Euro NCAP has ensured that any new car today which receives less than a 5-star rating is regarded by the public as below what is achievable. The success of Euro NCAP in the 1990s led auto clubs and top performing governments to establish EuroRAP in 2002 with support from the EU and motor industry.

EuroRAP quickly found that 1- and 2- star roads exist even on major national roads and the Trans European Road Network (TEN-T) resulting in high concentrations of deaths and serious injuries. Already leading countries working Towards Zero Deaths have declared that they will eliminate these unacceptably high risk roads during the UN Decade of Action for Road Safety 2011-2020.

EuroRAP and Euro NCAP are institutions designed to create transparency and “market pull” for safer roads and safer cars. They provide an internationally consistent way of measuring the overall safety of roads and cars. Their independence means they can speak as trusted bodies and communicate complex technical issues to policy makers and public. The technical support they receive from research and technical institutions means their analysis is widely accepted despite the technical shorthand necessary to set broad goals and keep public and policy makers engaged.

Programmes based on Euro NCAP and EuroRAP continue to spread across the globe. As the knowledge base expands rapidly, international RAP and NCAP organisations have been created to transfer know-how across developed and developing countries.

The publication of this first joint report Roads that Cars can Read by Euro NCAP and EuroRAP should come as no surprise. The development of the Safe System supported by the UN and EU Council of Ministers is based on promoting simultaneous action on safer roads, safer vehicles and safer drivers.

From the introduction of engine management systems and ABS – the first system to intervene in braking – the development of in-vehicle technology has advanced. Electronic stability control (often described as the greatest advance since the seat belt) has been followed by radar based technologies metering vehicle headway and speed. Now on the market there are lane departure systems that seek to read major road markings and head-up displays that can link to roadside signs. There is much more in the pipeline.

In the last 30 years there have been several international initiatives to link intelligent road infrastructure with intelligent vehicles. None has succeeded. Pre-competitive research programmes now create generally shared manufacturer visions for vehicles of the future. However, initiatives to include infrastructure continue to stumble on the significant institutional problems of involving more than a thousand road authorities in Europe alone who have varying local approaches.

The cat’s eye need not be the last success linking automobile technology with road infrastructure. The first task is tackled in this paper. It sets out a template describing the improvements to safety and comfort that are possible in a way that both the roads sector and vehicle sector can share.

This paper proposes simple steps to begin. It proposes beginning with lane marking and speed sign recognition which are already at or near market. It proposes focusing on the 10% of the total European network outside city centres where the majority of deaths happen and the majority of travel takes place. It proposes sample surveys to measure the real world variation in signing and marking across borders, define working tolerances and compare these with the quality being achieved today.

In the future, the “new heroes” of our transport system may well be those who work diligently to keep roads maintained to safe, consistent standards. It is even possible to see that EuroRAP and Euro NCAP could at some time recognise and award the authorities who serve the public best.

Roads that Cars can Read is a Consultation paper. It seeks to provoke debate and help define how roads of the future should combine with the vehicles of the future as technology advances. It is sure to be true that roads that can more easily be read by machines will be safer for road users generally too. If you have research that can help shape the approach, or views you want to share, please let us know.

JOHN DAWSON CHAIRMAN, EuroRAP
MICHEL VAN RATINGEN SECRETARY GENERAL, Euro NCAP

Contents

1. Introduction 4

2. The Adoption of the ‘Safe System’ as Common International Policy 5

3. The Design and Quality of Signing and Marking: British Case Study 9

4. Vehicles of Today and Tomorrow 14

5. National Variations in Signing and Marking: Scoping Survey Results 18

6. Do Users Understand Signs and Road Markings? 20

7. Summary of Recommendations and Conclusions 22
1. INTRODUCTION

The Swedish Government with support from the motor industry has asked EuroRAP and Euro NCAP to lead an initiative to define what motor manufacturers need, and can reasonably expect to have, so that vehicles of the future can read the road reliably. The Roads that Cars can Read initiative is also of importance to Europe's road authorities. Action on Safe Vehicles and Safe Roads are two of the pillars endorsed at global and European level by the international community for the decade to 2020.

Vehicles are developing with new technology at a quickening pace. SatNav is commonplace. Lane departure systems which read lane markings and adjust steering are already on the market. “Speed alert” systems are well developed but, to be valued by drivers, need the legally reliable speed limit information currently displayed on signs. In-car displays offer new opportunities to filter and present relevant information so as to make driving safer and more comfortable.

To make progress in assisting the driver and improving vehicle control, manufacturers now need to know how road information could best be reliably assimilated into the vehicle from a real world environment – and across national and international borders.

Regardless of machine readability, recent research is also challenging received wisdom in how roads and layout and perceived through the human eyes and brain. In particular, road layouts often do not make obvious the speed drivers should chose. Significant changes have recently been implemented in the Netherlands and Sweden. Meanwhile performance tracking evidence from EuroRAP in Britain reinforces how the simplest improvements to signing and marking can slash death and serious injury rates by making the road ahead more readable.

Despite more than a century of motoring and international conventions, the way road information is conveyed to the driver through signing, signalling, cats eyes, lining, and markings varies widely even between neighbouring countries - even traffic signal sequences and the colour of lines vary let alone vital matters such as pedestrian crossing protocols or the positioning of stop signals.

The vehicle of the future can know what country it is in. This policy paper sets out the issues and suggests practical plans to define the tolerances and logical structure needed to read the road by machine, survey the extent to assess to which existing major road networks fall short and can be put right – and do so in a way which makes it easier and safer for all road users to read the road.

