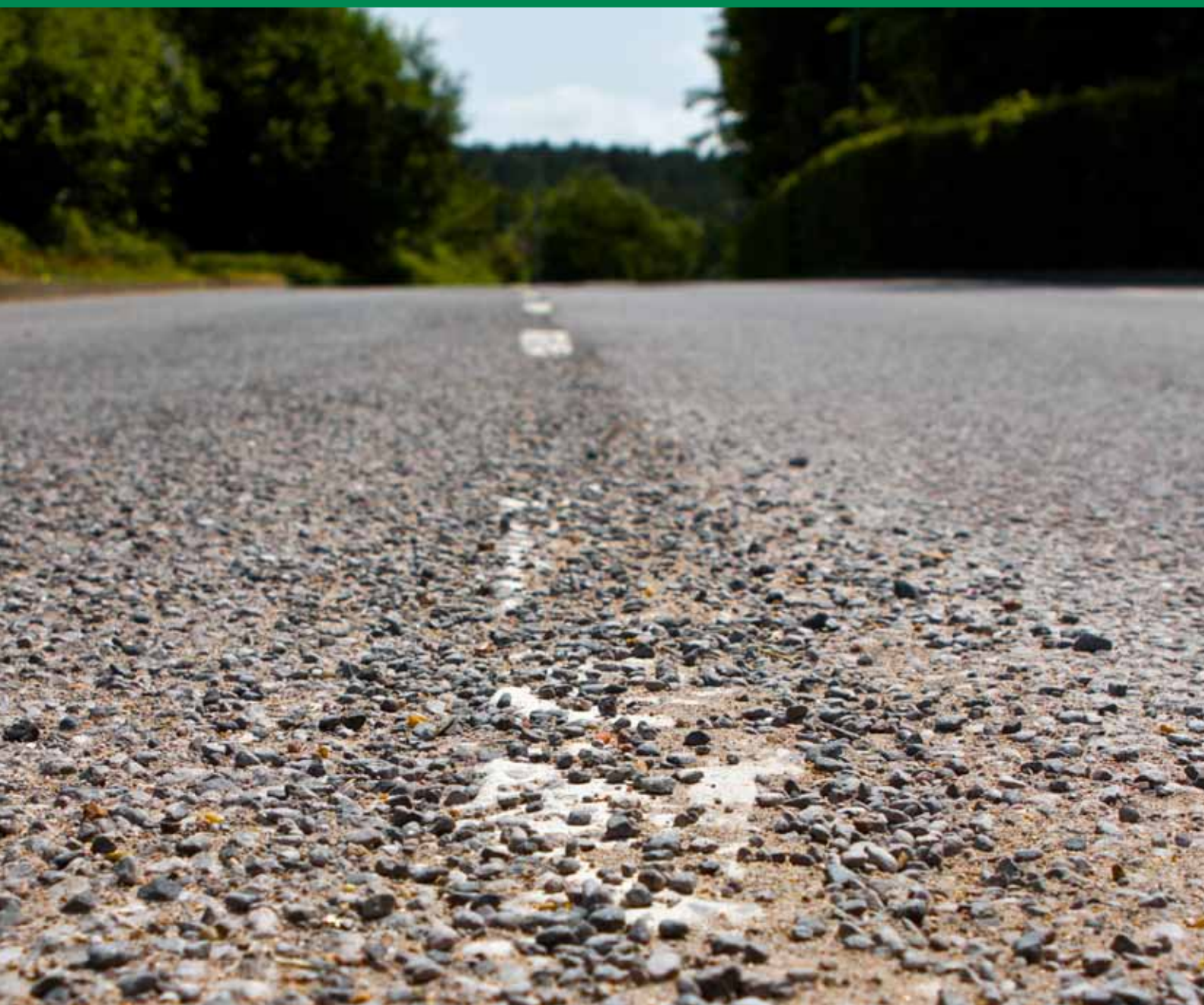


# ROADS THAT CARS CAN READ

A Quality Standard for Road Markings and Traffic Signs on Major Rural Roads



Proposals for Consultation



**EuroRAP**

EUROPEAN ROAD ASSESSMENT PROGRAMME



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The first consultation paper in the *Roads That Cars Can Read* series is available at:  
<http://www.eurorap.org/media/93768/20110629-Roads%20That%20Cars%20Can%20Read%20June%202011.pdf>

## FOREWORD

**John Dawson, Chairman, EuroRAP**

**Michiel Van Ratingen, Secretary General, Euro NCAP**



In many countries, improved car safety has been the single most important reason that road deaths have fallen in the last decade.

