The role of the safety aspect in European road design

Contribution to the Seminar 'Road Safety; Meeting Road Casualty Reduction Targets', Tunbridge Wells, March 20, 1996

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1. Introduction

Traditionally, in European countries, road design standards as well as traffic regulations were matters of national interest. As geographical, historical and psychological conditions differ largely between countries, it is to be understood that particularly road design was primarily treated on a national level. But traffic tends to cross borders and with the increase of international traffic, harmonization of both regulations and design standards is becoming more expedient.

With regard to the harmonization of the regulations, certain progress has already been made. The transition from national design standards towards international standards, however, is a very complex and time consuming process.

The most important organization in this respect is the European Union. Only this international organization can enforce by legal means, the agreements that may be reached. With the Maastricht treaty, new fields of competence were attributed to the Union. A new provision on road safety was inserted in article 75 and a whole new chapter on Trans-European networks (article 129) was added.

Given the discussions about 'subsidiarity' in the EU, the European Commission started to stimulate exchange of knowledge and commissioned several studies to identify the main points of interest, also in the field of road safety and infrastructure design. Later, the European Union can (and will) evolve towards the principle actor in this field, when Member States delegate power to the Union and the Union can (and will) enforce that power with legal means.

In the field of infrastructure, the Union is establishing a network, called the *Trans European Road Network* (TERN). This network was formally approved by the Council of the EU (CEE, 1993), but it will have to be approved once more along the new cooperation procedure. This procedure, also introduced by the Maastricht treaty, gives more rights to the European Parliament. Meanwhile, working groups have to provide the necessary background for this network. One of those working groups called START (Standardization of Road Typology) is elaborating road design standards (START, 1994).

2. Safety effects of road design standards

To be of assistance to START, a study was commissioned by the European Commission to SWOV Institute for Road Safety Research. The study called *Safety effects of road design standards* ' (Ruyters et al., 1994) was carried out in cooperation with a number of other European institutes. Its objectives were:

- to gather information about existing knowledge on the design of road infrastructure elements by:
  - a. drawing an inventory of *international* treaties and recommendations, with information about their legal status;
  - b. drawing an inventory of *national* road design standards and the underlying knowledge;
- to analyse the role *safety* arguments have played when road design standards were compiled;
- to draw a 'best practice' for road design standards in which considerations, background information and assumptions concerning road *safety* have been made explicit.

In the following sections, I will mention some results of the three items. It is obvious that the focus in the last two objectives was fully on the safety aspect.

2.1. Existing situation

Road design standards play a major role in road design in almost all EU Member States. But some important problems exist in this field. First of all, not all countries have road design standards for all *types* of roads. And if they have so, these standards are not always applied. When standards are applied, space of interpretation can lead to different road design even in the same jurisdiction. Also, there is no accordance between various countries on this subject. In *Table 1* (Ruyters, 1994b), it is indicated which Member States[1] have their own national standards, and which of these standards are mandatory.

	Rural		Urban	
	mandatory	non-mand.	mandatory	non-mand.
Belgium	X			
Denmark	X	X		X
France	X			
Germany	X			X
Greece				
Ireland		X		
Italy	X		X	
Luxemburg				
The Netherlands	X	X		X
Spain	X	X		
Portugal	X	X		
United Kingdom	X	X		X

Table 1. *Availibility of road design standards in EU countries.*

[1] Data was collected from the 12 Member States at that time, which means that information on the three new Member States (Austria, Finland and Sweden) is missing.

Table 2 (Ruyters, 1994a) gives a schematic representation of all international agreements or other cooperation forms, which are of relevance for road design and traffic operation.

