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GADGET

Guarding Automobile Drivers through Guidance Education and Technology.

Final Report.

Investigations on Influences upon Driver Behaviour - Safety Approaches in Comparison and Combination.

Kuratorium für Verkehrssicherheit (KfV)
Austrian Road Safety Board

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1. The objectives of GADGET

In the 4th FP task 7.2/14 was entitled as follows:

"Assessment of changes in driver behaviour resulting from the introduction of in-vehicle safety devices, visual modifications to the road environment, educational, training and legal measures, and safety campaigns."

Slow or irrational reaction to unforeseeable situations were explained as an issue, an improvement of driver responses and a reduction of casualties should be the aim. The project should assist in dissemination of good practice and provide a basis for a regulatory framework. An inventory of all measures from low tech to high tech was proposed as an approach and each measure should be assessed in terms of its costs and benefits. Special attention should be given to the issue of risk compensation.

The wide range of safety measures addressed in the task description made it necessary to group the measures according to the principles upon which they are based; we used the classical distinction - engineering, education and enforcement ("the three E's") - to denote three prime areas:

- technical standards regarding vehicles and environment,
- drivers' attitudes and opinions, drivers' skill and know how,
- probability of detection of errors and violations, consequences of misbehaviour in traffic.

The GADGET consortium subdivided the "three E's" once more and decided to structure the work in five different work-packages.

Table 1: The three „E" and the work-package structure of GADGET:

ENGINEERING		EDUCATION		ENFORCEMENT
WP1 **Telematics**	**WP2** **Modifications to the road environment**	**WP3** **Education and training**	**WP4** **Safety campaigns**	**WP5** **Legal measures**

According to different traditions in traffic safety development, the five work-packages focused on different approaches:

WP1 on the influence of in-car safety devices.

WP2 on the influence of various road environments on driver behaviour.

WP3 on the influence of various education and training programs on driver behaviour.

WP4 on the influence of safety campaigns on driver behaviour.

WP5 on the influence of legal measures (including enforcement) on driver behaviour.

2. Work-structure and deliverables

2.1. Activities and reports from five thematic work-packages

The following research steps have been undertaken within the work packages for the very area:

- Listing all known traffic safety measures that target driver behaviour.
- Listing all known evaluation studies and describing the results.
- Developing a theoretic background which considers the peculiarities of the safety efforts known in the very approach.
- Providing an interpretation of the results of evaluation studies on the basis of theoretical background.

  It was further the aim:

- To describe research strategies and research needs on the basis of the theoretical background.
- To develop an assessment tool for expert judgement based on theory and models.

  Depending on the available data different work-packages could put more focus on some of the aspects mentioned above, other work-packages had to shift their activity to other aspects due to the lack of documented research.

  Additional goals (as far as possible):

- A comparison of the safety effects of various safety measures and an assessment of net effects and interaction of safety measures have been considered.
- Cost-benefit ratios were cited, obstacles and opportunities for the implementation of safety measures have been considered.

The work-package reports

Work-package reports have been completed and are available:

WP1:

Schulze, H., Christ, R., Heijer, T., Mäkinen, T., Nilsson, L. In Vehicle Safety devices. GADGET Work-package report. BASt, Bergisch-Gladbach, 1999

WP2:

Sagberg, F., Hakkert, S., Larsen, L., Leden, L., Schmotzer, C., Wouters, P. Visual modification of the road environment. Deliverable D2 from the EU project GADGET. Oslo: Institute of Transport Economics, 1999.

WP3:

Siegrist, S. (Ed.). Driver Training, Testing and Licensing – towards a theory based management of young drivers' injury risk in road traffic, bfu-report, Bern (in Press). 1999. Authors: Assailly, J.-P., Baughan, Ch., Chatenet, Fr., Glad, A., Goldenbeld, Ch., Gregersen N.P., Hatakka, M., Keskinnen, E., Twisk, D., Siegrist, S., Skladany, P.

WP4:

Delhomme, P., Vaa, T., Meyer, T., Harland, G., Goldenbeld, Ch., Järmark, S., Christie, N., Rehnova, V. Evaluated road safety media campaigns: An overview of 265 evaluated campaigns and some meta-analysis on accidents. INRETS, Paris, 1999.

WP5:

Mäkinen, T., Biecheler-Fretel, M.-B., Cardoso, J., Goldenbeld, Ch., Fuller, R., Hakkert, S., Jayet, M.-C., Sanchez Martin, F., Skladana`, P., Vaa, T., Zaidel, D. GADGET WP-5-report, Legal measures and enforcement. VTI, Espoo, 1999.

2.2. The background of the work-package activities and the background of the summary report

In fact GADGET developed to be a cluster of projects rather than one comprehensive project.

The five work-packages themselves already form considerable projects. Within the work-packages a lot of information had to be collected and structured in a very short period of time. Since safety measures start from different angles each work-package had to develop its specific principles how to structure the information.

The character of a "cluster of projects" is determined by the fact that the general aim of the study was to assess the effect of various safety measures on the driver. So driver behaviour is the link between the clusters. Therefore a model of driver behaviour was proposed as a common perspective, it should finally allow to interpret empirical findings from the work-packages on a common level.

The following table shows the different levels of background that had to be considered in this project:

Table 2: Two dimensions of theoretical background are the basis for assessment and interpretation of empirical studies

<table>
<tr><td></td><td>General theories and models concerning the driver
General model of behaviour regulation, behaviour acquisition and behaviour adaptation</td></tr>
<tr><td>Theories and models concerning the measure</td><td rowspan="6">Interpretation of empirical results from evaluation studies based on:
Theories and Models concerning specific interactions between the driver and the measure

Assessment and expert judgement based on:
Theories and Models concerning specific interactions between the driver and the measure</td></tr>
<tr><td>Specific models concerning characteristics of in-car-devices</td></tr>
<tr><td>Specific models concerning characteristics of road layout</td></tr>
<tr><td>Specific models concerning characteristics of young drivers and education and training measures</td></tr>
<tr><td>Specific models concerning characteristics of safety campaigns</td></tr>
<tr><td>Specific models concerning characteristics of traffic-law-enforcement</td></tr>
</table>

The large cell on the bottom right of this table indicates the intended content of this comprehensive project report. It should combine the perspectives from the work-packages (left column) with the general ideas about driver behaviour.

On the level of the measure quite different theories and models must be taken into consideration for the categorisation of measures. These considerations have been undertaken in the work-packages and are indicated in the first column.

The discussion on the appropriate model of driver behaviour (right column top) started at the same time or even before the work of the work-packages. A general model of behaviour regulation, behaviour acquisition and behaviour adaptation has been proposed as a general frame to bring the various aspects together. A previous, more theoretical model was found to be difficult to apply in the steps conducted in the work packages. However, the discussion in the subsequent phase succeeded in translating these assumptions into a less scientific language. After all, the considerations could be used to structure the output from the work-packages.

The expected benefit from a combination of theories as described in this matrix is that the model of driver behaviour is very general and the models and categories from the work-package issues are very specific. Especially for the discussion of questions whether results from single studies may be considered as generally applicable, linking these perspectives will be advantageous.

This report describes the proposed model for driver behaviour regulation, behaviour acquisition and behaviour adaptation in the next chapter. The following chapters point out the results of the work-packages. The subsequent conclusions integrate the work-package results into the general view about driver behaviour.

3. Driver behaviour - the target of all safety measures

Many attempts have been made to describe driver behaviour and the driving task. Well-known concepts are the division into strategic, tactical and operational level or the division into knowledge-based, rule-based and skill-based behaviour. Prerequisites for driving like special abilities are considered as well as expectations and decision making in driving. A special issue concerning safety are all the considerations on behavioural adaptation to changed subjective risk.

The purpose of all these models is to understand why drivers behave as they do. All those descriptions imply that many distinctions have to be considered, and that drivers also behave quite differently depending on circumstances.

Apart from these sophisticated descriptions of driver behaviour psychology (fortunately) developed general models of behaviour regulation, behaviour acquisition and behaviour adaptation. These general models are used in GADGET to understand driver behaviour, they also seem to provide a tool for the comparison of various measures.

3.1. Behaviour regulation, behaviour acquisition and behaviour adaptation

From the view of psychology, observed behaviour is considered as a result of several influences. What we currently observe is subject to actual regulatory processes, but is also dependent on prior experiences of the observed individual (the individual has “learned” to behave like this) and the experience of the currently observed behaviour and its consequences may modify the future behaviour of this very individual (adaptation processes).

For all these aspects – actual regulation, learning and behaviour modification – the same set of mechanisms is considered to be relevant. Starting from the basic Stimulus-Response-Model, a very comprehensive model known as the SORC-model has been developed in the meantime.

This model considers:

- S - Stimulus (an input or impact that initiates and determines certain patterns of behaviour)
- O - Organism (an umbrella for any variables that might modify behaviour like disposition and abilities, environmental aspects, cognitive aspects)
- R - Reaction (behaviour)
- C - Consequence (of the behaviour - positive or negative consequence for the individual? "reinforcement or punishment")

This model is designed for behaviour analysis and a common tool in psychotherapy, especially if the behaviour and cognitive approach is pursued. It is used to investigate the origin of certain habits (which the clients suffers from and wants to alter) and for the development of strategies to establish new desirable habits.

For the purpose of this project this approach has been simplified and translated into a language more commonly used.

3.1.1. Three levels of impact

Any impact on an individual person (driver) – of a safety measure for example - can address one or more of the three levels we are going to introduce here.

We distinguish influences upon:

- Level 1: the condition of the person (basis)
- Level 2: the principles of behaviour regulation (direct factors)
- Level 3: adaptation processes caused by consequences of behaviour (feedback)

3.1.1.1. Seven mechanisms address three different levels

For the purpose of this project seven mechanisms are considered to be of importance.

Two mechanisms address the basic conditions of the individual, three principle determinants of behaviour regulation and two mechanisms to understand adaptation processes have to be distinguished.

- *Level 1: condition of the driver (basis)*

The general state of an individual can be described in terms of the two dimensions - psychophysiological condition (1) and affective-mental condition (2). This state can be understood as the background, the basis for all behaviour. The state of a person may be influenced by a lot of things. The state varies over time and in any case the state determines how the below mentioned principles of behaviour regulation will be enacted.

- *Level 2: principles of behaviour regulation (direct factors)*

The actual behaviour of a person is determined by

- The quantity and quality of the input he gets on the various sensory channels (3).
- Assessment patterns (preparedness and experience determine how input is perceived and assessed) (4)
- Beliefs on how to behave in certain situations (5)

- *Level 3: adaptation processes (feed back from consequence of behaviour)*

Any activity of a person has consequences for her/his future behaviour. Activities that are perceived as successful will be maintained and unsuccessful activities will be altered.

There are two mechanisms that determine adaptation processes.

- An automated process, also described as feedback learning, which operates on a "primitive" level without affecting higher cognitive representations. Depending on the outcome of the behaviour the assessment of input is modified in one or another direction (e.g. decreasing or increasing speed dependent on the forces felt on the steering wheel). (6)
- Human beings, however, observe and reflect their behaviour. They develop ideas on how to behave in certain situations. These ideas and beliefs, however, are not stable, but may also be modified by experience. People are looking for explanations for outcomes of behaviour, try to explain success or failure. The range of explanations is ample and there is a great chance to develop "irrational" beliefs - also concerning driving and safety. (7)

The elements introduced here are illustrated by the following figure.

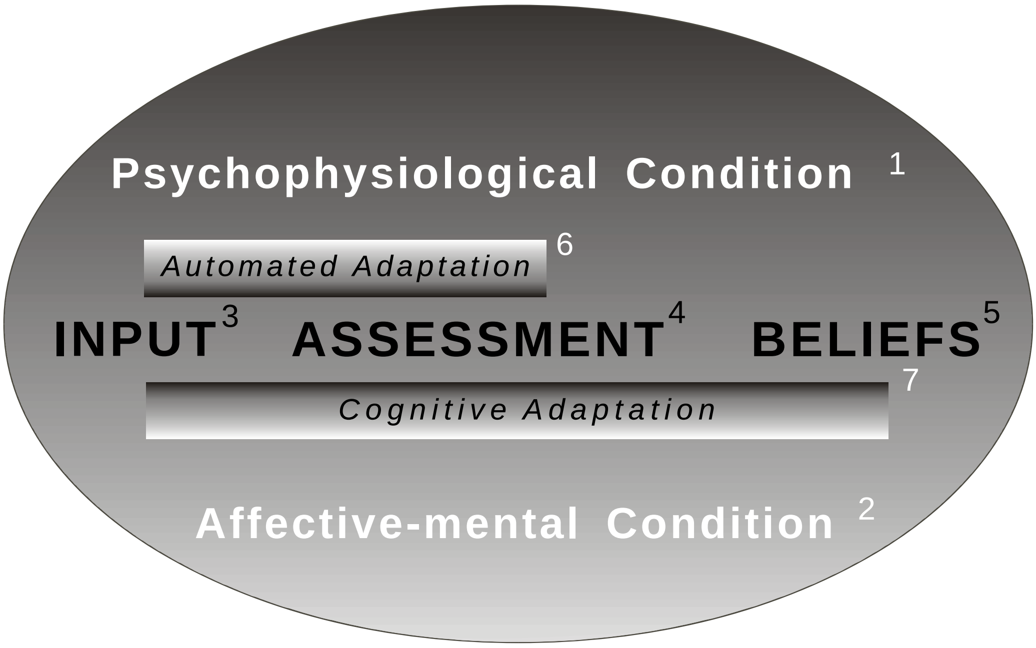

Figure1: The elements/mechanisms determining actual behaviour, behaviour acquisition and behaviour adaptation"

- *Intention and motivation*

Some readers might notice the absence of one important element in the model described above. Motivational aspects are not explicitly mentioned as mechanisms, the use of such elements, however, is important for the explanation of behaviour both in traffic and in general.

In terms of the presented model, motivational factors are themselves influenced by the described processes.

The motive is understood as a longer lasting peculiarity of the individual (trait) and motivation is the actual state of the individual. The motive is a more stable disposition and motivation is more determined by external factors.

In terms of the model, the motive (e.g. to obey regulations or to violate them, to respect other road users etc.) is something closely related to beliefs.

Motivation, after all, is a result of the interaction between the condition of the driver (especially with regard to moods), inputs and beliefs (motives).

From this model, it can be seen that there are several methods to influence motivational factors, most importantly that of changing / influencing the affective condition and the beliefs of the driver.

3.2. The application of the model of behaviour regulation, behaviour acquisition and behaviour adaptation to questions raised in traffic safety

3.2.1. Translation, common terminology

Traffic safety experts use a different terminology and different approaches than therapists. Therefore some effort is put into the translation of the proposed model into terms of traffic safety terminology.

- *The perspective of accident and safety analysis*

In traffic safety we are confronted with accident causes which are found in the statistics as “alcohol”, “speed” etc. In a next step explanations are applied to understand why people do so – drinking and driving, speeding, overtaking, lose control etc..

If traffic safety experts consider the underlying reasons for inept behaviour the following hypothesis may be used:

The driver did so because:

- he was not in a good condition for optimal driving performance (qu1),
- he was not in a good affective condition and therefore behaved differently than desired (qu2),
- he got too much or too little or too complicated information regarding the traffic situation (input was missing or driver was distracted by other occurrences) (qu3),
- he did not recognise the relevance of some available and important information (qu4),
- he had wrong ideas/ beliefs about adept driving (qu5),
- he had not learned to act properly in this kind of situations. He has no automated behaviour pattern which deals with this hazard. He has acquired automated processes that are dangerous. (qu6)
- he has not learned to recognise the outcome of his actions in traffic. He/ she does not recognise the relation between his/ her actions with occurrences and outcomes of traffic situations. (qu7)

- *The relationship between the perspective of accident analysis and the model of behaviour regulation, behaviour acquisition and behaviour adaptation.*

The relation between the most common assumptions from safety research with assumptions from the model of behaviour regulation, behaviour acquisition and behaviour adaptation will be illustrated in the following table.

Table 3: Hypothesis of safety research and accident analysis and related assumptions in the model of behaviour regulation, behaviour acquisition and behaviour adaptation

Hypothesis arising from accident analysis	Assumptions in the model of behaviour regulation, behaviour acquisition and behaviour adaptation
The driver was not in a good condition for optimal driving performance. (qu1)	The psychophysiological condition (activation e.g.) determines the range of behaviour that can be performed.
The driver was not in a good affective condition (qu2)	Different affective-mental conditions (anger, fear e.g.) favour different behaviour patterns.
The driver got too much or too little or too complicated information (input was missing or driver was distracted by other occurrences). (qu3)	Only part of the input from the environment can be observed and processed. In connection with assessment patterns selective attention has to be considered.
The driver did not recognise the relevance of some available and important information. (qu4)	The assessment of certain stimuli/ input from the environment is a result of preparedness and experience (individual history). Assessment determines whether the "stimulus" evokes some specific behaviour. Preparedness means that there are stimuli that are frightening in general, others that are pleasant in general). Individual history means that each individual has experienced pleasant and unpleasant events in connection with specific stimuli.
The driver had wrong ideas/ beliefs about adept driving. (qu5)	Culture and individuals have developed ideas on how to behave in certain situations, these ideas (social or legal norms) usually limit the range of displayed behaviours.
The driver had not learned to act properly in this kind of situations. He/she has no automated behaviour pattern which deals with this hazard. He/she has acquired automated processes that are dangerous. (qu6)	Some feedback learning takes place on a "primitive" level without affecting higher cognitive representations. The assessment of input is modified dependent on the outcome of the behaviour (“success or failure”). The outcome determines the future assessment of this stimulus or similar stimuli. Thus a driver may have developed inappropriate assessment of traffic situations since dangerous habits during his driving experience yielded benefits and the same actions had no or little negative consequences (only few misjudgements result in accidents).
The driver has not learned to recognise the outcome of his actions in traffic. He/she does not recognise the relation between his/her actions with occurrences and outcomes of traffic situations. (qu7)	People are looking for explanations for outcomes of behaviour, they try to explain success or failure. The range of explanations is ample and there is a great chance to develop "irrational" beliefs, wrong explanations. Ideas and beliefs on how to behave may be quite long-lasting but are not necessarily stable and they may be modified by experience. Thus a driver who usually blamed other road users, technical issues or fate for his accident involvement might modify his way of drawing conclusions and make him look for his own responsibilities (from “external to internal” attribution).

3.2.2. The approach and it's implications on the assessment of traffic safety measures

3.2.2.1. The range of impacts on behaviour / the range of safety measures

The presented approach tries to structure all well-researched influences on behaviour.

The model of behaviour regulation, behaviour acquisition and behaviour adaptation shows the range of opportunities to influence behaviour. Any effort to influence behaviour can use one or several of the mechanisms mentioned. The three different levels show, however, that the mechanisms, at least in the long term, are not independent, much closer relations have to be considered.

In safety work, like in everyday life, we try to solve problems is searched by using single measures and thinking of single mechanism of impact.

Thus safety work has developed several methods:

To provide appropriate information is one of the most traditional engineering methods, to establish appropriate beliefs is one of the traditional ideas of traffic education and to improve assessment is an aim of skill training. Campaigns address beliefs and partly affective issues.

It is obvious that safety efforts already consider all of the principle mechanisms (level 2) mentioned in the model of behaviour regulation, behaviour acquisition and behaviour adaptation. However, we are convinced that the point of view which has been described here provides a more detailed basis for the consideration of effects.

3.2.2.2. The interactive nature of influences on behaviour

The model of behaviour regulation, behaviour acquisition and behaviour adaptation indicates that an influence on one mechanism may have consequences on other mechanisms.

The distinction of the three levels of mechanisms - level 1: condition of the driver, level 2: principles of behaviour regulation, level 3: adaptation processes - helps to understand how modifications of one mechanism may also result in modifications described in the other mechanisms.

This structure underlines the following assumptions:

- Safety efforts without (potentially unfavourable) side effects can only be expected by measures which address the condition of the driver – the psychophysiological and the affective-mental state (level 1). Since these basic conditions are not involved in feedback mechanisms accompanied unexpected effects should not occur (but it is probably hard or even impossible to design a traffic safety measure which only operates on this basic level!).
- Any evaluation of a measure that includes aims of mechanisms on level 2 has to consider potential adaptation processes as described on level 3. Any modification of input, assessment or beliefs - has to consider whether there may be consequences on level 3. Adaptation processes, interactions on a complex level may modify the desired effect of a safety measure.

Thus this structure shall offer a guarantee not to omit the consideration of important influences and especially side-effects when judging effects of safety measures.

There is one additional advantage of the presented perspective: this perspective provides a tool to develop and understand reasonable combinations of safety measures.

The potential of safety measures will be discussed with regard to the presented perspective in the work-package summaries (chapter 4), reasonable combinations of safety measures will be discussed in the recommendations (chapter 6).

4. Research steps conducted in the work-packages and achieved results

4.1. Summary WP1 - Telematics

Implementing various telematic in-vehicle safety devices (SDs) will influence the driving task which is composed of task components at three different hierarchical levels: strategic, tactical and control tasks. The task demands imposed on the driver are met by also three levels of driver control (behaviour): knowledge-based, rule-based and skill-based. They form the repertoire of driving skills which have to be adapted to the requirements of an implemented SD. A huge literature survey revealed that there is no sufficient empirical basis of evaluating the effects SDs might have on road safety in general and on driving behaviour in particular.

One important step to compensate the considerable deficits of evaluation studies is to develop an elaborated evaluation system which enables researchers and planners to gather those missing empirical results about the safety impact of SDs. A comprehensive evaluation system proposed by this group is based on general psychological theories and especially on traffic psychological knowledge. The elaborated system consists of five categories of influencing concepts: (1) cognitive-affective expectations, (2) concepts important in the actual process (e.g. attention), (3) cognitive and affective experiences (4) behavioural consequences in the medium or long run (e.g. risk homeostasis) and (5) systemic and further aspects (e.g. safety of the whole system). The potential safety problems associated with various forms of user interface have been widely recognised and researched. This has led to the formulation of a European Code Of Practice that defines a range of ergonomic and functional demands for the HMI (Human-Machine-Interface). Because of their potentially large impact on safety, these requirements have also been adopted in the GADGET questionnaire. It is very important to keep in mind that an evaluation process takes place in a pressuring race against time. Therefore appropriate methods have to be applied or developed to ensure that the results are available when they actually are needed. It is the ultimate goal of research in the area of SD to generate knowledge that extends beyond single technical solutions. The knowledge should be transferable also to future technological developments.

4.1.1. Aim of work-package 1

Lots of technical innovations allow the development of driver support devices which might result in safety benefits. Cars become more and more equipped with new devices, however the effects on driver behaviour can only partly be predicted. Work-package 1 of the EU project GADGET therefore deals with the assessment of potential safety impacts of those devices. The central aim is to set up a systematic allowing an evaluation of such systems. This systematism should also point out research gaps and provide a basis for the development of appropriate research designs to answer open questions.

4.1.2. Working method

At the start of the project (January 1998) the task of the work-package was broken down into three thematic areas.

- Evaluation of SDs in the frame of a literature survey
- Development of an evaluation guide for SDs
- Discussion of research needs

A detailed description of these worksteps will follow after a brief introduction into our research topic.

4.1.3. How safe are safety devices?

What are we actually doing when driving? What human abilities are necessary to perform the task and which factors influence the behaviour? The four chapters of work-package 1 are outlining possible effects of introducing different types of SDs from a psychological point of view, as well as methodological requirements to enable the assessment of the safety potential of SDs. The driving task is composed of task components at three different hierarchical levels: strategic, tactical and control tasks. The task demands imposed on the driver are met by also three levels of driver control: knowledge-based, rule-based and skill-based. To match the task demands by appropriate driving behaviour the driver must possess certain perceptual, cognitive and motor abilities. When the two hierarchical frameworks are combined it is obvious that there is not an inherent unambiguous relationship between driver control (behaviour) and task requirements. It is known that driving, after the first novice phase, to a large extent is automated and performed using behavioural rules (schemas) developed through practising the driving task. Implementing various SDs will influence the driving task by changing or removing certain sub-task and adding others. Therefore the repertoires of driving skills and rules developed by drivers have to be modified to meet the new tasks. Expectations and predictions have to include mental representations of the SD functionality. SD related factors expected to influence the driving task and the driver behaviour as well as their connection are listed.

Telematics is a combination of tele-communication and informatics and covers a wide range of systems, from complex and interrelated systems like traffic management on the one side, till simple stand-alone systems like reversing aids on the other. Telematics seems to be a subject, difficult to define with a fuzzy set of systems. Even if the definition is not precise and the effects of telematic systems are discussed controversially, there is no doubt about the market potential of telematics.

Active safety devices can be seen to some extent as a subset of telematic systems. Even it is intended not to need or use tele-communication for the operating of the systems, some of them would work with higher performance with additional information from other cars or an information centre. The restriction to on-board systems without the need of any infrastructure is merely influenced by financial and political than by technological reasons.

But, as a matter of fact, autonomous, SDs are developed and will further be developed. It is often taken for granted that safety devices increase safety on the road as it is intended. Unfortunately empirical studies or accident analysis like those on safety effects of anti-block systems are not performed due to existing standard evaluation procedures. It should be an undeniable demand that the potential benefit for the whole group of telematic systems in general and for active SDs in special must be evaluated within a definite time period. This is the only reliable way to state if a safety device is really safe.

4.1.4. What's the base of our knowledge?

4.1.4.1. Evaluation of In-vehicle safety devices – a literature survey

To get a systematic overview about our research field a huge literature survey according recent research documents on SDs was carried out. The main goal of this study was to find out where evaluation deficits for SDs exist, and to develop adequate evaluation criteria. Therefore current SDs have been analysed with respect to four main categories: (1) technology, (2) interaction concept (system-paced, initiated by the driver or on demand of the driver), (3) expected effects on traffic safety and (4) available evaluation studies. Those systems have been analysed which can be classified under the heading „In-vehicle safety devices“, i.e. systems installed in vehicles to increase car and/or traffic safety. Not covered are passive safety devices only moderating the consequences of an accident. In accordance with this definition 9 categories of systems have been focused:

Four types of systems belong to the category **car dynamics**: Anti-block systems (ABS), Traction control systems (ASR), Electronic stability program (ESP) and Adhesion monitoring, and Heading control systems (HCS).

The aim of **distance keeping systems** is the regulation of a safety distance to a leading car. Mostly systems for automatic cruise control are augmented with this feature. They are known under the name ACC (Adaptive Cruise Control), AICC (Autonomous Intelligent Cruise Control) or ADR (Automatic Distance Regulation). The main difference between distance keeping and collision avoidance is the lacking ability of ACC-systems of adequately reacting to stationary objects. They cover different safety problems, behaviour patterns and expectations of drivers. Therefore a distinction between the two systems is commonly accepted.

Collision warning and avoidance systems try to detect obstacles (cars or static obstacles) with the aid of CCD cameras, microwave radar or laser radar, or with a piezoceramic device (Polaroid), or they want to detect the distance to all sides (Delco). Eventually they brake automatically. Japanese manufacturers develop and test these kind of systems in test-vehicles. German car manufacturers and suppliers have been more reserved, partly based on the experiences of the PROMETHEUS project. To react adequately in all possible situations, extremely long time lags are necessary associated with the probability of many false alarms. A new approach, using multiple sensors, including computer vision, mechanically-scanned microwave radar, and sensor fusion to improve the sensor integrity and hence reduce the rate of false-alarms has been started with the AC-ASSIST project. For Europe and America concept cars and experiments are published. Two systems can be differentiated: warning and interrupt systems. While German and American manufacturers prefer warning systems, Japanese manufacturers favour an automatic braking intervention, if the driver does not react to an optical or acoustical warning of an obstacle. Collision avoidance systems can theoretically be seen as high-end ACC-systems, combined with features of parking assistant. But, according to the principle of operation, CA systems (with one exception) look only for obstacles ahead of the car disregarding intentions of the driver or other traffic participants. This isolated ‘view of the world’ is one weakness of these systems.