The paper aims to provoke discussion and seek contributions on whether the problem and the next steps have been adequately defined.

The key questions posed are:

- what data would manufacturers ideally like from the road infrastructure to make driving and vehicle control safer and more comfortable?
- how could the data which manufacturers need be reliably and efficiently read from the road infrastructure and augmented by other digital sources?
- what standards are currently achieved by infrastructure operators
- how can the road network, or a subset of it, be managed and independently assessed as suitable for general use by intelligent vehicles?
- what is the best available research on how signing and marking can be improved for human interpretation?
- can time consuming and inflexible legislation be avoided by a non-statutory approach to managing change?
- are any financial implications feasible?

2. THE ADOPTION OF THE ‘SAFE SYSTEM’ AS A COMMON INTERNATIONAL POLICY

2.1 THE SAFE SYSTEM

In the late 1990s, a number of countries leading road safety worldwide began the development of a Safe System approach to road safety based on re-designing the road transport system to eliminate road deaths. In the Safe System approach, it is accepted as in rail, aviation, or factory safety that human beings will always make errors. The engineering of the road and vehicle, when combined with education and enforcement, aims to contain drivers within a “normal driving” envelope.

Technologies which operate pre-crash (eg electronic stability control, forward alert, sleep warning, emergency brake assist etc) aim to re-capture normal driving before all is lost. Roads must be designed and laid out which are easy to read and avoid ambiguity and overload. Human beings in moderately stressful environments such as driving can be expected to have an error rate of around 1 in 500 decisions. To err is human.

And when a crash does occur, engineering of the road and vehicle needs to be designed to cushion the energies that kill and maim. Sudden, violent unsurvivable impacts need to be replaced with longer crashes in which lethal impacts on the head and body are removed, absorbed or dissipated.

Euro NCAP now has a Beyond NCAP challenge so that innovative manufacturers can be independently acknowledged for devices which can be shown to save life. The practical impact of electronic stability control, often called the most important vehicle innovation since the seat belt, illustrates how easy it is to underestimate the impact of inexpensive, targeted interventions.

2.2 ENERGY MANAGEMENT: THE KEY TO THE SAFE SYSTEM

Many tools contribute to energy management. The most basic is the separation of vulnerable road users from fast traffic. If this is not possible, vehicles must travel at low speed.

Inside heavily built-up areas speeds are now often limited to 50 kph on main arteries and 30kph on residential roads. These speeds are reinforced by chicanes, speed tables and other road layouts. Footpaths and narrowed pedestrian and cycle crossing points are the norm.

Crash energies when they occur between vehicles can usually be absorbed by Euro NCAP 4- and 5-star vehicles alone. Brutal bolts and spokes that can pierce the body even in low speed crashes have been eliminated. Crumple zones even in the most compact of cars, seat belt tensioners and many other design features have made today’s typical 4-star new car in Europe measurably safer that the typical 2-star NCAP car of even the 1990s. Today only a 5-star rating is truly acceptable. After years of debate, some of the most modern cars already anticipate legislation and offer systems to manage frontal pedestrian impacts.
2.3 CAR OCCUPANTS OUTSIDE BUILT UP AREAS IN EUROPE

There remain unacceptable risks in built-up areas and villages in Europe. Even new roads built with aid funds in Eastern Europe are replicating designs known to be unsafe which have been removed in Western Europe. However, unlike developing countries outside Europe, the common problem throughout all Europe, as in the USA and Australasia, is that the majority of fatal road victims are car occupants outside main urban areas.

Road deaths are concentrated on busy main national and regional roads which lack the protective equipment, markings and layouts that research has shown save lives at the permitted operating speeds. The problem is made worse still where operating speeds are higher than those seen on motorways in the same country - even carriageway roads typically average 5-10 times higher than permitted. Death rates on European regional single carriageway roads are typically 5-10 times higher than on motorways in the same country.

Death rates on European regional single carriageway roads are typically 5-10 times higher than on motorways in the same country.

Many individual elements of the Safe System have been well understood and implemented for decades such as:

- clear signing and marking at locations where human beings are most likely to misread the road such as at junctions and bends;
- rumble strips to warn when vehicles drift out of lanes or alert when approaching hazards;
- the installation of carriageway edge and median safety fences;
- the provision of separate safe turning lanes.

All these and many more are well researched, proven life savers.

However, it was not until the 1990s that systematic programmes of risk management across routes and networks began to become the new norm in leading countries.

The extreme example of systematic management of risk was the elimination of routine death on the Formula 1 racetrack. The death rate was so high that at its peak in the 1960s a third of drivers were killed within a handful of years. Today we expect race drivers to walk away from crashes at 200 kph or more as track and vehicle designs work together to dissipate energies more slowly inside the tolerances of the human body.

2.4 OECD’S TOWARDS ZERO

By 2008, the Safe System had gained such international traction that the OECD recommended in its Towards Zero report that member countries adopt the Safe System approach, focus on the economic gains from reductions in death and serious injury and examine how well their institutions could manage the new approach.

2.5 WHO REPORT INTO DEATH AND INJURY ON THE ROAD

A turning point in global recognition of the epidemic of road crashes came in 2005 with a report from the World Health Organisation (WHO). This outlined the sheer scale of the epidemic as economic growth has lead to a new wave of motorisation. Road crashes now account for a loss of around 3% of global GDP and the burden of death matches Malaria and TB.

