts, restaurants, advertising hoardings, etc. all competing for drivers’ visual attention. This in turn puts traffic signs at a disadvantage, potentially justifying the requirement for direct lighting of certain signs where a system of street lighting is present.
Although the last 15 years have seen further improvements in the performance of vehicle headlights, together with new, higher performing reflective traffic sign sheeting and a partial relaxation in the Traffic Signs Regulations and General Directions 2002 of the lighting requirements for some signs, the need to directly light many traffic signs has remained the same.

More recently, energy consumption by Highway Authorities has been the subject of increased scrutiny as energy costs become an important factor in highway budgets. Although much of this is associated with street lighting, the need to identify energy savings across the range has been identified and features highly on many political agendas, especially those relating to environmental impact.

Improvements in sustainable energy sources have seen the introduction of solar and wind powered direct traffic sign lighting, removing the need for separate mains supplies and costly connections. The continuing development of light emitting diode and electroluminescent technologies also serves to reduce energy requirements. It is clear that there is a need to review the requirements for direct lighting of traffic signs due to the demands placed upon the driver, advances in technology and rising energy costs.

As a result of the Government’s Accident Reduction Targets, the Agency is aiming to reduce the number of KSI accidents by 33 percent by the end of 2010 (compared to the 1994-1998 average). With night time accidents accounting for approximately one-third of all recorded injury accidents, it is important that any proposed changes to the illumination requirements of traffic signs are not detrimental to the current road safety initiatives.

The project raises a number of key research questions:

- How do signs generally perform in combinations of various levels of ambient lighting conditions with lit and unlit sign faces?
- Do different sign illumination technologies (either as a retroreflective sheeting or a direct light source) have a significant effect on sign performance and in what circumstances?
- For all combinations, what are the practical and whole life cost considerations that specifiers should take into account?

3. Methodology

3.1 Scoping report

Early in the project the format for achieving the individual task requirements was proposed. These included:

- engagement with manufacturers, suppliers and industry specialists;
- review of existing literature and reports from previous projects of a similar nature;
- identification of suitable location for and undertaking of off-road trials, and
- analysis of results, reporting and recommendations.
The specification of traffic signs on the Agency’s network is governed by numerous publications, these being:

- Regulations 18, 19, 20 and 21 of the Traffic Signs Regulations and General Directions 2002 (TSRGD 2002) contains the statutory requirements as to how traffic signs shall be illuminated. Schedule 17 – lists each traffic sign along with details as to under what circumstances with regards to which signs should be illuminated (and also how);
- Volume 8 Section 3 of the Design Manual for Roads and Bridges (TA 19/81) – provides guidance on the performance requirements of retroreflective traffic signs;
- Traffic Signs Manual – provides guidance on the design and use of traffic signs, and
- IAN xx/08 [to be published] – provides guidance on the implementation of new British and European Standards relating to traffic signs and related products.

Various British Standards and Accreditations:
- Non-retroreflective traffic signs (BS EN 12899-1:2007);
- Glass bead retroreflective traffic signs (BS EN 12899-1:2007);
- Transilluminated traffic bollards (BS EN 12899-2:2007);
- Microprismatic retroreflective sheeting (BS 8408:2005), and
- European Technical Approvals (BS EN 12899-1:2007 Clause 4.2)

European Technical Approval (ETA) for a construction product is a technical assessment of its suitability for an intended use, based on the contribution made by this product to the fulfilment of the six Essential Requirements, as stated in the CPD for the construction works in which the product is installed. In conjunction with an Attestation of Conformity procedure (which is intended to ensure that the product specification set out in an ETA is maintained by the manufacturer), ETAs allow manufacturers to place CE marking on their products.

Section 4.1 of “Use of New Materials to Reduce Traffic Sign Lighting – Literature Review”, produced by Atkins, covers the specific lighting requirements and standards referred to above in more detail.

This project forms part of a wider strategy by the Agency to reduce the environmental impact and energy consumption across the network. Other projects within this strategy include:

- development of whole life cycle code of practice for road lighting;
- investigating the feasibility of switching off road lighting on parts of the network;
- researching the use of low energy or long life bulbs for use in traffic signals;
- developing guidance on verge versus centre reserve lighting;
- reviewing maintenance standards for road lighting and traffic signals;
- investigating driver behaviour on lit and un-lit roads;
- identifying alternative, low-cost, non-energy consuming safety measures;
• research into alternative energy sources, and
• assessing energy efficient light sources.

The above is in addition to the Agency’s drive to reduce energy consumption across the network by 30 percent over a ten year period.

3.2 Industry Advisory Group

Atkins took an opportunity to engage with manufacturers, suppliers and industry specialists at an early stage to assist with this project to consider the use of new materials to reduce traffic sign lighting.

Atkins was pleased that the research generated a significant amount of interest with such companies and individuals. As a result, a number of suppliers kindly offered performance and technical data for their products.

3.3 Literature review

Produced in October 2009, “Use of New Materials to Reduce Traffic Sign Lighting – Literature Review” (herein after referred to as “the Literature Review”) enabled the Agency to consider the results of similar research projects which have been completed around the world. Please see the original document for a full list of references.

The literature review considered information obtained from a number of sources including:

• the National Standards Organisation;
• manufacturers and suppliers;
• Central and Local Government Departments and Agencies, and
• results of previous research projects

The review identified a number of factors which should be borne in mind when specifying and considering alternative materials and technologies for the illumination of traffic signs.

Although considerable research has already been undertaken throughout the US and Europe, similar research was still limited within the UK. Atkins reviewed previous research projects with a view to undertaking off-road trials to consider the effects that different ambient conditions and direct lighting of traffic signs had on drivers.

Retroreflectivity

The Literature Review highlighted a number of issues which required further research. Retroreflective sheeting is manufactured in such a way that light hitting the surface is reflected back to its source, in an expanding conical shape. Figure 3.1 illustrates the projection and retroreflection of light.

Drivers of large vehicles do not receive the same level of reflected light from traffic signs as car drivers. This is due to the increased distance between the headlight and the driver’s eye. Although this reduction in performance is recognised within the industry, there is little documented evidence to demonstrate the effects in the UK.

Drivers of large vehicles are therefore potentially disadvantaged as the amount of reflected light reduces as the distance from the source increases.
Direct lighting

Research (Guidance on the illumination of traffic signs and bollards, 2008) by the Association of Directors of Environment, Economy, Planning and Transport (ADEPT, previously the County Surveyors Society) identified that the average cost difference between installing a directly lit sign and a non-directly lit sign was in the region of £689, equivalent to 300 percent (further information on whole life costs can be found in Section 9). The time taken to implement a typical highway safety scheme could be increased by 2 months if there was a requirement to provide a mains electrical supply to directly light signs and bollards.

However, in order to achieve an acceptable level of luminance, the direct lighting of traffic signs is still mandatory in some scenarios where large vehicles make up a high proportion of road users.

The literature review also considered new lighting and energy technologies with the benefits of using renewable power sources, such as wind and solar energy, being documented. Developments in LED, electroluminescent and optical light film technologies were also researched allowing comparisons with signs directly lit using fluorescent tube luminaires.

For example, the use of LED sign luminaires allows for a reduction in energy consumption and increased reliability, reducing energy and maintenance costs. However, the initial, potentially higher cost of LED luminaires needs to be taken into account when considering their use.

New lighting technologies not only could reduce energy consumption, but can also reduce light spill (see Figure 3.2) and provide a more even distribution of light across the sign face, an issue which has been recognised for some time, especially on larger direction signs.
Other factors affecting sign performance

It is not only the subject of direct lighting where technologies have been developed. Microprismatic reflective sign sheeting, when used under certain circumstances, can provide a higher level of retroreflection than traditional glass bead technology where entrance angles are not particularly large. This increased light may also result in a sign being legible from a greater distance, allowing drivers additional time to read and react to the information as necessary. However, it can also have the effect of the sign being too bright, affecting legibility. For example, in some instances such as a low mounted sign with a high performance sheeting, the sign could become too bright and affect legibility within a low ambient background.

Other factors affect the legibility of signs, specifically in relation to drivers. It has already been established that drivers of large vehicles receive less retroreflected light than car drivers, but other factors include:

- the presence of obstructions – limiting the time available to view the signs;
- condition of driver’s eye sight – between 2 and 40 percent of drivers do not meet the eye sight requirements, depending on their age;
- headlamp performance – up to 60 percent of vehicles have headlamps which are not correctly aligned;
- driver age – beyond 45, a significant change in driver behaviour has been reported;
- sign location – the level of retroreflected light varies depending on the location of the sign in relation to the driver and can be as little as 36 percent when compared to some locations, and
• vehicle position – the position of the vehicle in relation to the sign affect the entrance angle and observation angle. Both of these factors can affect the amount of light which is returned to the driver.

Standards

The methodology detailed in BS8408:2005 shows that in most situations in which directional signs are found, the sheeting materials available perform sufficiently well that lighting is not required when viewed by car drivers.

Many direction signs have the option to remain unlit (TSRGD Schedule 17 Item 4) affording the Designer more scope not to provide direct lighting. However, for signs mounted on the exit of roundabouts, where the entrance angle for the sign can be greater than 30 degrees, the performance of retroreflective materials is reduced.

Furthermore, for drivers of large vehicles in the V2 category (Figure 4.3), retroreflective materials only meet the performance requirements where the signs are located in the lower left (P4) (Figure 4.1) position or a left hand verge sign viewed at the shortest distance class and at a narrow angle (P1, D4, A1) (Table 4.1 and 4.2). It may therefore be necessary to provide direct lighting of signs when viewed at such increased angles, although in the case of the exit of a roundabout, the entrance angle for the sign would be less for a significant proportion of the approach.

Continuing with the methodology detailed in BS8408:2005, the performance for warning and regulatory (symbolic) signs is more complex:

• For car drivers, where signs are located in the left or right hand verge and viewed at narrow entrance angles, all materials meet or are within 1% of the required performance index.

• For car drivers viewing signs at medium entrance angles (5 to 30º), all sign materials perform sufficiently when located in the left verge when viewed at approaches of 120-40 metres or 90-30 metres. Some materials met the requirements for longer approaches but none met the requirements for approaches between 20-50 metres.

• For car drivers, where signs are located in the right verge, materials in the 120-40 metres approach did not need to be directly illuminated, shorter approaches required lighting to achieve similar levels of performance.

• For drivers of large vehicles, the materials only met the performance requirements where the sign was located to the lower left position, or in three other situations where the viewing distance is short and the entrance angle is narrow.

• There was only one scenario in which signs on gantries did not require direct lighting for car drivers.

From the above it appears there are some scenarios in which direct lighting will have to be provided in order for the performance requirements to be met, particularly where HGVs could make up a large proportion of the road users.

The Literature Review also considered new technologies relating to energy and direct lighting. A number of alternative energy sources were investigated, including solar and
wind generated energy, together with illumination technologies such as the use of LEDs, electroluminescent and optical light films.

Research into new technologies offers a number of benefits when compared to the traditional fluorescent tube luminaire, including:

- Reduced energy consumption.
- Easier and quicker installation resulting in fewer delays and less cost (for solar powered signs).
- Reduced installation costs and delays to motorists when using low voltage "slot cut" road crossings.
- Less frequent maintenance required resulting in lower costs and less risk for highways personnel.
- More even distribution of light across the sign face giving better legibility, dependant of the type of LED arrangement and diffuser.
- Less light pollution (EL and internally illuminated LED).
- Because the luminaires do not contain mercury they are easier to dispose of and less harmful to the environment.

Previous research has quantified the performance of signs by measuring the legibility distance, conspicuity distance or pupil movement of the driver. Such research concluded that microprismatic materials may give longer legibility distances when compared to glass bead materials. However, the environment in which the signs were tested favoured microprismatic materials in that the signs where located where the entrance angles would not be particularly large.

Where different direct lighting methods were tested, electroluminescent signs performed better in terms of uniformity, contrast and amount of light pollution produced.

3.4 Trial Options

With a number of possible variables it was important to prepare a series of off-road trials which captured as many scenarios as reasonably practicable. The aim of the trials would be to assess driver perception when faced with different lighting levels and generic direct lighting technologies, rather than to test and report on manufacturers individual products.

In determining a suitable site for the location of off-road trials, the use of both physical and virtual facilities was considered.

Leeds University and the Transport Research Laboratory (TRL) have virtual simulators suited to research into driver behaviour. Both facilities use specially converted vehicles linked to computers to provide driver feedback and project a virtual world to the driver.

TRL use “CarSIM” and “TruckSIM” to enable virtual world testing from the perspective of a passenger car and a heavy goods vehicle. Although both systems use actual vehicle cockpits to increase the realism, the inclusion of accurate retroreflective sheeting properties would require significant programming and development.