Title	Year	Body
Convention on Road Traffic	1949 and 1968	UN-ECE
European Agreement	1971	UN-ECE
Convention on Road Signs and Signals	1949 and 1968	UN-ECE
European Agreement	1971	UN-ECE
Protocol on Road Markings	1973	UN-ECE
"European Highway Code"	1975	ECMT
"European Road Traffic Rules"	1990	UN-ECE
European Agreement on Main International Traffic Arteries (AGR)	1975 (amended annexes 1988)	UN-ECE
TEM - Standards and Recommended Practice	1992	UN-ECE
TERN	1993 (and 1995?)	EU

Table 2. *International agreements.*

Besides the 1968 Conventions on Road Traffic and on Road Signs and Signals, supplemented by the 1971 European Agreements and the 1973 Protocol on Road markings, the European Agreement on Main International Traffic Arteries (AGR) is of importance. The main text defines and establishes the international E-road network. In one of the Annexes to AGR, information can be found on the classification of international roads in relation to their geometric characteristics: general considerations, horizontal and vertical alignment, cross-section, intersections and 'equipment, environment and landscaping, maintenance'.

However, the classification of roads seems to be a weak point: the category of motorways is clearly defined, but express roads are not; the ordinary roads (also to be found within the E-road network!) are left almost without any values or standards.

Table 3 gives one example of the situation, based on information collected by O'Cinnéide et al. (1993). For different design speeds, the values for the minimum horizontal curve radius are given per country. Not for the sake of harmonization as such, but for the underlying safety reasons, it is to be found out whether some form of agreement on design standards can be reached. A research programme supporting the compilation of common road design standards is recommended because such a situation is expected to be more effective and productive, predominantly for the improvement of road safety.

	Minimum horizontal curve radius (m)											
Design speed	140	130	120	110	100	90	85	80	70	60	50	40	30
AGR	1000		650		450			240		120			
Austria	1000		700		450			250	180	125	80	45	
Belgium			750			350				130			
Denmark			872		492			265		130		50	
Finland			1100		650			350		170	110		
France			665		425			240		120			
Germany			800		500	380		280	200	135			
Greece			500		350			200	140		75	50	30
Iceland					450	350		250		125	80		
Ireland			600		400			240		130		50	
Italy	965		667		440			260		120		40	
Netherlands			750		450*	350		260*	185	130*	85		
Norway					430	320		230	160	110			
Portugal			700		450			230	170	120	80	40	
Spain	1000		650		450			250					
Sweden				625	500		350				160		
Switzerland		780	650		420			240		120			
United Kingdom			720		510		360		255	180	127		
TEM	1000		650		450			240					

Note: Above values represent "Absolute Minimum" for UK and "Minimum" for all other countries.
* Non-Motorway Design Speeds (NL)

Table 3. *Minimum horizontal curve radius for different design speeds in European countries.*

Besides with the problem of different design standards we are confronted with different philosophies regarding the application of the standards: when and how may one depart from the standards and what will be the safety consequences of such departures? This leads to the recommendation to look for the best practice concerning procedures for relaxations or departures from standards, whether they are mandatory or not. Secondly, it calls for a research programme in which safety consequences of design standards and departures from these standards are made as explicit as possible.

2.2. Preliminary considerations regarding the safety aspect

Each year, accidents are the cause of about 50,000 deaths and more than a million and a half injuries on the roads of the European Union. This high toll due to road accidents is considered as unacceptable, by all Member States and by the European Union itself.

To reduce road hazard, all countries have been taking and still take such kind of measures as legislation followed by police enforcement, improvement of road infrastructure and improvement of vehicle standards.

Although it is hardly possible to assess the effects of individual measures on road accident figures, road safety can be influenced in a positive way.

The cause of a traffic accident is seldom very simple to be assessed. More often, a number of circumstances play a role, in which man, road and vehicle are all of importance. Research reports from different countries conclude that 95% of the accidents are - at least partly - due to human error, 30% result from faults in road design and 10% are the result of mechanical defects (Rumar, 1985; total more than 100% because of occasional multiple causes).
One conclusion sometimes drawn from this is that directly addressing the road users by education, information, police enforcement, training etc. is the most important way of preventing accidents. This conclusion is erroneous. Are not road improvements, for instance, also intended to prevent human errors?

Erroneous conclusions might also be drawn if one relies on police reports in which the question of guilt is settled. At least one person involved in an accident has always violated the law in some way. However, this does not say anything about the most effective way in which the accident could have been prevented.