The UN Decade of Action for Road Safety was launched on 11 May 2011 aiming to save some 5 million lives by 2020 with new interventions particularly in the developing world. An often stated aspiration is that the developing world must bypass the half century of tragically slow learning endured by the developed nations.

The NCAP programme was commenced in 2010 in Latin America (aided by Euro NCAP) and will be extended further. The IRAP programme is built on EuroRAP foundations and is already working throughout Latin America, Eastern Europe, Africa and Asia Pacific with support from countries and financial institutions. Today, the International and European Road Assessment Programmes systematically inspect thousands of kilometres at a time of busy high risk roads in countries focusing on the network on which deaths are concentrated. RAP tests the life saving and economic effectiveness of any of 75 proven road engineering countermeasures 100 metre section by 100 metre section in order to generate high return investment plans.

2.6 THE MOTOR INDUSTRY

At the same time, the motor industry has invested substantially in modelling crash impacts on the human body, both physically with crash dummies and with computer models. Head injuries are a major cause of road deaths. Some 75% of the global hospital capacity for treating serious head injuries is consumed by road crashes.

Important new advances in understanding head injury and aortic rupture are being made so that car designers can design to prevent these lethal forces. Without a forgiving road infrastructure on higher speed roads, it is improbable this can happen outside built-up areas.

Euro NCAP independently tests and publishes the crash performance of new cars and identifies the potential for injury across the body.
2.7 DEVELOPMENTS IN SWEDEN

The OECD’s Towards Zero report captured a less visionary language with which the “pragmatic countries” like the US and UK could be more comfortable. This change has already permitted a core of US states to declare themselves as TZD states in a rapidly growing initiative that may overtake Europe.

The most visionary country of all, Sweden, had nonetheless by end-2010 achieved a world leading death rate of less than 2.9 deaths per 100k population, less than one third of the rate in the US. Sweden has also pioneered or applied the research and application of the new measures needed to implement the Safe System - such as the mileage driven where drivers, roads and vehicles all lie within the Safe System envelope. Simply put the Safe System envelope means sober, belted drivers obeying the speed limit driving on 5-star EuroNCAP roads.

By 2010, 99% of new vehicles in Sweden were fitted with electronic stability control; government purchasing mandated 5-star Euro NCAP vehicles; and the mileage driven on roads with median crash protection had near doubled in the period 2003-2010 through the provision of safety fencing on major single carriageways. The 30% of Swedish mileage driven under measured Safe System conditions has a death rate truly Towards Zero and accounts for just 3% of deaths.

Some manufacturers, like Volvo and Toyota, have committed themselves to a future in which no-one dies in their cars. Manufacturers see crashes as events that must be designed for. Volvo’s stretch target is to make crashes survivable no matter what the road environment up to 80kph. With this in mind, Sweden has implemented a major change in its speed limit system. Where road protection is not in place, speeds have been lowered to 80kph. Communities, especially rural communities, need functional roads that permit people to live their daily lives, so the Swedish model encourages investment in protection so that speed limits can rise to 100kph.

2.8 BRINGING ROAD ENGINEERING INTO THE SAFE SYSTEM

Until now, outside a small number of countries, the road engineering community generally has been little exposed to the fast changing international attitudes to death on the roads and how Safe System research is as relevant to civil engineering design codes and maintenance as to the motor industry. The Passive Revolution campaign in the UK is one notable exception.

There are also signs that the launch of the UN Decade of Action for Road Safety is creating a solid alliance across the globe of those who are aware much faster improvement is not only desirable but readily achievable. Organisations such as PIARC (the World Road Congress organisation) seem likely to help lead the roads sector to adopt more than incremental annual change.

Roads that Cars Can Read is the ideal project with which to begin the process of more general inclusion and capture the energy and enthusiasm of progressive road engineering communities.

3.3 BRITISH CASE STUDY

Great Britain has around 0.5 million kilometres of road. However, its network of busy main, national and regional roads is only around 10% of this - approximately 50,000 kms of so-called ‘A’ roads.

A key proposal of this paper is that manufacturers and policy makers should settle on a design goal that, by 2020, vehicles should be able to read the road for a limited network of national and busy main regional roads comprising 10% of Europe’s roads.

For policy makers, focusing on this 10% of network makes sense as this network is by far the most important to the economy and should be prioritised for investment. It also carries the majority of the road deaths. It is a targetable network in a short period of time.

For manufacturers, more than half of their customer mileage is travelled on approximately 10% of Europe’s road. Internationally, iRAP’s general finding is that the 10% rule of thumb holds true globally (except for some African states with very limited lengths of road.)

“Manufacturers like Volvo and Toyota have committed themselves to a future in which no-one dies in their cars. Without a forgiving road infrastructure, it is improbable this can happen on higher speed roads outside built-up areas”

3.2 MANAGING THE NETWORK OF NATIONAL AND MAIN REGIONAL ROADS

The British main road network varies in standard from motorway and high quality dual carriageways to narrow country lanes. Only 20% of its length is managed by national authorities. Well over 100 local authorities manage the rest. Each of these authorities makes its own decisions within a loosening national framework about how much it will allocate to roads generally and road maintenance specifically.

Political accountability is moderate – the public do care about the condition of roads, and maintaining good structural road condition is known to be a cheaper and better option over the economic life of a road. However, when budgets are tight only limited protection can in reality be expected despite:

• the increased whole life costs that result, and
• efforts over the last decade by the British Treasury (the Finance Ministry) to protect asset value
• increased capital spending during downturns in the economic cycle.