Whilst it is possible to vary ambient lighting levels and indeed weather conditions, the performance of retroreflective sign sheeting combined with vehicle headlights, together with the effects of direct external lighting, could not be accurately represented in a
computer model. This may have led to results that were not representative of the real world.

As a result, any recommendations made following the trials could prove difficult to justify and could potentially require further real-world trials in order to validate the data. For these reasons, driving simulators were not considered suitable for the trials.

3.4.1 Disused airfields and motor racing circuits

It was therefore necessary to identify a suitable location where real-world trials could be carried out in a controlled environment. Options included motor-racing circuits, disused airfields and transport research facilities.

Disused airfields were ruled out at an early stage due to logistical problems creating a typical road layout. Although the layout of a typical motor racing circuit could be adapted to represent the highway network, health and safety concerns, with specific regard to the erection of traffic signs and lamp columns adjacent to the track with little or no protection, meant that circuit operators were reluctant to allow such works to be carried out.

Furthermore, the potential for damage to either the verges or the carriageway was also an issue with operators aiming for a high standard of upkeep. As a result, a decision was taken not to follow up the use of motor racing circuits.

TRL and the Motor Industry Research Association (MIRA) have large test tracks available which could be used to undertake trials.

3.4.2 TRL

The Large Loop circuit at TRL is approximately two kilometres in length and varies between two and three running lanes. The circuit includes two gantry structures, although upon inspection these were considered unsuitable for the erection of traffic signs.

The majority of the circuit is surrounded by a wooded area which encroaches to the extremities of the carriageway, reducing the number of suitable locations for the erection of verge mounted signs and subsequently the visibility of them. Due to the location of TRL, part of the Large Loop circuit runs in close proximity to a number of residential properties.

This led to an issue over noise pollution, especially as the trials would need to be undertaken during the hours of darkness. TRL confirmed that their relationship with nearby residents was a high priority for them.

The issue of erecting signs in locations which afforded visibility in line with the Department for Transport Local Transport Note 1/94 together with concerns over noise pollution resulted in the facilities at TRL were therefore considered unsuitable for the trials.
3.4.3 MIRA

MIRA has a number of circuits available for use. Of particular interest was the “twin horizontal straights”. The circuit consists of a straight, two lane dual-carriageway, one mile long, joined at both ends by banked loops. A wire rope safety fence separates the carriageways with grass verges on both sides with sections of open box beam safety fencing as required (Figure 3.3).

The circuit is similar to a rural dual carriageway, although there were no lighting columns and only minimal traffic signs installed along the length. Discussions with MIRA representatives confirmed that they would be content to permit the installation of street lighting and traffic signs along the grass verges using a suitably experienced Contractor.

4. Off-road trials

4.1 Dynamic trials

In establishing the layout for the trials, the use of dynamic and static trials was considered beneficial to the project. The dynamic trials were designed to enable the effect of varying ambient lighting levels on different grades of retroreflective sign sheeting to be assessed from a vehicle travelling at typical highway speeds.


Correction factor for sign location

The correction factor for the location of the sign is determined by the position of the sign in relation to the driver. Figure 4.1 shows the positions indicated P1 to P4.
Correction factor for vehicle type

The correction factor for the vehicle type is based upon standardised dimensions for either a UK passenger car or a UK large vehicle, indicated as either V1 or V2 respectively. The vehicle specific dimensions are shown in figures 4.2 and 4.3.

Correction factor for distance subclasses

Four distance subclasses each represent the furthest and closest viewing distances in between which drivers may have a number of opportunities to read the sign before it is out of their field of view. The subclasses are represented as D1 – D4 shown in Table 4.1.
**Distance subclass**

<table>
<thead>
<tr>
<th>Distance subclass</th>
<th>Distance Range (m)</th>
<th>Typical x-height (mm)</th>
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<tbody>
<tr>
<td>Long (D1)</td>
<td>200 – 50</td>
<td>250-300</td>
</tr>
<tr>
<td>Medium (D2)</td>
<td>120 – 40</td>
<td>200</td>
</tr>
<tr>
<td>Short (D3)</td>
<td>90 – 30</td>
<td>100-150</td>
</tr>
<tr>
<td>Close (D4)</td>
<td>50 – 20</td>
<td>75</td>
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**Table 4.1 – Distance Subclasses**

**Correction factor for entrance angularity subclasses**

The entrance angularity subclasses categorise the maximum entrance angle of a sign relative to an approaching vehicle. The subclasses are represented as A1 – A3 in Table 4.2

<table>
<thead>
<tr>
<th>Entrance angularity subclass</th>
<th>Entrance angle ($\beta$)</th>
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<tbody>
<tr>
<td>A1 narrow</td>
<td>Up to 15º</td>
</tr>
<tr>
<td>A2 medium</td>
<td>Up to 30º</td>
</tr>
<tr>
<td>A3 wide</td>
<td>Up to 40º</td>
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**Table 4.2 – Entrance Angularity Subclasses**

**Correction factor for sign category**

Signs fall under two main categories, those comprising worded text, such as a direction sign and those that are largely symbolic, such as warning signs. The correction factors allows for the different luminance needs and are identified as either category A for signs with legends and category B for predominantly symbolic signs.

**Performance index needs for drivers**

Ambient lighting can have an impact of the conspicuity of traffic signs. As a result, certain signs require direct lighting to compensate for the lack of conspicuity. The ‘performance index needs’ allow for higher ambient lighting levels and are shown in Table 4.3.

<table>
<thead>
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<th>Sign type</th>
<th>Performance index needs</th>
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<tr>
<td>Legend (informatory signs)</td>
<td>1.0 1.0</td>
</tr>
<tr>
<td>Symbolic (warning and regulatory signs)</td>
<td>1.0 3.0</td>
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**Table 4.3 – Performance index needs**
Whilst the use of performance indices is specific to microprismatic material, it is clear that in practice it results in a sign which matches the need of the driver, rather than simply using the best performing materials.

More information on the correction factors and the performance of microprismatic materials can be found in BS 8408:2005.

It was considered beneficial to use both a passenger car and large vehicle, to replicate the V1 and V2 vehicle classes. The decision to include large vehicles mirrors the Highways Agency’s preference of using the V2 category as a result of the network carrying approximately half of the freight traffic in England, a high proportion of which will use the network during the hours of darkness. Specific details of the vehicles used for all of the tests and for specimen vehicles V1 and V2 can be found in tables 4.4 and 4.5.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Test vehicle (2009 Ford Focus)</th>
<th>V1 (BS 8408:2005)</th>
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<tr>
<td>Distance from ground level to centre of headlight (mm)</td>
<td>730</td>
<td>650</td>
</tr>
<tr>
<td>Distance from ground level to drivers eye level (mm)</td>
<td>1240</td>
<td>1200</td>
</tr>
<tr>
<td>Distance between headlights (centres) (mm)</td>
<td>1220</td>
<td>1000</td>
</tr>
</tbody>
</table>

Table 4.4 – Passenger vehicle characteristics

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from ground level to centre of headlight (mm)</td>
<td>990</td>
<td>800</td>
</tr>
<tr>
<td>Distance from ground level to drivers eye level (mm)</td>
<td>2390</td>
<td>2200</td>
</tr>
<tr>
<td>Distance between headlights (centres) (mm)</td>
<td>1820</td>
<td>1800</td>
</tr>
</tbody>
</table>

Table 4.5 – Large vehicle characteristics

In order to undertake testing of a number of scenarios from BS 8408:2005, twelve traffic signs were positioned to replicate the various scenarios shown in Figure 4.1. The layout of the dynamic trials enabled Atkins to design for speeds of 70mph for the outbound run and 40mph for the return run. Sixteen signs were originally to be used, although the limitations of the project resulted in four of them being removed (signs 1, 10, 11 and 14 shown in Appendix D of this report). The decision was taken not to re-number the remaining signs as doing so could lead to confusion as a number of them were already in production.
The signs were designed in accordance with the TSRGD, Chapter 7 of the Traffic Signs Manual and DfT Local Transport Note 1/94; with x-heights appropriate to the speed of approaching vehicles. Direct lighting was by means of either overhead or internal units to current standards. The twelve signs are shown in Appendix A and were located as shown in Appendix B. Table 4.6 summarises this information.

Two of the signs were positioned over the carriageway on a bespoke temporary gantry structure to replicate sign location factor P3 (Figure 4.1) which was installed as part of the trials (Appendix C).

The signs covered a variety of advance and local direction, warning and informatory signs incorporating a range of colours, symbols, panels and patches. All of the place names used are fictional to reduce the participant familiarity.

In order to comply with the Correction Factor, it was necessary to locate four signs in the P2 position in the carriageway resulting in surface foundations being used for some signs to so as not to damage the carriageway surface. The decision to use surface foundations was discussed with the Agency and was deemed not to detract from the aim of the trials.

To ensure that the tests were not biased towards a particular reflective sheeting supplier, all microprismatic products conforming to BS8408:2005 and encapsulated glass bead products conforming to BS EN 12899-1:2007 that were commercially available from the four main UK suppliers at the time of the trials were selected.

<table>
<thead>
<tr>
<th>Dynamic Sign</th>
<th>Description</th>
<th>Material</th>
<th>X-height (mm)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lane loss sign</td>
<td>Encapsulated glass bead</td>
<td>240</td>
<td>P2</td>
</tr>
<tr>
<td>3</td>
<td>Warning sign</td>
<td>Entry level microprismatic</td>
<td>150</td>
<td>P1</td>
</tr>
<tr>
<td>4</td>
<td>Advance direction sign</td>
<td>Premium microprismatic</td>
<td>225</td>
<td>P1</td>
</tr>
<tr>
<td>5</td>
<td>Gantry sign</td>
<td>Transilluminated microprismatic</td>
<td>225</td>
<td>P3</td>
</tr>
<tr>
<td>6</td>
<td>Countdown marker</td>
<td>Entry level microprismatic</td>
<td>100</td>
<td>P4</td>
</tr>
<tr>
<td>7</td>
<td>Advance direction sign</td>
<td>Encapsulated glass bead</td>
<td>100</td>
<td>P1</td>
</tr>
<tr>
<td>8</td>
<td>Gantry sign</td>
<td>Transilluminated microprismatic</td>
<td>150</td>
<td>P3</td>
</tr>
<tr>
<td>9</td>
<td>Advance direction sign</td>
<td>Premium microprismatic</td>
<td>100</td>
<td>P4</td>
</tr>
<tr>
<td>12</td>
<td>Direction sign</td>
<td>Entry level microprismatic</td>
<td>75</td>
<td>P2</td>
</tr>
<tr>
<td>13</td>
<td>Direction sign</td>
<td>Encapsulated glass bead</td>
<td>75</td>
<td>P2</td>
</tr>
<tr>
<td>15</td>
<td>Direction sign</td>
<td>Premium microprismatic</td>
<td>75</td>
<td>P2</td>
</tr>
<tr>
<td>16</td>
<td>Warning sign</td>
<td>Transilluminated microprismatic</td>
<td>100</td>
<td>P1</td>
</tr>
</tbody>
</table>

Table 4.6 – Signs used for dynamic trials

A system of street lighting, covering the extent of the signs, was also introduced. The required street lighting levels were designed in accordance with BS 5489-1:2003, BS EN 13201-2:2003 and DMRB TD 34/07 for a Typical Lighting Scheme and are detailed in Appendix D. All luminaires were provided as new units, giving optimum light outputs and
were fitted with 150w SON-T+ lamps. Power was provided by a series of silent running diesel generators, with carriageway and sign lighting circuits wired independently of each other to enable individual switching.

4.1.1 Data collection

In order to assess the effects of varying lighting levels, 40 independent participants, including 10 licensed to drive heavy goods vehicles, were invited to drive the circuit at the appropriate speeds. Observers, sat in the rear of the vehicle (or the passenger seat, in the case of the HGV) asked the drivers to identify certain elements on each sign.

Psychologists from the University of Leeds defined a series of questions, such as “What is the last letter of the destination” which would test each participants ability to read the signs.

Each driver undertook five runs covering the following lighting conditions:

- Drive 1 – Daylight conditions;
- Drive 2 – Street lights on, sign lights on;
- Drive 3 – Street lights on, sign lights off;
- Drive 4 – Street lights off, sign lights on, and
- Drive 5 – Street lights off, sign lights off

A different set of questions were used for each Drive to reduce the risk of participants familiarising themselves with the questions resulting in inaccurate response times. A full set of questions is included in Appendix E.

Each vehicle was fitted with GPS equipment capable of recording the speed and position of the vehicle when the observer pressed a trigger in relation to each sign. This allowed the observer to record the position of the vehicle at the end of each question, and again as the participant gave an answer. The data allowed calculation of the time taken and distance travelled whilst reading the signs and the distance from the sign when the answer was given.