Parking aids (PTS**)** are devices, related to collision warning, but technically less sophisticated. They are constructed for the detection of static obstacles at low speeds. They should assist the driver in narrow parking slots. Parking aids use different sensor techniques to measure distances to obstacles in the path of the vehicle. Most developers concentrate on the detection of obstacles behind the car, only one system looks for obstacles in the front, too. The systems differ in their way how to display the distance information to the driver. Better systems display it in the area of the rear window of the car, when the car moves back. Other systems provide very detailed display information with video and/or graphical representation of the surrounding.

Systems helping to prevent driving under influence of alcohol are called **alcohol control systems** (ACS). When a breath alcohol ignition interlock device in the vehicle is installed, prior to starting, the driver is required to provide a breath sample by blowing into the device. If the alcohol content of the breath sample exceeds a pre-set limit, the starter will be locked out and the vehicle cannot be driven. Once the vehicle is in motion, the driver is required to provide additional breath samples at random intervals. In the USA, drivers who lost their license because of driving drunk, get the license back if they agree to drive only with their car fitted with an alcohol control unit. These units are recommended for novice drivers.

Dealing with systems of **Driver alertness monitoring** (DAMS) you find two classes of methods which are used to monitor the driver's state of drowsiness, methods which analyse the stability of the driver’s steering actions (lane-related measures), and methods which use physiological parameters to estimate the condition of the driver (physiological measures). Whenever the performance, observed with one or both methods, falls below a certain threshold, the driver is supposed to be drowsy and a series of countermeasures are activated.

There are two main approaches in **Vision enhancement – systems** to enhance vision at night time or under bad weather conditions. The one (active VES) uses additional sensors, information sources like digital maps and special installations to concentrate the headlights on that part of the road ahead, which is of significant interest for the driver. In addition to that adaptation, intelligent in-car systems can adapt the light distribution depending on speed and steering angle. The second (passive VES) uses non-visible sources of illumination of the road, which have a broader or deeper range ahead. Special sensors receive the reflected emissions and transform them into visible light. The additional image of the road ahead is then displayed to the driver.

Pedestrian monitoring systems are designed to detect pedestrians (or simple obstacles) close to the vehicle or in the path of it. The different developers use different sensor techniques, and different scan areas to look for obstacles or pedestrians. Especially Japanese manufacturers follow the idea to detect pedestrians during night-time and to solve the blind corner problem. Research is purely technology driven, making no comments to user-centred information presentation.

Route information systems provide the driver with Information concerning the route. This information is directly transferred to the vehicle from a central or distributed information centre. Typical examples are: traffic information, info concerning route and road conditions, free parking slots or service stations. The main question for this kind of information is, how it is requested by and displayed to the driver. If this is done not too often and user-friendly, not overloading a sensory channel needed for observation of traffic scenes, the additional information can improve safety. Traffic safety can also be improved, when these systems help to transfer traffic to other transportation means. Under the keyword intermodality many attempts are discussed to ease the change from one transportation system (car) to others (public transport) to reduce for example traffic density. Reduction of motor traffic reduces the probability of accidents.

4.1.4.2. Conclusion of the literature survey

The huge literature survey which was carried out treating more than 140 single SDs revealed considerable deficits of evaluation studies, so that at present the estimation of impacts of SDs basically has to rely on experts judgements, if available. There is no sufficient empirical basis to evaluate the effects SDs might have on road safety. As a result of the literature analysis a research guideline is proposed for the development of SDs and the selection of appropriate evaluation procedures. The development, evaluation and introduction of active safety devices should follow a defined schedule, here called ideal R&D (research and development) process. An analysis of this ideal process can give valuable insights in the current status and deficits of evaluation studies. The process of research, development, evaluation and implementation should comprise 5 steps: (1) identification of deficits and problems of drivers, (2) definition of underlying reasons for this behaviour, (3) design of the system, (4) test and evaluation and (5) production and marketing. Further the need for developing an elaborate evaluation system which enables researchers to gather those missing empirical results about the impact of SDs on road safety is outlined.

4.1.5. Construction of an evaluation guide for in-vehicle safety devices

As up to now there is no sufficient empirical base to assess the safety impact of SDs, a major task of WP1 was seen in developing and constructing a behavioural scientific taxonomy to evaluate those systems. This evaluation guide is supposed to enable researchers to gather the urgently needed empirical results to improve driver's response and reduce casualties.

4.1.5.1. Goals of construction

The GADGET-evaluation system should be used as a „guide" helping to systematically assess the possible effects of technical systems. The evaluation guide is based on theories of general psychology and especially traffic psychology. It is a fundamental understanding, that human beings take in information, store it, process it and act according to the latest update of information. For the evaluation of safety devices it is essential to know which person-related and situation-related influences are responsible for disturbing adequate information processing. Started from a theoretical background of driving behaviour adequate concepts (e.g. subjective risk, mental load) have been chosen, which are supposed to have a causal link towards a special safety device. The result is a comprehensive system which consists of the following 5 categories of influencing concepts: (1) cognitive-affective expectations (e.g. reactance, subjective basic utility), (2) concepts important in the actual process (e.g. recognition, attention), (3) cognitive and affective experiences (e.g. reactance, subjective basic utility), (4) behavioural consequences in the medium or long run (e.g. risk homeostasis, driving habits) and (5) systemic and further aspects (e.g. flow of traffic, traffic density, traffic safety).

4.1.5.2. Theoretical basis

Car driving is a complex and dynamic control task carried out within a "system", i.e. in traffic. This road traffic system is not a stand-alone structure but a component of an even larger system. Therefore road traffic is influenced by a higher level system, the society, as well as by a lower level system consisting of for example road constructors, traffic engineers, equipment and service providers, and vehicle manufacturers.

In the traffic system an enormous amount of information is available to the driver. However, during a specific journey with a specific purpose only a small part of the information presented outside the car is usually of importance and necessary to reach the goal of travel. Most of the information can be considered as "noise". Therefore, in order to perform the dynamic control (driving) task, the driver must be able to distinguish necessary and important information from information being irrelevant. Car driving thus includes *selection* of relevant information as well as of the actions and manoeuvres it entails. The driver has to know *what* information is of relevance in various situations. Car driving also thus includes *readiness* for unexpected situations. The driver continuously has to revise original predictions and expectations and be prepared to modify and change how to act.

To meet the demands of driving interaction with the other system components have to be considered, i.e. adaptation to a continuously changing, partly stochastic environment offering a certain amount of relevant information hidden in "noise" information. The introduction of SDs aims at facilitating the driver's task by supporting the monitoring, selecting and action tasks described. The interaction between driver and vehicle can only fulfil the general task of supporting road safety, if the driver's perception and attention system is not significantly hampered and the cognitive system is not strained so that stress reactions are avoided. Stress manifests itself, if a person realises that his or her own capabilities no longer meet the demands of the situation. Attention, perception, decision and reaction are key-concepts of information processing, and in turn they have a causal relation to physiological, cognitive, motivational influences, stable characteristics of personality as well as situational components. Perception is understood as the process of interpreting information. Each of the four stages of the process can be subject to mistakes and are limited in their capacity. It is less common to explicitly consider the intertwining of affective processes of information processing when forming a model, but it is no less important when deciding how to act. In the relevant models in traffic psychology the subjective risk plays a crucial role in controlling behaviour. If SDs enhance safety objectively, this might also be reflected in an increased degree of subjective safety. According to Wilde's model of riskhomeostasis the consequence would be bargaining away the increase in safety, if the road user is willing to take on more of a risk than he or she is able to realise at that moment. The principle of homeostasis only applies if the motorist is free to redress the balance of the lack of risk perceived by driving more risky. SDs, which cause the vehicle to react automatically and thereby are outwith the driver's control, prevent an objective increase of danger brought about by risk homeostasis. According to risk homeostasis theory this does not diminish the factual imbalance between the perceived and the accepted risk. We are still left with a road-user who is prepared to take more of a risk than he ought to at that moment. This is the starting point for aggression, reactance or the rejection of the system. When considering telematic systems you have to distinguish three kinds of interaction: (1) interaction between the driver and the vehicle, (2) the interaction between the driver and his or her environment and (3) the interaction between the vehicle and the environment (Figure 2).

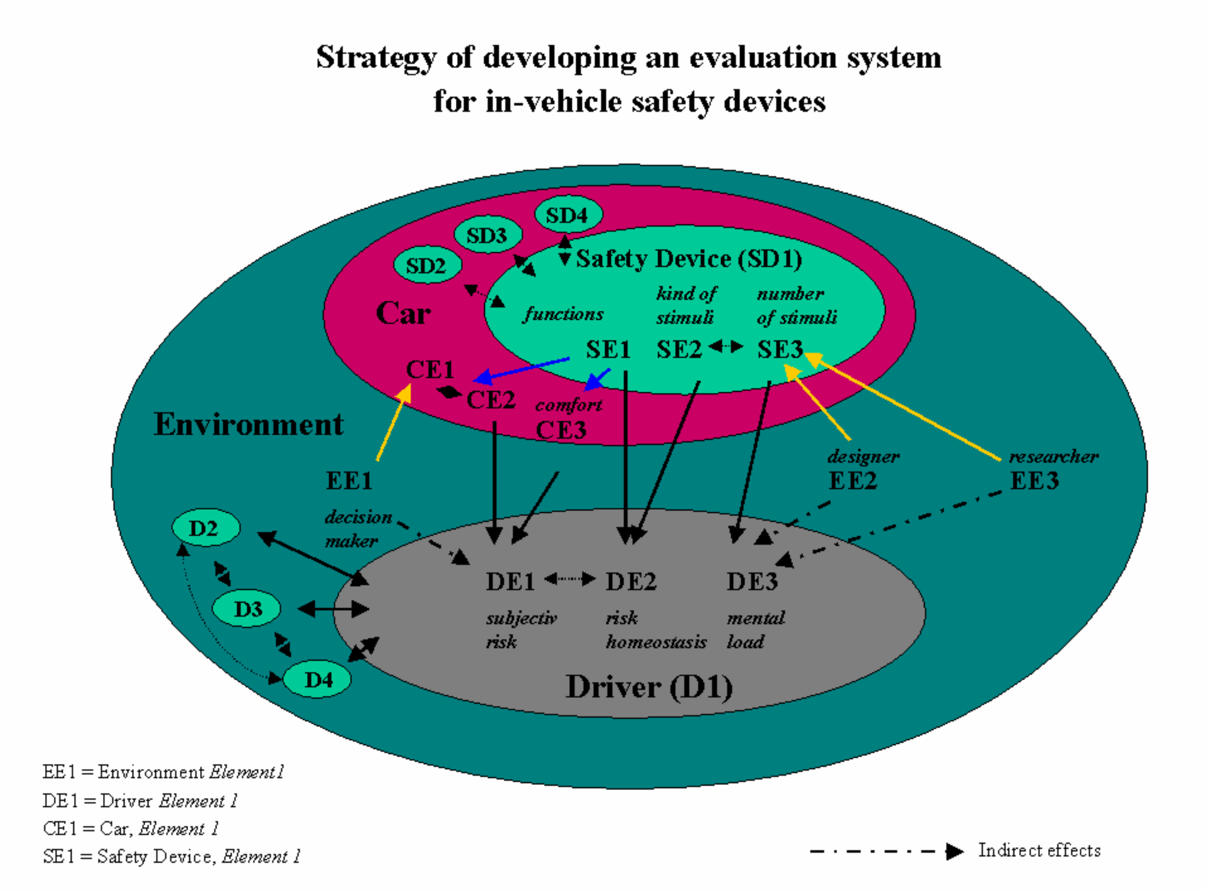

Figure 2: Topological model of the traffic system

The demands imposed on the driver from the driving task have to be met and controlled by different levels of driver control. Usually the control or driving behaviour is assigned to three different levels: knowledge-based, rule-based and skill-based behaviour:

Skill-based behaviour is described as data-driven. Acquired information is directly translated into specific actions or action patterns. The actions are executed without conscious control and the utilisation of attentional resources. Behaviour at the skill level is immediate and efficient.

Rule-based behaviour occurs when no automatic response to the situation at hand is available, or has been developed. It is performed under more or less conscious control and requires more or less attention. Therefore rule-based behaviour is more time-consuming and less ”efficient” than skill-based behaviour. The driver has to search among already developed behavioural rules in his/her mind and select the most suitable one.

Knowledge-based behaviour involves problem solving. It becomes necessary when there is no suitable rule how to act in a specific situation, or when the driver doesn't want to use an existing rule or hasn't developed a rule. Knowledge-based behaviour requires reasoning and needs the longest time to be completed.

To be able to match the appearing task demands by appropriate driving behaviour the driver must possess certain perceptual, cognitive and motor abilities. Perception by the human senses, mainly vision but also hearing and feeling, is necessary but not sufficient for driving. The perceived information has also to be processed and transferred into decisions how to handle the car and interact with other road users. For realising the decisions as manoeuvres and actions the driver has to have the relevant motor skills. Finally, the execution of the appropriate manoeuvres depends on the driver's motivation and willingness to act. Factors like immature skills, low experience, inappropriate expectations and rules, stress, overload, fatigue, alcohol and drugs can influence the abilities negatively. The human abilities required to drive safely can be summarised as follows:

- perceptual abilities (visual, audible, tactile)
- ability to search the environment and detect relevant information
- ability to detect relevant information within an available time frame
- ability to attend to relevant information
- ability to interpret information
- ability to make correct predictions, judgements and decisions
- ability to carry out actions
- ability to correctly judge the own performance limits
- ability to correctly judge the performance limits of the car
- motivation and willingness to drive safely.

Together with the human abilities and practising in traffic also the driver's **expectations** pay an important role in the quality of task performance. Appropriate expectations promote correct predictions and judgements, which in turn helps the driver to react quickly, efficiently and correctly. Two types of expectations can be distinguished, long-term a priori expectations and short-term ad hoc expectations. The a priori expectations are built during months and years of experience. For example, “red” means danger and a warning to stop what you are doing, while “green” means safety and a confirmation to go on with what you are doing. Ad hoc expectations are based on events that have occurred the last hours and minutes, e.g. sharp bends are warned for along the actual road. Consequently the expectation and therefore the possibility to make correct predictions in a specific traffic situation varies between drivers, due to for example driving experience and whether the environment is familiar or unfamiliar. From the discussion above, describing variables that influence driver behaviour, it is clear that the real effects of SD implementation on driving, and in prolongation on traffic safety will be determined by a variety of factors, e.g. the driver's understanding of the SD functionality, the driver's experienced advantage of the SD or the driver's motive to use or not use the SD

4.1.6. A system to evaluate the effects of In-Vehicle Safety Devices

The components of our taxonomic system are deducted from the basics of traffic-psychology on the one hand and from potential areas of operation of telematic installations on the other hand. Age-related variations for the respective psychological areas of reaction will have to be considered and therefore have to be included into the list of characteristics for classification of the system. The evaluation of each component of the system is focused on an **expected gain or loss of objective**

safety. The basis of all evaluations is a set of hypotheses about the causal relation between these components and objective safety. A reduction of objective safety for example is assumed, if the driver is sensory overloaded.

Before starting to evaluate a safety device it has to be noted, if this evaluation is restricted to special groups of persons (e.g. young drivers, female drivers, aggressive drivers, all drivers) or special traffic situations (a special constellation of environmental factors). Furthermore it has to be noted, if this safety device is co-operating with additional safety devices or not. In practice or research it happens quite often that the effects of a single SD is evaluated without taking into consideration the co-existing effects of other safety devices.

4.1.6.1. Essential functions of telematics

The two essential functions of telematic installations are as follows: (1) *enhancing competence* and (2) *relief*. Enhanced competence is targeted by providing information of either an orientation or warning character. Navigational systems and various techniques to control attention meet these functions. Relief, however, is attained with the help of measures, that cause an automatic reaction and thereby defy the driver's control. An automated distance control would be the respective telematic system. While enhancing competence safeguards freedom of decision making when steering a vehicle, relief reduces it.

4.1.6.2. Areas of examination

The introduction of telematic technology may have an effect on sensorial, cognitive, affective and behavioural reactions of road users as well as have an effect on the surrounding traffic environment. The new technology modifies vehicles and roads intending to render road use for individuals and for the whole of society safer and more comfortable, less expensive and more environment friendly. Accident rates, traffic flow, traffic density, pollution and the traffic climate which may take on a different quality through the possible changes in communication and interaction between individual road users, are indicative of those changes. In the end, however, it is the individual road user who by way of his acceptance, his attitude, his competence and use decides whether and to what extent those indicators are moving in the desired direction. The aspects of evaluation were classified according to five comprehensive points.

Pre-use phase

I. Cognitive-affective expectations (e.g. subjective safety, reactance)

Phase of using the SD

II. Evaluation of the actual process (e.g. recognition, attention)

III. Cognitive-affective evaluation based on experience (e.g. expected utility)

IV. Evaluation of the behavioural consequences in the medium or long run
(e.g. risk homeostasis*)*

Phase after technology has spread

V. Evaluation of systemic and further aspects
(e.g. flow of traffic, safety of the whole system*)*

For each area (e.g. cognitive-affective evaluation) a selection of concepts is presented which have in common the assumption of influencing objective safety in a traffic system. In order to assess the changes of a concept initiated by the introduction of a SD specific **questions** are asked. If we deal with „subjective safety“ for example we want to know if the driver perceives an increase of feeling safe, an increase of driving competence and an increase of comfort. The choice of specific questions is based on theories and knowledge gathered in this field of interest.

4.1.7. Discussion

4.1.7.1. State of the art

A prognosis of the effects of SDs can only be successful if the empirical and/or theoretical basis has proven to be valid. At best, empirical information on the subject has already been gained. But as specific empirical information up to now is not available, the evaluation of SD effects can only be based upon psychological theories known to be valid.

If an expert has to judge the quality of a technical system, he/she ideally should first observe the way the system is handled. In a second step, the expert should generate hypotheses about the short- and long-term behavioural consequences of the system's usability which are related to his/her empirical and theoretical background knowledge. If the procedure differs from these ideal proceedings in a way that the expert has to collect information about the structure and functions of the system only by means of a theoretical system manual, the ideas he develops about the functioning of the system might systematically bias his subsequent evaluation. If a rater is not able to view and to test out the system, it remains an abstract and fantasy-stimulating object.

In contrast to the PRO-GEN checklist which was developed in the context of the EUREKA project *Prometheus*, the GADGET-evaluation system is concept-based. Above all, we put a stronger emphasis on the actual driving process which is characterised by the driver's focussing his attention and perception to the handling of the car and to the traffic situation as well as by an additional memory performance. In contrast to the *Vienna Questionnaire* which is used to assess subjective risk in traffic situations, we left out a differentiated evaluation of the actual driving behaviour. This only makes sense if the judgement refers to real observations, which are not necessarily given in the application of our taxonomy. In case that behavioural observations are additionally required, the Vienna Questionnaire or single parts of this instrument represents a useful supplement to our evaluation system.

For the evaluation of systemic aspects, e.g. the accident rate, the flow of traffic, the traffic density, the traffic climate or the ecological and economic consequences, the extent to which the new technology is already disseminated has to be considered. If the new device promotes a change in the driving behaviour of its users (e.g. by driving faster or by braking more abruptly), a dehomogenisation of the traffic can be expected, especially if these changes get manifest in a greater number of drivers, as inhomogeneity increases with higher variability of driving behaviour. The more individuals make use of a new system that is promising safety, the more the traffic density is expected to increase. Drivers who feel safe in general will start driving more often and at longer distances. Safety encourages mobility, even if the environmental conditions remain objectively dangerous. Persons who feel safe on a wet road while using the new safety system will be on the road more often on rainy days – if external forces or necessities are disregarded – than persons who feel insecure on a wet road. And if an individual is driving more often, the probability increases that he/she will be affected by a traffic accident. With a higher number of drivers and a greater traffic inhomogeneity, the conflict potential determined by the kind and amount of interactions also increases, manifesting in the traffic climate. Observational studies have to answer the question if the use of SDs exerts a negative influence on the drivers' interaction behaviour (e.g. tailgating, obscene gestures, using the flasher). The issue concerning changes of the traffic climate can be answered by assessing the drivers' attitudes, apprehensions, and fears before and after the introduction of the new technology.

In the context of the introduction of a new safety device it is often suspected that an objective gain of safety might be levelled out by a rise of subjective safety. Risk homeostasis hovers over all these safety devices like the sword of Damocles. Even if general conditions (for example the perception of the effects of SD) have been specified which make „reactive behavioural adjustment“ more probable, the degree of dysfunctionality of a device due to risk homeostasis can only be clarified by means of an empirical study – which is exactly the problem. It will prove extremely difficult to attribute speed increases or a higher rate of dangerous driving behaviour observed in the real traffic system to this particular measure. Even if results from experiments or from simulation studies do allow valid statements about the causal relationship of independent and dependent variables, they permit only limited generalisations on the real traffic situation which is much more complex. In other words: It cannot be estimated how many light or heavy traffic accidents are prevented or caused by a single safety device. And the more time elapses with collecting empirical data, the closer comes the moment when an existing system will be improved or a new and better one will be introduced. Thus, the question about the effect of the safety gain is transferred to the new system which also becomes outdated soon and will be replaced by a new one itself. Therefore, the subject of traffic safety remains incontestable.

This criticism also relates to the frequently applied procedure of determining the influence of an SD via the analysis of accident data. If the probability decreases for ABS vehicles to crash into another vehicle, as it has been found out in the American studies, while the probability to be rammed by a non-ABS vehicle increases, nothing has been learned about the future effects of ABS in interaction with further new SD, as far as traffic safety is concerned. Multivariate analyses of accident data might have explained issues of the past very well, but due to rapidly changing technologies, they show only a very limited generalisability regarding the traffic situation of the present and future.

It is also important to look at the process of diffusion as mediating the influence of safety devices on the consequences in the medium and long run. Furthermore an evaluation process takes place in a pressuring race against time. Due to rapidly changing technologies, appropriate methods have to be chosen or developed, which ensure to get the result when they are needed. Otherwise safety will never reach state-of-the-art.

4.1.7.2. Research needs

The situation in the field of telematics safety devices (SD) in terms of the their behavioural and safety impacts is far from ideal currently. The development of in-vehicle telematics technology is very rapid. Several applications are already on the market, with many more about to enter the market. However, a clear overall view of SD safety potential is lacking, let alone a general agreement or clear-cut standards on how to measure the safety and behavioural effects of various in-vehicle telematics applications.

Existing standards deal with safety mainly indirectly through proposing good and recommendable ergonomics principles for the product development phase of various telematics applications, which can tackle only a very limited aspect of safety. Moreover, to a large extent they are not based on empirical research into driver behaviour. Examples of these standards and principles are as follows:

- Audibility: ISO (DIS) 15006 - Road Vehicles - Traffic Information and Control Systems (TICS) - Auditory Presentation of Information.
- Legibility: ISO (DIS) 15008 - Road Vehicles - Traffic Information and Control Systems (TICS). Ergonomic Aspects of In - Vehicle Information Presentation.
- Symbols: ISO 2575 - Road Vehicles - Symbols for Controls, Indications and Telltales.
- Visual behaviour measurement: ISO 15007 - Concerning visual behaviour measurement.
- European Statement of Principles on Human Machine Interface for in-vehicle information and communication systems. Expansion of the principles.

One of the primary tasks of future research on the SD effects is to agree on the criteria and create standards for measuring safety-relevant behaviour. First and foremost, logically the SD effects ought to be measured as a function of the use of SD and accidents. It is also obvious that accidents as a measure are problematic. Above all, they may be too late as a measure for verifying SD effects, in case the effects are also expected to be negative. In terms of several applications, there are good grounds for suspecting that the SD effects are not only positive. Behavioural variables would serve as an ideal measure of SD effects, since they make it possible:

- to anticipate safety effects, when the information needed is readily and quickly available compared to accident data;
- to use behavioural data that may be available already in the product development of SD;
- to have information also on other effects than safety, such as impacts on the environment.

4.1.7.3. Research on different telematics safety devices

The available and potential safety devices have been covered in chapter 2 and the general structure of the evaluation system in chapter 3 of work-package-1-report. It was the objective of GADGET to propose a plan for the future development of SD research. Ideas and data from the two above-mentioned chapters have been used in this paper, and in addition to this, a view on the development of the whole research area including methodological and methodical issues has been added.

Moreover, future research has been proposed in terms of the classification in chapter 2, and also the main research issues raised in chapter 3 have been considered, especially in terms of driver behaviour.

It is advisable to get as close to real driver behaviour as only possible. The principle of unobtrusiveness ought to be applied when applicable to obtain results with a good generalisation value. This means that usually the most suitable methods are related to the forms of behaviour similar or identical to those seen in real driving. Very often, only simulators and instrumented vehicles make this possible. Again, it is to be pointed out that this does not apply to all problems, but when the behavioural impacts of ready-made products or even prototypes are evaluated, there are no good alternatives available.

Some aspects of driver behaviour need to be addressed also by means of surveys and personal interviews. These are usually related to experiences, stress and the workload of drivers. Moreover, they often function as auxiliary methods for supporting the principal ones. It was not possible to cover here all the behavioural aspects associated with each safety device in detail. However, when investigating behaviour in a moving vehicle, a natural focus is on variables implying both the lateral and the longitudinal control of a vehicle. Rather, the research issues that ought to be covered and principal methods that are needed to address the effects of a particular SD are proposed. Each safety device needs further research for understanding certain behaviour patterns in case safety-related problems are discovered.

Table 4: Research issues and a principal research method by type of safety device (+ = to be covered, - = not a principal issue, method or behavioural level).

	Distance keeping	*Collision avoidance*	*Reversing/ parking aids*	*Alcohol control*	*Driver monitoring*	*Vision enhancm.*	*Pedestrian monitoring*	*Route guidance*
Research issue:								
system awareness	+	+	+	-	+	-	+	-
on- off effects	+	+	+	-	+	-	+	-
penetration effects	+	+	+	+	+	+	+	+
learning effects	+	+	-	-	-	+	+	-
Age etc. effects	+	+	+	-	+	+	+	+
rural-urban areas	+	+	-	-	-	+	-	-
combined effects	+	+	-	-	+	+	-	+
Principal method								
survey, interview	-	-	+	-	-	-	-	-
Simulator	+	+	-	-	+	+	-	+
Instrumented car	+	+	-	-	+	+	+	+
Accident statistics	+	+	-	+	+	+	+	+
Behavioural level*:*								
strategic	-	-	+	+	+	+	-	+
tactical	+	+	-	-	+	+	+	+
control	+	+	-	-	+	+	+	+

The main problem associated with the use of behavioural measures is establishing a link between behaviour and safety. There are several main areas the research telematics SD must be developed and agreed on in order to meet the challenges posed by new technology. The areas to be developed can be crudely divided into three main categories making a hierarchy and they are 1) development of research methodology, 2) development of research methods and 3) definition of research in terms of different SD applications. Telematics safety systems may have effects first on the *quality of exposure* measured through driver behaviour, conflicts or accidents. Another aspect is that they may have effects on the *quantity of exposure* measured in time or distance travelled. Both these aspects have got to be taken into account when defining research for various applications. Finally, totally new safety devices and concepts are currently being developed that need a careful safety evaluation before entering the market. These are among others dealing with automated driving concepts. It is the ultimate goal - however difficult it may be to reach - of research in the area of SD to generate knowledge that extends beyond single technical solutions. The knowledge should be transferable also to future technical generations.