In Britain, there are national and local standards for new construction, signs and markings, regular inspection and repair. Britain like virtually all European countries is a signatory to the Vienna Convention on signing which introduces some precise but basic global and European consistency to simpler features.

However, the Vienna convention does not cover many of the key features:

• colour and meaning of much road lining and markings
• traffic signal sequences and repeaters
• methods and heights of mounting signs and signals.

A full inventory is needed of the signings and markings which are in use in a sample of countries which may need to be machine readable together with whether or not these are covered by the Vienna convention.

“A key proposal of this paper is that manufacturers and policy makers should settle on a design goal that, by 2020, vehicles should be able to read the road for a limited network of national and busy main regional roads comprising 10% of Europe’s roads”
3.3 SAFETY RATING INSPECTIONS
In the last few years, around 10,000 kms of important British roads have been inspected by EuroRAP and star rated for safety using the Road Protection Score. The safety rating found particularly:

- defects in run-off protection throughout the network including 50% of motorway length
- defects in junction layouts endemic throughout the dual and single carriageway network.

3.4 VISUAL INSPECTIONS
In Britain, there is usually a monthly visual inspection and ‘critical defects’ response within 24 hours. Britain is not one of the 11 EU countries threatened with action in May 2011 for failing to implement the new EU Directive on Infrastructure Safety.

The main road defects covered are:

- potholes
- edge wear
- obscured or defective signs
- faded/worn road markings
- accident damage and debris (critical for motorcyclists are spills such as oil).

3.5 ROADWORKS
Roadworks are a significant interruption to normal service. Internationally, a rule of thumb is that crash rates double at roadworks.

The standards of care during British roadworks are notably higher than many countries according to a survey by FIA autoclubs.

“Lane rental” schemes whereby utilities and road contractors pay to occupy road space are common but not universal on busy roads to encourage quick completion of roadworks.

3.6 ASSET MANAGEMENT INSPECTIONS
Measurements of asset condition are increasingly taken through inspections using machine readings. A ‘deflectograph’ allows a measure of current construction strength. There is a measure of wet surface skid resistance (called SCRIM). The surface condition is assessed (eg rutting) through the “SCANNER” system.

3.7 SMART ROADS, STRUCTURES AND ITS SYSTEMS
As with navigable mapping, almost all available data of all types is historic but there is an ad hoc network of smart roads and structures.

The most intensely used motorways have ITS systems. Cooperative driving systems called “controlled motorways” in Britain are in limited use mainly on the very busy western section of the M25 London orbital motorway and on a section of the Birmingham orbital motorway.

3.8 BRITISH LEGISLATIVE FRAMEWORK FOR ITS SYSTEMS
The UK has special legislation in place to encourage investor confidence which permits private sector organisations to apply for a licence to install and operate roadside driver information systems across the whole network. TrafficMaster is the only current licence holder.

3.9 MEASUREMENT OF ROAD CONDITION
EuroRAP has only inspected major highways in Britain to date and does not have an independent assessment of road condition across the main road network.

Recent national road condition surveys using definitions used by British road engineers on the full main road network found the following:

- 5% of roads needed maintenance
- 25% of road length was a candidate for skid resistance intervention
- 5% of signs and road markings needed attention.

A key future requirement is to define how closely – or otherwise – the definition of deficits defined by road engineers reflects a deficit which would be shared by vehicle engineers with machine readable requirements.

It is plausible at this stage that the road engineer’s deficit is either more testing or less testing than the vehicle engineer’s.
3.10 BRITISH LOGICAL STRUCTURE FOR SIGNING AND MARKING

While Belgium’s delegation of signing to regional Ministries may provide the most complex structure in Europe, Britain (like France, Germany, Netherlands, Italy etc) has numerous examples of proprietary logical structure and form in its signing, marking and signalling.

At this stage, it is not possible to say whether all or some national variations can be read and interpreted by the vehicle and coherently presented to drivers as they travel from one country to another. And, if they can, whether it can be done economically. SatNav implementation does however show that flexibility is possible. Enhanced functions are possible in countries which follow a logical structure (eg postcode destination entry).

Examples of the distinct national logical structure in Britain include:

- left hand rule of the road (as Republic of Ireland)
- use of mph (not as Republic of Ireland)
- a national speed limit for a road type is assumed unless signed. This permits unsigned speed limit changes eg 70mph to 60mph when a dual carriageway changes to single and vice versa
- it has only recently been legal to repeat a 30mph sign once it was signed
- drivers were required historically to judge whether a 30mph limit was in force by judging the distance between lampposts.
- traffic signals feature extensive secondary signalling and the sequence includes red-amber
- vehicles may never pass through when pedestrians are signalled green
- despite the Vienna Convention, there is a complex, probably little understood system of hazard markings in the centre and side of the road. Centre lines are short or long dependent on overtaking opportunities or hazards
- private access markings and posts are sometimes used in different shapes and sizes

- double white lines in the road centre mean no overtaking - the single solid line is rarely used
- hatch markings are extensively used but the varying asphalt colours have no legal meaning
- zig zag markings prohibit parking at pedestrian crossings
- priority to pedestrians on crossings is established once a foot has been placed on it
- Clearways are defined in national legislation
- there are also Red Routes in London and Greenways in Edinburgh (cf Axes Rouges in Brussels or Paris) whose main meaning is that restrictions are more likely to be enforced
- there are Congestion Charging, clean air, restricted access and other zones.

As complexity increases in Europe’s urban areas, it is recommended manufacturers and policy makers focus on ‘open’ rural roads and villages where most deaths occur in the decade to 2020.