In others, additional

reductions have come from action on infrastructure or seat belts, drink and speed. But road crashes still result in 300,000 European deaths and serious injuries annually and a 2% loss of GDP.

The recent successes are encouraging but we can only move road deaths towards zero over the coming decades if we achieve 5-star driving in 5-star vehicles on 5-star roads. Modern cars and roads have a crucial role to play in nudging drivers back into a safe driving envelope when their human performance drifts.

Cars in the showroom today go much further in protecting life than vehicles a decade ago. Now they can warn, guide and brake by reading the road ahead including road markings and signs. At least half the travel on Europe's roads by 2025 will be in vehicles equipped with these advanced technologies. But vehicles, like drivers, cannot function well if basic road markings and signs are non-existent, non-compliant with international conventions, worn out, obscured, inconsistent or confusing.

The vast investment that Europe has made in advanced vehicle technologies and the huge savings in safety and comfort on offer now require some simple attention to detail. In retrospect, this should have been actioned years ago because the basic principles of good, consistent road signing and marking for drivers have not changed since the dawn of motoring.

This report identifies that the national and local variations in standards for basic road markings and signs can be migrated at low cost during normal replacement cycles over the years ahead if the common standards that exist today are now adopted and applied by all European nations. This means mainly ensuring simple consistency in the width of white lines and ensuring that they reflect back enough

light to be read by drivers and in-vehicle equipment in all weathers. It means removing the unnecessary inconsistencies in fonts, colours, sizing and shape that have crept in when nations have implemented basic safety signs defined in international conventions such as "stop", "give way", speed limits and banned turns. It means understanding the importance of marking the edges of roads.

Based on an overview of existing national practices and research and discussions between consumer associations, safety organisations, vehicle manufacturers and sign and marking industries, EuroRAP and EuroNCAP believe that road markings on Europe's roads should adopt a simple (and memorable) "150 x 150" standard. This standard is already commonly in use. Firstly, lane and edge marking should be a consistent 150 millimetres wide. Secondly, these markings in the dry should reflect light at 150 millicandela (formally 150 mcd/lux/m<sup>2</sup>). We plan to propose a quantitative definition of a "good sign" in early 2014.

Assuring the quality of Europe's roads must start with the network of greatest social and economic importance. Around 10% of Europe's roads – the motorways, national roads and busy regional road network – carry the majority of all Europe's travel. The majority of those killed in road crashes die on these roads. It is completely unacceptable that this busy network on which so many of us travel should not meet basic standards.

The next pathfinding step needed is an independent survey to find out the extent to which Europe's roads of economic importance already meet the standard so the scale of action that needs to be taken to make Europe's roads fit for the coming decade can be identified.

We would warmly welcome views on this report by 1st April 2014.





The majority of travel, and road deaths, happen on Europe's roads of economic importance that comprise just ten per cent of the entire road network. The importance of keeping this priority network of major roads well maintained for the effective operation of **Advanced Driver Assistance Systems (ADAS)** was highlighted by the EuroRAP and EuroNCAP consultation paper **Roads That Cars Can Read**.

It revealed that the combination of inadequate maintenance of roads and differences in national regulations for road markings and traffic signs across Europe were a major obstacle to the effective implementation of ADAS technologies. In particular, the consultation asked how road markings and traffic signs can be optimised to maximise the potential of two significant ADAS technologies: **Lane Departure Warning (LDW)/ Lane Keeping Assistance (LKA)** and **Traffic Sign Recognition (TSR)**

The European Union Road Federation (ERF) responded to the consultation and offered its support. As a result, two cross organisation working groups were set up under the auspices of EuroRAP to investigate how the road markings and signs industry (represented by ERF) could cooperate with the European automotive sector (represented by ACEA) to bring this concept

closer to fruition. The briefs given to the two working groups are in the Appendix, and can be summarised:

- WG 1 – Quality standards for road markings and traffic signs on major rural roads
- WG2 – Specification for a reference survey to assess the quality of road markings and traffic signs on major rural roads