4.1.8. Effects of in-vehicle safety devices on different mechanisms of behaviour acquisition, behaviour regulation and behaviour modification

This conclusion is structured according to the seven proposed mechanisms of impact on driver behaviour.

For each of these mechanisms it considers and describes:

- Expected positive effects
- Possible side effects
- Empirical evidence

- *Drivers‘ psychophysiological condition*

The effects of in-vehicle safety devices (SDs) on different psychophysical conditions depend on the design and the functions of these SDs. Generally, they are expected to reduce stress, which means that they make driving easier and more comfortable. On the other hand unintended negative effects of an SD also have to be taken into account, e.g. if an SD is not designed user-friendly, if it causes strong distraction and if its use is too difficult and complicated. Yet, empirical evidence of positive or negative effects of SDs is anything but common. A few devices are designed to prevent impaired people (by alcohol or fatigue) from driving.

- *Drivers‘ affective condition*

The effect of an SD on driver condition depends on its design and its functions as well. Assuming that the driver is satisfied with the use of this system, positive emotional states (e.g. relaxation, reduction of stress) will be expected including subjective safety. This also signifies that the driver’s need for an efficient and safe support is met by the system. In case the system has proved to be worthwhile, positive evaluations will be associated with it. An unintended effect of an SD could be a significant decrease of subjective risk, which could lead to more risky driving because of maintaining a balance between subjective risk and accepted risk according to Risk Homeostasis Theory (Wilde).

Negative consequences can be assumed, if the experiences of a driver differ from expectations he had in the system. Disapproval can arise and with that the willingness to disconnect the system, if possible. Frequently occurring errors can also cause agitation and annoyance which on the other hand can set off aggressive impulses. Nevertheless a lack of acceptance of a system may be followed by a loss of delight at driving. However, this remains to be verified empirically.

- *Drivers’ getting the appropriate input*

In-vehicle safety devices are conceived to support the driver’s complex information processing providing him with relevant information or relieving him of certain actions. Doing so the system takes care of interpretation and selection of information which also means an influence on the assessment of the input.

- *Drivers’ correct assessment of the relevance of input*

Interpretation and selection of information are frequently performed inadequately and faultily by the driver. The extent to which an SD supports the process of assessing available information again depends on structural and functional features of the system. It is expected that such a system works reliably. However, extensive usability research has to be done before launching it on the market.

- *Drivers’ ideas/beliefs about adept driving*

If an SD is used voluntarily and successfully, enhancement of subjective driving competence is expected. By getting positive experiences of ruling the system reliance on this system rises, which on the other hand enhances the subjective safety of a driver.

The observed behaviour in traffic and the behaviour performed by oneself determines the ideas about adept driving in another way. SDs that support e.g. appropriate following distances, obedience of speed limits etc. thus may influence the driver’s perception of the norms. As long as such devices are not in widespread use, this positive effect may be confounded with negative effects resulting from a more heterogeneous set of behaviours in traffic.

- *Drivers' automated judgement of feedback*

The acquisition of driving skills is dependent on feedback. These processes may be altered considerably by the introduction of SDs, by providing feedback in other qualities or with other thresholds.

With an increasing use of an SD the driver should be able to precisely assess the limits of the system. Whether this can be done successfully depends on the error tolerance of an SD and on the way and the extent the driver is provided with feedback. Empirical evidence for this effect is lacking so far.

On the other hand, we don't want to rule out the possibility that a driver loses his competence to drive a car that is not equipped with an SD after he had been driving an SD equipped vehicle for a certain period of time. But there is no empirical evidence for such a potential loss of competence by changing to an unequipped vehicle.

- *Drivers' cognitive judgement from feedback*

One surely might presume that using a perfectly functioning and accepted SD, safety is assessed much higher by the driver than without using this system. Whether this is actually going to happen depends on the perceived driving competence. If a driver experiences an enhancement of his driving competence an increase in subjective safety will be the consequence. If, however, a loss of competence is perceived, a state of uncertainty is likely to develop. Presumably the perception of a loss of competence depends on the age of the driver. It is also suspected that there is a tendency to believe that an accident that has occurred can be attributed to the use of the new technology. This delegation of responsibility from the driver to the vehicle can be regarded as self-protecting behaviour.

- *Intention and motivation*

The effect of using an SD-equipped vehicle on the intention and motivation of the driver depends on his experiences with this vehicle. If they are in accordance with his expectations reinforcement of existing motivations is presumed. If the experiences differ from expectations disapproval can arise and with that the willingness to disconnect the system, if possible. Frequently occurring errors can also cause agitation and annoyance which on the other hand can set off aggressive impulses. Nevertheless a lack of acceptance of a system may be followed by a loss of delight at driving. However, this remains to be verified empirically.

4.2. Summary WP2 - Modifications to the road environment

4.2.1. Aim of work-package 2

Work-package 2 of the EU project GADGET deals with effects on driver behaviour of various measures implying modifications of the visual stimuli from the road environment. The work-package had the following aims:

- Provide a list of road-related measures, which have been shown to influence traffic safety by changing driver behaviour, or which on the basis of theoretical considerations can be expected to have such effects.
- Present a state-of-the art description of research evidence (both empirical and theoretical) concerning the behavioural effects of these measures, based on a comprehensive screening of research literature, primarily material published during the '80s and 90's.
- Summarise results from available cost-benefit analyses of the listed measures.
- Present recommendations regarding implementations of measures.
- Point out possible weaknesses in the data basis regarding behavioural effects of the measures, and suggest what research efforts seem necessary to provide more definite conclusions.

4.2.2. Working method

At the start of the project in January 1998 the topic of work-package two was subdivided into the following four thematic areas:

- Road geometry, roadside layout and intersection design
- Road markings, traffic signs and roadside information
- Traffic signals
- Measures to influence driving under impaired visibility conditions

The first stage of the work was the literature search, which was performed separately, and by different work groups, for the four areas. The basic data sources for all working groups were the large international road transport databases IRRD, TRIS and Transdoc. Additional sources of data varied between the areas.

This search resulted in a list of about 600 literature references, which were tentatively classified in terms of a) *type of study*, b) *countermeasure studied (independent variable),*and c) *behaviour indicator (dependent variable)*. This preliminary list of references was presented in an internal work-package document in April 1998.

In the next stage the list of references was carefully screened for relevance, and for each of the four subtopics the most relevant references were grouped by countermeasure to provide an overview of the available research work for each combination of countermeasure and behaviour indicator. This overview was presented in an intermediate work-package report (‘Catalogue of research’) in June 1998. An important criterion for including studies in this stage of the process was the consideration of behavioural data. Since the effect of some of the measures on accident risk had been extensively documented in previous work, it was considered redundant and unnecessary to include an exhaustive assessment of accident studies in this project.

The final stage of work-package two consisted of an assessment of the measures, based on the literature included in the ‘Catalogue of research’. For each measure that has been assessed, one or more of the following categories of ‘results are presented: a) behavioural effects, b) benefit/cost assessment, c) effect on accident risk, d) recommendations, and e) identified research needs.

4.2.3. Theoretical background

4.2.3.1. Driver information needs

Since vision is the primary means for drivers to acquire information from the traffic environment, enabling them to perform the task of driving, it is almost a truism that visual modifications of the road environment can influence driver behaviour. In order to predict the effect of such measures it is important to have correct knowledge about the information processing capacities and limitations of drivers. The most pertinent question is what kind of information the drivers need to perform the driving task in a safe manner.

A very useful general classification of driver behaviour into a three-level hierarchy – macroperformance (navigation), situational performance (guidance), and microperformance (control) - was presented about 30 years ago. The highest level (navigation) comprises behaviours related to trip planning and preparation and route finding; the intermediate level (guidance) concerns ‘subtasks associated with response to road and traffic situations’; and the control level includes vehicle control tasks such as steering and speed control.

An essential feature of the driver information hierarchy is that the level of a given task determines the desired allocation of the driver’s attention to the task. For maximum safety, the tasks at the lowest level should have primacy. In particularly demanding situations, the lowest level tasks may require the total attention capacity of the driver, and tasks higher on the hierarchy will be shed. This “load-shedding” behaviour may for example result in drivers missing information from direction signs in complicated traffic situations.

This conceptualisation of driving in terms of a three-level hierarchy with the properties of attention primacy and “load-shedding” seems to be a promising frame of reference for analysing how the driver behaviour can be assumed to be influenced by various modifications of the road and its environment.

4.2.3.2. Basic visual functions

For predicting effects of the road environment on driver behaviour it is also important to take into consideration some basic properties of the visual sensory system. Some of the visual functions that may be relevant for perceiving the road environment include visual acuity (both static and dynamic), peripheral vision, contrast sensitivity, night vision, eye movements and visual search, colour vision, distance perception, and the perception of speed and motion. Of special interest for understanding accident risk in darkness is the distinction between *focal visual functions* (such as visual acuity and contrast sensitivity) on one hand, and *ambient (guidance) visual functions* on the other; the latter being of prime importance for orientation in space. On the basis of this distinction the so-called "selective degradation hypothesis" has been proposed, which implies that reduced luminance – e.g. during night driving - primarily affects the focal vision, whereas the guidance vision remains unaffected at luminances close to scotopic threshold levels. This hypothesis has strong implications concerning the effects of measures to influence darkness driving, depending on whether the measures provide support for the focal or the ambient visual functions.

4.2.3.3. Driver expectations

Violations of drivers' expectations is considered to be a common cause of road traffic accidents. Both planned and unplanned information from the road environment are important sources of drivers' expectations, which govern their behaviour. It is therefore of prime importance that the parts of the traffic system which can be controlled, are designed to suit the "driver information needs" discussed above in conjunction with the three-level model. In other words, correct expectations should be established by advance information by signs, road markings, road design etc. The construct of "positive guidance" has been introduced as a general principle for a good visual road environment, accompanied by the method of "Expectancy Analysis and Review" to assess whether a given road conforms to this principle. These concepts are clearly relevant for the assessment of behavioural effects of visual modifications of the road environment.

Driver expectancies are assumed to be based on different levels of the hierarchical model pointed out previously. An expectancy violation will disrupt performance of the particular subtask that the expectancy is associated with, and may also affect subtasks lower in the hierarchy, and thus create hazardous situations. For example, a violation of an expectancy concerning direction signs (strategic level) may distract the driver's attention so that he may miss information about other road users behaviour (tactical level) or concerning his own speed or lateral position (operational level).

4.2.3.4. Mental load

The capacity for information processing is limited. Therefore, when the amount of relevant information exceeds the driver's cognitive (attentional) capacity, some information is lost. If crucial information is lost, erroneous decisions may ensue, possibly resulting in accidents. Mental load can be considered an important intervening variable between the road environment and driver behaviour. An important aspect of information processing pertaining to mental load is the distinction between "controlled" and "automatic" processing. A consistent and predictable road environment (cfr. the discussion of expectancy above) is supposed to entail automatic information processing, and thereby a reduced mental load.

4.2.3.5. Risk compensation

On the basis of engineering considerations alone, a given safety measure can be estimated to have a large *ceteris paribus* risk-reducing effect. However, the ceteris paribus condition very often turns out not to be true, since it has been demonstrated that several measures actually result in behavioural adaptations that partially or completely offset the theoretically predicted effect. This kind of behavioural adaptation has been termed "risk compensation".

The three-level hierarchical model of driver behaviour is essential also for understanding the behavioural mechanisms behind risk compensation. Compensatory behaviour may take place on different levels. For example, at the strategic level, some drivers may for example be reluctant to drive in darkness on unlit roads, and therefor choose other modes of travel. More commonly, one thinks about behaviour adaptation *during driving*, i.e., on the tactical and operational levels, when talking about risk compensation. However, compensation at different levels may have similar effects on accident numbers. For accident prevention by influencing driver behaviour it is therefore important to know at what level the behavioural adaptation occurs.

An important concern when assessing behavioural effects of safety measures is to consider which measures are likely to result in risk compensation, in order to find modifications that may counteract such behavioural changes.

4.2.3.6. Driver behaviour and safety

Although the focus of the GADGET project is on influencing driver behaviour, the ultimate goal of changing the driver behaviour is to reduce accident risk. It is therefore crucial that measures to change driver behaviour rest on correct assumptions regarding the relationship between driver behaviour and accident risk. A documented effect of some road measure on some driver behaviour is not always easily interpreted in terms of safety. In addition, accident data or convincing theoretical arguments regarding relationships of the given behavioural observation to safety is needed.

4.2.4. Road geometry, roadside layout, intersection design

4.2.4.1. Road network and sections

A safety measure on a very general level, in order to provide drivers with correct expectations and support their information handling, is ‘categorisation of roads into a hierarchical network structure’, or the concept of ‘self-explaining roads’. The leading safety principle behind this is that traffic participants must be able to recognise unambiguously the function of the road - and thus the kind of traffic conditions they will have to deal with. As such, geometric design consistency is an important factor in avoiding driver errors.

In this context, the questions arise: do traffic participants rightly identify the type of road; what cues are applied in that; and, vice versa, what cues might support them in recognising the road category?

In a number of empirical studies, drivers generally seemed to be able to identify road classifications. And, vice versa, drivers generally were able to categorise roads into at least some broad groups.

In both cases, identification was the most consistent for upgraded, high speed roads and for low-speed types of roads.

Some rather general aspects or characteristics like ‘inside and outside built-up areas’ or ‘number and width of carriageways’, separately or in combination, might play a role or be helpful in this. Exact relations between driver behaviour and road categories, reliably applicable by, for instance, engineers in designing roadways as part of a consistent road classification, however, are not stated so far.

Concerning some examples of specific design elements, both superelevation and transition curves contribute to drivers’ expectations regarding the sharpness of a curve. Adding transition curves has been shown under certain conditions to convey misleading impressions about the distance to the curve and the radius of the curve. Further research is needed to determine the optimal combinations of design elements in order to provide expectations that result in safe curve negotiation.

Another overall safety measure is the area-wide implementation of traffic calming measures; e.g. in residential areas. Such measures have been shown to have considerable effect on driver behaviour, especially on speeds. Obviously, in an ‘area-wide’ treatment of residential areas, it is hardly possible to distinguish which element did cause the speed reductions: visual information, or physical and other type of measures. It is important to carry out further research to elucidate the relative effects of different elements, in order to optimise the total effects of the measures.

An assessment of road design from the point of view of the capacities and limitations of elderly drivers indicate that current standards for sight distances are insufficient. These sorts of findings lead, on the one hand, to recommendations for further research into the necessary length of time and, on the other hand, to develop a standard for road signs on highways and streets, taking minimum required sight distances for older drivers into account.

4.2.4.2. Intersections

Based on research results concerning non-signalised intersections the following principles concerning safety effects of measures can be stated:

- Generally, intersections should be planned and designed in an overall perspective to ensure a coherency along the route and to contribute to accordance between the drivers’ expectations and the intersection that he meets. Also, the importance of simplicity and “readability” as well as good visibility and perception conditions should be underlined.
- Roundabouts have the lowest risk of accidents of the various types of intersections independent of traffic from secondary roads.

- The safety effects of various types of duty to give way increases with increased demands for the driver to stop independent of the circumstances.
- In rural areas, traffic islands on secondary roads seem to reduce crossing accidents, but presumably only in 4-way intersections.
- Painted left-turn lanes have a safety effect on major roads in rural areas, especially in T-intersections.
- Replacing 4-way intersections with two staggered T-intersections is recommended if the size of the traffic from the secondary road is more than 30%.
- Attention between right-turning drivers and straight-ahead going cyclists is improved, if the parties are compelled to drive/ride close to each other, and the cycle track is made conspicuous.
- Painted cycle tracks or other kinds of markings increase attention towards cyclists, when drivers are turning right from a minor to a major road.
- 2-way cycle tracks should be avoided at least in urban areas with considerable non-signalised intersection density. If they are used, the visibility should be made sufficient in both directions at the intersection. Also, speed-reducing measures are recommended plus multiple warning signs.
- Humps or rumble strips on the minor road of an intersection will provide drivers with more time to pay attention to both directions, and to interpret the situation correctly, before entering the intersection.

Behavioural research has to some extent been carried out concerning drivers' difficulties at intersections. Such research often results in recommendations of measures that can help solving the problems, but implementation and evaluation of the behavioural effects of the proposed measure are usually not included.

At the same time there seems to be only limited research of the behavioural effects of various measures at intersections. When the effect of a measure is tested it is often in the shape of accident frequency. Nevertheless knowledge of behavioural changes will provide better opportunities to know the limitations and possibilities of the measures in a broader perspective.

Based on the research that came up through the search profile, it can generally be stated that research is needed mainly concerning drivers distribution of attention as well as their deceleration pattern before entering intersections. More specifically, this could be seen in relation to:

- Various kinds of duty to give way
- Various kinds of traffic situations
- Various kinds of driving manoeuvres
- Various kinds of geometric design, including roundabouts and intersections with restricted sight distance in one direction.

The above mentioned research should be followed up by studies of the behavioural effects of measures to prevent insufficient and erroneous attention.

Finally as drivers seem to have difficulties in assessing other vehicles high speeds, research is needed concerning the effect of speed reducing measures on the major road before intersections.

4.2.5. Road markings and traffic signs

4.2.5.1. Longitudinal road markings

The application of *wider edge-lines* has been discussed as a measure to improve steering behaviour of drivers. The main intention is to provide better visual guidance information leading to a reduction in single-vehicle accidents. There is no evidence of any effect on accident risk. A possible explanation may be risk compensation by increased driving speed.

On the basis of studies of the lateral position of vehicles it is recommended that centrelines should always be applied together with edge-lines. Vehicles tend to move to the centreline without the reference provided by an edge-line which probably leads to a higher rate of accidents with vehicles of opposite direction.

It has been estimated that benefits through the application of edge-lines on roads will by far exceed their costs and are therefore strongly recommended.

Longitudinal road marking is used also to indicate lane drop exits. *Lane drop markings* consist of larger-width lane striping that begins in a certain distance in advance of the theoretical gore point. White pavement marking arrows can also be included to indicate the situational demand on driver behaviour. Lane drop lines seem to be a very useful tool to improve drivers' orientation and to avoid hazardous erratic manoeuvres. A smooth flow of vehicles can be obtained by an early information (and its redundant repetition) using appropriate lane drop markings together with directional information.

Thermoplastic *raised-rib markings* (RRM, or rumble lines) comprise a continuously-screeded thermoplastic base line, with transverse ribs. Besides advantages in dark and wet conditions, the raised-rib pattern produces an audible noise and vibrations as a warning sign when a vehicle passes over it. This measure should result in better lane-keeping because of inducing discomfort when driving on the markings. On the other hand this device could be a problem for novice drivers in respect of being surprised and carrying out abrupt manoeuvres. This measure has been shown to result in large initial speed reduction. The effect seems to become less as drivers get adapted to the lines. It has been recommended that: a) RRM should be discontinued at defined pedestrian/cyclist crossing points; b) RRM should not be used as any form of centre of carriageway marking on curves less than 1.000 metres radius; c) RRM should stand up 6 +/-2 mm for all-purpose roads and 9 mm on motorways or roads where cyclists and pedestrians are permanently banned; d) RRM still have to be investigated for cost-effectiveness on urban roads; and e) riblines should be sited as close to a possible hazard as it is practicable.

Post-mounted delineators (PMD) are commonly used as a supplement to standard pavement markings at horizontal curves on two-lane rural highways. Adequate path delineation is particularly important at such curves. Because of difficulties in maintaining PMDs, *raised pavement markers* (RPM) are used as an alternative to or combined with PMD. The effectiveness of RPMs in relation to retro-reflectivity over time should be investigated and a minimum performance level should be estimated. The general problem of obliteration and regular maintenance intervals has to be considered.

4.2.5.2. Transverse road markings

Paint stripes are used as a series of lines across the carriageway with the spacing between them decreasing as a roundabout is approached. The markings are designed to help drivers to slow down after a period of sustained high-speed driving, during which they might become used to high speeds ("speed adaptation"). Appropriate speed behaviour, a better orientation and a reduced accident rate are the main expected effects. Paint stripes are a very cheap measure to implement, a reduction in speed and a change in braking behaviour at approaches to intersections can be expected. A reduction in accidents is likely. The best location for the markings would be where they produce maximum speed reductions. Paint stripes have been compared with *rumble strips*, which are painted lines that are elevated (12 to 15 mm above the pavement), thus producing auditory and tactile (vibration) stimulation in addition to the visual input. Rumble strips resulted in a larger deceleration and more long-lasting effects than paint stripes. A 150-m zone ahead of the intersections is long enough to produce the positive effects of rumble strips. The appropriate height of the strips is about 12mm.

4.2.5.3. Special pavement markings

Road markings in the shape of arrows (*chevrons* – inverted "v" painted on the surface) have been used in several countries to improve the drivers' following behaviour on high-speed roads. Such chevrons are laid on the road surface at regular intervals. As an easy to remember thumb-rule drivers should leave two chevrons between the front of their vehicle and the rear-end of the vehicle they are following in order to maintain a reasonably safe following-distance. This measure seems to result in decrease in close-following, a small speed reduction, and reduction of single-vehicle accidents (but not in rear-end collisions). Since there was no reduction in rear-end collisions, it is likely that the markings act as an alerting device. This general alerting function seems to be irrelevant to achieve the primary aim of the measure.

The use of 'crash cushions' to protect vehicles from crashes with fixed objects in freeway gore areas has become a widespread practice in the U.S. Although crash cushions reduce fatalities and injury severity, previous studies showed an increase in the frequency of traffic accidents. Additional delineation should reduce the problem of lacking conspicuity of crash cushions in gore areas. Investigations of *special markings to increase the conspicuity of the crash cushions* have failed to find any significant effects. As there is no evidence of effectiveness of the investigated measures, other warning - or visual guidance devices should be given priority.

4.2.5.4. Traffic signs

Improving the *retro-reflectivity of traffic signs* potentially could make a contribution to an earlier perception of traffic signs and therefore reduce accident rates. Whereas the relevance of retro-reflectivity is evident under night-time conditions, this feature also plays an important role under daytime conditions when the surrounding luminance tends to „mask“ traffic signs. Reductions in speed, conflicts and accident risk have been demonstrated. The use of high-retro-reflective and fluorescent sheeting for traffic signs are very effective measures to reduce speeding and accident rate at dangerous sites. Maintenance or cleaning intervals should take place not only according to a fixed time schedule but also according to weather conditions (e.g. traffic signs should be cleaned more often during wintertime).

Excessive sign posting can cause informational overload and lead to general ignoring of traffic signs by the drivers, so that even crucial information will be missed. In many countries there exists a tendency to compensate failures in road layout with over-regulation through traffic signs. This over-regulation mainly serves the interests of authorities in the case of accidents to avoid legal problems. A German study showed that following a systematic approach about 20% of all traffic signs could be removed without compromising road safety and traffic flow conditions.

Overload due to direction signs may also be a problem. An overloaded direction sign is defined as a sign with more destinations than can be read in the time available. Many signs contain more than the recommended maximum number of destinations (and other additional information). This is particularly the case in urban areas, where drivers may also have more demands drawing on their attention capacity and that are limiting the amount of time available to read direction signs. A limitation in the number of destinations at a single site seems to be necessary to obtain appropriate information processing by the drivers. A maximum of 6 destinations is recommended as the best compromise between informational load and the demand for directional information. Map signs should be used rather than a stack sign where possible. If the situation permits, flag signs pointing in opposite directions should better be mounted alongside each other than one above the other.

Poor combinations of traffic signs can lead to an increase in perception time and thus result in informational overload. Such combinations of traffic signs can produce undesirable qualities of „Gestalt“ that can also cause neglect (e.g. two triangles can produce a shape that is no direct warning stimulus anymore.) A standardised syntax for useful combinations of traffic signs as a measure to avoid informational overload and neglecting of information should be developed and consequently applied on the basis of psychological knowledge. Guidelines should also take into account that each combination of signs produces its specific “Gestalt” features.

The use of *supplemental plaques* serves the purpose of improving drivers’ comprehension and acceptance of the warning signs. The standard warning signs just provide the most general information. Recently, such plaques have mainly been used for speed limits and general warning signs. There exists evidence that supplemental plaques can be a useful tool to inform drivers about certain aspects of the situation. For descriptive information there remains the general problem that such information requires time for reading which often is short at intersections Additional studies should be carried out to answer open questions about complexity and amount of information on supplemental plaques.

Besides the official directional information that is presented to achieve orientation among drivers, supplemental information concerning tourist attractions, commercial sites or other services can often be observed. This information is added to the official ones more or less systematically. The question is whether such information disturb the main function of directional information or not. It has been shown that supplemental signing, in addition to the already existing official information, on a rural freeway interchange was generally impairing driver control behaviour (speed differential, lateral placement, acceleration noise and recognition distance). A possible solution could consist in a separate placement of official and unofficial information. This would clarify the situation for the approaching drivers.

Variable message signs (VMS) can serve the following goals of traffic regulation: a) to achieve a better distribution of the vehicles in the whole system; b) to achieve a better orientation of drivers; c) to show the best roundabout ways in respect of traffic flow; and d) to indicate dangerous situations in a more effective way. Favourable effects on accident risk have been demonstrated. Highly persuasive VMS configurations resulted in less hesitating behaviour than in conditions with a lower persuasiveness. As the costs for VMS are extremely high compared to static information, additional accident data analysis seems to be necessary to replicate benefit/cost estimations.

The purpose of *incident warning systems* (IWS) is to give drivers an early warning stimulus concerning some disturbance on the road ahead. It has been shown that IWS has positive effects on traffic safety: early speed reduction and early change of lane compared to the control group. The optimal detail in a message from an IWS seems to be that it depends on the type of incident and the type of action a driver has to perform. Before a decision is made on what type of IWS should be used for a certain road, the nature of probable incidents should be analysed.

High-speed signal-controlled intersections at unexpected or hidden locations provoke a potentially hazardous situation for drivers when the signal indication changes from green to yellow. *Advance warning signs* have been suggested to minimise so-called „dilemma zone problems". Drivers are uncertain what to do next: braking or rushing through. The use of dynamic signs that indicate the status of the traffic signal in advance should be given low priority, as they did not show to have any practical advantage compared to the cheaper static signs.

A *stop ahead* sign should warn drivers of an upcoming, unexpected, partially concealed stop sign and intersection. This could lead to better prepared and orientated drivers who are able to slow down in time and who will not be forced to perform hazardous „manoeuvres of the last minute". Changes in eye-scanning, velocity, longitudinal deceleration, and gas pedal deflection, lateral lane position have been observed after implementing this measure. However, since there was no change in the stopping behaviour between test and control condition, the 'stop ahead' sign doesn't seem to fulfil its purpose sufficiently. Additional warning devices could therefore be used to improve the stopping behaviour of drivers.

Signs with the function to warn motorists that traffic on the cross street does not stop can be found at some intersections that are not all-way stop controlled. These *cross traffic signs* function as an additional warning device at dangerous intersection sites. There exists a large variety of form, message, colour, and shape. Cross traffic signing can be an effective way to reduce accidents at dangerous intersections. Efforts concerning a standardisation in designing such signs are necessary. Advance warning signs ahead of passive railway crossings should alert drivers to prepare themselves for a complete stop at sites with restricted lateral sightline visibility. This measure is recommended, as such signing showed to be effective in reducing average speeds and as drivers will have more time to watch out and react in time.