3.11 DESIGN, BUILD, MAINTAIN OPERATE (DBFO) CONCESSIONS

British road maintenance is mainly funded from public sector budgets. Despite aspirations to manage preventive maintenance and whole life costs, the reality is that rational economic strategies can change to ‘patch and mend’ in the face of budget cuts. The exception is roads which are managed to set maintenance standards through concession contracts which are too expensive to break. The so-called dbo concessionaires are typically contractually paid through “shadow tolls” which depend on the usage of the road and the condition of the road.

The anomaly of islands of well maintained concession roads exists throughout Europe whether funded by “shadow tolls”, real tolls or the “vignettes” increasingly seen in Central Europe.

3.12 THE ROAD AUTHORITY IN EUROPE

According to the International Road Federation (IRF), there are 35m kms of road worldwide. IRAP estimate that $500bn is spent on the world’s roads annually in maintenance and new construction.

There are more than a thousand road authorities in Europe alone, often small. Where there are national road authorities, these are increasingly devolving the busy regional roads to local authorities as seen for example in France, Sweden and Britain.

Culturally, road authorities are distributed like individuals. Some are open and outwards looking and highly innovative. A few are introvert, almost military in their command and control structures. Like the motor industry, as big spenders, authorities are used to being able to be in charge and expect their suppliers to deliver to their requirements on a client-contractor relationship. Although working in partnership with the motor industry would bring major opportunities to manage major networks much better, some individual road authorities may see this as beyond their local objectives.

Some authorities will be cautious and conservative and others will be enthusiastic. EuroRAP/IRAP has achieved quick progress by working with respected innovative authorities backed by leading research groups with substantial commitment to outward communications. Similarly, Euro NCAP created critical mass to become a market norm.

It is recommended that a quorum of leading authorities and concession companies is invited to participate in the Roads that Cars can Read initiative based on offers from innovative authorities and professional associations, subject to:

- achieving representative European geographic coverage, and
- coverage in the early adopter markets needed for viability by motor manufacturers.
4. VEHICLES OF TODAY AND TOMORROW

4.1 CARS AND SYSTEMS AT MARKET NOW

When Euro NCAP first began crash testing new vehicles in the 1990s, the most advanced electronic technologies were typically engine management systems, anti-lock braking systems (ABS), and airbags and seat belt tensioners. The distinction between “passive” protection systems which deployed in the event of a crash and “active” protection systems that seek to avoid crashes or prevent their worst outcome was new.

The understanding of the forces the body can endure in crashes led top performing countries like the Netherlands and Sweden to review their road designs fundamentally using the same principles in the 1990s. The ‘Star Rating’ used by EuroRAP is similarly based. New road types such as the Swedish divided single carriageway arising from these reviews mean that it is not only on the race track that drivers can walk away from crashes shaken but uninjured.

The development of eSafety systems has now matured onto the market at a pace which can leave even showroom staff behind. The next decade will see a fast growing understanding of these systems and how they operate as they cascade into the cars everyone drives just as consumers know of ABS and the airbag today.

The most proven and prevalent of the new technologies is ESC – electronic stability control. It is estimated that ESC will save around 10% of all European road deaths which is why it is frequently called “the greatest invention since the seat belt.”

ESC stabilises the risk of a car skidding and losing control, a lifesaver when emergency manoeuvres are involved. It compares 25 times a second whether the driver’s steering corresponds to the direction in which the vehicle is moving and takes action if not. In countries like Sweden, over 90% of new vehicles are already fitted with ESC and the current level overall in Europe is two thirds. By 2014 over 80% of European new cars will have it and it will be required by law from 2014.

Many drivers are familiar with short range radar for parking sensors. Adaptive Cruise Control has been offered on upmarket vehicles for close to a decade using long range radar. Drivers can set a maximum speed and choose a preferred headway which allows the vehicle to cruise, accelerate and de-accelerate using engine braking in heavy traffic down to around 30kph. More recent applications allow lower speeds and braking.

Some studies suggest that benefits to the general traffic flow from Adaptive Cruise Control begin to kick in if just 10% of the vehicles are operating this technology. Road engineers following the same principles to smooth traffic flow have installed “cooperative driving” systems, for example on motorway sections close to London and Munich which have led to reductions in crashes and delays.

In the same way that ESC operates by integrating ABS and Traction Control systems, radar can be used for other functions. Drivers can be alerted if they are approaching a vehicle too fast and given an audible alert or, in some systems, by a touch on the brakes. Systems now go further and apply the brakes if the car is forecast to impact or ensure that maximum braking force is applied (particularly helpful for women).

Blind spot monitoring based on radar is another system now available which screens blind spots to the side of vehicles.

Head-up displays put information in front of drivers in new ways. The way the “real estate” in the car is used to convey information to drivers has moved from the world of basic analogue dials showing speed, fuel and warning lights to a significant field of ergonomic design. Today’s challenge is to meter information that the driver wants or needs onto multiple displays in a way that helps safety and comfort and does not hinder it. There are new ways to communicate with drivers but no new human capacity to absorb information.

Speed Alert introduces other issues that should be addressed in the 21st century. For example, the overwhelming majority of speed signing placed by road authorities is entirely reliable but in some countries the relationship between the sign – its position or the speed limit posted - and the legal authority for it has been questioned. Authorities across Europe are not yet required to register legally authorised speed limits linked to GPS coordinates. The electronic record of the speed limit should be the same as and as valid as the sign.

Speed Alert is one of two technologies at market that this paper proposes offer quick wins – the second is Lane Support systems.