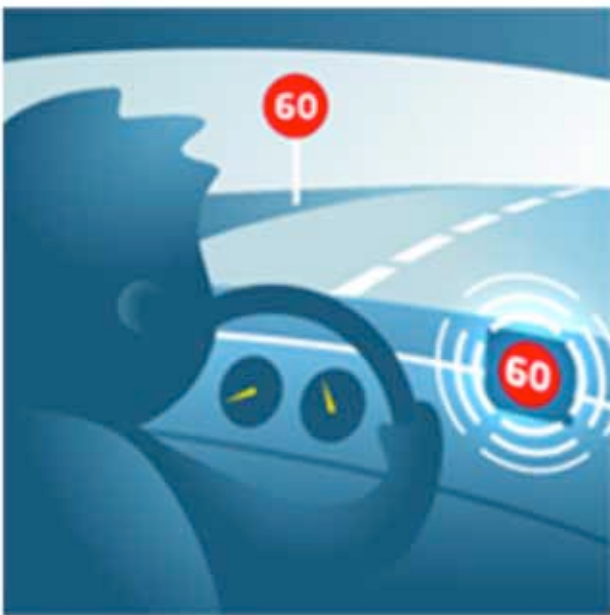
This report is the output of WG 1. It identifies how two core elements of the road infrastructure, road markings and traffic signs, need to be adapted to optimise the effectiveness of Advanced Driver Assistance Systems (ADAS) in vehicles, in particular **Lane Departure Warning (LDW)**, **Lane Keeping Assistance (LKA)** and **Traffic Sign Recognition (TSR)** (Box 1).

## BOX 1 - ADVANCED VEHICLE TECHNOLOGIES

- **Advanced Driver Assistance Systems (ADAS):** Now common in many vehicles, eg: SatNav, traffic information, Adaptive Cruise Control, Collision Avoidance, Intelligent Speed Adaptation, Night Vision
- **Lane Keeping Assistance (LKA)** and **Lane Departure Warning (LDW):** The systems read the road markings and give a visual, acoustic or tactile warning if the vehicle crosses the lane markings without signalling. For the driver, it can feel like running over a rumble strip even though no such strip exists. Lane Keeping Assistance, as well as warning, also gives the driver some steering support
- **Traffic Sign Recognition (TSR):** In-car systems that can read and interpret a range of traffic signs, including speed limits

Source: EuroNCAP/EuroRAP

ACEA provided the working group with information showing what was needed from road markings and traffic signs to make lane keeping and departure warning, and traffic sign recognition, feasible and effective. For their part the ERF provided technical advice on current technical standards for road markings and traffic signs and how the manufactures requirements could be met.



### The vehicle and the road: two sides of the same coin

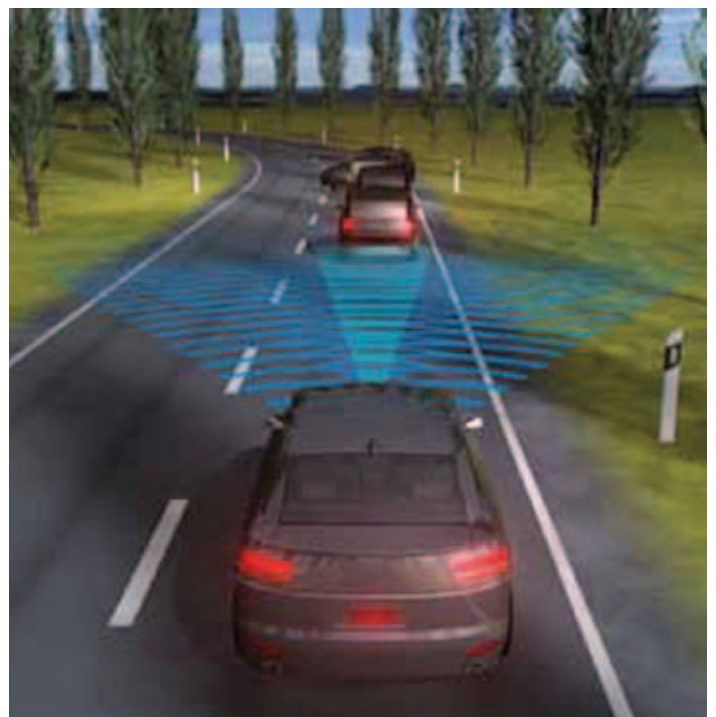
Since the early days of motoring, the basic principles of good road markings and traffic signs have not changed:

- They must be clearly visible so the driver can respond quickly to their message
- What they convey, be it guidance on keeping in lane or what the driver must do or not do, has to be clear, concise, and unambiguous
- They must be standardised and consistent along the route
- They must be checked regularly and be cleaned, and be replaced when worn out

Until recently, it has been the driver's eyes alone that have absorbed the information given by markings and signs to be able to read the road. The maintenance, consistency and uniformity of road markings are even more vital for safety and navigation now that cars as well as drivers must read the road.