Speed limit signs function as a regulatory and warning device when entering zones where a certain maximum driving speed is necessary to avoid exceeding of physical limits or mental overload, to guarantee safety for residents or for in-time preparation at approaching to intersections or work zones. A good design of curved sites is the best way to reduce speed and accident rate. The application of speed limit signs at ill-designed sites can improve the situation to a certain extent. *Embedded speed limits* (built-up area sign) should not be used instead of explicit speed limit signs. The most effective way to reduce speed at dangerous sites results when using flashing signs.

At special sites or under special conditions *advisory speed limit signs* are used. The main advantage of the advisory character is that drivers are not enforced to lower speeds when the actual situation does not fit the mandatory limit. This can be the case for seasonal or temporary changes in weather conditions. The idea is that drivers tend to ignore regulatory information in general, when discrepancies between situation and demanded behaviour occur very often. Sometimes the combination of warning signs together with advisory speed limits has been suggested. Additional advisory speed signs have not been shown to be more effective in motivate drivers to reduce their speeds through curves than the curve warning sign alone. New installations of speed limits at sites with an existing curve warning sign should be given low priority. The implicit information of curve warning signs to reduce speed seems to be sufficient. There exists no information about the principal functionality of advisory speed limits. A problem could be that the („weak") advisory information is neglected completely because of the yet well established selective obedience of the („strong") mandatory speed limits.

Repeated speed limit signs should remind drivers of the existence of an advisory speed limit hoping that they might respond by keeping their speed reduced or to adjust speed, in the case a driver ignored, overlooked or already forgot the first sign. This measure has not been shown to result in reductions of speeds or in the percentage of vehicles exceeding the speed limit. Speed limit repeater signs on highways/motorways should be given low priority. In many countries there already exist guidelines under which circumstances a sign has to be repeated.

Roadside feedback messages have been reported as powerful means to reduce speeding on US highways. A ‘mobile roadside speedometer’ measures the speed of individual vehicles before presenting it back on a display readable to the passing drivers. As the information is visible for all other drivers present at the scene, a decrease in the number of violations of the speed limit is expected due to social comparison mechanisms. Most drivers do not slow down in response to the standard speed limit signs at work zones. Therefore, additional speed feedback displays, designed to warn drivers that their speed exceeded the maximum safe speed, have been suggested to improve the situation. For all work zones on highways or expressways speed feedback should be used to control speed and speed variance effectively. Speed feedback seems to be a very useful tool to motivate drivers to reduce speed according to the limits. It still has to be investigated if the effect diminishes when the measure is used very often or over a longer time. Especially at the approach to work zones, schools or hospitals the application of this measure is recommendable.

4.2.6. Improving driver behaviour and safety at signalised intersections

The importance of improving safety at signalised intersections can be derived from the fact that in the USA, 39% of fatal crashes at urban intersections in 1991 occurred at intersections with traffic signals. Similar rates of fatal crashes were found in other countries.

Driving task at the guidance level is considerably simplified for signalised road intersections when compared with non-signalised intersections. The task of the road user in relation to the traffic signal lights is to register the signal, to recognise and interpret the information from the signal display, and to make a decision that leads to an adequate behaviour.

An example of an important behavioural aspect of the driver’s task is the decision whether to stop or to proceed when the signal changes from green to yellow and then to red. These types of decisions have safety consequences.

A possible precaution to provide drivers with extra time to clear the intersection if necessary, is an extension of the intergreen period by using all red. All red has a positive effect but should be treated with caution. If the all red period is too long, drivers may take advantage of it and proceed into the intersection at the end of the yellow interval.

As a result of the existing problems mentioned above, the optimising of the yellow interval has an important role in increasing safety at signalised intersections. Optimising the yellow interval reduces the number of vehicles in the dilemma zone and thereby reducing the number of red light infringements and rear-end collisions by using a dynamic approach. This is done, by detecting vehicles in the dilemma zone, and postponing a decided change from green to yellow. Yet, while optimising yellow interval, it should not be lengthened too much since long intervals make the driver’s decision-making process more difficult.

Non-optimised yellow interval results in red running violations. Red running is encouraged by long duration of cycle times, frequent waiting time in peak hours, and meeting many signal installations while driving. Mostly the red-running offences appear to take place at the first few seconds of the red phase in an intersection.

The major ways to deal with red running are good geometric design of the intersection, optimal design of intergreen timings, improved signal head design, surveillance and enforcement.

Another method to deal with red running is improving signal head design. Studies showed a significant reduction in total number of accidents as a result of improving signal head design. Results show that enhancing the signal visibility through the use of a larger, brighter traffic signal head design contributes to improve reaction time and safety, especially when distances between signals are long and speeds are high. Special attention should be paid not only to signal head design at urban areas, but also at rural junctions.

Another problem, which is familiar at signalised intersections, is left turns. Left turn movements during the ordinary green signal are often a complicated situation that creates a risk of misjudgement and wrong decisions. Permissive and protective signals have different effects on this problem. The protected signals are by far the best understood and they are also found to be the most preferred signals since they are associated with less confusion compared to the permissive signals.

Three programs were mentioned in this document:

- LHOVRA for safer traffic signal control of isolated intersections.
- The UK technique “Microprocessor Optimised Vehicle Actuation” MOVA for safer traffic signal control of isolated intersections, and
- The UK technique SCOOT optimising the split, cycle and offsets in a signal controlled network on line.

Positive safety effects of LHOVRA were observed in urban areas. There is an accident reduction of up to 49%, and no increase in the severity of accidents. The safety benefit of LHOVRA is mainly due to the fact that rear-end collisions are reduced. It is also noticed that percentage of drivers violating red is reduced when introducing LHOVRA at a signalised intersection. The percentage of drivers facing yellow in the dilemma zone, where a sudden braking manoeuvre can lead to rear-end collisions, is also reduced. SCOOT appeared, in several studies, to decrease accidents/casualties while in others there appeared to be an increase.

Among countermeasures, which purposes are to increase safety at signalised intersections, there are measures, which deteriorate safety instead of increasing it. Two of these are *right-turn-on-red* (RTOR) and *blinking green*. Both were found to have negative effects on safety.

Proponents of the *RTOR* cite the benefits of increased intersection capacity, reduction of vehicle pollution emissions, and savings of energy and time through reduced delay. Still, researchers found that RTOR causes a significant increase in right turn crashes involving vehicles, pedestrians and bicyclists as well. Effects of RTOR were more significant in urban areas, and were observed a long time after its implementation. Elderly people and people under 16 years of age are the most likely to be involved in RTOR conflicts.

The *blinking green period* is a phase at the end of the green signal, which indicates to the driver that the green light is about to end, and intends to allow drivers the opportunity to cross the intersection safely. Studies showed that blinking green increases accident rate, places additional decision pressure on the driver and creates greater opportunity for error. The practice of introducing a 2-3 second blinking green phase has consistently shown to be detrimental to safety, in all studies evaluating its effect.

4.2.7. Measures to influence driving under reduced visibility

Based on accident data and behavioural findings together the following measures can be assumed to have favourable safety effects under conditions of reduced visibility in darkness and/or inclement weather:

- Road lighting: Effective for reducing accidents in darkness in spite of increased driving speeds.
- Road lights with beam approximately perpendicular on the roadway increases visibility in fog
- Raised pavement markers: Effective in reducing erratic manoeuvres in darkness and rain. Probably more efficient as lane dividers than as edge-lines.
- Internal illumination of signs, and symbols as compared to text: Results in increased detection distance. Probably beneficial effect although behavioural and accident data are lacking.
- High-luminance pavement material.
- Fog warning signs, preferably controlled by both visibility and driving speeds.

Several other measures (post-mounted delineators, high-reflecting edge-lines, etc.) have been shown to provide increased preview of the road alignment. The safety effect of these measures is, however, uncertain, as long as they may result in increased speed without increasing the drivers’ possibility of detecting objects in the roadway. In other words, there is a risk of a selective improvement of ambient vision (spatial orienting) without a corresponding increase in focal vision.

For driving in tunnels, the following measures can be assumed to have favourable effects on safety:

- High luminance at entrance and exits, combined with low luminance of approach zone
- Uniform luminance in tunnel interior
- Counter-beam illumination
- Gradual narrowing of tunnel portals, and increased lateral clearance

- High and diffuse reflection of pavement and tunnel walls
- Horizontal lines to provide visual cues of upgrades and downgrades
- A minimum of signs in the approach sections
- A minimum of sharp vertical and horizontal curves

Most of these conclusions in this chapter are based on rather meagre research data. A general conclusion is therefore that there is a great demand of further behavioural research before any final recommendations can be made regarding the most efficient measures to influence drivers towards higher safety. Further research should, among other things, focus on the relationship between visibility of long-term guidance measures (showing road alignment), driver decision-making and behaviour, and accident risk.

For some of the measures, though, there is more firm documentation. The measures with the clearest empirically documented positive effects on safety are *road lighting* (accident data) and *fog warning signs* (speed data).

4.2.8. Effects of modifications to the road environment on different mechanisms of behaviour acquisition, behaviour regulation and behaviour modification

The description of the results from WP2 followed the inherent principles of classification of road environment especially taking the peculiarities of the visual functioning into consideration.

In this section the results will be summed up according to the general perspective proposed within the GADGET project, putting the focus on the assumptions of the model of behaviour regulation, behaviour acquisition and behaviour adaptation.

This conclusion is structured according to the seven proposed mechanisms of impact on driver behaviour.

For each of these mechanisms it considers and describes:

- Expected positive effects
- Possible side effects
- Empirical evidence

- *Drivers' psychophysiological condition*

Road side information can do a lot to keep drivers in good psychophysical condition. A medium complexity of road environment helps to maintain an appropriate level of activation and thus can counteract boredom and fatigue.

- *Drivers' affective condition*

No special considerations on the relation between road environment and the emotional state of the driver have been found so far. Of course aesthetic aspects of roads gain more attention and may have an impact. Positive aspects of aesthetics are assumed to have positive effects on the psychophysical condition, monotonous design, of course, will have undesirable effects.

- *Drivers getting the appropriate input*

Roadside information that considers the needs of drivers and provides information in a way that it matches the visual functions of people and will help to perceive the relevant input and to distinguish it from irrelevant information.

There are hardly any unfavourable effects to be expected. The positive effects found from road environment measures are mostly attributed to this factor.

- *Drivers' correct assessment of the relevance of input.*

The more road layout meets the expectations of a driver and the more it considers features that evoke correct reflexes (S-R links that are prepared or well-trained and very common) the better the chance to avoid wrong assessment of input.

- *Drivers' ideas/beliefs about adept driving*

Road layout itself can limit the range of behaviour that can be performed. Thus the danger of developing wrong ideas about driving can be counteracted.

- *Drivers' automated judgement of feedback*

Another reason for dangerous behaviour may be influenced by roadside information. Different road layout and different roadside information provide drivers with different feedback about objective risk. Thus the development of habits that do not reflect the real risk can be opposed at least to some extent.

- *Drivers' cognitive judgement of feedback*

Hardly any effects on this level are expected. Road layout should be optimised in a way that it supports automated behaviour patterns and relieves from complex cognitive activities.

4.3. WP3 Summary: Driver Education, Training and Testing

4.3.1. Road crashes as a major public health problem in young adults

Road crashes are the leading cause of external road transport costs. Road fatalities are also the main cause of deaths in the EU in the age group 15 to 24. Compared to other causes of death, such as cancer and cardiovascular disease, road crashes produce a much higher average number of potential years of life lost. Every year in the EU about 15,000 young people die due to a road accident. The road fatality rate per 100,000 inhabitants is twice as high in this age group as in the case of older drivers.

In order to improve the health situation in this age group, or even to attain the objective of 'vision zero' (no severe injuries or fatalities due to road accidents), improvement of driver education is an important element.

Improvements in this field necessitate new concepts and testing procedures but also a high and uniform level of training for driving instructors. Improved driver training and licensing systems also require more money, although there are some ideas as to how costs can be kept down. For this reason the realisation of the best practice presented in this report also depends on the willingness of politicians to improve the health situation of young European citizens.

4.3.2. Aim and Method

The objective was to assess different models of driver education, training and testing with respect to their safety benefit and produce recommendations for best practice. This was realised by

- summarising the relevant theoretical background
- presenting the relevant aims of driver education, training and testing according to the conceptual hierarchical framework
- assessing of the influence on driver behaviour by main programs and methods
- drawing conclusions for best practise in driver training and testing

It was not possible to apply scientific meta-analysis for two reasons. First, only very few controlled studies exist; second, it was the intention also to assess new ideas that are not in practice yet. The assessment of existing or planned measures was therefore based on expert opinions.

4.3.3. Theoretical background as a basis for the assessment

Guidelines for driver education can be derived from traffic-psychological theories and recent theoretical approaches in the psychology of learning and education.

The basic assumption is that driver behaviour is organised on four hierarchical levels. The idea in a hierarchical approach is that both failures and successes on higher levels affect demands on lower levels. The training curriculum should cover all levels in the hierarchy. The training process should start with the acquisition of the necessary basic vehicle-manoeuvring automatism, and then progress to the mastery of traffic situations. Seeking to improve driver education by simply increasing the amount of training will only have limited success.

Explicit and well-designed methods for supporting the process of dealing with the two highest levels in the hierarchy are also needed. These higher levels are not accessible with teacher-centred methods like lecturing, or a longer training period. Active learning methods are needed. Driver training should be open to the view of driver behaviour as a multi-level task. Without this, the driver will not be able to learn from experience about risks connected with motives and goals at the highest hierarchical levels. Practising self-evaluative and meta-cognitive skills should therefore be included in training programmes as this offers a possibility for developing post-training expertise and for reaching and modifying motives and objectives at the highest level. There are three main driver-training contents, each containing subgoals which can be placed on the four hierarchical levels of driver behaviour.

The theoretical framework and the referring structure of driver-training matters is summarised in Table 5.

This theoretical framework was developed in order to have a concrete criterion for the main assessment. This main criterion is safety resulting from of a change in behaviour. Besides safety as the main quality criterion, measures were also judged as to their efficiency, as well as their impact on the environment and social equality. This led to a grid of questions that had to be answered for all measures. The expert opinions were based on answers to the following four groups of questions:

- Assessment of the goals that are addressed by the measure in question
- Assessment of the pedagogic methods and principles that are in use
- Assessment of the correspondence between the training programme as proposed by programme designers and practice
- Assessment of the impact on safety-related behaviour and additional criteria (economy, environment, social equality)

Table 5:
Hierarchical levels of behaviour and referring structure of driver-training contents

		Essential curriculum		
		Knowledge and skills	**Risk-increasing factors**	**Self-evaluation**
Hierarchical levels of behaviour	**Goals for life and skills for living** (general)	**Knowledge about/control over how life-goals and personal tendencies affect driving behaviour** • lifestyle/life situation • peer group norms • motives • self-control, other characteristics • personal values etc.	**Risky tendencies** • acceptance of risks • self-enhancement through driving • high level of sensation seeking • complying with social pressure • use of alcohol and drugs • values, attitudes towards society etc.	**Self-evaluation/awareness of** • personal skills for impulse control • risky tendencies • safety-negative motives • personal risky habits etc.
	Driving goals and context (journey-related)	**Knowledge and skills concerning** • effects of journey goals on driving • planning and choosing routes • evaluation of requested driving time • effects of social pressure inside the car • evaluation of necessity of the journey etc.	**Risks connected with** • driver's condition (mood, BAC, etc.) • purpose of driving • driving environment (rural/urban) • social context and company • additional motives (competitive, etc.) etc.	**Self-evaluation/awareness of** • personal planning skills • typical driving goals • typical risky driving motives etc.
	Mastery of traffic situations	**Knowledge and skills concerning** • traffic regulations • observation/selection of signals • anticipation of the development of situations • speed adjustment • communication • driving path • driving order • distance to others/safety margins etc.	**Risks caused by** • wrong expectations • risk-increasing driving style (e. g. aggressive) • unsuitable speed adjustment • vulnerable road-users • not obeying regulations/ unpredictable behaviour • information overload • difficult conditions (darkness, etc.) • insufficient automatism or skills etc.	**Self-evaluation/awareness of** • strong and weak points of basic traffic skills • personal driving style • personal safety margins • strong and weak points for hazard situations • realistic self-evaluation etc.
	Vehicle manoeuvring	**Knowledge and skills concerning** • control of direction and position • tyre grip and friction • vehicle properties • physical phenomena etc.	**Risks connected with** • insufficient automatism or skills • unsuitable speed adjustment • difficult conditions (low friction, etc.) etc.	**Awareness of** • strong and weak points of basic manoeuvring skills • strong and weak points of skills for hazard situations • realistic self-evaluation etc.

4.3.4. Overall training and licensing systems

The overall licensing systems that are analysed range from pre-test education and training to post-test measures as long as they are parts of a specified licensing system.

There are many descriptions of overall systems in the relevant literature but few evaluations. There are also very few systems where the curricula, educational content or goals have been described. Most presentations cover the administrative frameworks of the systems, such as age limits, restrictions, number of hours of training, time spent in different phases, etc. As the scope of the study does not permit any new empirical studies, the intention has been to take the best from existing literature. However, programmes are currently being developed in several countries in which new goals, training methods and structural changes are discussed. To some extent this development process was covered.

Each country has its own licensing system. No country is identical to another. It is thus impossible to discuss each system individually. The systems need to be classified. The following systems have been chosen for a detailed presentation and assessment on the basis of the theoretical framework:

- One phase systems (Denmark, UK, USA, DeKalb County)
- One phase system with probationary licence (Sweden, Germany)
- Two phase systems with probationary licence (Luxembourg)
- Two phase system with provisional licence (Finland)
- Graduated licensing system (New Zealand, Victoria, New South Wales, Ontario)

A general conclusion that can be drawn from the review is that the systems that have shown safety-increasing effects are systems that have not only increased the amount of formal education and training, but introduced other components, such as graduated licensing, increased experience through lay instruction or risk awareness training.

The young novice driver's safety can be addressed in two ways. One, which has been dominating in research up to now, is to reduce the factors that increase accident involvement. The other, which has occasionally been discussed, is to increase the influence of factors that define safe drivers. Both approaches are probably needed, but in order to adopt both there is a need to define safe driving. What is it that makes the safe driver safe and what do we mean by safe? There is still much research to be done in this field, but we also know a lot from earlier research. Translated into goals for driver education and training the grid presented in Chapter II defines two dimensions that should be considered. One dimension defines the hierarchical levels of driver behaviour and the other defines the essential curriculum. The efforts of programme designers and decision makers should be directed at covering as much of the grid as possible. From today's traditional education, which focuses on the lower left corner of the grid, future education should aim to include the upper right corner. In terms of actual goals, driver education should expand from the knowledge and skills of vehicle manoeuvring and the mastery of traffic situations to include more about driving goals and context as well as about goals for life, risk awareness and self-evaluation. A modified combination of the graduated licensing system (GLS) framework and a specified education and training programme with content that is specified by the dimensions of the grid would seem to be a promising direction of development.

Another general impression was that the environmentally-oriented use of the car was not especially emphasised in training systems. This is something that needs to be taken more seriously. It should be considered as a problem if a driver-training system aimed at making young people start practising driving already at the age of 16, encourages them to choose a private car as the main means of transport. This should be avoided. There may be role conflict in driver instruction. Traffic schools depend on the fact that people need licences. On the other hand, they should be educating people to refrain from driving, unless absolutely necessary.

- *Recommendations for best practice:*

- Graduated licensing systems can be recommended because in several cases evaluations have shown a reduction in accident involvement in those countries where the licensing age is below 18 years and where safety problems are especially serious.
- There is also some evidence in Europe (Germany, Austria) that probationary licence systems offer some safety benefit.

- It makes sense to increase ‘protected experience’.
- No system covers the whole evaluation grid, which indicates that there is considerable potential for developing overall systems.
- If the social and psychological context as well as behavioural self-analysis methods are covered in the training programme, many of the well-known accident-related factors associated with young novice drivers may be dealt with.
- A combination of the ideas contained in a graduated system and an educational content aimed at the upper right corner of the grid would seem promising in safety terms.
- Social equality problems cannot be significantly improved by systems based mainly on private instruction. Selection effects may cause problems.

4.3.5. School based measures

Two kinds of school-based approaches that aim to improve the driving behaviour of novice drivers are possible: school-based pre-training education and school-based driver training. In both cases it is possible to use the traditional curriculum and training methods but also to benefit from the special environment by introducing new subjects and methods.

School-based pre-training education can be understood as an instrument for preparing young people for their role as ‘mobility consumers’, especially as car drivers. This strategy is aimed at those who are still just too young to take part in driver training. In Europe it is usually between the ages of 15 and 17 that traffic education is no longer offered and driver training hasn’t yet begun.

Although there is a lack of empirical experience, there are arguments in favour of follow-up traffic education up to the age of 18. Road safety education at school is more likely to have an impact on subsequent road user behaviour if programmes refer to the whole range of subjects shown in the grid. Understanding the complexity and social dimension of traffic as well as one’s own behavioural tendencies, and developing self-perception skills may have a positive impact on exposure and driving style. This impact is hardly likely to be a direct one. According to expert opinions, the advantage of proper traffic education at school for subsequent car driving behaviour is that it enables and enhances the effectiveness of later driver training.

In *school-based driver training,* the training itself, and possibly also the testing, is integrated in the school system, which means that external driving instructors only make a complementary contribution by teaching mainly the practical elements of driving. Recent thinking suggests that better use should be made of the teachers’ pedagogic experience as well as of the opportunities provided by the school environment in order to apply new methods and to work in existing peer groups. In such a case, the aims are to make the learning process more detailed, to stress the social dimension of driving and to widen the training objectives.

The assessment of existing and planned measures has shown that school-based driver training is an interesting approach that offers new options. However, several possible methods must be carefully separated and their effects discussed. One main criterion is the choice of methods and curriculum. If school offers no more than a platform for ordinary driver training, focusing mainly on rule knowledge of the regulations and manoeuvring a vehicle, a safety benefit can hardly be expected. There is also the problem that school-based training can act as an incentive to start driving earlier. Since exposure is clearly an important condition for a car accident, school-based measures should seek to exclude such effects. This would be possible by expanding the curriculum and methods, which is easier to implement than in conventional driving schools. It is also possible to learn in existing groups and to apply the pedagogic repertoire of the teacher.

- *Recommendations for best practice:*

- Follow-up traffic education probably improves the effectiveness of subsequent driver training.
- Be aware of the possible negative effects of an increase in mileage and starting to drive earlier.
- Simply increasing the amount of traditional training or bringing it into school does not improve safety. It is necessary to extend the contents.
- The school environment offers unique opportunities to include new contents and methods in driver training (mobility training rather than driver training).

- Covering the psychological and social dimensions of driving, and teaching self-evaluation skills would be possible in the school setting.
- Interventions should always be accompanied by evaluation studies, if possible case control studies.

4.3.6. Driver Testing

The main objective of driving tests is concerned with road safety. Driving tests attempt to meet the safety objective by means of driver selection – which means that those who lack the required competence to drive in traffic are not permitted to enter the system. An additional – and probably even more important – function of the driving test is to influence the training and practice undertaken by learner drivers.

Depending on the design of the testing, training and licensing system, a driving test may influence driver training in several ways:

- The test syllabus and test standards directly influence the curriculum, standards and amount of training and practice;
- The test may constitute important training in itself for both passing and failing candidates;
- Specifically, failed candidates are returned for more training and practice, and the test result indicates the areas on which this training and practice needs to concentrate.

The reliability of a test is its ability to produce consistent results; a test is considered to be reliable if it would produce substantially the same results when repeated under identical circumstances. In general, the validity of a test is the extent to which it measures what it purports to measure. In the case of a driving test, this might be defined in terms of competence and of propensity for being a safe driver. However, there is a sense in which a test may be judged to be valid if it meets its objectives. Thus a driving test would have good 'consequential' validity if, when introduced into a testing/training/licensing system, it influenced the amount and quality of training and practice undertaken by learner drivers so as to achieve acceptable levels of safety and competence.

It is important to bear this in mind, since there are special characteristics of driving tests that mean they may have low reliability and predictive validity for candidates who actually come forward for test, but may still induce good training and practice and thus have high consequential validity.

To judge whether current driving tests, and possible improvements to them, are likely to achieve this goal, heavy reliance on the validity of the curriculum is necessary – covering both the subject matter and quality of the test, and the training and practice that it is likely to induce. The hierarchical model of driver-training goals presented in Chapter II of this report presents a theoretical framework that is ideally suited for this purpose.

In most European countries the driving test is focused on skills regarding basic vehicle manoeuvring and mastery of different traffic situations. In some countries new tests are being developed or used that attempt to measure higher-order cognitive functions, mainly hazard perception. Other skills, such as reliable self-evaluation of driving behaviour, are very seldom referred to in driver tests. However, there is experience in Finland that self-evaluation can be successfully implemented in driver testing. Although testing reliability will perhaps be even lower in higher-order skills, such tests will have a beneficial effect on the driver-training process. Adding more safety-relevant aspects to the failure criterion might also help to screen out drivers with a high accident liability and to improve training in these areas.

Additional conclusions from the evaluation of testing procedures are:

1. The short descriptive overview of driver testing in Europe already points to some practical limitations to high-quality testing in some countries: for example, relatively short testing time, short time for feedback, emphasis on pure knowledge testing, workload of examiners.
2. The theoretical assessments of driver testing in the Netherlands and Finland show that driver testing only covers part of the possible range of driver-training goals.
3. There is good potential for improving current driver testing in Europe. Specific suggestions can be given as to how to improve the testing itself. It should, however, be borne in mind that because driver-testing and licensing systems vary so much from country to country, and because many

possible improvements to testing have not been evaluated, it is not possible to give specific recommendations for best practice that will be suitable for every country.

- *Suggestions for good practice:*
- Cover a wide range of driving conditions.
- Give good post-test feedback to candidates and instructors.
- Improve coverage of higher-order skills, such as hazard perception and self-evaluation.
- Make use of minor, but nevertheless potentially risky faults as a failure criterion.
- Attempt to find ways of using examiners' assessments of overall performance, driving style and future accident liability as failure criteria.
- Attempt to find ways of including attitude-related items that predict future unsupervised driving behaviour and accidents.
- Change the training and licensing system outside the test so as to improve the training and practice accumulated by learner drivers and to exert a continuing supervisory influence during early solo driving.

4.3.7. Driver Improvement (mandatory post-test courses for novice, delinquent drivers)

Driver Improvement (DI) is based on the observation of the limited efficiency of a purely punitive approach to illegal and dangerous driving behaviour. DI measures are designed to complement the more punitive consequences of illegal behaviour, including warning letters, interviews, actions concerning the driving licence (suspension, withdrawal, probation), non-punitive approaches (rewards, incentives and reinforcements) and programmes for groups.

DI programmes for young delinquent drivers represent a combination of educational, psychological interventional, punitive and social approaches. They are either integrated in a probationary licensing or point system, as in Germany, Austria and France or, as in some US States, in a single post-test measure.

The philosophy common to all the programmes is the following: the causes of non-compliance with traffic regulations are different for young drivers and older, more experienced drivers. Specific causes relate to their stage of life and the associated psycho-social aspects, their inexperience and to some extent also to specific physiological aspects. It is mainly their risk-taking behaviour (as a by-product of basic motivation) as well as their general and BAC-related high risk level that are specific to young drivers. DI programmes for young drivers aim to match the intervention to the problem.