Road users are called road users because they use roads. The way they do this is to a large extent determined by the shape, the layout, the features and the properties of the road. Proper road design is crucial to prevent human errors in traffic, and less human errors will lead to less accidents. Thus, proper road design can further reduce the number of accidents and the accident rates compared to the existing situation in Europe.

The next question is, of course, which road design can be regarded as - 'proper'. This problem can be treated in a more traditional and in a revolutionary way. The revolutionary way will only shortly be presented in Section 4.

Starting with the *traditional* way, it must admitted that the relationships between road features and safety are still not well understood quantitatively. The finding of clear relationships between road design and road safety is obscured by a variety of factors (driver, vehicle, risk increasing circumstances, traffic regulation).

Most national road design standards give definite instructions for the layout of the various elements of a road, but information on the background of these instructions is only rarely added. There is mostly no indication of the relative importance that was given to road safety in comparison with traffic flow, easy reach of destinations, environmental interests, costs, etc. Often, it is not even clear to what extent a certain standard was based upon factual figures and relations, and to what extent upon underlying assumptions.

When checking carefully the figures needed to arrive at a sound road design it turns out that *factual* figures constitute a minority; most figures are *assumed* ones albeit that the assumptions can usually be considered as being of a universal nature: they are not likely to vary between countries because they refer to figures with a predominantly objective character, such as human reaction time, friction coefficients, dimensions of design vehicles, acceptable gradients.

At least, they should not vary. Yet, assumptions of this kind are not at all identical in the national standards. This partly explains the differences in certain values for concrete design elements in the various standards. This conclusion requires to first harmonize the underlying assumptions.

More generally speaking, when designing a road frequent use is being made of figures and relations, but not all figures and relations used are equally firm. A distinction must be made between factual and assumed figures and relations. It is essential to have knowledge about this, when talking about harmonization. An attempt to classify the standards with regard to their firmness was made in the Dutch standards for roads inside built-up areas. The facilities described in those standards are distinguished by means of a star system, as follows:

*****	*regulations* to be complied with;
****	*guidelines* which can be deviated from only with a sound motivation;
***	*recommendations* to be preferably followed because it is assumed that their effect is favourable;
**	*suggestions* of which a favourable effect is expected;
*	*possibilities* of which a favourable effect is suspected only.

There is a need for a better understanding of the degree of technical firmness of respective standards, with special regard to the safety aspect. This information, reflected in a differentiation of the status of each standard, as just presented, will enable the designer to make use of it in the most appropriate way.

To meet the need for departures from the standards, a practical possibility might be to indicate margins around certain values, which may be used by the designer 'in emergency'. As international harmonization is concerned, the very question how to treat departures from standards will repeatedly be raised. This requires a set of well-founded instructions indicating when departures are tolerated.

2.3. Some results from detailed studies

For the identification of the main criteria for road *cross-section* dimensions, three sources were taken into consideration (Michalski, 1994):

- existing knowledge concerning the relationships between road geometry and operational, economical and safety aspects;
- conclusions from the comparison of dimensions provided in different standards;
- facts and assumptions presented in national guidelines.

The comparison of *motorway* cross-section width showed relatively great agreement between standards. The majority of countries uses a lane width of 3.75 m. The width of 3.25 is rarely used and only for a design speed of 90 km/h. However, from a safety point of view it can be stated:

- Widening a traffic lane over 3.5 m causes no significant improvement of the accident rates; so a lane width of 3.5 m can be recommended.
- Safety effects of 3.25 m lane width for urban motorways should be investigated in order to determine safety consequences and using conditions.

For paved shoulders (emergency stopping lanes), only two countries use a width below the value tentatively recommended by START, i.e. 2.5 m.
- Widening a paved shoulder over 2.5 m causes no significant improvement of the accident rates.

This would mean that a total width for 2 traffic lanes and a paved shoulder could be less than 10 m. However, it is also recommended:
- The safety effects should be investigated of a total pavement width for one carriageway of a 2x2-lane motorway of about 11.5 - 12.0 m, which is required for maintenance reasons (to enable temporary use of one carriageway as a four-lane two-way road).