**Lane Keeping Assistance (LKA)**, **Lane Departure Warning (LDW)**, and **Traffic Sign Recognition (TSR)** supplement the driver's eyes and guide and warn so making driving safer, and less stressful.

The technology is similar to the human eye: it reads the road markings and the traffic signs; it assists the driver to keep in lane, keep on the correct side of the road and warn of potential hazards ahead. But like the human eye, the technology cannot work effectively if it cannot see the road markings and traffic signs if they are worn out or hidden, or if they are confusing.







## FACTORS IMPEDING THE RECOGNITION OF ROAD MARKINGS

Effective road markings must be clearly visible to the driver, day and night, and in all weathers. Their effectiveness depends on their luminance (how well the marking stands out on the road), and their retro-reflectivity (the amount of light reflected back to the driver to make the marking visible).

There are European standards that stipulate different levels of retro-reflectivity in varying weather conditions<sup>1</sup>. The performance level a “good” road marking should achieve under both wet and dry conditions has been proposed by ERF (Box 2). This level is already in place in some European countries, is realistic, technically feasible and cost effective.

For their part, the vehicle manufacturers (ACEA) have identified and prioritised high, medium and low factors that could adversely impact on the operation and performance of lane departure and lane keeping systems:

- High Factor: Road surface condition (wet, ice etc), worn out markings, multiple confusing road markings, old road markings not completely obscured even if blacked out
- Medium Factor: Road gradient, road curvature, boundaries between multiple lanes
- Low Factor: Lane width (too narrow, too wide), visibility (eg fog)

## Achieving improved performance of road markings

The manufacturers also identified improved standards that road authorities need to implement to ensure optimal performance of lane departure and lane keeping systems (Box 3). If implemented during normal maintenance and replacement cycles, these improved standards would be low cost and be cost effective:

- Road markings to be a maintenance budget priority with all roads properly marked and maintained so they are clearly visible and not confusing
- Use retro-reflective markings that are visible under all weather conditions (the simple and memorable “150 x 150” standard – Box 2)
- Harmonise across Europe the colour and dimensions of lane and carriageway edge markings
- Install continuous lines to delineate the edge of the carriageway

## BOX 2 - THE ROAD MARKING STANDARDS REQUIRED

Based on a collection of data of intervention and maintenance standards from a number of European countries<sup>2</sup>, the ERF has determined a good road marking to be one whose **minimum performance level under dry conditions is 150 mcd/lux/m<sup>2</sup> and which has a minimum width of 150 mm for all roads; for wet conditions, the minimum performance level should be 35 (RW2).** Given that these requirements are already in place in some EU member states; the ERF believe this proposal is realistic, technically feasible and cost-effective

## BOX 3 - WORKING GROUP PROPOSALS FOR ROAD MARKINGS

Proposal 1	All roads to be properly marked and the markings maintained to be clearly visible and not confusing
Scope	Pan-European with special emphasis on roads of economic importance
Feasibility	Implementation and maintenance standards are already defined and just need implementing
Cost	Low – Some additional cost counterbalanced by the expected safety gains

Proposal 2	Use of retro-reflective markings that are visible under all weather conditions
Scope	Pan-European with special emphasis on roads of economic importance
Feasibility	High- Implementation standards are already defined and just need adopting; the “150 x 150” road marking standard ( Box 2) needs to be adopted in all countries
Cost	Low - Some additional cost counterbalanced by the expected safety gains; some research needed to show the interaction of LDWS/LKA with retro-reflective markings that are visible under all weather conditions

Proposal 3	Harmonise the colour and dimensions of road markings
Scope	Pan-European with special emphasis on roads of economic importance
Feasibility	Medium
Cost	Low - Some additional cost counterbalanced by the expected safety gains; some research needed to show the interaction of LDWS/LKA with retro-reflective markings that are visible under all weather conditions

Proposal 4	Use continuous edge of road markings
Scope	Pan-European with special emphasis on roads of economic importance
Feasibility	Medium - Will require member states to agree to ensure effective implementation Europe wide
Cost	Low – If implemented during replacement cycles

<sup>1</sup> (European Norm 1436: Road Marking performance for road-users)

<sup>2</sup> Austria, Belgium, Czech Republic, Denmark, France, Germany, Italy, UK and Sweden.