DI measures producing convincing results have been evaluated, although such results do not prove a direct link between DI measures and road safety. However, DI measures seem to have a positive effect on compliance with traffic regulations. In the United States several evaluation studies have been published, going back as far as 1967. A review of courses for traffic offenders (but not specifically for young offenders) concluded that those which addressed attitude and attempted to alter motivation were more effective in changing behaviour than were courses aimed primarily at developing knowledge. European evaluation studies almost exclusively refer to attitude and lifestyle-oriented interventions that apply an inventory of psychological and psychotherapeutic tools, because only very few DI courses exist where knowledge or manoeuvring skills are the main element of the measure.

The following conclusions can be drawn with respect to different evaluation studies as well as to the assessment of three selected models: Until now, the change in delinquent behaviour and attitudes resulting from DI measures has not resulted in clear and unanimous conclusions within the framework of an epidemiological assessment model (effect on collisions). However, these changes have been significant in statistics concerning the education model (effect on knowledge and attitudes) and the health model (effect on behaviour patterns, such as alcohol consumption).

Although DI group programmes represent a considerable effort, and target quite a small group of road users, there is no alternative to this complementary and at least partially effective measure. DI programmes have another positive effect: driver-training measures can benefit from DI measures.

DI interventions start from problem definition that refers to psychological and social behaviour determinants. Vehicle manoeuvring skills and mastery of traffic situations are not covered on these courses. On the other hand, the role of a driver's personal situation in life and the social context are judged as essential. For this reason, basic motivation and social influence are of key importance when defining the course curriculum. DI programmes address the relevant causes of unsafe behaviour and they have developed methods that go beyond ordinary driver training.

- *Recommendations for best practice:*

- DI programmes should be part of every driver-training system.
- Make sure that your DI programmes meet high quality standards (for example, with respect to the psychological education of instructors).
- In order to be effective in influencing behaviour, driver training also has to cover matters and intervention procedures that are referred to in DI programmes.

4.3.8. Voluntary post-test courses

In several European countries car drivers take advanced driving courses after they have obtained their driving licence. We define advanced driver training as voluntary training for licensed car drivers aimed at teaching or improving cognitive, perceptual or vehicle-handling skills in order to establish more efficient, more safe or more economic (environmentally-oriented) driving behaviour.

Some evidence concerning the effectiveness of voluntary driver courses is available. The conclusions from reviewing the relevant literature are the following:

1. Virtually no studies have been found concerning the effects of advanced on-road training on drivers' accident involvement.
2. In some studies, indications have been found that instruction on a closed circuit can lead to improvements in attitudes and behaviour and reduction of accident risk. In other studies of advanced driving courses where the emphasis was on the improvement of skills, the negative effects of accident involvement were shown, suggesting that one-sided reliance on car-craft skills may prove to be counter-productive.
3. The description of the programme being evaluated in the studies is often very scanty. The description of the attitudes and skills which the programme is trying to improve is often inadequate.
4. Research into the effects of training on the accident risk are plagued by methodological pitfalls. Reliable conclusions are therefore almost impossible.
5. Swedish research has shown that effects on accident involvement can also be achieved by other means, such as a group discussion or a bonus system.

- *Recommendations for best practice:*

- Improve the quality of the programme and the instructor (for example, the course contents and methods should also cover higher-order and self-perception skills).
- Adapt the course to the target group.
- Make use of the group process (for example, use methods such as group discussion).
- Be aware that the safety potential of voluntary driving courses may be diminished by a process of self-selection.

4.3.9. Guesses about cost-benefit/ratio of driver training and testing

There was insufficient data to be able to make conclusive statements within this project about the cost-efficiency of driver training and licensing systems.

Nevertheless, a conclusion that can be made is that, even though several kind of methods connected with driver education and driver testing have been developed, the willingness to employ them is not great. In several countries and also in the discussions within the group working on this report, the costs have been a major concern in the evaluation of systems. Also when making suggestions and ideas for developing new systems. The problem is a kind of paradox. The educational system should produce safe drivers with reasonable experience before independent driving begins, and some things should be done after licensing in order to improve the attained skill level further or to guide problematic drivers to follow the system's requirements. At the same time, however, the system should be free of charge. The notion that drivers could be influenced at no cost is simply not feasible. Furthermore, educational methods, especially, are expected to be free of charge. Investment in technology is considered to be a proper policy (for example, anti-locking brake systems, even though their positive effects on safety are debatable). Well-designed educational methods are not harmful, sometimes even profitable. Furthermore, they can also be commercial products. As in any product, the price of training varies according to its quality. Training based on lecturing large groups is cheap, but high-quality personal training aimed at increasing personal awareness of a driver's own typical behaviour in traffic, for example, will inevitably generate cost. Good personally-adapted training is not cheap.

The underlying philosophy therefore seems to be that driver education is a private matter, despite the fact that novice drivers' accidents are a major public health problem.

The objective of driver education is to produce safe drivers. If it can be shown that this objective is achieved by 'better' driver education, then the effort is worthwhile. However, it is very difficult to demonstrate the effectiveness of driver education. This requires a thorough evaluation of 'best practice training systems'. It is a fact that in all countries in which the standard of safety can be considered to be good, there is a system for controlling driver training by established testing systems, by direct control of the training system, or both.

- *The proposal is:*
- To use expert information (such as this report) to create and implement improved driver education/testing systems
- To organise and finance a thorough evaluation.
- To make a cost-effectiveness assessment.

4.3.10. Three steps for permanent improvement of driver training

No country has a good permanent system for monitoring the results of driver training. Whenever a new element is incorporated in driver training, evaluation studies have to start from zero and resources are lost. A method should be established to continuously evaluate the training system and its product. Parts of this method could be based on material obtained from driver testing. In order to fulfil this task, it is necessary to **establish a European driver-training evaluation working group**. Such a permanent group would initially establish standards for monitoring and evaluating driver licensing systems before starting to collect and interpret national data. This work should be co-ordinated with one from other European evaluation groups in the public health area. In this way it would be possible to have a permanent and up-to-date best-practice target.

Driver training must also respond to changes in basic social and economic conditions. For example, better perception of environmental problems reflects a change in a societal value system. This would present new requirements and opportunities – also for driver training. Although it is difficult to demonstrate a clear scenario of general development, and especially of the development of European traffic systems, it is certain that conditions will change over the next 30 years and that international harmonisation (also of driver-training guidelines) will bring more efficient solutions. Changes in the following fields also affect driving opportunities, the driving task and thus also driver training:

- political and economic development (European integration and harmonisation)
- changes in society (such as shifts in age and income groups)
- European tendencies in transport (for example, in combining of different means of transport)
- changes in the environment (such as an increase in temperature and less stable weather conditions)
- changes in infrastructure and technical development

In addition, trends in other safety measures need to be monitored and discussed in terms of their consequences for driver training. For this reason, the results produced by other GADGET working parties (telematics, visual modification of road environment, safety campaigns, legal measures and enforcement) were analysed. Table 6 summarises how these road safety measures are interrelated.

Table 6: How the five GADGET project work packages are interrelated

	Best practice in driver training necessitates the following changes in these fields	Best practice in these fields necessitates the following changes in driver training
Telematics	No direct link. (Of course, general claims are mainly valid for young drivers: systems should control routine behaviour and provide the driver with enough feedback.)	In-car devices will change the character of the driving task. Driver training will therefore continue to be necessary. However, its curriculum and methods must change from time to time in response to technical progress. Learning to learn will become more important: driver training must involve learning from the driver's own experience, using active learning methods.
Visual modification of road environment	No direct link. (Guidelines for best practice in road environment design should generally allow for the possibilities, limitations and behaviour patterns of novice drivers.)	No implications. (Best practice in road design is self-explanatory)
Safety campaigns	Subject matter, methods and organisation of driver licensing systems will become more and more complex. It will therefore be necessary to apply marketing techniques. In order to influence the motivation of learner drivers' to comply, safety campaigns aimed at the situation and wishes of young drivers will therefore be necessary.	No direct link. (Campaigns must be aimed at young people's situations and needs, be based on empirical knowledge and theoretical assumptions, involve pre-testing and be linked to enforcement issues.)
Enforcement	Driver licensing systems are characterised more and more by a combination of education and enforcement strategies, (graduated licensing systems, combination of probationary and provisional systems). It is therefore necessary to design enforcement strategies for novice drivers.	No direct link. Enforcement activities must be aimed at young drivers' behaviour habits (time and place of visible enforcement and detection, time and place of information about enforcement).

4.3.11. Effects of driver training, testing and licensing on different mechanisms of behaviour acquisition, behaviour regulation and behaviour modification

In chapter 3 on driver behaviour, seven levels of behaviour acquisition and behaviour control have been discussed. On each level we find possible reasons for unsafe driver behaviour. These levels therefore offer a possibility to represent the effects of measures we have assessed in work-package 3. The advantage of this procedure is the comparability of results from different work-packages. On the other hand, the following statements have to be interpreted with caution, as the effects, of course, depend to a certain extent on the specific characteristics of a measure. Within work-package 3 the whole range of driver education-, training- and testing- contents and methods as well as their combinations with organisational and legal issues has been covered. The expected positive effects reported hereafter do not refer to a specific measure but to a hypothetical best practise. Therefore no single empirical results may be referred to. (These you can find in the long version of wp3 report cf bfu-report, Siegrist [ed.], 1999).

- *Drivers' psychophysiological condition:*

Driver training may increase the awareness for the importance of the psychophysiological condition. No negative side effects are to be expected, but the effect will be considerably stronger if such an issue is treated within a curriculum using active learning methods and if the issue is embedded in subjects as trip related goals and context of driving as well as general goals and skills for living. As even low BAC-levels increase novice drivers' accident risk considerably, an important and – as empirical evidence shows – efficient element of licensing systems is a BAC-limit of 0.

- *Drivers' affective condition:*

In order to prevent negative influences on driver behaviour resulting from affective driver condition, driver training works as it does in the case of drivers' psychophysiological condition. Again the effect on behaviour is expected to be low if the content is just presented in a cognitive way. The effect is probably higher if - beside knowledge and skills - the risk-increasing role of affective condition is analysed in detail as well and if students learn to be aware of their own affective conditions using self-evaluation techniques. Moreover this content has to be treated as an element of interaction within a social system like the traffic system.

- *Drivers getting the appropriate input / Drivers' correct assessment of the relevance of input*

Young drivers' accident risk is partly due to missing or wrong selection of information as well as wrong interpretation of the visual input from the environment. Driver training is expected to help novice drivers to detect and interpret the information in order to drive safely. Research has shown that such skills are related to safe and experienced behaviour. Driver training and driver testing methods therefore are more successful if they cover these aspects. As in other cases good training of hazard perception may even result in over-confidence in young drivers. Training of perception and interpretation skills therefore can only be successful if driver training and testing covers the whole range of contents (including motivational aspects).

- *Drivers' ideas / beliefs about adept driving*

Driver training and testing may play an important role in correcting young drivers' wrong beliefs about necessary conditions of good driving. Research has shown that good psychophysical conditions as well as perfect vehicle manoeuvring is not enough. Good driver training makes novice drivers learn and experience all the other influences related to driving and they try to assess their own capabilities and limitations with regard to all of these parameters. Raising the acceptance of regulations by providing insight into the need and background of traffic rules should play an important role in driver education.

- *Drivers' automated judgement from feedback*

Extended contents and methods of driver training offer an opportunity to stop negative learning processes resulting from dangerous behaviour that is not followed by a perceived accident risk. Intermediate criteria of safe driving can be established by driver training. Driver training is more efficient in this respect if driving style is also judged within the driver test, if driver training is able to trigger a 'learning-to-learn-process' and if young drivers are supported and are given feedback in the first phase of solo driving.

- *Drivers' cognitive judgement of from feedback*

The theoretical framework presented above is based on the following assumption: providing information to the novice driver is not enough, in order to influence behaviour, regulatory processes are necessary. These may be initiated by sophisticated technical means (in car devices) or by the driver himself. That means, the driver needs a clear definition of safe driving as well as techniques to monitor own behaviour and to draw correct conclusions. Driver training may offer such a learning opportunity if teacher-centred methods are replaced by student-centred feedback methods.

- *Intention and motivation*

Novice drivers should understand reasons and consequences of basic motivation. This is possible if driver training is not restricted to vehicle manoeuvring and mastery of traffic situations. Young people should understand the role of motivation for the decision to drive as well as for the quality of driving. Including such higher order levels and new methods in driver training is inevitable, although its effect is not easy to assess.

4.4. WP4 Summary - evaluated road safety media campaigns

4.4.1. Objectives

The main objectives of our project on „evaluated road safety campaigns“ are:

- to collect a large international sample of campaigns that have been evaluated;
- to provide an accurate description of this sample using a detailed coding scheme and focusing on the design of the evaluation;
- to evaluate the effect the campaigns have on accidents as a function of certain variables;
- to suggest policy guidelines for future road safety campaigns.

Our precise point of interest in this project is **evaluated road safety media campaigns**. One or more dependent measures (self-reported attitude, observed speed, accidents, offences, etc.) are aimed to qualify and quantify the effects of the campaign.

First, we have described our methodology. Second, we have presented the main results of our investigation. In the conclusion, we have identified what we can learn from previous evaluated campaigns. Finally, we have given some recommendations for future road safety campaigns.

4.4.2. Method

First, we developed a pragmatic strategy aimed at yielding a reliable description of evaluated road safety campaigns. Public communication campaigns can be defined as:

1) purposive attempts
2) to inform, persuade, or motivate attitude and(or) behaviour changes in a safe manner
3) a relatively well-defined and more or less wide audience
4) generally for non-commercial benefits to the individuals and/or society at large
5) typically within a given time period
6) by means of organised communication activities involving media
7) often complemented by interpersonal support
8) campaigns are very often combined with other actions or they can be viewed as an integral support element for other countermeasures (enforcement, education, legislation, commitment, rewards, etc.).

Our work was divided into the three steps as described below.

(1) **sampling of documents on evaluated road safety media campaigns**

As our knowledge of evaluated campaigns is relatively poor when we consider Europe as a whole, and because we knew that the evaluation of campaigns in Europe was rarely carried out -except in the Netherlands-, we decided to collect documents with few a priori restrictions. The main criteria for the initial selection were:

- all **evaluated** road safety campaigns (i.e. with at least one evaluation result presented in the document)

- all themes concerning driver (alcohol, speeding, seat-belt use, etc.), safety devices in the car (front and(or) rear seat belts, etc.) and car.

- on all scales: national, provincial (or regional), local or cities. We excluded small-scale experiments whose primary aim was to test the validity of research models.

- all genres of documents. In order to avoid a classical bias of overrepresentation of well designed campaigns reported in scientific journals, we developed a strategy for finding a variety of documents including unpublished reports, especially those available in the countries of the Gadget participants. We collected documents on evaluated road safety campaigns carried out from 1975 until 1997 and published from 1980 to 1997. We looked for them by consulting databases IRRD, PSYCINFO, TRB-TRIS, ECMT-TRANSDOC. For the non-indexed documents, we contacted some of the other Gadget' partners, other researchers in the field of transport, and some persons who are in charge of campaign development.

We looked for documents on evaluated road safety campaigns from 22 countries: 17 European (within and outside of the EEC) and 5 non-European countries (Australia, Canada, Japan -only English documents-, New Zealand, and the United States).

(2) **coding scheme and content analysis**

To describe the evaluated road safety campaigns, we carried out a content analysis. We built a coding scheme to classify the information in the documents from work which has already been done in this field. This grid allowed us to record information on:

- **Collected documents on the evaluated road safety campaigns** (number of documents, country, type of document, year of publication of the document)

- Preparation of the campaigns (was campaign development based on a theoretical model and previous analysis, was there an explicit development to build the message, what was the potential size of the target audience)

- **The campaign itself** (theme(s), target(s), scale, type of media, starting date of the campaign, length of the campaign, number of periods of the campaign, information on the message)

- **Evaluation of the campaigns** (what variables were measured, breakdown of the sample, how many self-reported data were registered, designs used, length of evaluation, time interval between phases of evaluation, and the results).

(3) **meta-analysis**

The statistical integration of the results of several independent studies is the purpose of meta-analysis. Such a method was applied on the effect of evaluated road safety campaigns (Elliott, 1993) on a variety of self-reported dimensions (awareness, knowledge, attitude, motivation, behaviour) and the observed behaviour, but not on accidents. We have concentrated our efforts on exploring the accident dimension, because it is the focus of safety policy. Of course, accident change is not the only success criterion, for instance, media campaigns can be successful in changing attitudes and knowledge without directly influencing accidents. Nevertheless, the selection of data for the meta-analysis has to be directed by hypotheses about a small range of variables.

4.4.3. Summary of main results

First, we presented an overview of the campaigns which gives more detailed information about European and non-European evaluated road safety campaigns than is available elsewhere. Secondly, we focused on the evaluation of the campaigns (dependent measures and designs of evaluation). For this, we split our sample between campaigns evaluated with one measure only[1] and those evaluated with two measures at least on one dimension[2]. Finally, we presented the first results of a meta-analysis of the estimated effects of the campaigns on accidents.

4.4.3.1. Overview

- *A large international database*

Out of the 22 countries reviewed, we collected 265 evaluated road safety campaigns from 18 countries: the Netherlands (N=43), the United States (N=38), Belgium (N=36), Canada (N=34),

[1] Campaigns which were evaluated in only one phase period, generally after the campaign was carried out or sometimes during the campaign.

[2] Campaigns which were evaluated on one dimension at least in more than one phase period, mainly with before-after periods, but also some with before-during periods and some with before-during-after periods.

Australia (N=33), France (N=25), Denmark (N=13), Spain (N=9), Sweden (N=8), Norway (N=5), the United Kingdom (N=5), Switzerland (N=4), Austria (N=3), Germany (N=3), New Zealand (N=2), Scotland (N=2), Portugal (N=1) and Japan[3] (N=1). So, 59,2% of the studies were European, 40,8% were from-outside Europe. We found no evaluated campaigns from the Czech Republic, Italy, Greece, and Luxembourg.

- *Heterogeneity of documents*

The documents on evaluated road safety campaigns were deliberately heterogeneous in order to reduce a selection bias of best reports. We found mostly published reports (36,2%) and unpublished documents (31,7%), and fewer papers in scientific journals (18,5%), conference proceedings or chapters of books (9,1%) and other published documents (papers in non-scientific journals for instance) (4,5%). The length of the documents varied from 2 pages to more than 100 pages.

- *Preparation of the campaign: little information on the rationale of the campaign*

- *Few theories, more previous analysis*

The evaluation reports gave only limited information about the design of the campaigns. Only 11,7% reported development based on an explicit theoretical framework. There were more reports of development based on previous analysis (66,4%), mainly of behaviour data (32,1%), accident statistics (27,7%), on previous campaigns and (or) programme intervention without explicit mention of type of data used (10,6%), and(or) survey data (questionnaire and/or interview) (10,2%).

- *Little information about the basis of messages*

Only 36,6% of the evaluation reports specified that the campaign message had any explicit basis, mainly from previous campaigns (21,5%). All in all a lot of information was lacking on how and why the campaign message was developed.

- *Few pilot tests*

Only 6 % of the studies reported any pilot testing before the campaign was launched.

- *Campaign itself*

- *Few reported costs*

The cost of the publicity was given in only 19,2% of the evaluation studies.

- *Alcohol, seat-belt use and speeding*

In our sample, 41 different themes were involved, alone or with other themes. The most common themes were alcohol (35,1%), seat-belt use (30,6%), speeding (26,8%), accidents (15,5%) and driving carefully (10,2%).

The distribution of themes was not uniform across countries:

- alcohol was most often found in Australia (17/33)[4], the Netherlands (16/43) and Belgium (12/36),
- seat-belt use was most often found in the United-States (21/38), Canada (15/34), and the Netherlands (11/43),
- speeding was most often found in the Netherlands (16/43).

66% of the evaluated campaigns were aimed at only one theme. The most frequent solo themes were: alcohol (21,5%), seat-belt-use (18,5%), and speeding (12,8%). Accidents, and driving carefully, which

[3] Only English documents.

[4] As the number of evaluated campaigns per country is very different, we chose to present the results not as a percentage but in numbers per country. For instance, in Australia, campaigns on alcohol were found in 17 out of 33 campaigns.

were frequent themes rarely appeared alone in campaigns (respectively in 1,5%, and 2,3% of the studies): they were, in the majority of cases, associated with other themes in the campaigns.

20,8% aimed at 2 themes, 4,9% aimed at 3 themes, and 8,3% aimed at more than 3 themes.

- *Three-quarters of the evaluated campaigns were aimed at all drivers*

76,2% of the evaluated campaigns concerned all holders of a driver's license. Only 23,8% tried to reach a more specific group, mainly in Denmark (12/13), followed by Australia (16/33).

The potential size of target audience was given in only 23% of the evaluation studies.

- *From national to local scale*

Most of the evaluated campaigns were carried out on a national scale (38,1%), then on a provincial scale (or on a regional scale) (30,2%), local scale (15,1%) and in cities (10,6%). Few of them combined different scales.

Almost all of the evaluated campaigns were on a national scale in Belgium (36/36), France (24/25), Spain, (9/9), Switzerland (4/4), New Zealand (2/2), Portugal (1/1). The evaluated campaigns were mainly on a provincial (or regional) scale in the Netherlands (26/43), Australia (18/33), and Canada (14/34). In the United States campaigns tended to be mainly on a local scale (16/38) or on a provincial scale (11/38).

- *Publicity + enforcement, publicity + educational programme*

26,4% of evaluated campaigns were carried out alone. Campaigns can be combined with one or several actions. The most frequent evaluated campaigns were combined with enforcement (with or without other action) (49,8%), followed by an educational programme (with or without other action) (24,5%).

The campaigns alone were mainly conducted in France (13/25) and Belgium (13/36) and we found them only in Spain (9/9), Switzerland (4/4), and Scotland (2/2).

Evaluated campaigns combined with enforcement were more often found in the Netherlands (30/43), the United States (26/38), Canada (22/34), Australia (21/33), and Belgium (12/36).

Evaluated campaigns combined with educational programme were most often found in the United States (24/38).

The campaigns without supporting actions were most often carried out on a national scale (70%). The campaigns combined with enforcement were carried out mainly on a provincial scale (43,9%), on a national scale (21,2%), on a local scale (15,1%), in cities (13,6%). Those with an educational programme were mainly on a provincial scale (35,4%), on a local scale (27,7%), and on a national scale (16,9%).

- *TV, billboards, radio, brochure/leaflets, press*

There was great diversity of media in the campaigns evaluated, ranging from leaflets handed out, to large-scale media (TV, radio). The most frequent media were TV (67,5%), followed by billboards/posters (66%), radio (57,4%), brochure/leaflets (54,4%) and then by articles in newspapers, press (49,4%).

- *Few local activities, more go-betweens*

The media used in campaigns were sometimes associated with local activities[5], and(or) a go-between[6].

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[5] Local activities can be organised during the campaigns, for instance games, street theatre, etc.

[6] A go-between is an intermediary (or interface) between the drivers and campaign organisers: barmen, police, taxi drivers, teachers, etc. For instance, a taxi association co-operated by having the participating

Local activities were found in 24,9% of evaluated campaigns mainly in the Netherlands (19/43) and the United States (12/38), or in campaigns carried out mainly on a provincial scale (34,8%) and on a national scale (24,2%).

65,3% of studies used a go-between in each country, mainly in the Netherlands (36/33), the United States (30/38), Australia (26/33), Canada (24/34), Belgium (21/36) and France (11/25) (a go-between was absent in Switzerland, Spain, Portugal, and Scotland), or was used in campaigns carried out mainly on a provincial scale (38,1%), a national scale (26,6%), local scale (15%) and in cities (12,7%).

- *178 days, 1 period*

The length of the campaigns was on average 178 days (N=234). Most of the evaluated campaigns had only one period (71,7%), 14% had repeated periods mainly in the Netherlands (13/43), France (7/25), and the United States (7/38).

- *Few reports on message content*

We found too little information about the frequency and intensity of publicity to be able to draw any valid conclusions.

32,5% of campaigns showed an accident victim in the publicity. 26,4% of the evaluation reports recorded that the publicity did not include victims, mainly in Belgium (23/36), Canada (13/34) and France (12/25). The presence or absence of victims was not stated in 41,1% of the reports.

Humour was reported as used in 6,8%, as not used in 37,3% and was not stated in 55,9%. Spokespersons were reported as used in 17,4%, as not used in 19,2% and not stated in 63,4%. In 10% of campaigns music was reported as used and not stated in 90%.

4.4.3.2. Evaluation of campaigns

- *Self-reported dimensions, overt behaviour, fewer accidents*

Depending on the objective(s) of the campaigns, the evaluation might involve self-reported dimensions, overt behaviour, accident data and(or) offence statistics. Self-reported dimensions were the most frequent (behaviour, attitude, knowledge, risk apprehension, awareness, etc.) (75,8% of the studies), then overt behaviour (52,4%), accident data (24,9%), and offence statistics (16,2%).

- *Only one dependent measure? Designs: post-test only and sometimes more*

The most frequent designs used for the 201 campaign evaluations on self-reported dimensions were After without any control group (59,7%), Before-After without any control group (Between subjects measures) (13,9%), and During without any control group (4,5%).

The most frequent designs used for the 139 campaign evaluations on overt behaviour were Before-After without any control group (Between subjects measures) (18,7%), After without any control group (10,8%), Before-During-After without any control group (10,1%), Single (Experimental) subject design (8,6%), During without any control group (7,2%), and During with control group (7,2%).

The most frequent designs used for the 66 campaign evaluations on accidents were Before-During without any control group (19,7%), and Before-During with control group (13,6%).

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taxi drivers place a sticker on their bumper bar and ensure that their rear seat passengers used seat belts and.

- *A quarter of control*[7] *or comparison*[8] *group*

23,4% of the evaluated campaigns (N=62) used a control or comparison group. More studies recording accidents used a control or comparison group (47%, N=31/66), then studies recording overt behaviour (21,6%, N=30/139), and fewer studies recording self-reported dimensions (10%, N=20/201) used a control or comparison group.

Out of these 62 studies with a control or comparison group,

- 45 studies that recorded only one type of data including:
  - 4 studies that recorded only self-reported dimensions with a control or comparison group,
  - 17 studies that recorded only overt behaviour with a control or comparison group,
  - 24 studies that recorded only accidents with a control or comparison group.
- 17 other studies recorded several types of data including:
  - 10 studies that recorded self-reported dimensions with a control or comparison group and overt behaviour with a control or comparison group,
  - 4 studies that recorded self-reported dimensions with a control group and accidents with a control or comparison group,
  - 2 studies which recorded self-reported dimensions with a control or comparison group and overt behaviour and accidents with a control or comparison group,
  - 1 which recorded overt behaviour with a control group and accidents with a control or comparison group.

Only 33,9% of the studies, which used a control or comparison group, came from Europe and these were mainly from the Netherlands (N=12), then from Sweden (N=4), Germany (N=2), Norway (N=2) and the United Kingdom (N=1). 66,1% of studies came from outside Europe: from the United States (N=17), Australia (N=11), Canada (N=11), Japan (N=1) and New Zealand (N=1).

- *Length of the evaluation: 2 months for each of Before and During, and 1 month for After*

We have only reported the length of the evaluation of overt behaviour[9] here. For overt behaviour, the evaluation was carried out in the Before phases, in several During phases (most often in During1 and During2), in several After phases (most often in After1 and After2). The evaluations were on average 65,8 days for the Before phases, 60 days for During1 phases and 48 days for During2 phases, 35,8 days for the After 1 phases and 43 days for the After2 phases.

- *Time interval between phases: many short-time evaluations for self-reported dimensions and overt behaviour*

For this assessment we could only consider those campaigns that were evaluated with 2 measures on at least one dimension (generally for evaluations with one measure only, the evaluation was carried out just at the end of the campaign).

