This research considers improving traffic safety on the Trans European Road Network by the harmonisation of fixed traffic signs and road markings. The paper presents, in full, the background to the work and the approach taken. It then summarises the methods used and the results obtained in terms of where traffic signing and marking changes are anticipated to have road safety benefits.

1. BACKGROUND

The continuing increase in vehicular traffic in the EU, together with the greater movement of freight across Europe, has resulted in the need to have dedicated road networks. The White Paper of 1993 (EC 1993) identified serious imbalances in Europe’s transport system. In order to correct these imbalances the common transport policy seeks, and needs, to pursue seven objectives among which it recommends the establishment of a Trans-European Road Network. In theory, this network will help citizens to travel and deliver their goods with minimal hindrance or risk from one end of the EU to the other. The characteristics of the TERN can be characterised as follows:

- Motorways and high quality roads: especially for long-distance traffic, bypassing main urban centres, providing connections with other modes of transport or linking landlocked and peripheral regions to central regions of the EU.
- Links that guarantee drivers a high, uniform and continuous level of services, comfort and safety.

Figure 1 illustrates a version of the network; this includes existing and planned roads. Thus, the TERN is defined by means of maps. However, these maps represent only the routes and not the specific roads which belong to the TERN: in some instances several roads could allow travel along the routes defined by the maps.

The increased importance of the TERN is one reason for the EC to demand better road safety standards. Fixed, vertical traffic signs and road markings accomplish an important contribution to traffic safety. Deployment of traffic signs is a national duty; however, road signing systems on European roads vary between countries. This variation may have a significant impact on traffic safety.
1.1. Previous Harmonisation measures

Signing harmonisation measures and agreements have long existed. The Vienna Convention on Road Signs and Signals from 1968 concerns the design of static traffic signs and represents the basis for international harmonisation. Likewise, the UN ECE (United Nations Economic Commission
for Europe), with its annual meetings, is the international body for further
development of international commitments in the area of sign harmonisation.
Differences between EU countries of the time were previously considered e.g.
in the works of Action Group START (1994) on standardisation of typology on
the Trans European Network, COST 331 (1999) on horizontal motorway road
marking, and RIGHTWAY (2001) on direction signing system.

In the field of standard traffic signs, harmonisation has been implemented to
quite an advanced degree. However, in the field of direction signing and road
markings, the design and permitted colours differ by country. Various road
types within the TERN add to the complexity of signing even though the
European Geneva Agreement of Main International Traffic Arterials 1975 &
1988 (A.G.R.) provides “E” road numbers for the TERN to a large extent.

For new fixed traffic signs and for road markings there are several European
norms (especially EN1436 "Road marking materials – Road marking
performance for road users" and EN12899-1 "Fixed, vertical road traffic signs
- Part 1: Fixed signs") that deal with instructions for technical requirements of
standardisation. However, further work is needed to adapt the technical
requirements of traffic signs and road markings in Europe.

2. AIM AND SCOPE OF THE RESEARCH

An important milestone for traffic safety is the year 2010 by which time the EU
aims to have halved the number of people killed in road traffic compared with
2002 (EC 2001). This research aims to show what role harmonisation of fixed
traffic signs and road markings among EU countries on the TERN could play
in achieving that target. Thus, in this context, harmonisation means the
elimination of significant differences in road signing.

In this research, road signing involves fixed vertical traffic signs and road
markings. Variable message signs (VMS) and other Intelligent Transport
Systems (ITS), and issues related to tunnels and road works were excluded
as they are dealt with in other projects. Nor were factors related to driver
comfort a focal point. The only issue was the safety implications of differences
in road signing among EU countries.

When the differences in directions signing were evaluated, one principal
assumption about drivers was made: the driver has some previous knowledge
of his or her destination from maps or other sources. Drivers, for example,
know in what country the destination city is located. Thus, the demand for a
safe direction signing system need not extend to guiding a driver, wholly
unfamiliar with a map, to reach his or her destination.

3. THE RESEARCH APPROACH TAKEN

Traffic safety is influenced by three factors: exposure, accident rate (accident
risk) and injury severity (Nilsson, 2004; Elvik and Vaa, 2004). Road signs and
road markings may affect accident risk and injury severity if they have an effect on driver behaviour (e.g. Horberry et al., 2004). For example, comprehension of non-local unfamiliar signs can sometimes be very low; even opposite misinterpretations of their true meaning are possible (Shinar et al., 2003). On the other hand, the safety effects of road signs and markings are rarely measurable by accident studies, as crashes are relatively rare events and the contribution of road signs and markings to accidents is exceedingly difficult to directly quantify. Specifically, the most reliable accident statistics are available for fatal accidents. However, the numbers of such accidents are too low to reveal almost any effect of road signs or markings. Thus, the evaluation of potential safety effects of differences in road signs and markings in this study was based almost exclusively on the estimated effects on driver behaviour.