5. Static trials

In addition to the dynamic trials, twelve signs were setup in a gallery formation as shown in Appendix F. The aim was to establish which method of direct lighting performed best. Each sign was provided with direct lighting using a number of technologies currently available, as shown in table 5.1. The twelve signs were identical 600mm diameter 7.5 tonne weight limit signs (TSRGD diagram number 622.1A)

The weight limit sign was chosen as a typical regulatory sign which included characters rather than just a symbol. This allows us to identify the effect of the different lighting technologies on the legibility of the characters.

The signs were mounted at a minimum of 1500mm above ground level, as shown in Appendix F.
The mean luminance level specified for the signs was to be in accordance with Table 19 (transilluminated signs) and Table 22 (externally illuminated signs) of BS EN 12899-1:2007 to Class LS, L1, E1 or E2 (Tables 4.8 and 4.9 below). All of the signs were manufactured from microprismatic retroreflective sheeting to BS 8408:2005 except sign 9 which was manufactured from a dual-colour moulding with no additional retroreflective properties.

Classes L1, L2, L3 and L4 are comparable to classes E2, E3, E4 and E5 respectively.

<table>
<thead>
<tr>
<th>Static Sign</th>
<th>Direct Lighting</th>
<th>Static Sign</th>
<th>Direct Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>External LED</td>
<td>7</td>
<td>Back-lit LED</td>
</tr>
<tr>
<td>2</td>
<td>Electroluminescent</td>
<td>8</td>
<td>Back-lit LED</td>
</tr>
<tr>
<td>3</td>
<td>Electroluminescent</td>
<td>9</td>
<td>Internal fluorescent</td>
</tr>
<tr>
<td>4</td>
<td>Edge-lit LED</td>
<td>10</td>
<td>External fluorescent</td>
</tr>
<tr>
<td>5</td>
<td>Back-lit LED</td>
<td>11</td>
<td>External LED</td>
</tr>
<tr>
<td>6</td>
<td>Back-lit LED</td>
<td>12</td>
<td>External LED</td>
</tr>
</tbody>
</table>

* Sign 1 was not included in the test due to it being powered by a battery charged by a solar panel. There was no method of switching the lighting from ground level which was a health and safety requirement for the operators.

Table 5.1 – Method of direct illumination – static trials

The mean luminance level specified for the signs was to be in accordance with Table 19 (transilluminated signs) and Table 22 (externally illuminated signs) of BS EN 12899-1:2007 to Class LS, L1, E1 or E2 (Tables 4.8 and 4.9 below). All of the signs were manufactured from microprismatic retroreflective sheeting to BS 8408:2005 except sign 9 which was manufactured from a dual-colour moulding with no additional retroreflective properties.

<table>
<thead>
<tr>
<th>Colour</th>
<th>Class L1</th>
<th>Class L2</th>
<th>Class L3</th>
<th>Class LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>$40 \leq L \leq 150$</td>
<td>$150 \leq L \leq 300$</td>
<td>$300 \leq L \leq 900$</td>
<td>$10 \leq L \leq 40$</td>
</tr>
</tbody>
</table>

Table 5.2 – Mean luminance $L$ of transilluminated signs (cd-m$^{-2}$)
Two passenger cars were located 30 metres in advance of the gallery at angles of 5 degrees and 40 degrees. These angles represent the “straight ahead” and the “A3 Wide” Entrance Angularity Sub-classes to BS 8408:2005. The vehicle headlights were not used as the tests were to identify the benefits of alternative methods of direct lighting. Street lighting was switched on throughout.

The test comprised two parts. For the first part of the test pairs of signs were lit for 10 seconds. Forty participants were asked to indicate which of the two signs was more legible. This was carried out until all twelve signs had been compared against each other. Each participant carried out the test once, giving approximately 20 sets of results for each vehicle position.

For the second part of the test, applicants were asked to rate each sign individually. Each sign was lit for 10 seconds randomly with applicants indicating their preference separately in terms of “clarity” and “uniformity” on a scale from 1 (very poor) to 10 (very good).

For both tests, the participants were advised as to the meaning of legible, clarity and uniformity. The key was to ensure that participants did not simply single out the brightest signs as being the best performers.

6. Weather conditions

The trials were carried out during November 2009. This ensured that there were sufficient hours of darkness to complete the tests each evening. It is acknowledged that the build up of dew on sign faces can significantly reduce the performance of the retroreflective sheeting. The temperature at which dew begins to form on a sign face is referred to as the dew point. Dew will form on a sign face when moist air cools as it comes in to contact with a cooler surface and the air temperature falls below the dew point.

Wind speed can have a positive effect on reducing the risk of dew forming as the air in the vicinity of the sign is constantly changing. The presence of direct lighting can marginally increase the surface temperature of a sign face to the point where it reduces the risk of dew forming.

Prior to each Drive, the signs on the dynamic trial were checked for the presence of dew. The formation of dew was not reported at any point during the trials. The location and topography at MIRA resulted in fairly consistent wind speeds which, together with the actual air temperature reduced the risk of formation of dew to a point where it was not considered to have any noticeable effect on the performance of the signs. Details of the weather conditions including the average air temperature were recorded (Appendix G).
7. Interpretation of results

7.1 Analysis of results for static trials

The results of the static trials enable consideration to be given to the performance of alternative direct lighting technologies based on the two tests described in Section 5. For the "paired comparison" test, the results are detailed below.

The total scores for the 11 signs were calculated by counting the number of times each sign was selected in preference over the other.

It should be noted that Sign 1 was not included in the trials. This was due to it being powered by a battery charged by a solar panel. There was no method of switching the sign from ground level, which was a Health and Safety requirement for the operators.

<table>
<thead>
<tr>
<th>Entrance angle</th>
<th>Static Sign 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>5º</td>
<td>n/a</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>40º</td>
<td>n/a</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 7.1 – Average scores in paired comparison analysis for legibility (static)

Using a score of eight (from a maximum of 10) as being indicative of a strong performance, Table 7.1 shows that at a 5º entrance angle, signs 9 and 12 were considered to be the most legible, with Signs 2, 3, 8 and 10 also performing well. For the 40º entrance angle, Signs 2, 3, 9 and 10 performed well. From the results, Signs 2, 3, 9 and 10 were considered as the best performers from both the 5º and 40º entrance angles.

Sign 9 was considered to be one of the most legible signs for both entrance angles. The product has been on the market in one form or another for approximately 50 years and comprises twin fluorescent tubes in a moulded self coloured acrylic housing.

For the second test, the average ratings for both uniformity and clarity for each sign were recorded.

Figure 7.1 shows that Sign 4 performed best in terms of clarity and uniformity, followed closely by sign 11. Signs 2 and 3 were considered the worst performers although these had the lowest luminance levels of all the signs in the static trials, averaging 19.91cd/m² and 13.79cd/m² respectively (Appendix H). Signs 2 and 3 are two of only three signs which fall into the LS luminance category, along with sign 10 (Table 5.2).
Although closely linked, the two tests identified different signs as being the best and worst performers. The results indicate that the uniformity and clarity of the sign when lit had less effect on the overall legibility than was anticipated.

The results highlight differences in uniformity for a number of the products tested. The controlled method of testing the uniformity of luminance is specified in BS EN 12899-1:2007. It was not possible to undertake detailed testing of the uniformity of luminance due to the number of signs to be tested, the method of test and the limited time available during the trials. However, luminance levels were recorded for all signs to determine conformity to the values detailed in Tables 5.2 and 5.3 (Appendix H).

The results of the luminance readings (Appendix H) show that signs 1, 4, 6, 7, 9 and 11 exceeded the specified mean luminance levels LS or L1 (for transilluminated signs, Table 5.2) and E1 or E2 (for externally lit signs, Table 5.3) which could beneficially affect the performance of the signs.

A number of participants also opted to indicate the sign which they felt performed best in terms of clarity and uniformity when all of the signs were lit together.

<table>
<thead>
<tr>
<th>Sign</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Votes</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 7.2 – Number of times each static sign was selected as the best performer in terms of clarity and uniformity when all signs were illuminated

Although not forming part of the trial, the information can be used to supplement the results with sign 4 being considered the best performer (Table 7.2).

A number of manufacturers confirmed that the luminance levels for their products can be varied during manufacture allowing individual units to be tailored to suit the surrounding
ambient light levels. Increasing the luminance levels of a sign which is intended to be used in an area with medium to high levels of ambient lighting can result in the sign being more conspicuous. Signs located in areas with low ambient lighting levels do not require the same level of luminance. The trade-off with increasing the luminance levels is an increase in energy consumption and a potential decrease in the lifespan of the sign, reducing the initial benefits of electroluminescent and LED technologies and an increase in whole life costs.

7.2 Analysis of results for dynamic trials

The time (in seconds) taken to read the sign was determined using the GPS dataset. It shows the effects of sign and ambient lighting on a driver’s ability to read the signs.

The typical reading time for worded signs can be calculated based on the number of words or destinations on the sign, using the following formula (for determination of sign x-height) which is available to download from the DfT website (http://www.dft.gov.uk/pgr/roads/tss/tsmanual/chapter2/tsschapter2-x-height.pdf):

\[
\text{Reading time} = 2 + \left(\frac{N}{3}\right) \text{ seconds}
\]

(where N is the number of words or destinations on the sign)

For a sign containing two words or destinations, the reading time would be 2.67 seconds, a sign with six words or destinations would require 4 seconds, which is considered to be the maximum desirable time for reading the sign. This allows time for the sign to be scanned twice to assimilate the information. As a result, the number of destinations on a sign should not exceed six.

Due to the lack of published information relating to the calculation of an appropriate equivalent number of pieces of information from various combinations of words and destinations, for the purposes of deriving values of N for this project, the following have been used:

- Destination and route number: N=1
- Symbol and separate associated distance: N=2
- Junction number patch: N=1
- Distance to junction/destination: N=1
- Emergency diversion symbol: N=1
Table 7.3 illustrates the minimum and maximum recorded reading times compared to reading time calculated from the above formula

<table>
<thead>
<tr>
<th>Sign</th>
<th>Maximum recorded reading time (seconds)</th>
<th>Minimum recorded reading time (seconds)</th>
<th>Difference (seconds)</th>
<th>Approach speed (mph)</th>
<th>Units of information</th>
<th>Reading time based upon DfT formula (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.86 [5]</td>
<td>1.84 [1]</td>
<td>3.02</td>
<td>70</td>
<td>2</td>
<td>2.67</td>
</tr>
<tr>
<td>7</td>
<td>4.55 [5]</td>
<td>2.01 [2]</td>
<td>2.54</td>
<td>40</td>
<td>6</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Numbers in square brackets relate to the Scenarios in section 4.1.1
* Sign 6 contained no words or destinations, but a minimum of 1 unit of information was assumed.

Table 7.3 – Relationship between maximum and minimum average reading times for each sign

Considering the data in Figure 7.2, the least reading time was required to read the signs when the street lights were switched off and the sign lighting switched on (Drive 4). This scenario provides the highest level of contrast and provides legibility over and above that found during daylight conditions. This would suggest that the ambient light afforded by daylight conditions affects the legibility of the signs because their conspicuity is reduced. The legibility decreases with the reduction in the conspicuity of the sign face, whether as a removal of direct sign lighting, or as an increase in ambient light levels. The results combine the data gathered for drivers of the car and HGV. Section 7.3 provides further information regarding HGV drivers.
The ‘x’ heights used are detailed with the sign designs as part of Appendix A of this report and were based upon the approach speed of traffic. It should be noted that the approach speed was 70mph on the NE approach and 40mph on the SW approach. Location details are included within Appendix B of this report and mounting heights were based upon figure i.3 within BS8408:2005.

The results show that changes to ambient lighting and sign lighting affect a driver’s ability to read information on traffic signs; although the effect may vary between drivers of different age, gender or driving experience.

 Whilst Drive 4 may not be representative of that currently found on the network, it does however replicate typical ambient light levels during a period when street lighting may be switched off for the purposes of conserving energy. This provides a positive benefit to road users in terms of increased legibility of traffic signs.

It is possible to ascertain that direct lighting of traffic signs has a positive impact on the overall legibility of the sign. Whilst premium microprismatic materials are generally provided to permit legibility from greater distances, the governing factor may still be an individual’s eye sight which for the purposes of driving requires that a vehicle registration plate (post 1st September 2001), comprising 79mm tall characters, can be read from a distance of 20.5 metres.

Sign 7 appears to go against the general results and performed better during the “street lighting on, sign lighting on” scenario. This result may indicate greater importance of direct lighting when considering large ‘map type’ ADS with a large amount of information present. The sign in question was not manufactured for the purposes of the trials and had been stored externally for a period of approximately 12 months and was not in good condition. The sign was lit by means of two overhead light units on outreach arms.
It is evident that during periods when street lighting is switched off, there is a clear benefit to leaving the sign lighting switched on. This is illustrated as the difference between the scenarios “street lighting off, sign lighting on” and “street and sign lights off”.

This finding may be relevant for highway authorities who plan to implement projects to switch off street lighting in periods of low traffic flow.