[7] A control group gets no special treatment (here no road safety campaign) whereas the experimental group gets specific treatment (here road safety campaign combined or not with an action such as enforcement, reward, etc.) and the subjects were randomly assigned to experimental or control condition.

[8] A comparison group gets no special treatment (here no road safety campaign) whereas the experimental group gets specific treatment (here road safety campaign combined or not with an action such as enforcement, reward, etc.) and the subjects were not randomly assigned to experimental or control condition, those in experimental condition are generally as similar as possible to those in control condition.

[9] For self-reported dimensions, people responded at one time, and for accidents it depends on the criteria which were taken into account.

- *- for self-reported dimensions*

The evaluation Before finished on average 71 days from the beginning of the campaigns. The evaluation During was carried out on average 50 days from the beginning of the campaigns. The evaluation After1 was carried out on average 52 days from the end of the campaigns, and the evaluation in After2 was carried out on average 174 days from the end of the campaigns.

For the After1 phases, out of 50 time intervals reported in the studies, most of the evaluations were carried out during the first month (N=38), 7 evaluations were carried out between the second month and the sixth months, 4 evaluations were carried out between the seventh and twelfth months and only one evaluation carried out more than 1 year after the end of the campaign.

For the After2 phases, out of 7 time intervals reported in the studies, one evaluation was performed during the first month, 3 evaluations were carried out between the second and sixth months and 3 evaluations were carried out between the seventh and twelfth months after the end of the campaign.

For the After3 phase, only one evaluation was carried out between the second and sixth months after the end of the campaign.

- *- for overt behaviour*

The evaluation Before finished on average 34 days from the beginning of the campaigns. The evaluation During1 began[10] on average 30 days from the beginning of the campaigns, that for During2 began on average 125 days from the beginning of the campaigns. The evaluation for After1 began on average 29 days from the end of the campaigns, the evaluation in After2 began on average 184 days from the end of the campaigns, and the evaluation for After3 began on average 290 days from the end of the campaigns.

For the After1 phases, 74 time intervals were reported in the studies. The majority of these began during the first month (N=57), only 15 evaluations began between the second and sixth months, and 2 evaluations began between the seventh and twelfth months after the end of the campaign.

For the After2 phases, out of 18 time intervals reported in the studies, 2 evaluations began during the first month, 10 evaluations began between the second and sixth months and 5 evaluations began between the seventh and twelfth months, and one evaluation began more than 1 year after the end of the campaign.

For the After3 phases, only 3 evaluations began between the seventh and twelfth months after the end of the campaign.

- *Few benefit-costs analyses*

The cost-benefit information was rare; only 6% of evaluations included these data.

4.4.3.3. Main differences between 1 measurement only and 2 measurements at least on one dimension

To what extent do campaigns which were evaluated with one measurement only differ from campaigns evaluated with two measurements at least on one dimension?

35,1% of the campaigns (N=93) were evaluated with one measurement only and 64,9% of the campaigns (N=172) were evaluated with two measurements at least on one dimension. Regarding the year of the beginning of campaigns, we found more campaigns evaluated with one measurement only from 1990 until 1997 (N=61) than from 1977 until 1989 (N=28). The prevalence of campaigns with 1 measurement only in recent years can be attributed to the greater availability of recent evaluation reports compared to older reports which were more difficult to collect.

Regarding the continent/country, in our sample the campaigns evaluated with:

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[10] The overt behaviour is recorded, as we saw just above generally for several days, or months, so the time interval for During and for After must be understood as the time **from** which the recording of several data begins.

- 1 measurement only were more numerous in Europe (87,1%) than outside Europe (12,9%). They came mainly from France (21/25) and Belgium (29/36). They were the only type in Switzerland (4/4), Spain (9/9), Portugal (1/1), and Scotland (2/2);
- 2 measurements at least on one dimension were not significantly more numerous outside Europe (55,8%) than in Europe (44,2%). They mostly came from the Netherlands (39/43), the United States (37/38), Australia (29/33) and Canada (27/34).

„ One measurement only “ campaigns compared with „ 2 measurements at least on one dimension “ campaigns showed the main following differences:

- more available in unpublished documents (74,2% vs. 8,7%) than in published reports (15% vs. 47,7%) or scientific papers (2,2% vs. 27,3%)
- more at a National scale (80,7% vs. 15,1%) than a regional (7,5% vs. 42,4%) or local scale/cities (11,8% vs. 63,3%)
- shorter length (77 vs. 218 days)
- more campaigns carried out alone (47,3% vs. 15,1%), so less combined with other actions (enforcement, educational programme, etc.)
- less reported local activities (11,8% vs. 32%) and a go-between (40,9% vs. 78,5%)
- fewer evaluations mentioned that the campaign development was based on an explicit theoretical framework (1,1% vs. 17,4%)
- fewer reported that the campaign development was based on previous behavioural data analysis (5,4% vs. 46,5%) and(or) statistical accident (9,7% vs. 36,6%) previous analysis
- more messages without a victim in the publicity (40,9% vs. 18,6%)
- the evaluation was more frequently based on self-reported dimensions (96,8% vs. 64,5%) and less often on overt behaviour (15,1% vs. 72,7%) and(or) accidents (2,2% vs. 37,2%)
- more often only one type of data recorded in each campaign (87,1% vs. 40,1%)
- more often only the After phase of recording data (91,5% vs. 17%).

4.4.3.4. Meta-analysis: some effects of campaigns evaluated with a control group, comparison group or specific comparison group on accidents

- *Choosing criteria for selection*

One of the main purposes of our database was to compute some meta-analysis about the effect of safety campaigns. Because it is time consuming, we decided to just concentrate our attention on accidents. To our knowledge, no meta-analysis was available on this area.

We had to make empirical judgements about the methodological quality of the studies. A first step was to select a set of criteria to determine which studies would be included in the meta-analysis and which aspects of studies would be coded.

A first requirement for inclusion in the final group of studies subjected to meta-analysis, was that the evaluation design that was used in each of the studies, had to include some kind of reference group:

the presence of a control or comparison group, or specific comparison group[11]. Hence, studies having applied simple before-after comparisons or before-during comparisons without any reference group, are all excluded from meta-analysis.

[11] We refer to a specific comparison group when there is no random allocation to the experimental or control condition, and the campaign is aimed at a specific part of the population the comparison may be with subjects in the same locality but in an adjoining segment of the population (for instance a 17-19 yr. group (experimental group) can be compared to 26-55 years group (specific comparison group), night-time accidents (experimental group) can be compared to day-time accidents (specific comparison group), Accidents related to alcohol (experimental

A second requirement for inclusion were the data themselves. We selected only data on accidents which were presented with **counts** (number of accidents for a period of time). We did not take into account the accident :

- presented with **rates** only (%) because we did not have the numbers of accidents in order to calculate the weight (see just below sub-sections 4.2. and 4.3.).
- presented without before, for instance only during-after or after (with or without a reference group)
- or when the period of time was not clear, for instance sometimes the accidents were presented for after with some of them partly during the campaign

- *Accident counts as raw data*

The basic entity of a meta analysis is a *result*. By a *result*, for example from an evaluation study, we mean an estimate of the change in the number of accidents, accident risk, number of injuries or injury risk. Meta analysis may be described as a procedure for summing up all the individual results from different studies about the same measure, by a weighted average. The weights of each of the results are calculated in such a way that the statistical uncertainty in the weighted average would be as low as possible. The weights in turn depend on the accident counts, which means that the more accidents an individual result is based on, the higher the statistical weight concerning that result would be.

One study may present more than one result. There has been some consideration regarding the lowest cut-off point for the number of results on which to apply meta-analysis. Clearly, to apply meta-analysis on the basis of one result does not make sense. Using only two results may not be advisable as it could mask two opposite results as a zero effect. A number of three or four results might be justified, but in general, we chose to set five results as the norm for the lowest cut-off number on which to apply meta-analysis. We have, however, not been categorical about this, and a meta-analysis of three or four results may appear in some cases.

The data are checked for dependency, i.e. whenever a study had more than one result, the data are inspected and ruled out if we had reason to believe that the results within that single study were judged to be interdependent.

As usual in meta-analysis these criteria drastically reduced the size of the database. Only 35 studies (with a total of 61 results) were selected for meta-analysis among 66 which reported accident data (cf. above). Seventeen studies were with a specific comparison group: they come from Australia (N=8), Denmark (N=4), Norway (N=2) and United states (N=3). Nineteen studies were with a control or a comparison group: they come from Australia (N=4), Germany (N=2), Japan (N=1), the Netherlands (N=3), New Zealand (N=1), Sweden (N=2), United Kingdom (N=1) and the United States (N=4).

- *Formula*

The formula for converting accident counts to mean effect is the following (Fliess, 1981 for the rationale):

The calculation of an effect of a given campaign is done by converting the accident numbers into a log-odds ratio. Meta analysis proceeds from steps 1 to 3 for every single study that contains appropriate accident numbers:

1. Calculation of odds ratio:

$$\text{odds ratio (effect)} = \frac{\dfrac{After_{(T)}}{Before_{(T)}}}{\dfrac{After_{(C)}}{Before_{(C)}}}$$

where:

$After_T$ = Accident numbers in after-period – treatment group

$Before_T$ = Accident numbers in before period – treatment group

group) compared to accidents non related to alcohol (specific comparison group), etc.

$After_C$ = Accident numbers in after-period – control group

$Before_C$ = Accident numbers in before-period – control group

2. Calculation of weights: Weight = $1/(1/B_T + 1/A_T + 1/B_C + 1/A_C)$

3. Calculation of log-odds * weight: ln (effect) * weight

Having done the calculations for all single studies, meta analysis proceeds through steps 4 and 5:

4. For all studies 1 .... n, the weights are summed up: Σ $Weights_{1 \ldots n}$

5. For all studies 1 .….n, the product ln Σ Ln(effects) * $weights_{1 \ldots n}$ is summed up across all studies

6. The overall effect, i.e. across all studies 1 …. n, is then calculated and given by the following formula:

$$\text{Overall effect} = e^{\Sigma (\text{Ln(effects)} * \text{weights})/ \Sigma \text{weights}}$$

- *Main results*

Estimates of the overall effects of the campaigns gave reductions from before the campaign of:

- 7,8% measured during the campaign period (32 studies and 50 results).
- 14,8 % measured after the campaign (13 studies and 20 results).

Both estimates are statistically significant. These results must be attributed to all components of the campaign (other actions like enforcement, reward, legislation, educational programme, etc.), not only to the media campaign itself.

The following breakdown was applied to the results:

- specific comparison group (N=17) vs. control or comparison group (N=18);
- accident injury levels: personal injury accidents (N=14) vs. fatal accidents (N=5);
- theme of the campaign: alcohol (N= 17), speed (9);
- scale of the campaigns: national scale (N=5), provincial scale (N=16), local scale (N=6) and cities (N=8);
- campaigns carried out alone (N=7) or combined with other actions, with enforcement (N=7), with enforcement and educational programme (N=2), with enforcement and legislation (N=2), and with reward (N=4);
- presence of an explicit theoretical framework (N=7) used for the campaign development vs. absence (N=28);
- using TV (N=21) or not (N=14).

Greater significant effects were found for small scale campaigns on a local scale (reduction of the number of accidents by 13,5% Before-During periods with 6 studies and 9 results) and in cities (reduction of the number of accidents by 16,1% Before-During periods with 6 studies and 7 results, and by 13,4% Before-After periods with 4 studies and 7 results) compared to provincial (reduction of the number of accidents by 5% Before-During periods with 16 studies and 23 results) and national campaigns (reduction of the number of accidents by 10,7% Before-During periods with 3 studies and 8 results).

Reductions from the combination of a campaign with:

- enforcement alone (reduction of the number of accidents by 7,1% Before-During periods with 13 studies and 25 results),
- enforcement and legislation (Random Breath Testing) (reduction of the number of accidents by 16,8% Before-During periods with 2 studies with 3 results),
- reward (reduction of the number of accidents Before-During periods by 20,2% with 4 studies and 4 results).

The presence of an explicit theoretical framework was associated with accident reductions of 20,1% Before-During periods (with 6 studies and 8 results) and of 23,4% Before-After periods (with 5 studies and 6 results).

We obtained large effects that are the result of a small sample of well designed and well evaluated campaigns. These large effects could strongly reflect the data from Australian evaluations that are associated with very special long term campaigns (changes in legislation, high public support, intensive use of highly professional and emotional TV-commercials, intensive enforcement levels, sustained campaign efforts over long periods, a very professional and autonomous traffic police division). Such campaigns are hardly typical of the general campaigns in Europe and the United States. Also, of course large effects depend on the baseline level, if the baseline level of accidents is high we can expect large effect. And we must not forget that it is, very likely that there is a possible bias because successful campaigns may be over represented in literature.

Finally, these results are based on the small number of available evaluated studies for each moderator variable (scale of campaign, combination with enforcement, etc). Moreover, these moderator variables were probably correlated. Given the limits of these analyses, generalisations from the results must be made with caution. In particular, it is hard to interpret observed links as causal relationships.

4.4.4. Conclusions

Can we learn from previous world-wide campaigns? The answer is yes. But before being able to carry out more subtle analysis and insightful research, we had to systematically describe what the evaluated campaigns, the defining components of an evaluation and how they are influenced by the associated campaign. We believe that the classification developed will contribute to better understanding of the design and implementation of evaluations and hence to more effective publicity campaigns.

Meta-analysis of casualties has revealed significant quantitative benefits arising from road safety publicity. These findings go beyond the more usual qualitative assumptions arising from measurement of awareness (awareness of the issue, recall, etc.), attitudes and self-reported behaviour.

- *the data base: an unusual sample of evaluated campaigns*

A primary contribution of Gadget WP4 is the database itself. This is a valuable sample of road safety publicity campaign evaluations. To our knowledge it is the largest database in this field. However, the sample is not representative of evaluations conducted in the World nor even in Europe. The sample is biased by the availability of documents. Campaigns evaluated with only one measurement of effect are presumably underrepresented. We know that, with some outstanding exceptions (mainly the Netherlands), this remains the current format of evaluations in Europe. Nevertheless, the overrepresentation of better-designed evaluations is useful when we are using content analysis or meta-analysis to elicit guidelines for future evaluations and publicity.

- *first content analysis*

The content analysis confirms many results observed with previous research.

What is the portrait of the typical evaluated road safety media campaign within our sample?

As far as can be told from the available evaluation reports, the typical media campaign is rarely grounded on an explicit model or theory (as it was already stated by Elliott, 1993 or in OECD report, 1993). In general very little or no information is given on the campaign rationale[12]. The evaluated

[12] In many cases, the people responsible for the evaluation are not necessarily the same people as those who designed or implemented the campaign. And those who evaluated the campaign may not be informed of all the stages of campaign development. It is, moreover, difficult to know what institutional sources were involved in the campaign. For some countries, like the Netherlands, this information was often given, but was rarely given in other countries of Europe. It was also difficult to discover the institutional source of the author’s document. In Australia, Canada, the Netherlands, and the United-States, this information was often given and we found that researchers from Institutes and academics took part in evaluation and the campaign. In France or in Spain, the evaluations were generally conducted by a

campaigns are mostly about one of the main sources of risk in driving: alcohol, seat belt, or speed. TV is the preferred medium, then billboard, and radio. The reasons and content of the main arguments of the message or action are generally described briefly or not at all in the evaluation reports. Campaigns last nearly six months and are generally combined with another action (enforcement for example).

Most commonly, the design of evaluation included only one post-test measurement (with national campaigns this is generally a self-reported dimension) or two measurements at least on one dimension (generally self-reported dimensions or overt behaviour) before and after the campaign. Control or comparison group data were reported for only a quarter of campaigns. The evaluation after the campaign is carried out most often during the first month after the end of the campaign. Long term effects were very rarely available even with casualty counts.

There were massive variations between evaluations and also between campaigns but the typical portrait outlined above brings out many of the main tendencies we have encountered.

Many researchers have reported difficulties in compiling data for the purpose of meta-analysis and we had to expend enormous time and energy to retrieve multilingual documents and organise them in a coherent way. On the one hand, this problem reveals the wide differences among campaigns and among countries, especially within the EEC. On the other hand, the need for minimal normalisation of report content is a crucial issue if we want to build common knowledge based not on assumptions about media influence but on the measured effects of campaigns.

- *Evaluation of the campaigns.*

Most evaluation designs concentrated on ways of deciding about the size and probability of the effects of the campaign and even this is often flawed. Evaluation design seemed to be more the consequences of organisational habits -specific to each country- than the result of a scientific examination of available designs that are most likely to detect significant effects of a predetermined minimum size.

There was a paradox between the painstaking methodology of sampling, that was generally used to evaluate self-reported dimensions, compared to the weak methodology of questioning (some questions did not really test the effect of campaigns, for instance those on awareness of the theme, on the recall, some other questions, for instance on attitudes were too biased) and the weak methodology of evaluation (one measurement only, 2 measurements at least on one dimension without a control or comparison group).

We assume that our sample of evaluated campaigns might not be representative of evaluated campaigns. But nobody knows the population of evaluated safety campaigns because campaigns are not systematically reported and indexed. Many safety campaigns will not contribute to a shared knowledge of the effects of campaigns. We would not go so far as to say that badly evaluated campaigns had no effects.

- *Meta-analysis on accidents:*

Our first meta-analysis on accidents is the first example of the kind of work that it is now possible with a reliable database. Only accidents have been explored in the present report. This focus was motivated by the fact that no meta-analysis was available about accidents. Our results provide empirical evidence for the statement that road safety campaigns could help to significantly reduce the frequency of accidents especially when they are combined with other actions. The values observed were plausible compared with quantitative analysis based on specific local programmes.

- *Beyond this project:*

It was an exceptional task to provide a wide sample of evaluated road safety campaigns and to organise this data in meaningful categories. This report is only a first analysis of the database. We have now to explore fine-grained associations between variables. Typologies and factorial analysis (correspondence analysis) will help to sum up correlation data.

The initial purpose of the database was to develop some meta-analysis. Other meta-analysis could be conducted with more moderator variables and more dependent variables. Given the widespread

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publicity agency. Often in other countries from Europe, the institutional source of author’s document was not always easily found.

dependence on recall, attitudes and self-reported behaviour as measurements of effect an examination of the relation between these variables and changes in casualty numbers could be very valuable. To this end, a meta-analysis on overt behaviour and self-reported dimensions could be planned if the means were available.

4.4.5. Recommendations

- *Recommendations: the challenge of shared knowledge and realistic evaluation*

The formulation of effective social policy about road campaigns is crucially dependent on the availability of a valid base of facts and knowledge shared by safety researchers and practitioners. The formulation of effective social policy about road campaigns is crucially dependent on the availability to practitioners of a valid base of facts and knowledge. So all actions that contribute to encourage the development of such a base should improve future safety initiatives significantly. Progress of future campaigns depends crucially upon the availability of good and rigorous evaluation reports. Appropriate measurements of effect could help practitioners to reach a higher level of expertise. But availability of reports and reliability of results are not sufficient conditions. Policy makers and communication practitioners must be convinced of the applicability of such knowledge.

Following our observations, our main recommendations are about the documentation and the evaluation of the campaigns. We will also more generally discuss the impact of true evaluation on the politics of campaigns.

- Governments and local authorities should no longer be willing to spend taxation on campaigns that do not include a detailed report of the rationale and detailed results of the campaign.
- Governments and local authorities should no longer spend taxation if a campaign presents no or weak methodology of evaluation.
- Co-operation between policy makers, safety researchers and communication practitioners must be encouraged leading to better evaluation of future campaigns.
- Process-oriented and effectiveness-oriented research on road safety campaigns must be supported

- *Documentation: the development of standards of reporting campaigns could be a useful short-term task.*

- *increased availability*

a report should be available in a library and indexed in a database whatever the design of evaluation, and whatever the results of the campaigns (positive, negative or no effect).

It will be useful to develop an international database that indexes the reports and the quantitative results. The WP4 database could be a first step. On-line access to a multimedia database about road safety campaigns could help safety practitioners to develop campaigns that fit their own objectives.

- *better quality*

A good report should include the rationale of the campaign. Moreover, the qualifications of the staff involved in both the campaign and the evaluation should be explicitly reported for each. At present, the process of the campaign itself is rarely described. The design of the evaluation has to be more explicit. All campaigns should be tested over the short term and more campaigns should also be tested over the long term (i.e. more than 6 months after the end of the campaign). More information on the development of the messages and on the frequency and intensity of the messages must be given. A lot of the evaluation reports lack basic statistical information (mean, frequencies, standard deviation), which should be systematically given in the reports in order to get useful data for future (meta-) analysis.

- *Some consequences of evaluation on the practice and politics of campaigns*

- *better preparation*

Development of the campaigns must be based more on solid analysis (theoretical model, behavioural analysis). All in all, a lot of information is lacking on how the message was built. The most plausible hypothesis is that the messages were often based on tacit knowledge. Obviously, we need more research in this field in order to optimise the potential effect of campaigns (campaigns carried out alone or combined with other actions). **In health for instance, a lot of research has been carried out on the building of messages, but much less in the case in road safety.**

- *Better designs of evaluation*

Principles of good methodology must be more systematically applied (i.e. be aware that the basis of measurement is a comparison). As it was already stated in 1971 by Wilde et al., **campaigns carried out at a non national scale must be evaluated with a control (or comparison) group. As the effect of National campaigns can't be by definition tested with a control (or comparison group), national campaigns must be systematically pre-tested with a control or comparison group.**

Such more sophisticated evaluation also changes the planning of media campaigns. Pre-test measurements must be planned before the campaign is implemented. So, the scientific method should be applied to the planning and development of campaigns as well as to their evaluation.

- *policy and practice of campaigns in the EEC*

- *increasing short-term cost*

We are aware that if, in the medium and long-term, benefits of evaluation are obvious, such a policy could in the short term consequentially increase the cost of campaigns especially in many European countries where such habits do not prevail.

- *awareness of evaluation*

The policy and practice of campaigns are based on organisational habits and routines that will not change immediately. In many European countries there is little if any recognition of the need for evaluation. The usefulness of evaluation seems underestimated, or is thought not useful in many national contexts (a large majority of EEC countries).

- *better integration of research-based with practitioner-based knowledge*

A majority of campaigns were developed on empiricist bases and the tacit knowledge of communication practitioners and policy makers (implicit theory of media influence).

In Europe, few scientific experts (safety researchers, academics, etc.) are involved in the campaign from the phase of development to the phase of evaluation or only in the phase of evaluation. Even if they have much to learn from practitioners of communication, they can contribute to the rationale of the campaign, the design of their evaluation and the reporting. More systematic involvement of safety researchers will enhance the theoretical perspective that helps to organise data in meaningful ways. In such a complex field, integration of knowledge is required. Better collaboration with governments and local authorities, and practitioners in the field of media communication are a key challenge in many European countries that have very different cultural habits in this domain.

- *Recommendations for follow up on this work: more meta-analysis*

The time-consuming work of building a large and reliable database led us to focus the meta-analysis on accidents. More meta-analysis of the other available measurements would be valuable (overt behaviour and self-reported dimensions: behaviour, attitudes, risk apprehension, knowledge, awareness, etc.) and a need to integrate many moderating variables. The results presented are by no means complete as the breakdown strategy used only involves one breakdown variable at a time, i.e. it is only a bivariate, not multivariate type of analysis. We do not know the relative contributions of the different elements of the campaign, - i.e. the independent variables, upon the dependent variables (accidents, overt behaviour, self-reported dimensions). We suggest that a multiple regression model, or another appropriate statistical method, could be built in order to provide a better consideration of the relative strength of the different elements, such as theme, type of media used, theoretical framework, scale, etc. In addition, we also consider that an analysis at a more sophisticated and qualitative level of detail is required in order to be able to distinguish between effective and non-effective safety campaigns more easily, and hence, to provide policy makers with improved recommendations on how to plan, build and perform effective safety campaigns.

4.4.6. Effects of safety campaigns on different mechanisms of behaviour acquisition, behaviour regulation and behaviour modification

The description of the results from WP4 followed the inherent principles of classification of road safety campaigns.

In this section the results will be summed up according to the general perspective proposed within the GADGET project, focusing on the assumptions of the model of behaviour regulation, behaviour acquisition and behaviour adaptation.

This conclusion is structured according to the seven proposed mechanisms of impact on driver behaviour.

For each of these mechanisms it considers and describes:

- Expected positive effects
- Possible side effects
- Empirical evidence

- *Drivers' psychophysiological condition*

Safety campaigns mostly target impaired driving. Thus many of them try to increase the awareness of the importance of the psychophysiological condition for driving. It is not confirmed that a campaign alone can really achieve the goal to reduce the number of drivers using drugs, drinking alcohol or driving when tired.

It can be assumed that safety campaigns have long-term rather than short-term effects on impaired driving (see below).

Still, campaigns play an important role in a set of measures to overcome the problem of impaired driving. Unfavourable side effects are possible if campaigns do not consider specific groups and specific conditions. Therefore it is vital to include experts and evaluation as early as in the design phase.

- *Drivers' affective condition*

Speed and aggression have been targeted by safety campaigns. This can mean a reflection of the importance of the affective condition when driving.

Campaigns against speeding and aggressive driving run along the same lines as campaigns on impairment. Even if there may not be a direct effect in the short term, at least in the long-term effects on beliefs (see below) can be assumed. Combinations with legal measures and enforcement and the use of pre-tested concepts to avoid unfavourable side effects applies as well.

- *Drivers' getting the appropriate input*

These behavioural mechanisms are not specifically affected by safety campaigns.

- *Drivers' correct assessment of the relevance of input*

These behavioural mechanisms are not specifically affected by safety campaigns.

- *Drivers' ideas/beliefs about adept driving*

Safety campaigns address social norms and especially the norms on driving. They can provide adequate knowledge on manoeuvring and mastery of traffic situations, initiate reflection on driving, goals and context of driving and of course they can address the issues of impaired driving and driving under certain affective conditions. If messages are correct (persuasion models and more specifically message framing have to be used) and campaigns are made in a professional way potential side effects (reactance, comparative optimism, illusory self-assessment) can be overcome.

- *Drivers' automated judgement of feedback*

These behavioural mechanisms are not specifically affected by safety campaigns.

- *Drivers' cognitive judgement of feedback*

Safety campaigns need not be restricted to the promotion of norms, they can inform about the dangers and how they emerge. Detailed knowledge about risk, risk determining factors helps drivers to come to appropriate interpretations of experience gained in traffic. But, this information on dangers can lead to a possible adverse effect: it can make a driver overestimate his own driving abilities and his feeling of control over driving-related decisions.

4.5. WP5 Summary - Legal measures and enforcement

4.5.1. Objectives of the work

It was the objective of WP5, *Legal measures and enforcement* to point out the needs in improving legal measures and enforcement influencing driver behaviour in Europe. This was made by:

- selecting four different and important areas of driver behaviour as examples in selected EU countries and participating partner countries for listing and evaluation,
- these four areas are alcohol, safety belts, speed and young drivers,
- legal measures and enforcement in the four areas are covered in terms of 1) legislation (passing a law and adjudication) and 2) enforcement,
- the work was done by carrying out a literature review, statistical data and surveys targeted to selected authorities responsible for legislation and enforcement in Europe,
- the task ends in the recommendations for the best practises in legal measures in four important areas of driver behaviour in the Europe. The target is especially authorities involved in the whole chain of legal measures. Moreover, these four key areas of driver behaviour will also serve as examples how to proceed later to other essential areas of driver improvement through legal measures and enforcement.