3.1 Driver groups on the TERN

The approach to safety and harmonisation evaluations was mainly from the point of view of foreign drivers on the TERN. Depending on their nationality and destination they were classified as follows with respect to their position on the TERN (Table 1):

<table>
<thead>
<tr>
<th>Driver</th>
<th>Entrance to the TERN</th>
<th>Driving on the TERN</th>
<th>Exit from the TERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 3</td>
</tr>
<tr>
<td>Foreign</td>
<td>Group 4</td>
<td>Group 5</td>
<td>Group 6</td>
</tr>
</tbody>
</table>

Drivers can, of course, belong to several of these groups along their journey. Furthermore, the requirements for road signing on the TERN may differ within each group. Two basic differentiating factors between drivers are the language used on the signs and unfamiliarity with the road signing system. Both can increase the driving task demands within the traffic situation. This study focused on foreign driver groups 4-6. However, the domestic driver groups 1-3 have to be considered in order to check that the TERN and national systems do not conflict.

Drivers may differ not only in their knowledge of the road signing system, but also in terms of their driving capabilities. The proportion of older drivers in road traffic is increasing all over Europe (European Conference of Ministers of Transport, 2001). Age-related decline in driving abilities (e.g. McKnight and McKnight, 1999; Simões, 2001) may cause safety problems, especially on unfamiliar roads where the amount of information can exceed the capabilities of the driver. This, of course, also concerns the average (non-older) driver. Thus, accident prevention strategies should focus on critical mismatches between driving task demands and driver capability (Fuller, 2005).

3.2 Drivers' information processing

Driving is mainly based on visual information input. There are many types of visual information, but road signs and road markings are important because
they can provide relevant information for the driver to execute his or her task. Therefore, road signing may constitute an important road safety factor. The characteristics of road signing may have negative effects on traffic safety in the following cases (e.g. Castro and Horberry, 2004):

- The driver does not detect the sign/marking;
- The driver is not able to identify the sign/marking properly;
- The driver does not understand the sign/marking;
- The driver does not have enough time to (a) decide and (b) take the action(s) needed;
- The sign/marking does not meet the driver’s expectations;
- The sign’s message is not heeded by the driver (does not change behaviour);
- The information on the sign is wrong / inappropriate;
- The driver does not remember the sign for the necessary time.

Based on these criteria, specific evaluations were conducted in this research that provided information on whether and to what degree the differences in road signing between EU member states are relevant to safety.

In order to avoid the above negative effects, several criteria must be met for symbolic signs to be effective. Dewar (1999) provides general guidelines for the design of public information symbols. These guidelines are utilised in our study for the design of symbolic traffic signs. Initially, the sign must command attention or be easily detected by the driver. Traffic signs usually meet this criterion relatively well if standardised colours and shapes have been used. The signs must be legible at the appropriate distance and must be legible when seen for a brief time or under adverse viewing conditions (e.g. low illumination, glare, etc).

Given that there is a set of traffic signs, including several relatively similar visual objects, they must also be distinguishable from each other. In addition to the legibility of an individual sign, the driver is expected to detect and identify all traffic signs that are relevant for his or her driving task.

On the other hand, the road environment frequently includes too much information for drivers to allocate their attention sufficiently to all directions needed (e.g. Cohen, 1987; Luoma and Janson 1990). Information overload is especially high in unfamiliar environments which also results in high accident risk (Engels and Dellen, 1989). Too frequent signing is a particular problem that has been recognised for years. The density of traffic signs and the amount of information provided by the direction signs are too high in some locations. Consequently, traffic safety may decrease due to increasing difficulties in the acquisition and processing of relevant traffic information, and thereby result in hazardous behaviour. Some road authorities have guidelines for the maximum number of signs on one pole and the maximum number of destinations on direction signs as well as the minimum distance between signs. However, in most cases these guidelines are not based on comprehensive scientific evaluation.
If the driver has detected a sign and identified the sign type and the symbol, his or her task is to interpret the message of the sign. In general, both the sign type and symbol must be clearly understood and the action to be taken in response to the message should be immediately obvious. Comprehension has been assessed to be the most important design criterion for traffic sign pictograms, followed by conspicuity, reaction time and legibility distance, although little empirical evidence is available (Dewar, 1988).