Non-motorway divided roads showing one or more motorway characteristics have high accident rates. The use of wide paved shoulders on these roads in some countries results from additional factors like road network structure, landscaping and multifunctional road links. Even though wide paved shoulders on these roads can have some safety advantages, the possibility of emergency stopping is probably only a minor benefit. Therefore, a paved shoulder with a width comparable to the full width of an emergency stopping lane seems not to be necessary; safe bays (lay-bys) can be a cheaper and effective alternative.

Undivided rural roads have considerably different dimensions of traffic lanes and shoulders. In several cases, two-lane roads do also have paved shoulders, and are occasionally used as four-lane roads. Based on safety research one can conclude:
- Cross-section dimensions with environmental features should make the impression of a 'narrow cross-section' being simultaneously a 'wide soft road space'.
- Four-lane undivided roads should be avoided in rural areas.
- On higher speed roads of this kind, a paved shoulder can have a width of 1.8-2.0 m; a different colour or type of paving should stress the special functions of these lanes, different from the functions of the main lanes.
- The application of emergency lay-bys every kilometre and wide verges can be recommended to design practice.

For a strategy with respect to the design of *verges* (Schoon, 1994), three general design principles can be distinguished which are applicable to both divided and undivided roads:
- A fully obstacle free zone is regarded as the safest of all; there are no hazard areas or obstacles. Vehicles leaving the road can go on running freely or perhaps can be brought under control.
- Second best is a zone with single obstacles. Roadside equipment such as lighting poles and traffic signs has to be designed in a way that, if hit by a motor vehicle, it does not endanger the occupants. The rigid objects, if there is no way to remove them, will have to be protected

separately (i.e. with a crash barrier of short length or with an impact attenuator).
- In the relatively least safe situation, there is a hazard area close to the carriageway. This should entirely be protected lengthwise by a crash barrier, creating a fully protected zone.

A survey on cross-section design standards showed a European agreement on how median and shoulders should be protected by crash barriers. However, it is unknown whether these guidelines are being followed. Moreover, a road safety assessment could indicate whether recent developments of the circumstances on the roads (higher masses, less space) ought to result in new design standards for roadside features.

Less agreement exists between countries regarding the safe design of the unprotected medians and shoulders. Especially, the question remains to establish the widths of the obstacle free zones, so that no crash barriers are required.

Another study focused on *bends in two-lane roads*. Statistical research (Brenac, 1994) has shown that the accident rate (accidents per vehicle kilometre) is high for low values of horizontal radius, and decreases when the radius increases. However, according to several studies, the alignment in which a curve occurs is also very important in the determination of the safety at this curve. The accident rate at small radius bends is very high when the average curvature of the whole alignment is low, but relatively low when the average curvature is higher. High accident rates are observed at a bend when it follows a long straight section, when its radius is smaller than the radii in preceding bends and when the number of bends per kilometre is low.

Other factors found as unfavourable for road safety were: a severe bend in a steep down grade and a short sight distance (during the approach) on the bend or on the end of it.

Some studies show that internal factors (factors depending on the design of the curve itself) also have important effects on safety, especially at bends having a small or medium average curvature. The main defect is irregularity of the curvature inside the bend, characterized by the presence of locally very small radii compared to the average radius of the bend. In bends with a transition curve, the perception of the bend deteriorates and results in an over-estimation of the final radius and of the possible speed.

Regarding the curves, most standards in Europe have a sort of common basis which contains the design speed concept and rules concerning the minimal values of some main characteristics (especially the radius of the curve). However, from a safety point of view, the conclusion is justified that the definition of a minimum radius depending on the design speed is both insufficient and unnecessarily constraining. Therefore, some countries take the actual speeds into account and/or define the conditions for the succession of different elements of horizontal alignment.

The introduction of the 'actual speed approach' can be considered as an improvement. But even if this approach is properly implemented, it does not appear sufficient to avoid some alignment inconsistencies resulting in safety problems.