The results also show that with the street lighting and sign lighting switched on, participants need more time to read the sign than when than when sign lighting alone was switched on, suggesting that the increased ambient light levels have a negative effect on the legibility of the signs.

The results also give an indication as to the performance levels of the retroreflective sheeting used. The comparatively flat line for the “street lighting on, sign lighting off” scenario suggests that the sheeting, made little difference to the time spent reading the signs regardless of whether glass bead, entry level or premium microprismatic products were used.

The difference between the shortest and longest reading times and the equivalent distances travelled for the outbound run (70mph approach speed) and inbound run (40mph approach speed) are detailed in Tables 7.5 and 7.6.

The required reading time for each sign used in the dynamic trials was compared to the average recorded reading times (Table 7.7). This shows that for the scenarios of street lights off signs lights on (shortest reading time) and daylight (second shortest reading time) the observed average reading time (averaged over all participants) was comparable to that calculated using the “Determination of x-height” formula. This is illustrated in Figure 7.2.

### Table 7.4 – Scenario ranking for dynamic trials

<table>
<thead>
<tr>
<th>Rank</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best</td>
<td>Street lighting off, sign lighting on (Drive 5)</td>
</tr>
<tr>
<td>Second</td>
<td>Daylight (Drive 1)</td>
</tr>
<tr>
<td>Third</td>
<td>Street lighting on, sign lighting on (Drive 2)</td>
</tr>
<tr>
<td>Fourth</td>
<td>Street lighting on, sign lighting off (Drive 3)</td>
</tr>
<tr>
<td>Worst</td>
<td>Street lighting off, sign lighting off (Drive 4)</td>
</tr>
</tbody>
</table>

The official engineering design services provider for the London 2012 Games
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Maximum recorded reading time (seconds)</th>
<th>Minimum recorded reading time (seconds)</th>
<th>Difference (seconds)</th>
<th>Distance travelled (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight</td>
<td>2.58 [4, 6]</td>
<td>1.84 [1]</td>
<td>0.74</td>
<td>23.16</td>
</tr>
<tr>
<td>Street lighting on, Sign lighting on</td>
<td>3.21 [4]</td>
<td>2.68 [1]</td>
<td>0.53</td>
<td>16.59</td>
</tr>
<tr>
<td>Street lighting on, sign lighting off</td>
<td>3.72 [1]</td>
<td>3.64 [3]</td>
<td>0.08</td>
<td>2.50</td>
</tr>
<tr>
<td>Street lighting off, Sign lighting on</td>
<td>2.30 [5]</td>
<td>1.99 [1]</td>
<td>0.31</td>
<td>9.70</td>
</tr>
</tbody>
</table>

Numbers in square brackets relate to the sign reference

Table 7.5 – Relationship between maximum and minimum average reading times at 70mph

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Maximum recorded reading time (seconds)</th>
<th>Minimum recorded reading time (seconds)</th>
<th>Difference (seconds)</th>
<th>Distance travelled (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight</td>
<td>3.13 [16]</td>
<td>2.46 [15]</td>
<td>0.67</td>
<td>11.99</td>
</tr>
<tr>
<td>Street lighting on, sign lighting off</td>
<td>3.73 [15]</td>
<td>3.40 [16]</td>
<td>0.33</td>
<td>5.91</td>
</tr>
<tr>
<td>Street lighting off, Sign lighting on</td>
<td>2.32 [7, 8]</td>
<td>1.75 [9]</td>
<td>0.57</td>
<td>10.20</td>
</tr>
<tr>
<td>Street lighting off, Sign lighting off</td>
<td>4.77 [12]</td>
<td>4.54 [16]</td>
<td>0.23</td>
<td>3.93</td>
</tr>
</tbody>
</table>

Numbers in square brackets relate to the sign reference

Table 7.6 – Relationship between maximum and minimum average reading times at 40mph
<table>
<thead>
<tr>
<th></th>
<th>Sign 1</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>12</th>
<th>13</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daylight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave</td>
<td>1.84</td>
<td>2.55</td>
<td>2.58</td>
<td>2.50</td>
<td>2.58</td>
<td>2.53</td>
<td>2.63</td>
<td>2.48</td>
<td>2.53</td>
<td>2.71</td>
<td>2.46</td>
<td>3.13</td>
</tr>
<tr>
<td><strong>Street lighting on, sign lighting on</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave</td>
<td>2.68</td>
<td>2.87</td>
<td>3.21</td>
<td>2.77</td>
<td>3.05</td>
<td>2.01</td>
<td>3.10</td>
<td>3.24</td>
<td>2.90</td>
<td>3.23</td>
<td>3.40</td>
<td>2.89</td>
</tr>
<tr>
<td><strong>Street lighting on, sign lighting off</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave</td>
<td>3.72</td>
<td>3.64</td>
<td>3.67</td>
<td>3.66</td>
<td>3.67</td>
<td>3.70</td>
<td>3.71</td>
<td>3.69</td>
<td>3.59</td>
<td>3.66</td>
<td>3.73</td>
<td>3.40</td>
</tr>
<tr>
<td><strong>Street lighting off, sign lighting on</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave</td>
<td>1.99</td>
<td>1.98</td>
<td>2.19</td>
<td>2.30</td>
<td>2.25</td>
<td>2.32</td>
<td>2.32</td>
<td>1.75</td>
<td>1.80</td>
<td>1.76</td>
<td>1.89</td>
<td>1.95</td>
</tr>
<tr>
<td><strong>Street lighting off, sign lighting off</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave</td>
<td>4.86</td>
<td>4.52</td>
<td>4.88</td>
<td>4.93</td>
<td>4.48</td>
<td>4.55</td>
<td>4.67</td>
<td>4.71</td>
<td>4.77</td>
<td>4.67</td>
<td>4.56</td>
<td>4.54</td>
</tr>
</tbody>
</table>

Tables 7.7 – Average recorded reading times (seconds)
<table>
<thead>
<tr>
<th>Sign</th>
<th>Type</th>
<th>Material</th>
<th>Location</th>
<th>Daylight</th>
<th>Street lights on, sign lights on</th>
<th>Street lights off, sign lights on</th>
<th>Street lights on, sign lights off</th>
<th>Street lights off, sign lights off</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lane loss sign</td>
<td>Encapsulated Glass bead</td>
<td>P2</td>
<td>1.84</td>
<td>2.68</td>
<td>3.72</td>
<td>1.99</td>
<td>4.86</td>
</tr>
<tr>
<td>3</td>
<td>Warning sign and supplementary plate</td>
<td>Entry level microprismatic</td>
<td>P1</td>
<td>2.55</td>
<td>2.87</td>
<td>3.64</td>
<td>1.98</td>
<td>4.52</td>
</tr>
<tr>
<td>4</td>
<td>Advance direction sign</td>
<td>Premium microprismatic</td>
<td>P1</td>
<td>2.58</td>
<td>3.21</td>
<td>3.67</td>
<td>2.19</td>
<td>4.88</td>
</tr>
<tr>
<td>5</td>
<td>Gantry sign</td>
<td>Transilluminated microprismatic</td>
<td>P3</td>
<td>2.50</td>
<td>2.77</td>
<td>3.66</td>
<td>2.30</td>
<td>4.93</td>
</tr>
<tr>
<td>6</td>
<td>Countdown marker</td>
<td>Entry level microprismatic</td>
<td>P4</td>
<td>2.58</td>
<td>3.05</td>
<td>3.67</td>
<td>2.25</td>
<td>4.84</td>
</tr>
<tr>
<td>7</td>
<td>Advance direction sign</td>
<td>Encapsulated Glass bead</td>
<td>P1</td>
<td>2.53</td>
<td>2.01</td>
<td>3.70</td>
<td>2.32</td>
<td>4.55</td>
</tr>
<tr>
<td>8</td>
<td>Gantry sign</td>
<td>Transilluminated microprismatic</td>
<td>P3</td>
<td>2.63</td>
<td>3.10</td>
<td>3.71</td>
<td>2.32</td>
<td>4.67</td>
</tr>
<tr>
<td>9</td>
<td>Advance direction sign</td>
<td>Premium microprismatic</td>
<td>P4</td>
<td>2.48</td>
<td>3.24</td>
<td>3.69</td>
<td>1.75</td>
<td>4.71</td>
</tr>
<tr>
<td>12</td>
<td>Direction sign</td>
<td>Entry level microprismatic</td>
<td>P2</td>
<td>2.53</td>
<td>2.90</td>
<td>3.59</td>
<td>1.80</td>
<td>4.77</td>
</tr>
<tr>
<td>13</td>
<td>Direction sign</td>
<td>Encapsulated Glass bead</td>
<td>P2</td>
<td>2.71</td>
<td>3.23</td>
<td>3.66</td>
<td>1.76</td>
<td>4.67</td>
</tr>
<tr>
<td>15</td>
<td>Direction sign</td>
<td>Premium microprismatic</td>
<td>P2</td>
<td>2.46</td>
<td>3.40</td>
<td>3.73</td>
<td>1.89</td>
<td>4.56</td>
</tr>
<tr>
<td>16</td>
<td>Warning sign</td>
<td>Transilluminated microprismatic</td>
<td>P1</td>
<td>3.13</td>
<td>2.89</td>
<td>3.40</td>
<td>1.95</td>
<td>4.54</td>
</tr>
</tbody>
</table>

Table 7.8 – Relationship between sign type, material, location and the average time taken to read sign
### 7.3 Considering drivers of large vehicles

In order to identify the effect of varying lighting levels on drivers of large vehicles, it is possible to compare the data recorded to identify the average distance from the vehicle to the sign at the point when the participant responded to the question. Due to the format of the questions and the use of a single HGV, it is not possible to compare all signs (Table 7.9). A full set of questions and signs used for each drive are detailed as part of Appendix E of this report.

<table>
<thead>
<tr>
<th>Sign</th>
<th>Description</th>
<th>Drive 1 (Daylight)</th>
<th>Drive 2 (Sign Lighting on, Street Lighting on)</th>
<th>Drive 3 (Sign Lighting on, Street Lighting off)</th>
<th>Drive 4 (Sign Lighting off, Street Lighting on)</th>
<th>Drive 5 (Sign Lighting off, Street Lighting on)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HGV</td>
<td>Car</td>
<td>HGV</td>
<td>Car</td>
<td>HGV</td>
</tr>
<tr>
<td>1</td>
<td>Lane indicator sign</td>
<td>160</td>
<td>242</td>
<td>-</td>
<td>-</td>
<td>94</td>
</tr>
<tr>
<td>3</td>
<td>Warning sign</td>
<td>-</td>
<td>-</td>
<td>515</td>
<td>76</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>ADS</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>85</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Gantry sign</td>
<td>166</td>
<td>199</td>
<td>292</td>
<td>157</td>
<td>117</td>
</tr>
<tr>
<td>7</td>
<td>ADS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>Gantry sign</td>
<td>47</td>
<td>108</td>
<td>155</td>
<td>95</td>
<td>16</td>
</tr>
<tr>
<td>9</td>
<td>ADS</td>
<td>-</td>
<td>-</td>
<td>124</td>
<td>52</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>Direction sign</td>
<td>13</td>
<td>16</td>
<td>14</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>Direction sign</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>Direction sign</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>16</td>
<td>Warning sign</td>
<td>84</td>
<td>90</td>
<td>106</td>
<td>88</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 7.9 – Distance from vehicle to sign when response received (metres)

Table 7.9 illustrates that drivers of cars in the trial were generally able to read information on signs at a greater distance than drivers of large vehicles. This confirms that an increase in the vertical distance between the driver and the vehicle headlights has a negative effect on the amount of light returned and hence the legibility of the signs. This confirms the amount of light returned decreases as the distance from the source increases (Figure 3.1).

Drive 2 (street lighting on, sign lighting on) goes against this trend with drivers of large vehicles having a significant advantage over car drivers for all but three of the signs tested.

Of particular interest is the effect on large vehicles of the removal of direct lighting on signs located in position P3 (overhead, Figure 4.1). For car drivers, the reading distance for sign 5 increased by 8 metres between Drive 2 (street lighting on, sign lighting on) and Drive 3 (street lighting on, sign lighting off), equivalent to an increase of 5%. For HGV drivers, the removal of direct sign lighting resulted in an increase of 175 metres or 60%.
For sign 8, the effect is an increase in reading distance of 139 metres and 46 metres for Drive 2 and 3 respectively.

The use of backlit electroluminescent and LED sign lighting requires the use of translucent retroreflective sheeting. Although available from multiple suppliers, it is only manufactured as a premium prismatic material. As a result, it is not possible to make a direct comparison between microprismatic and glass bead materials in this scenario.

8. Additional comments received

8.1 Participants

A number of participants also gave generic comments as to the colour, uniformity and legibility of various signs used in the dynamic trials (Table 8.1).