Figure 1: Examples of different implementation of the “Vienna Convention” signs in 5 countries

ROAD SIGNS	Great Britain (GB)	Greece (GR)	Netherlands (NL)	Poland (PL)	Serbia (SRB)
Stop (and give way)					
Give way (to traffic on major road)					
No entry for vehicular traffic					

## FACTORS IMPEDING THE RECOGNITION OF TRAFFIC SIGNS

The principle of retro-reflectivity applies equally to traffic signs: the sign's visibility is determined by the amount of light reflected back to the driver (European standard EN 12899). **Traffic Sign Recognition** technology works through a built-in camera that sees and interprets the traffic sign's colour, shape, message etc. However, to be effective, the sign has to be clearly visible to both the human eye and the in-car technology that is reading it.

As with road markings, the vehicle manufacturers ranked from high to low the factors impeding the effective recognition of conventional traffic signs using traffic sign recognition:

- High factors: Vandalism/graffiti, sign position, obscured signs eg summer foliage
- High-medium factors: Confusion with traffic signs on immediately adjacent roads, signs wrongly positioned, sign angle to the driver
- Medium factors: Quality of the sign surface, inconsistent placement of the signs, cross border differences in sign colour and shape
- Medium-low factors: Confusion of multiple signs at the same location, ambient illumination

### Factors impeding recognition of Variable Traffic Signs

Variable Traffic Signs (sometimes called Variable Message Signs) are often difficult to read with camera sensors because they are using technologies and control systems designed for the human eye.

Action is now needed to define and recommend the requirements that Variable Traffic Signs have to fulfill so they are captured accurately in the image recorder of digital cameras.

### Cross border problems: Achieving optimum performance of traffic signs

In response to the question ‘Are Cross border differences relevant to recognition accuracy?’ manufacturers identified this as a highly relevant point and they identified solutions to achieve a more optimal performance of Traffic Sign Recognition:

- Harmonisation of traffic signs across Europe (colours, shapes, fonts) that will require a review of the practical implementation of Vienna Convention signs in Europe (Figure 1 shows examples)
- Standardised pan-European guidelines for the mounting positions, numbers of signs and, installation angle etc, based on the finding of independent research
- Use of more durable materials which do not lose their visibility features over time
- Systematic maintenance of signs that ensure they are clearly visible in all conditions
- Variable Traffic Signs must be developed so they can be read by cameras as well as the human eye

The working group's proposals, their scope, feasibility and likely cost are summarised in Box 4.



## BOX 4 - WORKING GROUP PROPOSALS FOR TRAFFIC SIGNS

Proposal 1	Harmonisation of principal regulatory traffic signs (eg Stop, Give Way, banned turns etc) across Europe in respect of colours, shapes, fonts etc (Figure 1 shows examples)
Scope	Pan-European
Feasibility	Low in the short term
Cost	Low - If implemented during replacement cycles

Proposal 2	Drafting best practice guidelines for the mounting position, numbers of signs, angle etc
Scope	Pan-European
Feasibility	Medium
Cost	Low to medium - Would require some research to define standards applicable at EU level

Proposal 3	Use of more durable materials which do not lose their visibility features over time
Scope	Pan-European
Feasibility	High – Standards already exist and just need implementing
Cost	Low - Additional material costs counterbalanced by lower maintenance needs and if implemented during replacement cycles

Proposal 4	Proper maintenance of signs
Scope	Pan-European
Feasibility	High
Cost	Low - Additional maintenance counterbalanced by expected safety gains

Proposal 5	Variable Traffic Signs must be developed so they can be read by cameras as well as the human eye
Scope	Pan-European with possible extension to UN-ECE regulation
Feasibility	High
Cost	To be defined – Suppliers have to change the way they implement Variable Traffic Signs to avoid /reduce conflicts with the image acquisition process in vehicle camera sensors



By 2025, the majority of car travel will be by vehicles with advanced technology that can read the road ahead. Road marking and traffic signing across Europe will have to be adapted to cater for the needs of these intelligent vehicles otherwise the enormous safety benefits may not be realised. The working group identified the scope, feasibility, cost and constraints of achieving road markings and traffic signs that can be read by both drivers and their in-car technologies.