Thus, recommendations concerning consistency in the succession of the different elements of the horizontal alignment (radius of a curve following a straight section, compatibility of radii of two near curves) seem also necessary. For instance, the use of complex curves containing a succession of circular curves and transition curves in the same direction may generate safety problems and should be avoided. Moreover, the rules for the calculation of the length of transition curves should be re-analyzed.

Concerning the *signing* of curves and its effects on safety, it seems that research results are still not sufficient to constitute a solid background for improving standards. With regard to the use of signing in relation to the difficulty and situation of the bend, the lack of an homogeneous approach is also to be mentioned: in the national regulations, there are not always formal rules for using or not using signs (bend signs, chevron boards) at bends, and when they exist, they are rather different from one country to another, and even inside one country.

Vertical, regularly spaced elements of delineation along the outer side of the curve give information directly useful for the perspective task (estimation by the driver of distance, own speed, curvature). Unless the delineation is provided on the entire road section, and not only at curves, reverse effects due to an increase of speeds are possible.

3. SAFESTAR

As a follow-up of the project described in Section 2, a new project will start next month, called SAFESTAR (Safety standards for road design and redesign). It is more specifically aimed at developing safety standards for highway design and redesign. The following quote clearly indicates the motivation for this project.

In order to enhance road safety in Europe, continued improvement of road design standards is required. In fact, it has been estimated that engineering improvements on roads have made up one of the main factors behind the reduction in casualties on the roads of the EU countries in recent years. The objective of this research is to capitalize on this work and develop appropriate standards for road infrastructure. These standards would help to install good practice on all types of road throughout the Member States.

Final technical standards, or even proposals for these, cannot be produced from a safety perspective only. Therefore, the outcome of this research will at most be safety arguments for selecting certain design elements or for recommending certain dimensions. However, safety is usually among the criteria that are allowed for too implicitly: at every step in the design process, the designer is supposed to take decisions with safety in mind. Thus, at the end of the process, it is difficult to judge to which extent safety has really been taken into account.

In general, safety can be considered at four different levels:
- safety achieved through specific attention paid at every step during the detailed road design process;
- safety achieved through adherence to norms and standards of road design;
- the level of safety that can be achieved through road classification;
- the (explicit) amount of safety offered by the conceptual transport system satisfying the need for mobility.

The last three issues ask for a system of standards to be proposed as a result of this SAFESTAR project. This system could at least be used as a reference, and at most as an official international agreement. Carrying out the project at the level of the European Union will make it possible to promote uniformity in the best practice of safety standards throughout the Member States, which is important in the efforts of fulfilling the Union policies, in particular the common transport policy.

The European Commission indicated the aim of the SAFESTAR project as (SWOV, 1995): "Development of safety standards for highway design and redesign of all classes of road, including tunnels and bridges, taking account of the proposals for technical standards made in the TERN report".
The TERN report is a report prepared by the START working group mentioned earlier.

After analysing the TERN report a research consortium, comprising nine European research institutes, put together a programme, consisting of eight work packages (WP). The following information is to shortly introduce this research programme.

WP 1: Motorways; emergency lanes, shoulders and verges
Objectives: Based on an (in-depth) analysis of accidents on TERN motorways related to the use of emergency lanes and/or to vehicles leaving the carriageway, production of an accident typology and preparation of a first proposal how to prevent these types of accident or to reduce the severity of these accidents.

Two fields of activities were proposed:
- specific safety measures for emergency lanes on motorways;
- criteria for safety devices on motorways and express roads.

WP 2: Tunnels on motorways
Objectives: To guarantee safety in longer tunnels, including entries and exits, it is necessary to assess to what extent it is acceptable to deviate from standard motorway design criteria, and what additional criteria should be used.

Three fields of activities were proposed:
- literature review
- tunnel design
- validation of design features in simulator

WP 3: Express roads
Objectives: To produce safety standards for this road type, which has a poor accident record, often explained from its ambiguous character.