Again, whilst this information does not form part of the data collected for the purposes of this report, it does offer a view of the general motorist and is therefore included for information purposes.

<table>
<thead>
<tr>
<th>Dynamic Sign</th>
<th>Description</th>
<th>Material</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lane indicator sign</td>
<td>Encapsulated Glass bead</td>
<td>[Sign] was easy to read. Light was bright from other direction. [Light] lit up the road on both sides</td>
</tr>
<tr>
<td>5</td>
<td>Gantry sign</td>
<td>Transilluminated microprismatic (EL)</td>
<td>Sign wasn’t too bright. Had even light and colour</td>
</tr>
<tr>
<td>6</td>
<td>Countdown marker</td>
<td>Entry level microprismatic</td>
<td>Was very bright. [Sign] had stripes</td>
</tr>
<tr>
<td>7</td>
<td>ADS</td>
<td>Encapsulated Glass bead</td>
<td>Not as bright as others. Light not even</td>
</tr>
<tr>
<td>8</td>
<td>Gantry sign</td>
<td>Transilluminated microprismatic (LED)</td>
<td>Colour looked blue until close. Sign was very bright. Sign looked faded</td>
</tr>
<tr>
<td>12</td>
<td>Direction sign</td>
<td>Entry level microprismatic</td>
<td>Could see rainbow pattern on sign. Sign was stripy. Stripes made sign harder to read. Not as easy to read as sign below [sign 13]. [Sign] was looked darker because of the stripes</td>
</tr>
<tr>
<td>15</td>
<td>Direction sign</td>
<td>Premium microprismatic</td>
<td>Could see lights in sign making it harder to read. Lights made a dimpled pattern on sign</td>
</tr>
<tr>
<td>16</td>
<td>Warning sign</td>
<td>Transilluminated microprismatic (LED)</td>
<td>Sign was very bright. Colours looked faded, but could see from far away.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Static Sign</th>
<th>Description</th>
<th>Illumination</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight limit sign</td>
<td>External LED</td>
<td>Solar power good idea but looks too bulky and detracts from the sign</td>
</tr>
<tr>
<td>2</td>
<td>Weight limit sign</td>
<td>EL</td>
<td>Doesn’t seem bright enough but still easy to read</td>
</tr>
<tr>
<td>3</td>
<td>Weight limit sign</td>
<td>EL</td>
<td>Doesn’t seem bright enough but still easy to read</td>
</tr>
<tr>
<td>5</td>
<td>Weight limit sign</td>
<td>Back-lit LED</td>
<td>Works well, but bulky frame doesn’t look as good as others</td>
</tr>
</tbody>
</table>
8.2 Motorcyclists

The last 15 years has seen an increase in the popularity of motorcycling, both as a means of commuting and riding for pleasure with the number of licensed motorcycles increasing from 0.63M in 1994 to 1.291 in 2008. However, this popularity has resulted in an increase in the number of accidents involving powered two wheelers (PTWs).

With 1 in 14 accidents involving PTWs between 2006 and 2008 and with a PTW KSI casualty rate 40 times higher than for cars, six motorcycle riders were invited to experience the trials. Although the trials were not established to consider the causation of a motorcyclist losing control and colliding with roadside objects, Atkins was keen to gain an insight into how motorcyclists would respond to the different lighting conditions and what effect this could have on their riding, together with any additional information they could offer in terms of the performance of the traffic signs.

The information could prove useful in assisting the Agency to reduce the number of accidents involving PTWs, a figure which in 2008 increased by 7 percent from the 1994-1998 average.

Although it was not possible for the motorcyclists to undertake the same test as for the car and HGV drivers, they were given the opportunity to ride the circuit under some of the lighting conditions with a view to providing their own comments to supplement the data collected for the car and HGV drivers.

Due to the complexity of the circuit, a 40mph speed limit was imposed for the entire circuit, rather than just the return run. A number of the comments received relate to the colour and retroreflective properties of the signs (Table 8.2).

<table>
<thead>
<tr>
<th></th>
<th>Weight limit sign</th>
<th>Back-lit LED</th>
<th>Too bright, colours bleached especially red</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Weight limit sign</td>
<td>External LED</td>
<td>Could see each light reflecting in the sign</td>
</tr>
</tbody>
</table>

Table 8.1 – General comments received from participants

1. Strategic Road Network (SRN) Report for Motorcycling, Highways Agency
<table>
<thead>
<tr>
<th>Sign</th>
<th>Daylight</th>
<th>Street lighting on, sign lighting on</th>
<th>Street lighting on, sign lighting off</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No comment received</td>
<td>Extremely clear. Bike coming the other way takes off right hand side (3rd arrow) at certain angle.</td>
<td>Cleat at 1/4 mile sign</td>
</tr>
<tr>
<td>2</td>
<td>No comment received</td>
<td>No comment received</td>
<td>No comment received</td>
</tr>
<tr>
<td>4</td>
<td>Warley A31 1/2 mile didn't shine or stand out.</td>
<td>Bulb reflects. Can't see end of Warley</td>
<td>Ok</td>
</tr>
<tr>
<td>6</td>
<td>Very Reflective. Mirror like - too much. Should be matt finish.</td>
<td>Very good, but 2 &amp; 1 countdown too far from edge</td>
<td>Not so bright Brilliant Very bright.</td>
</tr>
<tr>
<td>7</td>
<td>Did not show very well, not too noticeable though.</td>
<td>No comment received</td>
<td>Too much information on it. Too much white draws attention away from detail on sign. Could be brighter.</td>
</tr>
<tr>
<td>8</td>
<td>Noticed Tattenhoe - not too noticeable though.</td>
<td>Unclear</td>
<td>Distinct white border. No contrast, green looks grey and difficult to read. Ok.</td>
</tr>
<tr>
<td>9</td>
<td>Noticed Tattenhoe - not too noticeable though.</td>
<td>No comment received</td>
<td>Tattenhoe green sign better in dark than when previous sign light on. Ok.</td>
</tr>
<tr>
<td>12</td>
<td>Didn't show</td>
<td>Bright but sequin effect - sparkles when close. Ok to read. Stood out</td>
<td>Not as bright as with lights but adequate.</td>
</tr>
<tr>
<td>13</td>
<td>Didn't show</td>
<td>Stood out</td>
<td>Not as bright as with lights but adequate.</td>
</tr>
<tr>
<td>15</td>
<td>Didn't shine or stand out</td>
<td>No comment received</td>
<td>No comment received</td>
</tr>
<tr>
<td>16</td>
<td>Ok</td>
<td>Ok.</td>
<td>Fine.</td>
</tr>
</tbody>
</table>

General

Nothing too noticeable. New to me and I was looking for them and thinking about them. Only Mira signs different. Signs were clear and could be read. Road numbers and place names perfectly ok. Nothing of note, 'clear'. A couple bright. Yellow backgrounds glare from headlights. More looking where to go. Motorcyclists focus on the road. Signs are peripheral and there are often too many signs. Too many or too high, the roundabout is an example

Generally ok, able to read. Noticed different coatings. Blue signs - would have trouble seeing at 70. Problem with lights coming the other way. Most others ok. Didn't like bollards on opposite side [cones used to mark lanes for trials], too much attention, ok nearby but not good in distance. Bend much better without lights

All Signs very good. Blues better than greens. Motorway Signs Excellent.

Motorcyclists did not ride under the following scenarios: street lighting off, sign lighting on and street lighting off, sign lighting off

Table 8.2– General comments received from motorcyclists
9. Whole life costs

9.1 Initial purchase and installation costs

The initial installation costs of products incorporating new technologies are often considered to outweigh the overall long term benefits. For example, a typical 600mm diameter electroluminescent sign costs in the region of £440. The cost of providing a "Type A" lighting unit fitted with fluorescent tubes is approximately £192.

It is clear to see how some Clients may be reluctant to use such products. However, it is necessary to take into account all costs, including installation costs (measured as a monetary cost and also as delays to road users), energy consumption, maintenance requirements and the potential for warranty issues and failure rates.

When considering the factors listed above, such products may result in reduced whole life costs when compared to traditional technologies which may require trenching, road crossings and increased periodic maintenance requirements.

9.2 Material Costs

The initial cost of a sign assembly is also affected by the materials used for the sign face. Several different materials offer a varying level of performance, although costs can also differ greatly depending on the material used. Table 9.1 compares alternative materials and their costs for a number of typical sign face areas using approximated material costs obtained from a number of sources.

Additional protective coverings such as a dew resistant coating and anti-graffiti sheeting would add to the costs detailed below.

<table>
<thead>
<tr>
<th>Typical Sign</th>
<th>Sign Area (m²)</th>
<th>Encapsulated Glass Bead (£120/m²)</th>
<th>HIP/HIM (£120/m²)</th>
<th>Premium Prismatic (£150/m²)</th>
<th>Enclosed Glass Bead (£80/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600mm high triangular sign</td>
<td>0.21</td>
<td>£25.20</td>
<td>£25.20</td>
<td>£31.50</td>
<td>£16.80</td>
</tr>
<tr>
<td>750mm diameter circular sign</td>
<td>0.44</td>
<td>£52.80</td>
<td>£52.80</td>
<td>£66.00</td>
<td>£35.20</td>
</tr>
<tr>
<td>1200mm diameter circular sign</td>
<td>1.13</td>
<td>£135.60</td>
<td>£135.60</td>
<td>£169.50</td>
<td>£90.40</td>
</tr>
<tr>
<td>1500mm high triangular sign</td>
<td>1.30</td>
<td>£156.00</td>
<td>£156.00</td>
<td>£195.00</td>
<td>£104.00</td>
</tr>
<tr>
<td>Directional sign</td>
<td>2.00</td>
<td>£240.00</td>
<td>£240.00</td>
<td>£300.00</td>
<td>£160.00</td>
</tr>
<tr>
<td>Directional sign</td>
<td>5.00</td>
<td>£600.00</td>
<td>£600.00</td>
<td>£750.00</td>
<td>£400.00</td>
</tr>
<tr>
<td>Gantry Sign</td>
<td>50.00</td>
<td>£6,000.00</td>
<td>£6,000.00</td>
<td>£7,500.00</td>
<td>£4,000.00</td>
</tr>
</tbody>
</table>

Table 9.1 – Sign face costs based on approximated material costs (supply only)
Table 9.1 shows that relatively small price differences can result in large savings if large signs are considered. This saving is also more apparent when considering the replacement or introduction of a large number of signs.

The cost comparison can be made clearer when represented as a percentage, with an Encapsulated Glass Bead (RA2) or HIP material costing 50% more that Enclosed Glass Bead (RA1). Premium Prismatic material costs 87.5% more than Enclosed Glass Bead and 25% more than HIP or Encapsulated Glass Bead.

The figures above show that a large cost saving may be available if Enclosed Glass Bead Material is used, although the performance level of this material may be lower than more expensive alternatives and should be the primary area of consideration.

9.3 Energy consumption & Environmental Issues

One of the main benefits of using new technology is reduced energy consumption. With many Highway Authorities seeking to reduce their costs, utilising products which require less energy to provide the same level of illumination can provide medium to long term benefits.

Environmental costs are also becoming more important as a greater emphasis is placed on reducing emissions and energy consumption.

“Type A” external light units are commonly used to provide direct lighting to 600mm diameter traffic signs. Table 9.2 illustrates the typical consumption and associated energy costs for a number of technologies.

<table>
<thead>
<tr>
<th>Method of direct lighting</th>
<th>Typical Energy consumption</th>
<th>Typical annual cost (based on 0.011p/w/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent external light unit</td>
<td>16 watts</td>
<td>£7.43</td>
</tr>
<tr>
<td>LED external light unit</td>
<td>12 watts</td>
<td>£5.57</td>
</tr>
<tr>
<td>Fluorescent internally lit</td>
<td>24 watts</td>
<td>£11.15</td>
</tr>
<tr>
<td>LED internally lit</td>
<td>24 watts</td>
<td>£11.15</td>
</tr>
<tr>
<td>Electroluminescent</td>
<td>6 watts</td>
<td>£2.78</td>
</tr>
</tbody>
</table>

Table 9.2 – Typical energy consumption and annual costs

Whilst the running costs for individual types of direct lighting are broadly similar, when scaled over a large network of several thousand signs, the cost differentials become more meaningful.

The above values show that a large energy saving could be possible with the use of an Electroluminescent sign face, with the least energy efficient direct lighting methods internal LEDs and internal fluorescent lamps. It should be noted that these energy consumption rates are typical rates and LED signs can operate at lower rate than specified in Table 9.2.

Whilst energy consumption is a key area of consideration when looking at environmental issues, disposal of sign faces and direct lighting equipment is also a concern. Following
the use of sign faces and direct lighting units, disposal is then required, which itself incurs a cost.

LED and Electroluminescent signs can both be disposed of reasonably cheaply and do not require any specific disposal techniques. Safe disposal of fluorescent tubes can be relatively costly due to mercury or sodium content within the bulbs. The frequency of disposal fluorescent tubes require is also greater than both Electroluminescent and LED units.