These recommendations would contribute towards a better optimisation between the intelligent car and road markings and traffic signs: some can be implemented immediately; some require additional research before implementation; other should be regarded as projects that will require broad consensus among stakeholders that may take a decade to implement.

Following years of underinvestment, (Figure 2) there seems to finally be a solid political consensus that more needs to be done to maintain roads and preserve what is an important societal asset to ensure that our roads remain safe and fit for purpose in the age of the intelligent car.

The recommendations set out in this paper represent cost-effective proposals that if implemented will bring significant reductions in fatalities and improved driver comfort at relatively low cost. What is important now is to mobilise industry, consumers and road authorities to achieve the necessary understanding and support to implement these actions.

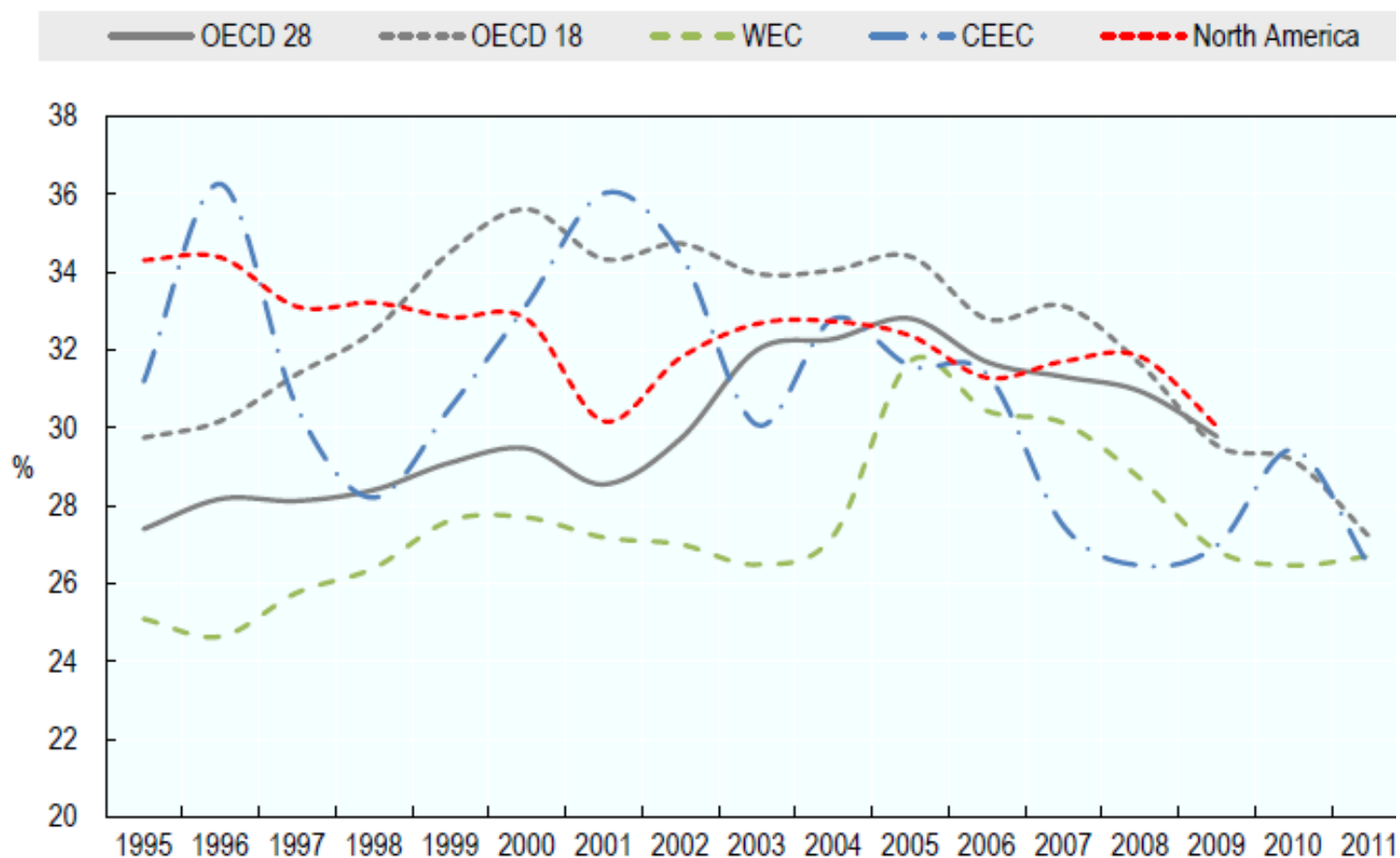




## ROAD MAINTENANCE IN RECENT DECLINE

Figure 2: Public road maintenance share of total road expenditure 2010

(Euro, current prices, current exchange rates)





## QUALITY STANDARD FOR SIGNS AND MARKINGS ON MAJOR RURAL ROADS

### 1. Objective

To prepare a draft quality standard for road signs and markings that are readable by both road users and by vehicle-based systems. The draft quality standard shall be expressed in units that are efficient to measure and apply by both road and vehicle engineers. The measurements and tolerances proposed may include references to international conventions but shall be independent of any proprietary national system for road signing or marking or of any manufacturer's proprietary system for vehicles. The draft shall be capable of providing the measurement basis for repeatable international surveys to determine the extent to which a representative sub-set of significant road signs and markings meet the quality standards set.

### 2. Context

The Working Group shall work in the context of:

- The Consultation Document Roads that Cars can Read <http://www.eurorap.org/media/93768/20110629-Roads%20That%20Cars%20Can%20Read%20June%202011.pdf>
- Summary Notes of the EuroRAP/Euro NCAP Workshop 30th June 2011
- Roads that Cars can Read - Response to the Consultation

The Working Group should focus on quality standards:

- Applicable to the European Economic Area
- Applicable to speed signs and lane markings in rural conditions at speeds greater than 70kph
- Applicable to the 10% of roads of economic importance which carry the majority of Europe's transport and on which the majority of Europe's transport deaths take place