4.5.2. Work content

- *Structure of WP5*

The task WP5 was broken down in two dimensions: 1) behaviour to be influenced: alcohol, speed, use of seat belts and young drivers and 2) phase of legal measures: legislation concerning passing a law, adjudication process and enforcing laws. Moreover, there is also a general review for each link of the legislative chain.

- *General review*

The work started by a general part describing the legal measures as a chain comprising of the above mentioned phases, legislation and enforcement. The chapters 4.5.4.1 – 4.5.4.4 focus on these phases separately in the four areas of driver behaviour and will tackle the essential issues characteristic for each area.

The first part, legislation covering both passing a law and adjudication concentrates on the following points:

- national policies and strategies as well as explicitly and quantitatively stated traffic safety goals in different parts of Europe and the role legislation in realising traffic safety policies,
- the use of a special traffic code, penal code and administrative code in creating norms for traffic behaviour is reviewed, comparisons are made how legislation is realised and what are the implications of using e.g. penal code instead of an administrative code in driver behaviour enforcement,

- also consequences, sanctions for breaking the law are reviewed generally here, as well as the relation of law and insurance policies in driver behaviour control.

Adjudication is dealing with sanctions and the way they are imposed. There are great differences in Europe in respect with the realisation of sanctions. The differences of interest may be manifest at least in the following points:

- the sanctions imposed may be based on penal code, traffic code or they are administrative, practical implications from the drivers' point of view are reviewed here,
- the way sanctions are put in effect vary also; there may be so called on-the-spot fines or the fines will be confirmed in court or the court appearance are need for the violator personally. Differences and thresholds in respect with these procedures vary a lot in different European countries,
- the severity of sanctions needs to be covered and the effects of severity on subsequent behaviour is an area where the process of adjudication has not been optimised,
- moreover, the swiftness and steps of the adjudication vary also a lot in Europe,
- the use of photographs in automated surveillance methods for the prosecution process varies too. In some countries both the driver and the licence plate of the vehicle have got to identified, whereas in other countries the principle of owner responsibility is used,
- demerit point systems are used in several countries even though little is known of their effects.

The review also assessed different types of enforcement systems and their implications for monitoring driver behaviour. It is above all the organisational factors that create the basis for effective use of available enforcement resources. Different practises exist especially in terms of the role the traffic police has in the police organisation. In some countries there are almost totally independent traffic police forces (e.g. highway patrols, mobile police or national traffic police forces). In other countries the traffic enforcement may be seen as a part of "all" police activities and consequently the police prevents both conventional criminality and enforces traffic. There are also systems in which the police has a special force for traffic for inter-urban roads only and for urban areas there are in major cities traffic units and in smaller cities the police is responsible for all the police duties. These systems are evaluated in respect with their efficiency from the traffic safety point of view. The issue whether all traffic enforcement activities should be carried out only by the police is also covered here. This question has relevance especially when the application of automated enforcement methods are evaluated.

Enforcement inputs in person years were compared as well as the effect of inputs evaluated, e.g. what is the share of field work and strategies and tactics used for surveillance (selectivity is one criteria).

Thresholds for intervention or so called tolerance levels for a punishment are also an issue on which there is tremendous variation from country to country and even within countries. This issue has been dealt only little so far.

An essential thing covered here deals with describing traffic behaviour in general, "traffic culture". There are certain objective measures such as degree of safety belt use, share of speeding vehicles in traffic flow, share of drunk drivers in traffic flow, alcohol involved drivers in accidents etc. A list of availability of these data needed for planning legal measures and enforcement is drawn up. Especially, attention is paid to differences in existence, quality and use of these data by different European authorities. A recommendation is made for using uniform set of variables used for describing traffic behaviour in Europe.

However, one essential and indicative aspect of traffic enforcement is the existence, degree of centralisation and the availability of statistical data describing the activities of the police in terms of surveillance and enforcement.

4.5.3. Principles of law and enforcement systems

4.5.3.1. Mechanism and the role of legislation and enforcement

The following makes a synthesis of the results of the whole WP 5 work comprising of two different tasks, the literature review and the description of legal measures and enforcement.

There is plenty of empirical evidence that the effective use of legal measures improve and downright, is critical for improving safety of road users. The laws regulating the use of alcohol, safety equipment and driving speeds have had a key role in decreasing traffic fatality rates during the past three decades. This has happened even though the passing and enforcing laws have been far from satisfactory in most European countries. It has been calculated that the slow adaptation of general speed limits in Finland alone cost the lives of about 5 000 road users.

The use of legal measures and enforcement has by no means been exhausted in improving safety of drivers, even though their effects have been convincingly shown in many areas of driver behaviour. There are many reasons for this. Perhaps, one of the most important causes for this is the fact that safety is not a need for drivers they are actively striving at. According to Näätänen & Summala’s zero risk theory most drivers most of the time under normal driving conditions perceive the risk of an accident practically as zero. Rather, norms regulating behaviour and authorities enforcing laws are seen as preventing drivers from satisfying their needs. The probability of a serious accident is low for an individual driver which prevents safety from becoming a need. It is not in the interests of authorities to seriously engage in activities that do not conform with the needs and wishes of road users.

Currently, there is ample space for considerably better application of legal measures. The examples are many ranging from excessive speeds, the neglect of the use of safety equipment to drink driving. There are flaws to be identified in the each link of the legal measures chain: passing laws, monitoring the obedience of them and in the process of adjudication. European legal measures system, to be effective, must use same norms consistently regulating driver behaviour *in the essential areas*. It is not realistic to expect every rule of many different European traffic codes to be made identical. There are, however, certain key areas that can have uniform regulations and uniform ways to enforce them. Moreover, the laws to be credible, in addition to uniformity need also effective enforcement throughout Europe, not only in so called safety oriented countries.

The general mechanism of enforcement can be described as follows (Figure 3):

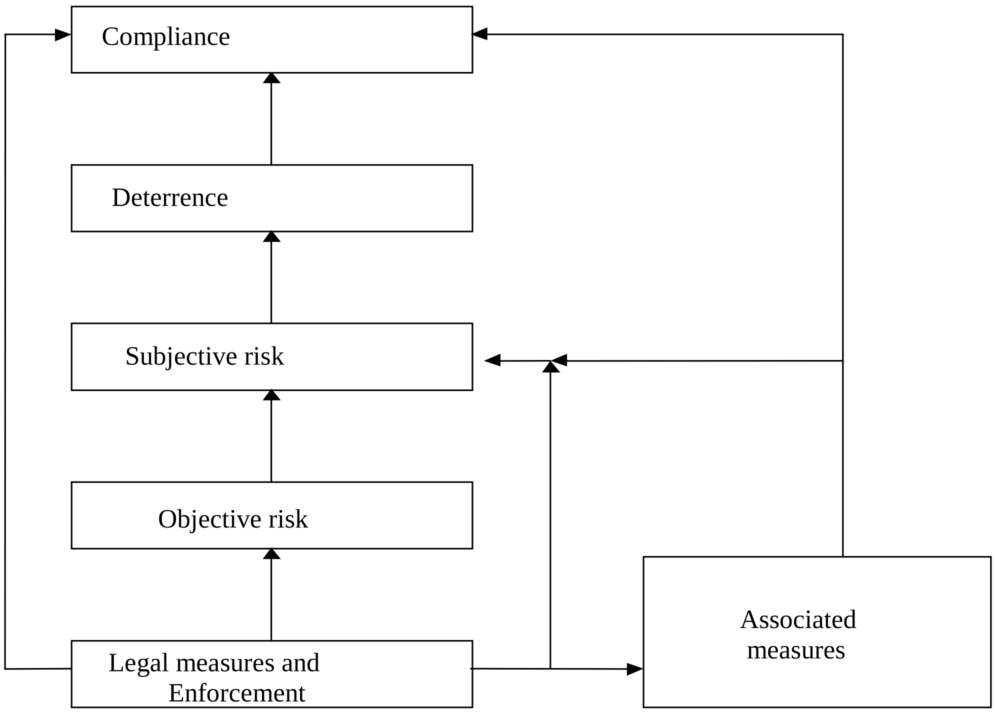

Figure 3: General working mechanism of traffic enforcement.

According to the figure, traffic enforcement creates first an objective risk of detection for traffic offences. This, again, has an impact on drivers' perceptions of possibilities for getting caught for infringements. Subjective risk of detection is drivers' own, more or less conscious and less explicit judgement on possibilities of getting caught for violations. Moreover, the associated measures such as media or a word of mouth (e.g. communication among professional drivers) may either increase or decrease subjective risk of detection. However, the effects of legislation and other sources of information often influence directly behaviour just by making road users aware of the norms or the codes of correct behaviour. For a part of road users, however, it is their conceptions and experiences of the enforcement system in the last phase that create the deterrence effect of enforcement and may make them comply with regulations.

Generally, the state of enforcement in European countries currently is such that enforcement creates very low objective risk of detection for most violations no matter what European country is focused on. This is mainly due to the huge size of transportation systems. No matter how effectively so called conventional enforcement is organised, there are no great possibilities to increase the deterrence effect of enforcement especially in terms of one key area, speeding and speeding related violations.

Success or failure of an enforcement policy is not only determined by the internal functioning of the police organisation only, but determined by the way different organisations, such as the police, road and transport authorities and publicity organisations work together in a professional network and co-ordinate their activities. In this view, the quality of traffic law enforcement is determined by the extent to which activities are geared to each other to make up an effective chain of enforcement and supporting measures.

Europe combines a great diversity of national Law and Policing systems. Despite this variety, most Western and Southern European countries share similar historical conditions of building up modern democratic systems of law and social control. Old European countries have behind them many centuries of law systems and social control. Legal competencies and powers have been marked by the accumulation of previous strata and tailored by deposits of a succession of types of government and historical events. This common background particularly concerns the key areas of justice and police powers, divisions and independence which highly condition the way in which law enforcement is in general ruled and applied. Strong ties with the long history of legal systems also creates plenty of diversity in the way laws are applied to traffic enforcement.

A second fact is that the map of Law in Europe is divided into two straightforward regimes of criminal sentencing:

- the Continental sentencing regime based on written codes ranking laws and penalties and involving a judiciary police power normally controlled by the justice,
- the British sentencing regime based on previous jurisprudence of cases (Common Law) and enough independent police bodies.

In the 1980s and early 1990s, several European countries totally or partly reformed their criminal law for different reasons : to update and adapt criminal contents to issues and areas arising from contemporary concerns but also to lighten the burden of the courts. It is also known that several European countries have recomposed the map of national and local administration powers. Both reforms may have mitigated the map of police power independence. This point needs to be checked since the development of deterrent enforcement methods assumes police systems which are sufficiently independent of the justice power .

In other respects, in each country law system encompasses a large range of public and private law branches. Traffic law can but rely on a public law branch such as criminal or administrative law. The police power consists of legal, but also, of territorial competencies which are ruled by legal requirements controlling their legality.

Finally, the European geography of traffic law systems mainly relies on the combination of several facts :

- the predominant type of law sentencing and social control,
- the fact that a country traffic control necessarily relies on a legal systems of public law and judiciary police power,
- the fact that the public law used for traffic law is either the criminal law, or the administrative law,
- the fact that police powers are more or less independent of Justice.

4.5.3.2. Criminal and administrative legal frames

Currently, criminal and administrative law mainly differs in terms of sanction process and sanction type:

- The criminal process of punishment usually follows three separate stages: detection, prosecution, sanction. Each stage is in the hands of a specific competent body so that sanctioning an offence requires a chaining of police, public prosecutor and judge interventions until the sentence. Criminal law usually provides a large range of penalty types from the loss or the restriction of liberty (prison penalty), of rights (driving licence), to the financial sanction pattern (day-fine, fine-unit, fines based on the social status) or alternative solutions such as community work (day-unit). Provisions of legal procedure are used for controlling the validity of detection and prosecution stages.
- In the administrative systems, the three sanction stages are mixed into a single one, there is no prosecution, no judgement, the violation of a rule is directly sanctioned. « Punishing without judging » is the formula for describing this systems. The administrative sanction cannot include liberty penalties but can apply loss or restriction of rights (driving licence) and mostly use the financial penalty with fixed or unfixed amounts.

When the administrative law systems support the action of traffic law enforcement, the achievement of the whole enforcement process moves on to the shoulders of the police bodies (even when the police does not receive the fine payment, and while an appeal in court is possible). Within the administrative frame, the traffic law systems win in autonomy while the role and power of police bodies are highly increased and decisive.

The administrative systems collect many ingredients of the deterrence thinking of enforcement: the condensation of the whole punishment process on the time of detection, the subsequent time reduction of the process duration, the automatic application of sanction (under the restriction of the police discretion impact or losses at the stage of fine payment).

4.5.3.3. Essential features of European traffic law systems

- #### *4.5.3.3.1. Some historic perspective on legal traffic law*

After the second world war and mostly since the 1970s, the evolution of the legal frame of traffic law has shown similar trends among European countries.

The first trend is a shift from the regulatory to the legislative ground. It is accompanied with increased criminal powers, and in parallel, an increasing ascendancy of central institutions to the detriment of local powers.

Then, for different reasons, a second shift from criminal to administrative law occurred in most countries. This last reform of the traffic law frame accompanies (Germany) or precedes the reforms of criminal law above mentioned (Italy, France, Spain). One of the main reasons for the reform was to lighten the load of criminal courts, overwhelmed by an ever increasing mass of traffic offences consecutive to the enforcement of new criminal behaviour and high levels of police monitoring.

In Germany, the early administrative reform was a means of focusing on education and prevention. Generally the change appears to be first a means of solving the bad-situation provoked in the criminal systems by the mass of traffic offences which disrupted both court and enforcement processes. The reform was rather an adaptive response, i.e. of reactive type, than a straight decision for promoting the deterrent enforcement policy.

- #### *4.5.3.3.2. The present map of traffic law systems*

The early change of legal frame made by the Federal Republic of Germany anticipated and summarised well enough the reform path followed, sooner or later, by six other countries (Belgium and Britain having kept strict criminal law systems). Either directly, or indirectly, the enforcement of most traffic offences has moved from the criminal to the administrative framework.

In Germany, most traffic offences (regulatory or minor offences, and a few downgraded ordinary criminal offences or misdemeanours) were depenalised in administrative violations and administrative fines by 1968. Italy (1992) and Spain (1983) have later applied the same straight reform while in France and Switzerland the legal frame became with time what is called a « Penal Administrative Law ». In France, from the late 1970s, there was a progressive extension of simplified criminal procedures encompassing standard sentences and fines for courts, and fixed fines enforced by the police bodies. They have brought about a de facto change of an administrative nature in the penal procedure framework. This French hybrid situation which is probably one of the worse, results from an ambiguous attitude of policy makers: while they view traffic law enforcement as a means of risk prevention, they are reluctant to depenalise traffic offences directly.

In all these countries, the criminal law framework was maintained for the most serious violations (e.g., drink-driving offences). There are nowadays a number of countries in Europe, such as Finland, Norway, Netherlands, Sweden and Switzerland having upgraded in criminal offences the highest excess of speed over the speed limit (Netherlands over 50 kph, Finland and Switzerland over 30 kph). The same project in France has recently turned to upgrading the category of regulatory offence for the speed excess of 50 kph over the limit (from the 4th to 5th rank), the rank of criminal offence being only applied to the recidivism.

In brief, the European map of legal frames of traffic law is divided into three zones :

- a first one relating to the countries with an administrative law for most of traffic offences (Germany, Italy, Netherlands, Spain),
- a second one, where traffic law is still strictly ruled by criminal law (Belgium, England and Wales),
- a third one, where the penal process is disqualified by the use of simplified procedures and sanctions (France, Switzerland).

- *4.5.3.3.3. Traffic criminal behaviour*

Parallel to the above trends, in certain countries a new traffic criminal offence has emerged. Although differently named, it basically addresses the notion of an "endangering " behaviour or an "aggravated" case, especially in terms drink driving be which are separated from any real damage. It was the objective of this classification to point out that this specific behaviour increased the risk of an accident considerably.

This new criminal behaviour was enacted in Spain by 1983 with the criminal code reform, in England with the new Traffic Act 1991, in France with the new criminal code of 1994. Only the courts are able to charge a dangerous or "endangering" or "aggravated" behaviour and it is in ample use in some countries, such as in Finland in terms of drink driving.

4.5.3.4. Police Organisation

Police systems in Europe are much more diversified and complex than the traffic law systems. Actually, it is a tangle of national divisions and subdivisions of different types, Switzerland being the only country with a single police body organised in federal police and « canton » police.

One first division is between civil and military bodies including, or not, a division of traffic police. Military systems are in general centralised whereas civil systems benefit from decentralised power and relative autonomy :

- Belgium, France, Italy, Spain have civil and military police bodies
- Belgium, Germany and Netherlands and Sweden have no traffic police bodies,

Another division is between national and regional levels (Netherlands, Finland, Norway) or between major territories of administration (German « Lands », British « County ») and community level (Germany).

In some countries, Police divisions were recomposed with the reform of administrative regions (The Netherlands, Spain), or in order to reduce the heterogeneity of divisions (Britain). In 1992, the Netherlands have reduced the number of regional divisions of Police to 25. In Britain the separated police forces were reduced to just over 40 during the 1960s. Spain has gained autonomous police bodies in the provinces having got their autonomy.

From a centralised administration or management view and for the issue of equal and uniform practices, this situation appears to be the weak point of the traffic enforcement policy. It makes it clear that unless there is a reform, which is probably unrealistic, the most operative level for identifying best practices, is to go beyond the country organisation of police systems and to focus on local conditions of traffic police enforcement.

4.5.3.5. Enforcement Systems interfaces

When traffic law is maintained in the criminal law framework and when the deterrent model of high level of traffic control is applied, it happens that the « two-wheeled » enforcement work encounters difficulties. A few references to the British and French situations indicate that there are several types of conflicts between deterrent and criminal enforcement methods.

The first and most simple type is that the great mass of traffic offences detected by high levels of police enforcement generates an ever-increasing backlog of cases in criminal courts. If reforms simplifying the criminal procedures are not applied, it can even lead to the suffocation of the judiciary process. First experiences of speed automotive control in Britain were abandoned for that reason.

A second problem of interface comes from the use, like in France, of reforms creating simplified procedures so as to escape suffocation. Ticket-fines which are a response to the majority of traffic regulatory offences, affect the penal nature of the law-enforcement process in two ways and provoke a paradoxical situation of criminal law enforcement. Firstly, the criminal process is taken out of its traditional context (courts): the punishment by fine is carried out in the area of the police systems. Secondly, treating the regulatory offences with an administrative process is in breach of the legal requirements of the criminal law process. A longitudinal analysis of the mass of regulatory offences from their detection to the issue of the fine payment emphasised the precarious balance of a penal system which is far from being a suitable instrument for a systematic and massive enforcement of traffic rules. This situation which questions the qualification of the fixed fine procedure as part of criminal law, also largely demonstrates that the best practice would be a migration of regulatory offences to the frame of the administrative law.

Another problematic interface arises with the severe punishment of serious traffic offences such as the drink-driving criminal offence (or misdemeanour). It comes from the discrepancy of enforcement objectives :

- the deterrent enforcement of drink-driving law which aims at large numbers of detection and severe sentencing for a collective effect (statistical impact),
- the penal doctrine of punishment which is based on fitted individual sentences and the judge's assessment of the seriousness of the fault.

4.5.3.6. Fixed fine procedure and effective sanctions

Fixed fines fits the deterrent aim of quickly sanctioning driving offences on condition that detection and payment are combined. It assumes that police bodies are competent in collecting the fine on the spot and that their power of discretion does not affect the achievement of the enforcement. When another solution is applied, i.e., when fines are collected by an organisation and the payment delayed, the issue of the amount of fines actually paid arises.

The impact in terms of shortened time between detection and sanction was assessed in the Netherlands after the MULDER LAW reform (1990 - 1992). Fines being in practice collected by a specific organisation, in average, the period running between offence detection and the fine collection was halved in more than 90% of cases. However it still took several months.

4.5.4. Key areas

4.5.4.1. Alcohol

The problem of driving and alcohol has existed as long as motorised traffic. Considering the size of the problem and its deep-going roots, European countries have been very inefficient to tackle this issue.

Compared to other traffic offences, drink driving is relatively infrequent, but dangerous. In European countries about 3% of all journeys are estimated to be associated with an illegal BAC (ETSC, 1995: overview of different studies), but about 30% of injured drivers were under the influence of alcohol. So, alcohol is definitely one of the major causes of accidents and is also an aggravated factor. Alcohol is also the major cause of accidents also from the road users' point of view. Some 85% of European drivers maintain that alcohol is often, very often or always the cause of accidents (SARTRE, 1994). While 93% of Swedish drivers are of this opinion, in western Germany the figure is about 20 percentage points lower (72%). This is a quite remarkable difference but the ratings concerning other accident causes differ even more.

Enforcement practises differ also considerably from country to country. In some countries the risk of being caught for drink driving is practically zero or drivers are tested only when involved in an accident. The other extreme is represented by countries where random breath testing is allowed and very actively applied so that some 40 % of drivers are tested annually (Finland). Moreover, testing techniques and principles vary a lot making testing easy and effective in some countries and slow and difficult process in other countries respectively. Also enforcement tactics vary due to organisational factors and attitudes towards alcohol in traffic. Methods for monitoring the trends and the role of alcohol in traffic are very deficient in most European countries making planning of alcohol enforcement tactics difficult. In addition to that, the parameters in use are far from comparable in Europe. In the evaluation of alcohol enforcement and the development of legal measures, also this aspect is covered.

A high level of subjective risk of apprehension has positive effects on compliance rates. As in terms of speeding, this depends partly on the objective probability of control and partly on the use of publicity and media as supporting the activities of the police. Random breath testing, where police officers randomly stop motorists and conduct breath tests, can increase compliance. Random breath testing is one of the major elements in an effective drink driving control. In Finland, where about 1,2 million breath tests are carried out annually, the proportion of drink drivers in the traffic flow (about 0.2 %) is among the lowest in the world.

Australia and Finland serve as good examples of the effectiveness of random breath testing aiming at both high objective and subjective risk of apprehension. These countries have exercised that practice on a regular basis a number of years by now (Finland since 1977 and Australia since 1983). This has brought about figures such as about 40 % (Finland) and 33 % (New South Wales, Australia) of drivers have been tested annually. While these activities have been also combined with massive publicity, the relatively high risk of detection has been widely recognised.

Adjudication process is something that needs a special treatment in relation with alcohol. In countries with heavy drinking patterns, for a great deal of drivers caught alcohol is a problem that can hardly be cured by imposing heavy fines or imprisonment. In most European countries individually tailored punishments, high objective risk of detection combined with information may well serve the purpose. Especially, in terms of recurrent offenders alcohol is a problem that needs more than only high objective and subjective probability of being caught. Only individually planned and realised rehabilitation programmes may help problem drinkers, but this is the way that takes time and devotion from the society.

New technologies combined with legislative changes also provide possibilities that need to be utilised. These are especially so called alcohol locks that prevent drivers from starting the car while under the influence of alcohol. The use of evidential breath testing device make the process of control considerably faster and cheaper compared to blood tests and consequently, increases the efficiency of the enforcement.

To summarise the following actions are needed to make alcohol enforcement more effective in Europe:

1. adopt a uniform legal limit of 0,5 per mill in Europe,
2. define also a limit for an aggravated case. This limit could be 1,2 per mile,
3. define drink driving control as one of the key target areas for traffic enforcement,
4. apply random breath testing as a leading principle for surveillance,
5. set realistic and credible quantitative targets for the number of breath tests,
6. develop measures for monitoring the results of alcohol enforcement in terms of the police activities and driver behaviour,
7. use publicity to support drink driving enforcement,
8. develop rehabilitation programmes for recurrent offenders,
9. use evidential breath testing device,
10. carry out experiments with alcohol locks.

4.5.4.2. Speed

Excessive speed, either too fast for conditions or over speed is without a question one of the main causative factors in road traffic accidents. Despite this fact probably the greatest opposition towards traffic safety work has been focused on restricting speeds.

It is especially interesting to show the historical background and the laborious creation of the general speed limit system in Europe - the task that has not even yet been fully accomplished. The Nordic countries were, however, among the first ones to pass the laws regulating speeds on public roads. Norway was probably the first country to introduce the general speed limit in 1912 the limits being 25 km/h. for rural roads and 15 km/h for urban areas. Even today speed limit systems in Europe are very different, even in the same cultural areas and neighbouring countries. A so called Energy Crisis caused by the war in Middle East in 1973 was needed before industrialised Western countries were prepared to start experimenting on general speed limits. This was only to save energy, not to increase traffic safety. Not until the safety effects of lower speeds were shown, there gradually rose an interest in speed limits as a transport safety measure.

In practise, it is the police that impose the real speed limits by defining the tolerance levels for the intervention when speeding is detected. These so called tolerance levels vary a lot from country to country, roughly from 5 - 25 km/h over the posted limit. However, there also great regional variations in tolerance levels making it difficult for drivers to know where the line between legal and illegal behaviour is drawn in practise. Philosophies behind reasoning and justification for different applications for tolerance levels should be assessed in relation to whether speed enforcement is seen as a means of monitoring traffic obedience in general, or whether speed tolerance levels ought to vary by site, time and traffic conditions.

While the creation of laws prescribing the highest allowed speeds has been difficult, so is the case with enforcing speeds. Even in the countries with so called effective enforcement systems, the risk of being ticketed for speeding is once in 10 years. The methods the police apply also vary, such is the case with allocation of resources to speed enforcement. Automated speed enforcement methods are not in wide use in European countries, even though first experiments on camera surveillance were carried out already a quarter of a century ago. Currently, the most advanced European countries in using automated enforcement methods are Austria, Finland, Norway, the Netherlands and United Kingdom.

However, it seems inevitable that speed enforcement to be more effective needs more automated methods than currently applied. An obvious way to improve the efficiency and perhaps the effectiveness of the enforcement process is introduce automation to various steps in the process. While automation is usually associated with technology, it can also be in the form of simplifying manual procedures so that quick decisions can be made in a shorter process. For example, applying a simple scheme of fixed fines and removing a mandatory court appearance for most traffic violations, increases the efficiency of policing dramatically.

Automating speed enforcement is an obvious objective both for the prevalence of speeding and for its importance to safety. The first step in automating the process is simply let a mobile photo-radar device in a patrol car take photos of speeding vehicles without stopping them downstream. The next step is to set-up a camera device in a box along side the road and leave it there permanently. This approach combines the incentive of mass ticketing with that of continuous presence at the enforcement site. The large number of possible citations requires more automation down the processing line.

Wet film technology imposes many administrative and logistic limitations on the actual amount of citations that can be generated. However, digital video based (and newer smart card concepts) detection, recording and communication technology offers more robust options for mass and continuous non-compliance detection and citation.

As traffic management, especially in congested areas, is becoming more exacting, high or complete compliance with the particular control and management schemes becomes essential for their success. Dedicated bus or truck lanes, high occupancy lanes, truck- exclusion road sections, zero tolerance speed control areas, are examples of such traffic management schemes. They are usually typified by well defined entry points and therefore can be controlled by appropriately placed automatic detection devices which are capable of detecting and registering every violation.

At the present most of these devices are video- based, or a combination of a sensor (such as a weight sensor) and a trigger to a camera. The most significant aspect of this type of automation incentive is that it is not aimed to actually issue many citations, but rather to prevent non-compliance by being there all the time and being able to register every offending vehicle. Such systems combine certainty of detection and fairness and are perhaps more convincing regarding the inherent need and rationale for complying.