The greater frequency and cost of disposal associated with fluorescent tubes can have an effect on the whole life cost of a sign assembly, and should be considered when choosing the method of direct lighting.

Considering the environmental and monetary costs relating to the energy consumption and disposal of a sign assembly, the above details suggest that Electroluminescent or LED lit signs may provide savings over the provision of fluorescent tubes.

9.4 Maintenance issues

Many signs on the network are installed in locations which make future access for maintenance more difficult, such as central reserves, traffic islands and gantries. IAN 69/05 Designing for Maintenance requires that consideration be given at the design stage to reducing the risk to operatives undertaking maintenance. Safety can be improved not only by designing safe access to equipment, but by also reducing the routine maintenance requirements.

The maintenance of lit traffic signs results in additional costs to the Highway Authority. Maintenance could be required due to a defective unit, or as part of routine inspections and bulk lamp changes.

Signs and light units may require unplanned maintenance due to premature failure of the lantern or vandalism. Directly lit signs require detailed inspections every 12 months and bulk lamp changes every two years (or 8000 burning hours) in accordance with TD 25/01 – Inspection and Maintenance of Traffic Signs on Motorway and all-purpose Trunk Roads. Bulk lamp changes are required for fluorescent, pressed glass, high pressure mercury and tungsten filament lamps.

A Transport for London (TfL) report (Illumination of Traffic Signs 2007) identified typical costs for carrying out inspections and bulk lamp changes, including typical traffic management costs, for signs directly lit by a number of different technologies over a ten year period (Table 9.3 and 9.4).
### Task 1: Bulk clean @ £17.50 (annually)
- Cost: £175.00

### Task 2: Lamp change @ £68.50 (every 2 years)
- Cost: £342.50

### Task 3: Internal wiring test @ £22.00 (every 6 years)
- Cost: £36.66

### Task 4: Fault repair @ £115.00 (every 3 years)
- Cost: £383.33

### Task 5: “Category 3” repair @ £30.00 (every 3.3 years)
- Cost: £90.90

**Total Cost:** £1,028.39

---

### Task 1: Bulk clean @ £10.37 (annually)
- Cost: £103.70

### Task 2: Internal wiring test @ £22.00 (every 6 years)
- Cost: £36.66

### Task 3: Fault attendance @ £72.50 (every 3 years)
- Cost: £217.50

### Task 4: “Category 3” repair @ £30.00 (every 3.3 years)
- Cost: £90.90

**Total Cost:** £448.76

---

The information indicates that there is a potential saving of approximately £500 over a ten year period based on maintenance and inspections alone. However, owing to the comparatively new technologies used in LED and electroluminescent lighting, information on the reliability is limited. The costs are therefore based on the assumption that the LED/electroluminescent signs require repairs at similar frequencies to traditional technologies, but do not require the entire sign unit to be replaced.

### 9.5 Long term savings

Whilst it is evident that the costs for products incorporating new technologies will result in a higher initial outlay, overall savings can be realised over a period of time. The following illustrates the annual costs and savings of an LED and electroluminescent illumination technologies when compared to the cost of a directly lit sign by means of a “Type A” lighting unit (Table 9.5 and 9.6). Costs stated in this section are based upon a 600mm circular regulatory sign.
When considering the typical energy costs, it is possible to achieve savings in a shorter period when using internal LED or electroluminescent technologies.

Table 9.5 – Typical costs (excluding energy and failure costs)

<table>
<thead>
<tr>
<th></th>
<th>“Type A” light unit</th>
<th>Electro-luminescent</th>
<th>LED externally lit</th>
<th>Fluorescent internally lit</th>
<th>LED internally lit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product cost</td>
<td>£192.00</td>
<td>£440.00</td>
<td>£246.53</td>
<td>£161.33</td>
<td>£330.00</td>
</tr>
<tr>
<td>Maintenance per year</td>
<td>£102.84</td>
<td>£44.88</td>
<td>£44.88</td>
<td>£102.84</td>
<td>£44.88</td>
</tr>
<tr>
<td>Cost after 12 months</td>
<td>£294.84</td>
<td>£484.88</td>
<td>£291.41</td>
<td>£264.17</td>
<td>£374.88</td>
</tr>
<tr>
<td>Cost after 24 months</td>
<td>£397.68</td>
<td>£529.76</td>
<td>£336.29</td>
<td>£367.01</td>
<td>£419.76</td>
</tr>
<tr>
<td>Cost after 36 months</td>
<td>£500.52</td>
<td>£574.64</td>
<td>£381.17</td>
<td>£469.85</td>
<td>£464.64</td>
</tr>
</tbody>
</table>

The long term benefits of new technologies, such as the use of internal LED or electroluminescent light units can be realised within as little as two years when compared to a traditional external fluorescent light unit, although this will largely depend on the failure rate and durability of the products.

Table 9.6 – Typical costs (excluding failure costs)

<table>
<thead>
<tr>
<th></th>
<th>“Type A” light unit</th>
<th>Electro-luminescent</th>
<th>LED externally lit</th>
<th>Fluorescent internally lit</th>
<th>LED internally lit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product cost</td>
<td>£192.00</td>
<td>£440.00</td>
<td>£246.53</td>
<td>£161.33</td>
<td>£330.00</td>
</tr>
<tr>
<td>Maintenance per year</td>
<td>£102.84</td>
<td>£44.88</td>
<td>£44.88</td>
<td>£102.84</td>
<td>£44.88</td>
</tr>
<tr>
<td>Energy costs per year</td>
<td>£7.43</td>
<td>£2.78</td>
<td>£5.57</td>
<td>£11.15</td>
<td>£11.15</td>
</tr>
<tr>
<td>Cost after 12 months</td>
<td>£302.27</td>
<td>£487.66</td>
<td>£296.98</td>
<td>£275.32</td>
<td>£386.03</td>
</tr>
<tr>
<td>Cost after 24 months</td>
<td>£412.54</td>
<td>£535.32</td>
<td>£347.43</td>
<td>£389.31</td>
<td>£442.06</td>
</tr>
<tr>
<td>Cost after 36 months</td>
<td>£522.81</td>
<td>£582.98</td>
<td>£397.88</td>
<td>£503.30</td>
<td>£498.09</td>
</tr>
</tbody>
</table>

The long term benefits of new technologies, such as the use of internal LED or electroluminescent light units can be realised within as little as two years when compared to a traditional external fluorescent light unit, although this will largely depend on the failure rate and durability of the products.

9.6 Break Even Periods

Although it is apparent that long term benefits can be achieved with the use of new technologies (see Tables 9.5 and 9.6), it is important to consider the length of time required for these benefits to be achieved.

Consideration of the break even period of new technologies and the potential savings after this period can help make an informed decision on which offers the best value for money.
The initial costs associated with both Electroluminescent and LED technologies far exceed those which are incurred with a standard “Type A” lighting unit and an sign internally lit with fluorescent tubes, with an electroluminescent sign initially costing up to £279 more. Despite the high initial costs, lower annual maintenance and energy costs enable an annual saving to be made. This saving can be seen in Table 9.7.

Directly comparing the initial and annual costs of a “Type A” installation with the other direct lighting technologies gives a clear indication of how long it would take for a saving to be made and which technology and direct lighting method would be most beneficial.

<table>
<thead>
<tr>
<th></th>
<th>“Type A” light unit</th>
<th>Electro-luminescent</th>
<th>LED externally lit</th>
<th>Fluorescent internally lit</th>
<th>LED internally lit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product cost</strong></td>
<td>£192.00</td>
<td>£440.00</td>
<td>£246.53</td>
<td>£161.33</td>
<td>£330.00</td>
</tr>
<tr>
<td><strong>Annual Maintenance and Energy costs</strong></td>
<td>£110.27</td>
<td>£46.66</td>
<td>£50.45</td>
<td>£113.99</td>
<td>£56.03</td>
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<tr>
<td><strong>12 month saving</strong></td>
<td>N/A</td>
<td>-£184.39</td>
<td>£5.29</td>
<td>£26.95</td>
<td>-£83.76</td>
</tr>
<tr>
<td><strong>24 month saving</strong></td>
<td>N/A</td>
<td>-£120.78</td>
<td>£65.11</td>
<td>£23.23</td>
<td>-£29.52</td>
</tr>
<tr>
<td><strong>36 month saving</strong></td>
<td>N/A</td>
<td>-£57.17</td>
<td>£124.93</td>
<td>£19.51</td>
<td>£24.72</td>
</tr>
<tr>
<td><strong>48 month saving</strong></td>
<td>N/A</td>
<td>£6.44</td>
<td>£184.75</td>
<td>£15.79</td>
<td>£78.96</td>
</tr>
</tbody>
</table>

Table 9.7 shows that despite the low initial cost of a “Type A” unit, other illumination methods provide a saving after a short period of time due to energy and maintenance savings and all other methods considered provided better value for money over a 48 month period.

The comparison in Table 9.6 compares the costs of direct lighting methods for a new installation, without any removal costs included. Therefore the figures in Table 9.7 only represent the costs associated with the replacement of an old sign in need of replacement. In some cases in which a number of signs are being replaced, the replacement of sign faces and lighting units which are working well could also occur. This would result in a longer break even period and lower savings due to the replacement costs and full initial cost of the new sign would be taken into account.

9.7 Warranty issues and failure rates

All of the major UK suppliers of traffic sign sheeting offer 12 month warranties on new products. However, although retroreflective sheeting carries a 12 year warranty, many signs remain in situ for considerably longer periods with light units being maintained as required.
The main disadvantage with new technologies, such as certain internally lit LED and electroluminescent signs, is the potential need to replace the entire sign unit should a fault develop with internal “non-serviceable” components.

The result of such a failure would see any savings minimised, or potentially leave the Highway Authority with a budget shortfall which could result in signs not being replaced. This could in render the sign unlawful (if required to be illuminated under Schedule 17 Item 1 of the TSRGD, for example). Signs with failed direct lighting could also pose a safety risk to road users. A number of LED internally lit sign units are available with serviceable components which may offer a more cost effective solution.

Another benefit with using LED lit signs is the durability of the LEDs. Most manufacturers claim that their LEDs have a lifespan of 50,000 hours use, and some claim their products have been positively tested after having over 150,000 hours use.
10. Additional Points

10.1 The performance of signs on the offside from a HGV drivers perspective

Only one sign (sign 1) was positioned in the offside position during the trials. This limited amount of data would not allow a definitive conclusion or recommendation relating to performance to be made.

The data collected indicates that car drivers were able to read sign 1 at greater a greater distance than HGV drivers in all 3 of the lighting scenarios for which this sign was tested (Drives 1, 3 and 5) and can be seen in Table 7.9. However, this extra reading time required by HGV drivers for sign 1 was also required for signs mounted on gantries and the nearside in many instances, therefore the data collected indicates that positioning signs on the offside gives no greater hindrance to the visibility or legibility of the sign for HGV drivers than in positions such as on the nearside.

10.2 The performance of signs from narrow angles

In the dynamic trials signs 12 and 13 were positioned on the exit from a mini roundabout and were intended to test the performance of signs when the driver was viewing the signs from an acute angle. However, although data was collected relating to each of these signs, the angle at which signs became visible was not recorded as only the visibility and legibility distances were recorded together with the corresponding reading times.

The static trials did give an indication of performance at different entrance angles with signs tested at 5° and 40°. The results from these tests indicated that signs generally performed better at a 5° angle than at 40° as would be expected. In order to investigate signs at very narrow angles and sign wash out (which can occur when viewing signs from narrow angles), further testing would be required.

10.3 Specular Reflection

In some circumstances in which light is reflected off a sign face, the light can be split into a number of colours in the direction of the observer. This can have a detrimental effect on the visibility and legibility of the sign, as symbols and text can appear blurred as the contrast between colours is affected. This is often experienced when light from the sun reflects off the sign face into the line of sight of a driver. As the position of the sun constantly varies this issue can be difficult to predict and mitigate, although the use of materials such as Glass Bead sheeting for a sign face is known to reduce this effect.

10.4 Motorcyclists

Although motorcyclists did not undertake the same test as car and HGV drivers, comments were still recorded from those using motorcycles (see Table 8.2). In all scenarios, the general feedback from motorcyclists was positive, with all signs appearing to perform as the car and HGV data suggests. However, in some cases (such as sign 4), the reflected light was too prominent and caused glare whilst the colours also appeared to affect the legibility. Such comments indicate that colour and glare should be considered as part of the design process, although not enough data was collected during the trials to produce a definitive conclusion or recommendation.
10.5 Effect of using LEDs without diffuser

Diffusers are used with LED technology in order to spread the light evenly across the sign face. Although not tested as part of the trials, an example of uneven distribution of light due to a lack of diffusers can be seen in the photograph of sign 15 in Appendix I of this report. Such uneven light distribution may affect both visibility and legibility of a sign. Because of this, diffusers should be used where with LEDs wherever possible to spread light uniformly over the sign face.