### 3. Method of Working

Following review of the objectives of the Working Group and associated papers, as outlined in the Workshop Summary Notes, the Working Group should initially review the accord reached between the Swedish Transport Administration and Volvo and the extent to which it can or cannot provide a working template for a general pan-European document.

The key and first deliverable of the Working Group is to propose reasoned working tolerances for the quality of lane marking and speed limit signing in well defined situations.



In making its proposals and considering both human and vehicle based systems and the evidence base where available, the Working Group should also review and report on:

- The extent to which existing national variations in implementation of the 1949 and 1968 UNECE protocol hamper efficient recognition of safety critical signs and markings
- The extent to which national language text plates should or should not be permitted to modify safety critical signs in an international system of signing and marking
- the extent to which “false markings” should be included in the quality standard (e.g., old markings not obscured; lane markings not in normal use; sealant lines for cables or drains)
- the extent to which national variations in logical structure should or should not be permitted with respect to changes in mandatory speed limits that are:
  - “Switched on” but not “switched off”, eg on bends (D)
  - Unsigned, egs village name signs (F); change in road type (UK)
- The extent to which national variations in logical structure should or should not be permitted in general
- Whether replica speed limit signs on the rear of vehicles (e.g., commercial vehicles) should be permitted.

The Working Group should in particular consider the extent to which:

- Recommendations for any improvements that can reasonably be undertaken over a period of time during routine periodic maintenance
- A requirement on road authorities to register the geo-codes of all legal mandatory signs by 2020 would have significant impact in reducing costs of systems, enhance safety and provide certainty in enforcement

The Working Group will ventilate their working proposals at an international conference in 2012 setting out clear principles for the choices made and reasoning for choices of parameters set.

### **Timeline**

The Working Group should make its recommendations on the working tolerances for the quality of lane marking and speed limit signing by end-April 2014 and report by end-June 2014.

### **Membership**

The Working Group shall comprise not less than 6 and not more than 12.

There will be an outer consultative group. Membership will be drawn from groups involved in relevant policy, roads, vehicles and consumer affairs fields.

The Secretariat shall be provided by EuroRAP and Euro NCAP.