Three fields of activities were proposed:
- accident analysis
- decision-making process in (some) EU Member States
- formulation of safety standards for express roads

WP 4: Cross-section of rural roads
Objectives: To find out the safety advantages of different kinds of rural single carriageway TERN cross-sections under different conditions.

Three fields of activities were proposed:
- safety evaluation of different kinds of cross-section
- analysis of head-on and run-off accidents
- alternative measures to prevent severe accidents

WP 5: Design of curves in rural roads
Objectives: The development of models to predict speed profiles in TERN two-lane single carriageway roads as a way to detect speed inconsistencies in curves and to develop a method to detect road geometric design inconsistencies which create speed patterns and manoeuvres leading to accidents.

Five fields of activities were proposed:
- literature review
- preliminary speed profile and design consistency models
- validation of assumptions regarding constant acceleration and deceleration
- verification and improvement of models
- best practice

WP 6: Marking of bends in rural roads
Objectives: By means of an experimental study testing different marking principles, i.e. by vertical signs and/or horizontal markings, to develop an efficient concept for the marking of bends in various danger categories.

Four fields of activities are foreseen:
- review of national rules and guidelines for marking bends and literature review
- defining of danger categories for bends and development of marking principles
- pre-testing in driving simulator
- full scale tests

WP 7: Junction design
Objectives: To establish basic knowledge and relationships between junction and traffic characteristics on the one hand, and safety indicators on the other hand. This knowledge should form the basis for establishing effective safety standards for junctions. Special attention will be given to roundabouts and signalized junctions.

Four fields of activities were proposed:
- review of knowledge on rural junctions
- review of knowledge on urban junctions
- empirical studies of urban junctions
- compiling the results in safety standards for junctions

WP 8: Safety audits
Objectives: To establish tools and procedures (strategical and practical) for a Road Safety Impact Assessment (RIA), including road safety audits, to be applied for new road schemes in the EU countries.

Three fields of activities were proposed:
- compilation of existing tools and procedures, and experiences with safety audits
- testing in practice of promising tools and procedures
- formulation of a 'best practice'

The research programme will take 24 months. Partial reports will be produced twelve months after the start of the project; they will be discussed with all partners and with representatives of the Commission, the START working group and national road authorities. Such a meeting is also foreseen shortly before finalizing the project, in which an attempt to integrate all research results will be very crucial.

4. Sustainable road safety

The *revolutionary* way of treating the question of proper road design is part of a new concept aiming at what is called 'sustainable road safety' (Slop, 1995).

The concept of sustainable road safety is based on the idea that *man* is the reference standard. Human beings are capable of many things, but present-day traffic makes excessive demands on their abilities, causing them to make mistakes, often with fatal consequences. Our task is to adapt the traffic system to people, so that they can behave safely, instead of insisting that people adapt to the system - on penalty of death or permanent mutilation. In other words, the objective is to create a system in which road users are virtually unable to make errors - and if they do, the consequences will not be serious.

Taking man as the starting point implies also that, as far as possible, his needs are met, his motives are taken into account and his task in traffic is facilitated.

Compared to the traditional way of organizing traffic, a sustainably safe traffic system is composed of:

- an *infrastructure* that is better adapted to the limitations of human capacities;
- *vehicles* fitted with more devices to simplify the tasks of man, and better constructed to protect the vulnerable human being;
- *road users* who are more adequately educated, informed and, where necessary, controlled.

This structurally safe traffic system should be shaped in such a way that human errors are prevented as much as possible.

I am confining myself to the infrastructure here. As to this aspect, the key to arrive at sustainable safety lies in the systematic and consistent application of three safety principles that reduce in advance the liability of encounters with implicit risk. The three safety principles are:

1. A *functional* use of the road network, by preventing unintended use of each road;
2. A *homogeneous* use, by preventing large differences in vehicle speed, mass and direction of movement;
3. A *predictable* use, thus preventing uncertainty amongst road users, by enhancing the predictability of the road's course and of the behaviour of fellow road users.