Lane Support reads lane markings and the position of the vehicle within the road lane. Lane Departure systems issue a visual, acoustic or haptic warning if the vehicle crosses the lane markings without signalling. For the driver, it can feel like hitting a rumble strip even though no such strip exists. Lane Keeping Support, as well as warning, also gives the driver some steering support. It is estimated that this technology could reduce deaths in Europe by around 5% and estimates in both the US and Europe put this figure higher when combined with other technologies such as blind spot monitoring.

BLIND SPOT MONITORING

Some current systems allow the car to tell the driver if a maximum preset speed is being exceeded. More usefully, systems based on SatNav can communicate with drivers in a limited way when they are not obeying the speed limits on longer sections of a particular road. This warning is based on surveys of speed limits in force or a national speed limit. The frequency of signing and marking changes by authorities however is a challenge. Every time any authority makes a change then the navigable mapping falls further out of date. Historic surveys undertaken for navigable mapping companies can only be as reliable as the last survey.

Speed Alert systems therefore also use speed sign recognition. Sign recognition systems identify roadside signs using video cameras. If signs conform to a limited range of size and patterns, are not obscured (eg by foliage), are sited in a normal place and in good condition, then it is practical to recognise them. If both SatNav data and the physical sign confirm a posted speed limit then Speed Alert can work. It is a technology which can and should become widespread in the UN Decade of Action. Addressing the conformity and quality of speed signing is within reach. It will help build the relationships and rehearse some of the steps needed for the technologies which are following.
4.3 FAILURE MODES AND LIMITATIONS

The current applications of Lane Support systems are already impressive and are based on more than a decade of development. For the driver, they appear intuitive. Currently, the systems are offered to drivers for use on roads with good markings and at speeds generally above 65kph. The systems typically “hunt” up to 200m ahead for readable road centre lines and edge markings and do not operate on tighter curves.

Currently, Lane Support Systems work best on well marked motorways. However, the serious crash rate on busy roads which are not motorways is on average 5 times higher. Run-off crashes – as witnessed by the flowers and shrines which line the edges of the highways of Europe – are one of three main causes of death on rural roads. The potential for extension is clear.

Currently, the main limitations identified for lane departure systems because they rely on greyscale images are, other than mud, heavy rain, fog and snow:

- old road markings not completely obscured even if blacked out
- Bitumen lines used to seal cabling or drainage in the roadway
- faded indistinct lines on asphalt surfaces
- slightly faded lines on concrete road surfaces which present poor contrast
- lane markings not in normal use
- discontinuous markings.

The problems of tolerance seem likely to increase in future as systems seek to sample shorter lengths of the road ahead in order to read curves or the presence of, say, a turning lane.
5. NATIONAL VARIATIONS IN SIGNING AND MARKING: SCOPING SURVEY RESULTS

5.1 THE SCOPING SURVEY

EuroRAP has enabled a small scoping survey for this paper in order to help define a wider survey that is now needed of the road signing and markings in practical use. Fuller results are available in a separate paper.

The signing and markings that road users face on the ground generally result from four decision points:

- whether a sign is included or is additional to those in the Vienna Convention
- National signing and marking regulations including proprietary national interpretations of the Vienna Convention
- local interpretation and implementation of national signing regulations
- quality of implementation and maintenance (which is also dependent on investment decisions).

It is commonplace that administrations and organisations state and believe that they adhere to a variety of laws, good practices, codes and guidelines. However, in practice, a “headquarters” belief may not fully comprehend the reality on the ground. A recent example in the roads sector is relevant. In May 2011, the EU took steps against 11 of its 27 Member states for non-compliance with the Infrastructure Safety Directive. This Directive requires only that countries apply, in any proprietary national form, best practices developed decades previously (eg safety audit on new road schemes; regular safety inspections to remove debris on main roads etc).

While EuroRAP and Euro NCAP seek to be supportive as their industries seek continuous improvement, their focus must be on the outcomes achieved rather than the means used to deliver them (the “inputs”). What concerns the public and consumers are whether roads and cars are as safe, fit for purpose and affordable as they should be.

With the help of auto clubs, information was collected from 7 sample countries - Germany, Great Britain, Netherlands, France, Poland, Greece and Serbia. The key findings from the sample were as follows:

5.2 RESULTS

Vienna Convention

- all countries appear to follow the principles of the UNECE protocol agreed in 1949 and revised in 1968. National interpretations mean that the detailed design varies from country to country.

National Signing and Marking Regulations

- all countries have some form of legal framework for prescribing signs and marking
- all countries appear to have some form of “Highway Code” or other reference for drivers
- it is known that countries such as the UK and Belgium (note: Belgium is not in the initial scoping survey) have some variation below nation state level

Key Regulatory Signs

- speed limit signs show consistency in entering the speed limit but less so when leaving it
- “Stop” and “No Entry” signs appear generally consistent

Warning Signs

- many warning signs show good general consistency between countries but some countries use yellow colours rather than white (eg Poland, Greece) for background
- significant national deviations in some signs exist, for example in signing the end of a dual carriageway or for the signing of staggered junctions
- the detailed design of some signs can be quite variable between countries such as signs for “Slippery Road”, “Steep Hill” or “Falling Rocks”

Road Markings

- some aspects of road markings, such as the use of continuous (solid) centre lines, are covered by a UNECE protocol as a supplement to the Vienna Convention
- most road markings are covered by national signing and marking regulations, but many have no formal legal status other than the empowerment of local road authorities to offer guidance through signs and markings

The principles of basic frequently occurring road markings appear similar between countries but there are variations in application:

- a double solid line prohibits overtaking but a single solid line may also prohibit overtaking (eg France, Germany and Poland)
- the markings on the approach to prohibited overtaking sections varies
- coloured green asphalt is sometimes used in the Netherlands to reinforce prohibited overtaking

5.3 RECOMMENDED SIGNS AND MARKINGS SURVEY

It is recommended that manufacturers should identify the general range of tolerances needed by road vehicles that will be on the market by 2015 to enable them to read i) centre line and edge lane markings and ii) enable automatic sign recognition.