The reflection of light back to the source producing glare was also noticed during the trials and can be seen in Figure 3.2. In this case the light from external units was reflected directly into the driver’s line of sight by the Glass Bead material used on the sign face. This type of glare can generally be avoided if the position and type of the light source (such as whether a diffuser is being used) as well as the location of vehicles is considered. This further highlights the reason for considering glare as part of the design process and consideration should be given to the angle of sign face, type of light source and sign face material as all are factors in the reflection of light to the driver.

10.6 Microprismatic Performance

During the trials, horizontal lines were noticed on one of the sign faces using microprismatic material and can be seen in the photograph of sign 12 in Appendix I of this report. These lines were visible from different angles and in different lighting conditions. However, it was not clear whether this effect hindered the performance of the sign face in any way, although such a pattern may be a cause for distraction in some cases. Designers should be aware of this effect although it should also be noted that no data was recorded during the trials indicating that this had a negative effect on the performance of the sign face.
11. Conclusions

The following is based upon information obtained from the various publications contained within the Literature Review, the outcome of the off-road trials and information and observations of the Atkins’ traffic sign specialists.

11.1 Design

11.1.1 Effective signing needs only initial cursory glances to enable the road user to see, read, understand and react to the message that the sign is giving.

11.2 Retroreflective sheeting

11.2.1 Whilst the current British Standards contain the performance requirements of each grade of material, Atkins is aware of numerous cases where the designer is not aware of recent changes in the terminology for grades of material, or the current Standards relating to them. It is still common practice for designers to specify reflective sheeting to Class Ref 2 to BS EN 12899-1:2001, a standard that was superseded by Class RA 2 to BS EN 12899-1:2007 or relevant ETA.

11.2.2 The UK benefits from a wide range of quality retroreflective sheeting from a number of well known suppliers. As good as these materials are, it is clear that each has advantages and disadvantages and designers need to be aware of these in order to specify the appropriate material for a particular situation taking performance and whole life cost into account.

BS 8408:2005 goes some way to negate these issues by considering the requirements of the driver. The Performance Index affords designers the opportunity to specify a material which performs to the standard for the given road, sign, location and user.

11.2.3 The required reading time for each sign used in the dynamic trials was compared to the average recorded reading times (Table 7.7). This shows that for the scenarios of street lights off signs lights on (shortest reading time) and daylight (second shortest reading time) the observed average reading time (averaged over all participants) was comparable to that calculated using the “Determination of x-height” formula. This is illustrated in Figure 7.2.

Table 7.9 illustrates that drivers of cars in the trial were generally able to read information on signs at a greater distance than drivers of large vehicles. Of particular interest is the effect on large vehicles of the removal of direct lighting on signs located in position P3 (overhead, see Figure 4.1). This confirms that an increase in the vertical distance between the driver and the vehicle headlights has a negative effect on the amount of light returned and hence the legibility of the signs.

11.2.4 Specifying either an encapsulated glass bead (RA2) or any microprismatic grade of retroreflective material which performs from both the minimum visibility distance for the approach speed to a point at the cut-off distance would provide adequate performance, for traffic signs set at an angle positioned 95° away from the general alignment of the left side edge of the carriageway in the locations P1, P2 and P4 shown in Figure 4.1. The brief did not include materials to Class RA1 whilst EGP was launched in the UK after this project began and therefore neither were included within the scope.
11.2.5 Consideration should be given to using internally lit products to reduce light spill and provide a more even distribution of light across the sign face. This was evident during the trials especially with Sign 1 (see Figure 3.2) and could improve the surrounding environment of a sign face.

11.2.6 Fluorescent tubes can be of particular concern when considering the environmental and monetary costs associated with the safe method of disposal required due to the possible presence of mercury or sodium. These additional costs can increase both the whole life cost and the time required to break even for a sign assembly. Those considering the use of LED technology should pay particular attention to the uniformity of illumination across the sign face.

11.2.7 The manufacturers of Microprismatic reflective sign sheeting, state that when used under certain circumstances, the material can provide a higher level of retroreflection when compared to traditional glass bead technology where entrance angles are not particularly large. Designers should ensure when specifying grades of material that this improved performance is not affected by colour and circumstance. This increase may also result in a sign being legible from a greater distance, allowing drivers additional time to read and react to the information as necessary. However, it can also have the effect of the sign being too bright, affecting legibility in certain situations. The results at the trials give an indication as to the performance levels of the retroreflective sheeting used. The comparatively flat line for the “street lighting on, sign lighting off” scenario suggests that the sheeting made little difference to the time spent reading the signs regardless of whether encapsulated glass bead, entry level or premium microprismatic products were used.

The above finding could therefore lead onto cost savings if an Encapsulated Glass Bead, Enclosed Glass Bead, or HIP/HIM sheeting was to be used instead of premium grade microprismatic sheeting. However, consideration should be given to the location and road user. Table 9.1 demonstrates the difference in costs based upon an approximated material cost. For example, the difference in saving for a 50m² gantry sign using Encapsulated Glass Bead rather than Premium Prismatic material would be £1500.00.

11.2.8 Two of the main contributory factors in the overall cost of a sign assembly are energy consumption and maintenance requirements. The energy consumption rates detailed in Table 9.2 show an Electroluminescent sign face to use the least amount of energy and therefore cost the least amount of money to run. Considering maintenance together with energy consumption as detailed in Table 9.6 highlights the high maintenance costs associated with using Fluorescent tubes or a “Type A” unit, whilst both LED and Electroluminescent technologies are shown to incur the lowest running costs.

11.2.9 Another finding established from the whole life costs exercise relates to the break even points. Although the initial costs associated with both Electroluminescent and LED technologies far exceed those which are incurred with a standard “Type A” lighting unit and a sign internally lit with fluorescent tubes, the high initial costs, lower annual maintenance and energy costs enable an annual saving to be made.

11.2.10 The whole life cost analysis also produced the different lengths of time required for each technology to break even following the installation of a new assembly, and compared them to a standard “Type A” installation. This analysis (shown in Table 9.7) highlighted LED externally illuminated signs to offer the best value over long return
periods, whilst all other technologies broke even in comparison to new “Type A” installations after 3 years.

11.2.11 The break even periods in Table 9.7 indicate that savings could be achieved at new installations with the use of technologies such as Electroluminescent or LED (both internal and external) illumination. However, replacements of existing assemblies may incur additional costs depending on the condition of each assembly in question.

11.2.12 Highway authorities who plan to implement projects to switch off street lighting in periods of low traffic flow should note the benefit shown with the use of sign lighting when street lighting is not provided. This can be seen to affect all vehicles in Figure 7.2 and Table 7.8. The removal of sign lighting can also be seen to adversely affect HGV drivers, with a 60% increase in reading time seen in one case.

12. Recommendations

This section draws on the above conclusions and details a number of recommendations relating to the direct lighting of traffic signs. Evidence and issues relating to each recommendation is also included.

12.1 Recommendation

From the evidence obtained within the trials, it can be recommended that all overhead mounted signs should be illuminated in accordance with Schedule 17 Item 1 and not 4 of the TSRGD 2002 due to the retroreflective sheeting’s observation angle relating to vehicles in the V2 category, as drivers of large vehicles receive less retroreflected light than car drivers.

Evidence

Table 7.9 shows that in all but Drive 2, the HGV was closer to the sign than the car when the answer was given for Signs 5 and 8 (gantry signs). The current Regulations require gantry signs located on the Motorway network where the sign is erected on a road within 50 metres of any lamp lit by electricity which forms part of a system of street lighting for that road furnished by means of at least three such lamps placed not more than 183 metres apart, it shall be directly illuminated by a means of internal or external lighting either for so long as that system is illuminated, or throughout the hours of darkness and may also be reflectorised. The trials did not provide evidence to suggest that a change to the Regulations is required.

The effect on vehicles with and without direct lighting on signs located in position P3 (overhead) is: For car drivers, the reading distance for sign 5 increased by 8 metres between Drive 2 (street lighting on, sign lighting on) and Drive 3 (street lighting on, sign lighting off), equivalent to an increase of 5%. For HGV drivers, the removal of direct sign lighting resulted in an increase of 175 metres or 60%. For sign 8, the effect is an increase in reading distance of 139 metres and 46 metres for Drive 2 and 3 respectively.

12.2 Recommendation

Where traditional fluorescent tubes currently exist on the Network, low energy technology such as LED or EL should be considered, to reduce energy consumption. This can be achieved using direct replacement gear trays, or replacement products. This should be subject to performance, WLC and environmental costs.
Evidence
Tables 9.2, 9.3, 9.4 and 9.5 shows that a reduction in energy costs can be realised with the use of low energy technology.

12.3 Recommendation
If the street lighting in an area is under consideration for being turned off during periods of low traffic flow, the evidence obtained from the trials indicate that retaining sign lighting should be considered as an improvement in legibility could be achieved.

12.4 Issues
No sign performed poorly during the trials, the recommendation is therefore based upon whole life costs/Authorities preference.
13. Acknowledgements

In undertaking the off-road trials, Atkins was able to benefit from extensive working relationships with a number of suppliers who kindly provided numerous products for testing and materials for setting up the trials.

Atkins is grateful for the support and assistance from the following suppliers, manufacturers and industry specialists:

- 3M UK Plc
- Avery Dennison/Lakeside Films
- Association for Road Traffic Safety and Management
- BAM Nuttall Signs
- Chromatica Limited
- Leeds University
- Local Authority Sign Manufacturers Association
- MIRA
- Mobile Traffic Solutions Limited
- Nuneaton Signs Limited
- One2seeSigns
- Pama Sign Services Limited
- Rennicks (UK) Limited
- Ringway Signs
- Route Signs Limited
- Signpost Solutions
- Simmonsigns Limited
- Transport for London
- TWM Traffic Control Systems Limited
- Walker Sign and Street Furniture Erectors Limited
- Zeta Signs
To be positioned in lane 2.
Actual method of mounting to be proposed by Contractor.
## Sign Reference 3a

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<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Height</td>
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<tr>
<td>Width</td>
<td>1360mm</td>
</tr>
<tr>
<td>Area</td>
<td>0.80sq.m</td>
</tr>
<tr>
<td>Material</td>
<td>Encapsulated glass bead</td>
</tr>
<tr>
<td>Mount Height</td>
<td>—</td>
</tr>
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* Area reduced for rounded corners.

## Scheme Ref.

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<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Letter colour</td>
<td>BLACK</td>
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<td>Background</td>
<td>WHITE</td>
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<tr>
<td>Border</td>
<td>BLACK</td>
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<tr>
<td>Material</td>
<td>Encapsulated glass bead</td>
</tr>
<tr>
<td>Area</td>
<td>0.82sq.m</td>
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## Scheme Ref.

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<tr>
<td>Material</td>
<td>Encapsulated glass bead</td>
</tr>
<tr>
<td>Area</td>
<td>3.24sq.m</td>
</tr>
</tbody>
</table>

To be erected using proprietary screw or plug type foundation.
Warley
A 31
18
1/2m

Scheme Ref.
Sign Ref.  4  x-height  225.0
Letter colour WHITE  SIGN FACE
Background BLUE  Width  3160mm
Border WHITE  Height  2756mm
Material Premium microprismatic  Area  8.71sq.m

To be erected using proprietary screw or plug type foundation
Scheme Ref.
Sign Ref. 5 x-height 225.0
Letter colour WHITE SIGN FACE
Background BLUE Width 4000mm
Border WHITE Height 1500mm
Material Transilluminated microprismatic (EL) Area 6.00sq.m

To be gantry mounted
To be positioned in lane 1.
Actual method of mounting to be proposed by Contractor.
Scheme Ref.

Sign Ref. B  x-height 170.0
Letter colour WHITE  SIGN FACE
Background GREEN  Width 3093mm
Border WHITE  Height 1211mm
Material Transilluminated microprismatic (LED) Area 3.75sq.m
Scheme Ref.
Sign Ref.  Sign 9 
Letter colour  WHITE 
Background  GREEN 
Border  WHITE 
Material  Premium microprismatic

To be erected using proprietary screw or plug type foundation

Safeguards: Health and Environmental Information

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

IN ADDITION TO THE HAZARDS/ROADS NORMALLY ASSOCIATED WITH THE TYPES OF WORK DETAILED ON THIS DRAWING, NOTE THE FOLLOWING SIGNIFICANT RISK FACTORS.

CONSTRUCTION

M AINTENANCE/CLEANING

U SE

D ECOMMISSIONING/DEMOLITION

Ref. Number: 5079603_108
Date: May 05, 2010 - 11:44am

Atkins Limited
Consulting Engineers
Bank Chambers
Renshaw Street
Liverpool, England.