The word 'prevention' is constantly used. This policy can indeed be characterized as a *preventative* one, which precludes the incidence of accidents as much as possible. This is in contrast to the more curative, and hence retrospective, traditional policy.

The first principle: a functional use of the road network, calls for first establishing the intended function of every road.

Roads are built with one major function in mind: to enable people and goods to travel from one place to another. We call this the *traffic function*. A distinction can be made between the following aspects:

- the *through* function: enabling rapid processing of mainly long distance traffic;
- the *distributor* function: serving districts and regions containing scattered destinations;
- the *access* function for traffic: granting direct access to destinations along a road.

The distinction between the functioning of roads described here is often not so clear. In the present situation, most roads are *multifunctional*. This is when problems arise because, then, roads and streets are expected to fulfil two or three incompatible functions in varying combinations. On such roads, the road user generally has to guess what to expect from the situation, and is not sure what others expect from him. This results inevitably in a large number of conflicts.

Multifunctionality leads to contradictory design requirements. Therefore, in a sustainably safe infrastructure, every road is, in principle, appointed only one specific function. This concept comes down to the removal of all function combinations by making the roads *monofunctional*.

In this approach, therefore, only three categories of road can be distinguished as regards traffic function: pure through roads, pure distributor roads and pure access roads.

It goes without saying that after reorganization of the road network into these new categories, it must be ensured that the roads and streets are designed and organized such that they optimally meet the corresponding functional requirements. A guarantee of optimal safety can be achieved by applying the other two safety principles: preventing differences in vehicle speed, mass and direction, and preventing uncertainty amongst road users. An important effect of the latter two principles is the careful selection of vehicle category combinations (and pedestrians) who are permitted to share the same traffic area.

If the functional classification of the roads is properly carried out, with a matching layout of the roads, the actual use of the roads will also agree.

Before sustainable road safety was thought of, the application of the safety principles mentioned had, to a large extent, already been successful on motorways and in 30 km/h zones. If properly implemented, each of these two road types performs virtually one function: motorways realize a through function, and 30 km/h streets an access function for traffic. As a consequence of this, these two road types show a relatively low accident risk. In contrast, arterial urban roads and non motorway rural roads, mostly multifunctional in their usual present appearance, demonstrate much higher risks.

5. Conclusions en recommendations

Proper road design is crucial to prevent human errors in traffic and less human errors will result in less accidents. It is to be expected that proper road design could reduce considerably the number of accidents and the accident rates compared to the existing situation in Europe.

Road design standards play a vital role in road design in all EU Member States, but major problems exist in this field: not all countries have road design standards for all types of roads, road authorities do not always apply their standards, some space for interpretation is possible, road safety arguments are dealt with rather implicitly in design standards and there is no accordance between various countries. Underlying to this, the relationships between road features and safety are not always well understood quantitatively.

The unavailability and non-accordance of road design standards for the road network in Europe increase risks and therefore contribute to the actual size of the safety problem on this continent. As the cross-bordering traffic increases, it becomes even more valid from a road safety point of view to harmonize road design standards on the level of the European Union and to expand this harmonization to other countries e.g. Central and Eastern European Countries as well.

A lot of knowledge is available and it is recommended to draft 'best practices reports' about relevant topics. Member States of the European Union and from Central and Eastern European Countries could co-operate in this field and the European Commission (DG I PHARE/TACIS) and DG VII (Transport) are encouraged to stimulate this development.

The European Commission has taken the initiative to launch a research programme in the field of road design (standards) and road safety. This initiative will result in more international cooperation as can be seen in the SAFESTAR project. Other interested parties are invited to indicate their interest in this development and to join this initiative.

A more revolutionary approach of the problem which road design is to be considered as 'proper' bases on the concept of sustainable road safety. This concept tries to minimize the number of human errors by taking man as the reference standard. The infrastructural aspect of this concept relies on three safety principles:

- prevent unintended use of each road;
- prevent large differences in vehicle speed, mass and direction of movement;
- prevent uncertainty amongst road users.

The further elaboration of this concept leads to the adoption of a monofunctional road classification and corresponding layout.

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