## SPECIFICATION FOR A REFERENCE SURVEY TO ASSESS THE QUALITY OF SIGNS AND MARKINGS ON MAJOR EUROPEAN RURAL ROADS

### 1. Objective

To prepare a full survey specification to assess independently the quality standards currently being achieved for a sample of safety critical road signs and markings on major European roads. To propose a pilot survey independent of commercial or national interests of sufficient size to draw meaningful initial conclusions about the quality of signs and markings on a sample of European major European roads. The pilot survey must be capable of being carried out in 2012.

### 2. Context

The Working Group shall work in the context of:

- The Consultation Document Roads that Cars can Read <http://www.eurorap.org/media/93768/20110629-Roads%20That%20Cars%20Can%20Read%20June%202011.pdf>
- Summary Notes of the EuroRAP/Euro NCAP Workshop 30th June 2011
- Roads that Cars can Read - Response to the Consultation

The Working Group should focus its survey planning on:

- countries of the EU and its accession candidates

- speed signs and lane markings in rural conditions at speeds greater than 70kph
- the 10% of road network of economic importance comprising national and busy regional roads which carry the majority of both Europe's transport and transport deaths

### 3. Method of Working

The Working Group should review of the objectives of the Working Group and associated papers. As outlined in the Workshop Summary Notes, the Working Group should review the Terms of Reference of Working Group 1. Working Group 1 will provide the detailed draft specification for the quality standards to be measured by survey.

A key objective for the Working Group is to design a survey which is practical, affordable, repeatable and statistically meaningful. The Survey must be capable of being piloted on a limited scale so as to gain initial meaningful results in 2012 and provide feedback for later larger scale surveys of progress across the European network.

The Working Group should consider carefully that, although the survey will provide important independent feedback to road operators and vehicle manufacturers, as with other EuroRAP and Euro NCAP results, it is not intended that this survey should repeat or replace proprietary surveys used by road operators and manufacturers.



The value added by this survey should be in the provision of independent, border-free measurement of the quality standards for human and machine-readable signs and markings being achieved and the progress being made over time.

The Working Group should clearly state the principal statistical attributes of interest for which the survey is designed. It should describe the main features of the statistical error structure and indicate the confidence which can be placed on the results of the proposed survey and the degree to which results can be generalised to European level. The Working group should pay special attention to repeatability. It should review the following indicative high-level attributes of interest.

i) the quality of signs and markings on Europe's major roads as a whole

ii) the quality of signs and markings on major roads within a country

iii) the quality of signs and marking on distinctly different road types within a country (e.g. TEN-T routes, routes of national significance; routes of regional significance)

It is a requirement that the survey can be delivered in a way that it is independent of any particular supplier's proprietary techniques and that – as with Euro NCAP crash testing and EuroRAP road inspections – future surveys can be tendered to alternative suppliers. Unless strong evidence quickly emerges to the contrary, it should be assumed that the most efficient method of carrying out the required survey and for storing, processing, analysing and retrieving road section data is by adjusting the survey attributes used in existing RAP inspection and analysis tools.

It is envisaged that a pilot survey in 6-8 countries would give meaningful insights into technique and

- general European road condition
- general variations between countries
- general variation between road types

Specifically, the Working Group should recommend the sample frame likely to achieve this for i) the pilot survey and ii) a more comprehensive data suitable for performance tracking by road type and national level across all European countries.

### **Timeline**

The Working Group should make its recommendations on the working tolerances for the quality of lane marking and speed limit signing by end-April 2012 and report by end-June 2012.

### **Membership**

The Working Group shall comprise not less than 6 and not more than 12.

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***“Road markings on Europe’s roads should adopt a memorable ‘150 x 150’ standard defining their width and how much light they must reflect back”***

At least half the travel on Europe’s roads by 2025 will be in vehicles which can read the road ahead including markings and signs. But vehicles, like drivers, cannot function well if basic road markings and signs are non-existent, non-compliant, worn out, obscured, inconsistent or confusing.

This paper, prepared in consultation with representatives of consumers, roads and vehicle industries and safety organisations, proposes that national and local variations for basic road markings and signs can be migrated to become fit for purpose at low cost during normal maintenance cycles if the common standards that exist today are adopted and applied by all nations consistently.

This means mainly simple consistency in the width of white lines and ensuring they reflect back enough light in all weathers to be read by drivers and vehicles. It means removing the inconsistencies that have crept into fonts, colours, sizing and shape for basic signs covered by conventions such as “stop” and “give way”. It means understanding the importance of marking the edges of roads.

***“Lane markings are the rails for the self-steering car”***

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