As Dewar (1999) underlines, these various criteria can be in conflict. For example, the specific features of symbols increase their understanding. At the same time, however, the legibility may decrease (Luoma, 1981). This conflict suggests that a sequential-component approach to sign design and modification to enhance both legibility and understanding should be applied (Dewar, 1999).

3.3 Hierarchical levels of driving task

The driver's basic task is to drive the vehicle safely from A to B. In order to perform this task information processing is needed at three levels (Fig. 2).

The strategic level comprises the general planning of a trip, route and modal choice. The manoeuvring level includes controlled action patterns such as turning at an intersection, overtaking, interaction with other road users, etc. The time taken for these actions is short, typically a few seconds. However, operational tasks need decision making within an even shorter time of milliseconds. This level of decision-making includes vehicle control such as keeping to a lane.
3.4 Road markings as a road guidance tool

Although the function of road signs and road markings is complementary, they also differ from each other in some respects. Road markings help drivers to keep the vehicle on the road and to anticipate the road alignment ahead. This is especially critical in poor visibility conditions (dark, rain, etc) when other aspects of the road environment give the driver fewer cues for lane-keeping and manoeuvring tasks (Rumar & Marsh, 1998). Road markings also define permitted areas for overtaking and lane changes on the road. Road markings often also support the (legal) information provided on road signs.

Figure 3 shows the ways in which road markings can influence traffic safety by altering the drivers’ time available for vehicle control. The controversial aspect of road markings is that they sometimes increase driving speeds (van Driel, Davidse & van Maarseveen, 2004), cutting the available time for avoiding potential hazards. An increase in average speed by 1 km/h raises the number of road fatalities by 6% (ETSC 1995, Ranta & Kallberg 1996, Andersson & Nilsson 1997). However, drivers also need visual guidance that enables them to follow the road without paying too much attention to the lane keeping task at the expense of some other information relevant to safety. This is especially important for motorways with high speed traffic and for primary roads with oncoming traffic. Drivers have been hypothesised to use two road-guidance functions, short- and long-range guidance (Rumar & Marsh, 1998). Actual lane keeping is based on information close to the vehicle obtained through peripheral vision (e.g. Land and Horwood, 1995); road markings, for example, provide cues for lateral position. Thus, clearly marked centre and edge lines are likely to enhance the lane-keeping task. Long-range guidance involves a more conscious prediction of the driving course by using central vision. When road markings are visible, they play a key role, especially in the dark, in directing the driver’s attention to long range guidance. Profiled road markings can also be used to raise the level of vigilance.

![Diagram](image)

**Figure 3.** Road markings as a road guidance tool from the safety perspective.
Based on more than 30 studies, Elvik & Vaa (2004) concluded that "The majority of road marking measures appear to have relatively little effect on the number of accidents." This did not include shoulder rumble strips and distance markers on motorways which can reduce certain kinds of accidents significantly (e.g. vehicles drifting off the road). In addition, combinations of road markings may have safety effects.

4. RESEARCH METHODOLOGY

To undertake the research, this study first focused on differences in road signing on the TERN between EU countries, and then assessed the effect of these differences on traffic safety from the viewpoint of costs and benefits. Thereafter, the work developed four harmonisation scenarios. Finally, institutional analysis was undertaken to elucidate the implementation steps and EU actions for harmonisation. Specifically, this research proceeded with the following Work Package structure:

- The first Work Package comprised a review of earlier harmonisation work and research at supra-national level and conducted a major survey of road signing practices among EU countries. It identified safety critical and institutional aspects of road signing between these countries.
- The second Work Package evaluated and classified differences in road signing based on their likely driver behavioural effects. This produced a list of harmonisation needs.
- The third Work Package identified harmonisation measures in different time spans and estimated probable costs and safety benefits of these measures. The basis for the cost-benefit results were estimations based on rational assumptions; the aim was to get an impression of the utility of the measures.

As the first step here, this work calculated both the number of fatal and injury accidents on the TERN and the costs of each accident type. Based on TERN length, percentage of TERN that is motorway/non-motorway and overall accident data on motorways in EU countries the number of fatal accidents on the TERN was calculated to be almost 5,000 per annum. Likewise, overall EC costs of fatalities and injury accidents were calculated based on previously published costs (for example, basing the average cost of a single fatality at 1 million Euros).

Thereafter, the costs and benefits were individually estimated to assess the harmonisation needs. Data on the number and cost of particular types of signs in different countries were used to derive a broad estimate of the costs that would be associated with changes to particular signs or markings. For benefits, previous research and expert judgement were used to estimate the potential accident savings from the different sign and road markings harmonisation measures. Where applicable, the so-called 1-million-Euro-test was employed; this rule-of-thumb proposes that every measure that costs less than 1 million
Euros per prevented road death is considered to be economically justified.