A logical extension of this approach is to implement a system that actually prevents vehicles or drivers from non- complying, thus side-stepping the need for additional external enforcement and the use of punishment. Such concepts (for example, an adaptive speed controller in a vehicle linked to speed limits in a designated area) are being tested empirically at the present.

However expensive these systems are they constitutes a small addition to the large investment in a fixed site EFC system that, obviously, has revenues. This is not the case for regular police enforcement that is much more spread out and, if successful, will not have much revenues from citations. Therefore, the direction of automated technology solutions in the context of EFC may not necessarily fit regular policing. Broader concepts of “fee for road use” envision alternative system concepts based on elements such as digital tachographs, smart cards, GPS and other sub-systems, with enforcement integrated in the total system.

Another interesting aspect of EFC related enforcement is the share of responsibilities between private, semi- public and government agencies, which may be adapted to other facets of traffic enforcement.

An issue on who are entitled to enforce speeds is an interesting one since in Germany speed enforcement in some communities is partly delegated to private companies. With the increasing possibilities to use new technologies in enforcement, it would be waste of the police resources to use it for the operation of automated systems only.

In addition to automated methods also traditional methods such as traffic calming can be effective in reducing speed at isolated sites. However their effects are localised in time and space, and have the additional drawbacks of poor public acceptability, secondary costs such as noise and pollution, and possible accident migration. Tools based on telematics offer a great flexibility and they give a broad possibility to manage speed also in variable conditions like adverse road and weather conditions (e.g. wet or slippery road, fog). In-car equipment has a good safety potential if it is of intervening type. However, drivers more prefer (before driving with such intervening equipment) equipment with informative functions only i.e. that simply provide advice. On the other hand, it has been found that driver acceptance usually increases after the driver has driven a vehicle equipped with such systems. The highest appropriate speeds in different traffic environments could be managed by simple speed-limiters in cars and adaptation to changing conditions by a dynamic system based on “intelligent” speed-limiters.

Adjudication related to speed violations varies especially in terms of the severity of sanctions. An interesting issue at this point is whether fixed fines should be used (efficiency principle) or should the fines be based on the social situation of an individual (justice principle) applied especially in some Nordic countries. This is also a general issue concerning all traffic violations. In several European countries there has been a tendency in sanction systems to move towards administrative type of fixed fines. This is partly due to the greater need for efficiency in enforcement and partly due to the requirements of automatic/camera enforcement.

In all, differences in adjudication and sanction systems are tremendous in Europe. Penalties for the same violation may vary 10-fold or even more. Also in terms of demerit point systems the countries differ a lot.

In addition to the above differences, there are obviously great differences in terms of the objective risk for getting caught for traffic violations. The comparison of countries in this respect is difficult, since there is little centralised and comparative data available in European countries.

To conclude the following measures are recommended to be adopted in European countries for suppressing excessive speeds:

1. Aim at harmonising speed limits on European roads,
2. define limits and criteria for aggravated speeding,
3. aim at clear and harmonised tolerance levels for speeding first nationally and later internationally,
4. define speed control as one of the key target areas of traffic enforcement,
5. set realistic and credible quantitative targets for speed enforcement,
6. simplify legal procedures in terms of speeding violations,

7. change laws making speed camera enforcement possible and more simple,
8. develop measures for monitoring the results of speed enforcement in terms of the police activities and driver behaviour,
9. consider using private companies in the operation of automated speed enforcement methods,
10. use publicity to support speed enforcement,
11. aim at adopting new technologies such as intelligent speed limiters in speed control.

4.5.4.3. Seat belts

It is possible that by increasing the seat belt wearing rates close to 100 % in EU countries, about

7 000 human lives could be saved annually. The benefits would be greatest in Southern European countries having the lowest wearing rates. The process of promoting seat belt use in Europe has also been a lengthy one, the roots of first efforts dating back to 1960's. The use of seat belts increased by voluntary means only little. Not until the laws making seat belt use mandatory the usage rates increased rapidly. This was preceded by a period from 5 to 15 years including laws making the installation of belts mandatory as well as numerous information campaigns. The most dramatic example for the significance of seat belt laws comes from Canada, where in the late 1980's after the introduction of a seat belt law, the user rates immediately increased from less than 30 % user rate over 70 %. However, for technical reasons the law cancelled, and consequently, the user rates also went quickly down.

The sanctions for not having the belts fastened are mild. There is actually no need for stiffer sanctions. The mere existence of sanctions seem to increase user rates considerably. It was found already in the first half of the seventies that the wearing rates in the countries, where sanctions for non-use existed, varied from 75% to 85% outside built-up areas, and from 60% to 70% within built-up areas. In countries where seat belt use was obligatory but without sanction, the percentages were lower, and varied from 40% to 63% and from 15% to 35% respectively. There is also evidence (Holland, USA) that through positive reinforcement belt usage rates may be increased in the areas where the rates are not very high.

The history of seat belt use enforcement is rather short. It has not been a primary target for the police in most European countries. The safety effects of even a few percentage points increase in belt usage rates were probably not fully understood by authorities until recently. The same applies to the use of rear seat belts as well. The emerging of air bags do not nullify the significance of seat belts. Only by having the belts buckled up and the car equipped with an air bags can the passive safety effects of a vehicle be optimised. This aspect will be covered especially when reviewing the opinions of the authorities involved in legal measures.

To conclude the following enforcement related measures are recommended to be adopted in European countries for increasing the restraint use:

1. aim at harmonising laws concerning the restraint use in Europe,
2. enforcement of restraint use should be primary enforcement focused only on the use of restraints,
3. combine publicity and enforcement,
4. concentrate enforcement mainly on urban areas.
5. concentrate in enforcement also on the correct use of restraints,
6. set quantitative targets for the enforcement of restraint use,
7. make the enforcement of restraint use one of the primary areas of traffic enforcement,
8. develop monitoring system for restraint use and enforcement,
9. work together with other traffic safety bodies for increasing the use of restraints,

4.5.4.4. Young drivers

The risk of a car accident is highest among young drivers. Especially high it is among young motor bike drivers. Young drivers, especially males, aged from 18 to 24 years are dramatically more often involved in accidents compared to drivers in the other age groups. This over-involvement of young male drivers in the accident statistics is one of the most consistently observed phenomena in traffic throughout the world. Moreover, it is one of the most difficult problems to tackle effectively.

The casualty figures show that in youngsters, death in traffic is the prime cause of death, of which a large proportion is car driver population.

The high accident involvement of young drivers has often been attributed to poorer risk perception, resulting in a larger discrepancy between subjective and objective risk for young male drivers. Jonah stated that, even though young drivers may perceive as much risk while driving as older drivers and thus do not deliberately seek more risk, they may be more confident in their ability to avoid an accident. Bragg and Finn found that specific behaviour patterns such as speeding and tailgating were perceived as less risky by young drivers. They hypothesised that the lower perception of risk in young drivers may be attributable to the greater confidence in their skill or belief in their ability to handle a particular hazardous situation. Some authors believe that the high accident involvement of young, and especially male, drivers is a lifestyle related phenomenon resulting in a higher deliberate risk acceptance. But in that case it would be expected that a higher percentage of accident involved young drivers are positive on alcohol and have higher BAC levels compared to older drivers. This is not the case.

Increasingly, researchers have come to realise that the high accident risk of young drivers cannot be explained adequately in terms of one dominant factor, such as for example faulty risk perception or life-style. There are many factors that contribute to inadequate driving performance and accident risk. On the basis of the international literature study Twisk mentions the following list of factors: immaturity, limited hazard perception skills, high risk acceptance, overestimation of driving skills, lack of robust driving routines, high exposure to dangerous conditions, and overload due to limited capacity to attend to all stimuli.

It may be difficult to bring about new knowledge on the causes of young drivers’ accidents. They seem to be a combination of factors associated in broad terms with immaturity and the process of growing up. More innovation is needed for the prevention of accidents, since it seems that only knowing the causation of accidents in traffic is not enough for decreasing them. The essential issue at this point is how legal measures could be better used and synchronised with driver education, which in itself seemed to have been insufficient in decreasing the risk of young drivers. Also the use of insurance policies should be considered. Moreover, it seems obvious that the right to drive needs more control during the first critical years. Extending the duration of the driver licensing process and having the licence in more than as a one step process are possibilities that need through experimentation.

The laws regulating novice drivers' behaviour after licensing are scant. There have been some special methods in use, such as the general speed limit of 80 km/h during the first year of licence (Finland). The use of these methods, as well as their effects has remained largely unknown. Finland has consequently abolished this practise.

The tailoring of adjudication process for young drivers is still taking its first steps. There is also a lot of variability in the tolerance between different European countries in respect with the first offences of young drivers. However, there are hardly any empirical experiences on the effects of special treatment of young drivers.

Selectivity of enforcement is especially important when focused on young drivers. The time and areas young drivers travel is often different compared to older car users. The key elements in enforcement at this points are drunk driving and speeding and the timing of these activities as well as the enforcement locations and sites.

Since education and information has so far not been effective alone. It is important to consider how the measures combined could be used more effectively to prevent young driver accidents.

To conclude the following enforcement related measures are recommended to be adopted in European countries for improving the safety of young drivers:

1. aim at creating sanction systems targeted to the novice driver phase,
2. selective enforcement in terms of young drivers' behaviour patterns needed,
3. young drivers are also a heterogenous group and methods for individually tailored enforcement practises are needed,
4. use of new technologies such as speed limiters and alcohol locks should be considered as a future measure,

5. impose restrictions on young drivers' motor vehicle use at night during the first year,
6. especially in terms of young drivers the integration of activities such legislation, enforcement, education, publicity, driver licensing, insurance policies and parental control is needed to address their safety problem,

4.5.5. Conclusions

The results based on both the literature review and the description of legal measures and enforcement in European countries suggest that legal measures and enforcement are applied only satisfactorily in most European countries. The reasons for that can be traced back to the position of the traffic police in the whole of the police organisation. Moreover, a clearly systematic approach including target-setting, integrated activities together with other traffic safety bodies as well as effective monitoring of the operations are missing in several countries. Even though legislation sets limits to effective policing, much more could be done within existing legislative frameworks. However, the most serious limitations for effective policing come from the fact that the resources of the police in any given country are small compared to the vast size of transportation systems.

Automation, information technology and new management concepts have been successfully used in many areas of social and economic activity to improve efficiency, productivity, and effectiveness. Similarly, also in the area of traffic law enforcement there are pressures, expectations, and hopes for improving efficiency and having a greater impact on safety, through the use of new technology, especially technology that helps in automating the enforcement process. A more innovative use of new technologies may help to solve many problems associated with the relative inefficiency of traditional traffic enforcement.

In the present context enforcement refers to the active policing, usually by police officers on the roads, of compliance with traffic laws. The typical, visible part of the enforcement process begins with a police officer patrolling a road and detecting a traffic violation committed by a driver. It proceeds with stopping the vehicle, identifying the driver and issuing a citation, and continues with a number of alternative legal procedures that have to be followed by both the driver, by the police officer and by the courts. Some form of punishment is levied against the offending driver in a due process that reflects the rules of evidence and the civil rights of offenders and citizens in general.

There is a less visible aspect to the enforcement process which involves a detailed planning of deployment to sites, times and tasks, and a detailed procedure of recording, processing, maintaining and reporting of information pertaining to citations and to enforcement activities. Legal court procedures may add further work to the policing agency. Both aspects of the process are labour intensive, time consuming and costly. These were the very aspects of the enforcement process that still remain largely unknown and that are also associated with the effectiveness of enforcement and moreover, they would give us information of possibilities to develop enforcement systems in European countries.

It is not realistic to propose European countries to change their legal measures and enforcement systems uniform and identical. There are, however, some areas in legislation including both laws and adjudication processes as well as in enforcement that have potential for increasing the effectiveness of the whole traffic control systems, and consequently should be applied in a uniform way in Europe. These bottle-necks can be listed as follows:

Law and adjudication:

- laws are too rigid in terms of some high risk offences, especially in terms of drink driving; the supportive role of laws in the rehabilitation of repeated offenders needs to be strengthened,
- effective enforcement methods such as random breath testing not allowed in all countries,
- use of new technologies in enforcement,
- effective use of camera enforcement is not possible in most countries,
- administrative laws not fully used in handling minor offences,
- laws should give more possibilities to individually tailored sanctions.

- *Enforcement:*

- traffic behaviour monitoring systems are missing in most countries making planning and data led operations difficult,
- accident data not fully used in the planning of enforcement,
- centralised and sufficiently detailed and structured data systems describing enforcement and surveillance activities missing in most countries,
- variable and inconsistent enforcement practises nationally and internationally and between different policing bodies,
- too high, variable and inconsistent tolerance levels for speed offences,
- enforcement concerning the use of occupant restraint systems largely neglected in most European countries despite its good cost/benefit ratio,
- selectivity of enforcement is not fully utilised (no clear priority areas),
- no clear, quantifiable and measurable targets set for enforcement
- enforcement not always deduced from the targets on national traffic safety work,
- research concerning effects of enforcement not systematic.

Finally, there are also areas in which more efforts to harmonise European legislation and enforcement practises are needed. These are as follows:

- uniform legal limits for drink driving are missing,
- great differences in legislation concerning speed limits, adjudication including sanctions and enforcement practises,
- repeated offences handled very differently in Europe partly depending on differences in behaviour monitoring systems,
- only in few countries legislation has been tailored to meet the challenges of new technologies. Legislation, in fact, makes a serious bottle-neck for effective use of automated enforcement methods,
- the creation and harmonisation of road user behaviour monitoring systems in Europe urgently needed,
- increase communication between European traffic enforcement agencies.

4.5.6. Effects of legal measures and enforcement on different mechanisms of behaviour acquisition, behaviour regulation and behaviour modification

Work-package 5 has focussed on conditions for good enforcement and on ways how to achieve such conditions. It is obvious that we have to consider legislation and enforcement as a system if we want to optimise the effects on driver behaviour.

The following conclusions discuss the potential impact of legislation and enforcement on driver behaviour, assuming a well established system. It should be mentioned that legislation and enforcement alone will be less effective than legal and enforcement measures linked with other safety approaches.

This conclusion is structured according to the seven proposed mechanisms of impact on driver behaviour.

For each of these mechanisms it considers and describes:

- Expected positive effects
- Possible side effects
- Empirical evidence

- *Drivers' psychophysiological condition*

Enforcement offers a considerable chance to prevent people from impaired driving. This should result in substantial safety effects. The amount of these effects and the chances to achieve such a success vary depending on consumption habits of people in certain countries (how easy is it to monitor all relevant occasions where a drink-driving conflict may occur) and on the acceptance to conduct enforcement measures targeted on this issue (opposition from economy - pubs, discos etc.). Empirical evidence on these effects is given. Important undesired side effects are not to be expected except during the stage of introduction. To avoid such effects support from safety campaigns is asked for.

- *Drivers' affective condition*

Relevant effects on drivers' affective condition are not to be expected. Adverse effects might arise if anger is evoked by an enforcement activity. But this can be overcome by fair enforcement tactics and support of legal measures by publicity campaigns underlining the need and benefit of the legal measures.

- *Drivers getting the appropriate input*

Enforcement should not aim at structuring or providing (additional) input to the driver – this is a matter of good traffic and road planning. It is much more important to avoid distraction from relevant traffic information by enforcement activities.

- *Drivers' correct assessment of the relevance of input*

In some cases visible enforcement may be useful to indicate risk to drivers. This tactics must be used carefully to avoid distraction on the one hand and to avoid the development of undesired adaptation processes on the other hand (see below).

- *Drivers' ideas/beliefs about adept driving*

Legislation is one of the main ways to establish and modify beliefs. Legal norms also have consequences on social norms and thus legislation has the chance to establish appropriate ideas and beliefs on adept driving. Enforcement combined with information and publicity have shown their great potential in changing fixed driving habits such as drink driving, speeding and not wearing seat belts. Again all aspects of legislation (including adjudication and enforcement) are crucial to avoid effects of undermining the normative character of legislation.

- *Drivers' automated judgement of feedback*

Visible enforcement and prompt enforcement - if it is addressing especially dangerous behaviour - can serve as a cue for risk and thus might influence the automated mechanisms that make drivers assess dangers as real dangers.

- *Drivers' cognitive judgement of feedback*

Both - legislation and enforcement - can help drivers to assess the results of dangerous behaviour more appropriately on a cognitive level. If an accident is preceded by unapt behaviour that also implies a violation of a rule, it is easier to recognise this as a reason for the accident. But, apart from accident occurrences, the experience of enforcement will influence drivers' critical perception of their driving habits and may be a mechanism which improves attitudes concerning driving.

5. Conclusions

Empirical evidence on safety effects is relatively poor. Obviously, the evaluation of measures is a difficult task. Often, well designed evaluation studies cannot be performed since decision making and the implementation of measures follow different principles than scientific ones. This problem can and is often solved by co-ordinating implementation and accompanying research.

Even if these procedures are increasingly considered, decisions which favour one safety measure out of the pool of available measures cannot be supported easily by the kind of evaluation studies available so far.

The following facts limit the potential relevance of evaluation studies:

- often, evaluation studies are restricted to accident data - and that implies also -
- that the mechanisms which determine the success of a measure are rarely considered in the studies,
- effects of mechanisms that might oppose the desired effects cannot be studied (i.e., effects that emerge in certain circumstances, in certain subgroups, in the long term),
- it cannot be understood why and how certain effects result from a combination of various measures.

Because of these limitations, it must be stressed that evaluation studies have to consider behavioural variables to a greater extent.

At present no sufficient empirical basis is available for cost-benefit analysis. Costs of measures are not documented sufficiently nor are sufficient data available concerning reduction of accidents and related costs.

However, it is assumed that GADGET prepared new perspectives for the assessment of safety measures.

- The work-package reports offer a structured and detailed description of the knowledge and evidence available so far.
- The theoretical assumptions upon the mechanisms of impact on driver behaviour allow a structured consideration of the most promising applications of the various safety approaches.
- This structured approach also allows a well based discussion on reasonable combinations of traffic safety measures.

These issues will be discussed in more detail in the recommendations.

6. Recommendations

6.1. Main areas of application for the various safety approaches

Table 7: Safety approaches and their main intended areas of application

\Safety approaches Causes for accidents and unsafe behaviour	In-car safety devices	Roadside information	Education and training	Safety campaigns	Legal measures/ enforcement
Level 1: condition of the person					
Drivers' psychophysical condition (1)	Hinder people from driving when impaired, Support appropriate levels of mental load	Support appropriate levels of mental load	Increase awareness of the importance of the psychophysio-logical condition	Increase awareness of the importance of the psychophysio-logical condition	Hinder people from driving when impaired
Drivers' affective condition (2)	Influence upon self esteem		Increase awareness of the importance of the affective condition	Increase awareness of the importance of the affective condition	Alter the mood of a driver
Level 2: principles of behaviour regulation (direct factors)					
Drivers getting the appropriate input (3)	Satisfy driver information needs, Input selection, Support basic visual functions, Support appropriate levels of mental load	Satisfy driver information needs, Support basic visual functions, Support appropriate levels of mental load			Attract the attention of drivers
Drivers' correct assessment of the relevance of input (4)	Indicate hazards	Satisfy driver expectations	Improve hazard perception		
Drivers' ideas/ beliefs about adept driving (5)	Limit opportunities to behave differently from other drivers, thus enforcing social norms	Limit opportunities to behave different from other drivers, thus enforcing social norms	Provide adequate knowledge, initiate reflection on driving	Provide adequate knowledge, initiate reflection on driving	Introduce social norms and thus ideas and beliefs about adept driving
Level 3: adaptation processes (feedback)					
Drivers' automated judgement of feedback (without consideration of conscious processes) (6)	Provide feed back that is related to objective risk	Provide feed back that is related to objective risk	Complement the non-occurrence of a dangerous event by continuous ("automated") feedback		Improve the correct assessment of hazards, establishing an automated link - dangerous habit and detection risk
Drivers' cognitive judgement of feedback (7)			Provide feedback that reflects the dangers on a cognitive level	Support appropriate inter-pretation of ex-perience gained in traffic, illustrate mechanisms of drawing wrong conclusions	Help the driver to reflect upon consequences of behaviour appropriately

Intention and motivational factors – in our model seen as an interaction of affective condition and beliefs – may be subject to influences from all the safety approaches considered. Each of the approaches might influence ideas and beliefs, the affective condition might be influenced by many measures, especially by in-car safety devices, education and training measures, safety campaigns and legal measures and enforcement measures.

It is assumed that combinations of safety measures will yield more desirable safety effects than stand alone measures or a variety of not well co-ordinated safety measures.

The table above is one way to introduce reasonable ways of influencing the various causes for accidents and unsafe behaviour. For each cause of accidents, sets of measures are available for implementation. But, what to do with this set of options – select all options or just one or two?

6.2. Combinations of safety measures

Instead of recommending "try all options to address a traffic safety problem" we will introduce reasonable combinations of approaches in this section. We will restrict the description to the combination of a maximum of two approaches at one time.

6.2.1. Combinations of measures from one approach

Within the approaches itself reasonable combinations must be considered. It is difficult to predict the effect of such combinations in any case.

- *Combination of various in-car safety devices*

Concerning the effects of in-car safety devices very little is known in general, even less of course is known about the effects of combinations of various devices. Much research is still necessary to allow sounder conclusions.

- *Combination of various road environment measures*

In the studies reviewed in work-package 2 there are a couple of examples of multiple-measure schemes involving combinations of road environment measures

The "hierarchical road network" system (or the concept of "self-explaining roads") is an example of a total road design approach consisting of several measures. It is, however, not yet known which single design elements are most important for drivers' categorisation of roads, or to what extent drivers' perceptions are based on combinations of measures rather than single elements. Concerning safety effects it is important to compare single elements with combinations of elements.

Traffic calming measures (especially in urban areas) are a similar example, where visual measures are combined with physical ones (humps etc.).

- *Combination of various education and training measures*

It has turned out that only combinations of various measures will result in good safety effects. Therefore in the work-package report the systems-approach proposed is described in detail.

- *Combination of various safety campaigns*

There is little systematic consideration on combining several safety campaigns so far. However, there is evidence that campaigns are more successful if they are targeted (specific issues, groups etc.). To achieve widespread effects it may be quite useful to design large campaigns as sets of a larger number of activities on a smaller scale.

- *Combination of various legal measures*

As for the issue of legal measures, the same is true as for education and training measures. The work-package has pointed out the relevance of a systemic approach, considering all aspects from legislation, adjudication to enforcement.

6.2.2. Combinations of measures from various approaches

The discussion of reasonable combinations will pick up each safety approach and analyse the support which this very approach can achieve from the combination with other approaches

Table 8: The safety approaches and their mutual support

	1 In-car safety devices	2 Roadside information	3 Education and training	4 Safety campaigns	5 Legal measures/ enforcement
1 In-car safety devices			**1/3**		
2 Roadside information	**2/1**		**2/3**	**2/4**	**2/5**
3 Education and training	**3/1**			**3/4**	**3/5**
4 Safety campaigns					**4/5**
5 Legal measures/ enforcement	**5/1**	**5/2**	**5/3**	**5/4**	

6.2.2.1. Support for effects from in car safety devices

- *(1/3) In-car safety devices and driver training*

Challenging developments of SDs and car technology put new and rapidly changing demands on driving skills. Research has shown that these technologies may cause an increase of drivers‘ mental workload which at least equal the intended benefits. Moreover one might predict that new kinds of danger signals arise due to the increasing use of SDs and car technologies. Drivers have to respond to them, i.e. to recognise and process them for a safe performance of their primary driving task. Novice as well as experienced drivers are confronted with these new demands.

Beside these developments innovative contents of driver training are required. First of all, these new danger signals have to be incorporated in driver training. Moreover, the adequate use of these systems must be systematically trained. The reason of this simply is that the amount of additional driver workload due to SDs and car technologies heavily depends on the amount of practice in using such systems. With increasing practice the information-processing resources required by a task decrease until they will be performed on an automatic level. These resources might be used e.g. for perceiving and processing danger signals.

6.2.2.2. Support for effects from road environment measures

- *(2/1) Road environment measures and in-car safety devices*

Within the road traffic informatics area, there may possibly be some applications where combining roadside information with in-car devices may be a better solution than each measure alone, for example to provide drivers with information about hazards.

- *(2/3) Road environment measures and education and training measures*

It is assumed that the effects of road markings and traffic signs can be increased considerably in combination with driver education. If drivers do not know the meaning of markings and signs, safety is likely to be compromised. Before suggesting measures to improve drivers' knowledge it should however be documented through accident research or behavioural studies that lack of knowledge is really a safety problem.

- *(2/4) Road environment measures and safety campaigns*

Concerning the use of speed feedback signs their effect might possibly be enhanced by combining the measure with speed-reducing campaigns, e.g. using mass media information.

- *(2/5) Road environment measures and legal measures*

Concerning e.g. traffic lights, maybe improving the visibility of the signals will be more efficient if combined with increased enforcement of red light running, and possibly also with stricter legislation regarding entering intersections during the yellow interval when it is possible to stop. Similar strategies may be applied to various kinds of warning signs and road markings.

The effect of traffic calming measures can be supported by legal measures (reduced speed limits) and enforcement measures.

6.2.2.3. Support for effects from education and training measures

- *(3/1) Education & training measures and in-car safety devices*

Driver training will have a supportive role during implementation phases of new technologies. However, new technologies might also support driver training. New technologies might also be used e.g. for training the perception and processing of danger signals. If this will be feasible depends on the designs.

- *(3/4) Education & Training and Safety campaigns*

Subject matter, methods and organisation of driver licensing systems will become more and more complex. It will therefore be necessary to apply marketing techniques. In order to influence the motivation of learner drivers to comply, safety campaigns aimed at the situation and wishes of young drivers will therefore be necessary.

- *(3/5) Education and training measures and legal measures*

Driver licensing systems are characterised more and more by a combination of education and accompanying legal measures and enforcement strategies, (graduated licensing systems, combination of probationary and provisional systems). It is therefore necessary to design enforcement strategies for novice drivers.

6.2.2.4. Support for effects from safety campaigns

- *(4/5) Safety campaigns and legal measures*

There are some results that indicate that safety campaigns are perceived better and attitudes are changed more into the desired direction if the message is accompanied with enforcement activities. It even seems that accompanied enforcement activities make drivers aware of more risks than just of those addressed in slogans of the campaign.

6.2.2.5. Support for effects from legal measures

- *(5/1) Legal measures/enforcement and in-car safety devices*

The use of SD-equipped vehicles which ensure safe and legal driving by technical means reduces the need for enforcement drastically. At least at the time being this is not a realistic scenario, because this would require a legal basis to control the driver's behaviour, which doesn't exist yet.

- *(5/2) Legal measures/enforcement and road environment measures*

Good road design should favour adept driving itself. Enforcement should not be used to compensate for bad traffic planning. Measures like traffic calming by road layout etc. should relieve the police from enforcing on any spot and give more chance for activities targeted on dangerous locations and problem drivers. Enforcement on the spot is considered to be very effective because of the direct feedback quality. Therefore the road network has to offer the police opportunities to stop drivers without affecting the safety of other road users.

- *(5/3) Legal measures/enforcement and education and training measures*

Driver education is an important means to inform about traffic legislation, its philosophy and importance and to support acceptance of legislation and enforcement.

- *(5/4) Legal measures/enforcement and safety campaigns*

Safety campaigns are a general means to influence acceptance of legislation and enforcement. The same is true for publicity about enforcement activities, and especially on success achieved by enforcement activities. A special issue is the supportive role of media campaigns with the introduction of new legislation.

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