A shared reference data set is essential for policy makers, vehicles designers and road engineers to make progress. It is therefore proposed that a structured sample of signing and markings in service should be collected. The basic survey design should be:

- a minimum 1000kms of road to be collected in each of 6-8 countries
- the roads selected should be from the most busily trafficked 10% of the network
- the roads selected should include motorway, national road and busy regional or local road
- the 1000km surveyed should include equally roads of different types (motorway; dual and other divided carriageway; mixed carriageway; single carriageway)
- the key attributes of the roads and their signing and marking including speed limits, centre line, edge markings and their quality and condition should be coded to 100m lengths
- the schedule of signs and markings included should be based on the Vienna Convention but supplemented where appropriate by relevant practice in the countries surveyed
- to control survey costs and be sympathetic with in-vehicle systems, the condition and visibility of road signs and markings should be classified to the tolerances available from high definition video
- the survey report should identify separately the responsible authority for the roads surveyed and identify results separately for the TEN-T road network; national roads; regional roads.
This initiative takes place at a time when there is considerable debate around road markings with:

- continuing consumer discontent about poor road condition
- objection to excessive signing “clutter” on environmental grounds
- conventional road markings being challenged in some built-up environments as providing too much comfort to drivers where pedestrians, cyclists and vehicles mix
- unambiguous evidence that signing and marking improvements bring very significant reductions in serious crashes in both urban and rural environments
- research demonstrating that consumers don’t understand the nuances of signing and road markings.

Consumers complain that, when speed limits change frequently, they are simply unsure of the prevailing speed limit – particularly when faced with speeding fines. In the Netherlands the new “Green Strip” has been introduced as an attempt to mark clearly the roads on which it is permitted to travel at 100kph.

The radical changes in road marking in the Netherlands are taking place with fresh research and debate. For example, the Royal Dutch Touring Club (ANWB) has worked with members and regional road authorities to survey what consumers say and think about road markings on 60kph and 80kph routes. With 1,000 participants and 150,000km of user experiences, the ANWB reported:

- driver uncertainty about prevailing speed limits and a desire for a way to deduce what the speed limit is from the road design
- driver support for good road markings as an excellent way to communicate road information but uncertainty about the meaning of many types of markings.

Such surveys can lead to change welcomed warmly by road engineers. For example, in the Netherlands, small poles carrying the speed limit have been installed at 100m intervals. The work of the German automobile club supported the introduction of similar roadside marker posts in Germany which help users to read the road.

In Britain, a survey found that half of drivers did not know what the maximum speed limit was for single carriageways. Occasional surveys into the public’s understanding of lesser known signs provide much amusement but little reassurance that all signing and marking adds value.

These surveys help to underline that systems that have been in place across Europe for many decades might benefit from modern consumer focused research. For example, it is possible that a significant percentage of drivers have little comprehension of the different meaning of short centre lines and long centre lines – not even subconsciously.

With up to €50bn spent annually in Europe on periodic road maintenance, sums need to be spent to good effect. If road users do understand, value and react to the smaller nuances in road markings that engineers are asked carefully to lay out – such as the varying spacing between centre lines – then the systems that manufacturers design should seek to reinforce these. If drivers do not perceive them, then not only manufacturers but also road engineers should focus on the signs and markings that add value.

There are therefore strong arguments to review dispassionately existing knowledge and research on road markings and develop a single reference document for use by:

- national road authorities preparing regulatory documents on signing and marking
- road authorities implementing signing and marking
- manufacturers developing systems.

As stated earlier, this document should cover roads outside built-up areas only. To enable early completion, it should take all the most commonly used Vienna Convention signs (“Stop”, “Give Way” etc etc) as a given. It should identify and cover only the most important markings that contribute to safety and comfort on the road including centre lines, edge markings, junctions and accesses. The central premise should be that what is important for drivers to read should be important for machines.
7. SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

These are the key conclusions and recommendations on which this Consultation seeks views:

• both the UN and the EU Council of Ministers have now endorsed the Safe System in which there is simultaneous action to address roads, vehicles and users.

• it is essential to moving towards zero road deaths that vehicle designers can rely on consistent “logical structures” and quality standards from the road network.

• the Swedish government have asked EuroRAP and Euro NCAP to provide “market pull” and help define what manufacturers need and can reasonably expect to have so vehicles of the future can read the road safely and reliably - and how can it be achieved.

• the Vienna Convention covering road signing and marking is the limit of international standardisation - it did not cover consistency in “logical structures”, assure quality standards and consistency of application nor many key road markings.

• there are more than a thousand road authorities in Europe following dozens of nationally or regionally drawn up regulations for signing and marking standards. Globally, there are around ten thousand authorities.

• it is not necessary for road authorities to abandon proprietary national or regional standards. It is necessary for them to be logically coherent, consistent and machine readable. Where technology (eg cameras) are mimicking humans, what is good for drivers is also likely to be good for machines.