- The fourth Work Package elaborated further the results from a workshop among project partners and from the earlier Work Packages, creating four harmonisation scenarios, including recommendations on how to improve traffic safety on the TERN.
- The fifth Work Package showed how the scenarios and recommended harmonisation measures should be carried out and who should take the initiative.

Full details of the research methods used in this work can be found in the IMPROVER SP4 report (2004).

5. SUMMARY OF THE RESULTS OBTAINED

The results presented here focus on the latter parts of the research: in particular, the results of four harmonisation scenarios. The authors believe that harmonisation of road signs and markings among EU countries may possibly prevent a significant number of road deaths on the TERN by means of the following scenarios, actions and recommendations:

The first scenario showed harmonisation of relatively low cost measures that could be realised in the short term. The first estimation of the measures showed that the safety benefits should exceed the costs within one year. An efficient way involving road signing to improve traffic safety on the TERN could be to harmonise the use of:

i. Exit lane countdown marker signs to all motorway exits and intersections,

ii. Retro-reflective road markings on the whole of the TERN,

iii. Better pre-trip information on the World Wide Web about the existence and meaning of various road signs and road markings for motorists in Europe.

The second scenario consisted of urgent harmonisation needs, but the exact means for harmonisation are not known until further work and research is undertaken. The task of driving safely on the TERN would be supported by the harmonised use of:

i. E-road numbers (only on E-roads which cross at least one border and only at their intersections) and

ii. Exit numbers on motorways.

A quick way to improve the situation according to first estimations would be to modify existing signs by means of adding ‘patches’ with E-road and exit numbers. However, national direction signing systems are different and therefore the solutions of how and where the numbers should be added may vary from country to country. For a final assessment of the value of these measures a concept for realisation has first to be developed. Based on this concept, costs have to be derived reliably. Since an exact safety benefit is hard to quantify, the number of accidents that the measure could affect has to be determined in order to get an impression of the maximum number of accidents that could be prevented.
Further research aiming to find out what is best practice is necessary concerning the following matters:

iii. Direction sign positions at intersections,
iv. Maximum number of destinations and letter size in direction signs,
v. Road numbers as a destination.

The authors believe that harmonisation of the above could produce significant road safety benefits. These harmonisation measures first require further clarification of, and research on, drivers' information processing capabilities in relation to inputs from the road environment. Nevertheless, the costs of these analyses are estimated to be minimal compared to the potential safety benefits after implementation. However, the costs of implementation cannot yet be predicted as the needed measures for harmonisation depend on results from studies.

The third scenario involved long-term measures, as the costs of harmonisation exceed the estimated safety benefits likely to be obtained in a single year. However, the harmonisation need is high-priority and safety would improve through:

i. Extending the use of profiled road markings and
ii. Improving night-time visibility of road markings.

Both should be applied on road sections with high accident rates (only accident types have to be considered on which road markings might have an effect) in the first instance.

The fourth scenario comprised a variety of details (14 aspects in total) in road signing differences among EU countries. Their safety effects were not assessed to be high separately, but together they demonstrated the clutter and inconsistency that foreign drivers have to face on the TERN. Thus, the combined effect of harmonisation may be substantial as it meets the general demand for continuity and uniformity of road signing on the TERN in the long term. Examples of these 14 aspects include:

• Criteria for the use and implementation of road studs
• Bilingual signs. If bilingual signs are used, potential overload problems should be minimized by limiting the total amount of information on the signs.
• Harmonisation of the background colour of destination signs.

6. CONCLUSIONS AND RECOMMENDATIONS

The authors argue that the harmonisation of road signing and markings among EU countries may prevent a significant number of the estimated 5,000 annual road deaths on the TERN through the implementation of measures contained within the above four scenarios.

6.1. Recommendation on updating the Vienna Convention

Further updating of the Vienna Convention is particularly recommended, as it offers an existing framework for
harmonisation. Further updating could be grouped into reasonable packages that would allow quicker ways towards harmonisation and the possibility of maintaining balanced and coherent changes. The changes to the Vienna Convention could include the following:

- Rules on the maximum number of destinations and size of lettering with respect to cross-border long distance traffic.
- Definition of minimum retro-reflectivity classes for different types of fixed road signs on the TERN.
- Criteria for the use and implementation of road studs.

We believe that the implementation of these recommendations will make a significant contribution to traffic safety in the EU.

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