A4
HIGHWAYS AGENCY

USE OF MATERIALS
TO REDUCE SIGN LIGHTING
632(387) ATK

OFF-ROAD TRIALS
TRAFFIC SIGN REF 9

Project
Client

©

Off-Road Trials

Title

Sheet Size

Drawing Number

Original

Date

Design/Drawn

Date

Checked

Date

Approved

Date

A4
NTS

632(387) ATK

5079603_109

1
Scheme Ref.
Sign Ref. 12  x-height 75.0
Letter colour BLACK  SIGN FACE
Background WHITE  Width 1410mm
Border BLACK  Height 487mm
Material Entry level microprismatic  Area 0.69sq.m

To be erected in a temporary barrel foundation
St Marks Church 2

Scheme Ref. 13
Letter colour BLACK
Background WHITE
Border BLACK
Material Encapsulated glass bead

x-height 75.0
SIGN FACE
Width 1370mm
Height 430mm
Area 0.59 sq.m

To be mounted 50mm below sign 12
To be erected in a temporary barrel foundation
### Sign Reference 16a
- **Height**: 900mm
- **Width**: 1020mm
- **Area**: 0.45sq.m
- **Material**: Transilluminated microprismatic (LED)
- **Mount Height**: —
  * Area reduced for rounded corners.

### For 2½ miles

### Scheme Ref.

<table>
<thead>
<tr>
<th>Sign Ref.</th>
<th>x-height</th>
<th>100.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>16b</td>
<td>1024mm</td>
<td>625mm</td>
</tr>
</tbody>
</table>

**Letter colour**: BLACK
**Background**: WHITE
**Border**: BLACK
**Material**: Transilluminated microprismatic (LED)
**Area**: 0.64sq.m

To be erected using proprietary screw or plug type foundation.
Appendix B
Appendix C
Appendix D
D.1 Lighting Levels

In accordance with BS 5489-1:2003 table B.2 the section of track replicating a typical highway trunk road will be lit to lighting class ME3a.

The calculations produced are for a dual carriageway section throughout due to the layout of the track it is not possible to light the single carriageway section separately.

The track has been classed as follows;

- Strategic Route
- Single Carriageway/Dual Carriageway
- <15,000 ADT

The mini roundabout has been classed in accordance with BS 5489-1:2003 table B.3 and will be lit to lighting class CE2 the conflict area lighting class for an ME3 traffic route.

The levels required are as shown the tables below;

**Table 1 – ME3a Lighting Levels**

<table>
<thead>
<tr>
<th>Class</th>
<th>Luminance of the road surface of the carriageway for the dry road surface condition</th>
<th>Disability glare</th>
<th>Lighting of surrounding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L in cd/m² (minimum)</td>
<td>U₀ (minimum)</td>
<td>U₁ (minimum)</td>
</tr>
<tr>
<td>ME3a</td>
<td>1.0</td>
<td>0.4</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Table 2 – CE2 Lighting Levels**

<table>
<thead>
<tr>
<th>Class</th>
<th>Horizontal illuminance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E in lux (minimum maintained)</td>
</tr>
<tr>
<td>CE2</td>
<td>20</td>
</tr>
</tbody>
</table>

The following assumptions have been made;

- C2 typical British road surface co-efficient
- No maintenance factor applied
### D.2 Lighting Equipment Specification

Table 3 below states the luminaire and columns used to comply with the levels detailed in section 1.

#### Table 3 – Equipment Specification

<table>
<thead>
<tr>
<th>Luminaire/Lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
</tr>
<tr>
<td>Urbis</td>
</tr>
<tr>
<td><strong>Model</strong></td>
</tr>
<tr>
<td>Sapphire 2</td>
</tr>
<tr>
<td><strong>Protector</strong></td>
</tr>
<tr>
<td>Flat Glass</td>
</tr>
<tr>
<td><strong>Lamp Type</strong></td>
</tr>
<tr>
<td>High Pressure Sodium SON-T+</td>
</tr>
<tr>
<td><strong>Lamp Wattage</strong></td>
</tr>
<tr>
<td>150W</td>
</tr>
<tr>
<td><strong>Optic Setting</strong></td>
</tr>
<tr>
<td>SPH2/FG/1963/115/-35/270105</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
</tr>
<tr>
<td>11.2kg</td>
</tr>
<tr>
<td><strong>Windage Area</strong></td>
</tr>
<tr>
<td>0.116m²</td>
</tr>
<tr>
<td><strong>Luminous Intensity Class</strong></td>
</tr>
<tr>
<td>G6</td>
</tr>
<tr>
<td><strong>Inclination</strong></td>
</tr>
<tr>
<td>Post-top mounted</td>
</tr>
<tr>
<td><strong>Control Gear Type</strong></td>
</tr>
<tr>
<td>Magnetic/Electronic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Column Type 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mounting Height</strong></td>
</tr>
<tr>
<td>10 metres</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Column Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mounting Height</strong></td>
</tr>
<tr>
<td>12 metres</td>
</tr>
</tbody>
</table>

1. All lighting equipment to be installed as per manufacturer’s instructions.

2. The contractor may propose alternative equipment; in this case the above details will be required to confirm achievable lighting levels.
Appendix E
E.1 Folder A (Car and HGV)
DRIVE 1

Street lighting OFF
Sign Lighting OFF

Task: Say NOW when the sign is legible

Press when they say NOW
Press when they say NOW

Press when they say NOW
DRIVE 2

Street lighting ON
Sign Lighting ON

Task: Read out some information on the sign

“What’s the first letter”
Press when they say Y
“What’s the first number”  
Press when they say 3

“When are the lines distinct”  
Press when they say Now
“What’s the motorway number”
Press when they say M68

“What’s the first letter of the destination”
Press when they say T
“What’s the first letter of the destination”
Press when they say **O**

“What’s the first letter of the destination”
Press when they say **D**
“What’s the hazard”
Press when they say **Deer ahead**
DRIVE 3
Street lighting ON
Sign Lighting OFF

Task: Read out some information on the sign

“What’s the first number”
Press when they say 2
“Identify the hazard”
Press when they say roundabout

“What’s the last letter of the destination”
Press when they say Y
“What’s the Hartleby road number”
Press when they say A666

“What’s the first destination”
Press when they say Tattenhoe
“What’s the B road number”
Press when they say B702

“What’s the last number”
Press when they say 6
“What’s the first word”
Press when they say For
DRIVE 4

Street lighting Off
Sign Lighting Off

Task: Read out some information on the sign

“What’s the middle number”
Press when they say 5
“What’s the destination”
Press when they say Warley

“What’s the road number”
Press when they say A31
“What’s the B road number”
Press when they say B3

“What’s the last letter of the destination”
Press when they say H
“What’s the last word”
Press when they say **Miles**
DRIVE 5

Street lighting OFF
Sign Lighting ON

Task: Read out some information on the sign

“How many yards”
Press when they say 200
“What’s the destination”
Press when they say Warley
“What’s the road number”
Press when they say A318

“What’s the destination”
Press when they say St Marks Church
“What’s the destination”  
Press when they say **Danbury**

“What’s the distance”  
Press when they say **2½**
E.2  Folder B (car only)
DRIVE 1

Street lighting OFF
Sign Lighting OFF OFF

Task: Say NOW when the sign is legible

Press when they say NOW

350 yds
Press when they say NOW

Port Lever Hartleby A666

Ring road

Maverton A6604

Doncastle A6604

Press when they say NOW
Press when they say NOW

- Tattenhoe A318

Press when they say NOW

- St Marks Church 2½
Press when they say NOW
DRIVE 2

Street lighting ON
Sign Lighting ON

Task: Read out some information on the sign

“How many arrows in total”
Press when they say 3
“What’s the junction no.”
Press when they say 18

“When are the lines distinct”
Press when they say Now
“What’s the Doncastle road number”
Press when they say A6604

“What’s the motorway number”
Press when they say M68
“What’s the distance” Press when they say \(2\frac{1}{4}\)

“What’s the first letter of the destination” Press when they say D
“What’s the hazard”
Press when they say Deer ahead
DRIVE 3

Street lighting ON
Sign Lighting OFF

Task: Read out some information on the sign

“Identify the hazard”
Press when they say roundabout
“What’s the last letter of the destination”
Press when they say Y

“What’s the Hartleby road number”
Press when they say A666
“What’s the last number”  
Press when they say 8

“What’s the first letter of the destination”  
Press when they say S
“What’s the last number”
Press when they say 6

“For 2½ miles”

“What’s the first word”
Press when they say For
DRIVE 4
Street lighting OFF
Sign Lighting OFF

Task: Read out some information on the sign

“What’s the middle letter”
Press when they say D
“What’s the road number”
Press when they say A31
“When are the lines distinct”
Press when they say Now

“What’s the Maverton road number”
Press when they say A6604
“What’s the destination”
Press when they say Tattenhoe
“What’s the destination”
Press when they say Orford

“What’s the road number”
Press when they say A606
“What’s the last word”
Press when they say Miles
DRIVE 5

Street lighting OFF
Sign Lighting ON

Task: Read out some information on the sign

“How many yards”
Press when they say 200
“What’s the road number”
Press when they say A31

“When are the lines distinct”
Press when they say Now
“What’s the Port Lever road number”
Press when they say A666

“What’s the road number”
Press when they say A318
“What’s the A road number”
Press when they say A421

“For 2½ miles”

“What’s the distance”
Press when they say 2½
Appendix G
G.1 Weather conditions

G.1.1 Monday 23 November 2009.
Light rain during initial setup. Circuit became dry throughout the evening.
Light wind.
Average temperature: 7ºC.

G.1.2 Tuesday 24 November 2009.
No rain prior to or during the trials.
Gusts of wind throughout the evening.
Average temperature: 5ºC.

G.1.3 Wednesday 25 November 2009.
No rain prior to or during the trials.
Light gusts of wind settling throughout the evening.
Average temperature: 6ºC.

G.1.4 Thursday 26 November 2009.
No rain prior to or during trials.
Light winds throughout evening.
Average temperature: 5ºC.
Appendix H
<table>
<thead>
<tr>
<th>Sign Reference</th>
<th>Sign Layout</th>
<th>Meter Reading</th>
<th>Date</th>
<th>Air temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.39 (White)</td>
<td>0.424 (Blue)</td>
<td>10.73 (White)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>91.35 (White)</td>
<td>63.98 (White)</td>
<td>26.48 (White)</td>
</tr>
<tr>
<td>3</td>
<td>Sign not used</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>74.46 (White)</td>
<td>1.88 (Blue)</td>
<td>12.01 (Yellow)</td>
</tr>
<tr>
<td>Sign Reference</td>
<td>Sign Layout</td>
<td>Meter Reading</td>
<td>Date</td>
<td>Air temp</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>---------------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>10.77</td>
<td>12.86</td>
<td>9.30</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>5.74</td>
<td>2.11</td>
<td>0.08</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>12.60</td>
<td>69.73</td>
<td>15.28</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>143.40</td>
<td>83.71</td>
<td>65.28</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>32.41</td>
<td>144.40</td>
<td>68.11</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>3.736</td>
<td>38.59</td>
<td>16.72</td>
</tr>
</tbody>
</table>
### Sign Layout and Meter Reading

<table>
<thead>
<tr>
<th>Sign Reference</th>
<th>Sign Layout</th>
<th>Date</th>
<th>Air temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td><img src="image" alt="St Marks Church Sign" /></td>
<td>25/11/2009</td>
<td>6ºC</td>
</tr>
<tr>
<td>15</td>
<td><img src="image" alt="Danbury A 606 Sign" /></td>
<td>25/11/2009</td>
<td>6ºC</td>
</tr>
<tr>
<td>16</td>
<td><img src="image" alt="For 2½ miles Sign" /></td>
<td>25/11/2009</td>
<td>6ºC</td>
</tr>
</tbody>
</table>

### Gallery Sign Reference

<table>
<thead>
<tr>
<th>Reading Position</th>
<th>Sign Layout</th>
<th>Date</th>
<th>Air temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><img src="image" alt="7.5 T Sign" /></td>
<td>27/11/2009</td>
<td>6ºC</td>
</tr>
<tr>
<td>B</td>
<td><img src="image" alt="7.5 T Sign" /></td>
<td>27/11/2009</td>
<td>6ºC</td>
</tr>
</tbody>
</table>

### Additional information

- Additional readings were taken from sign 8, although not reported, these were as follows:
  - Between lorry symbol and point B (white): 75.27
  - Reading at point B (from table above): 120.50
  - Between point B and inner border (white): 182.60

---

*Note: Images and tables are placeholders and should be replaced with actual visual content.*
Appendix I
I.1 Static Trials
I.2 Dynamic Trials – Daylight

Sign 1

Sign 3
1.3 Dynamic trials – Darkness

Sign 1

Sign 3
Sign 16
Peter Whitfield

Atkins Ltd
Bank Chambers
Faulkner Street
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M1 4EH

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