• consistency and quality should be financially possible at least on busy national and regional main roads outside major built-up areas. These roads are of economic importance. They comprise 10% of the network but more than half of traffic and deaths.

• an explicit programme of outreach and communication is needed so that the road engineering community can now be included more directly in development of the 21st century Safe System, in particular:

  • engineering standards and codes needed review and development in relation to the reduction of forces causing death and serious injury
  
  • the economics of investment in the Safe System needed to be better understood

• a higher priority needs to be given to quality management of maintenance.

• Western European road authorities are shifting emphasis to managing networks better. Those delivering quality maintenance with high consistency in implementation need to be promoted by civil society groups representing road users as “the new heroes”. civil society groups need to review constructively the sanctions and law available where it is evident that authorities are not adhering to legal requirements for providing safe infrastructure such as serviceable linings and markings.

• the usability of different national and regional variations by machine readable systems needs to be assessed.

• medium term, EuroRAP/Euro NCAP potentially has a role in independently assessing the integrity of networks and, in the absence of enforceable legislation, using publication of results and consumer transparency as a lever to raise quality. EuroRAP has in place accredited organisations who can inspect roads to consistent criteria across borders.

• medium term, when good practice is widely agreed, this could be incorporated in legislation, for the TEN-T network to create momentum for adoption on all main roads.

• Lane Support Systems, which are already at market, should be one of two specific systems addressed by a project. The second system should be Speed Alert which requires recognition of Speed Limit Signs prescribed by the Vienna Convention.

• the use of defined specific systems in a project would help unlock mutual understanding between road and vehicle engineers of the new need for roads of the future to have coherent logical structures and meet quality standards for machine readability.

• a case study using existing definitions of tolerance by a project would help unlock mutual understanding between road and vehicle engineers of the new need for roads of the future to have coherent logical structures and meet quality standards for machine readability.

• A study case using existing definitions of tolerance by road engineers shows that only 5% of the main road network might need signing and marking replaced or treated. This suggests revised tolerances to include the needs of both humans and machines is more about specifications and practices than any need to increase periodic maintenance budgets.

• EuroRAP and Euro NCAP should be invited to develop a project with support from the Swedish government, motor industry, auto clubs and leading road authorities with the following key components:

  • focusing on at-market Lane Support Systems and Speed Alert Systems as a specific, a reference database should be created of the in-service quality of signing and road marking across different major road types in up to 8 participating countries

• the results of the road quality survey should become a shared reference for policymakers and road vehicle industries. This evidence base would enable policy development and advocacy as well as benchmarking tolerances for manufacturers and main road operators

• the detailed tolerances required for machine readable signing and marking need to be defined. Preliminary work suggests fast signs and markings are a problem for both drivers and machines. It suggests care is required in removing old markings and avoiding road treatments that create long false high contrast lines eg black sealants on concrete.

• EuroRAP and Euro NCAP should be invited to develop a project with support from the Swedish government, motor industry, auto clubs and leading road authorities with the following key components:

  • focusing on at-market Lane Support Systems and Speed Alert Systems as a specific, a reference database should be created of the in-service quality of signing and road marking across different major road types in up to 8 participating countries

• the results of the road quality survey should become a shared reference for policymakers and road vehicle industries. This evidence base would enable policy development and advocacy as well as benchmarking tolerances for manufacturers and main road operators

“Medium term, when good practice is widely agreed, this could be incorporated in legislation for the TEN-T network to create momentum for adoption on all main roads”

ACKNOWLEDGEMENTS

EuroRAP and Euro NCAP are grateful to the following for help and support in the planning and preparation of this document: Robert Bosch GmbH, Daimler AG, Volkswagen AG, Volvo, Swedish Transport Administration, English Highways Agency, UK ADEPT (Association of Development, Environment, Planning and Transport Officers), UK Department for Transport, Conference of European Directors of Roads (CEDR), European Transport Safety Council (ETSC), Royal Dutch Touring Club (ANWB), German Automobile Association (ADAC), Royal Automobile Club of Catalonia (RACC), Automobile and Touring Club of Greece (ELPA), Automobile Club of Serbia (AMSS), L’Automobile Club, France, Royal Swedish Automobile Club (Motormännin), Polish Automobile Club (PZM), Foundation for Civil Engineering Development, Gdańsk University of Technology (FRL), FIA Foundation, UK Road Safety Foundation (RSF), FIA, eSafety Aware, European Automobile Manufacturers’ Association (ACEA). Additional images courtesy of Neil Moss.
“New working tolerances and quality standards are needed to ensure Europe's roads can be read by 2020 by the cars then on the road. Starting with lane marking and speed sign recognition systems can lead change. There should be focus on the 10% of busy national and regional roads where most die and where most travel takes place”

SUMMARY

Leading road authorities and vehicle manufacturers want quick wins in cutting serious crashes as technology advances. *Roads that Cars can Read* seeks to help remove the institutional barriers that stop road and vehicle engineering working as one Safe System towards zero road deaths.

The paper proposes starting with lane marking and speed sign recognition systems to lead change. Cars with these systems are already at the showroom. It proposes focusing on just 10% of the European network - the busy national and regional roads outside city centres where most die and most travel takes place. It proposes practical reference surveys to measure the real world variation in signing and marking across borders, define new working tolerances and set out the quality standards needed to ensure Europe's roads can be read by 2020 by the cars then on the road.

The cat's eye should not be the last word in linking automobile technology with road infrastructure. If you have knowledge that can help shape the future, please send us your response to this Consultation.